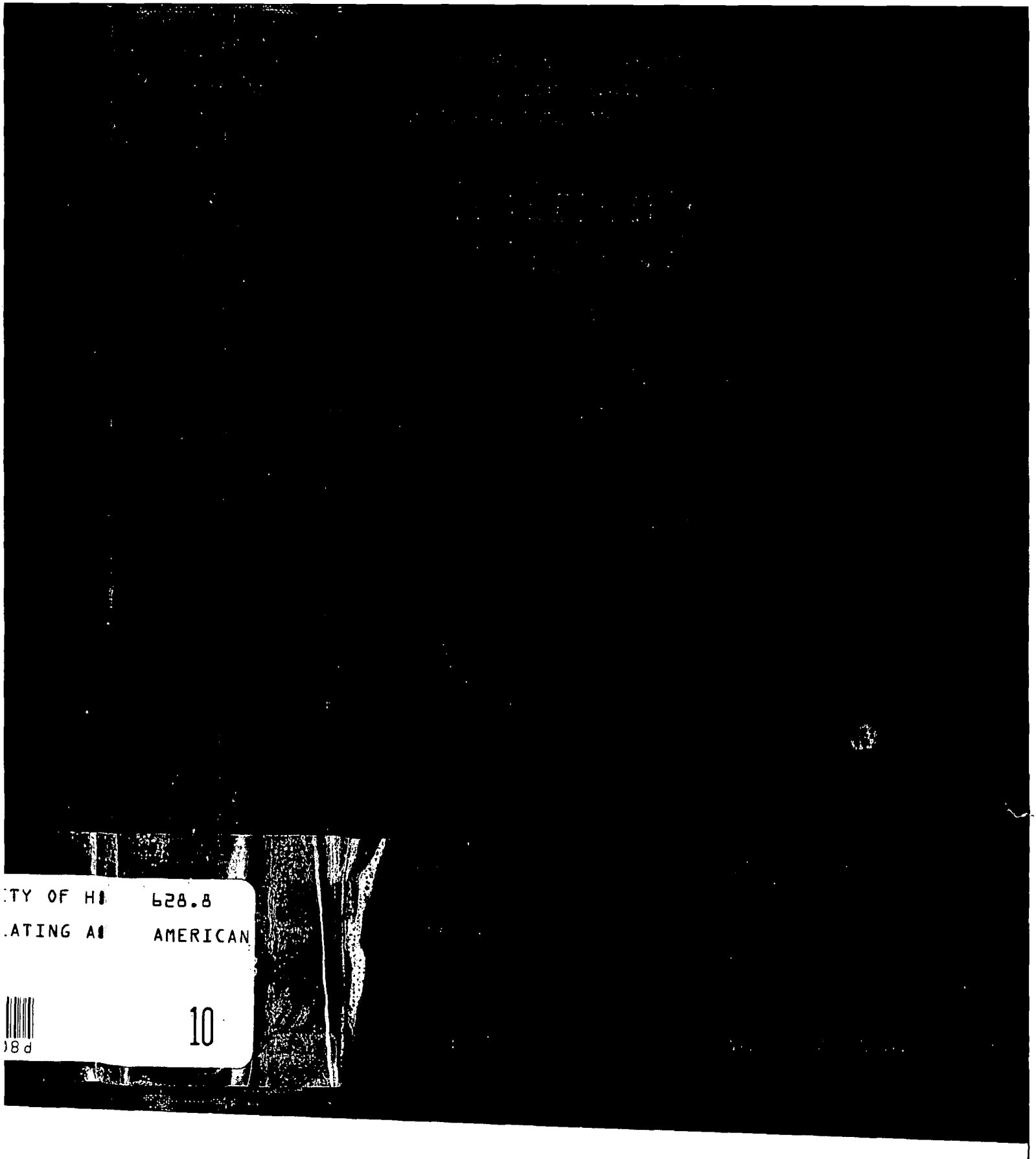

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AMERICAN SOCIETY *of* HEATING *and* VENTILATING ENGINEERS GUIDE

1932

AN INSTRUMENT OF SERVICE PREPARED FOR THE PROFESSION—AND CONTAINING REFERENCE DATA ON THE DESIGN AND SPECIFICATION OF HEATING AND VENTILATING SYSTEMS—BASED ON THE TRANSACTIONS—THE INVESTIGATIONS OF THE RESEARCH LABORATORY AND COOPERATING INSTITUTIONS—AND THE PRACTICE OF THE MEMBERS AND FRIENDS OF THE SOCIETY

TOGETHER WITH A

MANUFACTURERS' CATALOG DATA SECTION CONTAINING ESSENTIAL AND RELIABLE INFORMATION CONCERNING MODERN EQUIPMENT

ALSO

THE ROLL OF MEMBERSHIP OF THE SOCIETY

WITH

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PREFACE TO 10th EDITION

THE GUIDE 1932 is the *tenth* in a series of annual editions amplified and revised to keep pace with the notable engineering developments that have been recorded during the last decade. In contrast to the 1st edition published in 1922 the Text Section alone of this 10th edition contains nearly twice the number of pages as were devoted to the combined text and catalog sections in original GUIDE.

In the enlargement of THE GUIDE the ideals of its founders have been carefully preserved by each Guide Publication Committee. New subjects have been added and the scope and usefulness of THE GUIDE have been extended as progress in the art required.

The significant additions and revisions that make THE GUIDE 1932 distinctive are: The increased number of chapters, the inclusion of over 50 per cent new subject matter and the rewriting of nearly every chapter. A new grouping of subjects has been made and more extensive cross indexing will assist the user in locating needed specific information.

In Chapter 1 the abbreviations and definitions used in the Text Section have been grouped. Comprehensive information on concealed heating units of various types is given a new Chapter 7 entitled Gravity Convectors. The latest research in hot water heating is the basis for Chapter 8. An entirely new treatment of the subject of handling condensate and air is given in Chapter 10. Practical data on hot and cold water requirements of buildings, Chapter 13, is new and valuable material. Entirely new information is to be found in the Chapters on Draft and Chimneys, Mechanical Stokers, and Automatic Temperature Control. Many changes in the presentation of the subjects of Ventilation and Air Conditioning have been necessary in order that the profession may benefit from recent research discoveries. Chapter 36, Unit Ventilators and Chapter 37, Unit Air Conditioners are new and, with the exception of a little previously published information, Chapters 38, 39 and 40 give new data.

It is hoped that engineers, architects, contractors and others who use THE GUIDE 1932 will find in the 552 pages of technical data adequate information to solve the problems that arise in daily practice.

With more than 300 pages in the Catalog Data Section modern equipment can be selected for any heating and ventilating service. Detailed descriptions, sizes, capacities, and dimensions are invaluable in supplementing the facts contained in the Text Section.

The manufacturers who make a careful and complete presentation give essential facts and figures on their specific products thereby amplifying the text. This unique method effectively covering both practice and

equipment in a thorough and authoritative manner has gained for THE GUIDE worldwide recognition and acceptance as the standard reference work on heating and ventilating.

This effective means of advertising is selected by leading manufacturers to promote the use of modern equipment and payment for the service rendered enables the AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS to publish and distribute THE GUIDE and to extend its wholly philanthropic services to the general advancement of the profession and its allied industries.

This 10th edition of THE GUIDE totals 12,000 copies, surpassing in number any previous volume, and is released by the Guide Publication Committee with the sincere wish that it may serve the profession at large as the indispensable reference authority of this highly specialized and progressive field.

D. S. BOYDEN, *Chairman*

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EDITORIAL ACKNOWLEDGMENT

FOR 10 years THE A.S.H.V.E. GUIDE has held unchallenged its enviable position as the authority for the heating and ventilating profession and industry because it is dependable and up-to-date. The achievement of worldwide recognition and prestige among engineers has been possible only because of the willingness of outstanding men to contribute freely from their knowledge and experience for the benefit of their professional brethren.

THE GUIDE 1932 stands upon a solid foundation of research, experience and practice, and the Guide Publication Committee this year has followed in the path of its predecessors by enlisting the aid of the ablest engineers to prepare this 10th anniversary edition.

The following specialists have cooperated in the production of THE GUIDE 1932 without thought of compensation for their services other than the pleasure and satisfaction derived from doing their bit in the interest of better engineering:

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The members of the Society and other users of THE GUIDE 1932, are deeply indebted to these engineers and the GUIDE Publication Committee gladly acknowledges this indebtedness to public service and commends the enthusiasm, cooperation and devotion of these workers who built this bigger and better GUIDE 1932.

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ENGINEERING work has become an increasingly important factor in the progress of civilization and in the welfare of the community. The engineering profession is held responsible for the planning, construction and operation of such work and is entitled to the position and authority which will enable it to discharge this responsibility and to render effective service to humanity.

That the dignity of their chosen profession may be maintained, it is the duty of all engineers to conduct themselves according to the principles of the following Code of Ethics:

1—The engineer will carry on his professional work in a spirit of fairness to employees and contractors, fidelity to clients and employers, loyalty to his country and devotion to high ideals of courtesy and personal honor.

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10—He will interest himself in the public welfare in behalf of which he will be ready to apply his special knowledge, skill and training for the use and benefit of mankind.

AMERICAN SOCIETY *of* HEATING *and* VENTILATING ENGINEERS GUIDE 1932

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Chapter 1

DEFINITIONS AND ABBREVIATIONS

Interpretation of Physical and Heating and Ventilating Terms Used in the Text

DEFINITIONS

Absolute Temperature: The temperature of a substance measured above *absolute zero.*

Absolute Zero: The temperature (−459.6 F) at which the molecular motion of a substance theoretically ceases which is the temperature at which the substance theoretically contains no heat energy.

Air Cleaner: A device designed for the purpose of removing air borne impurities such as dusts, fumes and smokes. (Air cleaners include air washers and air filters.)

Air Conditioning: The simultaneous control of the temperature, humidity, air motion and air distribution within an enclosure. Where human comfort and health are involved, a reasonable air purity with regard to dusts, bacteria and odors is also included. (This term is frequently applied to the control of the moisture content of the air.)

Air Infiltration: The inleakage of air through cracks and crevices, and through doors, windows and other openings, caused by wind pressure and/or temperature difference.

Blast: This word was formerly used to denote forced air circulation, particularly in connection with central fan systems using steam or hot water as the heating medium. As applied in this sense, the word *blast* is now obsolete.

Boiler: A closed vessel in which steam is generated or in which water is heated by fire.

Boiler Heating Surface: The heat transmitting surfaces in contact with the water (or steam) in the boiler on one side and the fire or hot gases on the other.

British Thermal Unit: The quantity of heat required to raise 1 lb of water from 63 F to 64 F. This is substantially equal to $\frac{1}{180}$ of the heat required to raise the temperature of 1 lb of water from 32 F to 212 F (*Mean Btu*).

Calorie (*small*)*:* The quantity of heat required to raise one gram of water from 17 C to 18 C. This is substantially equal to $\frac{1}{100}$ of the heat required to raise one gram of water from 0 to 100 C (*Mean calorie*).

Central Fan System: A mechanical indirect system of heating, ventilating or air conditioning consisting of a central plant where the air is heated and/or conditioned and then circulated by fans or blowers through a system of distributing ducts.

Chimney Effect: The tendency in a duct or other vertical air passage for air to rise when heated due to its decrease in density.

Coefficient of Transmission: The amount of heat (Btu) transmitted *from air to air* in one hour per square foot of the wall, floor, roof or ceiling for a difference in temperature of one degree Fahrenheit *between the air on the inside and outside of the wall, floor, roof or ceiling*. (The velocity of air passing over the surfaces and the distances from the surfaces at which the temperatures are measured affect the coefficient of transmission.)

Column Radiator: A type of direct radiator. (This radiator has not been listed by manufacturers since 1926.)

Comfort Line: The effective temperature at which the largest percentage of adults feel comfortable.

Comfort Zone: The range of effective temperatures over which the majority (50 per cent or more) of adults feel comfortable.

Concealed Radiator: See convector.

Conductance: The amount of heat (Btu) transmitted *from surface to surface* in one hour through one square foot of a material or construction *for the thickness or type under consideration* for a difference in temperature of one degree Fahrenheit between the two outside surfaces.

Conduction: The transmission of heat through and by means of matter unaccompanied by any obvious motion of the matter.

Conductivity: The amount of heat (Btu) transmitted in one hour through one square foot of a homogeneous material *one inch thick* for a difference in temperature of one degree Fahrenheit between the two surfaces of the material.

Conductor (*heat*)*:* A material capable of readily conducting heat. The opposite of an insulator (or insulation).

Convection: The transmission of heat by the circulation of a liquid or a gas such as air. (Convection may be *natural* or *forced*.)

Convector: A concealed *radiator*. An enclosed heating unit located (with enclosure) either within, adjacent to, or exterior to the room or space to be heated, but transferring heat to the room or space mainly by the process of convection. A shielded heating unit shall also be termed a convector. (If the heating unit is located exterior to the room or space

to be heated, the heat is transferred through one or more ducts or pipes; see Chapter 7.)

Degree-Day (*Standard*)*:* A unit which is the difference between 65 F and the daily mean temperature when the latter is below 65 F. (The 65-F temperature is an empirically determined base which has been assumed by the *American Gas Association* to be the temperature above which heat is not required.)

Dew-Point Temperature: The temperature corresponding to saturation (100 per cent relative humidity) for a given moisture content.

Diffuser: A vaned device at an air supply opening.

Direct-Indirect Heating Unit: A heating unit located in the room or space to be heated and partially enclosed, the enclosed portion being used to heat air which enters from outside the room.

Direct Radiator: Same as *radiator*.

Direct-Return System (*Hot water*)*:* A hot water system in which the water, after it has passed through a heating unit, is returned to the boiler along a direct path so that the total distance traveled by the water is the shortest feasible distance and so that there are considerable differences in the lengths of the several circuits composing the system.

Down-Feed One-Pipe Riser (*Steam*)*:* A pipe which carries steam downward to the heating units and to which the condensation from the heating units drains.

Down-Feed System (*Steam*)*:* A steam heating system in which the supply mains are above the level of the heating units which they serve.

Dry-Bulb Temperature: The temperature of the air as determined by a thermometer when dry. (The dry-bulb temperature is an indication of the sensible heat.)

Dry Return: A return pipe in a steam heating system which carries both water of condensation and air. See *wet return*.

Dynamic Head or Pressure: The total or impact pressure. This is the sum of the radial pressure and the velocity pressure at the point of measurement.

Effective Temperature: An experimentally determined temperature which unlike the dry-bulb and wet-bulb temperatures, is a true measure of a person's feeling of warmth in all combinations of temperature, humidity and air motion.

Extended Heating Surface: See *heating surface*.

Extended Surface Heating Unit: A heating unit having a relatively large amount of extended surface which may be integral with the core containing the heating medium or assembled over such a core, making good thermal contact by pressure, or by being soldered to the core or by both pressure and soldering. (An extended surface heating unit is usually placed within an enclosure and therefore functions as a convector.)

Fan Furnace System: See *warm air heating system*.

Furnace: That part of a boiler or warm air heating plant in which combustion takes place. Also, a fire-pot.

Gravity Warm Air Heating System: See *warm air heating system*.

Grille: A perforated covering for an air inlet or outlet usually made of wire screen, pressed steel, cast-iron or plaster. (Grilles may be plain or ornamental.)

Heat: A form of energy generated by the transformation of some other form of energy, as by combustion, chemical action, or friction. [According to the molecular theory, heat consists of the kinetic and potential energy of the molecules of a substance. The addition of heat energy to a body increases the temperature or the kinetic energy of motion of its molecules (*sensible heat*) or increases their potential energy of position but does not increase the temperature, as when melting or boiling occurs (*latent heat*).]

Heat Capacity: The amount of heat (Btu or calories) required to raise the temperature of a body (of any mass and variety of parts) one degree (Fahrenheit or centigrade) at the mean temperature.

Heat Unit: In the foot-pound-second system, the British thermal unit (Btu); in the centimeter-gram-second system, the calorie (cal).

Heating Medium: A substance such as water, steam, air, electricity or furnace gas used to convey heat from the boiler, furnace or other source of heat or energy to the heating unit from which the heat is dissipated.

Heating Surface: The exterior surface of a heating unit. *Extended heating surface (or extended surface):* Heating surface having air on both sides and heated by conduction from the prime surface. *Prime Surface:* Heating surface having the heating medium on one side and air (or extended surface) on the other.

Heating Unit: A device which transmits heat from the heating medium to the air and surrounding objects having a temperature lower than its exterior surface temperature. (See Chapters 6 and 7.)

Horsepower: A unit to indicate the time rate of doing work equal to 550 ft-lb per second or 33,000 ft-lb per minute. (One horsepower = 745.8 watts.)

Hot Water Supply Boiler: A closed vessel in which water is heated, usually for domestic use.

Hot Water Heating System: A heating system in which water is used as the medium by which heat is carried through pipes from the boiler to the heating units.

Humidity: The water vapor (steam or moisture) mixed with the air. *Relative Humidity:* The ratio of the weight of moisture contained in a given volume of the mixture to the weight of moisture which the same volume of the mixture would hold at the same temperature, if saturated. Relative humidity is expressed as a percentage. Air is said to be saturated or to have a relative humidity of 100 per cent when it is mixed with the maximum possible amount of vapor at the given temperature. *Absolute Humidity:* The actual weight of water vapor contained in a given volume of a mixture of air and water vapor at the observed temperature.

Humidostat: A regulator which controls an operating medium such as air, electricity or water and which medium opens or closes a valve for controlling the humidity.

Hygrostat: Same as humidostat.

Insulation (*heat*)*:* A material having a relatively high heat resistance per unit of thickness.

Latent Heat: See *heat.*

Mil-Inch: One one-thousandth of an inch.

Neutral Zone: The level within a room or building at which the pressure is exactly equal to the outside barometric pressure.

Oil Burner: A combination of devices for the preparation and combustion of oil fuel and air.

One-Pipe Supply Riser (*Steam*)*:* A pipe which carries steam upward to a heating unit and which also carries the condensation from the heating unit in a direction opposite to the steam flow.

One-Pipe System (*Hot water*)*:* A hot water system in which the water flows through more than one heating unit before it returns to the boiler, and consequently the heating units farthest from the boiler are supplied with cooler water than those near the boiler in the same circuit.

One-Pipe System (*Steam*)*:* A steam heating system consisting of a main circuit in which the steam and condensate flow in the same pipe and usually in opposite directions. Ordinarily there is but one connection to each heating unit which must serve as both the supply and the return, although separate supply and return connections may be used.

Overhead System: Any steam or hot water system in which the supply main is above the heating units. (With a steam system the return must be below the heating units; with a water system, the return *may* be above the heating units.)

Panel Radiator: A heating unit placed on or flush with a flat wall surface and intended to function essentially as a radiator.

Panel Warming: A method of heating involving the installation of the heating units (pipe coils) within the wall, floor or ceiling of the room, so that the heating process takes place mainly by radiation from the wall, floor or ceiling surfaces to the objects in the room.

Plenum Chamber: An air compartment maintained under pressure and connected to one or more distributing ducts.

Prime Surface: See *heating surface.*

Pyrometer: A high temperature thermometer.

Radiation: The transmission of heat in a straight line through space.

Radiator: A heating unit located within the room or space to be heated and exposed to view. (A radiator transfers heat by radiation to objects "it can see" and by conduction to the surrounding air which in turn is circulated by natural convection; a so-called *radiator* is also a *convector* but the single term *radiator* has been established by long usage.) *Concealed Radiator:* See convector. *Indirect Radiator:* Obsolete.

Recessed Radiator: A heating unit set back into a wall recess but not enclosed.

Register: A grille with a built-in damper or shutter.

Return Mains: The pipes which return the heating medium from the heating units to the source of heat supply.

Reversed-Return System (*Hot Water*)*:* A hot water heating system in which the water from several heating units is returned along paths

arranged so that all circuits composing the system or composing a major subdivision of the system are practically of equal length.

Roof Ventilator: A device placed on the roof of a building to permit egress of air.

Sensible Heat: See *heat.*

Smokeless Arch: An inverted baffle placed in an up-draft furnace toward the rear to aid in mixing the gases of combustion and thereby to reduce the smoke produced.

Specific Heat: In the foot-pound-second system, the amount of heat (Btu) required to raise one pound of a substance one degree Fahrenheit. In the centimeter-gram-second system, the amount of heat (cal) required to raise one gram of a substance one degree centigrade. (The specific heats of gases and vapors usually are higher for constant pressure than for constant temperature.)

Split System: A system in which the heating is accomplished by radiators or convectors and ventilation by separate apparatus.

Square Foot of Heating Surface (*equivalent*)*:* Equivalent direct *radiation* (EDR). By definition, that amount of heating surface which will give off 240 Btu per hour when filled with the heating medium at 215 F and surrounded with air at 70 F. (The *equivalent* square foot of heating surface may have no direct relation to the actual surface area.)

Static Head or Pressure: The radial pressure with an enclosure, that is, the pressure tending to burst the enclosure. (This is also termed frictional or resistance pressure or maintained resistance.)

Steam: Water vapor which exists in the vaporous state due to the fact that sufficient heat has been added to the water, from which the steam has been formed, to supply the latent heat of evaporation, and thereby to change the liquid into a vapor. Steam in contact with the water from which it has been generated may be *dry-saturated* steam or *wet-saturated* steam. The latter contains more or less actual water in the form of mist. If steam is heated, and the pressure maintained the same as when it was vaporized, its temperature will increase and it will become *superheated.*

Steam Heating System: A heating system in which heat is transferred from the boiler or other source of steam, to the heating units by means of steam at, above or below atmospheric pressure.

Steam Trap: A device for allowing the passage of condensate and for preventing the passage of steam, or for allowing the passage of air as well as condensate.

Superheated Steam: See *steam.*

Supply Mains (*Steam*)*:* The pipes through which the steam flows from the boiler or source of supply to the run-outs and risers leading to the heating units.

Surface Conductance: The amount of heat (Btu) transmitted by radiation, conduction and convection *from a surface to the air or liquid surrounding it,* or vice versa, in one hour per square foot of the surface for a difference in temperature of one degree between the surface and the surrounding air or liquid.

Synthetic Air Chart: A chart for evaluating the air conditions maintained in a room.

Thermostat: An instrument which responds to changes in temperature and which directly or indirectly controls the source of heat supply.

Tube (or Tubular) Radiator: A cast-iron heating unit used as a radiator and having small vertical tubes (pipes).

Two-Pipe Supply Riser (*Steam or water*)*:* A vertical pipe which supplies the heating medium to the heating unit but does not carry the heating medium from the heating unit, the heating medium returning through a separate return pipe or riser.

Two-Pipe System (*Steam or water*)*:* A heating system in which one pipe is used for the supply of the heating medium to the heating unit and another for the return of the heating medium to the source of heat supply. (The essential feature of a two-pipe system is that each heating unit receives a direct supply of the heating medium which medium cannot have served a preceding heating unit.)

Underfeed Distribution System (*Hot water*)*:* A hot water heating system in which the main flow pipe is below the heating units.

Underfeed Stoker: A stoker which feeds the coal underneath the fuel bed.

Unit Air Conditioner: A self-contained air conditioning plant which provides for humidification or dehumidification, air washing, heating or cooling, and includes spray nozzles, air re-heater, fan, pump, automatic control, all within a common enclosure. (As a rule the outlets are designed to accomplish air distribution without ducts.)

Unit Cooler: A combination of a cooling coil and fan or blower, erected as a unit and having a common enclosure. (As a rule the outlets are designed to accomplish air distribution without ducts.)

Unit Heater: Any combination of a heating unit, and a fan or blower having a common enclosure, and placed within or adjacent to the space to be heated; generally no ducts are attached to the inlets or outlets. (Unit heaters are designed primarily for industrial use.)

Unit Ventilator: A unit heater designed to use all or part out-door air with or without alternate provision for handling recirculated air. (Unit ventilators are intended primarily for school and office ventilation.)

Up-Feed System (*Steam*)*:* A steam heating system in which the supply mains are below the level of the heating units which they serve.

Vacuum Heating System: A two-pipe steam heating system equipped with the necessary accessory apparatus which will permit operating the system below atmospheric pressure when desired.

Vapor: Any substance in the gaseous state.

Vapor Heating System: A steam heating system having separate supply and return pipes, which operates under pressures at or near atmospheric and which returns the condensation to the boiler or receiver by gravity. (Vapor systems have thermostatic traps or other means of resistance on the return ends of the heating units for preventing steam from entering the return mains; they also have a pressure-equalizing and air-eliminating device at the end of the dry return, which device is of a proprietary nature.) *Direct Vent Vapor System:* A vapor heating system with air valves which do not permit re-entry of air.

Velocity Head or Pressure: The head or pressure required to create the velocity of flow, that is, the head or pressure required to accelerate the mass from a state of rest to the velocity at the point measured.

Ventilation: Air change. *Natural Ventilation:* Air change produced by natural forces (wind and gravity) only. *Mechanical Ventilation:* Air change produced by mechanical means (fans and blowers).

Warm Air Heating System: A warm air heating plant consists of a heating unit (fuel-burning furnace) enclosed in a casing, from which the heated air is distributed to the various rooms of the building through ducts. If the motive head producing flow depends on the difference in weight between the heated air leaving the casing and the cooler air entering the bottom of the casing, it is termed a *gravity* system. A booster fan may, however, be used in conjunction with a gravity-designed system. If a fan is used to produce circulation and the system is designed especially for fan circulation, it is termed a *fan furnace* system or a *central fan furnace* system. A fan furnace system may include air washers, filters, etc.

Wet-Bulb Temperature: The lowest temperature which a water wetted body will attain when exposed to an air current. (This is the temperature of adiabatic saturation.)

Wet Return: That part of a return main of a steam heating system which is filled with water of condensation. (The wet return usually is below the level of the water line in the boiler, although not necessarily so.)

ABBREVIATIONS

British thermal unit	Btu	foot	ft
calorie	cal	gallon	gal
centigram	cg	gallons per minute	gpm
centimeter	cm	gallons per second	gps
centimeter-gram-second	cgs	horsepower	hp
cubic	cu	inch	in.
cubic foot	cu ft	meter	m
cubic feet per second	cfs	miles per hour	mph
cubic feet per minute	cfm	minute	min
degree	deg	ounce	oz
degree centigrade	C	parts per million	ppm
degree Fahrenheit	F	revolutions per minute	rpm
direct-current (as adjective)	d-c	revolutions per second	rps
feet per minute	fpm	square foot	sq ft
feet per second	fps	square inch	sq in.

Chapter 2

ESTIMATING HEAT LOSSES

Procedure to be Followed; Inside Temperatures; Outside Temperatures; Wind Movement; Heat Sources; Examples of Heat Loss Computations.

THE size of the heating plant required for a building is based on the maximum heat demand. This maximum heat demand depends on many factors, most of which are seldom, if ever, in equilibrium. These include the following:

1. Outside temperature. 2. Rain or snow. 3. Sunshine or cloudiness. 4. Wind velocity.	*Outside Conditions (The Weather)*
5. Heat transmission of exposed parts of building. 6. Infiltration of air through cracks, crevices and open doors and windows. 7. Heat capacity of materials. 8. Rate of absorption of solar radiation of exposed materials.	*Building Construction*
9. Inside temperatures. 10. Stratification of air. 11. Type of heating system. 12. Ventilation requirements. 13. Period and nature of occupancy. 14. Temperature regulation.	*Inside Conditions*

The *inside conditions* vary from time to time, the physical properties of the *building construction* may change with age, and the *outside conditions* are changing constantly. Just what the worst combination of all of these variable factors is likely to be in any particular case is therefore conjectural.

Because of the nature of the problem, extreme precision in estimating heat losses at any time is very unlikely. However, studies now in progress at the A.S.H.V.E. Research Laboratory will, it is hoped, increase the accuracy with which it is possible to combine all of the various factors involved to determine the maximum effect thereof. The data published in this and Chapters 3, 4, and 28 have been largely derived from the investigations at the A.S.H.V.E. Research Laboratory since it was established in 1919, and also at cooperating institutions. Studies of sun effect and heat capacity have been under way for about two years.

The procedure to be followed in determining the heat loss from any building can be divided into seven consecutive steps, as follows:

1. Determine on the inside air temperature, at the breathing line, which is to be maintained in the building during the coldest weather. (See Table 1, p. 10).

TABLE 1. INSIDE TEMPERATURES USUALLY SPECIFIED

TYPE OF BUILDING	DEG. FAHR.
SCHOOLS—	
Class Rooms	68
Assembly Rooms	66 – 68
Gymnasiums	55 – 65
Toilets and Baths	70
Wardrobe and Locker Rooms	65 – 68
Kitchens	66
Dining and Lunch Rooms	65 – 68
Playrooms	60 – 65
Natatoriums	75
THEATERS—	
Seating Space	68 – 72
Lounge Rooms	68
Toilets	68
HOSPITALS—	
Private Rooms	70
Private Rooms (surgical)	70 – 80
Operating Rooms	70 – 95
Wards	68
Kitchens and Laundries	66
Toilets	68
Bathrooms	70 – 80
HOTELS—	
Bedrooms and Baths	70
Dining Rooms	70
Kitchens and Laundries	66
Ball Rooms	65 – 68
Toilets and Service Rooms	68
HOMES—	
Where 68 F is generally the desirable standard of temperature a guarantee of 70 F is customarily exacted.	
STORES	65 – 68
PUBLIC BUILDINGS	68 – 70
WARM AIR BATHS	120
STEAM BATHS	110
FACTORIES AND MACHINE SHOPS	60 – 65
FOUNDRIES AND BOILER SHOPS	50 – 60
PAINT SHOPS	80

TABLE 2. DESIRABLE INDOOR TEMPERATURES IN SUMMER CORRESPONDING TO OUTDOOR TEMPERATURES

DEGREES OUTSIDE	DEGREES INSIDE		
Dry Bulb	Dry Bulb	Wet Bulb	Effective Temperature
95	80.0	65.2	73.4
90	78.0	64.5	72.2
85	76.5	64.0	71.1
80	75.0	63.5	70.2
75	73.5	63.0	69.3
70	72.0	62.5	68.2

2. Determine on an outside air temperature for design purposes, based on the minimum temperatures recorded in the locality in question, which will provide for all but the most severe weather conditions. Such conditions as may exist for only a few consecutive hours are readily taken care of by the heat capacity of the building itself. (See Table 3, p. 14).

3. Select or compute the heat transmission coefficients for outside walls and glass, also for inside walls, floors, or top-floor ceilings, if these are next to unheated space; include roof if next to heated space. (See Chapter 3).

4. Measure up net outside wall, glass and roof next to heated spaces, as well as any cold walls, floors or ceilings next to unheated space. Such measurements are made from building plans, or from the actual building.

5. Compute the heat transmission losses for each kind of wall, glass, floor, ceiling and roof in the building by multiplying the heat transmission coefficient in each case by the area of the surface in square feet and the temperature difference between the inside and outside air. (See pars. 1 and 2).

6. Select unit values and compute the heat equivalent of the infiltration of cold air taking place around outside doors and windows. These unit values depend on the kind or width of crack and wind velocity and when multiplied by the length of crack and the temperature difference between the inside and outside air, the result expresses the heat required to warm up the cold air leaking into the building per hour. (See Chapter 4).

7. The sum of the heat losses by transmission (par. 5) through the outside wall and glass, as well as through any cold floors, ceilings or roof, and the heat equivalent (par. 6) of the cold air entering by infiltration represents the total heat loss equivalent for any building.

Item 7 represents the heat losses after the building is heated and under stable operating conditions in coldest weather. Additional heat is required for raising the temperature of the air, the building materials and the material contents of the building to specified standard inside temperature.

The rate at which this additional heat is required depends upon the heat capacity of the structure and its material contents and upon the time in which these are to be heated.

This additional heat may be figured and allowed for as conditions require, but inasmuch as the heating system proportioned for taking care of the heat losses will usually have a capacity about 100 per cent greater than that required for average winter weather, and inasmuch as most buildings may either be continuously heated or more time be allowed for heating-up, during the few minimum temperature days, no allowance is made except in the size of boilers or furnaces.

INSIDE TEMPERATURES

Winter

The inside air temperature which must be maintained within a building and which should always be stated in the heating specifications, is understood to be the temperature at the breathing line, 5 ft above the floor and not less than 3 ft from the outside walls. Inside air temperatures, usually specified, vary in accordance with the use to which the building is to be put and Table 1 presents values which are in conformity with good practice.

Effect of Humidification: In connection with inside temperatures for winter where humidifying means are provided, approximately 1 deg variation for each 10 per cent variation in relative humidity should be provided. For example: If the relative humidity is raised from a condition of 15 per cent to one of 45 per cent by artificial humidification it is desirable

to lower the indoor temperature about 3 deg as indicated by the Effective Temperature Line on the Comfort Chart. (See Chapter 28, p. 394). The temperatures given in the table are for normal dry air with dew-points approximately equivalent to outdoor air. A reduction in the temperatures will be required corresponding to the raise of the moisture content by artificial humidification.

Temperature at Proper Level: In making the actual heat-loss computations, however, for the various rooms in a building it is often necessary to modify the temperatures given in Table 1 so that the air temperature at the proper level will be used. By *air temperature at the proper level* is meant, in the case of walls, the air temperature at the mean height between floor and ceiling; in the case of glass, the air temperature at the mean height of the glass; in the case of roof or ceiling, the air temperature at the mean height of the roof or ceiling above the floor of the heated room, and in the case of floors, the air temperature at the floor level. In the case of heated spaces adjacent to unheated spaces, it will usually be sufficient to assume the temperature in such spaces as the mean between the temperature of the inside heated spaces and the outside air temperature, excepting where the combined heat transmission coefficient of the roof and ceiling can be used, in which case the usual inside and outside temperatures should be applied. (See Table 32, Chapter 3, and discussion regarding the use of combined coefficients of pitched roofs, unheated attics and top-floor ceilings on p. 38).

The air temperature at the mean height between floor and ceiling is the *breathing-line* temperature, Table 1, for rooms not over 10 ft in height. For rooms above this height, the temperature should be increased according to the difference between the mean height of the vertical wall, glass, roof or ceiling surface, and the height of the breathing line. The amount of the increase per foot of height will depend on the inside breathing-line temperature; the outside temperature; the wall and roof construction, and the type and location of heaters and other factors.

High Ceilings: Research data concerning stratification of air in buildings are lacking, but in general it may be said that where the increase in temperature is due to the natural tendency of the warmer or less dense air to rise, as where a direct radiation system is installed, the temperature of the air at the ceiling increases with the ceiling height. The relation, however, is not a straight-line function, as the amount of increase per foot of height apparently decreases as the height of the ceiling increases, according to present available information.

Therefore, the temperature of the air at any level in a building such as at the mean height of walls, is not necessarily proportional to the distance from the floor or breathing line, although in general the temperature increases as the height increases. It is the common practice of engineers to allow 2 per cent per foot of height above the breathing line in determining the probable air temperature at any given level for a direct radiation system; and this value is, no doubt, sufficiently accurate in most cases, although it is not probable that this rule applies to heights above 20 ft.

With certain types of heating and ventilating systems, which tend to oppose the natural tendency of warm air to rise, the temperature differential between floor and ceiling can be greatly reduced. These include

unit heaters, fan-furnace heaters, and the various types of mechanical ventilating systems. The amount of reduction is problematical in certain instances, as it depends upon many factors such as location of heaters, air temperature, and direction and velocity of air discharge. In some cases it has been possible to reduce the temperature between the floor and ceiling to a few degrees, whereas, in other cases, the temperature at the ceiling has actually been increased because of improper design, installation or operation of equipment. So much depends upon the factors enumerated, that it is not advisable to allow less than 1 per cent per foot (and usually more) above the breathing line in arriving at the air temperature at any given level for any of these types of heating and ventilating systems, unless the manufacturers are willing to guarantee that the particular type of equipment under consideration will maintain a smaller temperature differential for the specific conditions involved.

Rietschel's Formula: Rietschel states that the average mean temperature t_m never exceeds 1.15 t for the highest ceilings. His formula is:

$$t_m = t\,[\,1. + 0.017\,(h - 10)\,]$$

in which h is the height of the ceiling or outside walls. Substituting $t_m = 1.15\ t$, it is found that $h = 19$ ft, so that for heights over 19 ft a value of $t_m = 1.15\ t$ may be used.

Temperature at Floor Level: In determining mean air temperatures just above floors which are next to ground or unheated spaces, a temperature 5 deg lower than the breathing-line temperature may be used, provided the breathing-line temperature is not less than 55 F.

Summer

Where buildings are being artificially cooled for human comfort during the summer a different scale of inside temperatures is required and this inside temperature must depend to a large extent upon the variation in outside temperatures. It is manifestly undesirable and impracticable to maintain a temperature of 70 F inside when it is 95 F outside, nor can it be said that the inside temperature should be as much as 15 deg below the outside temperature. At 95 F outside, and dry air, a temperature somewhat lower than 80 F might be desirable. On the other hand with 85 F outside a 70 F temperature inside would be entirely too cold. In other words, the spread between the inside and outside temperature must be varied as the outside temperature varies.

Table 2 is based on average moisture conditions outside and upon the assumption of relative humidities inside, between 50 and 60 per cent, which is usual in such installations.

OUTSIDE TEMPERATURES

Winter

The outside temperature used in computing the heat loss from a building is seldom taken as the lowest temperature ever recorded in a given locality. Such temperatures are usually of short duration and are rarely repeated in successive years. It is therefore evident that a temperature somewhat higher than the lowest on record may be properly assumed in making the heat-loss computations.

Table 3. Climatic Conditions Compiled from Weather Bureau Records

Col. A	Col. B	Col. C	Col. D	Col. E	Col. F
State	City	Average Temp., Oct. 1st–May 1st	Lowest Temperature	Average Wind Velocity Dec., Jan., Feb., Miles per Hr.	Direction of Prevailing Wind, Dec., Jan., Feb.
Ala.	Mobile	57.7	−1	8.3	N
	Birmingham	53.9	−10	8.6	N
Ariz.	Phoenix	59.5	16	3.9	E
	Flagstaff	34.9	−25	6.7	SW
Ark.	Fort Smith	49.5	−15	8.0	E
	Little Rock	51.6	−12	9.9	NW
Cal.	San Francisco	54.3	29	.....	N
	Los Angeles	58.6	28	.....	NE
Colo.	Denver	39.3	−29	7.4	S
	Grand Junction	39.2	−16	5.6	SE
Conn.	New Haven	38.0	−14	9.3	N
D. C.	Washington	43.2	−15	7.3	NW
Fla.	Jacksonville	61.9	10	8.2	NE
Ga.	Atlanta	51.4	−8	11.8	NW
	Savannah	58.4	8	8.3	NW
Idaho	Lewiston	42.5	−13	4.7	E
	Pocatello	36.4	−20	9.3	SE
Ill.	Chicago	36.4	−23	17.0	SW
	Springfield	39.9	−24	10.2	NW
Ind.	Indianapolis	40.2	−25	11.8	S
	Evansville	44.1	−15	8.4	S
Iowa	Dubuque	33.9	−32	6.1	NW
	Sioux City	32.1	−35	12.2	NW
Kans.	Concordia	38.9	−25	7.3	N
	Dodge City	40.2	−26	10.4	NW
Ky.	Louisville	45.2	−20	9.3	SW
La.	New Orleans	61.5	7	9.6	N
	Shreveport	56.2	−5	7.7	SE
Me.	Eastport	31.1	−23	13.8	W
	Portland	33.6	−17	10.1	NW
Md.	Baltimore	43.6	−7	7.2	NW
Mass.	Boston	37.6	−13	11.7	W
Mich.	Alpena	29.1	−27	11.3	W
	Detroit	35.4	−24	13.1	SW
	Marquette	27.6	−27	11.4	NW
Minn.	Duluth	25.1	−41	11.1	SW
	Minneapolis	29.6	−33	11.5	NW
Miss.	Vicksburg	56.0	−1	7.6	SE
Mo.	St. Joseph	40.3	−24	9.1	NW
	St. Louis	43.3	−22	11.8	NW
	Springfield	43.0	−29	11.3	SE
Mont.	Billings	34.7	−49	.....	W
	Havre	27.7	−57	8.7	SW
Nebr.	Lincoln	37.0	−29	10.9	N
	North Platte	34.6	−35	9.0	W
Nev.	Tonopah	39.6	−7	9.9	SE
	Winnemucca	37.9	−28	9.5	NE
N. H.	Concord	33.4	−35	6.0	NW
N. J.	Atlantic City	41.6	−7	10.6	NW
N. Y.	Albany	35.1	−24	7.9	S
	Buffalo	34.7	−14	17.7	W
	New York	40.3	−6	13.3	NW
N. M.	Santa Fe	38.0	−13	7.3	NE

Table 3. Climatic Conditions Compiled from Weather Bureau Records—(Continued)

Col. A	Col. B	Col. C	Col. D	Col. E	Col. F
State or Province	City	Average Temp., Oct. 1st–May 1st	Lowest Temperature	Average Wind Velocity Dec., Jan., Feb., Miles per Hr.	Direction of Prevailing Wind, Dec., Jan., Feb.
N. C.	Raleigh	49.7	−2	7.3	SW
	Wilmington	53.1	5	8.9	SW
N. D.	Bismark	24.5	−45	.....	NW
	Devil's Lake	18.9	−44	11.4	W
Ohio	Cleveland	36.9	−17	14.5	SW
	Columbus	39.9	−20	9.3	SW
Okla.	Oklahoma City	48.0	−17	12.0	N
Ore.	Baker	34.1	−20	6.0	SE
	Portland	45.9	−2	6.5	S
Pa.	Philadelphia	41.9	−6	11.0	NW
	Pittsburgh	40.8	−20	13.7	NW
R. I.	Providence	37.6	−9	14.6	NW
S. C.	Charleston	56.9	7	11.0	N
	Columbia	53.7	−2	8.0	NE
S. D.	Huron	28.1	−43	11.5	NW
	Rapid City	32.3	−34	7.5	W
Tenn.	Knoxville	47.0	−16	6.5	SW
	Memphis	50.9	−9	9.6	NW
Texas	El Paso	53.0	−2	10.5	NW
	Fort Worth	54.7	−8	11.0	NW
	San Antonio	60.7	4	8.2	N
Utah	Modena	38.1	−24	8.9	W
	Salt Lake City	40.0	−20	4.9	SE
Vt.	Burlington	29.3	−27	12.9	S
Va.	Norfolk	49.1	2	9.0	N
	Lynchburg	45.2	−7	5.2	NW
	Richmond	47.4	−3	7.4	S
Wash.	Seattle	45.3	3	9.1	SE
	Spokane	37.5	−30	.....	SW
W. Va.	Elkins	38.8	−21	4.8	W
	Parkersburg	41.9	−27	6.6	S
Wis.	Green Bay	28.6	−36	12.8	SW
	La Crosse	31.2	−43	5.6	NW
	Milwaukee	33.0	−25	11.7	W
Wyo.	Sheridan	31.0	−45	5.3	NW
	Lander	28.9	−36	3.0	NE
Alta.	Edmonton	23.3	−57	4.5	W
B. C.	Victoria	43.8	−2	8.9	N
B. C.	Vancouver	41.7	2	4.2	E
Man.	Winnipeg	17.2	−46	12.4	SW
N. B.	Fredericton	27.1	−35	8.7	NW
N. S.	Yarmouth	35.5	−12	13.0	NW
Ont.	London	32.5	−26	.....	....
Ont.	Ottawa	26.9	−33	7.5	W
Ont.	Pt. Arthur	21.6	−51	.....	....
Ont.	Toronto	32.0	−26	13.5	SW
P. E. I.	Charlottetown	30.1	−23	8.7	NW
Que.	Montreal	27.4	−27	15.4	SW
Que.	Quebec	24.4	−34	15.0	SW
Sask.	Prince Albert	14.7	−70	3.2	SW
Yukon	Dawson	1.6	−68	.....	....

The outside temperature to be assumed in the design of any heating system must not be more than 15 deg above the lowest recorded temperature as reported by the Weather Bureau (Table 3) during the preceding 10 years for the locality in which the heating system is to be installed. In the case of massive and well-insulated buildings in localities where the minimum does not prevail for more than a few hours, it is possible that more than 15 deg above the minimum may be allowed, due primarily to the *fly-wheel* effect of the heat capacity of the structure. The outside temperature assumed and used in the design should always be stated in the heating specifications.

If Weather Bureau reports are not available for the locality in question, then the reports for the station nearest to this locality are to be used, unless some other temperature is specifically stated in the specifications.

In computing the average heat transmission losses for the heating season in the United States the average outside temperature from October 1 to May 1, shall be used. This is to be that reported by the U. S. Weather Bureau during the preceding 10 years, for the locality in question.

Summer

The maximum cooling load in summer may be calculated for an outside dry-bulb temperature not to exceed 95 F and a wet-bulb temperature not to exceed 77 F. While higher outside dry-bulb temperatures are frequently observed they are either of short duration or accompanied by low relative humidities. Weather Bureau reports are frequently misleading in this respect as they report the maximum temperature for the day with the relative humidity, which occurs during a different period and which usually is much higher than the relative humidity occurring at the maximum temperature. Any statement of weather condition which gives a wet-bulb temperature higher than 80 F in the United States is questionable.

WIND MOVEMENT

The effect of wind on the heating requirements of any building should be given consideration under two heads:

1. Wind movement increases the heat transmission of walls, glass, and roof, affecting poor walls to a much greater extent than good walls.

2. Wind movement materially increases the infiltration (inleakage) of cold air through the cracks around doors and windows, and even through the building materials themselves, if such materials are at all porous.

It is entirely possible that a building may require more heat on a windy day with a moderately low outside temperature than on a quiet day with a much lower outside temperature. It will, therefore, be evident that the wind movement in any locality must be given careful consideration in computing the probable heating requirements of a building, and for the purposes of calculation, not less than the average wind movement in any locality during December, January and February should always be provided for in computing (1) the heat transmission of a building, and (2) the heat required to take care of the infiltration of outside air.

The first condition is readily taken care of, as explained in Chapter 3, by using a surface coefficient f_o for the outside wall surface, which is based on the proper wind velocity. In case specific data are lacking for any given locality, it is sufficiently accurate to use an average wind velocity of approximately 15 mph which is the velocity upon which the heat transmission coefficient tables in Chapter 3, are based.

In a similar manner, the heat allowance for infiltration through cracks and walls (Tables 1 and 2, Chapter 4) must be based on the proper wind velocity for a given locality, as explained in Chapter 4. In the case of *tall buildings*, special attention must be given to infiltration factors, as also explained in Chapter 4.

Wind movement involves both *direction* and *velocity*, and hence after transmission and infiltration losses have been computed, using coefficients which allow for the proper velocity, a further allowance must be made for the direction of the prevailing wind in any given locality. This shall be done by adding 15 per cent to the wall and glass transmission losses and the infiltration losses on the sides of the building exposed to the prevailing winds. Those walls which lie in the two adjacent sides of the building most nearly facing the prevailing wind are to be considered in making this correction. (See Fig. 8, Chapter 4). This is not necessarily the same as adding 15 per cent to the total heat loss of a room on the exposed sides of the building.

The correction for exposure to the prevailing wind may also be made by using the average *prevailing* wind velocity for sides exposed to the prevailing winds and the average *non-prevailing* wind velocity for other sides of the building. The most common practice, however, is to use the average wind velocity during the three coldest months of the year for estimating the infiltration losses for all sides of the building and to add 15 per cent to both the infiltration and transmission losses on the sides exposed to the prevailing wind.

HEAT SOURCES

Heat Available from Sources other than Heating Plant

The heat supplied by persons, lights, motors and machinery should always be ascertained in the case of theaters, assembly halls, and industrial plants, but allowances for such heat sources must be made only after careful consideration of all local conditions. In many cases, these heat sources should not be allowed to affect the size of the installation at all, although they may have a marked effect on the operation and control of the system later. In general, it is safe to say that where audiences are involved, the heating installation must have sufficient capacity to bring the building up to the stipulated inside temperature before the audience arrives. In industrial plants, quite a different condition exists, and heat sources, if they are always available during the period of human occupancy, may be substituted for a portion of the heating installation. In no case should the actual heating installation (exclusive of heat sources) be reduced below that required to maintain at least 40 F in the building.

Motors and the machinery which they drive, if both are located in the room, convert all of the electrical energy supplied into heat, which is

retained in the room if the product being manufactured is not removed until its temperature is the same as the room temperature.

If power is transmitted to the machinery from the outside, then only the heat equivalent of the brake horsepower supplied is used. In the first case the Btu supplied per hour = $\frac{\text{Motor horsepower}}{\text{Efficiency of motor}} \times 2{,}546$, and in the second case Btu per hour = bhp. × 2,546, in which 2,546 is the Btu equivalent of 1 hp-hour. In high-powered mills this is the chief source of heating and is frequently sufficient to overheat the building even in zero weather, thus requiring cooling by ventilation the year round.

The heat (in Btu per hour) from electric lamps is obtained by multiplying the watts per lamp by the number of lamps and by 3.415. One cubic foot of producer gas gives off about 150 Btu per hour; one cubic foot of illuminating gas gives off about 535 Btu per hour, and one cubic foot of natural gas gives off about 1000 Btu per hour. A Welsbach burner averages 3 cu ft of gas per hour and a fish tail burner, 5 cu ft per hour.

The rate of heat dissipation to the atmosphere by persons depends upon the height and weight of the individuals and state of activity, and for other than moderate temperatures, it varies somewhat with the effective temperature (see Fig. 1, Chapter 28). As an engine for performing mechanical work, the human body is extremely inefficient, and hence the major part of the energy transformation within the body as determined by metabolism is dissipated as heat. Table 2, Chapter 28, gives the metabolic rates at moderate temperatures for an average size man for various degrees of activity in Btu per square foot per hour. This is the total rate of heat dissipation from the body which is divided into sensible and latent heat loss in percentages, varying widely with the temperature and humidity of the atmosphere. See Figs. 5, 6 and 7, Chapter 28.

For intermittent heating allow 10 per cent additional for rooms heated in the day time only, and for longer intervals of several days or more, add 25 per cent in determining minimum heating requirements, and size of plant.

EXAMPLES OF HEAT LOSS COMPUTATIONS

Factory Building. (See Fig. 1.)

1. LOCATION.....Philadelphia, Pa.

2. LOWEST OUTSIDE TEMPERATURE. (Table 3).....– 6 F

3. BASE TEMPERATURE:

In this example a design temperature 10 deg F above lowest on record instead of 15 deg F is used. Hence the base temperature =

$$(-6 + 10) = +4 \text{ deg F.}$$

4. DIRECTION OF PREVAILING WIND (during Dec., Jan., Feb.).....Northwest

5. BREATHING-LINE TEMPERATURE (5 ft from floor).....60 F

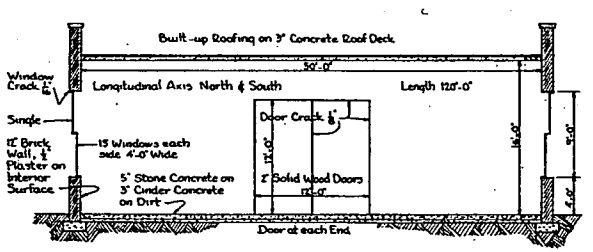


FIG. 1. ELEVATION OF FACTORY BUILDING

TABLE 4. CALCULATION SHEET SHOWING METHOD OF ESTIMATING HEAT LOSSES OF BUILDING SHOWN IN FIG. 1

PART OF BUILDING	EXPOSURE	WIDTH IN FEET	HEIGHT IN FEET	NET SURFACE AREA OR CRACK LENGTH	COEFFICIENT	TEMP. DIFF.	NET BTU	EXPOSURE FACTOR	TOTAL BTU
Brick, 1/2 in. plaster	N	50	16	656	0.277	59.6	10,820	1.15	12,460
Doors (2 in. Wood)	N	12	12	144	0.382	57.2	3,150	1.15	3,620
1/8 in. Crack	N	1 pair doors		60	3.34	57.2	11,440	1/2[a] x 1.15	6,580
Brick, 1/2 in. plaster	W	120	16	1380	0.277	59.6	22,800	1.15	26,200
Glass, (Single)	W	15 x 4	9	540	1.13	60.2	36,800	1.15	42,400
1/8 in. Crack	W	Double Hung Windows (15)		450	1.67	60.2	45,200	1/2[a] x 1.15	26,000
South Wall	Same as N	See Above						1/2[a]	19,690
East Wall	Same as W	See Above						1/2[a]	82,200
Roof, 3 in. Concrete and Slag-surfaced built-up roofing.	No Ceiling	50	120	6000	0.610	69.3	254,000	None	254,000
Floor, 5 in. Stone Concrete on 3 in. Cinder Concrete.	On Dirt	50	120	6000	0.521	5	15,630	None	15,630
GRAND TOTAL of heat required for building in Btu per hour at + 4 deg with 11-mile northwest wind.									488,780

[a]*Notes.*—(1) This building has no partitions and whatever air enters through the cracks on the windward side must leave through the cracks on the leeward side. Therefore, only one-half of the total crack will be used in computing infiltration for each side and each end of building.

(2) An exposure allowance of 15 per cent is also to be added to the wall and glass transmission losses and to the infiltration losses on the two adjacent sides of the building most nearly facing the prevailing wind as stated on page 17.

(3) It is also possible to compute the heat required to take care of infiltration on the basis of half of an air change per hour as given in Table 3, Chapter 4 for a factory with minimum conditions. Volume = 50 × 120 ×16 = 96,000 cu ft and heat required per hour is

$$96{,}000 \times \tfrac{1}{2} \times 0.075 \times 0.24 \times 59.6 = 51{,}500 \text{ Btu}$$

Based on infiltration through one-half the total crackage in all walls, the heat to be supplied per hour is from Table 4,

$$6{,}580 + 26{,}000 + 5{,}720 + 22{,}600 = 60{,}900 \text{ Btu}$$

The value based on crackage should be used, but if building is to be heated intermittently, not less than one air change per hour should be allowed.

6. INSIDE AIR TEMPERATURE AT ROOF:

The air temperature just below *roof* is higher than at the breathing line. Height of roof is 16 ft, or it is 16 − 5 = 11 ft above breathing line. Allowing 2 per cent per foot above 5 ft, or 2 × 11 = 22 per cent, makes the temperature of the air under the roof = 1.22 × 60 = 73.3 F.

7. INSIDE TEMPERATURE AT WALLS:

The air temperature at the mean height of the *walls* is greater than at the breathing line. The mean height of the walls is 8 ft and allowing 2 per cent per foot above 5 ft, the average mean temperature of the walls is 1.06 + 60 = 63.6 F. By similar assumptions and calculations, the mean temperature of the *glass* will be found to be 64.2 F and that of the *doors* 61.2 F.

8. AVERAGE WIND VELOCITY (Table 3).....11.0 mph

9. OVER-ALL DIMENSIONS (See Fig. 1).....120 x 50 x 16 ft

10. CONSTRUCTION:

Walls—12-in. brick, with ½-in. plaster applied directly to inside surface.
Roof—3-in. stone concrete and built-up roofing.
Floor—5-in. stone concrete on 3-in. cinder concrete on dirt.
Doors—One 12 ft x 12 ft wood door (2 in. thick) at each end.
Windows—Fifteen, 9 ft x 16 ft single glass double-hung windows on each side.

11. TRANSMISSION COEFFICIENTS:

Walls—(Table 9, Chapter 3)..... $U = 0.277$
Roof—(Table 29, Chapter 3)..... $U = 0.610$
Floor—(Table 28, Chapter 3)..... $U = 0.521$
Doors—(Table 33B, Chapter 3)..... $U = 0.382$
Windows—(Table 33A, Chapter 3)..... $U = 1.13$

12. INFILTRATION COEFFICIENTS:

Windows—Crack assumed 1/16 in. The leakage per foot of crack for an 11-mile wind velocity is 92.7 cfh, for a plain window. (By interpolation from Table 2, Chapter 4). The heat equivalent per hour per degree is

$$92.7 \times 0.075 \times 0.24 = 1.67 \text{ Btu}$$

Doors—Assume infiltration loss through door crack twice that of windows or

$$2 \times 1.67 = 3.34 \text{ Btu}$$

13. CALCULATIONS:

See calculation sheet, Table 4.

Residence. (See Fig. 2.)

1. LOCATION.....Chicago, Ill.
2. LOWEST OUTSIDE TEMPERATURE (Table 3).....− 23 F
3. BASE TEMPERATURE.....(− 23 + 15) = − 8 F
4. DIRECTION OF PREVAILING WIND (during Dec., Jan., Feb., Table 3).....Southwest
5. INSIDE TEMPERATURE.....70 F
6. TEMPERATURE DIFFERENCE (item 5 − item 3).....78 F
7. AVERAGE WIND VELOCITY (during Dec., Jan., Feb., Table 3).....17 mph

8. CONSTRUCTION:

Walls—Wood siding, building paper, wood sheathing, studding, wood lath and plaster.
Roof—Wood shingles on 1 x 4 strips spaced 2 in.
Attic Ceiling—Wood lath and plaster on roof rafters
First Floor (over basement)—Maple flooring on rough flooring on floor joists
Doors (outside)—Three, 3 ft x 7 ft x 1¾ in.; one, 2 ft 8 in. x 7 ft x 1¾ in. No weatherstripping
Windows—Double-hung, single glass, weatherstripped.

9. TRANSMISSION COEFFICIENTS:

Walls—(Table 21, Chapter 3)..... $U = 0.262$
Roof (including attic ceiling)—(Table 31, Chapter 3)..... $U = 0.288$
Floor (over basement)—(Table 26, Chapter 3)..... $U = 0.339$

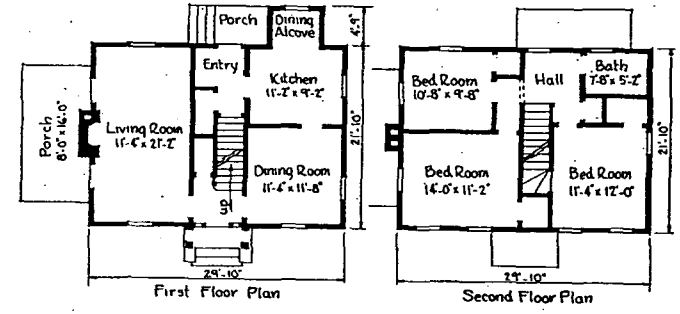


FIG. 2. FLOOR PLAN OF SIX-ROOM RESIDENCE
(Plan 6-F-3, Architects Small House Service Bureau.)

Doors—(Table 33B, Chapter 3)..... $U = 0.421$
Windows—(Table 33A, Chapter 3)..... $U = 1.13$

10. INFILTRATION COEFFICIENTS:

Windows—The leakage per foot of crack for weatherstripped, double-hung, wood sash windows is 27.7 cu ft per hour for a 17-mile wind velocity. (By interpolation from Table 2, Chapter 4). The heat equivalent is

$$27.7 \times 0.075 \times 0.24 = 0.5 \text{ Btu per hour per foot of crack.}$$

Doors—Assume 1/16 in. crack. Leakage = 139 cu ft per hour. (Table 2, Chapter 4). The heat equivalent is

$$139 \times 0.075 \times 0.24 = 2.50 \text{ Btu per hour per foot of crack.}$$

11. CALCULATIONS:

See summary of heat loss calculations, Table 5-A, and heat loss calculation sheet for living room, Table 5-B.

TABLE 5-A. SUMMARY OF HEAT LOSS CALCULATIONS FOR RESIDENCE SHOWN IN FIG. 2

Room or Space No.	Room	Glass Transmission Losses	Other Transmission Losses	Infiltration Losses	Total
1	Living Room	7,100	9,040	8,970	25,110
2	Dining Room	2,640	4,640	742	8,022
3	Kitchen	1,060	3,300	663	5,023
4	Dining Alcove	1,370	3,718	807	5,895
5	Entry	1,888	1,312	4,320	7,520
6	Vestibule	1,854	1,436	3,900	7,190
7	Bedroom (A) and Closet	3,773	3,558	1,445	8,776
8	Bedroom (B) and Closet	3,960	4,070	1,445	9,475
9	Bedroom (C) and Closet	2,900	3,765	1,660	8,325
10	Upstairs Hall	1,450	920	1,660	4,030
11	Bath	1,450	1,940	1,660	5,050
12	Attic (heated)	3,040	28,021	1,125	32,186
GRAND TOTAL of heat required for building in Btu per hour at −8 F with a 17-mile southwest wind					126,602

TABLE 5-B. HEAT LOSS CALCULATION SHEET FOR LIVING ROOM (FIG. 2)

Part of Building	Exposure	Net Surface Area or Crack Length	Coefficient	Temp. Difference	Net Btu	Exposure Factor	Total Btu
Wall	E	75.6	0.263	78	1,550		1,550
Glass	E	15.0	1.13	78	1,320		1,320
Crack 1/16 in.[a]	E	19.0	0.5	78	(742)[d]		
Wall[b]	S	127.6	0.263	78	2,620	1.15	3,010
Doors	S	42.0	1.13[c]	78	3,710	1.15	4,260
Crack 1/16 in.	S	40.0	2.50	78	7,800	1.15	8,970[d]
Wall	W	75.6	0.263	78	1,550	1.15	1,780
Glass	W	15.0	1.13	78	1,320	1.15	1,520
Crack 1/16 in.[a]	W	19.0	0.50	78	(742)[d]		
Floor	Over Basement	241.0	0.339	33[e]	2,700		2,700
GRAND TOTAL of heat required for room in Btu per hour at −8 F with a 17-mile southwest wind							25,110

[a] Windows weatherstripped.

[b] Chimney figured as part of wall, that is, of the same construction.

[c] Transmission coefficient taken same as glass for entire door.

[d] Three sides of this room are exposed and therefore only the wall having the greatest infiltration loss is used in estimating the total leakage for the room. If the infiltration loss for the south side of the room containing the two outside doors had been less than half the total infiltration loss for the room, then half the total leakage would have been used.

[e] Air temperature at floor assumed 65 F. Air temperature in basement assumed 32 F.

Chapter 3

HEAT TRANSFER THROUGH MATERIALS AND CONSTRUCTIONS

Transmission Coefficients by Test; Transmission Coefficients by Computation; Areas where Transmission Losses Occur; Calculations for Transmission Losses; Condensation on Building Surfaces; Sun Effect on Buildings.

THIS chapter relates primarily to the loss of heat by conduction through solid materials, such as the exterior walls, roof, glass, etc. of a building, under equilibrium conditions. These *transmission losses*, as they are termed, are computed by taking into account the heat transmission coefficients of the various structural members involved. (See par. 5, p. 11). These coefficients may be determined experimentally by test, or they may be calculated with sufficient accuracy when certain physical constants are known.

TRANSMISSION COEFFICIENTS BY TEST

The standard method of testing built-up wall sections is by means of the *guarded hot-box*.[1] The *Nicholls Heat Meter*[2] may be used for testing actual walls of buildings.

If the hot-box method is used, tests are usually run under still-air conditions, which means there was no wind movement during the test over the surfaces of the wall. In practice, some wind movement over the exterior surface of the wall should always be allowed for; hence, still-air coefficients cannot be used in actual work as they do not provide for the normal wind movement over the outside of the building in the locality in question during the heating season. Moreover, still-air transmission coefficients cannot be corrected to provide for moving-air conditions by multiplying by a single constant factor.

It would be obviously impossible to determine the air-to-air heat transmission coefficients of every type of wall construction in use with the heat meter or the hot-box on account of the great amount of time involved. Hence, the method of computing the coefficients from fundamental constants must be resorted to in most cases, but heat-meter and the hot-box tests can be used to good advantage in checking the accuracy of the computed values.

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[1] See *Standard Code for Heat Transmission through Walls* (A.S.H.V.E. TRANSACTIONS, Vol. 34, 1928).

[2] See *Measuring Heat Transmission in Building Structures and a Heat Transmission Meter*, by P. Nicholls (A.S.H.V.E. TRANSACTIONS, Vol. 30, 1924).

TRANSMISSION COEFFICIENTS BY COMPUTATION

Symbols and Definitions

The following symbols which are in agreement with the recommendations of the Committee on Heat Transmission of the *National Research Council* are used in the heat transmission formulae in this chapter:

U = Thermal transmittance or over-all coefficient of heat transmission and is the amount of heat expressed in Btu transmitted in one hour per square foot of the wall, floor, roof or ceiling for a difference in temperature of 1 deg F between the air on the inside and outside of the wall, floor, roof or ceiling.

k = Thermal conductivity and is the amount of heat expressed in Btu transmitted in one hour through 1 sq ft of a homogeneous material 1 in. thick for a difference in temperature of 1 deg F between the two surfaces of the material. The conductivity of any material depends on the structure of the material and its density. Heavy or dense materials, the weight of which per cubic foot is high, usually transmit more heat than light or less dense materials, the weight of which per cubic foot is low.

C = Thermal conductance and is the amount of heat expressed in Btu transmitted in one hour through 1 sq ft of a non-homogeneous material for the thickness or type under consideration for a difference in temperature of 1 deg F between the two surfaces of the material. Conductance is usually used to designate the heat transmitted through such heterogeneous materials as plaster board and hollow clay tile.

f = Film or surface conductance and is the amount of heat expressed in Btu transmitted by radiation, conduction and convection from a surface to the air surrounding it, or vice versa, in one hour per square foot of the surface for a difference in temperature of 1 deg between the surface and the surrounding air. To differentiate between inside and outside wall (or floor, roof or ceiling) surfaces, f_i is used to designate the inside surface or film-conductance and f_o the outside surface or film-conductance.

a = Thermal conductance of an air space and is the amount of heat expressed in Btu transmitted by radiation, conduction and convection in one hour through an area of 1 sq ft of an air space for a temperature difference of 1 deg F. The conductance of an air space depends on the mean absolute temperature, the width, the position and the character of the materials enclosing it.

R = Resistance or resistivity, the reciprocal of transmission, conductance or conductivity, *i.e.:*

$\frac{1}{U}$ = over-all or air-to-air resistance.

$\frac{1}{k}$ = internal resistivity.

$\frac{1}{C}$ = internal resistance.

$\frac{1}{f}$ = surface or film-resistance.

$\frac{1}{a}$ = air-space resistance.

x = thickness in inches.

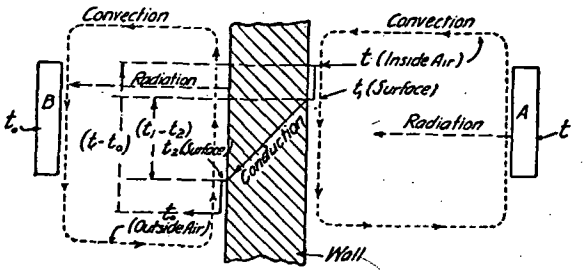
Fundamental Formulae

If heat transmission coefficients are to be computed, and in many, if not most cases, they should be computed, the following analysis of the transmission of heat through a simple, solid wall is used as the basis for such computations.

The diagram in Fig. 1 exhibits four important temperatures: *First*, the air temperature t inside of the building; *second*, the temperature t_1 of the inside surface of the wall; *third*, the temperature t_2 of the outside surface of the wall, and *fourth*, the air temperature t_o outside of the building.

Heat reaches or enters the inside surface of the wall by radiation and convection, since the air and objects A within the building are always warmer than the inside surface of the wall, when the inside air temperature t is greater than the outside air temperature t_o. This heat must then pass through the material of the wall from inside to outside surface by conduction, and is finally given off from the outside surface by radiation and convection, provided, of course, that equilibrium has been established and all four temperatures are constant.

The amount of heat reaching or entering the wall per hour depends on t and t_1 and the coefficient f_i varying with the character of the wall material. The symbol f_i may be defined as the Btu per hour entering each square foot of wall surface per degree difference between the inside air temperature t and the inside surface temperature t_1. Hence, the heat



A represents warm surfaces at temperature t of inside air;
B represents cold surfaces at temperature t_o of outside air.

FIG. 1. TEMPERATURE CURVE OR GRADIENT FROM AIR INSIDE TO AND THROUGH WALL TO AIR OUTSIDE, WALL MATERIAL ASSUMED AIR-TIGHT

received by the inner surface of the wall per hour by both radiation and convection is:

$$H_1 = f_i\,(t - t_1)\,S \tag{1}$$

where S is the inner-wall surface area in square feet and the other terms are as heretofore indicated.

Whatever amount of heat H_1 enters the inner-wall surface must be given off from the outer-wall surface, so that if H_2 represents heat emitted from outer surface,

$$H_1 = H_2 = f_o\,(t_2 - t_o)\,S \tag{2}$$

Now f_o may not equal f_i, in which case $(t_2 - t_o)$ will not equal $(t - t_1)$. Usually, in an actual wall exposed to wind on the outside, f_o (Table 2) is greater than f_i and $(t_2 - t_o)$ must be less than $(t - t_1)$. Moreover, the heat H_c passing through the wall by conduction is equal to H_1 and H_2, and if k is the thermal conductivity expressed in Btu transmitted per hour per square foot of material per 1 in. thickness per degree difference between the surface temperatures, then

$$H_1 = H_2 = H_c = \frac{k}{x}\,(t_1 - t_2)\,S \tag{3}$$

where x = wall thickness in inches.

These equations 1, 2 and 3 are fundamental and are used for determining values for f_i, f_o and k for actual wall materials by test. They cannot be used for computing heat losses in an actual building, since the surface temperatures t_1 and t_2 are seldom known, although these surface temperatures can be determined in a test by means of thermocouples. Hence, for actual conditions where the only temperatures known are the inside and outside air temperatures t and t_o, it is necessary to use the transmission coefficient U = Btu transmitted per hour per square foot of wall surface per degree difference between the inside and outside air temperatures. Values of U for many common types of construction are given in Tables 9 to 33, inclusive. The heat H transmitted per hour from air inside to air outside is then computed as follows:

$$H = U\,(t - t_o)\,S \tag{4}$$

TABLE 1. SURFACE COEFFICIENTS (f_i) FOR VARIOUS BUILDING MATERIALS UNDER STILL AIR (NO WIND) CONDITIONS

THE VALUES IN THE TABLE ARE IN BTU PER SQUARE FOOT OF WALL SURFACE PER HOUR PER 1 DEG F DIFFERENCE BETWEEN THE MEAN AIR TEMPERATURE IN THE ROOM AND THE INSIDE SURFACE TEMPERATURE OF THE WALL.

BUILDING MATERIAL	SURFACE COEFFICIENT f_i (STILL AIR)	
	Harding and Willard	Wood
Asbestos (sheet)	1.40	.....
Brickwork (ordinary)	1.40	.....
Cement Plaster (finished)	0.93	.....
Concrete	1.30	.....
Corkboard	1.25	1.20
Glass (window)	1.50	1.90[a]
Magnesia (blocks)	1.45	.....
Wood (finished surface)	1.40	.....
Building paper	.....	1.40
Average of all values	1.34	.....

[a]Average of both sides of glass 0.12 in. thick and for 70 F total temperature difference from air to air with moving air on one side. Probable value for still air on both sides 1.60.

and since $H = H_1 = H_2 = H_c$, the right-hand members of equations 1, 2, 3 and 4 are all equal.

The coefficient U may be computed for any wall provided values for f_i, f_o and k are known. By proper substitution in the four equations, the unknown temperatures t_1 and t_2 can be eliminated and the value of the transmission coefficient for a simple wall x inches thick is:

$$U = \frac{1}{\frac{1}{f_i} + \frac{1}{f_o} + \frac{x}{k}} \tag{5}$$

and for a compound wall of several materials having thicknesses in inches of x_1, x_2, x_3, etc., the coefficient is:

$$U = \frac{1}{\frac{1}{f_i} + \frac{1}{f_o} + \frac{x_1}{k_1} + \frac{x_2}{k_2} + \frac{x_3}{k_3} + etc.} \tag{6}$$

As in the case of the simple wall, f_i and f_o, are always the inside and outside surface coefficients for the two materials in contact with air. If the air is still (no wind), then for the same material f_i and f_o are the same, and $f_i = f_o$; but, if the outside air is in motion, then f_o is always greater than f_i and will increase as the wind velocity increases. Values for f_i in still air, as determined by various investigators, are given in Table 1.

Values for k and C, the conductivity and conductance of building materials and insulations, are given in Tables 4, 5, 6, 7 and 8, and are taken from the published values of various investigators. It should be noted that values of k and C as well as U are dependent on the temperature range, and it is therefore desirable that the investigator determine heat-transmission values under conditions approximating those existing under actual conditions.

TABLE 2. FACTORS TO BE USED IN DETERMINING VALUES OF OUTSIDE SURFACE COEFFICIENTS (f_o) UNDER MOVING AIR CONDITIONS

IN EACH CASE, THE MOVING AIR FACTOR IS BASED ON STILL AIR COEFFICIENT f_i FOR *same* MATERIAL. FOR CONDITIONS WHERE WIND VELOCITY IS NOT KNOWN USE THE FACTOR (3) OR TAKE f_o AS 3 f_i FOR SAME MATERIAL.

WIND VELOCITY IN MILES PER HOUR	BRICKWORK	MULTIPLIERS OF f_i[a] WOOD	AVERAGE
5	2.38	2.19	2.28
10	3.20	2.71	2.96
15	3.76	2.95	3.36[b]
20	4.22	3.02	3.62
Additional Values—Smooth Surface			
10	.....	2.20	.....
20	.....	2.60	.....
Above 20	.....	3.00	.....

[a]Taken from Engineering Experiment Station Bulletin No. 102, of the University of Illinois. Additional values from Engineering Experiment Station, Pennsylvania State College, reported by Professor Wood. Tests at Pennsylvania State College indicate character of surface, rough or smooth, more important than material of surface.

[b]This is usually taken as 3 even.

In the case of air-space construction, an air-space coefficient for each air space must be inserted in either equation 5 or 6. Thus for a simple wall with one air space,

$$U = \frac{1}{\frac{1}{f_i} + \frac{1}{f_o} + \frac{1}{a} + \frac{x}{k}} \tag{7}$$

and for a simple wall of several air spaces having conductances of a_1, a_2, a_3, etc., the coefficient is:

$$U = \frac{1}{\frac{1}{f_i} + \frac{1}{f_o} + \frac{x}{k} + \frac{1}{a_1} + \frac{1}{a_2} + \frac{1}{a_3} + etc.} \tag{8}$$

With certain special forms of materials which have irregular air spaces (such as hollow tile) or are otherwise non-homogeneous, it is necessary

to use the conductance (C) for the unit construction, in which case $\frac{x}{k}$ is replaced by $\frac{1}{C}$.

Air Spaces and Surface Coefficients

The following from Bulletin No. 102 of the Engineering Experiment Station of the *University of Illinois*, is pertinent:

In making calculations for heat transmission coefficients of compound walls, an air space may be treated in either of the following ways: the air space may be regarded as a solid insulating material through which the heat passes according to the so-called conductivity theory or considering the transfer by the three methods, radiation, convection, and conduction, the radiation and convection action may be combined into a single surface coefficient and the true conductivity of the air neglected. For every air space two surface coefficients, accordingly, would be considered. If different surfaces enclosed the air space, different surface coefficients would be used for the two walls.

TABLE 3. CONDUCTANCES OF AIR SPACES[a] AT VARIOUS MEAN TEMPERATURES

MEAN TEMP. DEG. FAHR.	CONDUCTANCES OF AIR SPACES FOR VARIOUS WIDTHS IN INCHES						
	0.128	0.250	0.364	0.493	0.713	1.00	1.500
20	2.300	1.370	1.180	1.100	1.040	1.030	1.022
30	2.385	1.425	1.234	1.148	1.080	1.070	1.065
40	2.470	1.480	1.288	1.193	1.125	1.112	1.105
50	2.560	1.535	1.340	1.242	1.168	1.152	1.149
60	2.650	1.590	1.390	1.295	1.210	1.195	1.188
70	2.730	1.648	1.440	1.340	1.250	1.240	1.228
80	2.819	1.702	1.492	1.390	1.295	1.280	1.270
90	2.908	1.757	1.547	1.433	1.340	1.320	1.310
100	2.990	1.813	1.600	1.486	1.380	1.362	1.350
110	3.078	1.870	1.650	1.534	1.425	1.402	1.392
120	3.167	1.928	1.700	1.580	1.467	1.445	1.435
130	3.250	1.980	1.750	1.630	1.510	1.485	1.475
140	3.340	2.035	1.800	1.680	1.550	1.530	1.519
150	3.425	2.090	1.852	1.728	1.592	1.569	1.559

[a] *Thermal Resistance of Air Spaces*, by F. B. Rowley and A. B. Algren (A.S.H.V.E. TRANSACTIONS, Vol. 35, 1929).

Because reliable air-space conductance values have not been available until recently, it has been the practice in the past, when calculating the heat transmission through constructions containing air spaces, to assign still-air surface values to the surfaces enclosing the air spaces, rather than to consider the air spaces as solid insulating materials. In the 1928 and 1929 editions of THE GUIDE the heat transmission tables were based on the average value of 1.34 for surfaces in still air taken from Table 1, which is equivalent to an air-space conductance of 0.67 Btu per hour per square foot per degree fahrenheit difference in temperature between the two sides.

According to tests conducted at the University of Minnesota, under the direction of Prof. F. B. Rowley, conductances of air spaces for various widths and mean temperatures average somewhat higher than 0.67 (Table 3). These tests indicate that there is practically no increase in the conductance of an air space beyond about 1 in. in width, and that the

average conductance of air spaces of this width or greater at a mean temperature of 40 F is about 1.10 Btu per hour per square foot per degree Fahrenheit difference in temperature, although this value is probably sufficiently accurate for all air spaces of ½ in. or more in width.

Surface coefficients increase with the velocity of air passing over the surface. Factors for determining conductances of outside surfaces under moving-air conditions are given in Table 2. It is the practice to increase the still-air surface coefficient by the factor 3 to allow for moving-air conditions, which is approximately equivalent to a wind exposure of 15 miles per hour. Thus, the conductance of the average surface for still air is 1.34, based on the values given in Table 1, and when increased by the factor 3 to allow for moving air, the outside surface coefficient is 3 × 1.34 or 4.02 Btu per hour per square foot per degree Fahrenheit difference between the surface and the air in contact with it.

The over-all transmission of any wall for a wind exposure other than 15 miles per hour, can be computed by assigning the proper outside surface coefficient, but in most cases the accuracy involved does not warrant this degree of refinement, and it is sufficiently accurate to base all calculations on the one wind exposure. For example: If the heat transmission coefficient of a certain wall is 0.20 based on the outside surface coefficient of 4.02 for a 15-mile wind velocity, this coefficient would not vary more than 1 per cent, plus or minus, for a variation in the wind velocity of 5 miles per hour, plus or minus, based on data contained in Table 2. Computed coefficients are not accurate to this degree of variation in most cases, particularly when it is considered that over-all coefficients will often vary to a much greater extent with the density of the materials used in the construction, the moisture content, the mean temperature, the quality of workmanship, and other factors.

Conductivities and Conductances

The majority of the conductivities and conductances of the building materials and insulations given in Tables 4, 5, 6, 7 and 8 were determined by the hot-plate method of testing.[3] Attention is called to the fact that conductivities per inch of thickness of materials or insulations do not afford a true basis for comparison, although they are frequently used for that purpose. Correct comparisons should take into consideration many different factors, including conductivities or conductances, thicknesses installed, manner of installation, etc., while the selection of an insulation should also give consideration to structural qualities, as well as material and application costs. At present there is no universally recognized method of rating insulations. Conductivities and conductances of building materials and insulations are useful to the heating engineer in determining over-all coefficients of heat transmission of walls, floors, roofs and ceilings.

Computed Transmission Coefficients

As previously stated heat transmission coefficients of many common types of building construction are given in Tables 9 to 33, inclusive, each construction being identified by a serial number. For example: The co-

[3] See *Standard Test Code for Heat Transmission through Walls* (A.S.H.V.E. TRANSACTIONS, Vol. 34, 1928).

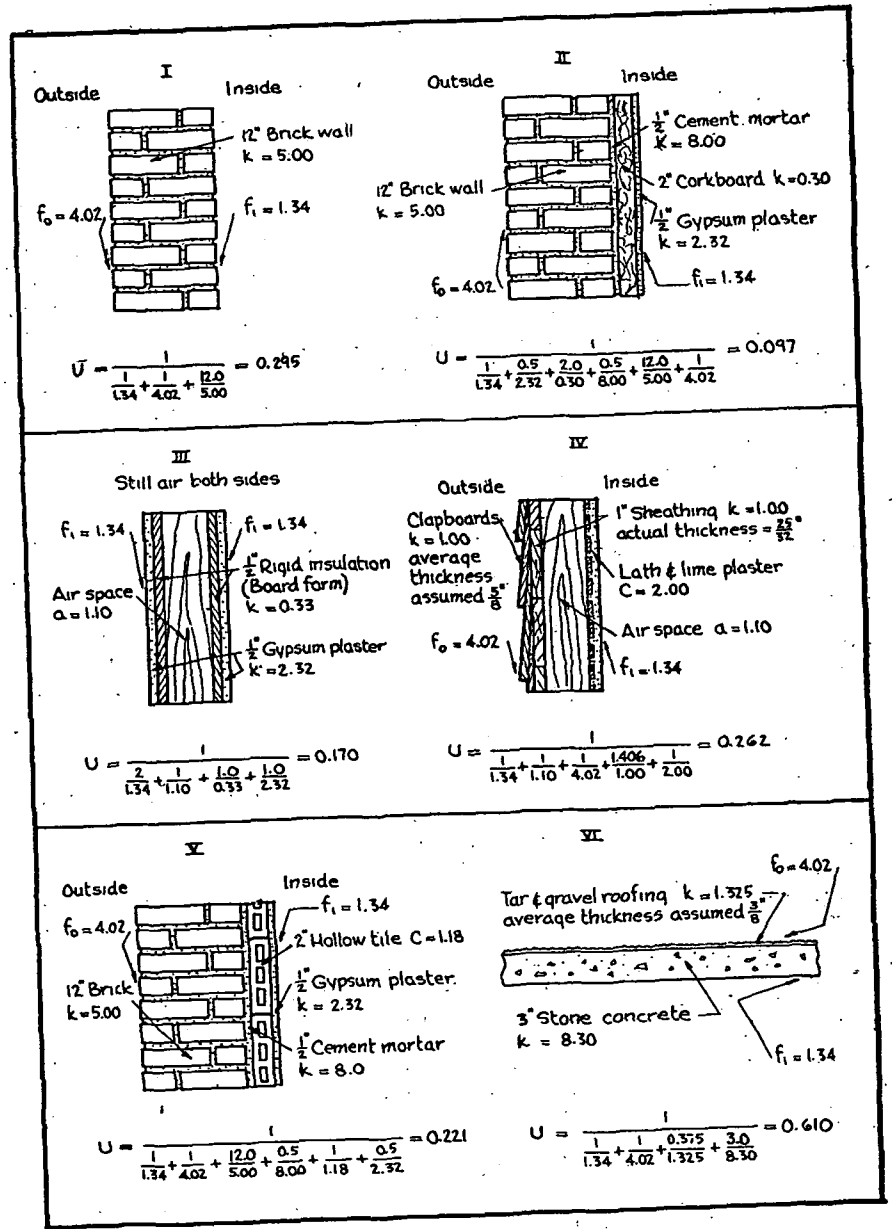


FIG. 2. EXAMPLES SHOWING METHOD OF COMPUTING HEAT TRANSMISSION COEFFICIENTS OF VARIOUS TYPES OF CONSTRUCTION

efficient of transmission (U) of a 12-in. brick wall, furring strips, and ¾-in. of gypsum plaster on metal lath, is 0.216, and the number assigned to a wall of this construction is *3-B*, Table 9.

The coefficients in these tables were determined by computations similar to those shown in Fig. 2, using the value of k (or C) indicated. The authorities for the conductivities used for computing these coefficients are given in Tables 4, 5, 6, 7 and 8. As in the case of the examples in Fig. 2, the average value of 1.34 given in Table 1 for f_i was used for all surfaces in still air. The value of f_o for outside wall and roof surfaces was taken as $3 \times f_i$, or 4.02, corresponding to a wind velocity of approximately 15 miles per hour. The conductance of air spaces ½ in. or more in width was taken to be 1.10 Btu per hour per square foot per degree Fahrenheit difference between the two sides enclosing the air space. (See Table 3.)

Problems involving the determination of the value of U from the conductivity constants can also be solved by what is sometimes known as the resistance method which is readily derived from the basic equation No. 5 as follows:

$$\frac{1}{U} = \frac{1}{f_i} + \frac{1}{f_o} + \frac{x}{k} = \Sigma\,[R_i + R_o + R_r]$$

or

$$U = \frac{1}{\Sigma\,[R_i + R_o + R_r]} \qquad (9)$$

The internal resistance of a material is equal to the reciprocal of its so-called internal conductivity (k) multiplied by its thickness and is represented by the fraction $\frac{x}{k}$, or $\frac{1}{C}$, in the case of materials for which the conductance is given in terms of the construction or thickness stated. For example: The internal resistance of 12 in. of brickwork on the basis of a value of k of 5.0 is $\frac{12}{5}$ or 2.40. The internal resistance of 2-in. hollow clay tile based on the value of C of 1.18 is $\frac{1}{1.18}$ or 0.847.

In the resistance method, the sum of the internal resistances of all the materials entering into the construction, is added to the sum of the surface resistances, which are the reciprocals of the surface coefficients or $\frac{1}{f}$. The resistance of a surface in still air, based on the average value of f_i or 1.34 is $\frac{1}{1.34}$ or 0.746. The resistance of an outside surface exposed to the wind, based on the average value of f_o or 4.02 (3×1.34) is $\frac{1}{4.02}$ or 0.249. The computed value of U obtained by the resistance method is obtained by taking the reciprocal of the sum of the internal and surface resistances of the construction. The solution of Example V in Fig. 2, by means of the resistance method is given in the summary on page 33.

TABLE 4. CONDUCTIVITIES (k) AND CONDUCTANCES (C) OF BUILDING MATERIALS AND INSULATIONS

Tests Conducted at the U. S. Bureau of Standards.[p] *Insulation Tests Based on Samples Submitted by Manufacturers*

Note.—THE COEFFICIENTS IN TABLES 4-8, INCL., ARE EXPRESSED IN BTU PER HOUR PER SQUARE FOOT, PER 1 DEG F, PER 1 IN. THICKNESS UNLESS OTHERWISE INDICATED BY NOTE [b].

MATERIAL	DESCRIPTION	DENSITY (LB. PER CU. FT.)	MEAN TEMP. (DEG. FAHR.)	CONDUCTIVITY (k) OR CONDUCTANCE (C)[a]
Asbestos Wood	Asbestos and cement compressed	123.0	86	2.70
Asbestos Mill Board	Pressed asbestos	60.5	86	0.84
Balsam Wool[b]	Chemically treated wood fiber between layers of paper	2.2	90	0.27
Cabots Quilt[b]	Eel grass between Kraft paper	4.6	90	0.26
Cabots Quilt[b]	Eel grass between Kraft paper	3.4	90	0.25
Celotex	Rigid insulation made from sugar cane fiber	13.2	90	0.34
Corkboard	Pure; no added binder	14.0	90	0.34
Corkboard	Pure; no added binder	10.6	90	0.30
Corkboard	Pure; no added binder	7.0	90	0.27
Corkboard (Eureka)	Asphaltic binder	14.5	90	0.32
Dry Zero[b]	Kapok between burlap or paper	1.0	90	0.24
Fibrofelt[b]	Flax and rye fiber	13.6	90	0.32
Flaxlinum[b]	Flax fiber	13.0	90	0.31
Gyplap	Gypsum between layers of heavy paper (½ in. thick)	53.5	90	2.60[b]
Hairinsul[b]	75% hair; 25% jute	6.3	90	0.27
Hairinsul[b]	50% hair; 50% jute	6.1	90	0.26
Hair Felt[b]	Felted cattle hair	13.0	90	0.26
Hair Felt[b]	Felted cattle hair	11.0	90	0.26
Insulex or Pyrocell	Cellular gypsum—dry	30.0	90	1.00
Insulex or Pyrocell	Cellular gypsum—dry	24.0	90	0.77
Insulex or Pyrocell	Cellular gypsum—dry	18.0	90	0.59
Insulex or Pyrocell	Cellular gypsum—dry	12.0	90	0.44
Insulite	Rigid insulation made from wood pulp	16.9	90	0.34
Linofelt[b]	Flax fibers between paper	4.9	90	0.28
Lith	Rock wool, flax and straw pulp with binder	14.3	90	0.40
Magnesia (Rigid)	85% magnesia, 15% asbestos	19.3	86	0.51
Plaster	Gypsum	46.2	86	2.32[i]
Regranulated cork	About ⅛ in. particles	8.1	90	0.31
Rock cork	Rock wool block with binders	16.7	86	0.37
Rock wool	Fibrous material, made from rock	10.0	90	0.27
Rock wool	Fibrous material, made from rock	14.0	90	0.28
Rock wool	Fibrous material, made from rock	18.0	90	0.29
Rock wool	Fibrous material, made from rock	21.0	90	0.30
Sawdust	Ordinary	.....	86	1.04
Shavings	Ordinary	.....	86	0.71
Sheetrock	Gypsum mixed with sawdust between layers of heavy paper (0.39 in. thick)	60.7	90	3.60[b]
Sprayo-Flake	Shredded paper with silica binder	4.2	94	0.28
Thermofelt[b]	Jute and asbestos fibers, felted	10.0	90	0.37
Thermofelt[b]	Hair and asbestos fibers, felted	7.8	90	0.28
Thermofill	Dry, fluffy, flaked gypsum	34.0	90	0.60
Thermofill	Dry, fluffy, flaked gypsum	26.0	90	0.52
Thermofill[b]	Dry, fluffy, flaked gypsum	19.8	90	0.35
Torfoleum	Peat moss compressed into sheet form	10.2	91.5	0.29
Woods:				
Balsa wood	Across grain	20.0	90	0.58
Balsa wood	Across grain	8.8	90	0.38
Balsa wood	Across grain	7.3	90	0.33
Cypress	Across grain	28.7	86	0.67
Maple	Across grain	44.3	86	1.10
Mahogany	Across grain	34.3	86	0.90
Virginia Pine	Across grain	34.3	86	0.96
White Pine	Across grain	31.2	86	0.78

[a] In addition to the conductivity values for the authorities listed, considerable work of importance pertaining to the heat transmission of various types of construction and materials has been done by the late Prof. John R. Allen and the late Prof. A. J. Wood of the Engineering Experiment Station of Pennsylvania State College.

[b] For thickness stated or used in construction, not per 1 in. thickness.

[h] Not compressed.

[i] The conductivity of plaster varies with the composition. Note range of values from 2.32 to 8.0. The average value for plaster is probably about 5.0. On account of the comparatively high conductivity of plaster and the fact that it is seldom applied more than ¾ in. thick, this material does not appreciably effect the over-all transmission of a construction, excepting in the case of thin uninsulated walls.

[p] See Chapter LX, by Chas. H. Herter of the Report of the Insulation Committee, *A. S. R. E.*, Annual Meeting 1922, Revised to 1924, entitled, Heat Transmission of Insulating Materials for a more comprehensive collection of heat transmission data relating to building and insulating materials.

MATERIAL	THICKNESS INCHES	INTERNAL CONDUCTIVITY OR CONDUCTANCE	SURFACE COEFFICIENTS f_i or f_o	INTERNAL RESISTANCE	SURFACE RESISTANCE
Brickwork	12	5.0 (k)	4.02 (f_o)	2.400	0.249
Cement Mortar	½	8.0 (k)	.....	0.063	.....
Hollow Clay Tile	2	1.18 (C)	.....	0.847	.....
Plaster (gypsum)	½	2.32 (k)	1.34 (f_i)	0.215	0.746
				3.525	0.995
					3.525
Total resistance (R)	.....	.....	.....	.....	4.520

$$U = \frac{1}{R} = \frac{1}{4.520} = 0.221$$ Btu per hour per square foot per degree difference in temperature between the air on the two sides of the wall.

In computing heat transmission coefficients of floors laid directly on the ground (Table 28), only one surface coefficient (f_i) is used. For

TABLE 5. CONDUCTIVITIES (k) AND CONDUCTANCES (C) OF BUILDING MATERIALS AND INSULATIONS

Based on Tests Conducted at the University of Illinois, By A. C. Willard, L. C. Lichty and L. A. Harding [p]

MATERIAL	DESCRIPTION	DENSITY (LB. PER CU. FT.)	MEAN TEMP. (DEG. FAHR.)	CONDUCTIVITY (k) OR CONDUCTANCE (C)[a]
Asbestos	Sheet	48.3	110	0.29
Asbestos Board	Corrugated	20.4	110	0.48
Brickwork	*Mortar bond and dry conditions*	132.0	100	4.00
Brickwork	Damp or wet	.....	.....	5.00[j]
Cement mortar		.....	.....	8.00[f]
Concrete	Stone 1-2-4 mix	140.0	110	8.30
Corkboard	Pure; no added binder	9.7	.....	0.32
2 in. hollow clay tile, ½ in. plaster both sides		120.0	110	1.00[b]
4 in. hollow clay tile, ½ in. plaster both sides		127.0	100	0.60[b]
6 in. hollow clay tile, ½ in. plaster both sides		124.3	105	0.47[b]
Magnesia Board		13.5	110	0.51
Plaster	Cement	.....	.....	8.00[i]
Roofing[b]	Built-up bitumen and felt, gravel or slag surfaced	.....	.....	1.325[d]
Roofing[b]	Built-up bitumen and felt, gravel or slag surfaced	.....	.....	5.30[d-b]
Stucco		.....	.....	8.00[f]
Wood (Fir, one-surface finished)	Across grain	33.4	.....	1.00

[a] In addition to the conductivity values for the authorities listed, considerable work of importance pertaining to the heat transmission of various types of construction and materials has been done by the late Prof. John R. Allen and the late Prof. A. J. Wood of the Engineering Experiment Station of Pennsylvania State College.

[b] For thickness stated or used in construction, not per 1 in. thickness.

[d] Calculated from 2 in. tile tests.

[f] Cement mortar and stucco assumed same as cement plaster.

[b] Roofing, 0.15 in. thick (1.34 lb per sq ft), covered with gravel (0.83 lb per sq ft), combined thickness assumed 0.25.

[i] The conductivity of plaster varies with the composition. Note range of values from 2.32 to 8.0. The average value for plaster is probably about 5.0. On account of the comparatively high conductivity of plaster and the fact that it is seldom applied more than ¾ in. thick, this material does not appreciably effect the over-all transmission of a construction, excepting in the case of thin uninsulated walls.

[j] Recommended value. See *Mechanical Equipment of Buildings*, by Harding and Willard, Vol. I, second edition, 1929, p. 182.

[p] See Chapter LX, by Chas. H. Herter of the Report of the Insulation Committee, *A. S. R. E.*, Annual Meeting, 1922, Revised to 1924, entitled, Heat Transmission of Insulating Materials for a more comprehensive collection of heat transmission data relating to building and insulating materials.

TABLE 6. CONDUCTIVITIES (k) AND CONDUCTANCES (C) OF BUILDING MATERIALS AND INSULATIONS

Tests Conducted at Armour Institute of Technology, by J. C. Peebles.[p] *Insulation Tests Based on Samples Submitted by Manufacturers*

MATERIAL	DESCRIPTION	DENSITY (LB. PER CU. FT.)	MEAN TEMP. (DEG. FAHR.)	CONDUCTIVITY (k) OR CONDUCTANCE (C)
Aerocrete	Cellular concrete	40.0	75	1.06
Aerocrete	Cellular concrete	50.0	75	1.44
Aerocrete	Cellular concrete	60.0	75	1.80
Aerocrete	Cellular concrete	70.0	75	2.18
Arborite	Rigid insulation made from wood pulp	15.2	....	0.33
Asbestos shingles		65.0	75	6.00[b]
Asphalt shingles		70.0	75	6.50[b]
Balsam Wool[b]	Chemically treated wood fibre between plain paper	3.62	70	0.25
Beaver Fibre Wallboard	Commercial thickness 5/8 in.	.....	....	0.50
Calicel	Granular fill insulation made from combined silicate of lime and alumina	4.2	72	0.24
Celotex	Rigid insulation made from sugar cane fibre	13.5	70	0.33
Certainteed Insulating Board	Commercial thickness 1/8 in.	25.9	....	0.39
Cincrete Block, 8 in. Hollow	Treated cinder aggregate concrete	.....	....	0.33[b]
Concrete	Stone	145.0	75	6.30
Concrete	Cinder	110.0	75	5.20
Dry Zero Blanket[b]	Pliable slab form of insulation made from ceiba fibres	1.9	75	0.23
Dry Zero Blanket[b]	Pliable slab form of insulation made from ceiba fibres	1.6	75	0.24
Dry Zero Blanket[b]	Pliable slab form of insulation made from ceiba fibres	1.5	75	0.24
Flax-li-numb	Flax fibre	12.1	70	0.30
Homasote "A" Building Board	Made from wood and other vegetable fibres chemically treated	22.2	75	0.38
Inso Board	Rigid insulation made from wheat straw	17.0	68	0.33
Insulite	Rigid insulation made from wood pulp	16.5	70	0.34
Keystone Hair[b]	Hair felt between layers of paper; 1/4 in. thick	11.0	75	0.25
Lith	Rock wool, flax and straw pulp with binder	14.5	75	0.38
Linoboard	Slab form of insulation made from rock wool and vegetable fibres	9.9	72	0.296
Maftex	Rigid insulation made from licorice roots	11.5	72	0.311
Maizewood	Rigid insulation made from cornstalks	16.1	81	0.34
Maple Flooring	Across grain	15.0	70.5	0.325
Masonite	Rigid insulation made from exploded wood fibre	40.0	75	1.20
Plaster Board	Gypsum between layers of heavy paper	19.8	75	0.33
Pyrocell or Insulex	Cellular gypsum—dry	62.8	70	1.41
Pyrocell or Insulex	Cellular gypsum—dry	30.0	75	0.92
Pyrocell or Insulex	Cellular gypsum—dry	24.0	75	0.74
Pyrocell or Insulex	Cellular gypsum—dry	18.0	75	0.57
Roofing	Composition or prepared	12.0	75	0.40
Sprayo-Flake	Shredded paper with silica binder	.....	75	6.50[b]
Temlok	Rigid Insulation made from wood fiber	4.5	....	0.25
Thermatex	Rigid Insulation made from wood fiber	15.0	70	0.33
Thermax	Made from shredded wood and cement	8.5	72	0.294
Thermofil	Dry, fluffy, flaked gypsum	24.2	72	0.46
Thermofil	Dry, fluffy, flaked gypsum	24.0	75	0.48
Thermasote "A" Insulating Board	Made from wood fibre, chemically treated	18.0	75	0.34
Torfoleum	Peat moss compressed into sheet form	18.6	75	0.34
Weatherwood	Rigid insulation made from hard wood fibres	11.0	70	0.26
Wood Lath and Plaster[k]	Lime plaster	15.2	70	0.32
Yellow Pine	Across grain	.....	75	2.0[b]
		.....	....	1.00

[a] In addition to the conductivity values for the authorities listed, considerable work of importance pertaining to the heat transmission of various types of construction and materials has been done by the late Prof. John R. Allen and the late Prof. A. J. Wood of the Engineering Experiment Station of Pennsylvania State College.

[b] For thickness stated or used in construction, not per 1 in. thickness.

[h] Not compressed.

[k] Thickness of lime plaster and wood lath from back of lath to face of plaster, about 3/8 in.

[p] See Chapter LX, by Chas. H. Herter of the Report of the Insulation Committee, *A. S. R. E.*, Annual Meeting, 1922, Revised to 1924, entitled, Heat Transmission of Insulating Materials for a more comprehensive collection of heat transmission data relating to building and insulating materials.

example, the value of U for a 1 in. yellow pine floor (actual thickness, $^{25}/_{32}$ in.) placed directly on 5 in. concrete on the ground, is determined as follows:

$$U = \frac{1}{\frac{1}{1.34} + \frac{0.781}{1.00} + \frac{5.0}{8.30}} = 0.472 \text{ Btu per hour per square foot}$$

per degree difference in temperature between the ground and the air immediately above the floor.

The thicknesses upon which the coefficients in Tables 9 to 33, inclusive, are based, are as follows:

Brick veneer	4 in.
Plaster and metal lath	3/4 in.
Plaster (on wood lath, plasterboard, rigid insulation, board form, or corkboard)	1/2 in.
Slate (Roofing)	1/2 in.
Stucco on wire mesh reinforcing	1 in.
Tar and gravel or slag-surfaced built-up roofing	3/8 in.
Wood shingles (average thickness)	5/8 in.
Wood siding or clapboard (average thickness)	5/8 in.
1-in. Lumber (S-2-S)	$^{25}/_{32}$ in.
1½-in. Lumber (S-2-S)	$1^{5}/_{16}$ in.
2-in. Lumber (S-2-S)	$1^{5}/_{8}$ in.
2½-in. Lumber (S-2-S)	$2^{1}/_{8}$ in.
3-in. Lumber (S-2-S)	$2^{5}/_{8}$ in.
4-in. Lumber (S-2-S)	$3^{5}/_{8}$ in.
Finish flooring (Maple or Oak)	$^{13}/_{16}$ in.

TABLE 7. CONDUCTIVITIES (k) AND CONDUCTANCES (C) OF BUILDING MATERIALS AND INSULATIONS

Based on Tests Conducted at the University of Minnesota, By F. B. Rowley [p]

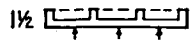
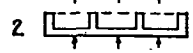
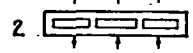
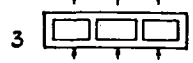
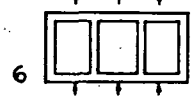
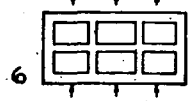
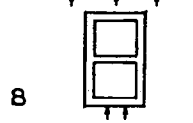
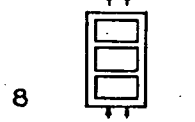
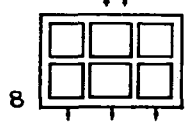
MATERIAL	DESCRIPTION	DENSITY (LB. PER CU. FT.)	MEAN TEMP. (DEG. FAHR.)	CONDUCTIVITY (k) OR CONDUCTANCE (C)
Concrete	Stone 1-2-4 mix	143.0	68.8	9.46
Dry Zero	Pliable slab form of insulation made from ceiba fibres	.....	.....	0.23
Fir sheathing and building paper		.....	30.0	0.71[b]
Fir sheathing, building paper and pine lap siding		.....	20.0	0.50[b]
Fir sheathing, building paper and stucco		.....	20.0	0.82[b]
Gypsum Tile	Solid	51.8	69.9	1.66
Gypsum Tile	Solid	75.6	75.9	2.96
Gypsum Fibre Concrete	87½% gypsum and 12½% wood chips	51.2	74.4	1.66
Lath and 3/8 in. Plaster	Total thickness 3/4 in.	.....	70.0	2.50[b]
Masonite	Rigid insulation made from exploded wood fibre	17.9	77.6	0.32
Pine lap siding and building paper	Lap siding 4 in. wide	.....	15.5	0.85[b]
Plaster	Thickness 3/8 in.	.....	73.0	8.8[b]
Sheet Rock Pyrofill Roofing, 2½ in. thick	Plaster board, gypsum fibre concrete and 3-ply roof covering	52.4	76.0	0.58[b]
Sprayo-Flake	Shredded paper with silica binder	5.9	61.1	0.28

[a] In addition to the conductivity values for the authorities listed, considerable work of importance pertaining to the heat transmission of various types of construction and materials has been done by the late Prof. John R. Allen and the late Prof. A. J. Wood of the Engineering Experiment Station of Pennsylvania State College.

[b] For thickness stated or used in construction, not per 1 in. thickness.

[p] See Chapter LX, by Chas. H. Herter of the Report of the Insulation Committee, *A. S. R. E.*, Annual Meeting, 1922, Revised to 1924, entitled, Heat Transmission of Insulating Materials for a more comprehensive collection of heat transmission data relating to building and insulating materials.

TABLE 8. CONDUCTIVITIES (k) AND CONDUCTANCES (C) OF BUILDING MATERIALS
Tests Conducted by Various Authorities.[p] *Insulation Tests Based on Samples Submitted by Manufacturers*

MATERIAL	DESCRIPTION	MEAN TEMP. (DEG. FAHR.)	CONDUCTIVITY (k) OR CONDUCTANCE (C)	AUTHORITY
Concrete	Stone 1-2-5 mix	95[c]	6.27	C. L. Norton, Boston, Mass.
Concrete	Cinder 1-2-4 mix	122	2.35	C. L. Norton, Boston, Mass.
Slate		201	10.37	Lees & Chorlton
Stone	Limestone or Sandstone	—	10.0	Estimated[e]
1½ in. Split Furring Clay Tile			1.40[b]	Estimated[m]
2 in. Split Furring Clay Tile			1.25[b]	Estimated[m]
2 in. Furring Clay Tile			1.18[b]	Estimated[m]
3 in. Furring or Partition Clay Tile			1.00[b]	Estimated[m]
4 in. Partition Clay Tile			0.93[b]	Estimated[m]
6 in. Partition Clay Tile			0.86[b]	Estimated[m]
6 in. Load Bearing Clay Tile			0.54[b]	Estimated[m]
8 in Backup Clay Tile			0.50[b]	Estimated[m]
8 in. Backup Clay Tile			0.39[b]	Estimated[m]
8 in. Load Bearing Clay Tile			0.49[b]	Estimated[m]

[a]In addition to the conductivity values for the authorities listed, considerable work of importance pertaining to the heat transmission of various types of construction and materials has been done by the late Prof. John R. Allen and the late Prof. A. J. Wood of the Engineering Experiment Station of Pennsylvania State College.

[b]For thickness stated or used in construction, not per 1 in. thickness.

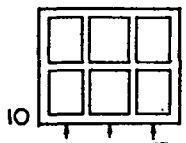
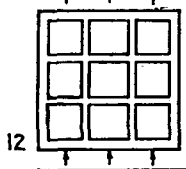
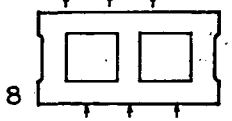
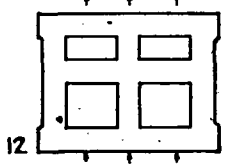
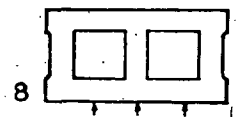
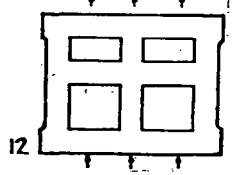
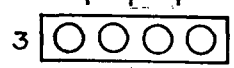
[c]Hot side of plate.

[e]Average of several values.

[m]Estimated from air space conductance data in Table 3, and Burned Clay conductivity of 5.0 per 1 in. Walls of load bearing tile assumed ¾ in. thick and webbs assumed ⅝ in. thick. Walls of all other tile assumed ⅝ in. thick and webbs ½ in. thick.

[p]See Chapter LX, by Chas. H. Herter of the Report of the Insulation Committee, *A. S. R. E.*, Annual Meeting 1922, Revised to 1924, entitled, Heat Transmission of Insulating Materials for a more comprehensive collection of heat transmission data relating to building and insulating materials.

TABLE 8. CONDUCTIVITIES (k) AND CONDUCTANCES (C) OF BUILDING MATERIALS (Continued)
Tests Conducted by Various Authorities.[p] *Insulation Tests Based on Samples Submitted by Manufacturers*

MATERIAL	DESCRIPTION	MEAN TEMP. (DEG. FAHR.)	CONDUCTIVITY (k) OR CONDUCTANCE (C)	AUTHORITY
10 in. Load Bearing Clay Tile			0.46[b]	Estimated[m]
12 in. Load Bearing Clay Tile			0.33[b]	Estimated[m]
8 in. Concrete Blocks (hollow)			0.84[b]	Estimated[n]
12 in. Concrete Blocks (hollow)			0.52[b]	Estimated[n]
8 in. Cinder Blocks (hollow)			0.45[b]	Estimated[n]
12 in. Cinder Blocks (hollow)			0.28[b]	Estimated[n]
3 in. Gypsum Tile (hollow)			0.55[b]	Estimated[o]
4 in. Gypsum Tile (hollow)			0.46[b]	Estimated[q]
Ten Test	Rigid insulation made from wood fiber	52	0.33	E. A. Allcut University of Toronto

[m]Estimated from air space conductance data in Table 3, and Burned Clay conductivity of 5.0 per 1 in. Walls of load bearing tile assumed ¾ in. thick and webbs assumed ⅝ in. thick. Walls of all other tile assumed ⅝ in. thick and webbs ½ in. thick.

[n]Estimated from air space conductance data in Table 3, and conductivity of concrete of 8.30 per 1 in. Shells and webbs assumed 2 in. thick. Conductivity of dry Cinder Concrete assumed 3.33.

[o]Estimated from air space conductance data in Table 3, and conductivity of gypsum tile of 1.66 per 1 in. It is assumed that each tile has 4 cores per 12 in. width, each 1¾ in. in diameter.

[q]Estimated from air space conductance data in Table 3, and conductivity of gypsum tile of 1.66 per 1 in. It is assumed that each tile has 3 cores per 12 in. width, each 2½ in. in diameter.

Note that actual thicknesses of lumber are used in the computations rather than nominal thicknesses.

On account of the fact that the internal resistances of metal and single thicknesses of building paper (used because of its value as a wind stop only) and roofing felt are very small, these resistances were neglected in the calculations, in accordance with standard practice. The computations for wood shingle roofs applied over wood stripping are based on 1 by 4 in. wood strips, spaced 2 in. apart. Since no reliable figures are available concerning the conductivity of Spanish and French clay roofing tile, of which there are many varieties, the figures for such types of roofs were taken the same as for slate roofs, as it is probable that the values of U for these two types of roofs will compare favorably.

The coefficients of transmission of the pitched roofs in Table 31 apply where the roof is over a heated attic or top floor, such that the heat passes directly through the roof structure including whatever finish, if any, is applied to the underside of the roof rafters. By a heated attic is meant an attic to which heat is supplied directly from the furnace or boiler by means of radiators, warm-air registers, or other means.

If the attic is unheated, the roof structure and ceiling of the top floor must both be taken into consideration, and the combined coefficient of transmission determined. The formula for calculating the combined coefficient of transmission of a top-floor ceiling, unheated attic space and pitched roof, per square foot of roof area, is as follows:

$$U = \frac{U_r \times U_{ce}}{n \times U_r + U_{ce}} \qquad (10)$$

where

U_r = coefficient of transmission of the roof.
U_{ce} = coefficient of transmission of the ceiling.
n = the ratio of the area of the roof to the area of the ceiling.

In using this formula, a correction-factor must be applied. As the amount of heat transferred through an air space is proportional to the difference of the fourth powers of the absolute temperatures of the surfaces enclosing the air space, a greater amount of heat is absorbed or emitted by radiation by the surfaces enclosing an unheated attic than by the surfaces of a wall or ceiling in a room under still-air conditions, where the surrounding objects are only slightly higher in temperature than the interior surfaces of the walls and ceiling. For example: According to the most reliable information at present available, the average coefficient of a surface in still air is 1.34 Btu per hour per square foot per degree Fahrenheit, whereas the average coefficient of an air space in an outside wall is about 1.10 Btu per hour per square foot per degree Fahrenheit difference between the two surfaces, at a mean temperature of 40 F. An air space coefficient of 1.10 is equivalent to a surface coefficient of 2.20 for each of the two surfaces enclosing the air space, where the over-all transmission is computed by using the coefficients of the two surfaces enclosing the air space instead of the coefficient of the air space itself. Hence, in determining the values of U_r and U_{ce} to be used in the formula, the coefficients for the surfaces of the roof and ceiling enclosing the attic should be increased to allow for the additional amount of heat

transferred by radiation, and a coefficient of 2.20 may be used with sufficient accuracy for each of these surfaces, although in very precise work a correction should be made to allow for the fact that the area of a pitched roof over an unheated attic is greater than the area of the ceiling, and hence, the amount of heat absorbed by radiation by each square foot of roof surface is less than is given off by radiation by each square foot of ceiling surface.

The following example will illustrate the use of this formula: Determine the combined coefficient of transmission of a roof constructed of asbestos shingles applied over wood sheathing on rafters, an unheated attic, and a wood lath and plaster ceiling, based on a roof having a ⅓ pitch, for which the value of n is 1.2.

$$U_r = \frac{1}{\frac{1}{4.02} + \frac{1}{2.20} + \frac{1}{6.00} + \frac{0.781}{1.00}} = 0.605$$

$$U_{ce} = \frac{1}{\frac{1}{1.34} + \frac{1}{2.20} + \frac{1}{2.00}} = 0.588$$

Substituting these values in the preceding formula:

$$U = \frac{0.605 \times 0.588}{1.2 \times 0.605 + 0.588} = 0.271$$

Btu per hour, *per square foot of roof area* per degree difference in temperature between the air near the underside of the ceiling and the outside air.

Combined coefficients for many common types of pitched roofs and top-floor ceilings for unheated attics are given in Table 32.

If the unheated attic space between the roof and ceiling has no dormers, windows or vertical wall surfaces, the combined coefficients given in Table 32 may be used for determining the heat loss through the roof construction between the attic and top-floor ceiling, but it should be noted that the coefficients given in Table 32 should be multiplied by the roof area and not by the ceiling area. If the unheated attic contains windows, ventilators or vertical wall surfaces, which would tend to reduce the temperature in the attic to a temperature approaching or equaling the outside temperature, the roof should be neglected and only the top-floor ceiling construction and the corresponding ceiling area taken into consideration, using the coefficients given in Tables 26 or 27. The attic temperature should then be taken the same as the outside temperature. In this case the reasoning regarding the loss of heat from a surface by radiation, referred to in the preceding discussion regarding the determination of the combined coefficients of a ceiling, unheated attic and roof, does not apply to the heat loss from the attic floor or top-floor ceiling, on account of the fact that the undersurface of the roof will have about the same temperature as the attic floor. As stated before, if the attic is heated, the top-floor ceiling should be neglected, and only the roof structure, with whatever ceiling is applied to the underside of the roof rafters, taken into consideration in determining the heat losses through the roof.

The temperature in an attic space containing no dormers, windows,

vertical wall spaces or ventilators may be estimated by means of the following formula:

$$t_b = \frac{t\,U_{ce} + n\,t_o\,U_r}{U_{ce} + n\,U_r} \qquad (11)$$

where

t = inside temperature near ceiling.
t_b = temperature in attic.
t_o = outside temperature.

If in the foregoing problem, involving the determination of the combined coefficient of transmission, the inside temperature t is 70 F and the outside temperature is − 10 F, the attic temperature based on equation 11 will be:

$$t_b = \frac{70 \times 0.588 + 1.2 \times (-10) \times 0.605}{0.588 + 1.2 \times 0.605} = 26 \text{ F.}$$

As previously stated, if the attic contains windows, ventilators, etc., the attic temperature will approach or equal the outside temperature, the roof will provide little or no resistance to the passage of heat, and the heat loss through the upper part of the building may be estimated by assuming the attic temperature to be the same as the outside temperature and using the heat transmission coefficient of the ceiling.

The heat loss through floors into basements and into unheated rooms kept closed may be computed by assuming a temperature for these rooms of 32 F.

AREAS WHERE TRANSMISSION LOSSES OCCUR

Heat is lost from a building by transmission through all of those surfaces which separate heated spaces from the outside air or from unheated colder spaces within the building. In general, five kinds of surfaces are involved: (1) outside walls; (2) outside glass; (3) inside walls or partitions next to unheated spaces; (4) ceilings of upper floors, either below a cold attic space or as the underside of a roof slab, and (5) floors of heated rooms above an unheated space. In most cases, only items (1) and (2), outside wall and glass surface, are considered. Failure to take account of the other heat-losing surfaces, items (3), (4) and (5), when they exist in a building, has generally resulted in more or less dissatisfaction with the operation of the heating plant, as a result of failure to heat the rooms having such surfaces as indicated by items (3), (4) and (5).

The net outside wall surface is usually determined by reference to the scale plans and elevations of the building concerned. In some cases, of course, the actual building may have to be measured. The total area of all outside openings which are occupied by windows and doors is accurately measured and listed as *glass*. The *glass* area is then deducted from the total outside wall area for each room and the difference is the net wall area. The outside wall areas for any floor should be based on the vertical floor-to-floor heights and the horizontal distance from center to center of partitions separating different rooms. If there are no partitions, measure from inside face of one wall to inside face of next wall. The areas of

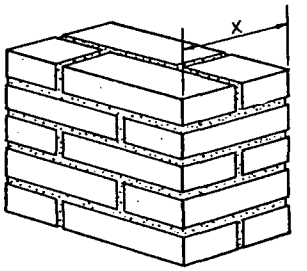
TABLE 9. COEFFICIENTS OF TRANSMISSION (U) OF SOLID BRICK WALLS[b]

Note.—THESE COEFFICIENTS ARE EXPRESSED IN BTU PER HOUR PER SQUARE FOOT PER 1 DEG FAHR DIFFERENCE IN TEMPERATURE BETWEEN THE AIR ON THE TWO SIDES AND ARE BASED ON AN OUTSIDE WIND EXPOSURE OF 15 MILES PER HOUR.

The values of U in this Table are based on the following Internal Conductivities or Conductances which are expressed in B.t.u. per Hr. per Sq. Ft. per 1°F

Brick	5.00	per 1"
Cement Mortar	8.00	per 1"
Plasterboard	3.13	per ⅜"
Plaster (Gypsum)	2.32	per 1"
Wood Lath & Plaster	2.00	as applied
Corkboard	0.30	per 1"
Rigid Insulation (Board form)	0.33	per 1"
Cellular Gypsum (18#)	0.59	per 1"
Flaked Gypsum, Dry (24#)	0.48	per 1"
Split Furring Tile	1½" = 1.40	2" = 1.25

Y = Thickness of Insulation where specified



Number	Interior Construction	Y	Thickness of Brick - X		
			8"	12"	16"
			A	B	C
1	Plain Walls - No Interior Finish		0.385	0.295	0.238
2	½" Plaster on Brick		0.356	0.277	0.227
3	¾" Plaster on Metal Lath - Furred		0.261	0.216	0.184
4	½" Plaster on Wood Lath - Furred		0.250	0.208	0.178
5	½" Plaster on ⅜" Plasterboard - Furred		0.251	0.209	0.179
6	½" Plaster on Wood Lath on 2" Furring Strips - Cellular Gypsum Fill[c]	1⅝"[a]	0.171	0.151	0.135
7	½" Plaster on Wood Lath on 2" Furring Strips - Flaked Gypsum Fill	1⅝"[a]	0.154	0.137	0.124
8	½" Plaster on Rigid Insulation (Board form) Furred	½"	0.191	0.166	0.146
9		1"	0.148	0.132	0.120
10	½" Plaster on Corkboard set in ½" Cement Mortar	1½"	0.127	0.115	0.104
11		2"	0.105	0.097	0.090
12	½" Plaster on 1½" Split Furring Tile set against Wall		0.284	0.231	0.195
13	½" Plaster on 2" Split Furring Tile set against Wall		0.277	0.227	0.192

[a] Based on 1⅝ in., the actual thickness of 2 in. furring strips.
[b] The coefficients on this page can also be used with sufficient accuracy for the Ideal Rolok-Bak Wall.
[c] The coefficient used for cellular gypsum, 0.59 is for 18 lb. weight—weights as low as 12 lb. may be used.

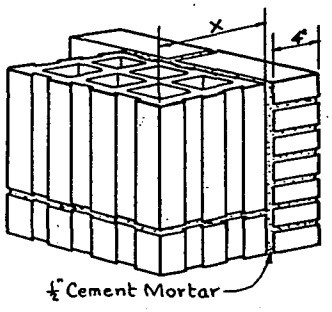
TABLE 10. COEFFICIENTS OF TRANSMISSION (*U*) OF BRICK VENEER ON HOLLOW TILE WALLS[c]

Note.—THESE COEFFICIENTS ARE EXPRESSED IN BTU PER HOUR PER SQUARE FOOT PER 1 DEG FAHR DIFFERENCE IN TEMPERATURE BETWEEN THE AIR ON THE TWO SIDES AND ARE BASED ON AN OUTSIDE WIND EXPOSURE OF 15 MILES PER HOUR.

The values of U in this Table are based on the following Internal Conductivities or Conductances which are expressed in B.t.u. per Hr. per Sq. Ft. per 1°F

Hollow Tile	6"-0.54 8"-0.49 10"-0.46 12"-0.33
Brick	5.00 per 1"
Cement Mortar	8.00 per 1"
Plasterboard	3.73 per $\frac{3}{8}$"
Plaster (Gypsum)	2.32 per 1"
Wood Lath & Plaster	2.00 as applied
Cork board	0.30 per 1"
Rigid Insulation (Board form)	0.33 per 1"
Cellular Gypsum (18#)	0.59 per 1"
Flaked Gypsum, Dry (24#)	0.48 per 1"

Y = Thickness of Insulation where specified



Number	Interior Construction	Y	Thickness of Hollow Tile – X			
			6"	8"	10"	12"
			A	B	C	D
1	Plain Walls – No Interior Finish		0.270	0.257	0.248	0.205
2	½" Plaster on Hollow Tile		0.254	0.243	0.235	0.196
3	¾" Plaster on Metal Lath – Furred		0.202	0.195	0.190	0.163
4	½" Plaster on Wood Lath – Furred		0.195	0.188	0.184	0.159
5	½" Plaster on ⅜" Plaster board – Furred		0.198	0.189	0.185	0.159
6	½" Plaster on Wood Lath on 2" Furring Strips – Cellular Gypsum Fill [b]	1⅝"[a]	0.144	0.140	0.137	0.123
7	½" Plaster on Wood Lath on 2" Furring Strips – Flaked Gypsum Fill	1⅝"[a]	0.131	0.128	0.126	0.114
8	½" Plaster on Rigid Insulation – (Board form) Furred	½"	0.158	0.153	0.150	0.133
9		1"	0.127	0.124	0.122	0.110
10	½" Plaster on Cork board set in ½" Cement Mortar	1½"	0.112	0.110	0.107	0.098
11		2"	0.094	0.092	0.091	0.085

[a] Based on 1⅝ in., the actual thickness of 2 in. furring strips.

[b] The coefficient used for cellular gypsum, 0.59 is for 18 lb. weight—weights as low as 12 lb. may be used.

[c] The 6 in., 8 in. and 10 in. tile figures are based on two cells in the direction of flow of heat. The 12 in. tile is based on three cells in the direction of flow of heat.

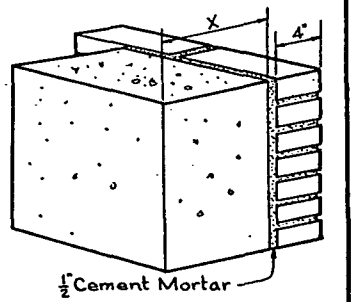
TABLE 11. COEFFICIENTS OF TRANSMISSION (*U*) OF BRICK VENEER ON CONCRETE WALLS

Note.—THESE COEFFICIENTS ARE EXPRESSED IN BTU PER HOUR PER SQUARE FOOT PER 1 DEG FAHR DIFFERENCE IN TEMPERATURE BETWEEN THE AIR ON THE TWO SIDES AND ARE BASED ON AN OUTSIDE WIND EXPOSURE OF 15 MILES PER HOUR.

The values of U in this Table are based on the following Internal Conductivities or Conductances which are expressed in B.t.u. per Hr. per Sq. Ft. per 1°F

Concrete (Stone 1:2:4 mix)	8.30 per 1"
Brick	5.00 per 1"
Cement Mortar	8.00 per 1"
Plasterboard	3.73 per ⅜"
Plaster (Gypsum)	2.32 per 1"
Wood Lath & Plaster	2.00 as applied
Cork board	0.30 per 1"
Rigid Insulation (Board form)	0.33 per 1"
Cellular Gypsum (18#)	0.59 per 1"
Flaked Gypsum, Dry (24#)	0.48 per 1"

Y = Thickness of Insulation where specified



Number	Interior Construction	Y	Thickness of Concrete – X				
			6"	8"	10"	12"	16"
			A	B	C	D	E
1	Plain Walls – No Interior Finish		0.387	0.355	0.327	0.303	0.264
2	½" Plaster on Concrete		0.358	0.330	0.305	0.285	0.250
3	¾" Plaster on Metal Lath – Furred		0.263	0.247	0.233	0.221	0.200
4	½" Plaster on Wood Lath – Furred		0.250	0.237	0.224	0.213	0.192
5	½" Plaster on ⅜" Plaster board – Furred		0.252	0.238	0.225	0.213	0.192
6	½" Plaster on Wood Lath on 2" Furring Strips – Cellular Gypsum Fill [b]	1⅝"[a]	0.172	0.165	0.158	0.152	0.142
7	½" Plaster on Wood Lath on 2" Furring Strips – Flaked Gypsum Fill	1⅝"[a]	0.154	0.149	0.144	0.139	0.130
8	½" Plaster on Rigid Insulation – (Board form) Furred	½"	0.192	0.183	0.175	0.168	0.156
9		1"	0.148	0.143	0.139	0.134	0.126
10	½" Plaster on Cork board set in ½" Cement Mortar	1½"	0.127	0.123	0.120	0.116	0.110
11		2"	0.105	0.102	0.100	0.098	0.093

[a] Based on 1⅝ in., the actual thickness of 2 in. furring strips.

[b] The coefficient used for cellular gypsum, 0.59 is for 18 lb. weight—weights as low as 12 lb. may be used.

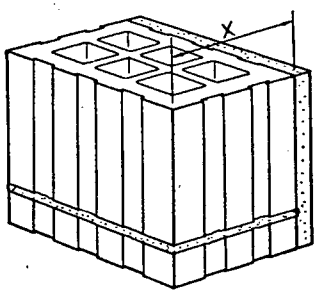
TABLE 12. COEFFICIENTS OF TRANSMISSION (*U*) OF HOLLOW TILE WALLS WITH STUCCO EXTERIOR FINISH [b-d]

Note.—THESE COEFFICIENTS ARE EXPRESSED IN BTU PER HOUR PER SQUARE FOOT PER 1 DEG FAHR DIFFERENCE IN TEMPERATURE BETWEEN THE AIR ON THE TWO SIDES AND ARE BASED ON AN OUTSIDE WIND EXPOSURE OF 15 MILES PER HOUR.

The values of U in this Table are based on the following Internal Conductivities or Conductances which are expressed in B.t.u. per Hr per Sq. Ft. per 1°F

Stucco	8.00 per 1"
Hollow Tile 8"=0.49 10"=0.46 12"=0.33 16"=0.25	
Cement Mortar	8.00 per 1"
Plaster board	3.73 per $\frac{3}{8}$"
Plaster (Gypsum)	2.32 per 1"
Wood Lath & Plaster	2.00 as applied
Cork board	0.30 per 1"
Rigid Insulation (Board form)	0.33 per 1"
Cellular Gypsum (18#)	0.59 per 1"
Flaked Gypsum, Dry (24#)	0.48 per 1"

Y = Thickness of Insulation where specified



Number	Interior Construction	Y	Thickness of Hollow Tile – X			
			8"	10"	12"	16"
			A	B	C	D
1	Plain Walls – No Interior Finish		0.317	0.304	0.241	0.195
2	$\frac{1}{2}$" Plaster on Hollow Tile		0.296	0.285	0.229	0.188
3	$\frac{3}{4}$" Plaster on Metal Lath – Furred		0.228	0.221	0.186	0.158
4	$\frac{1}{2}$" Plaster on Wood Lath – Furred		0.219	0.213	0.180	0.153
5	$\frac{1}{2}$" Plaster on $\frac{3}{8}$" Plaster board – Furred		0.220	0.213	0.180	0.153
6	$\frac{1}{2}$" Plaster on Wood Lath on 2" Furring Strips – Cellular Gypsum Fill [c]	1$\frac{5}{8}$" [a]	0.156	0.153	0.135	0.120
7	$\frac{1}{2}$" Plaster on Wood Lath on 2" Furring Strips – Flaked Gypsum Fill	1$\frac{5}{8}$" [a]	0.141	0.139	0.124	0.111
8	$\frac{1}{2}$" Plaster on Rigid Insulation – (Board form) Furred	$\frac{1}{2}$"	0.172	0.168	0.147	0.129
9		1"	0.137	0.134	0.120	0.108
10	$\frac{1}{2}$" Plaster on Cork board set in $\frac{1}{2}$" Cement Mortar	1$\frac{1}{2}$"	0.119	0.117	0.106	0.096
11		2"	0.099	0.098	0.090	0.083

[a] Based on 1$\frac{5}{8}$ in., the actual thickness of 2 in. furring strips.
[b] Figures on this page can be used with sufficient accuracy for hollow tile walls without stucco finish.
[c] The coefficient used for cellular gypsum, 0.59 is for 18 lb. weight—weights as low as 12 lb. may be used.
[d] The 8 in. and 10 in. tile figures are based on two cells in the direction of heat flow. The 12 in. tile is based on three cells in the direction of heat flow. The 16 in. tile consists of one 10 in. tile and one 6 in. tile, each having two cells in the direction of heat flow.

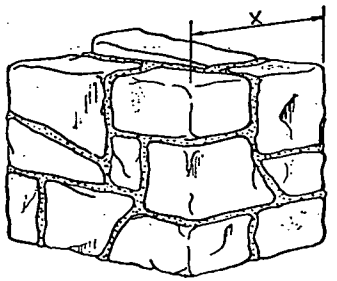
TABLE 13. COEFFICIENTS OF TRANSMISSION (*U*) OF LIMESTONE OR SANDSTONE WALLS

Note.—THESE COEFFICIENTS ARE EXPRESSED IN BTU PER HOUR PER SQUARE FOOT PER 1 DEG FAHR DIFFERENCE IN TEMPERATURE BETWEEN THE AIR ON THE TWO SIDES AND ARE BASED ON AN OUTSIDE WIND EXPOSURE OF 15 MILES PER HOUR.

The values of U in this Table are based on the following Internal Conductivities or Conductances which are expressed in B.t.u. per Hr per Sq. Ft. per 1°F

Stone	10.00 per 1"
Cement Mortar	8.00 per 1"
Plaster board	3.73 per $\frac{3}{8}$"
Plaster (Gypsum)	2.32 per 1"
Wood Lath & Plaster	2.00 as applied
Cork board	0.30 per 1"
Rigid Insulation (Board form)	0.33 per 1"
Cellular Gypsum (18#)	0.59 per 1"
Flaked Gypsum, Dry (24#)	0.48 per 1"

Y = Thickness of Insulation where specified



Number	Interior Construction	Y	Thickness of Stone – X					
			8"	10"	12"	16"	20"	24"
			A	B	C	D	E	F
1	Plain Walls – No Interior Finish		0.556	0.502	0.457	0.385	0.334	0.295
2	$\frac{1}{2}$" Plaster on Stone		0.497	0.452	0.415	0.356	0.311	0.277
3	$\frac{3}{4}$" Plaster on Metal Lath – Furred		0.330	0.310	0.292	0.261	0.236	0.216
4	$\frac{1}{2}$" Plaster on Wood Lath – Furred		0.312	0.294	0.277	0.250	0.227	0.208
5	$\frac{1}{2}$" Plaster on $\frac{3}{8}$" Plaster board – Furred		0.314	0.295	0.279	0.251	0.228	0.209
6	$\frac{1}{2}$" Plaster on Wood Lath on 2" Furring Strips – Cellular Gypsum Fill [b]	1$\frac{5}{8}$" [a]	0.198	0.191	0.184	0.171	0.160	0.150
7	$\frac{1}{2}$" Plaster on Wood Lath on 2" Furring Strips – Flaked Gypsum Fill	1$\frac{5}{8}$" [a]	0.175	0.169	0.163	0.153	0.145	0.137
8	$\frac{1}{2}$" Plaster on Rigid Insulation (Board form) Furred	$\frac{1}{2}$"	0.225	0.216	0.207	0.191	0.177	0.166
9		1"	0.168	0.163	0.157	0.148	0.140	0.132
10	$\frac{1}{2}$" Plaster on Cork board set in $\frac{1}{2}$" Cement Mortar	1$\frac{1}{2}$"	0.141	0.138	0.134	0.127	0.121	0.115
11		2"	0.114	0.112	0.109	0.105	0.101	0.098

[a] Based on 1$\frac{5}{8}$ in., the actual thickness of 2 in. furring strips.
[b] The coefficient used for cellular gypsum, 0.59 is for 18 lb. weight—weights as low as 12 lb. may be used.

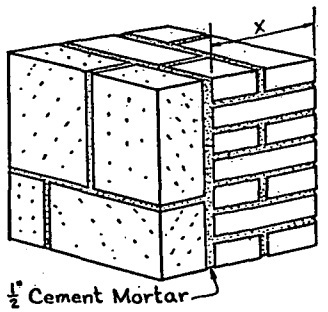
TABLE 14. COEFFICIENTS OF TRANSMISSION (*U*) OF 4-IN. CUT STONE VENEER ON BRICK WALLS

Note.—THESE COEFFICIENTS ARE EXPRESSED IN BTU PER HOUR PER SQUARE FOOT PER 1 DEG FAHR DIFFERENCE IN TEMPERATURE BETWEEN THE AIR ON THE TWO SIDES AND ARE BASED ON AN OUTSIDE WIND EXPOSURE OF 15 MILES PER HOUR.

The values of U in this Table are based on the following Internal Conductivities or Conductances which are expressed in B.t.u. per Hr. per Sq. Ft. per 1°F

Stone	10.00 per 1"
Brick	5.00 per 1"
Cement Mortar	8.00 per 1"
Plasterboard	3.73 per $\frac{3}{8}$"
Plaster (Gypsum)	2.32 per 1"
Wood Lath & Plaster	2.00 as applied
Cork board	0.30 per 1"
Rigid Insulation (Board form)	0.33 per 1"
Cellular Gypsum (18*)	0.59 per 1"
Flaked Gypsum, Dry (24*)	0.48 per 1"

Y = Thickness of Insulation where specified



Number	Interior Construction	Y	Thickness of Brick – X 8" A	12" B	16" C
1	Plain Walls – No Interior Finish		0.326	0.259	0.215
2	½" Plaster on Brick		0.306	0.246	0.205
3	¾" Plaster on Metal Lath – Furred		0.233	0.196	0.170
4	½" Plaster on Wood Lath – Furred		0.224	0.190	0.165
5	½" Plaster on ⅜" Plasterboard – Furred		0.225	0.190	0.165
6	½" Plaster on Wood Lath on 2" Furring Strips – Cellular Gypsum Fill [b]	1⅝" [a]	0.158	0.141	0.126
7	½" Plaster on Wood Lath on 2" Furring Strips – Flaked Gypsum Fill	1⅝" [a]	0.143	0.128	0.117
8	½" Plaster on Rigid Insulation – (Board form) Furred	½"	0.175	0.154	0.137
9		1"	0.139	0.125	0.113
10	½" Plaster on Cork board set in ½" Cement Mortar	1½"	0.120	0.110	0.100
11		2"	0.100	0.093	0.086

[a] Based on 1⅝ in., the actual thickness of 2 in. furring strips.
[b] The coefficient used for cellular gypsum, 0.59 is for 18 lb. weight—weights as low as 12 lb. may be used.

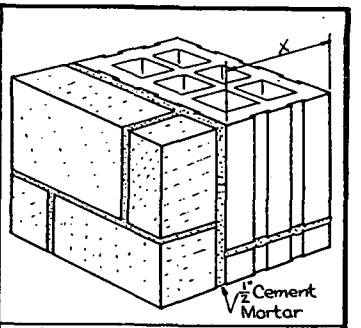
TABLE 15. COEFFICIENTS OF TRANSMISSION (*U*) OF 4-IN. CUT STONE VENEER ON HOLLOW TILE WALLS

Note.—THESE COEFFICIENTS ARE EXPRESSED IN BTU PER HOUR PER SQUARE FOOT PER 1 DEG FAHR DIFFERENCE IN TEMPERATURE BETWEEN THE AIR ON THE TWO SIDES AND ARE BASED ON AN OUTSIDE WIND EXPOSURE OF 15 MILES PER HOUR.

The values of U in this Table are based on the following Internal Conductivities or Conductances which are expressed in B.t.u. per Hr. per Sq. Ft. per 1°F

Hollow Tile 6"=0.54 8"=0.49	10"=0.46 12"=0.33
Stone	10.00 per 1"
Cement Mortar	8.00 per 1"
Plasterboard	3.73 per ⅜"
Plaster (Gypsum)	2.32 per 1"
Wood Lath & Plaster	2.00 as applied
Cork board	0.30 per 1"
Rigid Insulation (Board form)	0.33 per 1"
Cellular Gypsum (18")	0.59 per 1"
Flaked Gypsum, Dry (24")	0.48 per 1"

Y = Thickness of Insulation where specified



Number	Interior Construction	Y	Thickness of Hollow Tile – X [c] 6" A	8" B	10" C	12" D
1	Plain Walls – No Interior Finish		0.302	0.286	0.276	0.223
2	½" Plaster on Hollow Tile		0.283	0.270	0.260	0.213
3	¾" Plaster on Metal Lath – Furred		0.220	0.211	0.206	0.175
4	½" Plaster on Wood Lath – Furred		0.212	0.204	0.199	0.170
5	½" Plaster on ⅜" Plasterboard – Furred		0.212	0.204	0.199	0.170
6	½" Plaster on Wood Lath on 2" Furring Strips – Cellular Gypsum Fill [b]	1⅝" [a]	0.152	0.148	0.145	0.129
7	½" Plaster on Wood Lath on 2" Furring Strips – Flaked Gypsum Fill	1⅝" [a]	0.138	0.135	0.132	0.119
8	½" Plaster on Rigid Insulation – (Board form) Furred	½"	0.168	0.163	0.159	0.140
9		1"	0.134	0.131	0.128	0.115
10	½" Plaster on Cork board set in ½" Cement Mortar	1½"	0.116	0.114	0.112	0.102
11		2"	0.097	0.096	0.095	0.088

[a] Based on 1⅝ in., the actual thickness of 2 in. furring strips.
[b] The coefficient used for cellular gypsum, 0.59 is for 18 lb. weight—weights as low as 12 lb. may be used.
[c] The 6 in., 8 in. and 10 in. tile figures are based on two cells in the direction of heat flow. The 12 in. tile is based on three cells in the direction of heat flow.

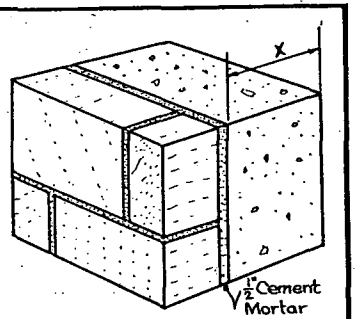
TABLE 16. COEFFICIENTS OF TRANSMISSION (*U*) OF 4-IN. CUT STONE VENEER ON CONCRETE WALLS

Note.—THESE COEFFICIENTS ARE EXPRESSED IN BTU PER HOUR PER SQUARE FOOT PER 1 DEG FAHR DIFFERENCE IN TEMPERATURE BETWEEN THE AIR ON THE TWO SIDES AND ARE BASED ON AN OUTSIDE WIND EXPOSURE OF 15 MILES PER HOUR.

The values of U in this Table are based on the following Internal Conductivities or Conductances which are expressed in B.t.u. per Hr. per Sq. Ft. per 1°F

Stone	10.00 per 1"
Concrete (Stone 1:2:4 mix)	8.30 per 1"
Cement Mortar	8.00 per 1"
Plaster board	3.73 per 3/8"
Plaster (Gypsum)	2.32 per 1"
Wood Lath & Plaster	2.00 as applied
Corkboard	0.30 per 1"
Rigid Insulation (Board form)	0.33 per 1"
Cellular Gypsum (18#)	0.59 per 1"
Flaked Gypsum, Dry (24#)	0.48 per 1"

Y = Thickness of Insulation where specified



Number	Interior Construction	Y	Thickness of Concrete – X				
			6"	8"	10"	12"	16"
			A	B	C	D	E
1	Plain Walls – No Interior Finish		0.459	0.413	0.377	0.345	0.296
2	1/2" Plaster on Concrete		0.418	0.380	0.348	0.321	0.279
3	3/4" Plaster on Metal Lath – Furred		0.293	0.274	0.257	0.242	0.217
4	1/2" Plaster on Wood Lath – Furred		0.279	0.261	0.246	0.232	0.209
5	1/2" Plaster on 3/8" Plasterboard – Furred		0.280	0.262	0.247	0.233	0.209
6	1/2" Plaster on Wood Lath on 2" Furring Strips – Cellular Gypsum Fill [b]	1 5/8" [a]	0.184	0.176	0.169	0.163	0.151
7	1/2" Plaster on Wood Lath on 2" Furring Strips – Flaked Gypsum Fill	1 5/8" [a]	0.164	0.158	0.152	0.147	0.137
8	1/2" Plaster on Rigid Insulation – (Board form) Furred	1/2"	0.208	0.198	0.188	0.180	0.166
9		1"	0.158	0.152	0.147	0.142	0.133
10	1/2" Plaster on Corkboard set in 1/2" Cement Mortar	1 1/2"	0.134	0.130	0.126	0.122	0.116
11		2"	0.110	0.107	0.104	0.102	0.097

[a] Based on 1 5/8 in., the actual thickness of 2 in. furring strips.
[b] The coefficient used for cellular gypsum, 0.59 is for 18 lb. weight—weights as low as 12 lb. may be used.

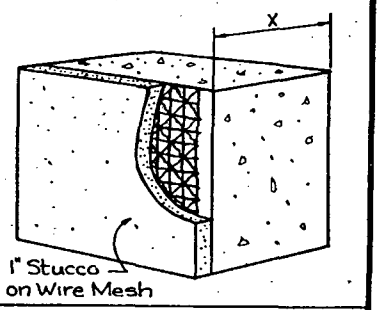
TABLE 17. COEFFICIENTS OF TRANSMISSION (*U*) OF CONCRETE WALLS WITH STUCCO AS EXTERIOR FINISH

Note.—THESE COEFFICIENTS ARE EXPRESSED IN BTU PER HOUR PER SQUARE FOOT PER 1 DEG FAHR DIFFERENCE IN TEMPERATURE BETWEEN THE AIR ON THE TWO SIDES AND ARE BASED ON AN OUTSIDE WIND EXPOSURE OF 15 MILES PER HOUR.

The values of U in this Table are based on the following Internal Conductivities or Conductances which are expressed in B.t.u. per Hr. per Sq. Ft. per 1°F

Stucco	8.00 per 1"
Concrete (Stone 1:2:4 mix)	8.30 per 1"
Plasterboard	3.73 per 3/8"
Plaster (Gypsum)	2.32 per 1"
Wood Lath & Plaster	2.00 as applied
Cork board	0.30 per 1"
Rigid Insulation (Board form)	0.33 per 1"
Cellular Gypsum (18#)	0.59 per 1"
Flaked Gypsum, Dry (24#)	0.48 per 1"

Y = Thickness of Insulation where specified



Number	Interior Construction	Y	Thickness of Concrete – X					
			6"	8"	10"	12"	16"	20"
			A	B	C	D	E	F
1	Plain Walls – No Interior Finish		0.544	0.481	0.431	0.391	0.329	0.284
2	1/2" Plaster on Concrete		0.486	0.437	0.395	0.361	0.308	0.268
3	3/4" Plaster on Metal Lath – Furred		0.326	0.302	0.282	0.264	0.234	0.210
4	1/2" Plaster on Wood Lath – Furred		0.308	0.287	0.268	0.252	0.225	0.203
5	1/2" Plaster on 3/8" Plasterboard – Furred		0.310	0.288	0.270	0.253	0.226	0.204
6	1/2" Plaster on Wood Lath on 2" Furring Strips – Cellular Gypsum Fill [b]	1 5/8" [a]	0.196	0.188	0.179	0.172	0.159	0.148
7	1/2" Plaster on Wood Lath on 2" Furring Strips – Flaked Gypsum Fill	1 5/8" [a]	0.173	0.167	0.161	0.154	0.144	0.135
8	1/2" Plaster on Rigid Insulation (Board form) Furred	1/2"	0.223	0.212	0.202	0.192	0.176	0.163
9		1"	0.167	0.160	0.154	0.149	0.139	0.130
10	1/2" Plaster on Corkboard set in 1/2" Cement Mortar	1 1/2"	0.141	0.136	0.132	0.127	0.120	0.114
11		2"	0.114	0.111	0.108	0.105	0.100	0.096

[a] Based on 1 5/8 in., the actual thickness of 2 in. furring strips.
[b] The coefficient used for cellular gypsum, 0.59 is for 18 lb. weight—weights as low as 12 lb. may be used.

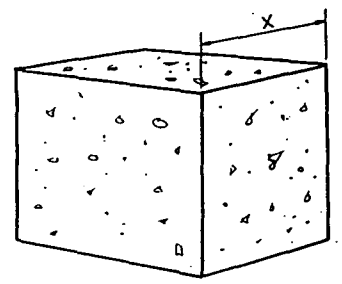
Table 18. Coefficients of Transmission (U) of Concrete Walls with No Exterior Finish

Note.—These coefficients are expressed in Btu per hour per square foot per 1 deg fahr difference in temperature between the air on the two sides and are based on an outside wind exposure of 15 miles per hour.

The values of U in this Table are based on the following Internal Conductivities or Conductances which are expressed in B.t.u. per Hr. per Sq. Ft. per 1°F

Concrete (Stone 1:2:4 mix)	8.30 per 1"
Plasterboard	3.73 per $\frac{3}{8}$"
Plaster (Gypsum)	2.32 per 1"
Wood Lath & Plaster	2.00 as applied
Cork board	0.30 per 1"
Rigid Insulation (Board form)	0.33 per 1"
Cellular Gypsum (18#)	0.59 per 1"
Flaked Gypsum, Dry (24#)	0.48 per 1"

Y = Thickness of Insulation where specified



Number	Interior Construction	Y	Thickness of Concrete – X					
			6"	8"	10"	12"	16"	20"
			A	B	C	D	E	F
1	Plain Walls – No Interior Finish		0.583	0.512	0.455	0.411	0.343	0.294
2	$\frac{1}{2}$" Plaster on Concrete		0.518	0.461	0.416	0.378	0.320	0.277
3	$\frac{3}{4}$" Plaster on Metal Lath – Furred		0.339	0.314	0.292	0.273	0.241	0.216
4	$\frac{1}{2}$" Plaster on Wood Lath – Furred		0.320	0.297	0.277	0.260	0.231	0.208
5	$\frac{1}{2}$" Plaster on $\frac{3}{8}$" Plasterboard – Furred		0.322	0.299	0.279	0.261	0.232	0.209
6	$\frac{1}{2}$" Plaster on Wood Lath on 2" Furring Strips – Cellular Gypsum Fill [b]	1$\frac{5}{8}$" [a]	0.202	0.192	0.183	0.176	0.162	0.151
7	$\frac{1}{2}$" Plaster on Wood Lath on 2" Furring Strips – Flaked Gypsum Fill	1$\frac{5}{8}$" [a]	0.177	0.170	0.163	0.157	0.146	0.137
8	$\frac{1}{2}$" Plaster on Rigid Insulation (Board form) Furred	$\frac{1}{2}$"	0.229	0.217	0.207	0.197	0.180	0.166
9		1"	0.170	0.164	0.157	0.152	0.141	0.132
10	$\frac{1}{2}$" Plaster on Corkboard set in $\frac{1}{2}$" Cement Mortar	1$\frac{1}{2}$"	0.142	0.138	0.134	0.131	0.122	0.116
11		2"	0.116	0.113	0.109	0.106	0.101	0.097

[a] Based on 1$\frac{5}{8}$ in., the actual thickness of 2 in. furring strips.
[b] The coefficient used for cellular gypsum, 0.59 is for 18 lb. weight—weights as low as 12 lb. may be used.

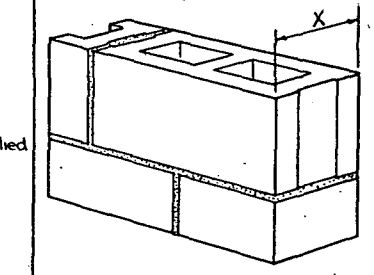
Table 19. Coefficients of Transmission (U) of Cinder and Concrete Block Walls [b-d]

Note.—These coefficients are expressed in Btu per hour per square foot per 1 deg fahr difference in temperature between the air on the two sides and are based on an outside wind exposure of 15 miles per hour.

The values of U in this Table are based on the following Internal Conductivities or Conductances which are expressed in B.t.u. per Hr. per Sq. Ft. per 1°F

Cinder Blocks	8" = 0.45	12" = 0.28
Concrete Blocks	8" = 0.84	12" = 0.52
Cement Mortar		8.00 per 1"
Plasterboard		3.73 per $\frac{3}{8}$"
Plaster (Gypsum)		2.32 per 1"
Wood Lath & Plaster		2.00 as applied
Cork board		0.30 per 1"
Rigid Insulation (Board form)		0.33 per 1"
Cellular Gypsum (18#)		0.59 per 1"
Flaked Gypsum, Dry (24#)		0.48 per 1"

Y = Thickness of Insulation where specified



Number	Interior Construction	Y	Thickness – X and Kind of Blocks			
			8" Cinder	8" Concrete	12" Cinder	12" Concrete
			A	B	C	D
1	Plain Walls – No Interior Finish		0.311	0.458	0.219	0.343
2	$\frac{1}{2}$" Plaster on Blocks		0.291	0.416	0.209	0.319
3	$\frac{3}{4}$" Plaster on Metal Lath – Furred		0.225	0.293	0.173	0.241
4	$\frac{1}{2}$" Plaster on Wood Lath – Furred		0.216	0.278	0.167	0.231
5	$\frac{1}{2}$" Plaster on $\frac{3}{8}$" Plasterboard – Furred		0.217	0.280	0.168	0.232
6	$\frac{1}{2}$" Plaster on Wood Lath on 2" Furring Strips – Cellular Gypsum Fill [c]	1$\frac{5}{8}$" [a]	0.155	0.184	0.128	0.162
7	$\frac{1}{2}$" Plaster on Wood Lath on 2" Furring Strips – Flaked Gypsum Fill	1$\frac{5}{8}$" [a]	0.140	0.163	0.118	0.146
8	$\frac{1}{2}$" Plaster on Rigid Insulation – (Board form) Furred	$\frac{1}{2}$"	0.171	0.207	0.139	0.180
9		1"	0.136	0.158	0.114	0.141
10	$\frac{1}{2}$" Plaster on Cork board set in $\frac{1}{2}$" Cement Mortar	1$\frac{1}{2}$"	0.118	0.134	0.102	0.122
11		2"	0.098	0.109	0.087	0.101

[a] Based on 1$\frac{5}{8}$ in., the actual thickness of 2 in. furring strips.
[b] The figures on this page may be used with sufficient accuracy for cinder and concrete block walls with stucco exterior finish.
[c] The coefficient used for cellular gypsum, 0.59 is for 18 lb. weight—weights as low as 12 lb. may be used.
[d] The form of the 8 in. blocks on which the figures in this table are based is shown in the above sketch. The 12 in. blocks are based on two air cells through the block instead of one.

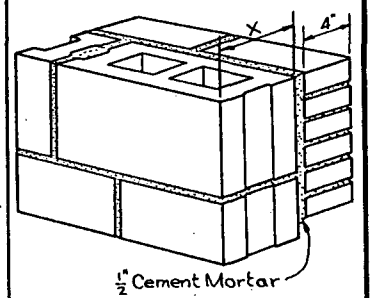
TABLE 20. COEFFICIENTS OF TRANSMISSION (*U*) OF BRICK VENEER ON CINDER AND CONCRETE BLOCK WALLS[c]

Note.—THESE COEFFICIENTS ARE EXPRESSED IN BTU PER HOUR PER SQUARE FOOT PER 1 DEG FAHR DIFFERENCE IN TEMPERATURE BETWEEN THE AIR ON THE TWO SIDES AND ARE BASED ON AN OUTSIDE WIND EXPOSURE OF 15 MILES PER HOUR.

The values of U in this Table are based on the following Internal Conductivities or Conductances which are expressed in B.t.u. per Hr. per Sq. Ft. per 1°F

Cinder Blocks	8"=0.45 12"=0.28
Concrete Blocks	8"=0.84 12"=0.52
Brick	5.00 per 1"
Cement Mortar	8.00 per 1"
Plaster board	3.73 per 3/8"
Plaster (Gypsum)	2.32 per 1"
Wood Lath & Plaster	2.00 as applied
Cork board	0.30 per 1"
Rigid Insulation (Board form)	0.33 per 1"
Cellular Gypsum (18#)	0.59 per 1"
Flaked Gypsum, Dry (24#)	0.48 per 1"

Y = Thickness of Insulation where specified



Number	Interior Construction	Y	Thickness – X and Kind of Blocks			
			8" Cinder	8" Concrete	12" Cinder	12" Concrete
			A	B	C	D
1	Plain Walls – No Interior Finish		0.245	0.328	0.184	0.264
2	½" Plaster on Blocks		0.233	0.306	0.177	0.250
3	¾" Plaster on Metal Lath – Furred		0.188	0.234	0.150	0.199
4	½" Plaster on Wood Lath – Furred		0.182	0.224	0.146	0.192
5	½" Plaster on 3/8" Plaster board – Furred		0.183	0.225	0.147	0.193
6	½" Plaster on Wood Lath on 2" Furring Strips – Cellular Gypsum Fill [b]	1 5/8" [a]	0.136	0.158	0.115	0.142
7	½" Plaster on Wood Lath on 2" Furring Strips – Flaked Gypsum Fill	1 5/8" [a]	0.125	0.144	0.107	0.130
8	½" Plaster on Rigid Insulation – (Board form) Furred	½"	0.149	0.176	0.124	0.156
9		1"	0.121	0.139	0.104	0.126
10	½" Plaster on Cork board set in ½" Cement Mortar	1½"	0.107	0.120	0.093	0.110
11		2"	0.090	0.100	0.081	0.093

[a] Based on 1⅝ in., the actual thickness of 2 in. furring strips.
[b] The coefficient used for cellular gypsum, 0.59 is for 18 lb. weight—weights as low as 12 lb. may be used.
[c] The form of the 8 in. blocks on which the figures in this table are based is shown in the above sketch. The 12 in. blocks are based on two air cells through the block instead of one.

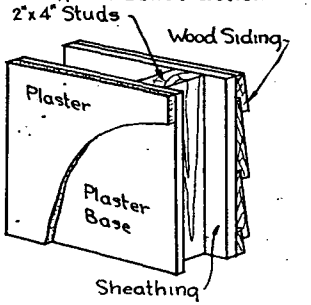
TABLE 21. COEFFICIENTS OF TRANSMISSION (*U*) OF WOOD SIDING OR CLAPBOARD FRAME WALLS

Note.—THESE COEFFICIENTS ARE EXPRESSED IN BTU PER HOUR PER SQUARE FOOT PER 1 DEG FAHR DIFFERENCE IN TEMPERATURE BETWEEN THE AIR ON THE TWO SIDES AND ARE BASED ON AN OUTSIDE WIND EXPOSURE OF 15 MILES PER HOUR.

The values of U in this Table are based on the following Internal Conductivities or Conductances which are expressed in B.t.u. per Hr. per Sq. Ft. per 1°F

Wood (Yellow Pine or Fir)	1.00 per 1"
Plaster (Gypsum)	2.32 per 1"
Plaster board	3.73 per 3/8" — 2.80 per ½"
Cork board	0.30 per 1"
Wood Lath & Plaster	2.00 as applied
Rigid Insulation (Board form)	0.33 per 1"
Flexible Insulation	0.27 per 1"
Cellular Gypsum (18#)	0.59 per 1"
Flaked Gypsum (24#)	0.48 per 1"

Typical Construction



Number	Type of Sheathing	Insulation between Studding	Plaster Base						
			Wood Lath	Metal Lath	3/8" Plaster-board	½" Rigid Insulation	1" Rigid Insulation	1½" Cork-board	2" Cork-board
			A	B	C	D	E	F	G
1	1" Wood [b]	None	0.262	0.275	0.263	0.198	0.153	0.117	0.098
2		Flaked Gypsum Fill (24#) [a]	0.096	0.098	0.096	0.086	0.076	0.067	0.060
3		Cellular Gypsum Fill (18#) [a-c]	0.111	0.113	0.111	0.097	0.085	0.073	0.065
4		½" Flexible Insulation	0.152	0.157	0.153	0.128	0.107	0.089	0.077
5	½" Rigid Insulation (Board form)	None	0.220	0.229	0.221	0.173	0.137	0.108	0.092
6		Flaked Gypsum Fill (24#) [a]	0.090	0.091	0.090	0.081	0.072	0.063	0.058
7		Cellular Gypsum Fill (18#) [a-c]	0.102	0.104	0.103	0.090	0.080	0.069	0.062
8		½" Flexible Insulation	0.137	0.140	0.137	0.117	0.099	0.083	0.073
9	½" Plaster-board	None	0.295	0.312	0.297	0.216	0.163	0.123	0.102
10		Flaked Gypsum Fill (24#) [a]	0.099	0.102	0.100	0.089	0.079	0.068	0.062
11		Cellular Gypsum Fill (18#) [a-c]	0.116	0.118	0.116	0.102	0.088	0.075	0.067
12		½" Flexible Insulation	0.163	0.167	0.163	0.135	0.112	0.092	0.080

[a] Thickness of fill assumed 3⅝ in., based on 2 in. by 4 in. studding.
[b] Based on 25/32 in., the actual thickness of 1 in. or ⅞ in. sheathing. Building paper neglected.
[c] The coefficient used for cellular gypsum, 0.59 is for 18 lb. weight—weights as low as 12 lb. may be used.

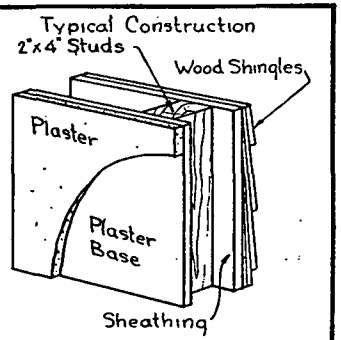
Table 22. Coefficients of Transmission (U) of Wood Shingle Frame Walls

Note.—These coefficients are expressed in Btu per hour per square foot per 1 deg fahr difference in temperature between the air on the two sides and are based on an outside wind exposure of 15 miles per hour.

The values of U in this Table are based on the following Internal Conductivities or Conductances which are expressed in B.t.u. per Hr. per Sq. Ft. per 1°F

Wood (Yellow Pine or Fir)		1.00 per 1"
Plaster (Gypsum)		2.32 per 1"
Plaster board	3.73 per $\frac{3}{8}$"	2.80 per $\frac{1}{2}$"
Cork board		0.30 per 1"
Wood Lath & Plaster		2.00 as applied
Rigid Insulation (Board form)		0.33 per 1"
Flexible Insulation		0.27 per 1"
Cellular Gypsum (18#)		0.59 per 1"
Flaked Gypsum (24#)		0.48 per 1"

Typical Construction



Number	Type of Sheathing	Insulation between Studding	Plaster Base: Wood Lath A	Metal Lath B	$\frac{3}{8}$" Plasterboard C	$\frac{1}{2}$" Rigid Insulation D	1" Rigid Insulation E	1$\frac{1}{2}$" Corkboard F	2" Corkboard G
1	1" Wood [c]	None	0.262	0.275	0.263	0.198	0.153	0.117	0.098
2		Flaked Gypsum Fill (24#) [a]	0.096	0.098	0.096	0.086	0.076	0.067	0.060
3		Cellular Gypsum Fill (18#) [a-d]	0.111	0.113	0.111	0.097	0.085	0.073	0.065
4		$\frac{1}{2}$" Flexible Insulation	0.152	0.157	0.153	0.128	0.107	0.089	0.077
5	$\frac{1}{2}$" Rigid Insulation (Board form) [b]	None	0.183	0.190	0.184	0.150	0.122	0.098	0.085
6		Flaked Gypsum Fill (24#) [a]	0.083	0.084	0.083	0.076	0.068	0.060	0.055
7		Cellular Gypsum Fill (18#) [a-d]	0.094	0.095	0.094	0.084	0.075	0.065	0.059
8		$\frac{1}{2}$" Flexible Insulation	0.122	0.125	0.122	0.106	0.091	0.077	0.069
9	$\frac{1}{2}$" Plasterboard [b]	None	0.233	0.243	0.234	0.181	0.142	0.111	0.094
10		Flaked Gypsum Fill (24#) [a]	0.091	0.093	0.092	0.083	0.074	0.065	0.059
11		Cellular Gypsum Fill (18#) [a-d]	0.105	0.107	0.105	0.093	0.081	0.070	0.063
12		$\frac{1}{2}$" Flexible Insulation	0.142	0.146	0.142	0.121	0.102	0.085	0.074

[a] Thickness of fill assumed 3$\frac{5}{8}$ in., based on 2 in. by 4 in. studding.
[b] Furring strips between wood shingles and sheathing.
[c] Based on $\frac{25}{32}$ in., the actual thickness of 1 in. or $\frac{3}{8}$ in. sheathing. Building paper neglected.
[d] The coefficient used for cellular gypsum, 0.59 is for 18 lb. weight—weights as low as 12 lb. may be used.

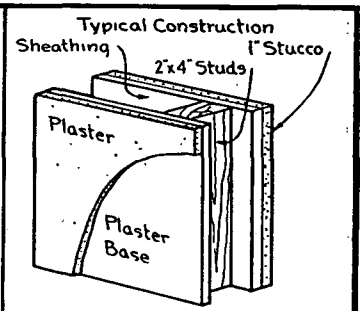
Table 23. Coefficients of Transmission (U) of Stucco Frame Walls

Note.—These coefficients are expressed in Btu per hour per square foot per 1 deg fahr difference in temperature between the air on the two sides and are based on an outside wind exposure of 15 miles per hour.

The values of U in this Table are based on the following Internal Conductivities or Conductances which are expressed in B.t.u. per Hr. per Sq. Ft. per 1°F

Wood (Yellow Pine or Fir)		1.00 per 1"
Plaster (Gypsum)		2.32 per 1"
Plaster board	3.73 per $\frac{3}{8}$"	2.80 per $\frac{1}{2}$"
Cork board		0.30 per 1"
Wood Lath & Plaster		2.00 as applied
Rigid Insulation (Board form)		0.33 per 1"
Flexible Insulation		0.27 per 1"
Cellular Gypsum (18#)		0.59 per 1"
Flaked Gypsum (24#)		0.48 per 1"
Brick		5.00 per 1"
Stucco		8.00 per 1"

Typical Construction



Number	Type of Sheathing	Insulation between Studding	Plaster Base: Wood Lath A	Metal Lath B	$\frac{3}{8}$" Plasterboard C	$\frac{1}{2}$" Rigid Insulation D	1" Rigid Insulation E	1$\frac{1}{2}$" Corkboard F	2" Corkboard G
1	1" Wood [b]	None	0.302	0.319	0.304	0.220	0.165	0.125	0.103
2		Flaked Gypsum Fill (24#) [a]	0.101	0.102	0.101	0.089	0.079	0.068	0.061
3		Cellular Gypsum Fill (18#) [a-c]	0.117	0.120	0.117	0.103	0.089	0.075	0.067
4		$\frac{1}{2}$" Flexible Insulation	0.165	0.169	0.165	0.137	0.113	0.093	0.080
5	$\frac{1}{2}$" Rigid Insulation (Board form)	None	0.247	0.259	0.248	0.190	0.147	0.114	0.096
6		Flaked Gypsum Fill (24#) [a]	0.094	0.095	0.094	0.084	0.075	0.065	0.058
7		Cellular Gypsum Fill (18#) [a-c]	0.108	0.110	0.108	0.095	0.083	0.072	0.064
8		$\frac{1}{2}$" Flexible Insulation	0.147	0.151	0.147	0.125	0.105	0.087	0.076
9	$\frac{1}{2}$" Plasterboard	None	0.347	0.369	0.349	0.243	0.178	0.131	0.108
10		Flaked Gypsum Fill (24#) [a]	0.105	0.107	0.105	0.093	0.081	0.070	0.063
11		Cellular Gypsum Fill (18#) [a-c]	0.123	0.126	0.124	0.107	0.092	0.078	0.069
12		$\frac{1}{2}$" Flexible Insulation	0.177	0.183	0.178	0.146	0.119	0.097	0.083

[a] Thickness of fill assumed 3$\frac{5}{8}$ in., based on 2 in. by 4 in. studding.
[b] Based on $\frac{25}{32}$ in., the actual thickness of 1 in. or $\frac{3}{8}$ in. sheathing. Building paper neglected.
[c] The coefficient used for cellular gypsum, 0.59 is for 18 lb. weight—weights as low as 12 lb. may be used.

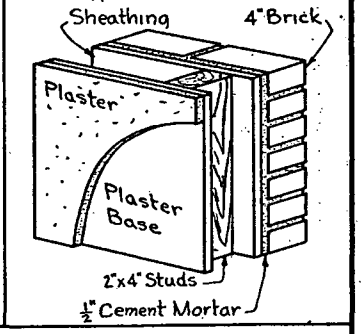
TABLE 24. COEFFICIENTS OF TRANSMISSION (*U*) OF BRICK VENEER FRAME WALLS

Note.—THESE COEFFICIENTS ARE EXPRESSED IN BTU PER HOUR PER SQUARE FOOT PER 1 DEG FAHR DIFFERENCE IN TEMPERATURE BETWEEN THE AIR ON THE TWO SIDES AND ARE BASED ON AN OUTSIDE WIND EXPOSURE OF 15 MILES PER HOUR.

The values of U in this Table are based on the following Internal Conductivities or Conductances which are expressed in B.t.u. per Hr. per Sq. Ft. per 1°F

Wood (Yellow Pine or Fir)	1.00 per 1"
Plaster (Gypsum)	2.32 per 1"
Plaster board 3.73 per 3/8"	2.80 per 1/2"
Cork board	0.30 per 1"
Wood Lath & Plaster	2.00 as applied
Rigid Insulation (Board form)	0.33 per 1"
Flexible Insulation	0.27 per 1"
Cellular Gypsum (18#)	0.59 per 1"
Flaked Gypsum (24#)	0.48 per 1"
Brick	5.00 per 1"

Typical Construction



Number	Type of Sheathing	Insulation between Studding	Plaster Base: Wood Lath	Metal Lath	3/8" Plaster board	1/2" Rigid Insulation	1" Rigid Insulation	1 1/2" Cork board	2" Cork board
			A	B	C	D	E	F	G
1	1" Wood [b]	None	0.247	0.258	0.248	0.189	0.147	0.114	0.087
2		Flaked Gypsum Fill (24#) [a]	0.094	0.095	0.094	0.084	0.075	0.065	0.058
3		Cellular Gypsum Fill (18#) [a-c]	0.108	0.110	0.108	0.095	0.083	0.072	0.064
4		1/2" Flexible Insulation	0.147	0.150	0.147	0.125	0.105	0.087	0.076
5	1/2" Rigid Insulation (Board form)	None	0.209	0.217	0.210	0.166	0.133	0.106	0.090
6		Flaked Gypsum Fill (24#) [a]	0.087	0.089	0.087	0.079	0.071	0.062	0.056
7		Cellular Gypsum Fill (18#) [a-c]	0.100	0.102	0.101	0.089	0.079	0.068	0.061
8		1/2" Flexible Insulation	0.133	0.136	0.133	0.114	0.098	0.082	0.072
9	1/2" Plaster board	None	0.276	0.290	0.277	0.206	0.157	0.120	0.100
10		Flaked Gypsum Fill (24#) [a]	0.098	0.100	0.098	0.087	0.077	0.067	0.060
11		Cellular Gypsum Fill (18#) [a-c]	0.113	0.115	0.113	0.100	0.086	0.074	0.066
12		1/2" Flexible Insulation	0.157	0.161	0.157	0.131	0.109	0.090	0.079

[a] Thickness of fill assumed 3 5/8 in., based on 2 in. by 4 in. studding.
[b] Based on 25/32 in., the actual thickness of 1 in. or 7/8 in. sheathing. Building paper neglected.
[c] The coefficient used for cellular gypsum, 0.59 is for 18 lb. weight—weights as low as 12 lb. may be used.

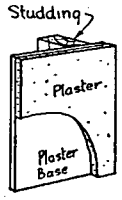
TABLE 25. COEFFICIENTS OF TRANSMISSION (*U*) OF INTERIOR WALLS AND PARTITIONS

Note.—THESE COEFFICIENTS ARE EXPRESSED IN BTU PER HOUR PER SQUARE FOOT PER 1 DEG FAHR DIFFERENCE IN TEMPERATURE BETWEEN THE AIR ON THE TWO SIDES AND ARE BASED ON STILL-AIR (NO WIND) CONDITIONS ON BOTH SIDES.

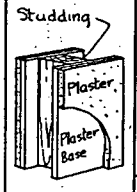
PLASTERED FRAME PARTITIONS

The values of U in this Table are based on the following Internal Conductivities or Conductances which are expressed in B.t.u. per Hr. per Sq. Ft. per 1°F

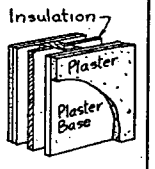
Plaster (Gypsum)	2.32 per 1"
Plaster board	3.73 per 3/8"
Wood Lath & Plaster	2.00 as appld.
Rigid Insulation (Board form)	0.33 per 1"
Flexible Insulation	0.27 per 1"
Cork board	0.30 per 1"
Cellular Gypsum (18#)	0.59 per 1"
Flaked Gypsum, Dry (24#)	0.48 per 1"



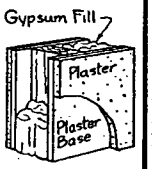
On one side of Studding only



On both sides of Studding



Insulation between Studding



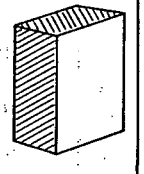
Gypsum Fill between Studding

No.	Plaster Base	A	B	C: 1/2" Rigid Insulation (Board form)	D: 1/2" Flexible Insulation	E: Cellular Gypsum Fill [a-d]	F: Flaked Gypsum Fill [a]
1	Metal Lath [b]	0.551	0.328	0.183	0.173	0.121	0.103
2	Wood Lath [c]	0.502	0.294	0.172	0.162	0.116	0.100
3	3/8" Plaster board [c]	0.506	0.297	0.172	0.163	0.117	0.100
4	1/2" Rigid Insulation (Board form) [c]	0.310	0.170	0.121	0.116	0.090	0.080
5	1" Rigid Insulation (Board form) [c]	0.211	0.113	0.088	0.086	0.071	0.064
6	1 1/2" Cork board	0.149	0.078	0.066	0.064	0.055	0.052
7	2" Cork board	0.119	0.062	0.054	0.053	0.047	0.044

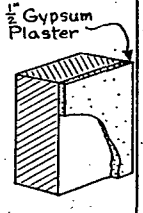
PLASTERED MASONRY PARTITIONS

The values of U in this Table are based on the following Internal Conductivities or Conductance which are expressed in B.t.u. per Hr. per Sq. Ft. per 1°F

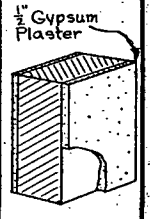
Hollow Clay Tile (4")	0.93 per 4"
Brick	5.00 per 1"
Hollow Gypsum Tile	0.46 per 4"



Plain Walls (No Plaster)



Walls Plastered one side



Walls Plastered both sides

No.	Wall Construction	A: Plain Walls (No Plaster)	B: Walls Plastered one side	C: Walls Plastered both sides
1	4" Hollow Clay Tile	0.390	0.360	0.333
2	4" Brick	0.437	0.400	0.367
3	4" Hollow Gypsum Tile	0.273	0.258	0.244

[a] The thickness of the gypsum fill is approximately 3 5/8 in., the approximate 4 in. dimension of 2 in. by 4 in. studding.
[b] Metal lath and plaster assumed 3/4 in. thick.
[c] Plaster assumed 1/2 in. thick.
[d] The coefficient used for cellular gypsum, 0.59 is for 18 lb. weight—weights as low as 12 lb. may be used.

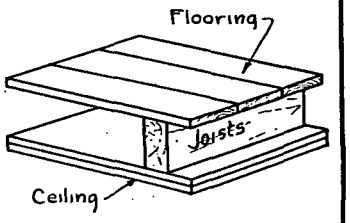
TABLE 26. COEFFICIENTS OF TRANSMISSION (*U*) OF FRAME CONSTRUCTION FLOORS AND CEILINGS

Note.—THESE COEFFICIENTS ARE EXPRESSED IN BTU PER HOUR PER SQUARE FOOT PER 1 DEG FAHR DIFFERENCE IN TEMPERATURE BETWEEN THE AIR ON THE TWO SIDES AND ARE BASED ON STILL-AIR (NO WIND) CONDITIONS ON BOTH SIDES.

The values of U in this Table are based on the following Internal Conductivities or Conductances which are expressed in B.t.u. per Hr. per Sq. Ft. per 1°F

Wood (Yellow Pine or Fir)	1.00 per 1"
Wood (Maple)	1.20 per 1"
Plaster (Gypsum)	2.32 per 1"
Plaster board	3.73 per $\frac{3}{8}$"
Wood Lath & Plaster	2.00 as applied
Cork board	0.30 per 1"
Rigid Insulation (Board form)	0.33 per 1"
Cellular Gypsum (18#)	0.59 per 1"
Flaked Gypsum, Dry (18#)	0.34 per 1"
Flexible Insulation	0.27 per 1"

Typical Construction



Number	Type of Ceiling	Insulation between Joists	Type of Flooring: No Flooring	1" Yellow Pine[b] Flooring on Joists	1" Yellow Pine[b] Flooring on ½" Rigid Insulation (Board form) on Joists	13/16" Maple or Oak Flooring on 1" Yellow Pine Sub-flooring on Joists
			A	B	C	D
1	No Ceiling	None		0.440	0.264	0.339
2	Metal Lath & Plaster ($\frac{3}{4}$")	None	0.551	0.298	0.200	0.239
3	Wood Lath & Plaster ($\frac{1}{2}$")	None	0.502	0.272	0.192	0.230
4	$\frac{3}{8}$" Plaster board & Plaster ($\frac{1}{2}$")	None	0.506	0.273	0.193	0.230
5	$\frac{1}{2}$" Rigid Insulation (Board form) & Plaster ($\frac{1}{2}$")	None	0.310	0.204	0.156	0.179
6	Wood Lath & Plaster ($\frac{1}{2}$")	$\frac{1}{2}$" Flexible[a] Insulation	0.210	0.155	0.126	0.140
7	Wood Lath & Plaster ($\frac{1}{2}$")	$\frac{1}{2}$" Rigid Insulation (Board form)[a]	0.226	0.163	0.131	0.148
8	Wood Lath & Plaster ($\frac{1}{2}$")	Cellular Gypsum Fill (2") [d-c]	0.186	0.141	0.117	0.129
9	Wood Lath & Plaster ($\frac{1}{2}$")	Flaked Gypsum Fill (2")[c]	0.127	0.105	0.090	0.098
10	$\frac{1}{2}$" Cork board & Plaster ($\frac{1}{2}$")	None	0.149	0.119	0.101	0.110
11	2" Cork board & Plaster ($\frac{1}{2}$")	None	0.119	0.100	0.087	0.093

[a]The value of *U* is the same if insulation is applied to underside of joists and lath and plaster ceiling separated by furring strips.

[b]Based on actual thickness of approximately 13/16 in. for 1 in. yellow pine flooring.

[c]Thickness of fill assumed 2 in.

[d]The coefficient used for cellular gypsum, 0.59 is for 18 lb. weight—weights as low as 12 lb. may be used.

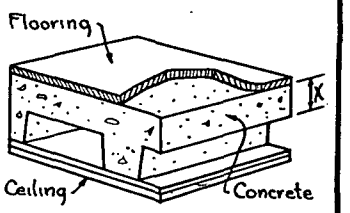
TABLE 27. COEFFICIENTS OF TRANSMISSION (*U*) OF CONCRETE CONSTRUCTION FLOORS AND CEILINGS

Note.—THESE COEFFICIENTS ARE EXPRESSED IN BTU PER HOUR PER SQUARE FOOT PER 1 DEG FAHR DIFFERENCE IN TEMPERATURE BETWEEN THE AIR ON THE TWO SIDES AND ARE BASED ON STILL-AIR (NO WIND) CONDITIONS ON BOTH SIDES.

The values of U in this Table are based on the following Internal Conductivities or Conductances which are expressed in B.t.u. per Hr. per Sq. Ft. per 1°F

Tile or Terrazzo	10.00 per 1"
Concrete (Stone 1:2:4 mix)	8.30 per 1"
Cement Mortar	8.00 per 1"
Wood (Yellow Pine or Fir)	1.00 per 1"
Wood (Maple)	1.20 per 1"
Plaster board	3.73 per $\frac{3}{8}$"
Plaster (Gypsum)	2.32 per 1"
Cork board	0.30 per 1"
Rigid Insulation (Board form)	0.33 per 1"

Typical Construction



Number	Type of Ceiling	X = Thickness	Type of Flooring: No Flooring[a] (Concrete bare)	1" Yellow Pine Flooring[b] on Wood Sleepers embedded in Concrete	13/16" Maple or Oak Flooring on 1" Yellow Pine Sub-Flooring on Wood Sleepers embedded in Concrete	1" Terrazzo or Tile Flooring on Concrete
			A	B	C	D
1	No Ceiling	4"	0.508	0.364	0.292	0.483
2		6"	0.452	0.334	0.273	0.433
3		8"	0.408	0.310	0.256	0.392
4		10"	0.372	0.288	0.241	0.358
5	½" Plaster applied directly to under-side of Concrete	4"	0.457	0.337	0.275	0.437
6		6"	0.411	0.311	0.258	0.395
7		8"	0.374	0.290	0.243	0.361
8		10"	0.344	0.271	0.230	0.332
9	Suspended or Furred Metal Lath & Plaster Ceiling	4"	0.312	0.251	0.215	0.303
10		6"	0.299	0.237	0.204	0.282
11		8"	0.272	0.224	0.195	0.264
12		10"	0.255	0.212	0.186	0.249
13	Suspended or Furred Ceiling of ⅜" Plaster board & Plaster	4"	0.297	0.241	0.208	0.289
14		6"	0.277	0.228	0.198	0.270
15		8"	0.260	0.216	0.189	0.254
16		10"	0.245	0.206	0.181	0.239
17	Suspended or Furred Ceiling of ½" Rigid Insulation (Board form) & Plaster	4"	0.217	0.185	0.165	0.212
18		6"	0.206	0.178	0.159	0.202
19		8"	0.197	0.170	0.153	0.193
20		10"	0.187	0.163	0.147	0.184
21	½" Plaster on 1½" Cork board set in ½" Cement Mortar on Concrete	4"	0.138	0.124	0.115	0.136
22		6"	0.133	0.121	0.112	0.132
23		8"	0.129	0.117	0.109	0.128
24		10"	0.125	0.114	0.106	0.124
25	½" Plaster on 2" Cork board set in ½" Cement Mortar on Concrete	4"	0.112	0.103	0.097	0.111
26		6"	0.109	0.101	0.094	0.108
27		8"	0.106	0.098	0.092	0.105
28		10"	0.104	0.096	0.090	0.103

[a]The figures in column "A" are sufficiently accurate for concrete floors covered with carpet or linoleum.

[b]The figures in column "B" are sufficiently accurate for 13/16 in. maple or oak flooring applied directly over the concrete on wood sleepers.

TABLE 28. COEFFICIENTS OF TRANSMISSION (*U*) OF CONCRETE CONSTRUCTION FLOORS ON GROUND[a]

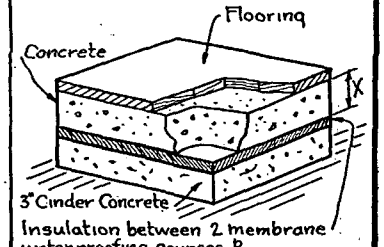
Note.—THESE COEFFICIENTS ARE EXPRESSED IN BTU PER HOUR PER SQUARE FOOT PER 1 DEG FAHR DIFFERENCE IN TEMPERATURE BETWEEN THE GROUND AND THE AIR OVER THE FLOOR AND ARE BASED ON STILL-AIR (NO WIND) CONDITIONS.

The values of U in this Table are based on the following Internal Conductivities or Conductances which are expressed in B.t.u. per Hr. per Sq. Ft. per 1°F

Tile or Terrazzo	10.00 per 1"
Concrete (Stone 1:2:4 mix)	8.30 per 1"
Cinder Concrete	5.20 per 1"
Wood (Yellow Pine)	1.00 per 1"
Wood (Maple)	1.20 per 1"
Rigid Insulation (Board form)	0.33 per 1"
Cork board	0.30 per 1"

Y = Thickness of Insulation in Inches where specified

Typical Construction



Number	Type of Insulation (Between Cinder & Stone Concrete)	Thickness Y	Thickness X	Type of Flooring: No Flooring (Concrete bare) A	1" Yellow Pine Flooring on Wood Sleepers embedded in Concrete [c] B	13/16" Maple or Oak Flooring on 1" Yellow Pine Sub-Flooring on Wood Sleepers embedded in Concrete C	1" Terrazzo or Tile Flooring on Concrete D
1	No Insulation	0"	4"	0.556	0.388	0.308	0.526
2		0"	5"	0.521	0.370	0.297	0.495
3		0"	6"	0.490	0.355	0.286	0.467
4		0"	8"	0.439	0.327	0.268	0.420
5	Rigid Insulation (Board form)	1"	4"	0.207	0.178	0.159	0.203
6		1"	5"	0.202	0.174	0.156	0.198
7		1"	6"	0.197	0.171	0.153	0.193
8		1"	8"	0.188	0.164	0.148	0.185
9	Cork board	2"	4"	0.118	0.108	0.101	0.117
10		2"	5"	0.116	0.107	0.100	0.115
11		2"	6"	0.115	0.105	0.098	0.113
12		2"	8"	0.112	0.103	0.096	0.110

[a] Assume ground temperature to be 50 deg. fahr.

[b] Membrane waterproofing neglected in calculations.

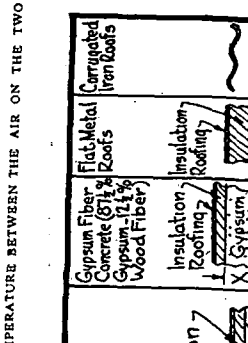
[c] The figures in column "B" may be used with sufficient accuracy for maple or oak flooring on wood sleepers embedded in concrete.

TABLE 29. COEFFICIENTS OF TRANSMISSION (*U*) OF VARIOUS TYPES OF FLAT ROOFS COVERED WITH BUILT-UP ROOFING WITHOUT CEILINGS. (UNDERSIDE OF ROOF EXPOSED)

Note.—THESE COEFFICIENTS ARE EXPRESSED IN BTU PER HOUR PER SQUARE FOOT PER 1 DEG FAHR DIFFERENCE IN TEMPERATURE BETWEEN THE AIR ON THE TWO SIDES AND ARE BASED ON AN OUTSIDE WIND EXPOSURE OF 15 MILES PER HOUR.

The values of U in this Table are based on the following Internal Conductivities or Conductances which are expressed in B.t.u. per Hr. per Sq. Ft. per 1°F

Roofing	1.325 per 1"
Concrete	8.30 per 1"
Gypsum (Fiber Concrete)	1.66 per 1"
Wood (Yellow Pine or Fir)	1.00 per 1"
Rigid Insulation (Board form)	0.33 per 1"
Flexible Insulation	0.27 per 1"
Cork board	0.30 per 1"
Plaster board	3.73 per 1"
Cellular Gypsum (24#)	0.77 per 1"
Lt. Wt. Heat treated Clay Aggregate Cement	1.62 per 1"



Number	Thickness of Insulation	Kind of Insulation	Concrete Roofs: Thickness-X 1 5/8" A	2" B	3" C	4" D	5" E	6" F	Wood Roofs: Thickness-X 1" G	1½" H	2" I	3" J	4" K	Gypsum Fiber Concrete (87½% Gypsum-12½% Wood Fiber) Thickness-X 2½" L	3½" M	Flat Metal Roofs N	Corrugated Iron Roofs O
1	0"	No Insulation	0.680	0.658	0.610	0.568	0.532	0.500	0.485	0.386	0.345	0.256	0.204	0.354	0.292	0.781	1.50[c]
2	½"	Rigid Insulation (Board form)	0.334	0.330	0.317	0.306	0.295	0.285	0.280	0.243	0.226	0.184	0.156	0.230	0.202	0.358	
3	1"		0.222	0.220	0.214	0.209	0.203	0.199	0.196	0.178	0.168	0.144	0.126	0.171	0.155	0.232	
4	1½"		0.166	0.165	0.162	0.159	0.156	0.153	0.151	0.140	0.134	0.118	0.106	0.136	0.126	0.172	
5	2"		0.133	0.132	0.130	0.128	0.126	0.124	0.123	0.116	0.112	0.100	0.091	0.112	0.106	0.136	
6	1"	Cork board	0.208	0.206	0.201	0.196	0.192	0.188	0.185	0.169	0.160	0.138	0.121	0.163	0.148	0.217	
7	1½"		0.154	0.153	0.151	0.148	0.145	0.143	0.142	0.132	0.126	0.124	0.101	0.128	0.119	0.160	
8	2"		0.123	0.122	0.120	0.119	0.117	0.115	0.114	0.108	0.104	0.095	0.086	0.106	0.099	0.126	
9	½"	Flexible Insulation (Not compressed)	0.301	0.297	0.286	0.277	0.268	0.260	0.256	0.225	0.210	0.174	0.148	0.214	0.190	0.319	
10	1"		0.193	0.191	0.187	0.183	0.179	0.175	0.174	0.159	0.151	0.131	0.116	0.153	0.140	0.201	
11	2"	Cellular Gypsum	0.246	0.243	0.236	0.229	0.223	0.217	0.214	0.193	0.182	0.154	0.133				

[a] Pre-cast cement tile. For heat-treated clay aggregate cement tile covered with roofing, $U = 0.55$ (1⅝ in. slab) and $U = 0.62$ (1 in. slab), based on a conductivity of 3.00 per 1 in.

[b] Nominal thicknesses specified—actual thicknesses used in computations.

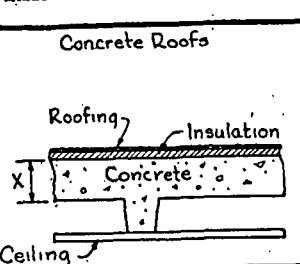
[c] No built-up roofing. The value for corrugated iron is obtained by assuming that the surface area is increased 50 per cent.

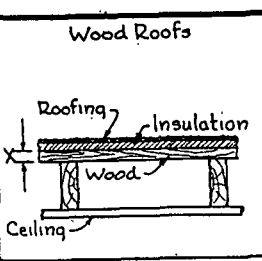
TABLE 30. COEFFICIENTS OF TRANSMISSION (*U*) OF FLAT ROOFS COVERED WITH BUILT-UP ROOFING WITH METAL LATH AND PLASTER CEILINGS[c]

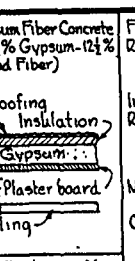
Note.—THESE COEFFICIENTS ARE EXPRESSED IN BTU PER HOUR PER SQUARE FOOT PER 1 DEG FAHR DIFFERENCE IN TEMPERATURE BETWEEN THE AIR ON THE TWO SIDES AND ARE BASED ON AN OUTSIDE WIND EXPOSURE OF 15 MILES PER HOUR.

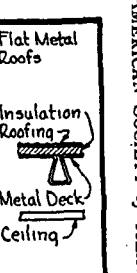
The values of U in this Table are based on the following Internal Conductivities or Conductances which are expressed in B.t.u. per Hr. per Sq. Ft. per 1°F

Roofing	1.325 per 1"
Concrete	8.30 per 1"
Gypsum (Fiber Concrete)	1.66 per 1"
Wood (Yellow Pine or Fir)	1.00 per 1"
Rigid Insulation (Board form)	0.33 per 1"
Flexible Insulation	0.27 per 1"
Corkboard	0.30 per 1"
Plaster board	3.73 per 3/8"
Cellular Gypsum (24#)	0.77 per 1"
Plaster (Gypsum)	2.32 per 1"









Number	Thickness of Insulation	Kind of Insulation	Thickness-X: 1⅝"[a]	2"	3"	4"	5"	6"	Thickness-X[b]: 1"	1½"	2"	3"	4"	Thickness-X: 2½"	3½"	
			A	B	C	D	E	F	G	H	I	J	K	L	M	N
1	0"	No Insulation	0.370	0.363	0.348	0.334	0.321	0.309	0.304	0.262	0.242	0.195	0.163	0.247	0.215	0.398
2	½"	Rigid Insulation (Board form)	0.237	0.235	0.228	0.222	0.216	0.211	0.208	0.187	0.177	0.150	0.131	0.179	0.162	0.248
3	1"		0.174	0.173	0.169	0.166	0.163	0.160	0.158	0.146	0.140	0.123	0.109	0.141	0.130	0.180
4	1½"		0.138	0.137	0.135	0.133	0.131	0.129	0.128	0.120	0.115	0.104	0.094	0.116	0.108	0.142
5	2"		0.114	0.113	0.112	0.110	0.109	0.108	0.107	0.101	0.098	0.089	0.082	0.099	0.093	0.117
6	1"	Corkboard	0.166	0.164	0.161	0.158	0.155	0.153	0.151	0.140	0.134	0.118	0.106	0.135	0.125	0.113
7	1½"		0.130	0.129	0.127	0.125	0.123	0.121	0.121	0.113	0.110	0.099	0.090	0.110	0.104	0.133
8	2"		0.107	0.106	0.105	0.104	0.103	0.101	0.101	0.096	0.092	0.085	0.078	0.093	0.088	0.109
9	½"	Flexible Insulation (Not compressed)	0.219	0.217	0.212	0.207	0.202	0.197	0.194	0.176	0.167	0.143	0.126	0.169	0.154	0.229
10	1"		0.156	0.155	0.152	0.150	0.147	0.144	0.143	0.133	0.128	0.113	0.102	0.129	0.120	0.161
11	2"	Cellular Gypsum	0.188	0.187	0.183	0.179	0.175	0.172	0.170	0.156	0.148	0.129	0.114			

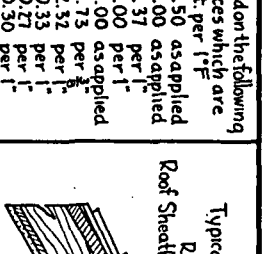
[a] Pre-cast cement.
[b] Nominal thickness specified—actual thicknesses used in computations.
[c] The figures in this table may be used with sufficient accuracy for wood lath and plaster ceilings.

TABLE 31. COEFFICIENTS OF TRANSMISSION (*U*) OF PITCHED ROOFS OVER HEATED ATTICS

Note.—THESE COEFFICIENTS ARE EXPRESSED IN BTU PER HOUR PER SQUARE FOOT PER 1 DEG FAHR DIFFERENCE IN TEMPERATURE BETWEEN THE AIR ON THE TWO SIDES AND ARE BASED ON AN OUTSIDE WIND EXPOSURE OF 15 MILES PER HOUR.

The values of U in this Table are based on the following Internal Conductivities or Conductances which are expressed in B.t.u. per Hr. per Sq. Ft. per 1°F

Asphalt or Composition Roofing	6.50 as applied
Asbestos Shingles	6.00 as applied
Slate Shingles	10.37 per 1"
Wood (Yellow Pine or Fir)	1.00 per 1"
Wood Lath & Plaster	2.00 as applied
Plaster board	3.73 per ⅜"
Plaster (Gypsum)	2.32 per 1"
Rigid Insulation (Board form)	0.33 per 1"
Flexible Insulation	0.27 per 1"
Corkboard	0.30 per 1"
Cellular Gypsum (18#)	0.59 per 1"
Flaked Gypsum (24") Dry	0.48 per 1"



Number	Type of Roofing and Roof Sheathing	Insulation between Roof Rafters	Type of Ceiling: No Ceiling	Metal Lath and ¾" Plaster	Plaster board ⅜" Lath and ½" Plaster	Wood Lath and ½" Plaster	½" Rigid Insula-tion and ½" Plaster	Rigid Insula-tion and ½" Plaster	½" Cork-board and ½" Plaster	2" Cork-board and ½" Plaster
			A	B	C	D	E	F	G	H
1	Wood Shingles on Wood Strips[a]	None	0.483	0.303	0.289	0.288	0.212	0.161	0.122	0.102
2		½" Flexible[b]		0.165	0.161	0.160	0.134	0.111	0.091	0.079
3		1" Flexible[b]		0.126	0.124	0.124	0.107	0.092	0.078	0.069
4		⅜" Cellular[c] ⅜" Flaked Gypsum		0.112	0.110	0.110	0.097	0.085	0.072	0.065
5		None	0.518	0.097	0.096	0.096	0.085	0.076	0.066	0.059
6	Asphalt Shingles or Composition Roofing on Wood Sheathing	½" Flexible[b]	0.518	0.316	0.301	0.300	0.219	0.164	0.124	0.103
7		1" Flexible[b]		0.169	0.165	0.164	0.136	0.113	0.092	0.080
8		⅜" Cellular[c] ⅜" Flaked Gypsum		0.129	0.126	0.126	0.109	0.094	0.079	0.070
9		None		0.120	0.117	0.117	0.102	0.088	0.076	0.067
10		½" Flexible[b]		0.102	0.101	0.101	0.089	0.079	0.068	0.061
11	Rigid Asbestos Shingles on Wood Sheathing	None	0.515	0.315	0.300	0.298	0.218	0.164	0.124	0.103
12		½" Flexible[b]		0.169	0.164	0.164	0.136	0.113	0.092	0.080
13		1" Flexible[b]		0.129	0.126	0.126	0.109	0.093	0.079	0.070
14		⅜" Cellular[c] ⅜" Flaked Gypsum		0.119	0.117	0.117	0.102	0.088	0.075	0.067
15		None	0.548	0.327	0.311	0.309	0.224	0.167	0.126	0.104
16	Slate or Tile and Roofing Felt on Wood Sheathing	½" Flexible[b]		0.172	0.167	0.167	0.138	0.114	0.093	0.081
17		1" Flexible[b]		0.131	0.128	0.127	0.110	0.095	0.080	0.070
18		⅜" Cellular[c] ⅜" Flaked Gypsum		0.121	0.118	0.118	0.103	0.089	0.076	0.067
			0.103	0.101	0.101	0.101	0.090	0.079	0.069	0.062

[a] Based on 1 in. by 4 in. strips spaced 2 in.
[b] Can also be applied to underside of roof rafters with furring strips between.
[c] Assumed 3⅛ in. thick, based on 2 in. by 4 in. rafters.
The coefficient used for cellular gypsum, 0.59 is for 18 lb. weight—weights as low as 12 lb. may be used.

TABLE 32. COEFFICIENTS OF TRANSMISSION (*U*)

Note.—THE FIGURES ON THESE PAGES ARE THE COMBINED COEFFICIENTS OF TRANSMISSION OF PITCHED ROOFS, UNHEATED ATTICS, AND TOP-FLOOR CEILINGS, AND ARE EXPRESSED IN BTU PER HOUR PER SQUARE FOOT OF ROOF AREA PER 1 DEG FAHR DIFFERENCE IN TEMPERATURE BETWEEN THE AIR UNDERNEATH THE CEILING AND THE OUTSIDE AIR. AN AVERAGE WIND EXPOSURE OF 15 MILES HAS BEEN ASSUMED. THESE COEFFICIENTS ARE BASED ON ONE-THIRD PITCHED ROOFS, BUT ARE SUFFICIENTLY ACCURATE FOR ROOFS RANGING FROM ONE-QUARTER PITCH TO ONE-HALF PITCH.

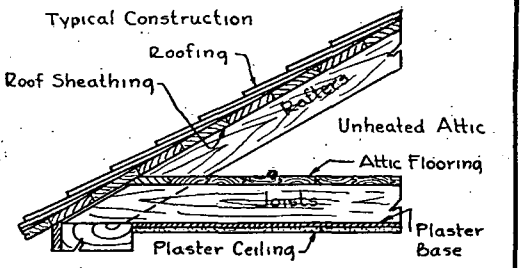
The values of U in this Table are based on the following Internal Conductivities or Conductances which are expressed in B.t.u. per Hr. per Sq. Ft. per 1°F

Asphalt or Composition Roofing	6.50 as applied
Asbestos Shingles	6.00 as applied
Slate Shingles	10.37 per 1"
Wood (Yellow Pine or Fir)	1.00 per 1"
Wood Lath & Plaster	2.00 as applied
Plaster board	3.13 per ⅜"
Plaster (Gypsum)	2.32 per ½"
Rigid Insulation (Board form)	0.33 per 1"
Flexible Insulation	0.27 per 1"
Cork board	0.30 per 1"
Cellular Gypsum (18#)	0.59 per 1"
Flaked Gypsum, Dry (18#)	0.34 per 1"

Number	Roofing and Roof Sheathing	Insulation between Ceiling Joists	No Attic Flooring			
			Wood Lath and Plaster Ceiling	⅜" Plasterboard & Plaster Ceiling	½" Rigid Insulation & Plaster Ceiling	1" Rigid Insulation & Plaster Ceiling
			A	B	C	D
1	Wood Shingles on Wood Strips[a]	None	0.263	0.264	0.190	0.141
2		½" Flexible[b]	0.141	0.141	0.116	0.096
3		2" Cellular[d] Gypsum	0.126	0.126	0.107	0.090
4		2" Flaked Gypsum	0.092	0.092	0.081	0.071
5	Asphalt Shingles or Composition Roofing on Wood Sheathing	None	0.272	0.273	0.194	0.143
6		½" Flexible[b]	0.143	0.143	0.118	0.097
7		2" Cellular[d] Gypsum	0.128	0.128	0.108	0.090
8		2" Flaked Gypsum	0.093	0.093	0.081	0.071
9	Rigid Asbestos Shingles on Wood Sheathing	None	0.271	0.272	0.194	0.143
10		½" Flexible[b]	0.143	0.143	0.118	0.097
11		2" Cellular[d] Gypsum	0.128	0.128	0.108	0.090
12		2" Flaked Gypsum	0.093	0.093	0.081	0.071
13	Slate or Tile and Roofing Felt on Wood Sheathing	None	0.280	0.281	0.198	0.145
14		½" Flexible[b]	0.145	0.145	0.120	0.098
15		2" Cellular[d] Gypsum	0.130	0.130	0.109	0.090
16		2" Flaked Gypsum	0.093	0.093	0.082	0.072

[a] Based on 1 in. by 4 in. spaced 2 in.
[b] Can also be applied to underside of ceiling joists with furring strips between insulation and ceiling.
[c] Based on actual thickness of 1 in. lumber of approximately 25/32 in.
[d] The coefficient used for cellular gypsum, 0.59 is for 18 lb. weight—weights as low as 12 lb. may be used.

OF PITCHED ROOFS WITH UNHEATED ATTICS



		1"x6" Yellow Pine Attic Flooring[c]					
1½" Corkboard & Plaster Ceiling	2" Corkboard & Plaster Ceiling	Wood Lath and Plaster Ceiling	⅜" Plasterboard & Plaster Ceiling	½" Rigid Insulation & Plaster Ceiling	1" Rigid Insulation & Plaster Ceiling	1½" Corkboard & Plaster Ceiling	2" Corkboard & Plaster Ceiling
E	F	G	H	I	J	K	L
0.106	0.088	0.172	0.172	0.136	0.109	0.087	0.074
0.078	0.068	0.109	0.109	0.094	0.080	0.068	0.060
0.074	0.064	0.101	0.101	0.088	0.076	0.064	0.057
0.061	0.054	0.078	0.078	0.070	0.062	0.053	0.049
0.107	0.088	0.175	0.175	0.138	0.110	0.087	0.075
0.079	0.068	0.110	0.110	0.095	0.081	0.068	0.060
0.075	0.064	0.102	0.102	0.088	0.076	0.064	0.057
0.061	0.054	0.078	0.078	0.070	0.062	0.054	0.049
0.107	0.088	0.175	0.175	0.138	0.110	0.087	0.075
0.079	0.068	0.110	0.110	0.095	0.081	0.068	0.060
0.075	0.064	0.102	0.102	0.088	0.076	0.064	0.057
0.061	0.054	0.078	0.078	0.070	0.062	0.054	0.049
0.108	0.089	0.179	0.179	0.140	0.111	0.088	0.076
0.080	0.068	0.111	0.111	0.096	0.081	0.068	0.060
0.076	0.065	0.103	0.103	0.089	0.076	0.065	0.058
0.061	0.054	0.078	0.078	0.070	0.062	0.054	0.049

[a] Based on 1 in. by 4 in. spaced 2 in.
[b] Can also be applied to underside of ceiling joists with furring strips between insulation and ceiling.
[c] Based on actual thickness of 1 in. lumber of approximately 25/32 in.
[d] The coefficient used for cellular gypsum, 0.59 is for 18 lb. weight—weights as low as 12 lb. may be used.

walls, ceilings and floors next to cold or unheated spaces are found, of course, by taking the inside dimensions of such areas, measured on the heated side.

CALCULATIONS FOR TRANSMISSION LOSSES

The calculations for heat transmission losses are made by multiplying the area A in square feet of wall, glass, roof or floor through which the loss takes place, by the proper coefficient U for such construction (Tables 9 to 33, or by computation as described under Transmission Coefficients by Computation) and by the temperature difference between the inside air temperature t at the proper level (in many cases not the *breathing line*) and the outside air temperature t_o. Therefore,

$$H_t = A\,U\,(t - t_o) \qquad (12)$$

where

H_t = Btu per hour transmitted through the material of the wall, glass, roof or floor.

A = area in square feet of wall, glass, roof or floor, taken from building plans or actually measured. (Use the net inside or heated surface dimensions in all cases).

$t - t_o$ = temperature-difference between inside and outside air, in which t must always be taken at the proper level. Note that t may not be the *breathing-line* temperature in many cases.

TABLE 33. COEFFICIENTS OF TRANSMISSION (U) OF DOORS, WINDOWS AND SKYLIGHTS

Note.—THESE COEFFICIENTS ARE BASED ON A WIND EXPOSURE OF 15 MILES PER HOUR, AND ARE EXPRESSED IN BTU PER HOUR, PER SQUARE FOOT, PER DEG FAHR DIFFERENCE IN TEMPERATURE BETWEEN THE AIR INSIDE AND OUTSIDE OF THE DOOR, WINDOW OR SKYLIGHT.

A. Windows and Skylights

	U
Single	1.13[a,c]
Double	0.45[a]
Triple	0.281[a]

B. Solid Wood Doors[b,c]

NOMINAL THICKNESS INCHES	ACTUAL THICKNESS INCHES	U
1	25/32	0.563
1¼	1 1/16	0.485
1½	1 5/16	0.432
1¾	1 3/8	0.421
2	1 5/8	0.382
2½	2 1/8	0.321
3	2 5/8	0.277

[a] See page 212, Volume I, *Mechanical Equipment of Buildings*, by Harding and Willard, second edition, 1929.

[b] Computed using $C = 1.0$ for wood; $f_i = 1.34$ and $f_o = 4.02$.

[c] It is sufficiently accurate to use the same coefficient of transmission for doors containing thin wood panels, as that of single panes of glass, namely, 1.13 Btu per hour per square foot per degree difference between inside and outside air temperature.

CONDENSATION ON BUILDING SURFACES[4]

Condensation on the interior surfaces of buildings is often a serious problem. Water dripping from a ceiling may cause irreparable damage to manufactured articles and machinery. It often results in short-circuiting of electric power and lighting systems, necessitating shut-downs and incurring costly repairs. It also causes rotting of wood roof structures, corrosion of metal roofs, and spalling and disintegration of gypsum and other types of roof decks not properly protected.

Condensation is caused by the contact of the warm humid air in a building with surfaces below the dew-point temperature, and can be remedied in two ways, (1) by increasing the temperature of such surfaces above the dew-point temperature, or (2) by lowering the humidity.

Dehumidification, of course, is not permissible where a high relative humidity is necessary for manufacturing processes. Hence, the only alternative is to increase the surface temperature by decreasing the inside surface resistance. This can be accomplished by increasing the velocity of air passing over the surface, or by increasing the over-all resistance of the wall or roof by installing a sufficient thickness of insulation.

The latter method is generally used, and the thickness of insulation is determined by ascertaining the amount of resistance to be added to increase the temperature of the interior surface above the dew-point temperature for the maximum conditions involved. This in turn is based on the fundamental principle that the drop in temperature is proportional to the resistance.

Condensation Chart

The chart (Fig. 3) can be used for approximating the thickness of insulation required to prevent condensation on the interior wall or roof surfaces of a building. Although this chart is intended primarily for roofs, it can be used for walls by taking the dry-bulb temperature and the corresponding relative humidity near the walls at the point which will necessitate the maximum heat resistance to prevent condensation, instead of using the temperature and humidity near the ceiling.

Example 1. Determine the thickness of insulation required to prevent ceiling condensation for the following conditions: Dry-bulb temperature near ceiling, 85 F; Relative humidity, 70 per cent; Lowest outside temperature, — 10 F; Construction of uninsulated roof, 1 in. yellow pine sheathing and built-up roofing; Coefficient of transmission of roof, 0.485; Conductivity of insulation to be used, 0.30.

Solution. The solution of this problem is indicated on the chart (Fig. 3) by the dotted line:

1. Locate the inside dry-bulb temperature of 85 F on scale A, and draw a line horizontally to the 70 per cent relative humidity curve, indicated on scale B.

2. Draw line *2* vertically downward from the intersection located as per paragraph 1.

3. Locate on scale D the temperature difference of 95 F between the ceiling temperature of 85 F and the lowest outside temperature of — 10 F, and draw a line horizontally until it intersects with line *2*.

4. From the point of intersection of lines *2* and *3*, draw a line to the point P.

[4] For additional information on this subject see, *Preventing Condensation on Interior Building Surfaces*, by Paul D. Close (A.S.H.V.E. TRANSACTIONS, Vol. 36, 1930).

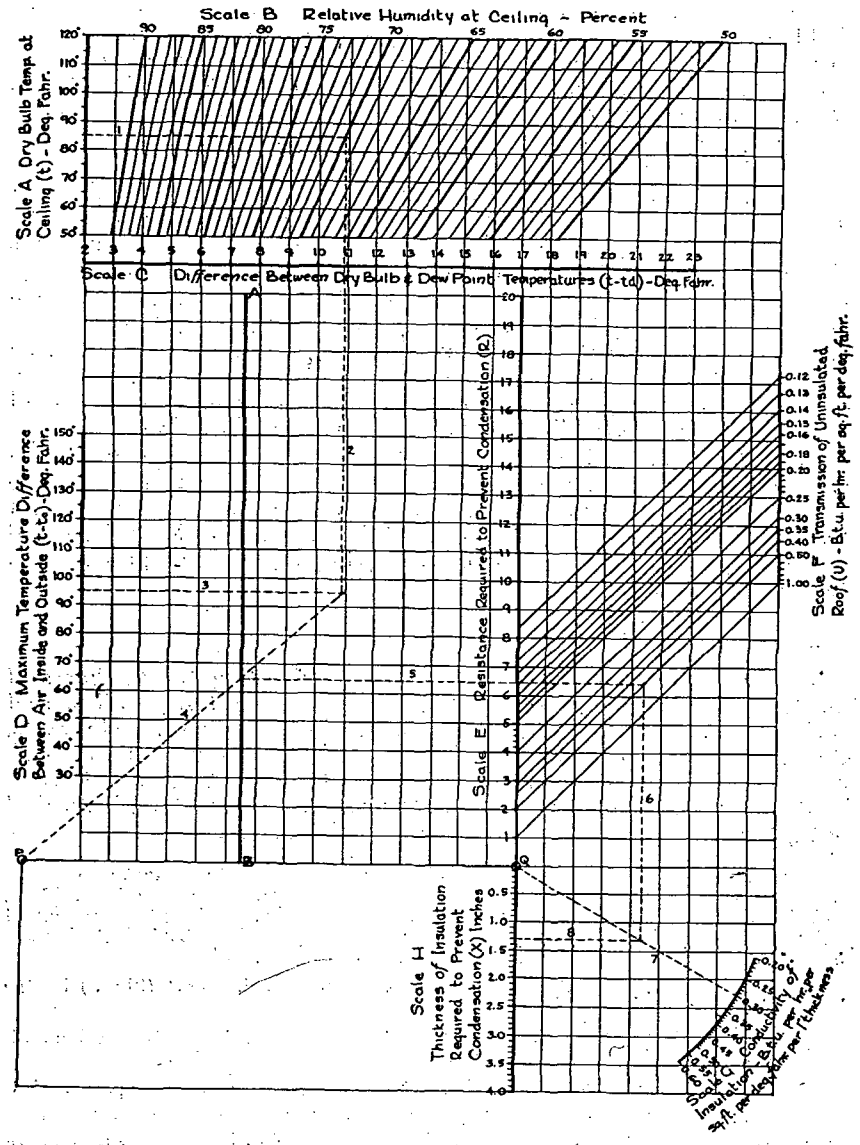


FIG. 3. CHART FOR DETERMINING THICKNESS OF INSULATION REQUIRED TO PREVENT CONDENSATION

5. From the intersection of lines *4* and *AB*, draw a line horizontally until it intersects with the diagonal line corresponding to a coefficient of transmission of the roof of 0.485, located on scale *F*.

6. From the intersection found as per paragraph 5, draw line *6* vertically downward.

7. Locate the conductivity of 0.30 Btu per hour per square foot per degree Fahrenheit of the insulation on scale *G* and draw a line to point *Q*.

8. From the intersection of lines *6* and *7*, draw a line horizontally to scale *H*, on which the thickness of insulation of this conductivity is indicated, which is 1.3 in. The nearest commercial thickness above 1.3 in. would, of course, be selected.

SUN EFFECT ON BUILDINGS

The absorption of solar radiation by the surfaces of a building exposed to the sun has an important bearing on the capacity of the refrigerating equipment required for air conditioning. This factor may also have a bearing on the size of heating plant required, but usually is not taken into consideration. These surfaces may be the exterior walls or the roof of the building, or interior surfaces which receive the sun's rays through window glass.

When equilibrium has been established, and the rate of heat flow is therefore constant, the heat transmitted per hour through a wall or roof is equal to the product of the conductance of the structure from the exterior surface to the interior air and the difference between the exterior surface temperature and the interior air temperature. This relation is expressed as follows:

$$H = C_1(t_r - t) \tag{13}$$

where

H = Heat transmitted through wall or roof, Btu per hour per square foot.
C_1 = Conductance of wall or roof between exterior surface and interior air, Btu per hour per square foot, per degree Fahrenheit difference in temperature.
t_r = Exterior surface temperature, degrees Fahrenheit.
t = Interior air temperature, degrees Fahrenheit.

Under actual conditions, the heat flow due to sun effect is almost never in equilibrium because of the heat capacity of the wall or roof structure. The exterior surface temperature of a wall or roof will usually approach the maximum for the day shortly after midday. On the other hand, the temperature of the interior surfaces of the building will lag, due to the heat capacity of the structure, and consequently the maximum interior surface temperature that would exist, if the heat flow were in equilibrium, may not be reached until some time after the maximum exterior surface temperature has been attained. Since at that time the exterior surface temperature has diminished, the maximum interior surface temperature (based on constant flow, and the maximum exterior surface temperature) will not actually be reached, and consequently the heat to be absorbed will be somewhat less than would be required according to Equation 13.

For materials of low heat capacity, the lag will be small and the error resulting from the use of equation 13 will be small. In any event, the result will be on the safe side. For materials of high heat capacity a correction for the temperature lag of the interior surfaces should be made,

although at present data are lacking for accurately evaluating the effect of heat capacity on the refrigerating requirements of air-conditioned buildings. If the maximum interior surface temperature is known, the heat transfer may be estimated by means of the following formula:

$$H = (t_s - t) \times f_i \qquad (14)$$

where

t_s = Maximum interior surface temperature.
f_i = Interior surface conductance.

For a further discussion of *heat capacity*, see p. 16, Chapter 2.

Chapter 4

AIR LEAKAGE FROM BUILDINGS

Causes of Air Leakage; Infiltration Through Walls; Infiltration Around Windows; Tall Buildings; Air Change Method; Heat Required for Warming Air Entering by Infiltration.

THE leakage of air from buildings constitutes a major source of heat loss and depends primarily on the tightness of the construction. This outleakage of heated air is accompanied by a corresponding inleakage or infiltration of cold air which must be warmed to the room temperature and which must be included in the heat loss calculations, as described in Chapter 2.

CAUSES OF AIR LEAKAGE

A building is a shell in which the internal pressure in general is not in equilibrium with the external pressure. At some places, the latter is greater than the former, and inflow will occur in such regions through any openings in the wall whether large or small. At other places the reverse is true. The internal pressure automatically assumes a value to correspond to the requirement that outflow must equal inflow. The agencies that cause leakage are the natural forces of wind and temperature difference, and those produced by fans if any are used. A consideration of all factors involved in causing pressure difference at various places about a building would present an exceedingly complex problem.

In tall single story buildings, the *chimney effect* caused by the inside-outside temperature difference becomes a factor of importance. Even in multi-story buildings it usually is not possible to isolate the several floors completely, and chimney effect is operative to a considerable degree, tending to force air in at the lower levels and out at the upper. Ventilating systems usually are designed to give a neutral pressure in the rooms, and fan pressures therefore have little effect upon infiltration.

Since the full force of the wind usually is not the effective pressure differential, owing to back pressure built up within the building, the actual amount of infiltration (cubic feet) is assumed to be 80 per cent of that determined in laboratory experiments, which means that the pressure drop is assumed to be about 64 per cent of the full wind pressure.

INFILTRATION THROUGH WALLS

Table 1 gives data on infiltration through brick and frame walls. From the results of recent experiments[1], it appears that the data in Table 1

[1] *Air Infiltration through Various Types of Brick Wall Construction*, by Larson, Nelson and Braatz (A.S.H.V.E. TRANSACTIONS, Vol. 36, 1930).

for brick walls are more probably representative of poor workmanship with porous brick and lime mortar. For good workmanship, the leakage through hard brick walls with cement-lime mortar does not exceed one-third the values given. These tests indicate that plastering reduces the leakage by about 96 per cent; a heavy coat of cold water paint, 50 per cent; and 3 coats of oil paint carefully applied, 28 per cent. The infiltration through walls ranges from 6 to 25 per cent of that through windows and doors in a 10-story office building, with imperfect sealing of plaster at the baseboards of the rooms. With perfect sealing the range is from

TABLE 1. INFILTRATION THROUGH WALLS

Expressed in cubic feet per square foot per hour[a]

TYPE OF WALL	WIND VELOCITY, MILES PER HOUR					
	5	10	15	20	25	30
8½ in. Brick Wall—Plain	1.75	4.20	7.85	12.2	18.6	22.9
8½ in. Brick Wall—Plastered	0.017	0.037	0.066	0.107	0.161	0.236
13 in. Brick Wall—Plain	1.44	3.92	7.48	11.6	16.3	21.2
13 in. Brick Wall—Plastered	0.005	0.013	0.025	0.043	0.067	0.097
Frame Wall, with lath and plaster[b]	0.03	0.07	0.13	0.18	0.23	0.26
Frame Wall, with lath and plaster[c]	0.02	0.05	0.10	0.15	0.20	0.25

[a]The values in this table are 20 per cent less than test values to allow for building up of pressure in rooms.

[b]Wall construction: Bevel siding painted, No. 1 common butt-edged sheathing, building paper, wood lath and 3 coats gypsum plaster.

[c]Wall construction: Cedar shingle, shiplap sheathing, building paper, wood lath and 3 coats gypsum plaster.

0.5 to 2.7 per cent or a practically negligible quantity, which indicates the importance of good workmanship in proper sealing at the baseboard. It will be noted from Table 1, that the infiltration through properly plastered walls can be neglected.

The value of building paper when applied between sheathing and shingles is indicated by Fig. 1, which represents the effect on outside construction only without lath and plaster. The effectiveness of plaster properly applied is no justification for the use of low grade building paper or of the poor construction of the wall containing it. Not only is it difficult to secure and maintain the full effectiveness of the plaster but also it is highly desirable to have two points of high resistance to air flow with an air space between them.

The amount of infiltration that may be expected through simple walls used in farm and other shelter buildings, is shown in Fig. 2. The infiltration there indicated is that determined in the laboratory and should be multiplied by the factor 0.80 to give proper working values.

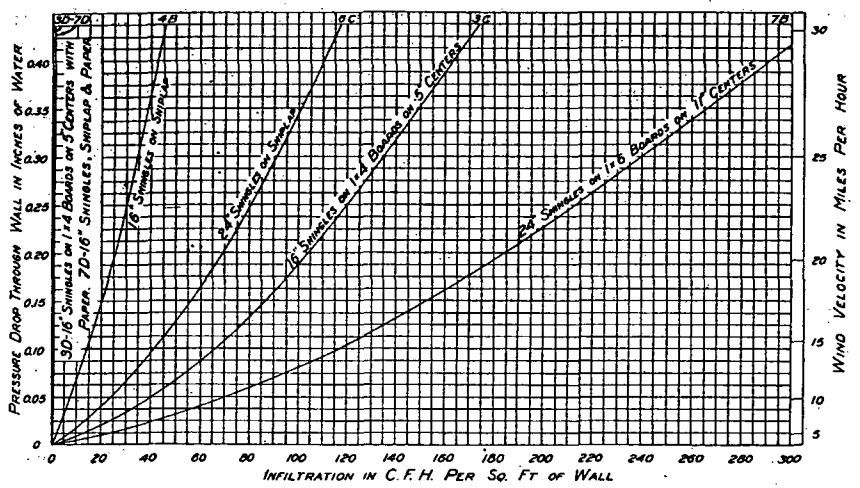


FIG. 1. INFILTRATION THROUGH VARIOUS TYPES OF SHINGLE CONSTRUCTION

INFILTRATION THROUGH WINDOWS

The amount of infiltration in cubic feet per hour per foot of crack for various types of windows is given in Table 2. The distinction between *crack* and *clearance* of a wood sash is shown by Fig. 3. *For window and sash leakage,* the length of crack in double-hung windows is equal to the perimeter of sash plus length of meeting rail. For steel sash the length of crack is the aggregate perimeter of the movable or ventilating sections

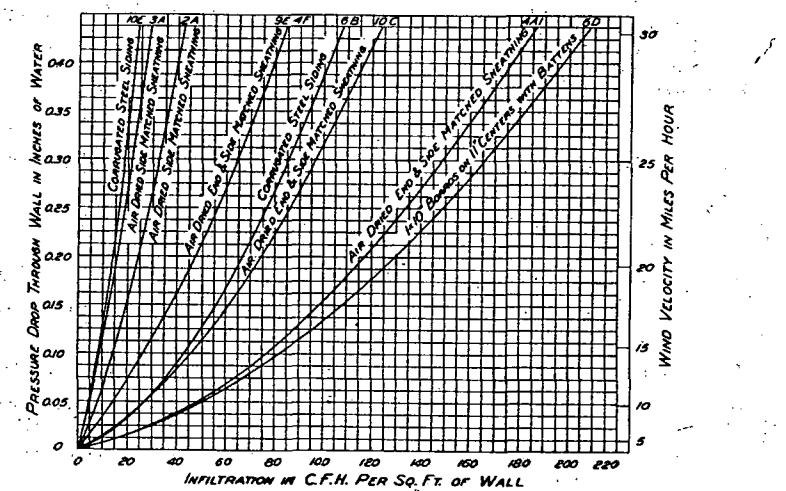


FIG. 2. INFILTRATION THROUGH SINGLE SURFACE WALLS USED IN FARM AND OTHER SHELTER BUILDINGS

plus the linear feet of sash section in contact with steel work (at a different leakage rate) at mullions. The crack length for *frame windows* (when frame is not calked) is the perimeter of the frame. Steel sash frame properly grouted with cement mortar into brickwork or concrete is not to be counted as crack. Leakage through various parts of wood windows is shown by the curves of Fig. 4. The effect of various clearances of wood sash is indicated by the curves of Fig. 5; the value of storm sash is shown by the curves of Figs. 6 and 7. A study of the curves leads to the conclusion that a storm sash is of little value in reducing infiltration when applied to a well fitted window, but that a reduction of 50 per cent might be expected when storm sash is applied to a poorly fitted or loose window. Infiltration through door cracks may be assumed to be twice that of window cracks.

TABLE 2. INFILTRATION THROUGH WINDOWS

Expressed in cubic feet per foot of crack per hour[a]

Type of Window		Wind Velocity, Miles per Hour					
		5	10	15	20	25	30
Double-Hung Wood Sash Windows (unlocked)	Around uncalked frame[b]	1.4	11.3	22.6	31.1	.....	53.6
	Around sash, 1/16-in. crack and 7/64-in. clearance.[c] Plain non-stripped[d]	39.3	84.9	124	161	.....	233
	Average weatherstripped[d]	3	11.7	22.9	34.9	.....	59.6
Double-Hung Metal Windows[e]	Non-weatherstripped, locked	20	45	70	96	125	154
	Non-weatherstripped, unlocked	20	47	74	104	137	170
	Weatherstripped, unlocked	6	19	32	46	60	76
Rolled Section Steel Sash Windows[j]	Industrial pivoted,[f] 1/16-in. crack	52	108	176	244	304	372
	Architectural projected,[g] 3/64-in. crack	20	52	88	116	152	208
	Residential casement,[h] 1/32-in. crack	14	32	52	76	100	128
	Heavy casement section, projected,[i] 1/32-in. crack	8	24	38	54	72	96
Hollow Metal, vertically pivoted window[e]		30	88	145	186	221	242

[a]The values given in this table are 20 per cent less than test values to allow for building up of pressure in rooms.

[b]Practically all leakage around frames can be stopped by proper calking.

[c]Most new sash are fitted with crack at least 1/16 in., which becomes greater as sash dries out and shrinks. Values of the table apply to any window of this type with crack up to 1/4 in.

[d]Values given include "elsewhere" leakage through frame but not leakage through uncalked crack around frame.

[e]Windows tested in place in building.

[f]Industrial pivoted window generally used in industrial buildings. Ventilators horizontally pivoted at center or slightly above, lower part swinging out.

[g]Architectural projected made of same sections as industrial pivoted except that outside framing member is heavier, and refinements in weathering and hardware. Used in semi-monumental buildings such as schools. Ventilators swing in or out and are balanced on side arms.

[h]Of same design and section shapes as so-called *heavy section casement* but of lighter weight.

[i]Made of heavy sections. Ventilators swing in or out and stay set at any degree of opening.

[j]With reasonable care in installation, leakage at contacts where windows are attached to steel framework and at mullions is negligible. With 1/4-in. crack, representing poor installation, leakage at contact with steel framework is about one-third, and at mullions about one-sixth of that given for industrial pivoted windows in the table.

WIND VELOCITY FACTORS

Although all authorities do not agree upon the value of the wind velocity that should be chosen for any given locality, it is common engineering practice to use the average wind velocity during the three coldest months of the year.[2] Until this point is definitely established the practice of using average values will be followed. Average wind velocities for the months of December, January and February for various cities in the United States and Canada are given in Table 3, Chapter 2.

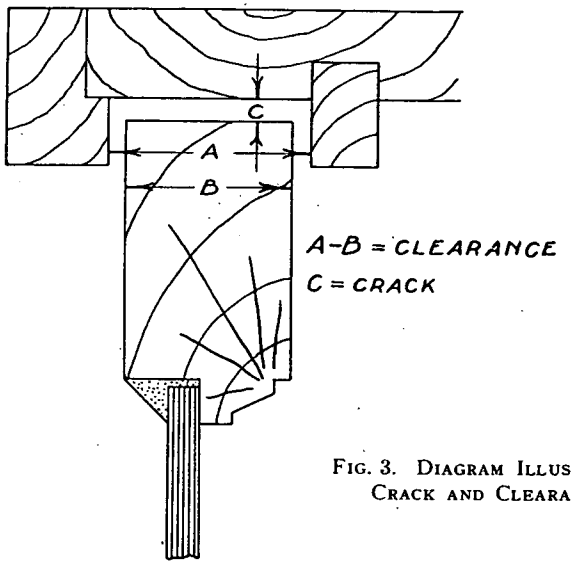


FIG. 3. DIAGRAM ILLUSTRATING CRACK AND CLEARANCE

The direction of prevailing winds may usually be included within an angle of about 90 deg. The windows that are to be figured for prevailing and non-prevailing winds will ordinarily each occupy about one-half the perimeter of the structure, the proportion varying to a considerable extent with the plan of the structure, as illustrated by Fig. 8. (See discussion of wind movement in Chapter 2).

AMOUNT OF CRACK TO USE

In no case should the amount of crack used for computation be less than half of the total crack in the outside walls of the room. Thus, in a

[2]See *Pressure Difference across Windows in Relation to Wind Velocity*, by Emswiler and Randall (A.S.H.V.E. TRANSACTIONS, Vol. 36, 1930).

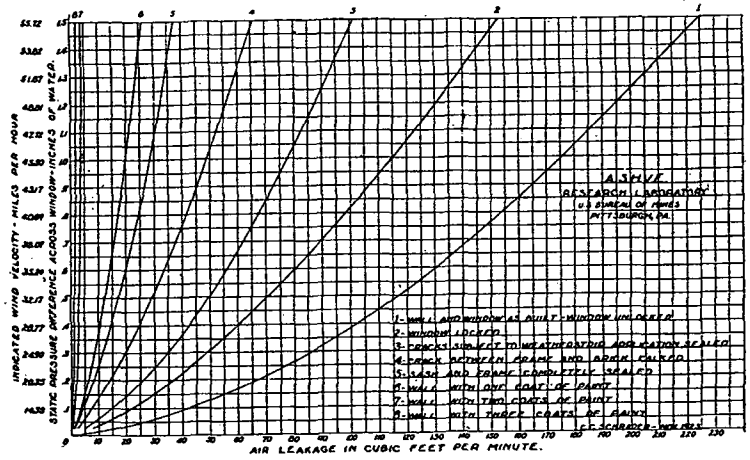


FIG. 4. RESULTS OF TESTS OF LEAKAGE THROUGH VARIOUS PARTS OF WINDOW AND FRAME

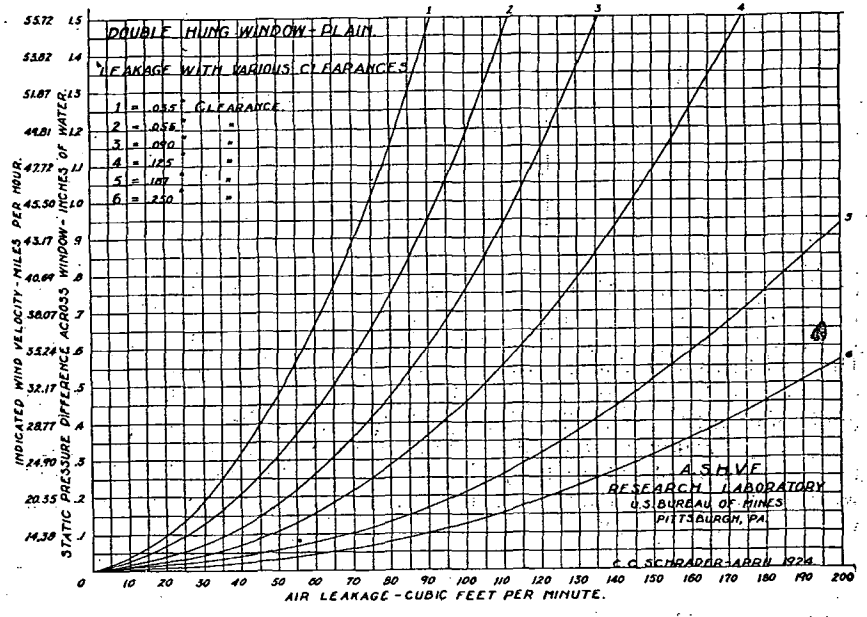


FIG. 5. LEAKAGE THROUGH PLAIN WOOD WINDOW WITH VARIOUS CLEARANCES

Note.—The curves show the leakage for the total crack. To obtain the leakage in cubic feet per hour per foot of crack, multiply by 60 and divide by 18.25.

room with one exposed wall, take all the crack; with two exposed walls, take the wall having the most crack; and with three or four exposed walls, take the wall having the most crack, but in no case take less than half the total crack. For a building having no partitions, whatever wind enters through the cracks on the windward side must leave through the cracks on the leeward side. Therefore, take one half the total crack for computing each side and end of the building.

ALLOWANCE FOR TALL BUILDINGS

In tall buildings, infiltration may be considerably influenced by temperature difference or chimney effect which will operate to produce a head that will add to the effect of the wind at lower levels and subtract from it at higher levels. On the other hand, the wind velocity at lower levels may be somewhat abated by surrounding obstructions. Furthermore, the chimney effect is reduced in multi-story buildings by the partial isolation of floors preventing free upward movement, so that wind and temperature difference may seldom cooperate to the fullest extent. Making the rough assumption that the *neutral zone*[3] is located at mid-height of a building, and that the temperature difference is 70 F, the following formulae may be used to determine an equivalent wind velocity to be used in connection with Tables 1 and 2 that will allow for both wind velocity and temperature difference:

$$M_e = \sqrt{M^2 - 1.75\,a} \qquad (1)$$

$$M_e = \sqrt{M^2 + 1.75\,b} \qquad (2)$$

where

M_e = equivalent wind velocity to be used in conjunction with Tables 1 and 2.

M = wind velocity upon which infiltration would be determined if temperature difference were neglected.

a = distance of windows under consideration from mid-height of building if *above* mid-height.

b = distance if *below* mid-height.

The coefficient 1.75 allows for about one-half the temperature difference head.

Example. If $M = 20$, the equivalent wind velocity at a height of 180 ft from the ground for a building 200 ft high would be

$$M_e = \sqrt{20^2 - 1.75 \times 80} = 16 \text{ mph}$$

For a window on the ground floor:

$$M_e = \sqrt{20^2 + 1.75 \times 100} = 24 \text{ mph}$$

For buildings of unusual height, Equation 1 would indicate negative infiltration at the highest stories which condition may, at times, actually exist, although probably greater wind velocities should be figured at such extremely high levels.

[3]See *Neutral Zone in Ventilating*, by J. E. Emswiler (A.S.H.V.E. TRANSACTIONS, Vol. 32, 1926).

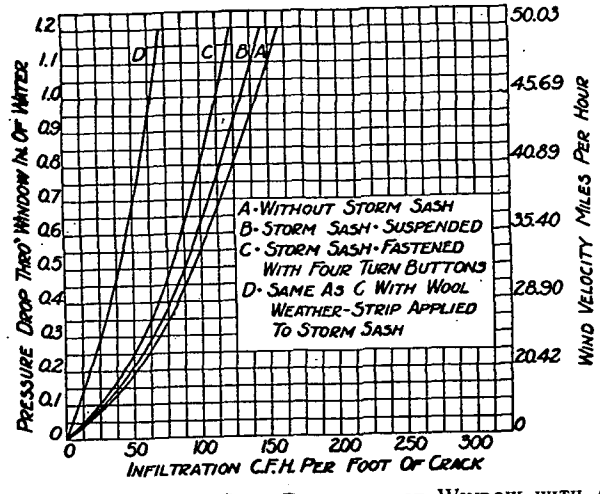


FIG. 6. INFILTRATION THROUGH SASH PERIMETER OF WINDOW WITH AND WITHOUT STORM SASH—5/64 IN. CRACK AND 1/32 IN. CLEARANCE

AIR CHANGE METHOD OF ESTIMATING INFILTRATION

The amount of air leakage is sometimes roughly estimated by assuming a certain number of air changes per hour for each room, the number of changes assumed being dependent upon the type, use and location of the room, as indicated in Table 3.

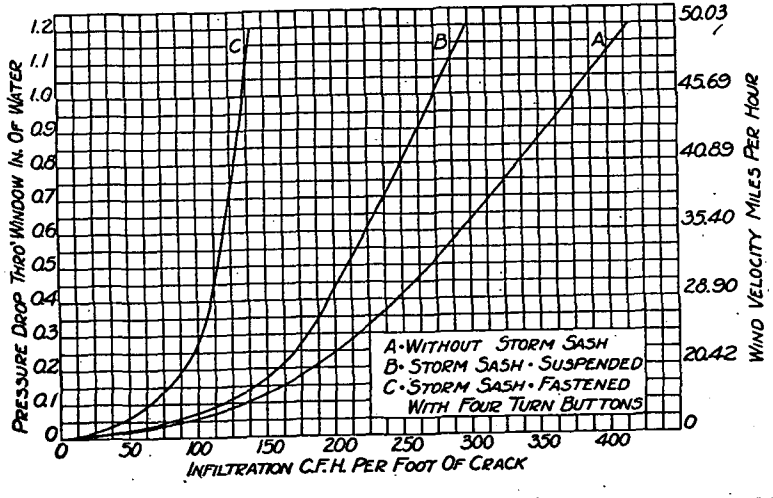


FIG. 7. INFILTRATION THROUGH SASH PERIMETER OF WINDOW WITH AND WITHOUT STORM SASH—1/8 IN. CRACK AND 1/8 IN. CLEARANCE

HEAT REQUIRED TO WARM AIR ENTERING BY INFILTRATION

Because of the influx of cold air by infiltration, provision must be made for the heat required to warm this air to room temperature. The heat required is given by the following equation:

$$H_i = 0.24\ Q\ d\ (t - t_o) \tag{3}$$

where

H_i = Btu per hour required for heating air leaking into building from outside temperature t_o to inside temperature, t.
Q = cubic feet of air entering per hour at inside temperature, t.
d = density (pounds per cubic foot) of air at inside temperature, t.
t = inside temperature at the proper level.
t_o = outside air temperature for which heating system is designed.
0.24 = specific heat of air.

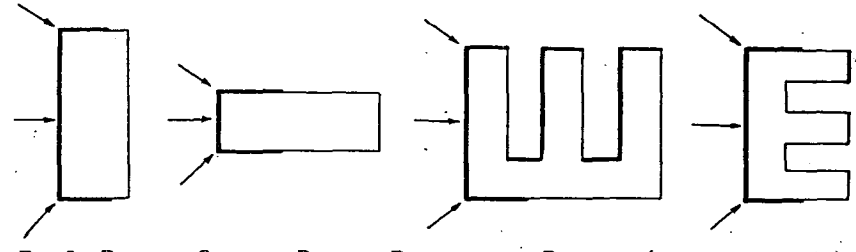


FIG. 8. DIAGRAM SHOWING PART OF PERIMETER OF BUILDING (IN HEAVY OUTLINE) FOR WHICH ALLOWANCE SHOULD BE MADE ON ACCOUNT OF EXPOSURE TO PREVAILING WINDS

It is sufficiently accurate to take $d = 0.075$ lb in which case the equation reduces to

$$H_i = 0.018\ Q\ (t - t_o) \tag{4}$$

While a heating reserve must be provided to warm inleaking air on the windward side of a building, this does not necessarily mean that the heating plant must be provided with a reserve capacity, since the inleaking air, warmed at once by adequate heating surface in exposed rooms, will move transversely and upwardly through the building, thus relieving other radiators of a part of their load. The actual loss of heat of a building caused by infiltration is not to be confused with the necessity for providing additional heating capacity for a given space. Infiltration is a disturbing factor in the heating of a building, and its maximum effect (maximum in the sense of an average of wind velocity peaks during the heating season, above some reasonably chosen minimum) must be met by a properly distributed reserve of heating capacity, which reserve, however, is not in use at all places at the same time, nor in any one place at all times.

Example. Consider a room with four 7 ft x 4 ft double-hung weatherstripped wood windows with 1/8 in. crack, and calked frame. Assume a wind velocity of 20 mph and a temperature difference of 70 F. Neglecting chimney effect, what is the maximum heat loss of this room due to infiltration?

TABLE 3. AIR CHANGES TAKING PLACE UNDER AVERAGE CONDITIONS EXCLUSIVE OF AIR PROVIDED FOR VENTILATION

KIND OF ROOM OR BUILDING	NUMBER OF AIR CHANGES TAKING PLACE PER HOUR
Rooms, 1 side exposed	1
Rooms, 2 sides exposed	1½
Rooms, 3 sides exposed	2
Rooms, 4 sides exposed	2
Rooms with no windows or outside doors	½ to ¾
Entrance Halls	2 to 3
Reception Halls	2
Living Rooms	1 to 2
Dining Rooms	1 to 2
Bath Rooms	2
Drug Stores	2 to 3
Clothing Stores	1
Churches, Factories, Lofts, etc.	½ to 3

Solution. From Table 2, the leakage per foot of crack is 35 cu ft per hour. Length of crack for room = 4 (windows) × (7 + 7 + 4 + 4 + 4) = 104 ft. The infiltration (Q) is equal to 35 × 104 or 3,640 cu ft per hour and the additional heat loss (maximum) due to infiltration is equal to 0.018 × 3,640 × 70 or 4,590 Btu per hour.

Example. What is the probable inleakage of air for a room with four windows on the first floor, if the wind velocity is 20 mph? The building is 100 ft high and is equipped with heavy casement section projected steel windows, with three ventilators each of a total perimeter of 36.5 ft, 1/32-in. crack.

Solution. For a temperature difference of 70 F the equivalent wind velocity (M_e) is equal to $\sqrt{20^2 + 1.75 \times 50}$ or 22 mph. Leakage per foot of crack for this type of window (Table 2, interpolating) is equal to 61 cu ft per hour. The total leakage rate (Q) is equal to 4 (windows) × 36.5 (ft of crack per window) × 61 or 8,910 cu ft per hour. For a similar room in the top story, on the same side of the building, the equivalent wind velocity (M_e) is equal to $\sqrt{20^2 - 1.75 \times 50}$ or 18 mph for which the leakage per foot of crack is 48 cu ft per hour (Table 2). The total inleakage of air into the room (Q) is equal to 4 × 36.5 × 48 or 7,010 cu ft per hour. For a similar room 20 ft above the ground (30 ft below mid-height), $M_e = \sqrt{20^2 + 1.75 \times 30} \doteq 21$ mph for which the unit crack leakage will be 58 cu ft per hour, and the total leakage for the room will be 8,470 cu ft per hour.

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Chapter 5

GRAVITY WARM AIR HEATING SYSTEMS

Description of Gravity System; Design Rules; Heat Loss Calculations; Leader Pipe Sizes; Wall Stacks; Register Area; Recirculating Ducts and Grilles; Size of Furnace; Application of Data; Forced or Booster Circulation.

IN the gravity warm air heating system described in this chapter, the motive head producing flow depends upon the difference in weight between the heated air leaving the casing and the cooler air entering the bottom of the casing. In the fan-circulating type, a fan may supply all or part of the motive head. The fan-circulating type may consist merely of a booster fan operated in conjunction with a gravity-designed system (see p. 94), or it may consist of the fan-furnace type described in Chapter 31. The majority of residence warm air installations are of the gravity type, although the use of fans is increasing.

DESCRIPTION OF GRAVITY SYSTEM

In general, a warm-air furnace heating plant consists of a fuel-burning furnace or heater enclosed in a casing of sheet metal or brick, which is placed in the basement of the building. The heated air, taken from the top or sides near the top of the furnace casing, is distributed to the various rooms of the building through sheet-metal warm-air pipes. The warm-air pipes in the basement are known as leaders, and the vertical warm-air pipes which are run in the inside partitions of the building are called stacks. The heated air is finally discharged into the rooms through registers which are set in register boxes placed either in the floor or in the side wall, usually at or near the baseboard.

The air supply to the furnace may be taken (1) entirely from inside the building through one or more recirculating ducts; (2) entirely from outside the building, in which case no air is recirculated, or (3) through a combination of the inside and the outside air supply systems.

DESIGN RULES

The design of a furnace heating system involves the determination of the following items:

a. Heat loss in Btu from each room in the building.

b. Area and diameter in inches of warm-air pipes in basement (known as leaders).

All figures and much of the engineering data which follow are from Bulletins Nos. 141, 188 and 189, Warm Air Furnaces and Heating Systems, Part II, by Professors A. C. Willard, A. P. Kratz, and V. S. Day, Engineering Experiment Station, University of Illinois.

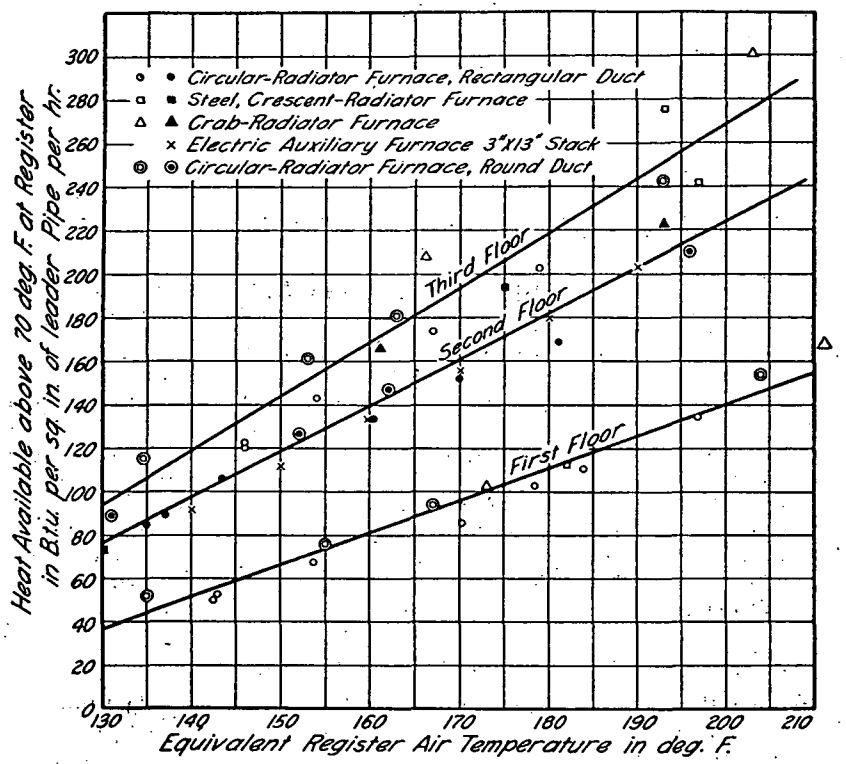


FIG. 1. VALUE OF SQUARE INCH OF LEADER PIPE AREA FOR FIRST, SECOND, AND THIRD FLOORS FOR SIMPLE SYSTEM HAVING LEADERS 8 FT IN LENGTH

c. Area and dimensions in inches of vertical pipes (known as wall stacks).

d. Free and gross area and dimensions in inches of warm-air registers.

e. Area and dimensions of recirculating or outside air ducts in inches.

f. Free and gross area and dimensions in inches of recirculating registers.

g. Size of furnace necessary to supply the warm air required to overcome the heat loss from the building. This "size" should include square inches of leader pipe area which furnace must supply. It is also desirable to call for a minimum bottom fire-pot diameter in inches, which is the nominal grate diameter.

h. Area and dimensions in inches of chimney and smoke pipe. If an unlined chimney is to be used, that fact should be made clear.

HEAT LOSS CALCULATIONS

The heat which will be required for each room in the building depends on (1) the heat transmission losses through walls and glass as well as through floors and ceilings when the latter two are next to unheated spaces, and (2) the infiltration of cold air through the cracks around outside windows and doors. Calculations for the heat required in Btu per hour should be made as indicated in Chapter 2, Estimating Heat Losses.

LEADER PIPE SIZES

In a gravity circulating warm-air furnace system the size of the leader to a given room depends on the temperature of the warm air entering the room at the register. A reasonable air temperature at the registers must, therefore, be agreed upon before the system can be designed. The *National Warm Air Heating Association* has approved an air temperature of 175 F at the registers as satisfactory for design purposes. At this temperature, the heat-carrying capacity (heat available above 70 F) per square inch of leader pipe per hour for first, second or third floors is shown by Fig. 1 at 175 F to be 105, 170 and 208 Btu respectively. For average calculations, the values 111, 166 and 200 will simplify the work and may be satisfactorily substituted for these heat-carrying capacities. If H represents the total heat to be supplied any room, the resulting equations are:

$$\text{Leader areas for first floor, square inches} = \frac{H}{111} = \text{approximately } 0.009H \quad (1)$$

$$\text{Leader areas for second floor, square inches} = \frac{H}{166} = \text{approximately } 0.006H \quad (2)$$

$$\text{Leader areas for third floor, square inches} = \frac{H}{200} = \text{approximately } 0.005H \quad (3)$$

In designing for a lower warm-air register temperature, say 160 F, the factors 111, 166 and 200 become 80, 140 and 166 (Fig. 1 at 160 F), and the resulting equations are:

$$\text{Leader areas for first floor, square inches} = \frac{H}{80} = \text{approximately } 0.012H \quad (4)$$

$$\text{Leader areas for second floor, square inches} = \frac{H}{140} = \text{approximately } 0.007H \quad (5)$$

$$\text{Leader areas for third floor, square inches} = \frac{H}{166} = \text{approximately } 0.006H \quad (6)$$

These equations are applicable to straight leaders from 6 to 8 ft in length. Longer leaders must be very thoroughly covered or else the vertical stacks must be increased in area as discussed under wall stacks. If some provision is not made for these longer leaders, the air temperature may be much lower than anticipated and the room will not be properly heated.

While Fig. 1 takes care of the drop in temperature in straight leaders up to 8 ft in length connected to stacks having about 75 per cent the area of the leader, the designer must make allowances for all other conditions. The temperature drop in leaders of various lengths at three different register temperatures is shown in Fig. 2, and should be used to obtain new register temperatures, lower than 175 F, on which to base selections from the curves of Fig. 1, and thereby new constants for equations 1, 2 and 3.

Leader sizes should in general be not less than obtained by equations 1 to 3 nor should leaders less than 8 in. in diameter be used. It is not considered good commercial practice to specify diameters except

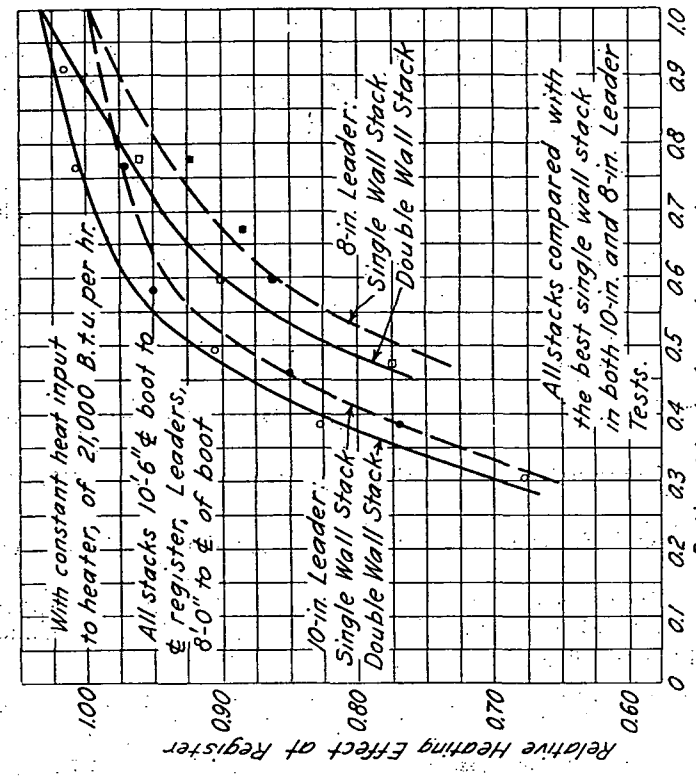


FIG. 3. RELATIVE HEATING EFFECT OF STACKS AT CONSTANT HEAT INPUT TO FURNACE

Note.—Pipe bare; bright tin except asbestos strips for joints.

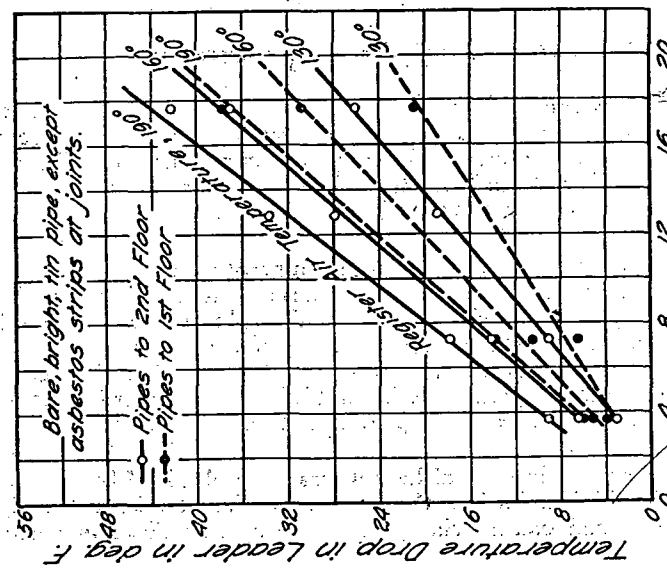


FIG. 2. INFLUENCE OF LEADER PIPE LENGTH ON TEMPERATURE LOSS OF AIR FLOWING THROUGH PIPE

in whole inches. The tops of leaders should be at the same elevation as they leave the furnace bonnet, and from this point there should be a

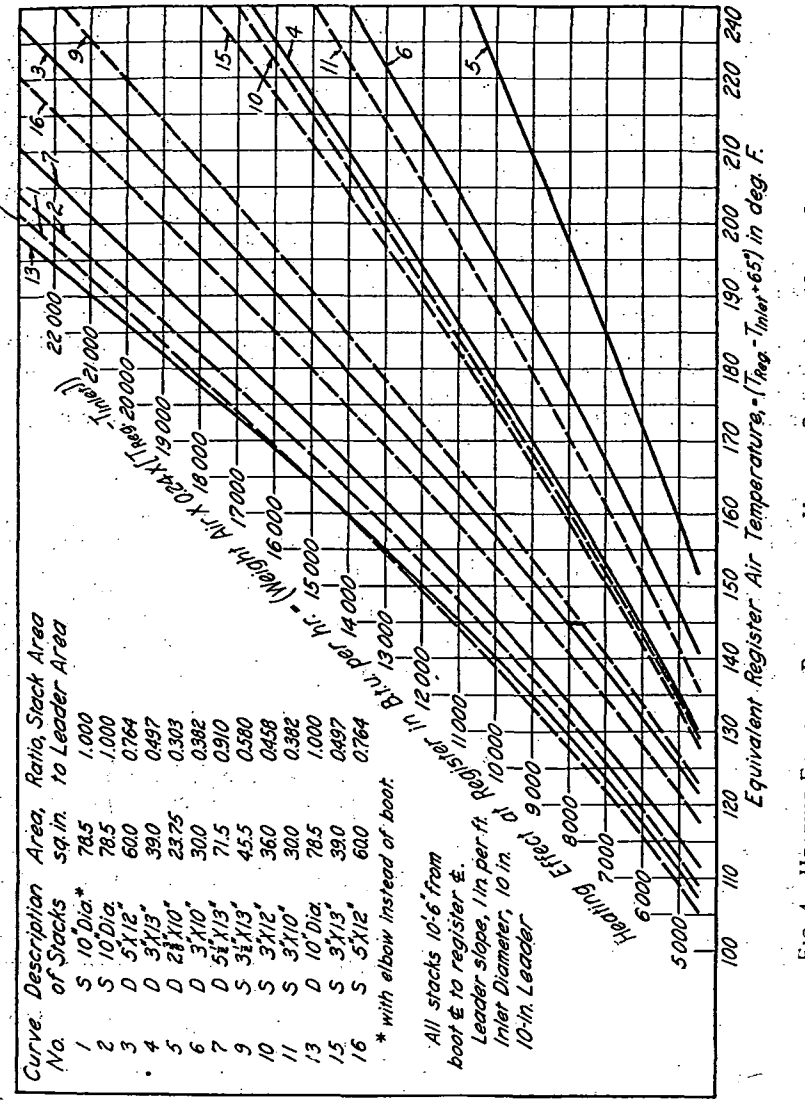


FIG. 4. HEATING EFFECT AT REGISTERS FOR VARIOUS STACKS WITH 10-INCH LEADER

uniform up-grade of 1 in. per foot of run in all cases. Leaders over 12 ft in length are to be avoided or should receive very special attention.

WALL STACKS

The wall stack for an upper floor should be made not less than 70 per cent of the area of the leader which has been selected from Fig. 1. So long as the leader is short and straight as was the case for Fig. 1, such a practice is probably justified since the loss (Fig. 3) in capacity occasioned by the smaller stack is not very serious for stacks having areas in excess of 70 per cent of the leader area. For leaders over 8 ft in length or for leaders which are not straight, the ratio of stack area to leader area should be greater than 70 per cent in order to offset the greater temperature losses (Fig. 2) in the longer leader. In gravity circulating systems, this stack to leader area ratio is a very important consideration. Specific data for a great variety of cases are presented in Figs. 4 and 5 and the designer should check the stack to leader combinations with the nearest comparable case as shown in these figures. Any second floor stack supplying heat to a room whose heat loss is 9,000 Btu or above (see Figs. 4 and 5 which show that high temperatures are necessary if rooms of more than 9,000 Btu requirement are heated by one stack each in 4-in. studding), should be run within 6-in. studded walls or should have multiple stacks. Stack sections, wherever possible, should be changed from the thin rectangular to the more nearly square shape.

REGISTER AREA

The registers used for discharging warm air into the rooms should have free or net area not less than the area of the leader in the same run of piping. The free area should be at least 70 per cent of the gross area of the register. No upper-floor register should be wider horizontally than the wall stack, and it should be placed either in the baseboard or side wall, if this can be done without the use of offsets. First-floor registers may be of the baseboard or floor type with the former location preferred.

RECIRCULATING DUCTS AND GRILLES

The ducts through which air is returned to the furnace should be designed to minimize friction and turbulence. They should be of ample area, in excess of the total area of warm-air pipes, and at all points where the air stream must change direction or shape, streamline fittings should be employed. Horizontal ducts should pitch at least one-half inch per foot upward from the furnace.

The recirculating grilles (or registers) should have a free area at least equal to the ducts to which they connect, and their free area should never be less than 50 per cent of their gross area.

The location and number of return grilles will depend on the size, details and exposure of the house. Small compactly built houses may frequently be adequately served by a single return effectively placed in a central hall. More often it is desirable to provide two or more returns, provided, however, that in two-story residences one return must be placed to effectively receive the cold air returning by way of the stairs.

Where a divided system of two or more returns is used the grilles must be placed to serve the maximum area of cold wall or windows.

Thus in rooms having only small windows the grille should be brought as close to the furnace as possible, but if the room has a bay window,

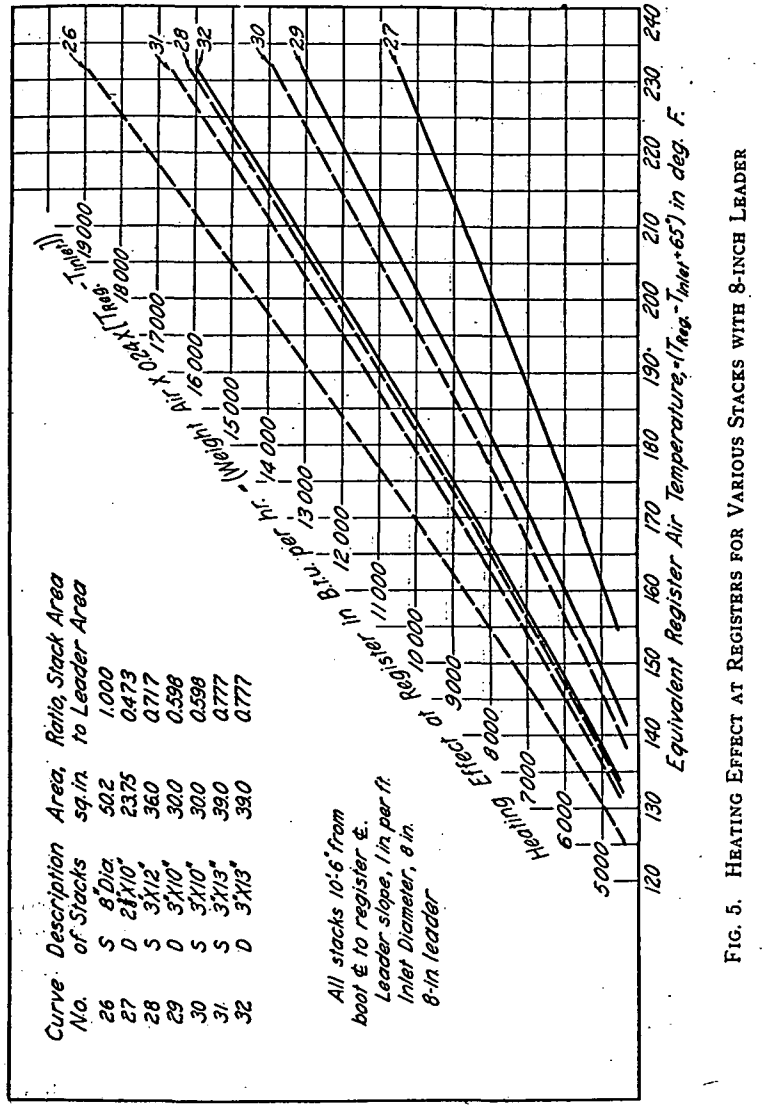


FIG. 5. HEATING EFFECT AT REGISTERS FOR VARIOUS STACKS WITH 8-INCH LEADER

french doors, or other large sources of cooling and leaking of cold air, the grille should be placed close by, so as to collect the cool air and

prevent drafts. When long ducts of this type are employed they must be made oversize and favored in every way. This precaution is particularly important when long ducts and short ducts are used in the same system. The long ducts must be oversize, if they are to operate satisfactorily in parallel with short ducts.

Return ducts from upstairs rooms may be necessary in apartments or other spaces closed off or badly exposed. Metal linings are advisable in such ducts. It is important that these ducts be free from unnecessary

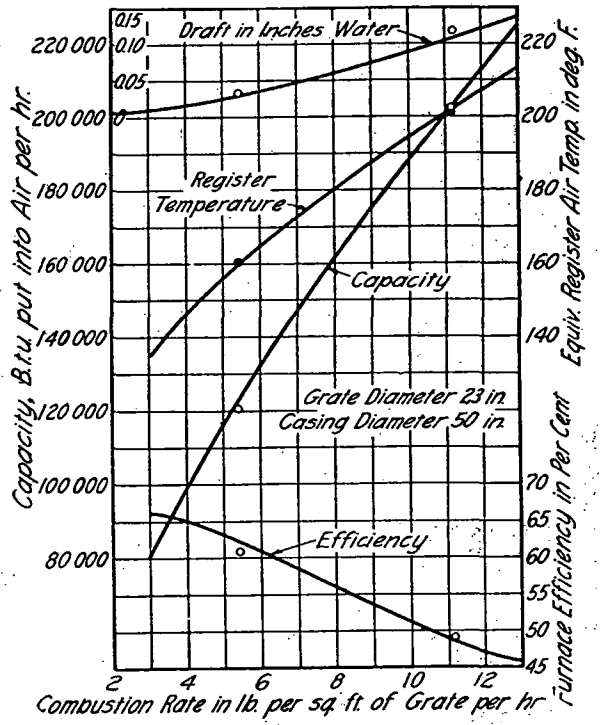


FIG. 6. TYPICAL PERFORMANCE CURVES FOR A WARM AIR FURNACE AND INSTALLATION IN A THREE-STORY TEN LEADER PLANT, OPERATING ON RECIRCULATED AIR

friction and turbulence, and that they be located to prevent preheating of the air before it reaches the furnace.

Return Connection to Furnace

Circulation is accelerated if the drop to the furnace is through a round inclined pipe with, say, two 45-deg elbows rather than through a vertical drop and two 90-deg elbows. The top of the shoe should never enter the casing above the level of the grate in the furnace. To accomplish this the shoe must be wide.

Tests of six different systems of cold air returns, Fig. 7, made at the University of Illinois,[1] resulted in the following conclusions:

1. In general, somewhat better room temperature conditions may be obtained by returning the air from positions near the cold walls.

2. Friction and turbulence in elaborate return duct systems retard the flow of air, and may seriously reduce furnace efficiency, and lessen the advantages of such a design.

3. The cross-sectional duct-area is not the only measure of effectiveness. Friction and turbulence may operate to make the air flow out of all proportion to the various duct areas.

SIZE OF FURNACE

The size of furnace should, of course, be such as will provide the necessary air heating capacity, usually expressed in square inches of leader pipe area, and at the same time provide a grate of the proper

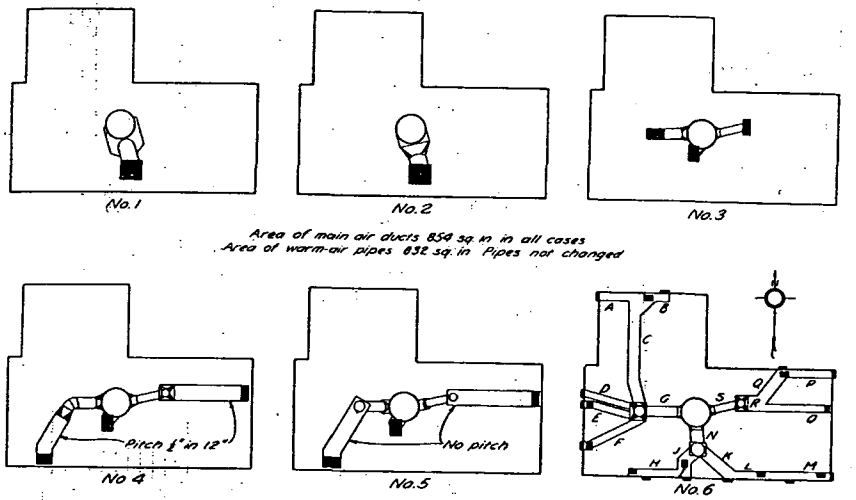


FIG. 7. ARRANGEMENT OF COLD AIR RETURNS FOR THE SIX INSTALLATIONS

area to burn the necessary fuel at a reasonable chimney draft. The total leader pipe area required is easily obtained by finding the sum of the leader pipe areas as already designated.

The grate area will depend on several factors of which four are very important. First of all, the air temperature at the register for which the plant has been designed must be determined. Usually, this temperature is taken as 175 F. Second in importance is the combustion rate, *which must always correspond with the register air temperature*, as is shown by reference to a set of typical furnace performance curves (Fig. 6) for a cast-iron circular radiator furnace with a 23-in. diameter grate and 50-in. diameter casing. The conditions shown on these curves which seem to

[1] *Investigation of Warm-Air Furnaces and Heating Systems*, Part N, by A. C. Willard, A. P. Kratz and V. S. Day (Engineering Experiment Station, *University of Illinois, Bulletin* 189).

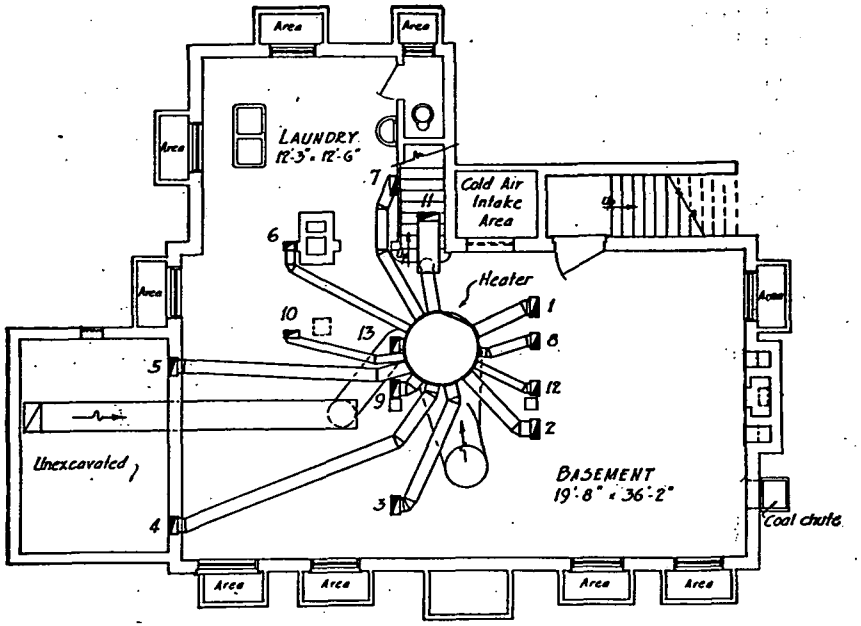


FIG. 8. BASEMENT PLAN, RESEARCH RESIDENCE

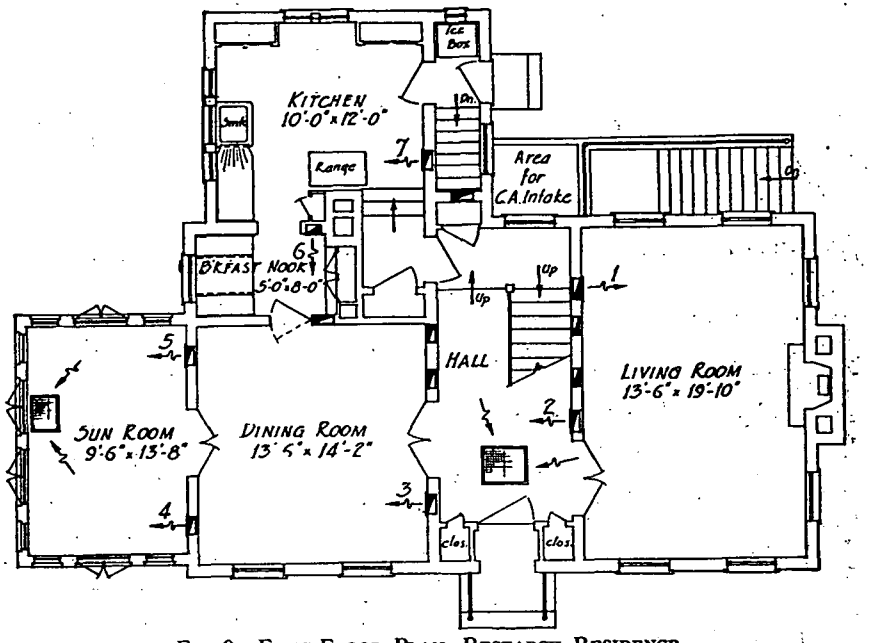


FIG. 9. FIRST-FLOOR PLAN, RESEARCH RESIDENCE

approximate nearest to the 175-F register warm-air temperature are—combustion rate, 7 lb; warm-air register temperature, 173 F; efficiency of the furnace, 58.5 per cent. The third factor is efficiency, which, in turn, is a function of the combustion rate varying with it as shown by the efficiency curve of Fig. 6. The fourth factor is the heat value per pound of fuel burned, which was 12,790 Btu, but is not shown on the curves since it was constant for all combustion rates.

From the relation existing between these factors it is found (Fig. 6) that the capacity of the furnace under test is 147,750 Btu per hour for the total grate, which gives the capacity at the furnace bonnet per square foot of grate as 51,300 Btu and per square inch of grate as 356 Btu per hour.

Suppose it is desired to select a furnace to deliver air to the rooms at a register temperature approximating 160 F rather than 175 F. Referring to the curves, the relation is—combustion rate, 5.5 lb; register warm-air temperature 160 F; and efficiency of the furnace 62 per cent. Under this condition the capacity of the furnace at the furnace bonnet per square foot of grate area is 43,300 Btu per hour, and per square inch of grate it is 300 Btu per hour. From these performance values, the grate area for any plant requirement will be, (allowing 20 per cent heat loss between furnace and registers):

$$\text{Grate area (175 F register temperature), square inches } \frac{1.2\ H}{356} = 0.0034H^* \quad (7)$$

$$\text{Grate area (160 F), square inches } = \frac{1.2\ H}{300} = 0.0040H^* \quad (8)$$

It is not always possible to obtain performance curves, and the following method is suggested as being a close check. An addition of 2 per cent of the furnace capacity is proposed for each unit that the heating surface-grate area ratio of the furnace exceeds 20. This addition is based on tests of four types of furnaces having various ratios of heating surface to grate area, at the University of Illinois.

Let E = efficiency of the furnace.
f = fuel value of the coal, Btu per pound.
p = pounds of coal burned per square foot grate per hour.
R = ratio of heating surface to grate area.
H = total heat requirements of the house.

$$\text{Grate area, square inches} = \frac{1.2 \times 144\ H}{Efp\ [1 + 0.02\ (R - 20)\ ]} \text{ for all inside air} \quad (9)$$

For coal having a heat value of 12,000 Btu, a furnace having 60 per cent efficiency, and 6-lb coal burned per square foot grate per hour, and 20 sq ft of heating surface for 1 sq ft of grate this becomes:

$$\text{Grate area, square inches} = \frac{1.2 \times 144\ H}{0.60 \times 12{,}000 \times 6} \text{ for all inside air} \quad (10)$$

*Let H = Btu heat loss from the entire house per hour = summation of all room losses $H_1 + H_2$ + etc. + the Btu necessary to heat the fresh air, if any, at intake. This fresh air loss in Btu per hour will be approximately 1.27 times the cubic feet of air admitted through the intake per hour on a zero day. For systems which recirculate all the air this value will be zero. For systems which have a fresh air intake, controlled by damper, this value might well be approximated, since this loss will probably be reduced to a minimum on a zero day. Assume for such cases, that the building loss is increased by 25 per cent, and that there is the usual 20 per cent loss between furnace and registers.

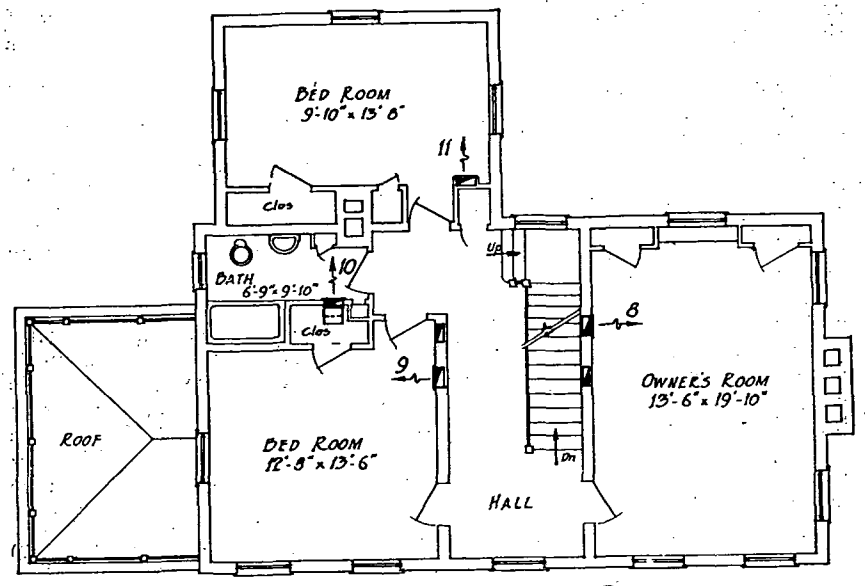


FIG. 10. SECOND-FLOOR PLAN, RESEARCH RESIDENCE

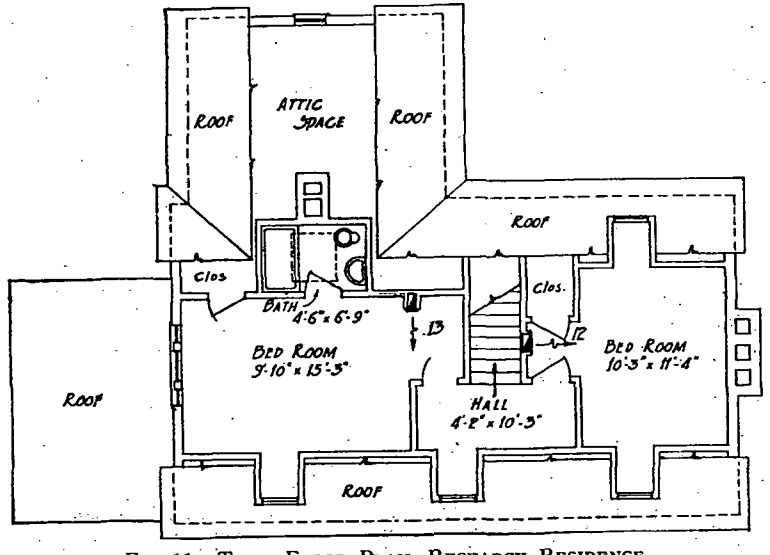


FIG. 11. THIRD-FLOOR PLAN, RESEARCH RESIDENCE

and for another furnace having 24 sq ft of heating surface for 1 sq ft of grate the expression is

$$\text{Grate area, square inches} = \frac{1.2 \times 144\,H}{0.60 \times 12{,}000 \times 6\,[1 + 0.02\,(24 - 20)]} \qquad (11)$$

The air temperatures at the registers corresponding to the conditions of equation 11 would be approximately 165 F and for 175 F and 12,000 Btu the combustion rate would be about 7.5 lb with an efficiency of 57 per cent, using the curves of Fig. 6 as a guide.

APPLICATION OF DATA

The application of the preceding data to an actual example may be of assistance to the designer. Figs. 8, 9, 10 and 11[2], represent the plans of the Warm Air Research Residence of the *National Warm Air Heating Association* erected at the University of Illinois.

Leaders, Stacks and Registers. (Direct Method)

Living Room, 1st floor:

17,250 ÷ 111 = 155 sq in. leader area. See summary, Table 1; also Example under Standard Code,[3] Art. 3, Basis of Working rules for pipes.

Leader diameter = 14 in.

Register size = 155 sq in. net area. Gross area = net area ÷ 0.7 = 14 × 16 in.

TABLE 1. SUMMARY OF DATA APPLIED TO WARM AIR RESEARCH RESIDENCE

Rooms	From Chapter 2 Estimating Heat Losses Btu Heat Losses H	Leader Area Sq In.	Stack Area Sq In. $0.7 \times LA$	Leader Diameter Inches	Stack Size Net	Register Size Gross
First Floor		$= 0.009H$				
Living	17250	155	....	14	.....	14 × 16
Dining	6810	61	....	9	.....	8 × 12
Breakfast	2300	21	....	8	.....	8 × 10
Kitchen	9210	83	....	11 or 12	.....	12 × 14
Sun	25710	230	....	Two 12	.....	Two 12 × 14
Hall and stair	12570	113	....	12	.....	12 × 14
Second Floor		$= 0.006H$				
Owners	15030	90	63	11 or 12	5 × 12	12 × 14
S. W. Bed	9800	59	41	9	3½ × 12	8 × 12
Bath	2450	15	10	8	3 × 10	8 × 10
N. Bed	14800	89	62	11 or 12	5 × 12	12 × 14
Third Floor		$= 0.005H$				
E. Bed	8220	41	29	8	3 × 10	8 × 10
W. Bed	8220	41	29	8	3 × 10	8 × 10

[2]Plans used with permission. Bath room on third floor not heated at present.

[3]Standard Code Regulating the Installation of Gravity Warm Air Heating Systems in Residences. This code has been sponsored by the *National Warm Air Heating Association*, the *National Association of Sheet Metal Contractors*, and the AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS. It is recommended that the installation of all gravity warm air heating systems in residences be governed by the provisions of this code, the eighth edition of which may be obtained from the *National Warm Air Heating Association*, 3440 A.I.U. Building, Columbus, Ohio.

Owner's Room, 2nd floor:

15,030 ÷ 167 = 90 sq in. leader area. See Summary Table; also Example under Standard Code,[3] Art. 3, Basis of working rules for pipes.

Leader diameter = 11.4, say 12 in.

Stack area = 0.7 × 90 = 63 sq in. = say 5 × 12 in.

Register area = 90 sq in. net area. Gross area = net area ÷ 0.7 = 12 × 12 or 12 × 14 in.

In like manner the leaders, stacks and registers are calculated for each room in the house.

Leaders, Stacks and Registers. (Code[3] Method. See Art. 3, Sec. 1, 2, 3.)

Living Room (Glass = 90, Net wall = 405, Cubic contents = 2405)

$$\text{Leader} = \left(\frac{90}{12} + \frac{405}{60} + \frac{2405}{800}\right) 9 = 155 \text{ sq in.}$$

Register, same as Direct Method.

Owner's Room (Glass = 68, Net wall = 394, Cubic contents = 2275)

$$\text{Leader} = \left(\frac{68}{12} + \frac{394}{60} + \frac{2275}{800}\right) 6 = 90 \text{ sq in.}$$

Stack and Register, same as Direct Method.

Assuming all air recirculated, the minimum furnace for the plant will be:

Grate Area = 0.0034 × 132,370 = 450 sq in. = 24 in. diam. at 175 F. register temperature. (7)

Grate Area = 0.0040 × 132,370 = 530 sq in. = 26 in. diam. at 160 F. register temperature. (8) (10)

If provision shall be made for certain outside air circulation, then increase the building heat loss by, say 25 per cent and obtain by equation 7 a 27-in. grate and by equations 8 and 10 a 29-in. grate.

FORCED OR BOOSTER CIRCULATION

Experiments at the University of Illinois[4] have shown that the capacity of a furnace may be increased nearly three times by an adequate fan, with a constant register or delivery temperature maintained, *provided that the rate of fuel consumption can be increased to provide the necessary heat.* In other words, the capacity of a forced circulation system *is limited by the ability of the chimney to produce a sufficient draft.*

Booster fans often may be arranged to operate when the gas and oil burners operate and to stop automatically when the burners shut down. The booster equipment is most effective in increasing output at low operating temperatures. According to tests, efficiencies may be advanced from 60 per cent for gravity to 70 per cent with boosters at low operating temperatures, but at high operating temperatures gravity and booster efficiencies are almost identical.[5] (See Chapter 31).

[4] See University of Ill. Eng. Exp. Sta. Bul. 120, p. 129.
[5] See Univ. of Ill. Eng. Exp. Sta. Bul. 141, p. 79.

Chapter 6

RADIATORS

Types of Radiators; Output of Radiators; Weights and Volumes of Radiators; Heating up the Unit; Location and Selection.

AN exposed heating unit placed in the room or space to be heated is termed a *radiator*. If it is placed in an enclosure located within, adjacent to, or exterior to a room or space to be heated, it is usually termed a *convector*. (See Chapter 7). A shielded heating unit located within the space to be heated may also be termed a *convector*.

All heating units emit heat by *radiation* and *conduction*. The percentage of heat emitted by each of these two processes depends upon whether or not the heating unit is exposed or enclosed, and upon the contour and surface characteristics of the material. The heat emission also depends upon the difference in temperature between the heating medium in the unit and the surrounding air. An exposed heating unit (radiator) emits less than half of its heat by radiation depending upon the size and number of sections. The balance of the emission is by conduction to the air in contact with the heating surface and the resulting circulation of the air thus warmed is known as *convection*.

TYPES OF RADIATORS

Radiators may be classified as tubular, wall, window and pipe coil. The column-type radiator is no longer listed by manufacturers in the United States. Radiators are made of cast or sheet ferrous and of sheet non-ferrous metals and of pipe or tubing.

Tubular-Type Radiators

The new tubular radiators are similar to the old column type radiators but have smaller columns, they are lighter and have less internal volume and more air space around the columns. They are more attractive in appearance since they do not look so ponderous as the column type which they have supplanted.

Wall Radiators

The wall-type radiator has been developed in recent years until it is now as efficient as the pipe-coil radiator and is much easier to handle because it is made up in unit sections of approximately 5, 7 or 9 sq ft (equivalent) in area, each of which may be assembled by screw or push nipples to secure a single radiator of any desired amount of surface. The space occupied by wall-type heating units is 30 to 60 per cent less than

TABLE 1. VARIATION IN DIMENSIONS AND CATALOG RATING OF 10-SECTION TUBULAR RADIATORS MADE BY SIX MANUFACTURERS

No. of Tubes	3	4	5	6	7
Width of Radiator, Inches	4.6–5.1	6.0–7.0	8.0–8.9	9.1–10.4	11.4–12.8
Length per Section, Inches	2.5	2.5	2.5	2.5	2.5–3.0
HEIGHT WITH LEGS—INCHES	HEAT EMISSION—EQUIVALENT SQUARE FEET				
13–14	.....	.....	.....	20	25.0–32.5
16–18	.....	.....	28.5	.....	30.0–38.3
20–21	15.0–17.5	20.0–22.5	25.0–31.2	30	36.7–45.0
22–23	20.0–21.3	25	30.0–33.9	35	40.0–45.2
25–26	20.0–26.7	25.0–27.5	32.5–39.8	37.5–40.0	50.0–53.5
30–32	25.0–30.9	33.3–35.0	40.0–48.6	50	63.3–62.5
36–38	30.0–36.7	40.0–42.5	50.0–56.5	60	70.0–75.4

the equivalent heating surface made up of 1¼-in. pipe coils. Wall radiators are particularly adapted for direct heating of industrial buildings, for heating small rooms such as baths or toilets, or for use at the ceilings of basement rooms or just below the skylights.

These radiators are assembled at the factory in stacks of from 3 to 5 sections, and these stacks may be connected later by right and left hexagon nut shoulder nipples to obtain large units. The method of hanging or supporting wall radiators is of great importance as the tendency of these radiators to tear loose the brackets or hangers is very marked, due to the expansion and contraction strains produced by the piping system as well as by weight of the radiators themselves. Wall sections are always installed with bars vertical in order to obtain the greatest efficiency.

Window Radiators

Low window radiators are usually of the flue type or of the tubular type and are designed to be placed below the stools or seats of very low windows. In construction, the flue type differs from the column and tubular radiators only in that the sections are usually flat hollow slabs with vertical ribs so cast upon them as to form flues of the interior surfaces of the radiator. This type is not made in heights above 20 in.

TABLE 2. HEAT EMISSION OF PIPE COILS PLACED VERTICALLY ON A WALL (PIPES HORIZONTAL) CONTAINING STEAM AT 215 F AND SURROUNDED WITH AIR AT 70 F.

Btu per linear foot of coil per hour (not linear feet of pipe)

SIZE OF PIPE	1"	1¼"	1½"
Single Row	132	162	185
Two	252	312	348
Four	440	545	616
Six	567	702	793
Eight	651	796	907
Ten	732	907	1020
Twelve	812	1005	1135

Pipe-Coil Radiators

Pipe-coil radiators are in more or less general use in factory and industrial plants and are usually made up of 1 or 1¼-in. standard black pipe screwed into manifolds. These coils may be of the miter type, or of the return or box-coil type using manifold tees or headers of cast-iron in each case. A coil made up of return bends and straight pipe is sometimes used, and is called a trombone coil. Its use is questionable since the long, continuous coil offers excessive friction to the steam or water. Pipe coils are intended to be hung on the side walls or from the ceiling, and suitable provision must be made for expansion. Vertical pipe radiators have also been used extensively in the past, and are made up by screwing short pieces of capped pipe into a cast-iron base forming a portable radiator very similar to the ordinary cast-iron column radiator.

Special Radiators

The *circular* radiator is often placed around columns in entrance lobbies and can be obtained in the one-, two-, and three-tube patterns, in all regular heights, but usually only on special order.

The *corner* radiator is also often used in entrance lobbies where the wall space is limited. It can be obtained in practically all patterns and heights except in the four-tube and in the ventilating flue style. As from 3 to 5 sections are required to make the corner, depending on the style of radiator, it is necessary to specify the number of sections in each arm as well as in the corner. The supply and return ends must be indicated also to provide the proper hub for each end.

OUTPUT OF RADIATORS

In the past the unit of measure recognized in computing heat emission of radiators was the square foot of actual surface. The use of this unit is gradually being discarded, however, for the reason that heat emission depends upon the design of the heating unit as well as upon its surface area. The engineer is interested primarily in the amount of heat emitted by, rather than the amount of surface in a heat-transferring agent. As a result, radiators are now rated on the heat given off either in Btu per hour or in equivalent square feet, based on 240 Btu per hour.

Output of Tubular Radiators

Table 1 illustrates the difficulty in tabulating tubular radiator outputs since there is so much variation between the products of the different manufacturers. Only on the four-tube and six-tube sizes is there any practical agreement in output value. The heat emission values appear as square feet but are entirely artificial, being based on the heat emission of the radiator and not on the measured surface.

Output of Pipe Coils

The heat emission of vertical pipe coils placed on a wall (pipes horizontal) is given in Table 2. This table has been developed by a method of deduction from the available data on such experimental work on pipe coils as has been recorded and does not represent definite experimental results of tests. For vertical wall coils (pipes vertical) the heat emission

TABLE 3. CONVERSION FACTORS FOR DIRECT CAST-IRON RADIATORS[a]

STEAM PRESSURE		TEMP. OF STEAM OR WATER IN DEG. FAHR.	TEMPERATURE OF ROOM					
Vacuum In. Hg.	Lb. Absolute		80 F	75 F	70 F	65 F	60 F	60 F
22.4	3.71	150	0.388	0.424	0.462	0.499	0.538	0.617
20.3	4.75	160	0.462	0.499	0.538	0.577	0.617	0.697
17.8	5.99	170	0.538	0.577	0.617	0.657	0.697	0.782
14.7	7.51	180	0.617	0.657	0.697	0.740	0.782	0.868
10.9	9.33	190	0.697	0.740	0.782	0.825	0.868	0.955
6.5	11.52	200	0.782	0.825	0.868	0.911	0.955	1.045
Lb. Gage								
1	15.7	215	0.911	0.955	1.000	1.045	1.091	1.183
2	16.7	219	0.947	0.991	1.036	1.081	1.128	1.220
3	17.7	222	0.973	1.018	1.063	1.109	1.155	1.249
4	18.7	225	1.000	1.045	1.091	1.137	1.183	1.277
5	19.7	227	1.018	1.063	1.109	1.155	1.202	1.296
6	20.7	230	1.045	1.091	1.137	1.183	1.230	1.325
8	22.7	235	1.091	1.137	1.183	1.230	1.277	1.373
10	24.7	240	1.137	1.183	1.230	1.277	1.325	1.421

[a]These conversion factors multiplied by the heat emitted by a radiator operating at 215 F in a room at 70 F, give the heat emitted by a radiator operating under the indicated conditions.

varies inversely as the height of the coil. It is customary to use an average emission of 100 Btu per linear foot of 1¼-in. pipe, 10 ft high. The heat emission of each pipe of ceiling coils placed horizontally (pipes horizontal) is equal to that of a single row coil. Allowance must be made, however, if the coil is at the ceiling in a higher temperature than that upon which Table 2 is based, namely, 70 F. The common practice is to allow 126 Btu,

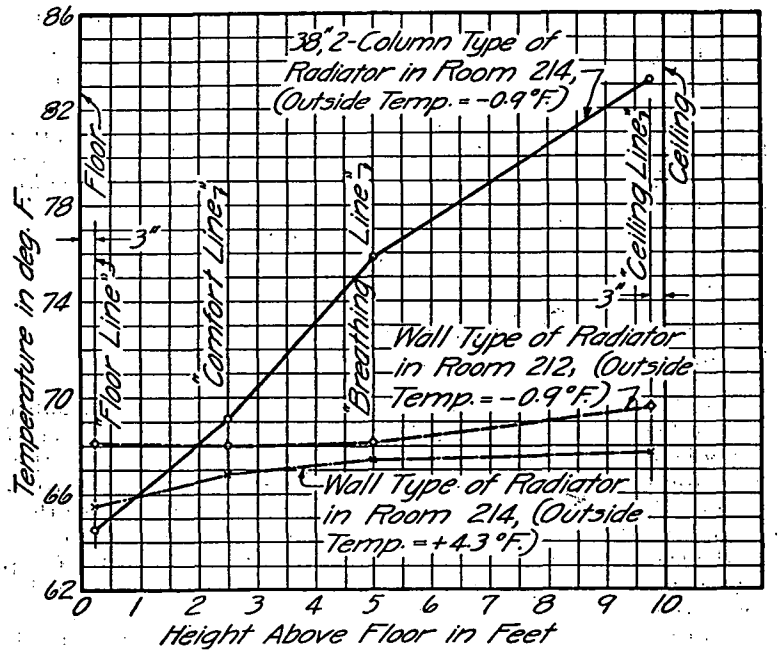


FIG. 1. AIR TEMPERATURE GRADIENTS FROM FLOOR TO CEILING FOR COLUMN AND WALL-TYPE RADIATORS

Note that all three radiators maintained about the same temperature at the *Comfort Level*.

156 Btu and 175 Btu per linear foot of pipe, respectively, for 1-in., 1¼-in. and 1½-in. coils.

Code for Testing Radiators

The A.S.H.V.E. Code for Testing Radiators[1] assumes the following relationship as applicable to the average run of cast-iron radiators:

$$H = K\,(t_s - t_r) \qquad (1)$$

where

H = the rate of heat emission in Btu per hour per square foot of surface.
K = a constant
t_s = the temperature of radiator (assumed to be the temperature of the steam or hot water).
t_r = the temperature of the room in which the radiator is located.

[1]A.S.H.V.E. TRANSACTIONS, Vol. 33, 1927.

TABLE 4. EFFECT OF PAINTING 32-IN. THREE COLUMN, SIX-SECTION CAST-IRON RADIATOR[2]

RADIATOR NO.	FINISH	AREA SQ FT	COEFFICIENT OF HEAT TRANS. BTU	RELATIVE HEATING VALUE PER CENT
1	Bare iron, foundry finish	27	1.77	100.5
2	One coat of aluminum bronze	27	1.60	90.8
3	Gray paint dipped	27	1.78	101.1
4	One coat dull black Pecora paint	27	1.76	100.0

[2]Comparative Tests of Radiator Finishes, by W. H. Severns (A.S.H.V.E. TRANSACTIONS, Vol. 33, 1927).

The Code for Testing Radiators also accepts 215 F and 70 F, respectively, as standard steam and room temperatures. On the basis of these temperatures, the heat emission for any other than standard conditions (H_x) is equal to:

$$H_x = H_s \left[\frac{t_s - t_r}{215 - 70} \right]^{1.3} \qquad (2)$$

where

H_s = the heat emission under standard conditions.

Correcting Output for Other Than Standard Conditions

If the radiator is to be used under any other than standard conditions of room and steam temperature, this fact should be given consideration. This may be done by applying formula 2 to the standard heat output of the radiator or more conveniently by multiplying its standard heat emission by the proper factor taken from Table 3. In estimating the size of radiator required for a room under other than standard conditions divide the estimated heat loss from the room by the factor for the prevailing conditions as given in Table 3, and choose a radiator which will supply this corrected heat loss when operating under standard conditions. Thus, if a room is to be heated to 60 F with steam at 200 F and the heat loss at this room temperature is 7200 Btu per hour, divide 7200 by 0.955 (the conversion factor for these conditions), and pick a radiator which will give $\frac{7200}{0.955}$ or 7539 Btu per hour when supplied with 215 F steam in a room having a temperature of 70 F.

For hot water, the same procedure may be followed using the mean temperature of the water in the radiator for selecting the proper conversion factor. For example, if the mean temperature of the water is 170 F and the air temperature is 70 F, the conversion factor will be 0.617. If the heat emission at 215 F and 70 F is 240 Btu per square foot, the emission at 170 F and 70 F will be 0.617 x 240 or 148 Btu per hour, and $\frac{100}{0.617}$ or 162 sq ft of heating surface will be required for every 100 sq ft required for the standard conditions of 215 F and 70 F.

TABLE 5. VOLUMES (INTERNAL) FOR VARIOUS RADIATORS[3]

KIND OF RADIATOR	AVERAGE VOLUME PER SQUARE FOOT OF SURFACE, (PINTS)	KIND OF RADIATOR	AVERAGE VOLUME PER SQUARE FOOT OF SURFACE, (PINTS)
Cast-Iron column	1.5	Pipe, 1-in. diameter, steel or wrought iron.	1
Cast-Iron flue	1.75	Pressed metal.	1
Cast-Iron wall sections	1.65		

[3]*Mechanical Equipment of Buildings*, by Harding and Willard, Vol. I, second edition, 1929.

Effect of Paint

Painting a radiator changes the emissivity constant of the radiating surface, but has practically no effect upon the heat lost by convection. It is, therefore, a surface effect and it makes no appreciable difference what paints are placed on the radiator as a priming coat; the results are always dependent upon the last coat of paint. In radiators having a large proportion of radiating surface such as pipe coils or wall coils, the effect of painting will be more marked than in tubular radiators having a comparatively small radiating surface in proportion to the amount of convecting surface. Most finely ground pigments have about the same radiation constant as black cast-iron. Therefore paints having finely ground pigments will usually have little effect. Bright metals have a much lower radiation constant and therefore, bronze metallic paints will reduce the direct radiation emission from a radiator.

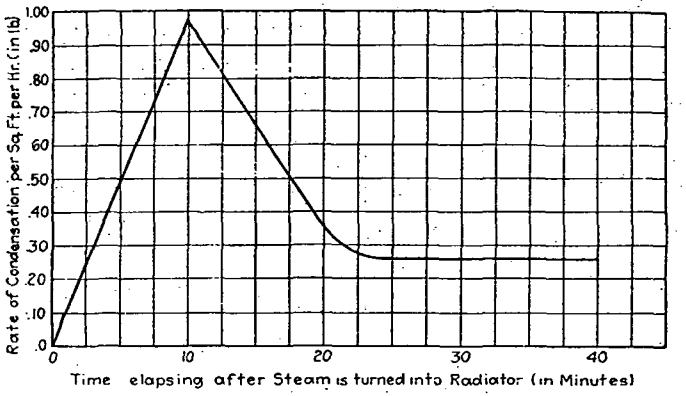


FIG. 2. CHART SHOWING THE STEAM DEMAND RATE FOR HEATING-UP A CAST-IRON RADIATOR WITH FREE AIR VENTING AND AMPLE STEAM SUPPLY

The effects of painting a six-section 32-in. three-column radiator as found in recent tests are given in Table 4.

The results of tests (Fig. 1)[4], conducted at the University of Illinois, with two types of radiators, lead to the following conclusions:

1. The heating effect of a radiator cannot be judged solely on the amount of steam condensed within the radiator.

[4]*The Effect of Two Types of Cast-Iron Steam Radiators in Room Heating*, by Prof. A. C. Willard and M. K. Fahnestock, *Heating, Piping and Air Conditioning*, March, 1930.

2. High column radiators placed at the sides of window openings do not produce as comfortable heating effects as long, low, direct radiators placed beneath a window opening.

3. Smaller floor to ceiling temperature differentials can be maintained with long, low, direct radiators, than is possible with high, direct, column radiators.

4. High column and tubular types of direct radiators give the major portion of the floor to ceiling temperature differential above the breathing line level.

5. The comfort level (approximately 2 ft-6 in. above floor) is below the breathing line level (approximately 5 ft-0 in. above floor), and temperatures taken at the breathing line may not be indicative of the actual heating effect of a radiator in the room. The comfort indicating temperature should be taken below the breathing line level.

WEIGHTS AND VOLUMES OF RADIATORS

The weights and volumes of radiators are often of considerable importance in heating problems. Cast-iron radiators average from 5 to 7 lb per equivalent square foot of heating surface, although specific types may vary somewhat from this figure.

The internal volume is often required for the purpose of making comparisons and for computing the amount of steam in a steam system and the amount of water in a hot-water system. Approximate values are given in Table 5.

HEATING UP THE UNIT

It is often very important to know the maximum condensation that occurs in a heating unit when steam is turned on. Fig. 2 shows a typical curve for the condensation rate in pounds per hour for the time elapsing after steam is turned into a cast-iron radiator. In practice the rate of steam supply to the heating unit while heating up is frequently retarded by controlled elimination of air through air valves or traps. Automatic control valves may also retard the supply of steam.

LOCATION OF RADIATORS

Radiators should be installed beneath or near the area of greatest heat loss. The best location is underneath an outside window for the following reasons:

1. Cold air leaking in through the window is warmed before it reaches the interior of the room or floor.

2. Air currents from the radiators pass upward, mingling with the cold infiltering air, and form a screen of warm air protecting against cold window drafts.

SELECTION OF RADIATORS

In selecting the proper radiators for heating a given room or space, the following procedure should be used:

1. Estimate the total loss from the room or space to be heated in accordance with the procedure outlined in Chapter 2, *making proper allowance for exposure, wind velocity,* height of ceiling, etc.

2. Decide upon the type and the number of radiators to be used. Then find from manufacturers' guaranteed performance tables for the particular type of radiator selected as given in the Catalog Data Section of THE GUIDE or elsewhere, the number of sections or the size of each unit required to supply the heat loss from the room.

Chapter 7

GRAVITY CONVECTORS

Cabinet or Wall-Enclosed Heating Units; Output of Wall or Cabinet Convectors; Selection of Wall or Cabinet Convectors; Gravity-Indirect Heating Systems.

A HEATING unit, if placed within an enclosure, is a convector. The unit may be placed in (1) a cabinet located within the room, (2) a flue in a wall adjacent to the room or (3) a casing or enclosure located exterior to the room. There are, however, various modifications of these arrangements. An inlet for the cooled air and an outlet for the heated air must necessarily be provided. If the heating unit is located in the basement, ducts leading to and from the enclosure must also be provided. If the air flow over the unit takes place by natural convection, it is termed a *gravity convector*, whereas if the air flow is produced by a fan or blower, it is termed a *fan convector*. (See Chapter 31, Design of Central Fan Systems).

It will be evident that a gravity convection system is essentially an indirect system of heating in which the air is recirculated from the floor of the room and delivered back again through the outlets at the top of the flue or cabinet at a temperature sufficiently great so that in cooling to the inlet temperature it gives up enough heat to supply the heat loss from the room. An exactly similar process goes on in a gravity circulating warm-air furnace heating system in which the air is returned to the furnace from the house. While gravity warm air heating could be included in this classification, the principles involved are entirely different and this type of system is treated separately in Chapter 5.

An enclosed heating unit containing steam or hot water (convector) emits practically all of its heat by conduction to the air surrounding it and this heated air is in turn transmitted by convection to the rooms or spaces to be warmed, the heat emitted by radiation being negligible. A small amount of heat is transmitted by radiation to the inside surface of the enclosure, the amount so transmitted diminishing as the surface temperature of the enclosure approaches the surface temperature of the heating unit. A partially shielded unit located within the space to be heated will transmit heat by radiation to the objects in the space it can *see*.

CABINET OR WALL-ENCLOSED HEATING UNITS

Radiator-Type Heating Units

The general effect of an enclosure placed about a heating unit of the type used as a direct radiator is to decrease the amount of steam that the

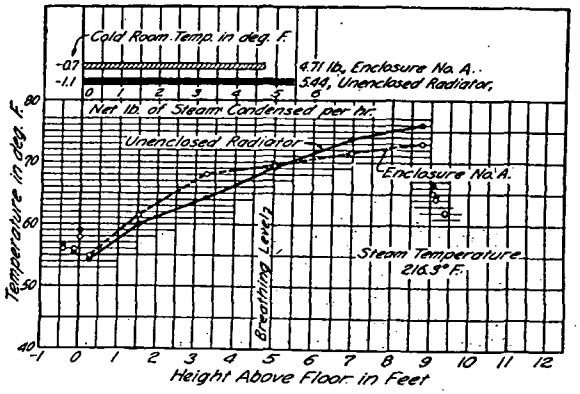


FIG. 1. ROOM TEMPERATURE GRADIENT AND STEAM CONDENSING RATE FOR RADIATOR WITH WELL DESIGNED ENCLOSURE

unit will condense per hour and thus to reduce the amount of heat given off by the unit. The results of recent investigations[1] indicate that only where the enclosure is made much higher than the heating unit, thereby producing a chimney effect, is the condensation rate equal to or greater than that of an identical radiator unenclosed.

The effects produced by an enclosure are dependent upon its design, so that the following results may be produced:

1. Better distribution of the heat below the breathing line level to produce greater heating comfort and lowered ceiling temperatures.
2. The lessened steam consumption may not materially change the radiator heating performance.
3. The enclosed radiator may inadequately heat the space.

[1]Effect of Enclosures on Radiator Performance, by A. P. Kratz and M. K. Fahnestock (A.S.H.V.E. TRANSACTIONS, Vol. 33, 1927).

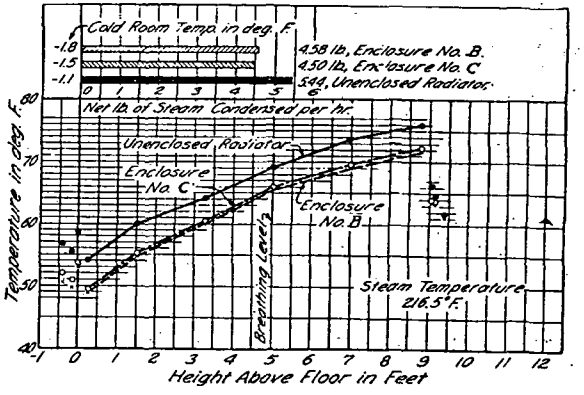


FIG. 2. ROOM TEMPERATURE GRADIENTS AND STEAM CONDENSING RATES FOR RADIATOR WITH IMPROPERLY DESIGNED ENCLOSURES

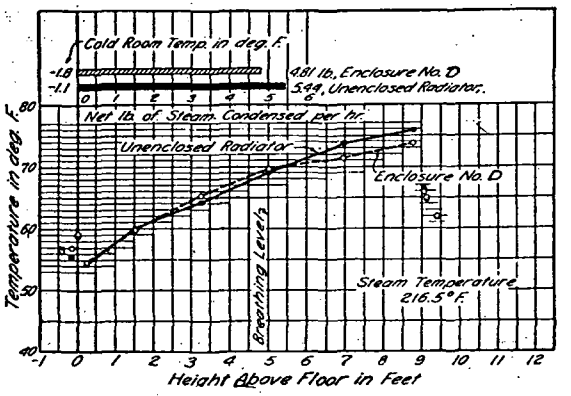


FIG. 3. ROOM TEMPERATURE GRADIENT AND STEAM CONDENSING RATE FOR RADIATOR WITH SHIELD

A comparison[2] between a bare heating unit and a heating unit fitted with a well designed enclosure, a poorly designed enclosure, a well designed shield, and a cloth cover, are shown by Figs. 1, 2, 3 and 4. Fig. 1 illustrates the relative heating effects of a bare heating unit and the same unit fitted with a well-designed enclosure. Comparison of the curves reveals that the enclosed heating unit used 13 per cent less steam than the bare unit, gave the same breathing line temperature, produced higher temperatures in the occupied zone, and gave reduced temperatures above the breathing level. This was a satisfactory heating performance. Fig. 2 shows the unsatisfactory effects produced by improperly designed enclosures. The effect of a well-designed shield placed above the heating unit is shown by Fig. 3. The performance obtained by the use of the

[2]Investigation of Heating Rooms with Direct Steam Radiators Equipped with Enclosures and Shields, by A. C. Willard, A. P. Kratz, M. K. Fahnestock and S. Konzo (A.S.H.V.E. TRANSACTIONS, Vol. 35, 1929).

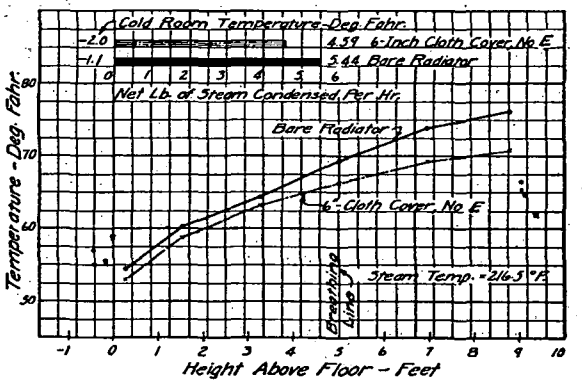


FIG. 4. ROOM TEMPERATURE GRADIENTS AND STEAM CONDENSING RATES FOR RADIATOR WITH A CLOTH COVER

shield was satisfactory as the condensation rate was decreased by 11 per cent, the temperatures above the breathing line were reduced, the breathing-line temperature was unchanged, and slightly higher temperatures were obtained below the breathing line. The effect of a cloth cover (Fig. 4) extending downward 6 in. from the top of the heating unit was to make the performance unsatisfactory and inadequate.

Specially-Designed Heating Units[3]

Although any standard heating unit (*i.e.*, radiator) may be concealed in a cabinet or other enclosure so that heat is conveyed to the room only by the process of convection, the best results are obtained where units of special design are used. Figs. 5 and 6 show typical cabinet and wall convectors using specially-designed heating units. These units usually consist of a relatively large amount of extended surface which may be integral with the core or prime surface containing the heating medium or assembled over such a core, making thermal contact by pressure, or by

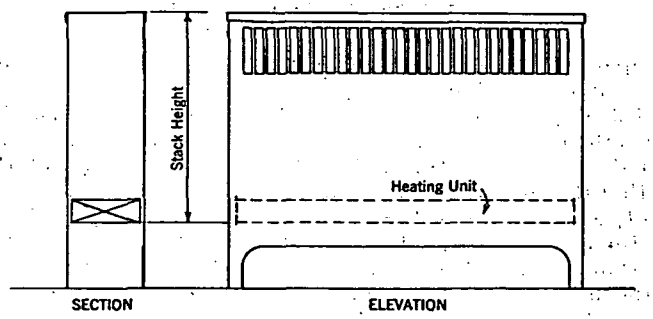


FIG. 5. TYPICAL FLOOR-TYPE CABINET CONVECTOR USING SPECIALLY DESIGNED HEATING UNIT

being soldered to the core, or by both pressure and soldering. (See Fig. 7). The ratio between the extended surface and prime surface may be as high as 25 to 1. The design and performance of enclosures should be carefully studied when heating units are to be selected for use with enclosures or when enclosures are to be applied to existing radiators.

OUTPUT OF WALL OR CABINET CONVECTORS

It has been the practice to state the output of direct radiators in terms of the *equivalent square foot* of heating surface. (See Chapter 6, Radiators, p. 97). With the development of convection-type heating units (extended surface units) the same procedure has been followed. However, an extended surface heating unit is entirely different structurally and physically from that of a direct radiator and since it has no physical measurement corresponding to the square foot of heating surface of a direct radiator, many engineers believe that heating units of this type should be rated in Btu output, rather than in equivalent square feet of heating surface.

[3]Specially designed heating units enclosed in a cabinet or wall have been commercially known as *concealed radiation*.

Convection-type heating units usually maintain room temperatures equivalent to those produced by exposed heating units with less steam consumption. This characteristic of the performance of convection-type heating units has been termed *heating effect*. Heating effect is attributed to (1) the minimization of radiant emission (2), the fact that the air which passes upward through a convection-type heating unit is drawn by gravity from the coolest strata in the room, *i.e.*, that at the floor level and (3) the heated air emitted from the air outlet of the enclosure is generally projected out into the room instead of rising directly to the ceiling.

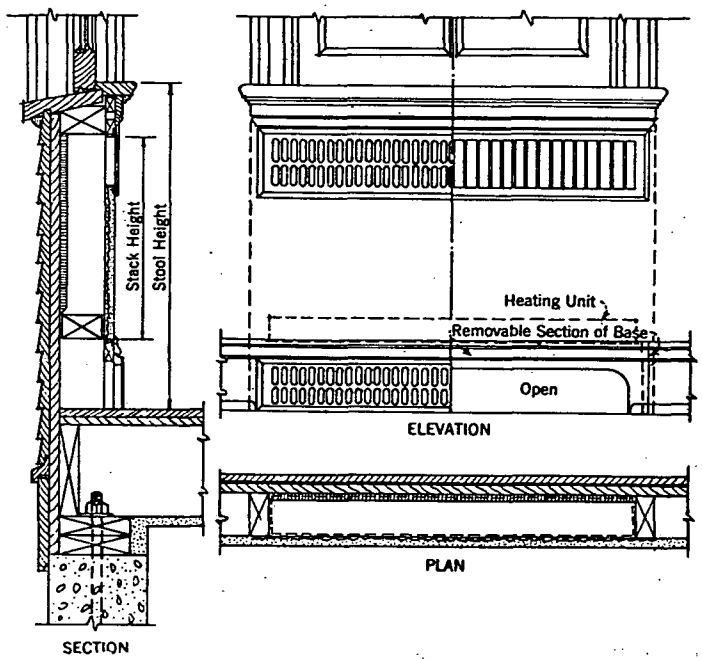
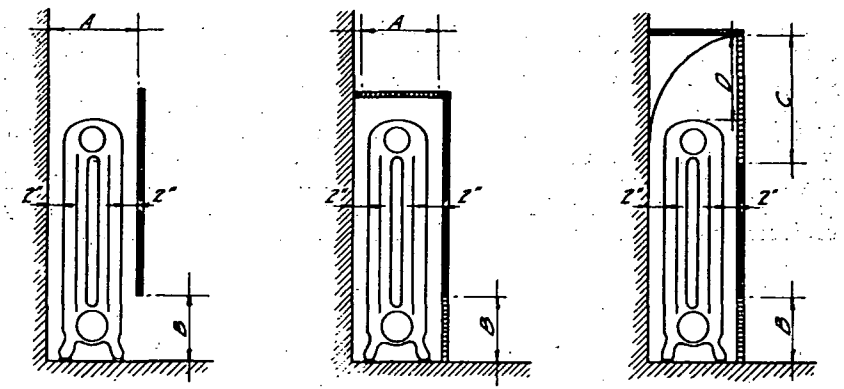


FIG. 6. TYPICAL WALL CONVECTOR USING SPECIALLY DESIGNED HEATING UNIT

Convectors of the cabinet or concealed type are usually sold complete as a unit including the cabinet and heating unit. As recommended in the A.S.H.V.E. Code for Testing and Rating Concealed Gravity Type Radiation[4], the heat emission or output of concealed heating units for steam should be stated in Btu per hour, but may also be expressed in terms of equivalent heating surface (E.D.R.) which is equal to the heat output for standard conditions divided by 240. For hot water the output may be expressed in Btu per hour and complete performance data should be given. The friction pressure drop through the heating unit, expressed in inches of water, should also be specified.

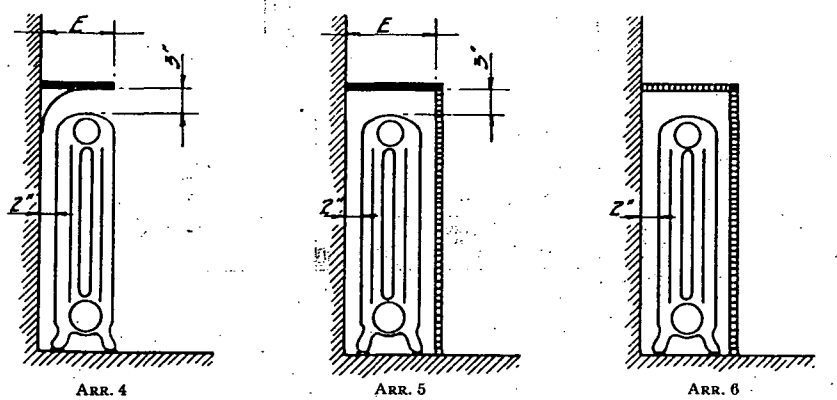
[4]See *Heating, Piping and Air Conditioning*, August, 1931.



ARR. 1

ARR. 2

ARR. 3



ARR. 4

ARR. 5

ARR. 6

TYPE	INSTALLATION CONDITIONS	HEAT EMISSION SHALL BE ALTERED BY PERCENTAGE INDICATED
Arr. 1	When dimension A is as shown in Arr. 1 and dimension B is equal to 80 per cent of A	10% increase
Arr. 2	When dimension A is as shown and dimension B is equal to 80 per cent of A	5% increase
Arr. 3	When dimension B is equal to 80 per cent of A (as in Arr. 1), dimension C is equal to 150 per cent of A and dimension D is equal to A	No change
Arr. 4	When dimension E is equal to 50 per cent of A	10% reduction
	When dimension E is equal to A	20% reduction
	When dimension E is equal to 150 per cent of A	35% reduction
Arr. 5	When dimension E is equal to A	30% reduction
Arr. 6	When as shown	5% reduction

[a]From A.S.H.V.E. Code of Minimum Requirements for the Heating and Ventilation of Buildings (edition of 1929).

FIG. 8. TYPES OF ENCLOSURES AND HEAT EMISSION OF ENCLOSED RADIATORS

The *stack height* is usually taken as the vertical distance from the bottom of the heating unit to the top of the enclosure. (See Figs. 5 and 6.)

SELECTION OF WALL OR CABINET CONVECTORS

The procedure for selecting wall or cabinet gravity convectors is as follows:

1. Estimate the total heat loss from the room or space to be heated in accordance with the procedure outlined in Chapter 2, making proper allowance for exposure, wind velocity, height of ceiling, etc.

2. *Radiators With Enclosures.* If heating units for which heat emission data are given only for use as exposed radiators, are to be used, estimate the percentage decrease in heat emission from a unit thus installed in accordance with Fig. 8, and add this percentage to the heat loss from the room as estimated in Paragraph 1. From the manufacturers' guaranteed performance data as given in the Catalog Data Section of THE GUIDE or elsewhere, find the number of sections or size of each heating unit to supply the corrected heat loss.

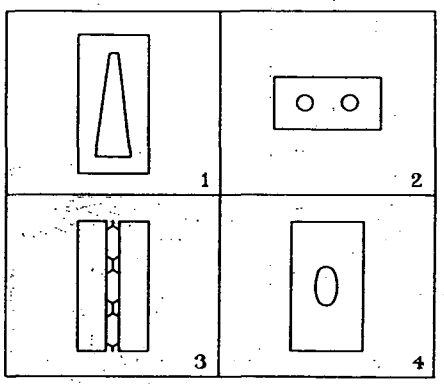


FIG. 7. SECTIONS THROUGH TYPICAL HEATING UNITS OF EXTENDED SURFACE TYPE

3. *Convectors (Concealed Radiation).* If convection-type units with enclosures are to be used, decide upon the type and the number of units to be used. Then find from manufacturers' guaranteed performance tables for the particular type of unit and enclosure under consideration as given in the Catalog Data Section of THE GUIDE or elsewhere, the number of sections or the size of each heating unit required to supply the heat loss from the room. No addition because of enclosure need be made to the ratings as guaranteed by the manufacturer.

GRAVITY-INDIRECT HEATING SYSTEMS[5]

If the heating units are placed in the basement, properly encased, and this enclosure connected to the room by means of supply ducts, it is usually termed a *gravity-indirect heating system.* (See Fig. 9). The heating units for this type of heating are likewise of special design, usually of the extended surface type, and give off their heat by conduction to the air passing over them.

[5]For further information on this subject see A.S.H.V.E. Code of Minimum Requirements for the Heating and Ventilation of Buildings (edition of 1929) and Mechanical Equipment of Buildings, by Harding and Willard, Vol. I, second edition, 1929.

The heated air then rises through vertical flues, due to its diminished density, and flows into the rooms above under the influence of gravity only. The temperature and volume of the air entering at the register must be great enough so that in cooling from the initial temperature to the room temperature the heat available will just equal the heat loss during the same time. It is not only necessary to provide ducts for supplying air to each room heated, but in order to establish and maintain a constant flow, provision must be made for positively removing the air in

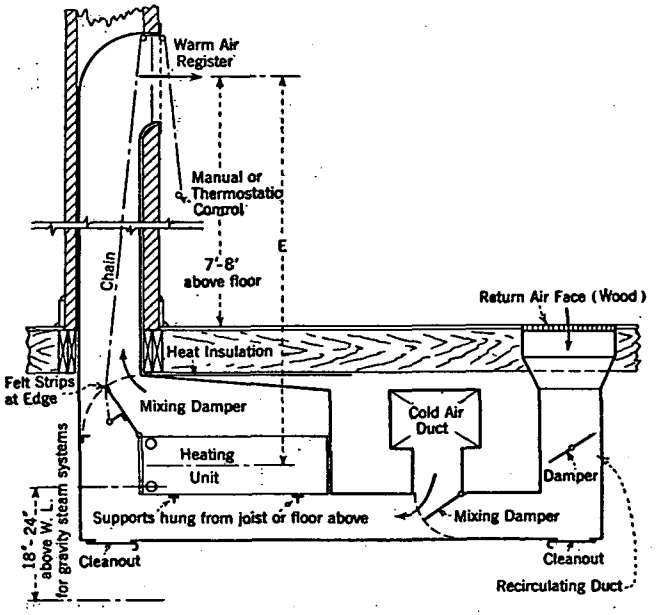


FIG. 9. GRAVITY-INDIRECT HEATING SYSTEM[6]

the room, after it has cooled to the desired room temperature, by a system of vent flues or ducts which take air at or near the floor line.

This system is very similar in principle to the ordinary gravity warm-air furnace system, except that it uses steam or hot water as the heating medium instead of hot furnace gases. It differs from the central fan system in that no fan or blower is used to force the air through the system, as the air flow is maintained entirely by gravity or natural draft conditions. Since this gravity head is very slight, it is necessary to make all ducts as short as possible, especially the runs from the heating units to the base of the vertical hot-air flues. In cases where ventilation is a requirement the air volume required for this purpose may become so large that the entering air temperature will be but slightly above the room temperature.

[6]See Mechanical Equipment of Buildings, by Harding and Willard, Vol. I, second edition, 1929.

Chapter 8

HOT WATER HEATING SYSTEMS AND PIPE SIZES

Heating Units; Piping Arrangements; Pipe Sizes; Forced Circulation System; Pipe Size Tables; Modulating Valves and Orifices; Permissible Variations in Pipe Sizes; Gravity Circulation; Expansion Tanks; Circulating Pumps; Piping Details; General Details.

HOT water heating systems may be divided into two general types, *forced circulation* and *gravity circulation* systems. In forced circulation systems the pressure heads maintaining flow are produced by pumps; in gravity circulation systems they are produced by the differences in weight of the water in the flow and return risers.

In designing a hot water heating system, it is necessary to determine:

1. The heat losses of the rooms or spaces to be heated. (See Chapter 2).
2. The size and type of heater. (See Chapters 14 and 20).
3. The location, type, and size of heating units. (See Chapters 6 and 7).
4. The type and size of piping.
5. The type and size of circulating pump (if forced circulation).
6. The type and size of expansion tank.
7. Piping details.

HEATING UNITS

Information relating to heating units may be found in Chapter 6, Radiators; and Chapter 7, Gravity Convectors. For steam radiators it is customary to use the *equivalent square foot* of heating surface which is the emission of 240 Btu per hour when the radiator is placed in air at 70 F, and filled with steam at 215 F, as explained in Chapter 6. This 240-Btu unit is also applicable to hot water heating when the average water temperature in the radiators is 215 F and the temperature of the surrounding air is 70 F.

Factors for obtaining the heat emission for mean temperatures other than 215 F are given in Table 3, Chapter 6. It would be well to abandon, as soon as practicable, the use of the *equivalent square foot* in hot water heating calculations and to base all calculations on units of 1000 Btu, and, having done that, to find from data supplied by manufacturers, the size radiators or convectors to be selected for the required number of 1000 Btu and for the average water temperature which is to exist in the radiators or convectors.

PIPING ARRANGEMENTS

Pipe systems may be divided into two general types, namely, *two-pipe* and *one-pipe* systems. In a two-pipe system the piping is arranged so that

the water flows through one radiator only during its circuit through the system, so that all radiators are supplied with water practically at the same temperature as that in the boiler. In a one-pipe system, the water flows through more than one radiator during its circuit. In that case, the first radiator receives the hottest water; the second radiator, somewhat cooler water; the third one, still cooler, and so on. As the temperature of the water supplied to a radiator is lowered, the size of the radiator must be increased, and consequently, the total heating surface for a one-pipe system is more than that for a two-pipe system for the same service. This increase in heating surface is objectionable, and one-pipe systems should be installed only when special reasons make them desirable.

Two-pipe systems may be divided into two classes, *direct return* systems (Fig. 1), and *reversed return* systems (Fig. 2). In a direct return system the water returns to the heater by a direct route after it has passed through its radiator and, as a result, the paths through the three radiators shown in Fig. 1 are of unequal lengths, the path through the first radiator being the shortest and that through the third radiator, the longest. In a reversed return system, the water returns to the heater by

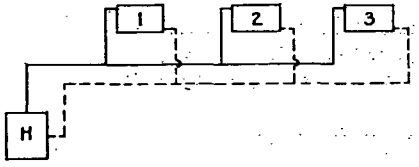


FIG. 1. A DIRECT RETURN SYSTEM

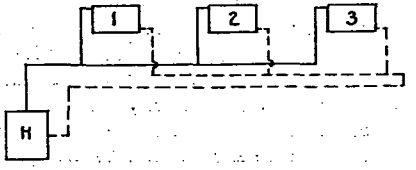


FIG. 2. AN INDIRECT RETURN SYSTEM

an indirect route after it has passed through the radiators so that the paths leading through the three radiators shown in Fig. 2 are practically of equal length.

The reversed return system has an advantage over the direct return system in that it is more likely to function satisfactorily even though the pipe system is not accurately designed. For example, if in Fig. 2 all pipes are of one size, each of the three radiators will receive approximately the same quantity of hot water because the three paths are practically of equal length, whereas in Fig. 1, if all pipes are of the same size, Radiator 1 will receive more water than the others because the path through it is shorter than those through the other radiators. As a result, Radiator 1 will be filled with water at a higher average temperature than the remaining two radiators, and will therefore dissipate more heat. To prevent this unequal distribution of heat it is necessary to throttle the paths through Radiators 1 and 2 so that the friction heads of the three paths are exactly equal when each radiator receives its proper quantity of water.

A comparison of Fig. 1 and Fig. 2 may suggest that a reversed return system requires considerably longer mains than a direct return system. This is not always the case. For example, note the reversed return system of Fig. 3.

PIPE SIZES

The pressure heads available in forced circulation systems are much larger than those in gravity circulation systems, consequently, higher velocities may be used in designing the system with the result that smaller pipes and smaller radiators may be selected, and the first cost of the installation reduced. As the pipes of a heating system are reduced in size, the velocity of the water and the cost of operating the circulating pump are increased. There is an optimum velocity of the water in a heating system for which the sum of the cost of the system and the cost of its operation is a minimum. This velocity should be determined by calculation for the particular system under consideration.

Since the velocities in forced circulation systems are higher than those

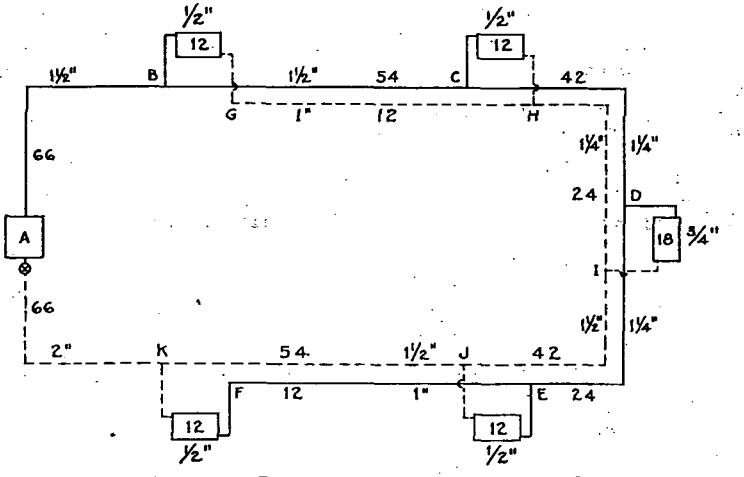


FIG. 3. A FORCED CIRCULATION INDIRECT RETURN SYSTEM[a]

[a]This system could be divided into two branches. This would permit the use of smaller pipes and would produce only slight changes in the total length of the pipe. It is shown as a single system here simply to illustrate the method of determining pipe sizes by means of pipe size tables. Note that the numbers on the radiators indicate thousands of Btu and not square feet.

in gravity circulation systems, and since the friction heads in a heating system vary almost as the squares of the velocities, a given error in the calculation or assumption of a velocity is less potential in a forced circulation system than in a gravity circulation system, and consequently, it is easier to design and to construct a satisfactory forced circulation system than a satisfactory gravity circulation system. For this reason it is best to begin the study of pipe sizes for hot water heating systems with that of forced circulation.

FORCED CIRCULATION SYSTEM

The following examples will illustrate the procedure to be followed in designing forced circulation systems:

Example 1. Assume that the paths through the five radiators shown in Fig. 3 consist each of 150 ft of mains, 5 ft of radiator connections, 1 boiler, 1 radiator, 1 radiator valve, 10 ells and 2 tees. Design the piping for this system.

Solution. The friction heads in the boiler, radiator, valve, and tee may be expressed in terms of the friction head in one elbow according to the values given in Table 1. Having done this, each of the five circuits consists of 155 ft of pipe and about 24 elbow equivalents. The friction head of one elbow is approximately equivalent to that in a pipe having a length equal to 25 diameters. Assuming that the average pipe size in this case will be about 1¼ in., one elbow equivalent may be placed equal to about 3 ft of pipe and the total length of the circuit equivalent to about 227 ft of pipe.

Having determined the equivalent pipe length, assume the rate at which the water is to be forced through the system. This rate may vary widely. The water may flow through the radiator so that it will cool 10 deg or 20 deg or any other reasonable number of degrees. In this case, assume a 10-deg drop. Since the system is to dissipate 66,000 Btu per hour, the pump must circulate 6600 lb of water per hour or 13.2 gpm based on the nominal density of water of 8.336 lb per gallon at 62 F. (One gallon of water per minute at this density will deliver 10,000 Btu per hour with a temperature drop of 20 deg).

The next step in the design is to assume the velocity at which the water is to circulate through the system. This also may vary materially. As the velocity is increased, the sizes of the pipes and the cost of the system are decreased, but the cost of operating the circulating pump is increased. The designing engineer should make a careful study to determine the velocity which will produce the most economical installation for the particular case in hand. In this case, assume a velocity of about 1½ fps for a 1¼-in. pipe.

Reference to Fig. 4 shows that for a 1¼-in. pipe and a velocity of 18 in. per second, the friction head is about 100 milinches per foot, or about 2 ft for a circuit of 227 ft, if the pipe sizes for that circuit are chosen so that the average friction head is about 100 milinches per foot of pipe.

The pipe sizes may now be selected from Fig. 4 by making allowance for the fact that Fig. 4 is based on a temperature drop of 20 deg and that the system to be designed is to

TABLE 1. ELBOW EQUIVALENTS[a]

1 90-deg elbow	1.0
1 45-deg elbow	0.7
1 90-deg long turn elbow	0.5
1 open return bend	1.0
1 open gate valve	0.5
1 open globe valve	12.0
1 angle radiator valve	2.0
1 radiator	3.0
1 heater	3.0
1 tee	(Note[b])

[a]The loss of head in one elbow can be expressed in terms of the velocity head by the formula:

$$h = \frac{v^2}{2g} \qquad (1)$$

where

h = the loss of head in feet, v = the velocity of approach in feet per second, and $2g$ = 64.4 ft per second per second.

[b]The loss of head in tees when water is diverted at right angles through a branch of the tee varies with the per cent diverted. When the water diverted is less than 60 per cent of that approaching the tee, the loss of head, in elbow equivalents, may be expressed as follows:

$$h_e = \frac{v_1^2}{v_2^2} \qquad (2)$$

where

h_e = the loss of head in elbow equivalents, v_1 = the velocity of approach, v_2 = the velocity of water diverted at right angles.

Values in elbow equivalents for the most common percentages of water diverted in a 1x1x1-in. tee are as follows:

25%	16.0
33%	9.0
50%	4.0
100%	1.8

For other percentages the approximate values may be secured by interpolation. When the water is diverted from the tee into a smaller size branch, as in a 1x1x¾-in. tee, approximate values may be secured by means of Formula 2.

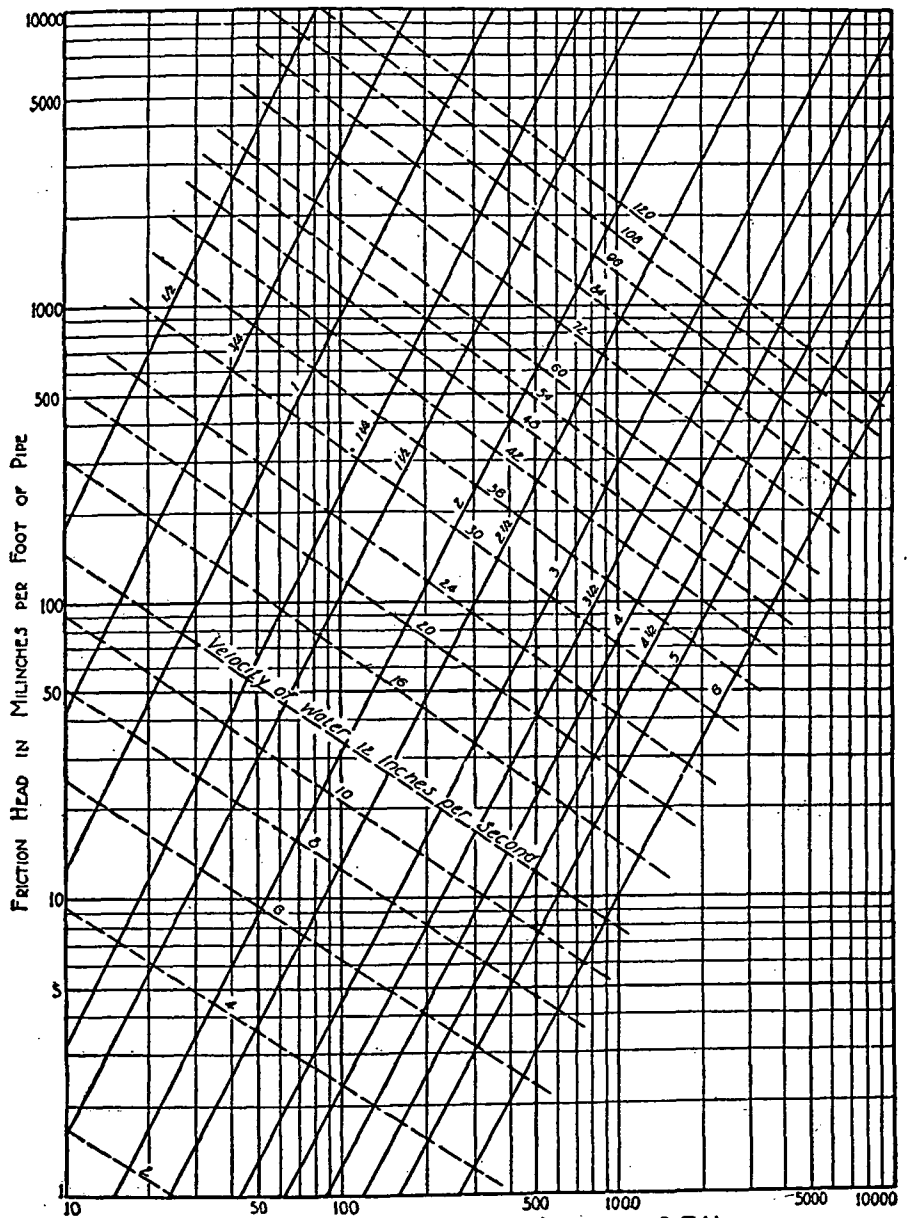


FIG. 4. FRICTION HEADS IN PIPES FOR A 20 DEG. TEMPERATURE DIFFERENCE OF THE WATER IN THE FLOW AND RETURN LINES

have a temperature drop of only 10 deg as follows: Sections *AB* and *KA* supply 275 sq ft of equivalent heating surface and hence carry 66,000 Btu with a temperature drop of 10 deg; if the temperature drop were 20 deg these sections would (with the same velocity and the same friction head) carry 132,000 Btu. Hence, refer to Fig. 4 for 132,000 Btu and a unit friction head of 100 milinches, and note that the correct size would be about half way between a 1½-in. and a 2-in. pipe. Therefore, select a 1½-in. pipe for Section *AB* and a 2-in. pipe for Section *KA*. The pipe sizes for the remaining eight sections and for the radiator connections can be selected in the same manner and recorded on the pipe diagram as shown.

The circulating pump for the system should be one which has its highest efficiency when it is delivering 13.2 gpm against a head of 2 ft.

TABLE 2. CAPACITIES OF PIPES IN EQUIVALENT SQUARE FEET OF HEATING SURFACE,[a] *and in 1000 Btu,* **and Velocities of Water in Pipes in Inches Per Second** FOR FORCED CIRCULATION SYSTEMS WITH A TOTAL FRICTION HEAD OF 2 FT AND FOR A MAXIMUM TEMPERATURE DROP OF 10 DEG[b]

1	2	3	4	5	6	7	8	9
PIPE SIZE (INCHES)	EQUIVALENT LENGTH OF PIPE (FEET[c])	EQUIVALENT TOTAL LENGTH OF PIPE IN FEET IN LONGEST CIRCUIT						
		100	150	200	250	300	350	400
		UNIT FRICTION HEAD, IN MILINCHES						
		240	160	120	96	80	69	60
½	1	26 *6.2* **15**	20 *4.8* **12**	17 *4.1* **10**	14 *3.4* **9**	12 *2.9* **8**	11 *2.6* **7.5**	10 *2.4* **7**
¾	2	55 *13.2* **18**	43 *10.3* **14**	36 *8.6* **12**	31 *7.3* **11**	26 *6.2* **10**	25 *6.0* **9**	23 *5.5* **8.5**
1	2.3	104 *25.0* **22**	80 *19.2* **17**	68 *16.3* **15**	60 *14.4* **13**	52 *12.5* **12**	50 *12.0* **11**	46 *11.1* **10.5**
1¼	3.0	220 *52.8* **27**	170 *40.8* **21**	145 *34.8* **18**	130 *31.2* **16**	116 *27.8* **15**	110 *26.4* **14**	100 *24.0* **13**
1½	3.5	330 *79.2* **30**	253 *60.7* **23**	213 *51.2* **20**	190 *45.6* **18**	170 *40.8* **16**	167 *40.0* **15**	150 *36.0* **14**
2	4.0	640 *153.8* **36**	500 *120.0* **28**	425 *104.0* **24**	390 *93.5* **22**	360 *86.4* **20**	340 *81.5* **18**	308 *73.8* **17**
2½	6.0	1040 *250.0* **41**	800 *192.0* **32**	685 *164.5* **28**	620 *149.0* **25**	580 *139.2* **22**	565 *135.8* **21**	510 *122.5* **19**
3	6.5	1850 *444.0* **48**	1450 *348.0* **37**	1225 *294.0* **32**	1124 *270.0* **29**	1060 *254.0* **26**	1000 *240.0* **24**	930 *223.0* **22**

[a]Based on 240 Btu per square foot.

[b]For other temperature drops the capacities of pipes are to be changed correspondingly. For example, for a temperature drop of 30 deg, the capacities shown in this table are to be multiplied by 3. The velocities remain unchanged.

[c]Approximate length of pipe in feet equivalent to one elbow in friction head. This value varies with the velocity.

Pipe Size Tables

If a number of heating systems are to be designed for similar conditions, *i.e.*, for a total friction head of 2 ft and a temperature drop through the radiators of 10 deg when the maximum quantity of heat is being delivered to the building, a table such as Table 2 may be prepared from the data of Fig. 4. Having this table, the pipe sizes for the system of Example 1 can be easily selected. For example, for Sections *BC* and *JK*, each supplying 225 sq ft (54,000 Btu), the equivalent pipe length of the system is 227 ft.

TABLE 3. CAPACITIES OF PIPES IN EQUIVALENT SQUARE FEET OF HEATING SURFACE[a] *and in 1000 Btu,* **and Velocities of Water in Pipes in Inches Per Second** FOR FORCED CIRCULATION SYSTEMS WITH A TOTAL FRICTION HEAD OF 6 FT AND FOR A MAXIMUM TEMPERATURE DROP OF 10 DEG[b]

1	2	3	4	5	6	7	8
PIPE SIZE (INCHES)	EQUIVALENT LENGTH OF PIPE (FEET[c])	EQUIVALENT TOTAL LENGTH OF PIPE IN FEET IN LONGEST CIRCUIT					
		200	300	400	600	800	1000
		UNIT FRICTION HEAD, IN MILINCHES					
		360	240	180	120	90	72
½	1	31 *7.4* **18**	25 *6.0* **15**	21 *5.0* **13**	16 *3.8* **10**	14 *3.4* **9**	13 *3.1* **7.5**
¾	2	66 *15.8* **22**	53 *12.7* **18**	45 *10.8* **16**	35 *8.4* **12**	32 *7.7* **11**	28 *6.7* **9**
1	2.5	125 *30.0* **27**	100 *24.0* **22**	85 *20.4* **19**	66 *15.8* **15**	58 *13.9* **13**	52 *12.5* **11**
1¼	3.3	270 *64.8* **33**	218 *52.5* **26**	185 *44.4* **23**	140 *33.6* **18**	125 *30.0* **16**	112 *26.8* **14**
1½	4.0	400 *96.0* **37**	320 *76.8* **31**	270 *64.8* **26**	210 *50.1* **20**	187 *44.7* **18**	170 *40.8* **15**
2	5.0	800 *192.0* **44**	640 *153.0* **36**	540 *130.0* **30**	420 *100.1* **24**	375 *90.0* **21**	330 *78.0* **18**
2½	6.0	1250 *300.0* **50**	1020 *244.0* **41**	860 *206.0* **35**	670 *161.0* **26**	600 *144.0* **24**	540 *130.0* **21**
3	7.5	2300 *550.0* **58**	1820 *436.0* **48**	1540 *368.0* **42**	1200 *287.0* **32**	1040 *249.0* **27**	950 *228.0* **24**

[a]Based on 240 Btu per square foot.

[b]For other temperature drops the capacities of pipes are to be changed correspondingly. For example, for a temperature drop of 30 deg, the capacities shown in this table are to be multiplied by 3. The velocities remain unchanged.

[c]Approximate length of pipe in feet equivalent to one elbow in friction head. This value varies with the velocity.

The length shown in the table nearest to this length is 200 ft. In the 200-ft column, a 1½-in. pipe is slightly too small and a 2-in. pipe is too large. The 1½-in. pipe will therefore be selected. For Sections *CD* and *IJ*, supplying 175 sq ft (42,000 Btu), a 1¼-in. pipe is too small and a 1½-in. pipe is too large, so 1¼ in. will be selected for the flow and 1½ in. for the return line. For larger systems, it will be economical to operate with higher friction heads, and tables similar to Tables 3 and 4, which are based respectively on total friction heads of 6 and 18 ft, may be prepared.

TABLE 4. CAPACITIES OF PIPES IN EQUIVALENT SQUARE FEET OF HEATING SURFACE[a] *and in 1000 Btu,* **and Velocities of Water in Pipes in Inches Per Second** FOR FORCED CIRCULATION SYSTEMS WITH A TOTAL FRICTION HEAD OF 18 FT AND FOR A MAXIMUM TEMPERATURE DROP OF 10 DEG[b]

1	2	3	4	5	6	7
PIPE SIZE (INCHES)	EQUIVALENT LENGTH OF PIPE (FEET[c])	EQUIVALENT TOTAL LENGTH OF PIPE IN FEET IN LONGEST CIRCUIT				
		200	400	600	800	1000
		UNIT FRICTION HEAD, IN MILINCHES				
		1080	540	360	270	216
½	1.0	53 *12.7* **32**	36 *8.6* **23**	30 *7.2* **18**	26 *6.2* **15**	23 *5.5* **13**
¾	2.0	115 *27.5* **40**	78 *18.7* **28**	63 *15.1* **22**	57 *13.7* **19**	48 *11.5* **17**
1	2.5	230 *55.0* **48**	154 *36.8* **34**	125 *30.0* **27**	110 *26.4* **23**	94 *22.6* **20**
1¼	3.0	510 *122.0* **59**	340 *81.5* **42**	276 *66.0* **33**	243 *58.3* **28**	210 *50.5* **25**
1½	4.0	760 *182.0* **66**	510 *122.0* **46**	410 *98.2* **37**	360 *86.2* **31**	310 *74.2* **27**
2	5.0	1550 *371.0* **80**	1050 *252.0* **56**	850 *201.0* **45**	750 *180.0* **38**	630 *151.0* **33**
2½	7.0	2500 *598.0* **91**	1700 *407.0* **65**	1350 *323.0* **51**	1200 *287.0* **43**	1000 *240.0* **38**
3	9.0	4600 *1110.0* **107**	3300 *790.0* **76**	2500 *598.0* **60**	2200 *527.0* **51**	1850 *443.0* **44**

[a]Based on 240 Btu per square foot.

[b]For other temperature drops the capacities of pipes are to be changed correspondingly. For example, for a temperature drop of 30 deg, the capacities shown in this table are to be multiplied by 3. The velocities remain unchanged.

[c]Approximate length of pipe, in feet, equivalent to one elbow in friction head. This value varies with the velocity.

Example 2. Design a direct return two-pipe forced circulation system for the layout shown in Fig. 5. For this system the length of the pipe line from the boiler to the highest radiator on the farthest riser and back to the boiler is about 250 ft. There are about 16 elbow equivalents having an equivalent pipe length of about 50 ft, so the total equivalent pipe length is about 300 ft.

Solution. The same pipe size tables may be used as those developed for the reversed return system of Fig. 3. Since this system is somewhat larger than that shown in Fig. 3, Table 3 which provides for a friction head of 6 ft may be used instead of Table 2 which provides for a friction head of only 2 ft.

Referring to the column for an equivalent total length of 300 ft for Sections *AB* and *KA*, each supplying 490 sq ft (117,600 Btu), it will be found that a 1½-in. pipe is too small and a 2-in. pipe is too large. Consequently, a 1½-in. pipe is selected for the flow line *AB*, and a 2-in. pipe for the return line, *KA*. For Sections *BC* and *JK*, each supplying 370 sq ft (88,000 Btu), a 1½-in. pipe is only slightly too small and it is selected. The remaining pipe sizes are selected in a similar manner and recorded in Fig. 5. This system has 490 sq ft and must supply 117,600 Btu per hour. For a temperature drop of 10 deg, 23.52 gpm of water must be circulated. The pump to select is one which has its highest efficiency when it is delivering 23½ gpm against a 6-ft head.

To secure a correct distribution of hot water among the several risers it is necessary, as previously stated, to introduce special resistances to balance the several risers, as follows:

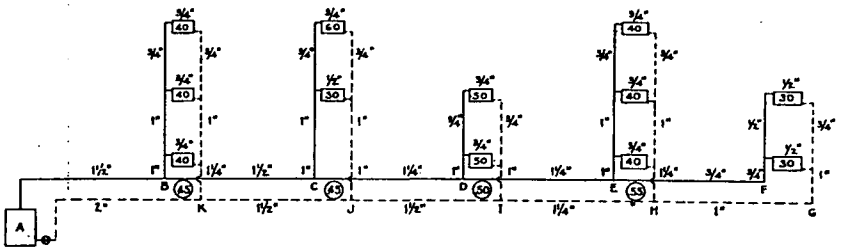


FIG. 5. A FORCED CIRCULATION DIRECT RETURN SYSTEM

The first riser is 80 ft nearer the boiler than the fifth riser. In order that the two may be balanced, *i.e.*, that they may operate under equal pressure heads, resistance must be added to the first riser equal to the friction head in the 80 ft of flow main from *B* to *F* plus that in the 80 ft of return main from *G* to *K*.

It will be noted from Table 3 that the unit friction head is about 240 milinches per foot. The total friction head in the flow and return mains between the first and fifth risers is therefore 160 × 240 or 38,400 milinches, or a little more than 3 ft, which must be supplied by additional resistance in the first riser to prevent its having an advantage over the fifth riser.

This resistance can be supplied by a calibrated and adjusted modulating valve or by an orifice resistor in a union. If the orifice resistor is to be used, its size may be selected from Table 5 as follows:

The lower part of the first flow riser supplies 120 sq ft (28,800 Btu). According to Table 3, it should be a 1-in. pipe and would have a velocity of 22 in. per second, if it were supplying 100 sq ft. Since it is supplying 120 sq ft, the velocity will be about 26 in. per second. From Table 5 it will be found that for a 1-in. pipe and a velocity of 24 in. per second, a 0.45-in. orifice will produce a loss of head of 37,000 milinches. For a velocity of 26 in. per second, the loss of head will be somewhat more, probably about 43,000 milinches; the difference between it and the required resistance will be about 10 per cent which is permissible, and the 0.45-in. orifice is selected.

The sizes of the orifice resistors for the second, third, and fourth risers are selected in a similar manner and found to be 0.45 in., 0.50 in., and 0.55 in. respectively.

TABLE 5. FRICTION HEADS (IN MILINCHES) OF CENTRAL CIRCULAR DIAPHRAGM ORIFICES IN UNIONS

DIAMETER OF ORIFICES (INCHES)	VELOCITY OF WATER IN PIPE IN INCHES PER SECOND									
	2	3	4	6	8	10	12	18	24	36
					¾-in. Pipe					
0.25	1300	2900	5000	11,300	20,800	32,000	45,000			
0.30	650	1450	2500	5700	10,400	16,000	23,000	57,000		
0.35	330	740	1300	2900	5200	8000	12,000	26,000	47,000	
0.40	170	380	660	1500	2600	4000	6800	13,000	24,000	53,000
0.45		185	330	740	1300	2000	2900	6500	12,000	27,000
0.50			155	350	620	970	1400	3200	5700	13,000
0.55			75	170	300	480	700	1600	2800	6400
					1-in. Pipe					
0.35	900	2000	3500	7800	14,000	22,000	32,000			
0.40	460	1000	1800	4000	7200	12,000	17,000	37,000	65,000	
0.45	270	570	1000	2300	4100	6400	9300	21,000	37,000	
0.50	160	330	580	1400	2300	3700	5400	12,000	22,000	50,000
0.55		190	330	750	1300	2200	3000	7000	13,000	28,000
0.60			200	440	800	1300	1800	4200	7400	17,000
0.65			120	260	460	720	1100	2400	4300	10,000
					1¼-in. Pipe					
0.45	1000	2250	4000	8900	16,000	25,000	36,000			
0.50	660	1450	2600	5800	10,400	16,400	23,000	53,000		
0.55	430	950	1700	3800	6800	10,500	15,000	34,000	60,000	
0.60	280	630	1100	2500	4400	6900	10,000	22,000	40,000	
0.65	190	420	750	1700	3000	4700	6700	15,000	27,000	60,000
0.70		285	510	1150	2000	3100	4500	10,000	18,000	40,000
0.75		190	330	750	1300	2100	3000	6700	12,000	26,000
					1½-in. Pipe					
0.55	850	1900	3300	7400	13,000	21,000	30,000			
0.60	600	1300	2300	5400	8600	16,800	21,000	50,000		
0.65	400	850	1500	3600	7200	10,400	14,000	30,000	53,000	
0.70	260	600	1100	2600	4400	7000	10,000	21,000	39,000	
0.75	180	400	760	1800	3000	5000	7000	14,000	28,000	
0.80		300	540	1200	2200	3200	5000	10,200	19,000	45,000
0.85		200	380	860	1600	2300	3000	7800	13,000	30,000
					2-in. Pipe					
0.70	1600	3700	6100	13,800	26,000	39,000	56,000			
0.80	1000	2200	4000	9800	16,000	25,000	36,000			
0.90	650	1400	2550	5800	9800	16,000	23,000	59,000		
1.00	420	830	1500	3600	6200	10,000	14,000	29,000	52,000	
1.10	220	520	900	2200	3800	6000	9000	19,000	34,000	
1.20		350	600	1300	2400	3800	5600	11,000	22,000	52,000
1.30		200	400	600	1600	2300	3300	7800	13,500	31,000

Note.—The losses of head for the orifices in the 1½-in. and 2-in. pipe were calculated from those in the smaller pipes, the calculations being based on the assumption that, for any given velocity, the loss of head is a function of the ratio of the diameter of the pipe to that of the orifice. This had been found to be practically true in the tests to determine the losses of head in orifices in ¾-in., I-in., and 1¼-in. pipe, conducted by the Texas Engineering Experiment Station, and also in the tests to determine the losses of head in orifices in 4-in., 6-in., and 12-in. pipe, conducted by the Engineering Experiment Station of the University of Illinois. (*Bulletin 109*, Table 6, p. 38, Davis and Jordan).

If the design of the system of Fig. 5 is to be extremely refined, the gravity pressure heads produced by the riser should be taken into consideration. With water at 220 F and 210 F, respectively, in the risers, the gravity head is 50 milinches per foot of water column or 25 milinches per foot of pipe, flow and return. The pump pressure head in this case is 240 milinches per foot of pipe, and the gravity head, being only one tenth as large as the pump head, may be neglected without serious error. This is generally done.

Temperatures of 220 F and 210 F would be used only during the coldest weather for which the system is designed. At other times the temperatures would be lower, the temperature drop smaller, and the gravity heads smaller. The pump pressure head remains constant throughout the

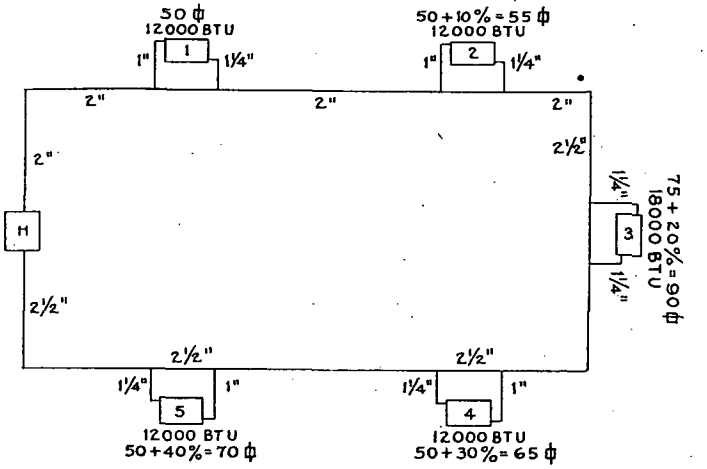


FIG. 6. A ONE-PIPE GRAVITY CIRCULATION SYSTEM

season if the pump is operated at a constant speed, and consequently, the gravity head is generally less than one tenth of the pump head.

Permissible Variations in Pipe Sizes

The pipe sizes for the several parts of the system selected from the tables are only approximately correct but the resulting error should be negligible as may be seen from the following study: Assume, as an extreme case, that the error in pipe size is so large that the water flows twice as fast through one of the radiators as through the others. This would make the friction head through this radiator almost four times as large as those through the other radiators. The result would be that the water, in flowing through the radiator, would cool 5 deg instead of 10 deg. The mean water temperature in the radiator would then be 217½ F instead of 215 F, and the mean temperature difference, water to air, would be 147½ deg instead of 145 deg. The heat dissipated by the radiator would therefore be about 2 per cent more than calculated. It is evident that this difference in heat dissipation is smaller than the difference

between the calculated heat losses and the actual heat losses, and also smaller than the average difference between the calculated radiator sizes and the nearest stock sizes selected.

GRAVITY CIRCULATION

For gravity circulation, the one-pipe system shown in Fig. 6 and the two-pipe, direct return system shown in Fig. 7 are probably in most common use.

The one-pipe system has the advantage that it can be easily designed and constructed so that it will function correctly. It has the disadvantage that the radiator nearest the boiler is the only one which receives water at approximately the temperature at which it leaves the boiler. All other radiators receive cooler water and must be increased in size proportionally with the result that the total heating surface in the system is considerably larger than that in a corresponding two-pipe system.

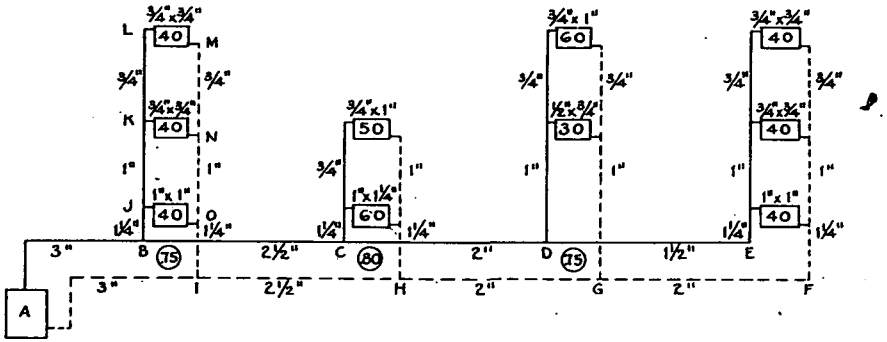


FIG. 7. A TWO-PIPE DIRECT RETURN GRAVITY CIRCULATION SYSTEM

The pipe sizes in gravity circulation systems may be varied materially. As the pipe sizes are decreased, the temperature drop through the radiators which produces circulation, is increased and it becomes necessary either to increase the temperature of the water leaving the boiler or to increase the size of the radiators. For example, Fig. 8 shows an elementary heating system diagramatically. This system will function with any reasonable pipe size; either a 1½-in. or a 1-in. may be used as follows: Let the radiator be required to deliver 27,000 Btu per hour (requiring 113 ft of equivalent heating surface), and let the circuit consist of 30 ft of pipe and 20 elbow equivalents. If a 1½-in. pipe is used, the system will operate correctly if the water temperature in the flow and return risers are 200 F and 180 F, respectively. The mean water temperature in the radiators will then be 190 F and if the radiator is located in air having a temperature of 70 F, the size of the radiator must be 152 sq ft. (See Table 3, Chapter 6).

If 1-in. pipe is used, the system will function correctly with water temperatures in the flow and return risers of 210 F and 170 F, or of 200 F

and 160 F. In the first case, the mean water temperature is again 190 F and the same size radiator may be used as with the 1½-in. pipe, but the temperature of the water leaving the boiler must be raised from 200 F to 210 F. In the second case, the temperature of the water leaving the boiler is the same as for the 1½-in. pipe, but the mean water temperature in the radiator is lowered from 190 F to 180 F, and consequently, the size of the radiator must be increased from 152 to 171 sq ft.

This illustration indicates the extent to which pipe sizes and radiator sizes may be decreased by increasing the temperatures of the water in the boiler as is possible in closed systems, and also in open systems in which the open expansion tank is located sufficiently high to secure the same pressure in the boiler as that existing in the boiler of the closed system.

Example 8. Design a one-pipe gravity circulation system for the layout shown in Fig. 6. Assume that the main circuit consists of 150 ft of pipe, 7 elbows, and one boiler.

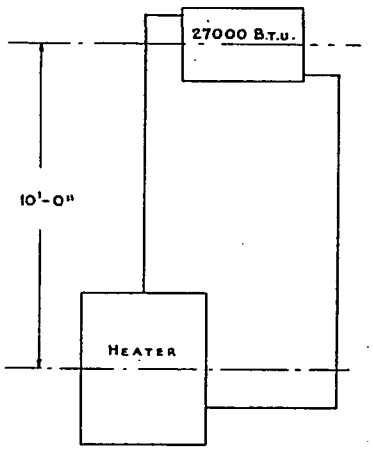


FIG. 8. AN ELEMENTARY SYSTEM

Solution. Replace the boiler by 3 elbow equivalents and assume that the size of the main will be about 2 in. According to Table 6, Column 2, a 2-in. elbow is equivalent to 4 ft of pipe, and the total equivalent length of the main will be about 150 plus 40, or 190 ft. Assuming that the center of the boiler will be about 4 ft lower than the horizontal portion of the main and that the temperature drop in the system is to be 35 deg, Table 6 may be used to determine the size of the mains. Note from Column 8, for a 200-ft length, that a 2-in. main will supply 200 sq ft and a 2½-in. main, 314 sq ft of equivalent heating surface. Since the system to be designed is to supply 275 sq ft, a 2-in. pipe is too small and a 2½-in. pipe too large. The solution is to use some 2-in. and some 2½-in. pipe. Since the 2½-in. is nearer the correct size than the 2-in., select 2-in. pipe for the first 50 or 60 ft out of the boiler and 2½-in. for the remaining pipe back to the boiler.

Tables 7 and 8 may be used to design the radiator risers and connections. According to Table 7, for 50 sq ft of equivalent heating surface, the flow riser should be ¾ in. and the return riser 1 in., and the riser branches should be 1 in. and 1¼ in. respectively. Note that according to Table 8, both radiator tappings should be 1 in. To simplify the construction, select 1-in. flow risers with 1-in. riser branches and 1-in. radiator tappings. Also select 1¼-in. return risers with 1¼-in. riser branches, and 1¼-in. radiator tappings. Similarly, for 75 sq ft of equivalent heating surface, select 1¼-in. flow and return risers and riser branches, and 1¼-in. radiator tappings.

TABLE 6. MAINS, CAPACITIES OF MAINS IN EQUIVALENT SQUARE FEET OF HEATING SURFACE[a], *and in 1000 Btu*, FOR ONE-PIPE AND FOR TWO-PIPE DIRECT RETURN GRAVITY CIRCULATION SYSTEMS WITH A TOTAL FRICTION HEAD OF 0.6 IN., A TEMPERATURE DROP OF 35 DEG, AND WHEN THE MAINS ARE 4 FT ABOVE THE CENTER OF THE BOILER

1	2	3	4	5	6	7	8	9	10	11
Pipe Size (Inches)	Equivalent Length of Pipe (Feet[b])	Equivalent Total Length of Pipe in Feet in Longest Circuit								
		75	100	125	150	175	200	250	300	350
		Unit Friction Head, in Milinches								
		8.0	6.0	4.8	4.0	3.4	3.0	2.4	2.0	1.7
1½	3.0	179 *43.0*	156 *37.5*	137 *33.0*	125 *30.0*	112 *27.0*	104 *25.0*	92 *22.2*	84 *20.2*	78 *18.7*
2	4.0	356 *83.0*	300 *72.0*	263 *63.0*	237 *57.0*	212 *51.0*	200 *48.0*	175 *42.0*	158 *38.0*	146 *35.0*
2½	4.5	583 *140.0*	480 *115.0*	417 *100.0*	375 *90.0*	338 *81.5*	314 *75.4*	280 *67.2*	254 *61.0*	233 *56.0*
3	5.0	975 *234.0*	850 *204.0*	730 *175.5*	667 *160.0*	576 *143.0*	555 *133.0*	458 *110.0*	446 *107.5*	417 *100.0*
3½	5.5	1446 *347.0*	1250 *300.0*	1080 *260.0*	985 *236.0*	890 *214.0*	834 *200.0*	738 *177.0*	667 *160.0*	608 *146.0*
4	6.0	2040 *490.0*	1760 *422.0*	1540 *370.0*	1390 *334.0*	1240 *297.0*	1160 *278.0*	1040 *248.0*	930 *223.0*	853 *205.0*

[a]Based on 240 Btu per square foot.
[b]Approximate length of pipe in feet equivalent to one elbow in friction head. This value varies with the velocity.

TABLE 7. RISERS[a], MAXIMUM CAPACITIES OF RISERS IN EQUIVALENT SQUARE FEET OF HEATING SURFACE[b], *and in 1000 Btu*, **and Velocities of Water in Pipes in Inches Per Second** FOR ONE-PIPE AND FOR TWO-PIPE DIRECT RETURN GRAVITY CIRCULATION SYSTEMS WITH A DROP OF 35 DEG THROUGH EACH RADIATOR

Pipe Size (Inches)		Equivalent Length of Pipe (Feet[d])	Sq Ft	1st Floor[c]			2nd Floor		3rd and 4th Floors	
				1000 Btu	Vel. (Ft per Sec.)[e]		Sq Ft	1000 Btu	Sq Ft	1000 Btu
Flow	Return				Flow	Return				
½	½	1.0					21	*5*	26	*6.2*
½	¾						27	*6.4*	33	*8.0*
¾	¾	1.5	37	*9*	2.3	2.3	42	*10.1*	58	*14.0*
¾	1		50	*12*	3.2	2.0	53	*12.8*	71	*17.1*
1	1	2.0	75	*18*	2.5	2.5	83	*20*	108	*26.0*
1	1¼		88	*21*	3.0	2.0	105	*25.2*	142	*34*
1¼	1¼	3.0	109	*26*	3.0	3.0	179	*43*	229	*55*
1¼	1½		142	*34*	4.0	2.5				
1½	1½	3.5	200	*48*	3.0	3.0				

[a]This table is based on pressure heads of 450, 1800, 3150 and 4500 respectively, for the first, second, third, and fourth floor radiators, and on friction heads of 200 milinches for the first floor radiators and connections, and 700 milinches for all other radiators and their connections.
[b]Based on 240 Btu per square foot.
[c]The riser branches, the piping which connects the risers to the mains, are to be one size larger than the risers.
[d]Approximate length of pipes in feet equivalent to one elbow in friction head. This value varies with the velocity.
[e]Velocities apply to the riser branches.

TABLE 8. RADIATOR CONNECTIONS, MAXIMUM CAPACITIES OF RADIATOR CONNECTIONS IN EQUIVALENT SQUARE FEET OF HEATING SURFACE[a], *and in 1000 Btu*, FOR ONE-PIPE AND FOR TWO-PIPE DIRECT RETURN GRAVITY CIRCULATION SYSTEMS WITH A TEMPERATURE DROP OF 35 DEG THROUGH EACH RADIATOR

Pipe Size		Equivalent Length of Pipe (Feet[b])	1st Floor		2nd, 3rd and 4th Floors	
Flow	Return		Sq Ft	1000 Btu	Sq Ft	1000 Btu
½	½	1.0	17	*4.1*	25	*5.9*
½	¾		22	*5.2*	31	*7.5*
¾	¾	1.5	29	*7.0*	43	*10.5*
¾	1		38	*9.1*	54	*13.0*
1	1	2.0	52	*12.5*	74	*17.8*
1	1¼		73	*17.5*	97	*23.2*
1¼	1¼	3.0	97	*23.3*	138	*33.2*

[a]Based on 240 Btu per square foot.
[b]Approximate length of pipe in feet equivalent to one elbow in friction head. This value varies with the velocity.

To develop a rule for determining radiator sizes, assume a system similar to that of Fig. 6, in which the total temperature drop is to be 35 deg and which is equipped with 7 radiators, all radiators dissipating equal quantities of heat. The mean temperature of the water in the radiators will be reduced 5 deg for each successive radiator. If the mean temperature of the water in the first radiator is 200 F, the mean temperature of the water in the seventh radiator will be 170 F, and, according to Table 3, Chapter 6, the heat dissipation of these two radiators will be to each other as 868 is to 617, or as 140 is to 100, and therefore if the last radiator is to dissipate as much heat as the first, its size must be 40 per cent larger. The following rule may therefore be formulated for determining radiator sizes for one-pipe hot water heating systems having two-pipe risers and a total temperature drop of 35 deg:

Determine the radiator sizes in the usual manner. If the mean temperature of the water in the radiator is 215 F, select the same size radiator that would be selected for steam at this temperature. If the mean temperature of the water is to be less than 215 F, increase the amount of heating surface above that required for steam, as explained in Chapter 6. Use the calculated sizes for the radiators on the first set of risers; increase the sizes of the radiators on the last set of risers 40 per cent; those on the middle set of risers, 20 per cent, and those on the remaining risers proportionally.

Applying this rule to the five radiators of the system shown in Fig. 6, the actual sizes will be found to be 50, 55, 90, 65 and 70 sq ft of equivalent heating surface, instead of the nominal sizes of 50, 50, 75, 50 and 50 sq ft.

Example 4. Design a two-pipe, direct return, gravity circulation system for the layout shown in Fig. 7. Assume that the main circuit from the boiler to the farthest flow riser and from the farthest return riser back to the boiler consists of 160 ft of pipe, 6 elbows, and 1 boiler.

Solution. Replacing the boiler by 3 elbow equivalents and assuming that the largest size of the main will be about 3 in., the total equivalent length of the main will be 160 plus 45, or 205 ft. Assuming that the center of the boiler will be about 4 ft lower than the horizontal portion of the main, and that the temperature drop will be 35 deg for the system, the pressure head caused by the difference in weight between the water in the

flow and return risers joining the flow and return mains to the boiler will be about 0.6 in. of water, or about one-fortieth of the pressure head produced by the circulating pump selected for the system of Fig. 3.

Table 6 may be used to determine the size of the main as follows: Refer to Column 8 and note that for Sections *AB* and *IA*, which supply 440 sq ft of equivalent heating surface, a 3-in. pipe is too large and a 2½-in. pipe is too small; hence, select 2½ in. for Section *AB* and 3 in. for Section *IA*. For Sections *BC* and *HI*, which supply 320 sq ft of equivalent heating surface, a 2½-in. pipe is almost exactly the correct size and is selected for both sections.

For the forced circulation system of Fig. 5, the pressure head produced by the circulating pump is used to force the water through the mains and also through the risers. Gravity circulation systems have two distinct pressure heads. One is produced by the difference in weight of the water in the flow and return risers adjacent to the boiler, and is the boiler pressure head, which in this case, is 0.6 in. The other pressure head is produced by the difference in weight of the water in the flow and return risers adjacent to the radiators, and is the radiator pressure head. If the temperature drop through the radiators is about 35 deg, and if the story heights of the building are 9 ft and the distance from the center of the first floor radiator to the average level of the main is 3 ft, the radiator pressure head of the first floor radiator is about 450 milinches and the pressure heads of the radiators on the upper floor are 1350 milinches greater than those on the next lower floors.

Tables 6 and 7 are based on the assumption that the boiler pressure head must be equal to the friction head in the mains and that the several radiator pressure heads must be equal to the respective radiator and riser friction heads.

To design the radiator risers, use Table 7 and begin with the set nearest the boiler. The first floor risers must supply 120 sq ft of equivalent heating surface. According to the table, 1¼-in. flow and return risers will supply 109 sq ft; if the return riser is increased to 1½ in., the capacity will be increased to 142 sq ft. This is considerably larger than necessary and 1¼-in. flow and return risers are selected. However, it must be remembered that the riser branches, *i.e.*, the connections from the flow and return mains to the flow and return risers, are to be one size larger than the risers, *i.e.*, 1½ in.

The second floor risers must supply 80 sq ft of equivalent heating surface. According to the table, the capacity of 1-in. flow and return risers is 83 sq ft, and that size is selected.

The third floor risers must supply 40 sq ft of equivalent heating surface. If a ½-in. flow and a ¾-in. return riser are used, the capacity will be 33 sq ft; if both risers are ¾ in., the capacity will be 58 sq ft. The ¾-in. pipe is selected for both risers.

To design the radiator connections, use Table 8 and note that for the first floor radiator connections the capacity of a ¾-in. flow and 1-in. return is 38 sq ft, and that of a 1-in. flow and a 1-in. return is 52 sq ft. The former is more nearly the correct size, but since it is difficult to secure a good flow through first floor radiators, the 1-in. flow and return connection is selected. For the two upper floors, the capacity of a ¾-in. flow and return connection is 43 sq ft, and that size is selected.

As explained in the design of the forced circulation system of Fig. 5, the two-pipe direct return system of Fig. 7 will not function correctly unless its four sets of risers are balanced among themselves. This necessary balancing is accomplished by adding resistances to all risers except the one farthest from the boiler equal to the excess boiler pressure heads available for those risers, above the boiler pressure head available for the farthest riser. For example, the first set of risers is 60 ft nearer the boiler than the last set. Since the flow and return mains are designed for a friction head of 3 milinches per foot (see Table 6, Column 8), the boiler pressure head available for the first set of risers is 360 milinches in excess of that available for the fourth set. The velocity in the riser branch is 3 in. per second (see Table 7) and, therefore, according to Table 5, a 0.75-in. orifice in a 1½-in. union should be used. This will provide a resistance of about 400 milinches. In the same manner it is found that for the second set of risers a resistance of 240 milinches is required and

that a 0.80-in. orifice in a 1½-in. union will provide a resistance of 300 milinches. For the third set of risers, a resistance of 120 milinches is required and a 0.75-in. orifice in a 1¼-in. union will provide sufficient resistance.

CIRCULATING PUMPS

Circulating pumps for hot water systems may be used to provide the motive head for forced circulation systems as already described, or to improve the operation of gravity-designed systems. Small specially-designed centrifugal pumps installed on a by-pass with the necessary gate or check valves near the point where the return main enters the heater, may be employed. Specially-designed, electrically-driven, propeller-type circulating pumps, or units may also be employed. The latter are usually installed directly in the return main and are available for all commercial pipe sizes used for hot water heating. The motor switch may be under manual control or automatic control using thermostatic elements or tied in with the oil or gas burner switch which starts and stops the burner. For large capacities these units may be installed in multiple.

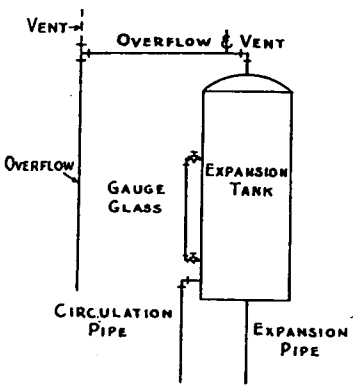


FIG. 9. AN OPEN EXPANSION TANK

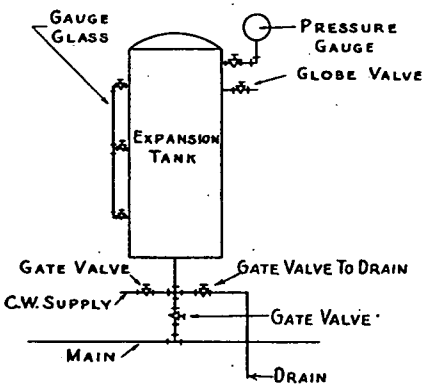


FIG. 10. A CLOSED EXPANSION TANK

For exceptionally large installations such as central heating plants, circulating pumps of the centrifugal single stage type, having an average operating efficiency of 70 per cent against heads up to 125 ft, are sometimes used. It is generally advisable to install the pumps in duplicate to provide for contingencies and to insure continuous operation. In such cases each pump may be made equal to two-thirds of the maximum capacity required.

EXPANSION TANKS

When water at ordinary temperature is heated or cooled, its volume is increased or decreased. This variation in the volume of the water in a heating system is generally provided for by means of an expansion tank into which the water can flow from the system during the heating-up

periods and from which it can flow back into the system during the cooling-down periods.

The expansion tank may be open or closed. In an open expansion tank (Fig. 9), the water is subjected to atmospheric pressure and can expand freely without a material increase in pressure. In a closed expansion tank (Fig. 10), the water is subjected to the pressure of the compressed air within the tank, and as the water expands the volume of the air in the tank is decreased and its pressure increased.

The open expansion tank must be placed at a sufficient elevation above the highest radiator to prevent boiling when the water in that radiator is at the highest temperature to which it is to be heated. For example, if the water is to be heated to 225 F on extremely cold days, the absolute pressure on the water in the highest radiator must be at least 19 lb per square inch. This pressure will be secured if the open expansion tank is

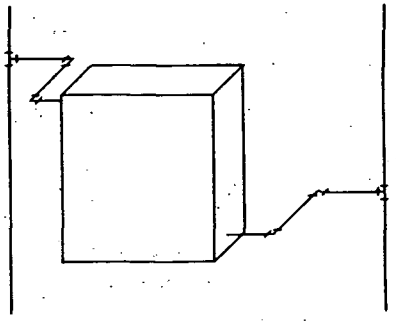


FIG. 11. METHOD OF CONNECTING RADIATOR TO ALLOW FOR EXPANSION OF PIPE

located 15 ft above the highest radiator. If a closed expansion tank is used and is located 30 ft below the highest radiator, an absolute pressure of about 32 lb per square inch must be maintained in the expansion tank if the water in the highest radiator is to be heated to 225 F without danger of boiling.

The type of expansion tank used in a heating system, whether open or closed, has no influence on the operation of the system. The only function performed by the expansion tank is to provide for the variation in the volume of the water in the system, and at the same time, to maintain a sufficient pressure in the system to prevent boiling when the water is at the highest temperature for which the system is designed. The use of an expansion tank may be dispensed with when the heating system is allowed to *float* on the water system, *i.e.*, when the connection between the heating system and the water system is kept open so that the water system replaces the expansion tank.

The capacity of the expansion tank should be at least twice the increase in volume produced when the water in the system is heated from its normal to its maximum temperature. When 25 gal of water are heated

from 40 F to 200 F, the volume of water increases to 26 gal. A safe rule, therefore, is to make the water capacity of the expansion tank equal to 10 per cent of the capacity of the heating system.

In a forced circulation system, the expansion tank should be connected to the return main near the circulating pump. In a gravity circulation system, the expansion tank should be connected to the flow riser so that air liberated from the water in the boiler may escape through the expansion tank, except where it is desired to maintain a temperature higher than 212 F in which case the connection should be in the return main to prevent possible boiling in the expansion tank.

The expansion tank should be protected so that the water in the tank or in the connecting pipe lines cannot freeze. If the water should freeze and the water in the system be heated to cause further expansion, the resulting force will burst the boiler or some other portion of the system.

INSTALLATION DETAILS

The detailed installation of the pipe system should be governed by four fundamental rules:

1. All piping must be pitched either up or down so that all gases which are liberated from the water can move freely to a vented section of the system. Whenever practicable, the pipe line should be pitched so that gases flowing to a vent will flow in the same direction as the water. When a pipe system cannot be installed without creating *air pockets*, that is, sections in the system from which liberated gases cannot escape, such sections must be provided with automatic air relief valves or with air valves which may be operated manually when necessary.

2. All piping must be arranged so that the entire system can be drained, either to permit alterations or repairs, or to prevent freezing if the system is not to be operated during a cold period.

It is well to install a gate valve and union in every riser near the main to permit the draining of individual risers without draining the entire system. It is also well, in large installations, to divide the system into branches and to provide each branch with unions and valves so that any one branch can be drained without disturbing the remaining branches.

The division of large heating systems into branches or zones and providing each zone with individual valves has the further advantage of permitting a varying temperature control. For example, if a building is equipped with a forced circulating system and if the south rooms are on one branch of the main and the north rooms are on a separate branch the valves may be set so that the water will circulate through the north branch with a temperature drop of, say, 10 deg, and through the south branch with a temperature drop of, say, 20 deg, thus delivering less heat to the south rooms than to the north rooms. This arrangement is especially valuable when the regulating valves are controlled thermostatically by the temperatures in the two zones, because no matter how accurately the heating system may have been designed, the heat demand of any group of rooms varies with sunshine and with wind velocity, and these intermittent variations can be provided for only by the individual control made possible by changing the valve settings controlling the heat supplied to particular groups of rooms.

3. All piping must be installed so that it is free to expand and contract with changes of temperature without producing undue stresses in the pipes or connections. For this purpose it is generally sufficient to allow for a variation in length of 1 in. for 100 ft of pipe.

4. The pipe system must be installed so that each circuit has its correct friction head. To bring this about, it is necessary, in some cases, to minimize the friction, *i.e.*, to make the pipe line as short as possible and to provide as few fittings as possible, and in other cases, it is necessary to increase the length of the pipe and the number of fittings so that, for every circuit, the friction head will be equal to the available pressure head.

The connections from the boiler to the mains should be short and direct to reduce the friction head. It is frequently possible to avoid an elbow and to reduce the length of the pipe by running the pipe in a diagonal direction, either in a horizontal or in a vertical plane.

The mains and branches should pitch up and away from the heater and generally not less than 1 in. in 10 ft. The flow main should always be covered; the return main should be covered except where it is to provide the heating surface for the basement.

The connections from mains to branches and to risers should be such that circulation through the risers will start in the right direction. Hence, in a one-pipe system, the flow connection must be nearer the heater than the return connection. In a correctly-designed two-pipe system, the pressure in the flow main is higher than that in the return main, and a slight variation in the distances of the flow and return connections from the heater is not material, but it is generally best to have the two connections about equidistant from the heater.

In some cases it may be advisable to take the flow connection off the top of the main and the return connection into the side, but in most cases both connections should be at an angle of 45 deg. This method shortens the lines and substitutes 45-deg ells for 90-deg ells.

Connections of flow risers to radiators should be to the upper tapping, unless, for æsthetic reasons, connections to the lower tappings are preferred. Connection of the return riser to a radiator should be to the lower tapping and on the end at which the return riser is located. When hot water enters at the top of a radiator it will distribute itself along the entire length of the radiator, and as it cools, settle gradually to the bottom; the cool water may then be taken out of the radiator at either end.

With forced circulation and high velocities, it is advisable to let the water enter at the top of the radiator and leave at the bottom of the opposite end. With gravity circulation and low velocities it makes little difference whether the water leaves at the same or at the opposite end at which it enters.

The connections of the risers to the radiators should be such that provision is made for the vertical expansion of the risers. This can be accomplished as indicated in Fig. 10 by using one tee and two ells for each connection. These connections should be pitched upward or downward, whichever may be necessary to prevent the formation of air pockets.

Radiator valves generally are not necessary. When used, they should be placed in the return connections.

Chapter 9

STEAM HEATING SYSTEMS AND PIPE SIZES

Gravity and Mechanical Systems; Transmission Mains and Service Piping; Flow of Steam in Pipes; Design of Steam Heating Systems.

A DIRECT steam heating system is one in which steam (at, above or below atmospheric pressure) is the medium by which heat is transmitted from the boiler (or other source of steam supply) to the heating units located in or adjacent to the rooms or spaces to be heated. The heating units and boiler are connected by means of a system of supply and return piping. There are many types of steam heating systems, the classification depending upon the piping arrangement, the accessories used, and whether the water of condensation is returned to the boiler by gravity or by mechanical means. The various terms used in describing these systems are defined in Chapter 1.

DISTRIBUTING MAINS AND SERVICE PIPING

The piping for steam distribution is divided into two classes: (1) distributing mains; (2) service piping.

Transmission mains are defined as those that convey steam for a considerable distance either through or between buildings such as in district heating plants. In this type the steam is usually generated and transmitted to the building under high pressure. The velocities of flow used in the transmission mains are limited by the available or allowable drop in pressure.

Service piping is defined as that which conveys the steam and condensate in the building, starting either at the boiler or other source of supply and comprising the mains, branches, risers, run outs and return piping. This part of the system usually is low pressure and the pipe sizes are larger than for the distributing piping, as the velocity of the steam is lower and the available or allowable drop in pressure is small. See Tables 9 to 16 for the service pipe sizes for various systems.

FLOW OF STEAM IN PIPES

The rate of flow of dry steam or steam with a small amount of water flowing in the same direction is in accordance with the general laws of gas flow and is a function of the length and diameter of the pipe, the density of the steam and the pressure drop through the pipe. This relationship has been established by Babcock in the formula given at the top of Table 1. In columns 1, 2, 3 and 4 of this table, the numerical values of the factors for different pressure losses, pipe diameters, steam densities and lengths of pipe have been worked out in convenient form

TABLE 1. FLOW OF STEAM IN PIPES

P = loss in pressure in pounds.
d = inside diameter of pipe in inches.
L = length of pipe in feet.
D = weight of 1 cu. ft. of steam.
W = pounds of steam per hour.

$$W = 5220\sqrt{\frac{PDd^5}{\left(1+\frac{3.6}{d}\right)L}}$$

$$P = 0.0000000367\left(1+\frac{3.6}{d}\right)\frac{W^2L}{Dd^5}$$

Pressure Loss in Ounces	Col. 1 $5220\sqrt{\frac{P}{100}}$	Pipe Size Nominal	Pipe Size Actual Internal Diameter	Internal Area of Pipe Sq. Inches	Col. 2 $\sqrt{\frac{d^5}{1+\frac{3.6}{d}}}$	Steam Press. by Gage	Col. 3 $\sqrt{D}$	Length of Pipe in Feet	Col. 4 $\sqrt{\frac{100}{L}}$
0.25	65.28	1	1.049	0.864	0.536	−1.0[a]	0.187	20	2.240
0.50	92.28	1¼	1.380	1.496	1.178	−0.5[a]	0.190	40	1.580
1.00	130.5	1½	1.610	2.036	1.828	0.0	0.193	60	1.290
2	184.6	2	2.067	3.356	3.710	0.3	0.195	80	1.120
3	226.0	2½	2.469	4.788	6.109	1.3	0.201	100	1.000
4	261.0	3	3.068	7.393	11.183	2.3	0.207	120	0.912
5	291.8	3½	3.548	9.887	16.705	5.3	0.223	140	0.841
6	319.7	4	4.026	12.730	23.631	10.3	0.248	160	0.793
7	345.3	4½	4.506	15.947	32.134	15.3	0.270	180	0.741
8	369.1	5	5.047	20.006	43.719	20.3	0.290	200	0.710
10	412.7	6	6.065	28.886	71.762	30.3	0.326	250	0.632
12	452.0	7	7.023	38.743	106.278	40.3	0.358	300	0.578
14	488.3	8	7.981	50.027	149.382	50.3	0.388	350	0.538
16	522.0	9	8.941	62.786	201.833	60.3	0.415	400	0.500
20	583.6	10	10.020	78.854	272.592	75.3	0.452	450	0.477
24	639.3	12	12.000	113.098	437.503	100.3	0.507	500	0.447
28	690.5	14	13.250	137.880	566.693	125.3	0.557	600	0.407
32	738.2	16	15.250	182.655	816.872	150.3	0.603	700	0.378
40	825.4					175.3	0.645	800	0.354
48	904.1					200.3	0.685	900	0.333
80	1167.2							1000	0.316
160	1650.7							1200	0.289
320	2334.5							1500	0.258
480	2859.1							2000	0.224

Column 1 × 2 × 3 × 4 = lb. of steam per hour that will flow through a straight pipe for a given condition.

Example: 1 oz. drop – 2 in. pipe – 1.3 lb. press. – 100 ft. equivalent length:

130.5 × 3.710 × 0.201 × 1 = 97.2 lb. per hour.
97.2 × 4[b] = 388.8 sq. ft. equivalent radiation.

Table 1 does not allow for entrained water in low-pressure steam, condensation in covered pipe and roughness in commercial pipe as found in practice.

[a]Pounds per square inch gage = 2.04 in. Vacuum, Mercury Column.
[b]The factor 4 is the approximate equivalent in square feet of steam radiation of 1 lb. of steam per hour.

so that the steam flowing in any pipe may be calculated by multiplying together the proper factors in each column as shown in the example at the bottom of the table.

Table 2 is a basic table giving the theoretical capacities of pipe in square feet of direct cast-iron radiation (Based on ¼ lb steam per hour per square foot) and the resulting velocity in feet per second for various pressure drops in ounces per 100 ft length of pipe with an initial steam pressure of 1 lb gage. This table was compiled from the values given in Table 1. In using Tables 1 or 2 the total pressure drop figured should never equal or exceed the initial pressure.

Example 1. In a 3-in. pipe, what pressure drop is required in ounces per 100 ft of length of pipe to supply steam to 2014 sq ft of equivalent heating surface? The initial steam pressure is 1 lb gage.

Solution. In Table 2, column for 3-in. pipe, find that steam for 2014 sq ft of equivalent heating surface will be supplied at 1 lb initial pressure and a pressure drop of 3 oz per 100 ft length of run.

Table 3 is to be used with Table 2 for calculating the capacity of a steam pipe, for other initial pressures and lengths when the capacity is known for 1-lb pressure and 100-ft length. To determine the capacity of any pipe for an initial pressure other than 1 lb, multiply the capacity given in Table 2 by the pressure factor in Column 2, Table 3, opposite the required pressure indicated in Column 1.

Example 2. What is the capacity of a 100-ft, 4-in. pipe with 2-lb initial pressure and pressure drop of 1 oz?

Solution. From Table 2, find 2457, the capacity of the 4-in. pipe with 1-lb initial pressure and 1-oz pressure drop. Multiplying 2457 by 1.03, the constant for 2-lb initial pressure (Column 2 of Table 3), gives 2531 as the capacity of the 4-in. pipe with 2-lb initial pressure and a pressure drop of 1 oz per 100-ft length.

To determine the capacity for any length other than 100 ft, multiply the capacity given in Table 2 by the length factor in Column *B*, Table 3, opposite the required length in Column *A*.

Example 3. What is the capacity of a 140-ft, 4-in. pipe with an initial pressure of 1 lb and a pressure drop of 2 oz in the 140 ft?

Solution. From Table 2 it is found that the capacity of a 100-ft, 4-in. pipe with 1-lb initial pressure and 2-oz pressure drop, is 3475 sq ft. Multiplying this value by 0.841 the constant for a 140-ft length as given in Table 3 gives 2922 which is the capacity for the given conditions.

Example 4. What is the capacity of a 140-ft, 4-in. pipe with 2-lb initial pressure and a pressure drop of 2 oz?

Solution. From Table 2 find 3475, the capacity of the 4-in. pipe with 1-lb initial pressure and 2-oz pressure drop. Multiplying 3475 by 1.03, the constant for 2-lb initial pressure (see Column 2, Table 3), and this by 0.841, the constant for 140-ft length (see Column *B*, Table 3), gives 3010 as the capacity of the 4-in. pipe with 2-lb initial pressure and a pressure drop of 2 oz in the 140-ft length.

Should lengths other than those given in Column *A*, Table 3, and under length of pipes in feet in Table 1 be desired the constant may be obtained from the formula in Column 4, Table 1, and used the same as the constants from Table 3.

Example 5. What would be the constant for 2500 ft of pipe to be used either in Tables 1 or 3?

Solution. The constant to be used $= \sqrt{\frac{100}{2500}} = 0.2$.

TABLE 2. PRESSURE LOSS, CAPACITY IN SQUARE FEET OF EQUIVALENT RADIATION AND VELOCITY RELATIONSHIP BASED ON TABLE 1, FOR VARIOUS PRESSURE DROPS WITH 1 LB. INITIAL STEAM PRESSURE

(NOTE.—No allowance for condensation in pipe—unusual friction—scale—corrosion or other factors.)

PRESSURE LOSS IN OUNCES PER 100 FT.	PIPE SIZE													
	1"		1¼"		1½"		2"		2½"		3"		3½"	
	Sq. Ft.	Velocity Ft. per Second	Sq. Ft.	Velocity Ft. per Second	Sq. Ft.	Velocity Ft. per Second	Sq. Ft.	Velocity Ft. per Second	Sq. Ft.	Velocity Ft. per Second	Sq. Ft.	Velocity Ft. per Second	Sq. Ft.	Velocity Ft. per Second
¼	28	7.5	61	9	95	11	193	14	318	17	581	21	869	23
½	39	12	87	15	134	17	273	21	449	24	822	30	1228	33
1	56	17	122	21	190	24	386	31	635	36	1163	42	1737	47
2	79	25	173	30	269	34	546	43	898	50	1645	60	2457	68
3	96	28	212	38	329	42	668	53	1100	62	2014	74	3009	84
4	111	35	245	43	380	49	771	62	1270	72	2326	85	3474	97
5	124	37	274	47	425	55	863	69	1421	80	2600	95	3884	109
6	136	40	300	52	466	59	945	77	1556	88	2848	105	4255	118
7	147	43	324	56	503	66	1020	83	1681	95	3077	113	4596	128
8	157	47	346	61	538	70	1091	89	1797	102	3289	122	4913	136
10	176	52	387	68	601	79	1220	99	2009	114	3677	135	5493	151
12	192	58	424	74	659	87	1336	109	2201	125	4028	148	6017	167
14	208	63	458	80	711	94	1443	118	2377	134	4351	164	6500	180
16	223	70	490	86	760	100	1543	126	2541	144	4651	175	6948	192
20	249	75	548	96	850	112	1806	148	2841	161	5200	196	7768	215
24	273	82	600	106	931	124	1890	154	3113	177	5697	215	8510	238

TABLE 2. (Continued)

PRESSURE LOSS IN OUNCES PER 100 FT.	PIPE SIZE													
	4"		5"		6"		8"		10"		12"		16"	
	Sq. Ft.	Velocity Ft. per Second	Sq. Ft.	Velocity Ft. per Second	Sq. Ft.	Velocity Ft. per Second	Sq. Ft.	Velocity Ft. per Second	Sq. Ft.	Velocity Ft. per Second	Sq. Ft.	Velocity Ft. per Second	Sq. Ft.	Velocity Ft. per Second
¼	1229	26	2273	29	3731	35	7766	42	14,172	48	22,746	52	42,470	62
½	1738	37	3214	41	5276	49	10,983	60	20,043	72	32,168	76	60,061	88
1	2457	52	4546	59	7462	70	15,533	86	28,345	100	45,492	108	84,940	125
2	3475	74	6429	84	10,553	94	21,967	112	40,085	140	64,336	152	121,012	180
3	4256	91	7874	104	12,924	121	26,904	144	49,094	172	78,795	184	147,120	220
4	4914	105	9092	121	14,924	139	31,066	164	56,689	192	90,985	212	169,879	252
5	5494	118	10,165	135	16,685	156	34,733	184	63,380	224	101,724	240	189,937	280
6	6019	128	11,135	148	18,278	168	38,048	204	69,430	244	111,433	264	208,059	308
7	6501	139	12,027	160	19,742	174	41,096	220	74,993	264	120,361	288	224,729	336
8	6950	148	12,858	172	21,105	196	43,934	234	80,171	284	128,672	304	240,245	356
10	7770	166	14,376	193	23,597	216	49,120	268	89,633	312	143,860	340	268,603	400
12	8512	182	15,748	212	25,849	232	53,808	288	98,188	344	157,590	372	294,236	436
14	9194	196	17,009	224	27,920	260	58,120	316	106,056	372	170,217	404	317,815	474
16	9829	211	18,184	234	29,848	276	62,132	340	113,378	394	181,969	428	339,758	508
20	10,989	235	20,331	260	33,371	316	69,466	380	126,768	444	203,448	480	379,861	568
24	12,038	249	22,270	280	36,556	332	76,096	412	138,859	484	222,866	520	416,117	624

Note 1.—Capacities based on ¼ lb. condensation per square foot equivalent radiation—steam and condensation flowing in same direction—actual diameter of standard pipe.

Note 2.—For capacity of pipe with a given pressure drop, in a length other than 100 ft., multiply the capacity in this table for the given pressure per 100 ft. drop by the factor for required length, Column *B*, Table 3.

Note 3.—For capacity with initial pressures other than 1 lb., multiply capacity given in this table by factor for the required initial pressure. Column 2, Table 3.

Note 4.—To determine pressure loss with a given capacity for other lengths of pipe than 100 ft., multiply pressure loss given in this table for the given capacity by the required length of pipe and divide by 100.

Note 5.—Extra length to be added to straight run of pipe, for various fittings and valves to determine equivalent length. (See Table 4).

Note 6.—All pipe should be well reamed and free from constrictions. (See Tables 6, 7 and 8.)

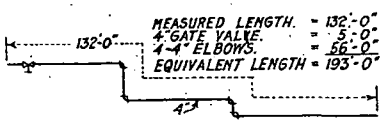
TABLE 3. CONSTANTS FOR VARIOUS LENGTHS AND INITIAL PRESSURES

STEAM PRESSURE GAGE LB.	CONSTANT BY WHICH TO MULTIPLY CAPACITY OF ANY PIPE FOR 1 LB. GAGE STEAM PRESSURE TO OBTAIN CAPACITY OF SAME PIPE FOR PRESSURE IN COL. 1	LENGTH OF PIPE FT.	CONSTANT BY WHICH TO MULTIPLY CAPACITY OF 100 FT. PIPE TO OBTAIN CAPACITY OF SAME SIZED PIPE WITH SAME PRESSURE, AND LENGTH AS GIVEN IN COL. A
Col. 1	Col. 2	Col. A	Col. B
0	0.92	20	2.240
1	1.00	40	1.580
2	1.03	60	1.290
5	1.11	80	1.120
10	1.24	100	1.000
15	1.35	120	0.912
20	1.45	140	0.841
30	1.63	160	0.793
40	1.79	180	0.741
50	1.94	200	0.710
60	2.08	250	0.632
75	2.26	300	0.578
100	2.54	350	0.538
125	2.79	400	0.500
150	3.02	450	0.477
175	3.23	500	0.447
200	3.44	600	0.407
...	....	700	0.378
...	....	800	0.354
...	....	900	0.333
...	....	1000	0.316
...	....	1400	0.267

TABLE 4. LENGTH IN FEET OF PIPE TO BE ADDED TO ACTUAL LENGTH OF RUN—DUE TO FITTINGS—TO OBTAIN EQUIVALENT LENGTH

SIZE OF PIPE INCHES	ST'D. ELBOW	SIDE OUTLET TEE	GATE VALVE	GLOBE VALVE	ANGLE VALVE
	Length in Feet to be Added in Run				
2	5	16	2	18	9
2½	7	20	3	25	12
3	10	26	3	33	16
3½	12	31	4	39	19
4	14	35	5	45	22
5	18	44	7	57	28
6	22	50	9	70	32
7	26	55	10	82	37
8	31	63	12	94	42
9	35	69	13	105	47
10	39	76	15	118	52
12	47	90	18	140	63
14	53	105	20	160	72

Example of length in feet of pipe to be added to actual length of run.



PIPE SIZES

The principal factors upon which the determination of pipe sizes for steam heating depends, are:

1. The equivalent length of the run from the boiler, or source of steam supply, to the farthest heating unit. (See Table 4).
2. The initial pressure and the total pressure drop, which may be allowed, between the source of supply and the end of the return system.
3. The maximum velocity of steam allowable for quiet and dependable operation of the system.
4. Unusual conditions in the building to be heated.

Equivalent Length of Run

The length of run must not only include the actual linear feet of straight pipe, but also the proper allowance for fittings, valves and other items which cause drop in pressure. Table 4 gives the allowance for fittings in feet of pipe to be added to the actual length of run to obtain the equivalent length.

Gate valves are recommended in all cases where service calls for the valve to be either entirely closed or open. They should never be used for throttling. Angle and globe valves should be used for throttling, such as the by-pass valve in a pressure-reducing outfit.

Initial Pressure; Pressure Drop

Theoretically there are several factors to be considered such as initial pressure and the pressure required at the end of the line, but it is most important that (1) the total pressure drop does not exceed the initial pressure of the system; (2) that the pressure drop is not so great as to cause high velocities and in the case of counter-flowing condensate to cause water hammer; (3) that there is a constant initial pressure; (4) that there is sufficient difference in level between the water line of the boiler and the lowest point of the steam main, dry return and heating units.

It is recommended that all systems be designed for low initial pressure and a reasonably small pressure drop. Such systems will operate under higher pressures without difficulty. When a system is designed for high pressure with a relatively large pressure drop and then operated at a low pressure, it is apt to be noisy and to have poor circulation.

It is recommended that the total pressure drop never exceed one-half of the initial pressure. This applies to cases where the condensate is flowing in the same direction as the steam, but in the case of counter-flowing condensate the capacities should not exceed those shown in Tables 5 and 6.

Maximum Velocity

The capacity of pipe of a given size in any part of a steam or vapor heating system depends upon the quantity of condensation present, as well as upon the available pressure drop in the pipe. Where no water is present or where a limited quantity flows by gravity in the same direction as the steam the available pressure drop only need be considered.

Where water and steam flow counter to each other the velocity of the steam must not exceed certain values above which disturbance between

the counter-flowing steam and water may produce objectionable sounds, water hammer, or may retain water in some parts of the system until pressure goes off. The velocity at which such disturbance takes place depends upon the size of the pipe, its position (whether vertical or horizontal), its pitch and the quantity of water flowing counter to the steam.

TABLE 5. MAXIMUM ALLOWABLE CAPACITIES OF UP-FEED RISERS FOR ONE-PIPE LOW PRESSURE STEAM

Based on A. S. H. V. E. Research Laboratory Tests

PIPE SIZE INCHES	VELOCITY FEET PER SECOND	PRESSURE DROP OUNCES PER 100 FT.	CAPACITY		
			Sq. Ft. Radiation	B.t.u. per Hour	Lb. Steam per Hour
A	*B*	*C*	*D*	*E*	*F*
1	14.1	0.68	45	10,961	11.3
1¼	17.6	0.66	98	23,765	24.5
1½	20.0	0.66	152	36,860	38.0
2	23.0	0.57	288	69,840	72.0
2½	26.0	0.54	464	112,520	116.0
3	29.0	0.48	799	193,600	199.8
3½	31.0	0.44	1144	277,000	286.0
4	32.0	0.39	1520	368,000	380.0

INSTRUCTIONS FOR USING TABLE 5

1. Capacities given in Table 5 should never be exceeded on one-pipe risers.
2. Capacities based on ¼ lb. condensation per square foot equivalent radiation and actual diameter of standard pipe.
3. All pipe should be well reamed and free from constrictions. Fittings should be up to size. (See Tables 7 and 8).

TABLE 6. COMPARATIVE CAPACITY OF STEAM LINES AT VARIOUS PITCHES[a]

Pitch of Pipe in Inches per 10 Ft.

PITCH OF PIPE—¼ IN.			½ IN.		1 IN.		1½ IN.		2 IN.		3 IN.		4 IN.		5 IN.	
Pipe Size Inches	Sq. Ft. Rad. Based on 240 B.t.u.	Max. Vel.	Sq. Ft. Rad. Based on 240 B.t.u.	Max. Vel.	Sq. Ft. Rad. Based on 240 B.t.u.	Max. Vel.	Sq. Ft. Rad. Based on 240 B.t.u.	Max. Vel.	Sq. Ft. Rad. Based on 240 B.t.u.	Max. Vel.	Sq. Ft. Rad. Based on 240 B.t.u.	Max. Vel.	Sq. Ft. Rad. Based on 240 B.t.u.	Max. Vel.	Sq. Ft. Rad. Based on 240 B.t.u.	Max. Vel.
¾	25.0	12	30.3	14	37.3	18	40.4	19	42.5	20	46.1	21	47.5	22	49.3	23
1	45.8	12	52.6	15	63.0	17	70.0	20	75.2	22	83.0	23	87.9	25	90.2	26
1¼	104.9	18	117.2	20	133.0	23	144.5	25	154.0	27	165.0	28	172.6	29	178.2	31
1½	142.6	18	159.0	21	181.0	23	196.5	25	209.3	27	224.0	28	234.8	30	242.6	31
2	236.0	19	263.5	20	299.5	23	325.5	25	346.5	27	371.5	28	388.4	29	401.1	30

[a]Data from A.S.H.V.E. Research Laboratory.

Buildings which are heated intermittently or which have less heating surface than is required for quick initial warming prior to occupancy, must have extra large piping in order to compensate for the unusual demand on the piping per unit of radiation.

Reaming

Tables 7 and 8 give the variation in capacity of pipe due to reaming and variation in size and smoothness of pipe as determined by experiments at the AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS Research Laboratory. There are certain variations in manufacture which apparently cannot be avoided, which actually caused a 20 per cent variation in the capacity of a 1 in. pipe, as indicated by Table 8. A factor of safety has been allowed in all of the capacity tables in this chapter so that Table 8, while interesting, need not be used to discount the other tables.

Pipe Size Tables

Tables for the selection of pipe sizes for steam heating systems have been developed through the cooperative research investigations of the

TABLE 7. EFFECT OF REAMING ENTRANCE TO ONE-INCH ONE-PIPE RISERS[a]

	MAXIMUM CAPACITY OF RISER	PER CENT DECREASE
Reamed entrances	24.7 lb. per hour	0.0
Rounded entrances	23.9 lb. per hour	3.2
Squared entrances	22.2 lb. per hour	10.1
Three wheel cutter	19.2 lb. per hour	22.2
Single wheel cutter	17.6 lb. per hour	28.7

TABLE 8. PER CENT DIFFERENCE IN CAPACITY DUE TO VARIATION OF PIPE SIZE AND SMOOTHNESS[a]

	MAXIMUM CONDENSATION, LB. PER HR.			
Size of Pipe	¾"	1"	1¼"	1½"
Minimum	14.00	24.89	45.42	70.50
Maximum	15.20	30.08	52.08	82.00
Per Cent Variation	8.6	20.8	14.7	16.3

[a]Data from AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS Research Laboratory.

AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS and the *Heating and Piping Contractors National Association.* (See Tables 9 to 16). While these tables, literally followed out, will serve as an efficient guide to the designer, it is impossible entirely to eliminate the factor of good engineering judgment. For example: While a given main might be calculated to begin at 5 in. and to end at 1½ in., better practice often would make it begin at 4 in. and end at 2½ in., since the dryer steam and higher velocity at the entry would compensate for the smaller size at the end.

DESIGN OF STEAM HEATING SYSTEMS

Steam heating systems may be broadly classified as (1) air-vent one-pipe, (2) air-vent two-pipe, (3) vapor and (4) vacuum.

The choice of air-vent one-pipe, two-pipe, vapor or vacuum return line systems depends upon the requirements as to first cost, convenience,

quality of service and local conditions. Theoretically, air-vent one and two-pipe and vapor and vacuum return line systems are substantially on a par as to heating efficiency; that is to say, the major portion of the heat delivered is, or should be, dissipated by the heating unit.

It is essential that any system circulate steam uniformly throughout the entire installation, as too often certain defective features of a system will require that heat be kept on longer or to a greater degree than would

TABLE 9. PIPE SIZES FOR ONE-PIPE AIR-VENT LOW PRESSURE STEAM HEATING SYSTEM, WHERE EQUIVALENT LENGTH OF RUN FROM BOILER OR SOURCE OF SUPPLY TO THE FARTHEST RADIATOR DOES NOT EXCEED 200 FT.

Capacity in Sq. Ft. of Equivalent Radiation

Based on Total Pressure Drop of 1 oz. per 100 ft.

Pipe Size Inches	Supply Main Dripped and Branches to Risers Dripped Steam and Condensate flowing in the same direction.	Supply Risers Up-Feed	Branches to Supply Risers and Radiators Not Dripped	Wet Return Main	Dry Return Main	Radiator Valve Sizes and Vertical Connections
A	*B*	*C*	*D*[a]	*E*	*F*	*G*
¾	.....	25	.....	.....	.....	.....
1	56	45	20	700	320	20
1¼	122	98	55	1200	670	55
1½	190	152	81	1900	1058	81
2	386	288	165	4000	2300	165
2½	635	464	260	6700	3800	.....
3	1163	799	475	10,700	7000	.....
3½	1737	1144	745	.....	10,000	.....
4	2457	1520	1110	.....	.....	.....
5	4546	.....	2180	.....	.....	.....
6	7462	.....	.....	.....	.....	.....

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INSTRUCTIONS FOR USING TABLE 9

[a]1. Radiator branches more than 8 ft. in length should be one size larger than shown in Col. *D*.

2. These tables apply where pipes are properly reamed. No allowances for defective material or workmanship have been made. (See Tables 7 and 8).

3. Capacities based on ¼ lb. condensation per square foot per hour equivalent radiation and actual diameter of standard pipe.

4. Extra length to be added to straight run of pipe, for various fittings and valves to determine equivalent length. (See Table 4).

5. Where it is necessary to drip a steam main, branch to riser or risers, same should be dripped separately into wet return.

6. Pitch of mains should be not less than ¼ in. in 10 ft.; on horizontal branches to radiators and risers at least ½ in. in 10 ft.

7. In general it is desirable not to have a supply main smaller than 2 in. in diameter. When the supply main is larger than 2½ in. at the beginning, it is desirable that it shall not be smaller than 2½ in. at the end.

otherwise be required uniformly and satisfactorily to heat the building. This will result in waste and overheating. The one important thing to be remembered in connection with all systems is that they shall circulate steam freely and uniformly to the heating units and shall remove and return the condensation noiselessly.

The following should be kept in mind in laying out any type of system:

1. The initial pressure should be kept as low as possible, not exceeding 5 lb. gage.

2. The drop in pressure in the mains and riser to the farthest heating unit should not exceed 1 oz. per 100 ft. of straight pipe or its equivalent length, with a lower rate of drop for systems with long runs.

3. In small installations, such as residences, where the longest actual run is seldom over 200 ft. and where the firing periods extend over several hours, resulting in boiler pressure, fluctuating from zero to about 1 lb., the total pressure drop should not exceed 2 oz. for gravity systems. In large buildings, where boilers are under the constant care of a fireman and a uniform pressure is maintained, and where the water-line difference will permit, the total drop in pressure may range from 3 to 8 oz., depending upon the equivalent length of the longest run.

4. The total allowable drop in pressure depends upon (*a*) the water-line difference, (*b*) the equivalent length of main and riser from the boiler to the farthest heating unit, and (*c*) the regularity of the pressure maintained at the boiler or source of steam supply.

5. The water-line difference, or distance between the water line of the boiler and the low point of steam main and dry return main should be not less than 24 in., because of the heavy drop in pressure from condensation in heating up a cold system. This difference should be increased 2 in. for every ounce pressure-drop in the system. If the total pressure-drop were 6 oz., the water-line difference should be $6 \times 2 + 24$ or 36 in.

6. There should be a nearly uniform drop in pressure between the source of steam supply and the farthest heating unit on every riser. Care should be taken, however, to see that the maximum allowable velocity for smooth operation is not exceeded.

7. In using this method of proportioning a system, care must be exercised to see that no pipe carrying condensate counter to the steam is loaded to a capacity above the maximum for the particular part of a system in question.

Air-Vent One-Pipe System

The air-vent one-pipe system (Fig. 1) is considered by many engineers to be the simplest steam circulating system. It may be either of the atmospheric or of the vacuum type depending on whether or not vacuum-type or non-return air valves are used on radiators and return mains. If vacuum-type air valves are used the entire system must be tight and reasonably free from air leaks through supply valves, piping and boiler trimmings.

Each radiator has but a single pipe connection, through which steam must enter and through which the condensation also must return, flowing in the opposite direction to the steam flow. The main from the boiler should pitch downward from the highest point above the boiler, and at the end of this main it should drop down and be sealed independently below the boiler water line. This may be done at the remote end of the main or the main may loop back, above the boiler water line, to a point near the boiler, where it may be more convenient to seal it. Steam and condensation flow in the same direction in this supply main and the branches from the main are taken off the top.

The ends of the supply mains, before they are sealed below the water line, must be vented. Each radiator must have an air valve. Perfect grading of the mains and radiators so that no pools of water will lie in depressions in the pipes is imperative with this system, since these water

pools always cause objectionable noise. Radiators with this system usually require that the supply valve be all-open or all-closed, since any intermediate valve-position is likely to cause interference with the necessary return of condensation.

It should be emphasized that in any part of a system in which water from the heating units returns counter to the steam the velocity of the steam must be kept below the point where it will seriously interfere with the returning water. The maximum allowable velocity of steam for satisfactory operation has been determined by the AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS Research Laboratory. Table 5 gives the maximum allowable capacity and velocities of flow for up-feed one-pipe risers while Table 6 gives the maximum capacity and velocity for horizontal pipes with various pitch.

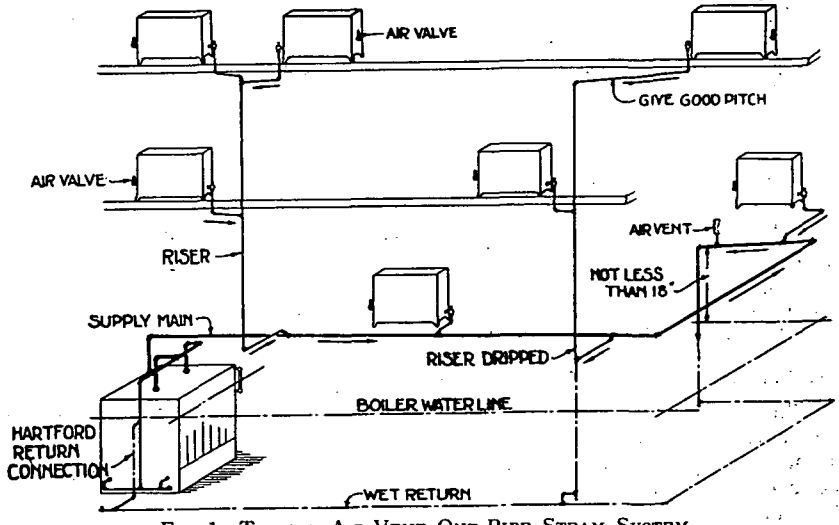


FIG. 1. TYPICAL AIR-VENT ONE-PIPE STEAM SYSTEM

Since the maximum velocity must not be exceeded in any part of the system, if silent and satisfactory operation are desired, care should be exercised to eliminate obstructions due to poor pipe, lack of or faulty reaming and improper use of pipe *dope*.

Table 9 is to be used in designing one-pipe systems up to 200 ft. equivalent length of run. For designing larger one-pipe systems where uniform distribution of steam to all parts of the building is difficult to obtain, Table 10 shall be used.

Air-Vent One-Pipe Down-feed System

The air-vent one-pipe down-feed system illustrated in Fig. 2 is a modification of the one-pipe up-feed system and the same tables apply to it as for the up-feed system. The branches may leave the overhead main from the top, in which case the condensation drains at the end,

or the branches may leave the overhead main from the bottom, in which case each branch drains the condensation, and in which case the installation of eccentric fittings in the overhead main may be avoided. The illustration indicates no drain at the base of the main supply riser. When this riser is more than very few feet from the boiler a connection from the bottom of the riser into the wet return should be made.

Air-Vent Two-Pipe System

Two-pipe systems, Fig. 3, require separate supply and return mains and a separate supply and return connection for each heating unit. Like one-pipe systems, they require air valves on heating units and mains. The steam connection may be either at the top or the bottom of the unit, but the outlet is always at the bottom so that all condensation will drain through this to the return mains.

The return connection from each heating unit preferably should be

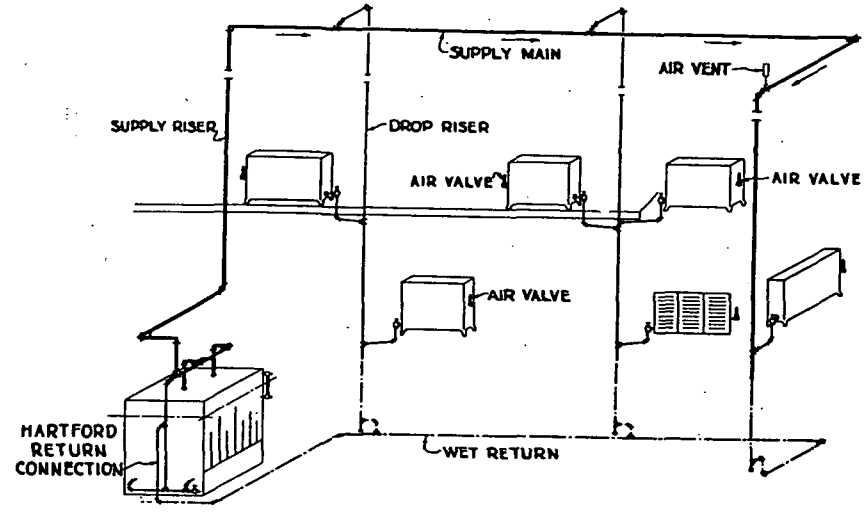


FIG. 2. TYPICAL AIR-VENT ONE-PIPE DOWN-FEED STEAM SYSTEM

carried separately to a wet return below the water line of the boiler. Valves are required on the steam connection and on the return connection to each heating unit. The use of dry returns with air-vent, two-pipe systems, employing manual shut-off valves or check valves on the return connections to the heating units should be avoided. The air-vent two-pipe system is obsolete.

Vapor System

Fig. 4 illustrates a vapor system. The device at the end of the dry return main is usually of a proprietary nature. Its function is to vent the air and in some cases it prevents the reentry of air. Some of these devices are designed to maintain a constant differential between the pressure in the supply main and the pressure in the return main. A wet

return main is not always essential, though in many cases it is a useful auxiliary.

Steam is prevented from entering the return main by thermostatic traps or other means of resistance on the return ends of the heating units and at drainage or venting points on the supply mains. There are no air valves, as such, on the heating units. With vapor systems the amount of vapor admitted to each heating unit is under throttle control at each supply valve. In addition some proprietary systems have a method of balancing steam flow by the use of an orifice with a fixed area proportioned in accordance with the size of each heating unit, while others use a supply valve which is of standard size and has an orifice that may be adjusted for each individual heating unit. In many of them the pressure in the supply main is under self-contained, automatic control.

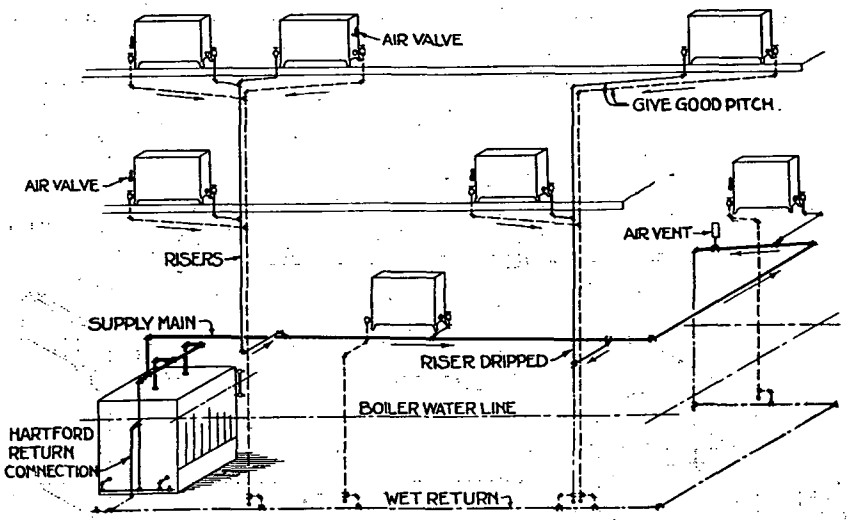


Fig. 3. Typical Air-Vent Two-Pipe Steam System

Although in any type of two-pipe system the condensation from the heat-emitting units returns through separate piping, the condensation from radiator branches and risers must return through these pipes counter to the steam. The velocity of steam flow in such pipes must be kept below a certain maximum or this water will be held up until it accumulates in sufficient quantity to produce objectionable sounds and to interfere with proper circulation.

Table 11 gives the maximum capacity and velocity of steam for two-pipe risers as determined by the Research Laboratory.

Table 12 is for comparatively small vapor systems. One ounce pressure drop may be understood to mean that the water in the vertical pipe, which drains the end of the supply main, will stand about 2 in. higher than the water line in the boiler under normal conditions.

Table 13 shows the pipe sizes for larger vapor systems than those in

Table 12. Using these sizes, the water in the vertical pipe, which drains the end of the supply main, will stand about 4 in. higher than the water line in the boiler under normal operation.

Table 14 shows the pipe sizes for vapor systems where a still greater difference in water line may be allowed between that in the boiler and in the return drop-pipe under normal operation. Where the basement is high and where all heaters are well above the water line, and where they do not have unusual condensing power, these sizes are permissible. The difference here is 4 oz., or approximately 8 in.

Vacuum Pump Systems

Fig. 5 shows a typical vacuum system of steam heating, using a pump which handles both the air from the system and the water of condensation

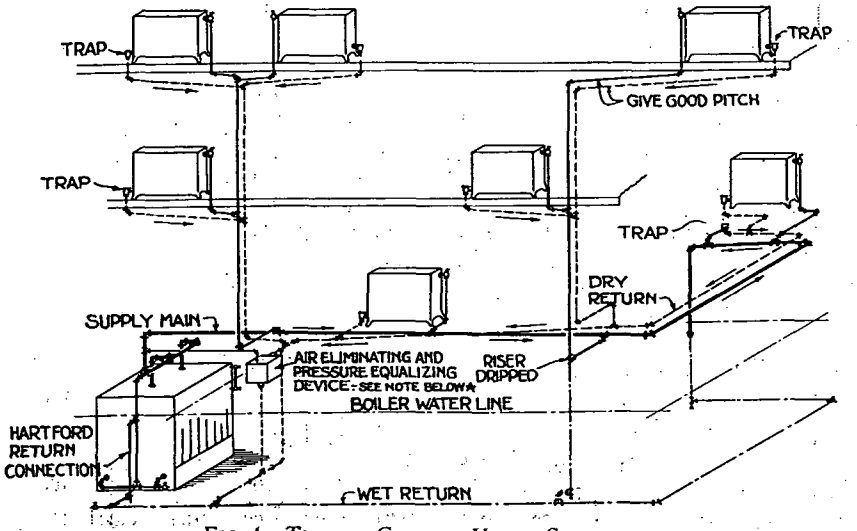


Fig. 4. Typical Gravity Vapor System

Proper piping connections are essential with special appliances for pressure equalizing and air elimination.

from it. With such arrangements a wide difference in pressure between that in the supply main and that in the return main is permissible. A greater temperature range within the system than that obtainable with vapor systems is insured. Heaters may be below the water line of the boiler, and even may be lower than the level of the pump, though such an arrangement generally should be avoided.

Table 15 gives approved pipe sizes for vacuum pump systems of comparatively small size, with a pressure drop not exceeding 4 oz., or a rise in the return connection of about 8 in., which, of course, easily can be overcome by the vacuum pump.

Table 16 gives pipe sizes for larger systems in which the vacuum pump is expected to maintain a greater suction, the allowable rise in the return connection being about 16 in.

TABLE 10. PIPE SIZES FOR ONE-PIPE, AIR-VENT, LOW PRESSURE STEAM HEATING SYSTEMS, WHERE EQUIVALENT LENGTH OF RUN FROM BOILER OR SOURCE OF SUPPLY TO FARTHEST RADIATOR Exceeds 200 FT.

Capacity in Sq. Ft. of Equivalent Radiation

Based on 4 oz. Total Pressure Drop

Pipe Size Inches	Equivalent Length of Pipe from Boiler to Farthest Radiator, Including Main and Riser. (See *Note 5.*) Supply Main Dripped and Branches to Risers Dripped—Steam and Condensate flowing in same direction.						Maximum Capacities		
	100 Ft.	200 Ft.	300 Ft.	400 Ft.	500 Ft.	600 Ft.	Supply Risers Up-Feed	Branches to Supply Risers and Radiators Not Dripped	Radiator Valves and Vertical Connections
A	*B*	*C*	*D*	*E*	*F*	*G*	*H*	*Ia*	*J*
1	111	79	65	56	49	46	45	20	20
1¼	245	173	141	122	110	100	98	55	55
1½	380	269	220	190	165	155	152	81	81
2	771	546	446	386	345	315	288	165	165
2½	1270	898	734	635	568	518	464	260	.....
3	2326	1645	1342	1163	1040	948	799	475	.....
3½	3474	2457	2006	1737	1552	1419	1144	745	.....
4	4914	3475	2828	2457	2196	2011	1520	1110	.....
5	9092	6429	5250	4546	4062	3712	.....	2180	.....
6	14,924	10,553	8618	7462	6669	6094	.....	.....	.....
8	31,066	21,967	17,935	15,533	13,880	12,682	.....	.....	.....
10	56,689	40,085	32,730	28,345	25,334	23,144	.....	.....	.....
12	90,985	64,336	52,530	45,492	40,660	37,145	.....	.....	.....

Pipe Size Inches	Dry Return Main. Equivalent Length of Run from Boiler to Foot of Farthest Riser in Feet						Wet Return Main. Equivalent Length of Run from Boiler to Foot of Farthest Riser in Feet					
	100	200	300	400	500	600	100	200	300	400	500	600
K	*L*	*M*	*N*	*O*	*P*	*Q*	*R*	*S*	*T*	*U*	*V*	*W*
1	460	412	368	320	275	227	1400	1000	820	700	640	580
1¼	962	868	770	670	579	480	2400	1700	1390	1200	1080	990
1½	1512	1362	1210	1058	909	757	3800	2700	2180	1900	1710	1570
2	3300	2960	2640	2300	1980	1630	8000	5600	4520	4000	3560	3240
2½	5450	4900	4380	3800	3300	2770	13,400	9400	7600	6700	6000	5300
3	10,000	9000	8000	7000	6000	5000	21,400	15,000	12,500	10,700	9400	8500
3½	14,300	12,900	11,500	10,000	8600	7200	32,000	22,000	18,500	16,000	14,400	13,200
4	21,500	19,300	17,200	15,000	12,900	10,700	44,000	31,000	25,500	22,000	19,900	18,300

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INSTRUCTIONS FOR USING TABLE 10

[a]1. Radiator branches more than 8 ft. in length should be one size larger than shown in Column *I*.

2. These tables apply where pipes are properly reamed. No allowances for defective material or workmanship have been made. (Also see Tables 7 and 8).

3. Capacities based on ¼ lb. condensation per square foot per hour equivalent radiation and actual diameter of standard pipe.

4. Extra length to be added to straight run of pipe for various fittings and valves to determine equivalent length. (See Table 4).

It may be desirable in some cases to utilize a condensation pump rather than a vacuum pump where the heaters are too close to, or must be below, the boiler water line. Fig. 6 illustrates an approved hook-up for such a condition though, of course, the apparatus may be used with a wet return as well as with the dry return shown. It will be noted that each heater has a trap.

When a condensation pump is used with a one-pipe system a false water line should be established so that the sealing of each dry return against the others, so important with one-pipe systems, shall be maintained. Sometimes, in this contingency, it is desirable to place a float trap on the end of each separate dry return connection to the pipe which supplies the pump-suction.

Piping systems used with vacuum pumps where zone control of the heating is employed, demand the subdivision of the supply piping with valves for each division. The return piping for each of these divisions also should be separate and in many cases a separate vacuum pump is provided for each zoned division.

There are a number of meritorious proprietary types of steam, vacuum return line, differential, and vapor heating systems, which vary in certain particulars from the foregoing typical examples. These systems have

INSTRUCTIONS FOR USING TABLE 10 (Continued)

5. Mains are to be proportioned according to the equivalent length of run from the boiler or source of supply to the farthest radiators supplied by the main.

Determine equivalent length of run then use figures in corresponding Columns (*B* to *G*) for supply mains; (*L* to *Q*) for dry-return mains; (*R* to *W*) for wet-return mains for sizing the entire run.

For example: If the distance from boiler or source of supply to the farthest radiator on the longest main should be 300 ft., all mains are to be sized from Column *D*; if 400 ft., Column *E*; if 600 ft., Column *G*.

Risers are to be proportioned according to the equivalent length of run from the boiler or source of supply to the farthest radiator on each particular riser.

Determine the distance to the farthest radiator then use the figures in the corresponding Columns (*B* to *G*) for sizing each riser; providing the amount of radiation for that riser does not exceed amounts shown in Column *H*. Where riser capacities are found to be in excess of amounts in Column *H*, step up to necessary size indicated in that column.

For example: If the distance from the boiler or source of supply to the farthest radiator on a supply riser is 300 ft., that riser is to be sized from Column *D*, providing the amount of radiation does not exceed the amount shown in Column *H*. If the amount exceeds that in Column *H*, use amounts shown in Column *H* for sizing that entire riser.

If another riser taken from the same main as the one above is only 200 ft., this riser should be sized from Column *C*, providing the amount of radiation does not exceed that as shown in Column *H*.

6. For practical purposes the pipe sizes on the usual heating system may be determined by using the pressure drop indicated by the longest main and riser on that system, neglecting the separate computations for each separate shorter run.

7. Where it is necessary to drip a steam main, branch to riser or risers, same should be dripped separately into wet return.

8. Pitch of mains should be not less than ¼ in. in 10 ft.; on horizontal branches to radiators and risers at least ½ in. in 10 ft.

9. In general it is desirable not to have a supply main smaller than 2 in. in diameter. When the supply main is larger than 2½ in. at the beginning, it is desirable that it shall not be smaller than 2½ in. at the end.

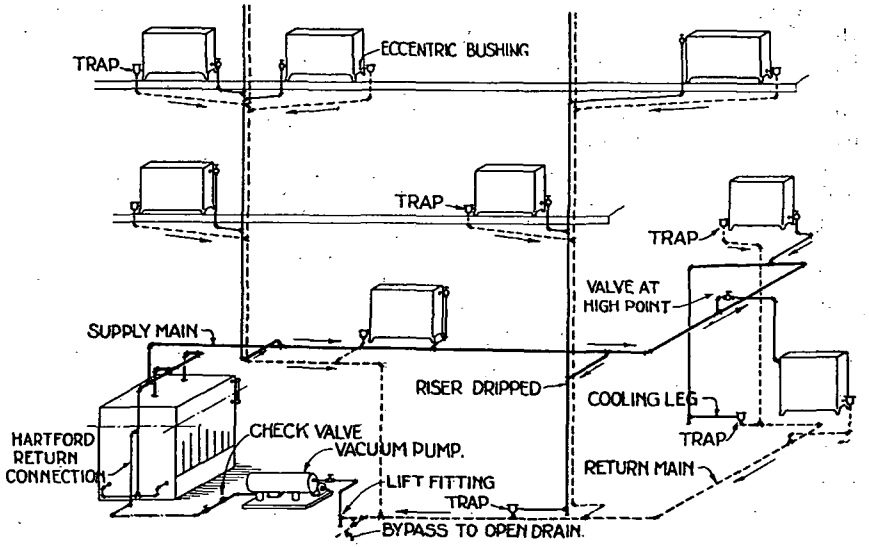


FIG. 5. TYPICAL INSTALLATION USING VACUUM PUMP

been developed to meet the requirements of the newer architecture of modern building construction and are based on well established engineering principles of control for occupancy, wind and sun effect, zone demands, etc. Descriptions of these systems will be found in the catalog section of THE GUIDE.

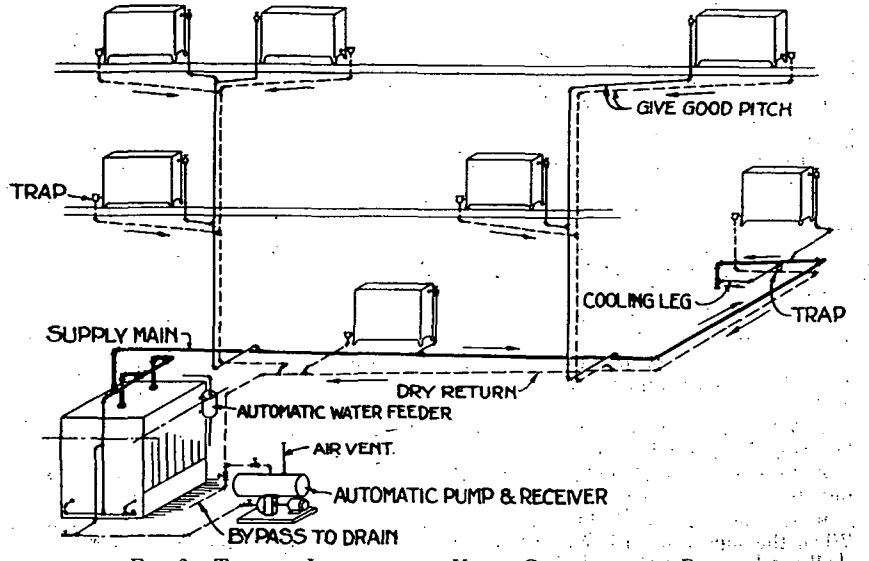


FIG. 6. TYPICAL INSTALLATION USING CONDENSATION PUMP

TEMPERATURE CONTROL

The heating surface installed in buildings must emit sufficient heat to maintain the desired temperature in the coldest weather. For higher outside temperatures, the radiators will be of greater capacity than required, and overheating will result unless the heat output is reduced. The amount of heat delivered by a steam radiator can be reduced by any one of the following three methods:

1. By lowering the pressure and thus the temperature of the steam.
2. By admitting steam to the radiator intermittently and thus reducing the length of time it is filled with steam.
3. By restricting the flow of steam into the radiator.

Vacuum or Pressure Control

If large buildings are controlled by a single thermostat, the heating surface should be carefully balanced against the heat losses of the building. The heat emission of the radiators may then be varied according to the heat losses of the structure by varying the pressure or vacuum on the system. The higher the vacuum the lower will be the temperature, and thus the temperature in the radiator will be reduced. This method is sometimes supplemented with thermostatically operated valves in rooms

TABLE 11. MAXIMUM ALLOWABLE CAPACITIES OF UP-FEED RISERS FOR TWO-PIPE LOW PRESSURE STEAM

Based on A. S. H. V. E. Research Laboratory Tests

PIPE SIZE INCHES	VELOCITY FEET PER SECOND	PRESSURE DROP OUNCES PER 100 FT.	CAPACITY		
			Sq. Ft. Radiation	B.t.u. per Hour	Lb. Steam per Hour
A	*B*	*C*	*D*	*E*	*F*
¾	20	.....	40	9550	10.0
1	23	1.78	74	17,900	18.45
1¼	27	1.57	151	36,500	37.65
1½	30	1.48	228	55,200	57.0
2	35	1.33	438	106,100	109.5
2½	38	1.16	678	164,100	169.4
3	41	0.95	1129	273,500	282.2
3½	42	0.81	1548	375,500	387.0
4	43	0.71	2042	495,000	510.5

INSTRUCTIONS FOR USING TABLE 11

1. The capacities given in this table should never be exceeded on two-pipe risers.
2. Capacities based on ¼ lb. condensation per square foot equivalent radiation and actual diameter of standard pipe.
3. All pipe should be well reamed and free from constrictions. Fittings should be up to size. (See Tables 7 and 8).

TABLE 12. PIPE SIZES FOR TWO-PIPE VAPOR[b] SYSTEMS, WHERE EQUIVALENT LENGTH OF RUN FROM BOILER OR SOURCE OF SUPPLY TO FARTHEST RADIATOR DOES NOT EXCEED 200 FT.

Capacity in Sq. Ft. of Equivalent Radiation

Based on Total Pressure Drop of 1 oz. per 100 ft.

PIPE SIZE INCHES	SUPPLY MAIN DRIPPED AND BRANCHES TO RISERS DRIPPED Steam and Condensate flowing in same direction.	SUPPLY RISERS Up-Feed	BRANCHES TO SUPPLY RISERS AND RADIATORS NOT DRIPPED	RETURN RISERS	WET RETURN MAIN	DRY RETURN MAIN
A	*B*	*C*	*D*[a]	*E*	*F*	*G*
¾	---	30	---	190	-----	-----
1	56	56	26	450	700	320
1¼	122	122	58	990	1200	670
1½	190	190	95	1500	1900	1058
2	386	386	195	3000	4000	2300
2½	635	635	395	.....	6700	3800
3	1163	1129	700	.....	10,700	7000
3½	1737	1548	1150	.....	-----	10,000
4	2457	2042	1700	.....	-----	-----
5	4546	.....	3150	.....	-----	-----
6	7462	**Different makes of supply and return valves, steam traps and other specialties vary as to capacity, therefore use size as recommended for any particular make. Vertical connections to be of same size as valve and trap used. Return horizontal runout to be not less than ¼ in.**				

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INSTRUCTIONS FOR USING TABLE 12

[a]1. Radiator branches more than 8 ft. in length should be one size larger than shown in Column *D*.

[b]2. This table is for systems which are open to atmosphere or operate under slight pressure or partial vacuum without use of vacuum pumps.

3. These tables apply where pipes are properly reamed. No allowances for defective material or workmanship have been made. (Also see Tables 7 and 8).

4. Capacities based on ¼ lb. condensation per square foot per hour equivalent radiation and actual diameter of standard pipe.

5. Extra length to be added to straight run of pipe for various fittings and valves to determine equivalent length. (See Table 4).

6. Where it is necessary to drip a supply main, supply riser or branch to a supply riser, same should be dripped separately into a wet return. The drip for a vapor or vacuum system may be taken into a dry return through a steam trap.

7. Pitch of mains should be not less than ¼ in. in 10 ft.; on horizontal branches to radiators and risers at least ½ in. in 10 ft.

8. In general it is desirable not to have a supply main smaller than 2 in. in diameter. When the supply main is larger than 2½ in. at the beginning, it is desirable that it shall not be smaller than 2½ in. at the end.

or spaces where overheating is likely to occur, or where the same temperatures are not desired in all the rooms or spaces of the building.

Orifice Control[1]

In using the last method, the rate of flow of steam into a radiator can be controlled by means of (1) a restriction of variable area such as is obtained by throttling the radiator valve, or (2) a fixed restriction, such as a fixed orifice, a variable flow being obtained by varying the pressures on the two sides of the orifice.

The use of a fixed orifice makes it possible to reduce the heat output of a radiator to any desired extent. The radiator may be kept full of steam when the maximum heat output is needed, by adjusting the pressure on the inlet side of the orifice so that it is sufficiently above that in the radiator. In mild weather the flow of steam into the radiator may be reduced to such an extent by reducing the difference in pressure between the two sides of the orifice that only a small part of the radiator is heated.

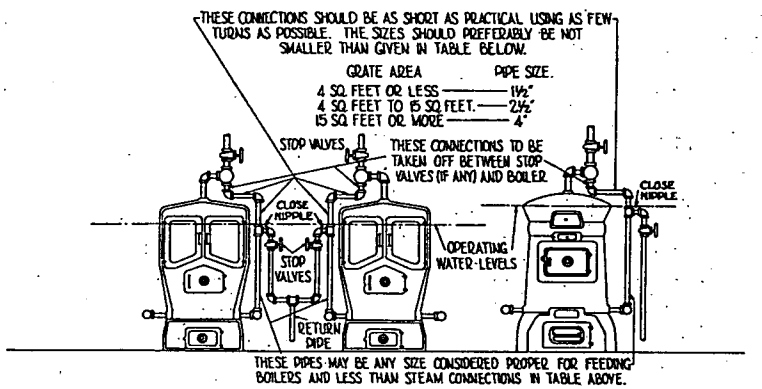


FIG. 7. USING THE HARTFORD RETURN CONNECTION

Between these extremes, the pressure differential may be adjusted to give the flow of steam required for weather conditions encountered at any time during the heating season.

Radiator orifices can be inexpensively made and installed. When an orifice system is properly operated, it is possible to obtain highly satisfactory control of building temperature, resulting in economy in the use of steam for heating.

For additional information on temperature control, refer to Chapter 23.

PIPING CONNECTIONS

Hartford Return Connections

The Hartford return connection illustrated in Fig. 7 and in other piping layouts in this chapter is recognized as safer and preferable to

[1]For additional information on this subject, refer to Flow of Steam through Orifices into Radiators, by S. S. Sanford and C. B. Sprenger [*Heating, Piping and Air Conditioning*, June, 1931].

Table 13. Pipe Sizes for Two-Pipe Vapor Heating Systems, where Equivalent Length of Run from Boiler or Source of Supply to Farthest Radiator Exceeds 200 Ft.

Capacity in Sq. Ft. Equivalent Radiation

Based on 2 oz. Total Pressure Drop

Pipe Size Inches	Equivalent Length of Pipe from Boiler to Farthest Radiator, Including Main and Riser. (See *Note 6.*) Supply Main Dripped and Branches to Risers Dripped—Steam and Condensate flowing in same direction.				Maximum Capacities		
	100 Ft.	200 Ft.	300 Ft.	400 Ft.	Supply Risers Up-Feed	Branches to Supply Risers and Radiators Not Dripped	Return Risers
A	*B*	*C*	*D*	*E*	*F*	*G*[a]	*H*
¾	----	----	----	----	30	----	190
1	79	56	46	39	56	26	450
1¼	173	122	100	87	122	58	990
1½	269	190	155	134	190	95	1500
2	546	386	315	273	386	195	3000
2½	898	635	518	449	635	395	.....
3	1645	1163	948	822	1129	700	.....
3½	2457	1737	1419	1228	1548	1150	.....
4	3475	2457	2011	1738	2042	1700	.....
5	6929	4546	3712	3214	.....	3150	.....
6	10,553	7462	6094	5276	**Different makes of supply and return valves, steam traps and other specialties vary as to capacity, therefore use size as recommended for any particular make. Vertical connections to be of same size as valve and trap used. Return horizontal runout to be not less than ¾ in.**		
8	21,967	15,533	12,682	10,983			
10	40,085	23,345	23,144	20,043			
12	64,336	45,492	37,145	32,168			

Pipe Size Inches	Dry Return Main: Equivalent Length of Run from Boiler to Farthest Radiator in Feet				Wet Return Main: Equivalent Length of Run from Boiler to Farthest Radiator in Feet			
	100	200	300	400	100	200	300	400
I	*J*	*K*	*L*	*M*	*N*	*O*	*P*	*Q*
1	355	320	285	248	1000	700	580	500
1¼	745	670	595	520	1700	1200	990	850
1½	1173	1058	943	822	2700	1900	1570	1350
2	2680	2300	2140	1880	5600	4000	3240	2800
2½	4300	3800	3470	3040	9400	6700	5300	4700
3	7800	7000	6250	5480	15,000	10,700	8500	7500
3½	11,100	10,000	8800	7880	22,000	16,000	13,200	11,000
4	16,700	15,000	13,400	11,700	31,000	22,000	18,300	15,500

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INSTRUCTIONS FOR USING TABLE 13

[a]1. Radiator branches more than 8 ft. in length should be one size larger than shown in Column *G*.

2. This table is for systems which are open to atmosphere or operate under slight pressure or partial vacuum without use of vacuum pumps.

3. These tables apply where pipes are properly reamed. No allowances for defective material of workmanship have been made. (Also see Tables 7 and 8).

4. Capacities based on ¼ lb. condensation per square foot per hour equivalent radiation and actual diameter of standard pipe.

5. Extra length to be added to straight run of pipe for various fittings and valves to determine equivalent length. (See Table 4).

6. Mains are to be proportioned according to the equivalent length of run from the boiler or source of supply to the farthest radiators supplied by the main.

Determine equivalent length of run then use figures in corresponding Columns (*B* to *E*) for supply mains; (*J* to *M*) for dry-return mains; (*N* to *Q*) for wet-return mains for sizing the entire run.

For example: If the distance from boiler or source of supply to the farthest radiator on the longest main should be 300 ft., all mains are to be sized from Column *D*; if 400 ft., Column *E*.

Supply and return risers are to be proportioned according to the equivalent length of run from the boiler or source of supply to the farthest radiator on each riser.

For supply risers determine the distance from the boiler to the farthest radiator served by that riser then use the figures in the corresponding Columns (*B* to *E*) for sizing each supply riser; providing the amount of radiation for that riser does not exceed amounts shown in Column *F*. Where supply riser capacities are found to be in excess of amounts shown in Column *F*, step up to necessary size indicated in that column.

For example: If the distance from the boiler or source of supply to the farthest radiator on a supply riser is 300 ft., that riser is to be sized from Column *D*, providing the amount of radiation does not exceed the amount shown in Column *F*. If the amount exceeds that in Column *F*, use amounts shown in Column *F* for sizing that entire riser.

If another riser taken from the same main as the one indicated is only 200 ft., this riser should be sized from Column *C* providing the amount of radiation does not exceed that as shown in Column *F*.

For return risers determine the equivalent length of run in feet from the top of each riser to the boiler, then use the figures in the corresponding Columns (*J* to *M*) for sizing each riser.

7. For practical purposes the pipe sizes on the usual heating system may be determined by using the pressure drop indicated by the longest main riser on that system, neglecting the separate computations for each separate shorter run.

8. Where it is necessary to drip a supply main or a supply riser or a branch to a supply riser, same should drip separately into a wet return. The drip for a vapor or vacuum system may be taken into a dry return through a steam trap.

9. Pitch of mains should be not less than ¼ in. in 10 ft.; on horizontal branches to radiators and risers at least ½ in. in 10 ft.

10. In general it is desirable not to have a supply main smaller than 2 in. in diameter. When the supply main is larger than 2½ in. at the beginning, it is desirable that it shall not be smaller than 2½ in. at the end.

Table 14. Pipe Sizes for Two-Pipe Vapor Heating Systems, where Equivalent Length of Run from Boiler or Source of Supply to Farthest Radiator Exceeds 200 Ft.

Capacity in Sq. Ft. of Equivalent Radiation

Based on 4 oz. Total Pressure Drop

Pipe Size Inches	Equivalent Length of Pipe from Boiler to Farthest Radiator, Including Main and Riser. (See *Note 6.*) Supply Main Dripped and Branches to Risers Dripped—Steam and Condensate flowing in same direction.						Maximum Capacities		
	100 Ft.	200 Ft.	300 Ft.	400 Ft.	500 Ft.	600 Ft.	Supply Risers Up-Feed	Branches to Supply Risers and Radiators Not Dripped	Return Risers
A	*B*	*C*	*D*	*E*	*F*	*G*	*H*	*Ia*	*J*
¾	----	----	----	----	----	----	30	----	190
1	111	79	65	56	49	46	56	26	450
1¼	245	173	141	122	110	100	122	58	990
1½	380	269	220	190	165	155	190	95	1500
2	771	546	446	386	345	315	386	195	3000
2½	1270	898	734	635	568	518	635	395	------
3	2326	1645	1342	1163	1040	948	1129	700	------
3½	3474	2457	2006	1737	1552	1419	1548	1150	------
4	4914	3475	2828	2457	2196	2011	2042	1700	------
5	9092	6429	5250	4546	4062	3712	------	3150	------
6	14,924	10,553	8618	7462	6669	6094			
8	31,066	21,967	17,935	15,533	13,880	12,682			
10	56,689	40,085	32,730	28,345	25,334	23,144			
12	90,985	64,336	52,530	45,492	40,660	37,145			

Different makes of supply and return valves, steam traps and other specialties vary as to capacity, therefore use size as recommended for any particular make. Vertical connections to be of same size as valve and trap used. Return horizontal runout to be not less than ¾ in.

Pipe Size Inches	Dry Return Main — Equivalent Length of Run from Boiler to Farthest Radiator in Feet						Wet Return Main — Equivalent Length of Run from Boiler to Farthest Radiator in Feet					
	100	200	300	400	500	600	100	200	300	400	500	600
K	*L*	*M*	*N*	*O*	*P*	*Q*	*R*	*S*	*T*	*U*	*V*	*W*
1	460	412	368	320	275	227	1400	1000	820	700	590	480
1¼	962	868	770	670	579	480	2400	1700	1420	1200	1020	860
1½	1512	1362	1210	1058	909	757	3800	2700	2260	1900	1560	1300
2	3300	2960	2640	2300	1980	1630	8000	5600	4500	4000	3360	2800
2½	5450	4900	4380	3800	3300	2770	13,400	9400	7600	6700	5700	4800
3	10,000	9000	8000	7000	6000	5000	21,400	15,000	12,300	10,700	9300	7800
3½	14,300	12,900	11,500	10,000	8600	7200	32,000	22,000	24,000	16,000	13,600	11,400
4	21,500	19,300	17,200	15,000	12,900	10,700	44,000	31,000	26,000	22,000	20,500	15,400

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INSTRUCTIONS FOR USING TABLE 14

[a]1. Radiator branches more than 8 ft. in length should be one size larger than shown in Column *I*.

2. This table is for systems which are open to atmosphere or operate under slight pressure or partial vacuum without use of vacuum pumps.

3. These tables apply where pipes are properly reamed. No allowances for defective material or workmanship have been made. (Also see Tables 7 and 8).

4. Capacities based on ¼ lb. condensation per square foot per hour equivalent radiation and actual diameter of standard pipe.

5. Extra length to be added to straight run of pipe for various fittings and valves to determine equivalent length. (See Table 4).

6. Mains are to be proportioned according to the equivalent length of run from the boiler or source of supply to the farthest radiators supplied by the main.

Determine equivalent length of run then use figures in corresponding Columns (*B* to *G*) for supply mains; (*L* to *Q*) for dry-return mains; (*R* to *W*) for wet-return mains for sizing the entire run.

For example: If the distance from boiler or source of supply to the farthest radiator on the longest main should be 300 ft., all mains are to be sized from Column *D;* if 400 ft., Column *E;* if 600 ft. Column *G*.

Supply and return risers are to be proportioned according to the equivalent length of run from the boiler or source of supply to the farthest radiator on each riser.

For supply risers determine the distance from the boiler to the farthest radiator served by that riser then use the figures in the corresponding Columns (*B* to *G*) for sizing each supply riser; providing the amount of radiation for that riser does not exceed amounts shown in Column *H*. Where supply riser capacities are found to be in excess of amounts shown in Column *H*, step up to necessary size indicated in that column.

For example: If the distance from the boiler or source of supply to the farthest radiator on a supply riser is 300 ft., that riser is to be sized from Column *D*, providing the amount of radiation does not exceed the amount shown in Column *H*. If the amount exceeds that in Column *H*, use amounts shown in Column *H* for sizing that entire riser.

If another riser taken from the same main as the one indicated is only 200 ft., this riser should be sized from Column *C*, providing the amount of radiation does not exceed that as shown in Column *H*.

For return risers determine the equivalent length of run in feet from the top of each riser to the boiler then use the figures in the corresponding Columns (*L* to *Q*) for sizing each riser.

For example: If the distance from the boiler or source of supply to the farthest radiator on a return riser is 300 ft., that riser is to be sized from Column *N*, providing the amount of radiation does not exceed the amount shown in Column *J*. If the amount exceeds that in Column *J*, use amounts shown in Column *J* for sizing that entire return riser.

7. For practical purposes the pipe sizes on the usual heating system may be determined by using the pressure drop indicated by the longest main and riser on that system, neglecting the separate computations for each separate shorter run.

8. Where it is necessary to drip a supply main or a supply riser or a branch to a supply riser, same should drip separately into a wet return. The drip for a vapor or a vacuum system may be taken into a dry return through a steam trap.

9. Pitch of mains should be not less than ¼ in. in 10 ft.; on horizontal branches to radiators and risers at least ½ in. in 10 ft.

10. In general it is desirable not to have a supply main smaller than 2 in. in diameter. When the supply main is larger than 2½ in. at the beginning, it is desirable that it shall not be smaller than 2½ in. at the end.

Table 15. Pipe Sizes for Vacuum Pump Systems, where Equivalent Length of Run from Boiler or Source of Supply to Farthest Radiator Exceeds 200 Ft.

Capacity in Sq. Ft. of Equivalent Radiation

Based on 4 oz. Total Pressure Drop

Pipe Size Inches	Equivalent Length of Pipe from Boiler to Farthest Radiator, Including Main and Riser. (See *Note 6.*) Supply Main Dripped and Branches to Risers Dripped—Steam and Condensate flowing in same direction.						Maximum Capacities	
	100 Ft.	200 Ft.	300 Ft.	400 Ft.	500 Ft.	600 Ft.	Supply Risers Up-Feed	Branches to Supply Risers and Radiators Not Dripped
A	*B*	*C*	*D*	*E*	*F*	*G*	*H*	*Ia*
¾	.....	....	....	....	....	....	....	....
1	111	79	65	56	49	46	56	26
1¼	245	173	141	122	110	100	122	58
1½	380	269	220	190	165	155	190	95
2	771	546	446	386	345	315	386	195
2½	1270	898	734	635	568	518	635	395
3	2326	1645	1342	1163	1040	948	1129	700
3½	3474	2457	2006	1737	1552	1419	1548	1150
4	4914	3475	2828	2457	2196	2011	2042	1700
5	9092	6429	5250	4546	4062	3712		3150
6	14,924	10,553	8618	7462	6669	6094	.....	.....
8	31,066	21,967	17,935	15,533	13,880	12,682	.....	.....
10	56,689	40,085	32,730	28,345	25,334	23,144	.....	.....
12	90,985	64,336	52,530	45,492	40,660	37,145	.....	.....a

Pipe Size Inches		Return Mains and Risers					
Riser	Main	100 Ft.	200 Ft.	300 Ft.	400 Ft.	500 Ft.	600 Ft.
	K	*L*	*M*	*N*	*O*	*P*	*Q*
....	¾	800	568	462	400	358	326
¾	1	1400	994	810	700	626	570
1	1¼	2400	1704	1387	1200	1073	976
1¼	1½	3800	2696	2195	1900	1698	1547
1½	2	8000	5680	4622	4000	3575	3256
2	2½	13,400	9510	7745	6700	5990	5453
2½	3	21,400	15,190	12,360	10,700	9565	8710
3	3½	32,000	22,710	18,490	16,000	14,300	13,020
3½	4	44,000	31,220	25,430	22,000	19,660	17,910

Different makes of supply and return valves, steam traps and other specialties vary as to capacity, therefore use size as recommended for any particular make. Vertical connection to be of same size as valve and trap used. Return horizontal runout to be no less than ¾ in.

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INSTRUCTIONS FOR USING TABLE 15

a1. Radiator branches more than 8 ft. in length should be one size larger than shown in Column *I*.

2. It is not generally considered good practice to greatly exceed 1 oz. drop in pressure in each 100 ft. equivalent length of run nor to exceed 1 lb. total pressure drop in any system.

3. These tables apply where pipes are properly reamed. No allowance for defective material or workmanship have been made. (Also see Tables 7 and 8).

4. Capacities based on ¼ lb. condensation per square foot per hour equivalent radiation and actual diameter of standard pipe.

5. Extra length to be added to straight run of pipe, for various fittings and valves to determine equivalent length. (See Table 4).

6. Mains are to be proportioned according to the equivalent length of run from the boiler or source of supply to the farthest radiators supplied by the main.

Determine equivalent length of run then use figures in corresponding Columns (*B* to *G*) for sizing the entire run.

For example: If the distance from boiler or source of supply to the farthest radiator on the longest main should be 300 ft., all mains are to be sized from Column *D;* if 400 ft., Column *E;* if 600 ft., Column *G*.

Supply risers are to be proportioned according to the equivalent length of run from the boiler or source of supply to the farthest radiator on each riser. Determine the distance to the farthest radiator then use figures in corresponding Columns (*B* to *G*) for sizing each riser; providing the amount of radiation for that riser does not exceed amounts shown in Column *H*. Where riser capacities are found to be in excess of amounts shown in Column *H*, step up to necessary size indicated in that column.

For example: If the distance from the boiler or source of supply to the farthest radiator on a supply riser is 300 ft., that riser is to be sized from Column *D*, providing the amount of radiation does not exceed the amount shown in Column *H*. If the amount exceeds that in Column *H*, use amounts shown in Column *H* for sizing that entire riser.

If another riser taken from the same main as the one indicated is only 200 ft., this riser should be sized from Column C, providing the amount of radiation does not exceed that as shown in Column *H*.

7. For practical purposes the pipe sizes on the usual heating system may be determined by using the pressure drop indicated by the longest main and riser on that system, neglecting the separate computations for each separate shorter run.

8. Return mains and risers are to be proportioned according to the equivalent distance in feet, from farthest radiator to the vacuum pump; using capacities in corresponding Columns (*L* to *Q*) for sizing entire return riser (Column *J*) and return main (Column *K*). The return pipe sizes are conservative and are subject to revision upon the completion of pending research investigations.

9. Where it is necessary to drip a supply main, supply riser or branch to a supply riser, same should be dripped separately through a steam trap into vacuum return. Never drip a supply riser into a vacuum return, except through a steam trap.

10. Lift fittings. (See page 161).

11. Pitch of mains should be not less than ¼ in. in 10 ft.; on horizontal branches to radiators and risers at least ½ in. in 10 ft.

Table 16. Pipe Sizes for Vacuum Pump Systems, where Equivalent Length of Run from Boiler or Source of Supply to Farthest Radiator Exceeds 200 Ft.

Capacity in Sq. Ft. of Equivalent Radiation

Based on 8 oz. Total Pressure Drop

Pipe Size In.	Equivalent Length of Pipe from Boiler to Farthest Radiator, Including Main and Riser. (See *Note 6.*) Supply Main Dripped and Branches to Risers Dripped—Steam and Condensate flowing in same direction.									Maximum Capacities	
	100 Ft.	200 Ft.	300 Ft.	400 Ft.	500 Ft.	600 Ft.	800 Ft.	1000 Ft.	1200 Ft.	Supply Risers Up-Feed	Branches to Supply Risers and Radiators Not Dripped
A	*B*	*C*	*D*	*E*	*F*	*G*	*H*	*I*	*J*	*K*	*La*
1	157	111	92	79	70	65	56	49	46	56	26
1¼	346	245	200	173	154	141	122	110	100	122	58
1½	538	380	310	269	240	220	190	165	155	190	95
2	1091	771	630	546	487	446	386	345	315	386	195
2½	1797	1270	1036	898	803	734	635	568	518	635	395
3	3289	2326	1896	1645	1470	1342	1163	1040	948	1129	700
3½	4913	3474	2838	2457	2196	2006	1737	1552	1419	1548	1150
4	6950	4914	4022	3475	3106	2828	2457	2196	2011	2042	1700
5	12,858	9092	7424	6429	5747	5250	4546	4062	3712	.....	3150
6	21,105	14,924	12,168	10,553	9433	8618	7462	6669	6084	.....	.....
8	43,934	31,066	25,364	21,967	19,638	17,935	15,533	13,880	12,682	.....	.....
10	80,171	56,689	46,288	40,085	35,836	32,730	28,345	25,334	23,144	.....	.....
12	128,672	90,985	74,290	64,336	57,516	52,530	45,492	40,660	37,145	.....	.....
16	240,245	169,879	138,381	121,012	107,389	98,500	84,849	75,917	69,671	.....	.....

Pipe Size Inches		Return Mains and Risers									
Riser	Main	100 Ft.	200 Ft.	300 Ft.	400 Ft.	500 Ft.	600 Ft.	800 Ft.	1000 Ft.	1200 Ft.	
M	*N*	*O*	*P*	*Q*	*R*	*S*	*T*	*U*	*V*	*W*	
.....	¾	1130	800	653	568	505	462	400	358	326	Different makes of supply and return valves, steam traps and other specialties vary as to capacity, therefore use size as recommended for any particular make. Vertical connection to be of same size as valve and trap used. Return horizontal runout to be not less than ¾ in.
¾	1	1977	1400	1143	994	884	810	700	626	570	
1	1¼	3390	2400	1960	1704	1515	1387	1200	1073	976	
1¼	1½	5370	3800	3103	2696	2400	2195	1900	1698	1547	
1½	2	11,300	8000	6533	5680	5050	4622	4000	3575	3256	
2	2½	18,925	13,400	10,940	9510	8460	7745	6700	5990	5453	
2½	3	30,230	21,400	17,460	15,190	13,510	12,360	10,700	9565	8710	
3	3½	45,200	32,000	26,130	22,710	20,200	18,490	16,000	14,300	13,020	
3½	4	62,180	44,000	35,950	31,220	27,800	25,430	22,000	19,660	17,910	
4	5	109,300	77,400	63,200	54,920	48,800	44,720	38,700	34,600	31,500	
5	6	175,100	124,000	101,200	88,000	78,200	71,700	62,000	55,410	50,450	

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INSTRUCTIONS FOR USING TABLE 16

a1. Radiator branches more than 8 ft. in length should be one size larger than shown in Column *L*.

2. It is not generally considered good practice to greatly exceed 1 oz. drop in pressure in each 100 ft. equivalent length of run nor to exceed 1 lb. total pressure drop in any system.

3. These tables apply where pipes are properly reamed. No allowances for defective material or workmanship have been made. (Also see Tables 7 and 8).

4. Capacities based on ¼ lb. condensation per square foot per hour, equivalent radiation and actual diameter of standard pipe.

5. Extra length to be added to straight run of pipe, for various fittings and valves to determine equivalent length. (See Table 4).

6. Mains are to be proportioned according to the equivalent length of run from the boiler or source of supply to the farthest radiators supplied by the main.

Determine equivalent length of run, then use figures in corresponding Columns (*B* to *J*) for sizing the entire run.

For example: If the distance from boiler or source of supply to the farthest radiator on the longest main should be 300 ft., all mains are to be sized from Column *D;* if 400 ft., Column *E;* if 600 ft., Column *G*.

Supply risers are to be proportioned according to the equivalent length of run from the boiler or source of supply to the farthest radiator on each particular riser. Determine the distance to the farthest radiator then use figures in corresponding Columns (*B* to *J*) for sizing each riser; providing the amount of radiation for that riser does not exceed amounts shown in Column *K*. Where riser capacities are found to be in excess of amounts shown in Column *K*, step up to necessary size indicated in that column.

For example: If the distance from the boiler or source of supply to the farthest radiator on a supply riser is 300 ft., that riser is to be sized from Column *D*, providing the amount of radiation does not exceed the amount shown in Column *K*. If the amount exceeds that in Column K, use amounts shown in Column *K* for sizing that entire riser.

If another riser taken from the same main as the one indicated is only 200 ft., this riser should be sized from Column *C*, providing the amount of radiation does not exceed that as shown in Column *K*.

7. For practical purposes the pipe sizes on the usual heating system may be determined by using the pressure drop indicated by the longest main and riser on that system, neglecting the separate computations for each separate shorter run.

8. Return mains and risers are to be proportioned according to the equivalent distance in feet, from farthest radiator to the vacuum pump; using capacities in corresponding Columns (*O* to *W*) for sizing entire return riser (Column *M*) and return main (Column *N*). The return pipe sizes are conservative and are subject to revision upon the completion of pending research investigations.

9. Where it is necessary to drip a supply main, supply riser or branch to a supply riser, same should be dripped separately through a steam trap into vacuum return. Never drip a supply riser into a vacuum return except through a steam trap.

10. Lift fittings. (See page 161).

11. Pitch of mains should be not less than ¼ in. in 10 ft.; on horizontal branches to radiators and risers at least ½ in. in 10 ft.

12. In general it is desirable not to have a supply main smaller than 2 in. in diameter. When the supply main is larger than 2½ in. at the beginning, it is desirable that it shall not be smaller than 2½ in. at the end.

the use of check valves. In using this connection, the wet return connects through the shortest possible horizontal pipe 2 in. below the normal boiler water line into the pipe which joins the boiler outlet and boiler inlet on the boiler side of the stop valves. By this arrangement, if a careless operator should close the boiler outlet valve and should forget to close the boiler inlet valve, no water below the level of the inlet connection to the loop could leave the boiler. It is of value only when the boilers are used in gravity circulating systems.

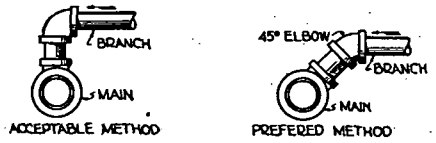


FIG. 8. ACCEPTABLE AND PREFERRED METHODS OF TAKING BRANCH FROM MAIN

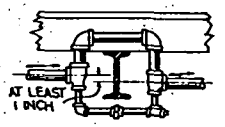


FIG. 9. LOOPING MAIN AROUND BEAM

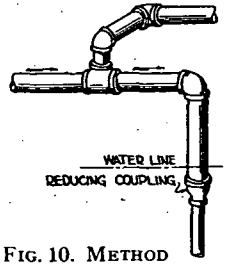


FIG. 10. METHOD OF DRIPPING MAIN WHERE IT RISES TO HIGHER LEVEL

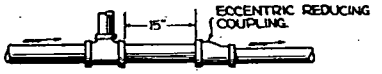


FIG. 11. METHOD OF REDUCING SIZE OF MAIN

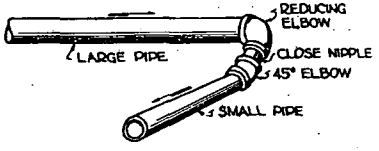
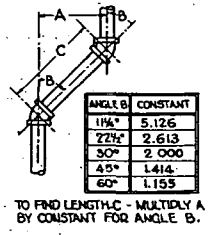


FIG. 12. REDUCING SIZE OF MAIN AT SWING CONNECTION



ANGLE B	CONSTANT
11¼°	5.126
22½°	2.613
30°	2.000
45°	1.414
60°	1.155

FIG. 13. CONSTANTS FOR DETERMINING PROPER LENGTH OF OFFSET PIPE

Connections to Mains

Fig. 8 shows two methods of taking off branches from mains on one-pipe systems. They apply equally well, however, to other systems of up-feed piping. On one-pipe plants the branches are always made one pipe-size larger than the risers or the radiator connections which they serve. The method of carrying a main past an obstructing beam shown in Fig. 9 may be used advisedly with any system of piping.

Fig. 10 shows a detail of piping at the end of a single-pipe main or at any point where it becomes desirable to rise for a fresh start at a higher level, the steam rising off the top of the main and the water draining

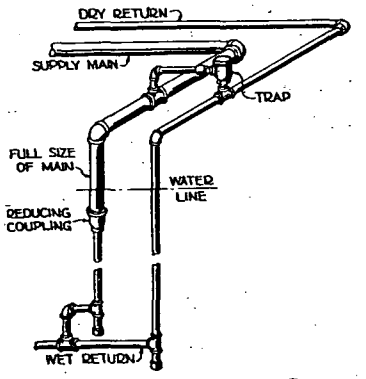


FIG. 14. DRIPPING ENDS OF SUPPLY AND DRY RETURN MAINS. (DRY RETURN TOO SMALL TO BE VENTED)

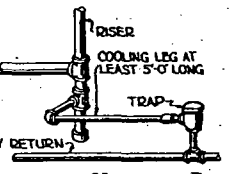


FIG. 15. DRIPPING HEEL OF RISER INTO DRY RETURN. (A GATE VALVE IS RECOMMENDED AT THE INLET SIDE OF THE TRAP)

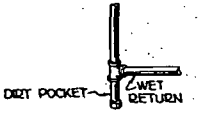


FIG. 16. DIRT POCKET CONNECTION

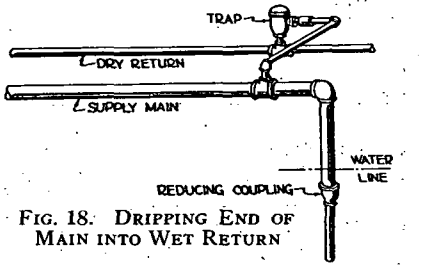


FIG. 18. DRIPPING END OF MAIN INTO WET RETURN

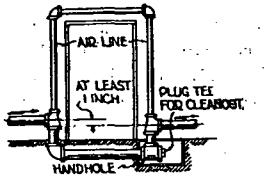


FIG. 17. LOOPING DRY RETURN MAIN AROUND OPENING

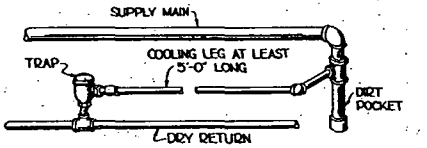


FIG. 19. DRIPPING END OF MAIN INTO DRY RETURN. (A GATE VALVE IS RECOMMENDED AT THE INLET SIDE OF THE TRAP)

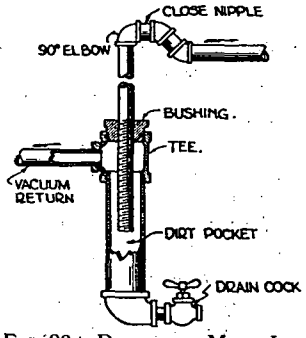


FIG. 20. DETAIL OF MAIN LIFT FITTING TO VACUUM PUMP

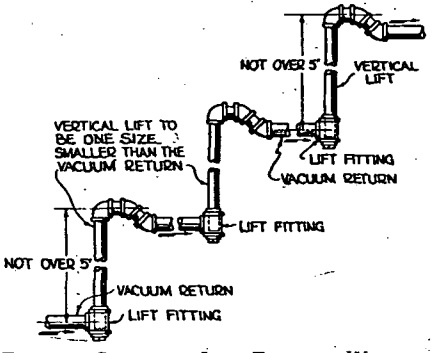


FIG. 21. SERIES OF LIFT FITTINGS WHERE LIFT IS MORE THAN 5 FT.

down to the wet return below the boiler water line. If the detail shown in Fig. 10 is used at the end of the main, an air valve must be installed above the water line.

Where it is desired to reduce the size of a supply main, an eccentric fitting always must be used, as shown in Fig. 11, or a reducing elbow must be installed, as in Fig. 12, so that complete drainage is accomplished. These details also apply to any other system of steam piping.

A handy rule for cutting the proper length of offset pipe is illustrated in Fig. 13.

Piping Connections for Vapor and Vacuum Systems

In Figs. 14 to 19, inclusive, are illustrated some of the piping details which are recommended in connection with vapor and vacuum heating. Figs. 14 and 18 show methods of draining and venting the ends of supply mains where a return below the boiler water line is used. Fig. 19 shows the same detail where the return main is above the water line. Fig. 15 shows the method of draining the ends of long branches from supply mains to risers or to remote radiators. Fig. 16 shows a sediment chamber which will catch debris in any vapor or vacuum system, this being cleaned occasionally, preventing the foreign matter from stopping up or injuring the traps or other mechanisms. Fig. 17 illustrates an approved method for carrying a return main which runs near the floor, past a door. The air in the upper part of the main rises freely over the door, while the water passes in the trench under the door.

It is considered good practice, when it is necessary to use a lift for the returns of part of a vacuum pump system, to cause the returns from all of the system to be lifted at the vacuum pump. With this condition, the float governor, often furnished with vacuum pumps for normal gravity flow conditions, should be omitted, as its presence on a system with a lift usually leads to misunderstanding and eventual trouble.

Figs. 20 and 21 illustrate approved details of the return pipes leading to vacuum pumps where there must be lifts from low-lying mains up to the pump. These lifts should be avoided wherever possible.

Heater Connections

Figs. 22, 23 and 24 are typical illustrations of various approved heater connections. They may apply to vapor systems and to vacuum systems.

Fig. 25 shows the typical vacuum or vapor system connections to an old-fashioned steam-type radiator. Fig. 26 shows approved connections to a heater below the supply main, with the valve above the main. Fig. 27 shows approved down-feed connections to a wall-type heater with returns and drips running to a wet return main. When such an arrangement as this is used for the supply connections it becomes permissible to place the valve at the radiator inlet in the conventional manner.

Figs. 28 to 34, inclusive, illustrate typical approved connections to cabinet-enclosed and other non-ferrous heaters. Connections to such heaters often are troublesome. It is desirable where practicable, to place both the supply valve and the trap in the basement or at least to place them outside of the heater enclosures. It is exceedingly important that no expansion and contraction strains from the piping shall be brought to

bear against any convector, since not only damage but also annoying creaking noises may follow such strain.

Figs. 36 and 37 show typical connections to indirect cast iron convector-

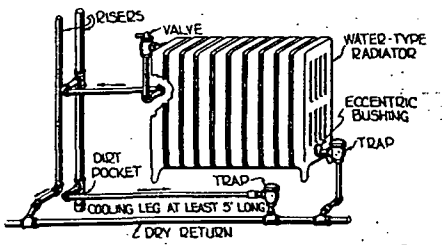


FIG. 22. TOP AND BOTTOM OPPOSITE END RADIATOR CONNECTIONS WITH HEEL OF DOWN FEED RISER DRIPPED INTO DRY RETURN

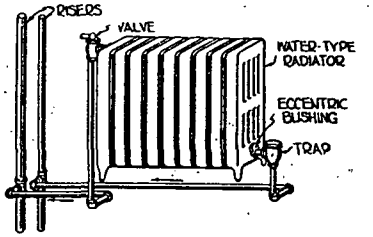


FIG. 23. TOP AND BOTTOM OPPOSITE END RADIATOR CONNECTIONS FROM UP OR DOWN FEED RISERS

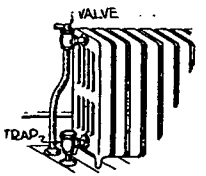


FIG. 24. TOP AND BOTTOM SAME END RADIATOR CONNECTIONS FROM UP OR DOWN FEED RISERS. (NOT TO EXCEED 8 TO 10 SECTIONS).

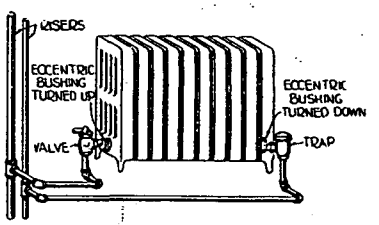


FIG. 25. CONNECTIONS TO STEAM TYPE RADIATOR

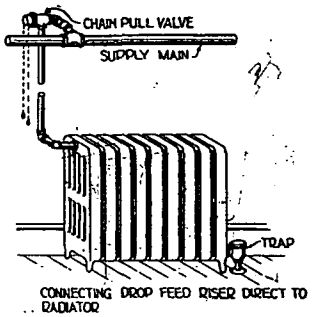


FIG. 26. CONNECTING DROP FEED RISER DIRECT TO RADIATOR BY TURNING VALVE ON ITS SIDE

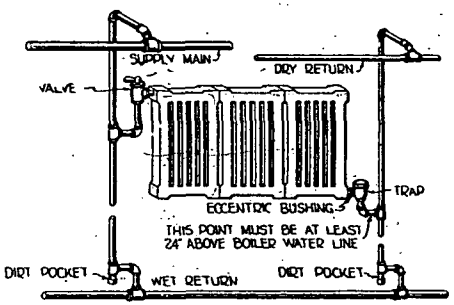


FIG. 27. CONNECTIONS TO RADIATOR HUNG ON WALL

heaters, and apply to vapor and vacuum systems especially. Figs. 35 and 38 show duct connections to such heaters.

Pipe Coil Connections

Fig. 39 shows practicable piping connections to pipe coils. It is important that the supply valves for all radiators which come below the

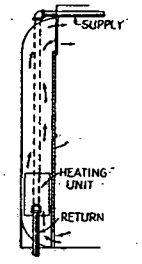


FIG. 28. FIN TYPE RADIATOR NEAR BASEMENT CEILING

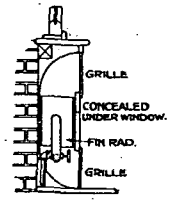


FIG. 29. FIN TYPE RADIATOR CONCEALED UNDER WINDOW

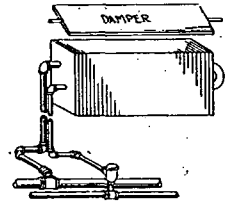


FIG. 30. FIN TYPE RADIATOR CONNECTIONS SAME END

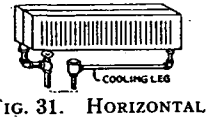


FIG. 31. HORIZONTAL SECTIONAL FIN TYPE RADIATOR

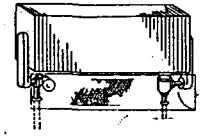


FIG. 32. FIN TYPE RADIATOR VALVES BEHIND GRILLE

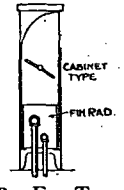


FIG. 33. FIN TYPE RADIATOR CONCEALED IN CABINET

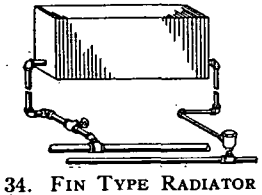


FIG. 34. FIN TYPE RADIATOR WITH VALVES IN BASEMENT

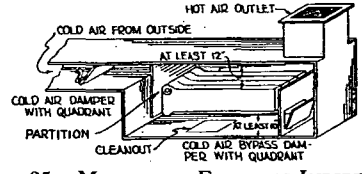


FIG. 35. METHOD OF ENCASING INDIRECT RADIATOR WITH HOT AIR OUTLET IN FLOOR

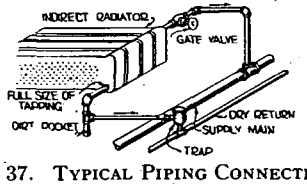


FIG. 37. TYPICAL PIPING CONNECTIONS TO INDIRECT RADIATORS WITH DRY RETURN

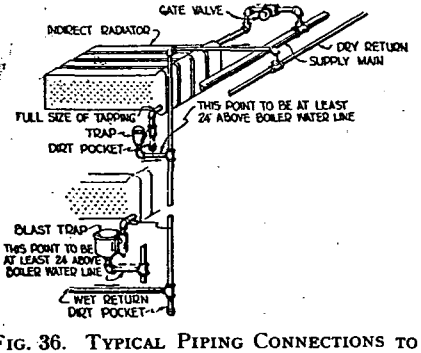


FIG. 36. TYPICAL PIPING CONNECTIONS TO INDIRECT RADIATORS WITH WET RETURN

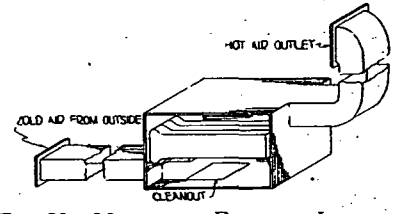


FIG. 38. METHOD OF ENCASING INDIRECT RADIATOR WITH HOT AIR OUTLET IN WALL

supply mains shall be above these mains, or that there shall be a drainage connection consisting of a trap or of a pipe leading to the wet return, depending on the type of system, above these supply valves. Without such provision water will condense above the valves when they are closed,

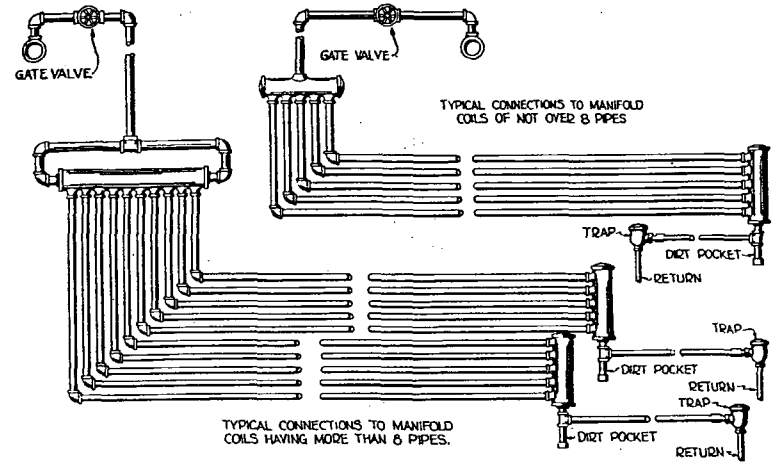


FIG. 39. TYPICAL PIPE COIL CONNECTIONS

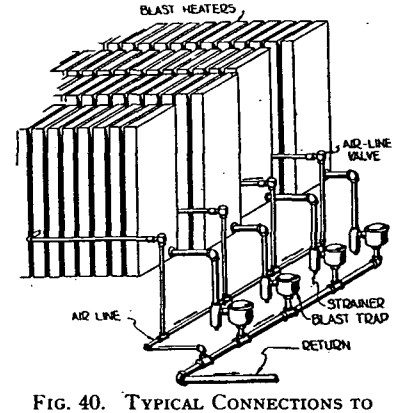


FIG. 40. TYPICAL CONNECTIONS TO BLAST COILS EXCEEDING 12 SECTIONS

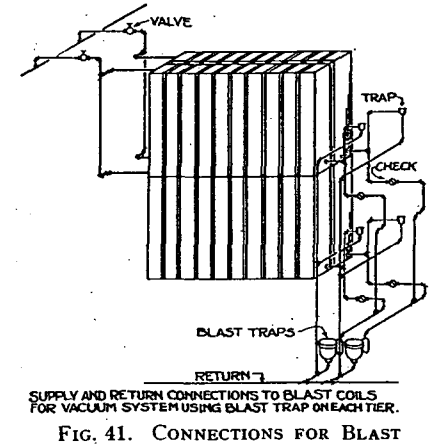


FIG. 41. CONNECTIONS FOR BLAST HEATERS

and this may cause objectionable noise or damage when the valves are opened.

Blast Heater Connections

Fig. 40 shows vacuum system returns for fan-blast heaters with the auxiliary air vent piping and air-line valves usually required with these heaters, especially when they are of cast-iron.

Fig. 41 illustrates another typical blast heater piping hook-up frequently encountered, but with which only the return ends have auxiliary air vents. It is to be noted that while the two super-imposed heaters may drain to a trap common to both, the successive layers of heaters with reference to the air flow from the fan should each have a separate trap, since the condensation rate varies in each successive layer after its predecessor has warmed the entering air.

Unit Heater Connections

When unit heaters are used with steam heating systems the designer must always take into consideration the great condensing capacity of these devices. They must be placed high enough above the boiler water line to compensate for the pressure drop or must be used with systems having pumps or other positive return devices, and must always have pipe connections proportional to their maximum heat emission. Some typical details of unit heater connections are shown in Chapter 35.

Equalizer Connection

Low pressures may be produced in the supply piping and in the boiler of any well-built vacuum heating system by means of the vacuum of condensation. This may prevent drainage of the heating units to the pump despite the efforts of the vacuum pump.

It is desirable, therefore, to install a cross-connection with a check valve between the supply main and the vacuum return main, which will:

1. Prevent such an induced vacuum in the supply main exceeding the vacuum in the return main, by opening a check valve to equalize the pressures in the two mains.
2. Allow a higher vacuum to be carried in the return main than in the supply main by keeping the check valve closed.

This device has solved many complaints, especially where oil or gas fuels are used.

IMPORTANCE OF LAYOUT

With the increasing use of automatic temperature control, the proper layout of the steam mains to secure even distribution of the steam to all the radiators is of importance. It is not sufficient that the pipes be properly designated to carry the maximum amount of steam. Steam heating systems are operated at their maximum capacity only for a fraction of the time and they should be designed to distribute evenly at reduced capacity. Almost any piping layout will give heat in sufficient quantities to all the radiators for zero weather if the pipes are large enough, but this is only one of the requirements; the system must be capable of operating efficiently at reduced capacities. Hence the importance of careful and intelligent arrangement of the steam mains.

Chapter 10

DEVICES FOR HANDLING CONDENSATE AND AIR

Weight of Condensate; Condensation Pumps; Vacuum Heating Pumps; Traps.

THIS chapter deals with certain proprietary devices used with steam heating systems. Other equipment and accessories for steam systems, such as boilers, radiators and piping are treated elsewhere in THE GUIDE. Information concerning specific products will be found in the Catalog Data Section. The *Hydraulic Society's Standards* give descriptions of pumps for various services, standard equipment and installation data.

In the selection of devices for handling condensate it is, of course, necessary to know the weight of condensate to be handled. For systems employing the use of direct radiators, the normal rate of flow is 0.25 lb of condensate per square foot of equivalent direct *radiation* (EDR) per hour. However, an allowance must be made for the increased rate of condensation during heating-up periods.

The rate of condensation per square foot per hour for a cast-iron column type radiator for the time elapsing after the steam is turned into the radiator is given by Fig. 2, Chapter 6. The maximum rate of condensation occurs about 10 minutes after steam is turned into the cold radiator and amounts to approximately 3½ times the normal rate. At the end of about 25 minutes the radiator reaches a normal rate of condensation. The average rate of condensation during the first 20 to 25 minutes as found by integrating the area under the curve and determining the mean ordinate is 0.50 lb per square foot per hour or twice the average rate. With pressed metal or pipe coil radiators the condensation rate would be somewhat less due to the fact that the weight of metal being heated is less per square foot than with the cast-iron types.

The normal weight of condensate to be handled from indirect or central fan systems may be estimated by means of the following formula:

$$W = \frac{Q \times 60 \times T}{55.6 \times h_{fg}} \qquad (1)$$

where

W = weight of condensate, pounds per hour.
Q = volume of air, cubic feet per minute.
T = temperature rise of air, degrees Fahrenheit.
h_{fg} = latent heat of steam in the system, Btu per pound.

CONDENSATION PUMPS

Condensation pumps are in general required when the elevation of the boiler with respect to the heating units is such that the condensate will not return by gravity or when the boiler pressure is greater than that supplied the heating units, as for example, a high pressure boiler installation supplying steam through a reducing valve to the heating units. The condensate is generally returned by gravity to a receiver, ordinarily vented to the atmosphere, from which it flows to the pump and forced into the boiler. This is not a closed circuit and the relative elevation of the heating units and the boiler water line is not important, as it is where the condensate is returned to the boiler by gravity due to the static head of water in the return mains.

Condensation return pumps are assembled with tank or receiver and arranged for either continuous operation or for automatic starting and stopping by float control. Any style of water pump may be employed for this service, and the source of power will determine the mode of drive, either steam or electric. For low pressure heating systems, the motor-driven, automatic, centrifugal pump and receiver has, however, found wide acceptance in practice.

Capacity ratings are given in equivalent square feet (EDR) and are based on condensation values 2 to 3 times the normal rate. An indication of capacities with power requirements for one type of electric condensation pump is given in Table 1. These commercial capacities, however, are for water at a temperature of 180 F. For any higher temperature of condensate, which may be due to steam leaking into the returns, a correction factor is necessary to allow for the inability of the pump to handle its full capacity under this operating condition. The capacity of the unit selected should be increased according to the following factors:

Temperature at Suction Pump (Deg Fahr)	Factor
190	1.15
200	1.56
204	2.00

If a special assembly be made so that the receiving tank is some height above the pump suction inlet, to give sufficient static head, it may be possible to handle water temperatures slightly higher than 180 F without increasing the size of pump over that for standard requirements.

VACUUM HEATING PUMPS

Vacuum pumps differ from condensation pumping units by the additional feature of mechanical or positive means for the removal of air from the system. A vacuum heating pump is therefore a combination for the removal of air and water, and for the return of the condensate to the boiler, or to some other intercepting device that may be employed in plants having mixed systems of heating and other services. Pumps of this classification may be driven by steam or electrical means; they may be continuous in operation, or automatic, with float control or vacuum control in one or more combinations.

Motor-Driven Vacuum Pumps

Motor-driven return-line vacuum pumps may be classified as follows

1. Separation of air by venting to atmosphere.
   - *a.* Water piston pumps.
   - *b.* Water jet pumps.
     - (1) Stationary jet.
     - (2) Rotary jet.
2. Separation of air under a vacuum.

Separation by Venting to Atmosphere

Water Piston Pumps. Pumps operating under this principle may or may not have a receiver between the pump suction and the return system. They are equipped with one rotor, which withdraws air or water, or both air and water, depending on conditions in the receiver or in the system, and this rotor discharges all of the air and water handled into a separating tank. The separating tank is vented to the atmosphere so that the air is freed against atmospheric pressure. The water, after separation, is then handled a second time by a centrifugal rotor and discharged to the boiler.

Stationary Jet Pumps. These pumps may or may not be equipped with a receiver between the pump suction and the return system. When the jet type of pump is handling air it is discharging this air and some water withdrawn from the system into a receiver, which is vented to the atmosphere. This water of condensation is then picked up by a second centrifugal water impeller and discharged. At times water handled by the pump for the vacuum producing jet may be by-passed to the boiler by means of a valve operated by a float in the receiver.

Rotary Jet Pump. The operation of rotary jet pumps equipped with rotary jets is similar to the operation of pumps equipped with stationary jets. To secure increased air capacity, however, a rotary jet pump employs an impeller which discharges an annular screen of water from its

Table 1. Characteristics of Centrifugal Return Pumps and Receivers Delivering Against Various Pressures

Rating Square Feet Equivalent Cast-Iron Direct Radiation	Actual Measured Water Capacity Gallons per Minute	Motor Horsepowers Discharge Pressure, Pounds per Square Inch at Pump					
		10 lb.	20 lb.	30 lb.	40 lb.	50 lb.	60 lb.
2,000	4	⅓	½	¾	1	1	2
4,000	6	⅓	½	¾	1	1	2
6,000	8	⅓	½	¾	1	1½	2
8,000	11	⅓	½	¾	1	1½	2
10,000	13	⅓	½	¾	1	1½	2
12,000	16	½	¾	1	1½	1½	...
16,000	22	½	¾	1	1½	1½	...
26,000	35	¾	1	1½	3	5	7½
40,000	60	1½	2	3	5	7½	10
65,000	90	1½	3	5	5	7½	10
100,000	150	2	5	7½	7½	10	15
150,000	200	3	5	7½	10	15	15

periphery, thus constituting the rotary jet. These pumps employ a second impeller to pick up the condensate from the separating tank and discharge it to the boiler.

Separation Under a Vacuum.

Pumps operating under this principle are equipped with a receiver maintained under vacuum, located between the pump suction and the return line. These pumps have individual air and water rotors which take their respective suctions directly from this receiver, simultaneously delivering the air to the atmosphere and the condensation to the boiler. The air pump is water-sealed, a small volume of water continually passing through the air pump back to the receiver.

Reciprocating Vacuum Pumps

Reciprocating return-line vacuum heating pumps may be either steam-driven or power-driven. The determination of the size of reciprocating vacuum pumps should take into consideration the following factors:

1. The degree of tightness of system.
2. The efficiency of the radiator traps.
3. The temperature of the condensate at the pump.
4. The probable cooling effect of the return piping.
5. The use of lifts in the return.
6. Vacuum to be maintained at the pump.
7. Introduction of large volumes of high temperature water into the return piping near the pump.
8. The use of long runs of piping from the source of steam supply to the farthest radiator.

Steam cylinder sizes of reciprocating vacuum pumps should include the effect of frictional resistance of the piping system, the pump resistance and the possible drop in steam pressure under unusual conditions. When this analysis is not feasible the following formula may be used:

$$A_s = A_w S \left(\frac{\frac{V}{2} + P_d}{P_b} \right) \qquad (2)$$

where

A_s = area of steam piston, square inches.
A_w = area of water piston, square inches.
P_b = boiler pressure, pounds per square inch.
P_d = discharge pressure, pounds per square inch.
V = vacuum at pump expressed, inches of mercury.
$\frac{V}{2}$ = approximate vacuum, pounds per square inch (2 in. mercury = approximately 1 lb per square inch).

Water cylinder sizes of steam-driven reciprocating vacuum heating pumps may be determined from Table 2. All pumps of this type should be provided with mechanical lubricators. The piston speed in feet per minute of steam-driven pumps should not be more than 20 times the square root of the number of inches in the length of stroke.

The volumetric displacement rate of the water cylinders of steam or

power-driven pumps should be from 8 to 10 times the volumetric rate of flow of the condensate to be handled. The speed of crank shafts of power-driven reciprocating return-line vacuum pumps should not exceed the following:

LENGTH OF STROKE (INCHES)	MAXIMUM CRANK SHAFT SPEED (RPM)
3	80
6	50
8	50
12	40
20	25

Air and Water Capacities

The water and air capacities of vacuum heating pumps are usually referred to in terms of square feet of equivalent heating surface (radiation).

Air to be Handled. The volume of air to be handled depends to a large extent on the vacuum carried and on the type of heating system, that is, whether direct or indirect (central fan). The air requirements are in general proportional to the square feet of equivalent heating surface (240 Btu per square foot) but should be assumed on a decreasing ratio. Approximate values are given in Table 3. The amount of air to be handled for central fan systems or so-called fan blast heaters, although actually less than that for direct heating systems, is usually estimated on the same basis.

Air Capacity of Pumps. In reciprocating pumps the actual volume of air handled may be easily calculated and is equal to the displacement

TABLE 2. CAPACITIES OF VARIOUS SIZES OF DIRECT DOUBLE ACTING STEAM-DRIVEN RECIPROCATING VACUUM PUMPS (FOR STEAM PRESSURE 50 LB. AND ABOVE)

SIZE, INCHES	SQUARE FEET OF DIRECT RADIATION
4 x 3 x 6	1,700
4 x 3⅝ x 6	2,500
4 x 4 x 6	3,000
4 x 4½ x 6	3,800
4 x 5 x 6	4,700
4 x 5 x 8	6,500
4½ x 6 x 8	10,000
5 x 6 x 10	11,000
5 x 6½ x 10	13,000
5 x 7¼ x 10	17,000
6 x 8 x 12	25,000
8 x 10 x 12	40,000
8 x 12 x 12	55,000
10 x 14 x 12	75,000
10 x 14 x 16	85,000
10 x 14 x 20	100,000
12 x 16 x 20	130,000
14 x 18 x 20	160,000
16 x 20 x 20	200,000
16 x 22 x 20	240,000

minus the slip. In rotary and jet pumps, however, it is not usually possible to calculate displacement volumes nor are volumetric efficiencies of these pumps known. Tests are therefore necessary in order to ascertain the amount of air the pump will handle. One method is by means of orifices one-eighth of an inch thick with sharp edges. Orifices having varying diameters of openings are placed in the return line and the vacuum which the pump will produce against each orifice is recorded. In this way the capacities may be determined at several points throughout the operating range of the pump and a characteristic curve plotted. Fig. 1 may be used for approximating the volume of air which can be

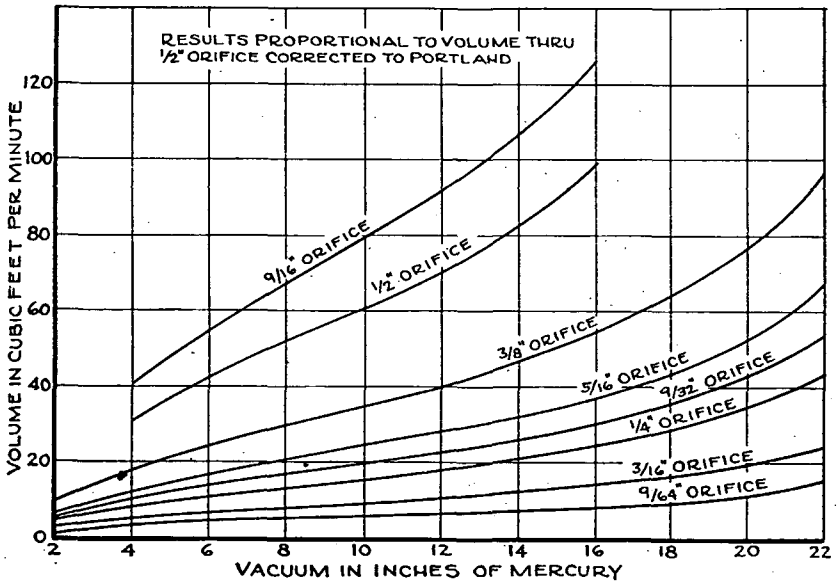


FIG. 1. VOLUME OF AIR IN CUBIC FEET PER MINUTE THROUGH ORIFICES FOR VARIOUS DEGREES OF VACUUM[a]

[a]The curves for ½ in. and 9/16 in. orifices are based on tests conducted on thin plate, ⅛ in. thick orifices with sharp edges. The volumes for the other orifices are estimated from these two curves. All volumes are based on the vacuum indicated. The volume corresponds to the displacement multiplied by the volumetric efficiency of a reciprocating unit.

handled with various sizes of orifices and degrees of vacuum. It should be noted that the volumes given are measured at the vacuum referred to and are not in terms of free air per minute. The air volume thus shown in Table 3 corresponds to the net volume which, in the case of a reciprocating pump, would be the displacement times the volumetric efficiency. With some types of pumps the air capacity is decreased if the pump is discharging the condensate against a head. Accordingly, when making such a test for vacuum the water capacity of the pump in gallons per minute against some specified head should be stated.

Water Capacity. The water capacity of vacuum heating pumps should be based on not less than ⅔ lb of condensate per hour per square foot of equivalent cast-iron direct radiation with condensate at a temperature of

180 F when the pump is delivering the rated capacity of condensate against the specified gage pressure at the discharge of the pump. In some types of pumps the air capacity is diminished at the maximum rate of discharge of condensate. Hence, any statement regarding the water capacity should include a simultaneous reading of the orifice size and the vacuum maintained. In estimating the water capacity no additional allowance need be made for covered mains or risers, but exposed mains or risers used as heating surfaces should be included in computing the equivalent square feet of direct radiation.

TRAPS

Traps are used for draining the condensate from radiators, steam piping systems, kitchen equipment, laundry equipment, hospital equipment, drying equipment and many other kinds of apparatus. The usual function of a trap is to allow the passage of condensate and to prevent the passage of steam. In addition to these functions, traps are frequently required to allow the passage of air as well as condensate. Traps are also required to allow the passage of air and to prevent the passage of either water or steam, or both.

In addition, traps are used for returning condensate either by gravity, by steam pressure, or by both, to a boiler or other point of disposal. Also for lifting condensate from a lower to a higher elevation, or for handling condensate from a lower to a higher pressure.

The fundamental principle upon which the operation of practically all traps depends is that the pressure within the trap at the time of discharge shall be equal to, or slightly in excess of, the pressure against which the trap must discharge, including the friction head, velocity head and static head on the discharge side of the trap. If the static head is in favor of the trap discharge it is a minus quantity and may be deducted from the other factors of the discharge head.

Traps may be classified according to the principle of operation as (1) float, (2) bucket, (3) thermostatic, or (4) tilting traps.

Float Traps. A discharge valve is operated by the rise and fall of a float due to the change of water level in the trap. When the trap is empty the float is in its lowest position, and the discharge valve is closed. A gage glass indicates the height of water in the chamber.

Unless float traps are well made and proportioned there is danger of considerable

TABLE 3. WATER AND AIR CAPACITIES FOR VACUUM HEATING PUMPS

(Air and Water at 70 F. Pressure, 10 lb. Vacuum, 10 in.)

RATING (EDR)	WATER CAPACITY (GPM)	AIR CAPACITY AT 10 IN. OF MERCURY (CFM)
2500	4	3
5000	9	3
10,000	14	6
16,000	22	9
26,000	35	15
40,000	60	19
65,000	90	34
100,000	140	50

steam leakage through the discharge valve due to unequal expansion of the valve and seat and the sticking of moving parts. The discharge from a float trap is usually continuous since the height of the float, and consequently the area of the outlet, is proportional to the amount of water present.

Bucket Traps. Bucket traps are of two types, the upright and inverted, and although they are both of the open float construction, their operating principle is entirely different. In the *upright bucket* trap, the water of condensation enters the trap and fills the space between the bucket and the walls of the trap. This causes the bucket to float and forces the valve against its seat, the valve and its stem usually being fastened to the bucket. When the water rises above the edges of the bucket it flows into it and causes it to sink, thereby withdrawing the valve from its seat. This permits the steam pressure acting on the surface of the water in the bucket to force the water to a discharge opening. When the bucket is emptied it rises and closes the valve and another cycle begins. The discharge from this type of trap is intermittent.

In the *inverted bucket* trap, steam floats the inverted submerged bucket and closes the valve. Water entering the trap fills the bucket which sinks, and through compound leverage opens the valve and the trap discharges. It is impossible to install a water gage glass on an inverted bucket trap, but if visual inspection is necessary, a gage glass can be placed on the line leading to the trap. No air relief cocks can be used, but this is

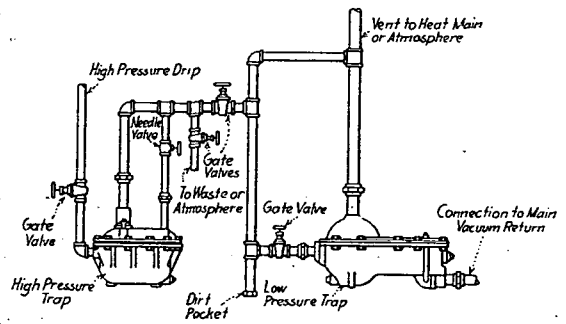


FIG. 2. METHOD OF DISCHARGING HIGH-PRESSURE APPARATUS INTO LOW-PRESSURE HEATING MAINS AND VACUUM RETURN MAINS THROUGH A LOW-PRESSURE TRAP

unnecessary, as the elimination of air is automatically taken care of by air passing through the vent in the top of the inverted bucket regardless of temperature.

Thermostatic Traps. Thermostatic traps are of two types, those in which the discharge valve is operated by the relative expansion of metals, and those in which the action of a volatile liquid is utilized for this purpose. Thermostatic traps of large capacity for draining blast coils or very large radiators, are called *blast* traps.

Tilting Traps. With this type of trap, water enters a bowl and rises until its weight over-balances that of a counter-weight, and the bowl sinks to the bottom. As the bowl sinks, a valve is opened thus admitting live steam pressure on the surface of the water and the trap then discharges. After the water is discharged, the counter-weight sinks and raises the bowl, which in turn closes the valve and the cycle begins again. Tilting traps are necessarily intermittent in operation. They are not ordinarily equipped with glass water gages, as the action of the trap shows when it is filling or emptying. The air relief of tilting traps is taken care of by the valves of the trap.

Thermostatic traps are generally used for draining radiators and heaters, except for very large capacities where bucket, float or blast-type thermostatic traps are used. Thermostatic traps for this service usually pass both condensate and air and in the case of float and upright bucket traps the air is usually relieved through an auxiliary thermostatic trap in

a by-pass around the main trap. Sometimes this auxiliary air trap is an integral part of the trap.

Blast-type thermostatic traps are sometimes used on vacuum heating systems for connecting old one or two-pipe gravity systems in parallel

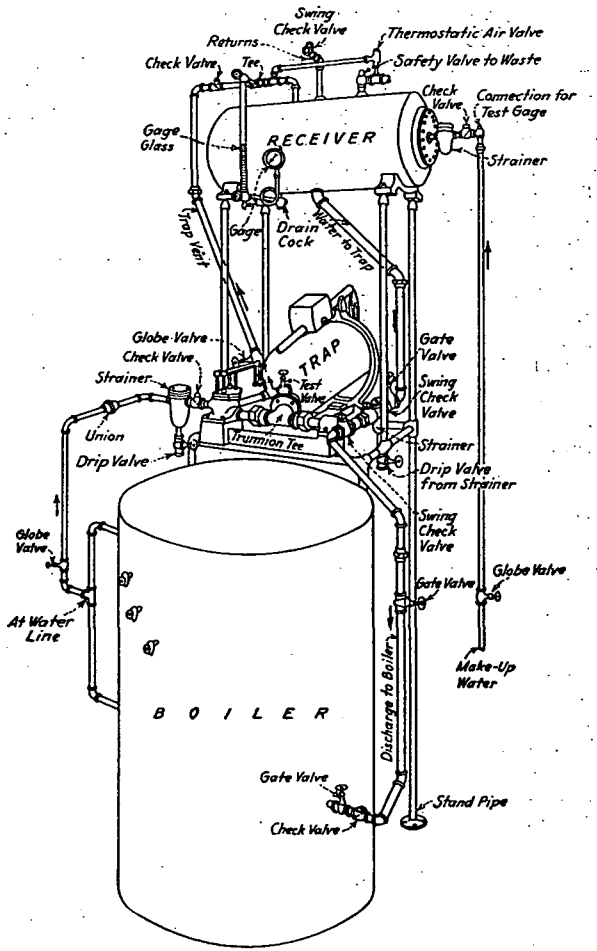


FIG. 3. RETURN TRAP AND RECEIVER FOR AUTOMATIC BOILER FEED

with vacuum return line systems, in which case the blast-type thermostatic traps should not be provided with auxiliary air by-pass, as the action of this will allow the vacuum to draw air into the old system through its air valves, especially when the steam is wholly or partially cut off. The air from the returns of such old systems should be relieved just ahead of the traps by means of quick-venting automatic air valves,

preferably of the non-return type, especially if the other air valves on the old system are non-return valves.

Tilting traps used for discharging to a higher or a lower pressure are provided with two or three valves operated by the action of the trap. In the case of the two-valve tilting traps, one valve closes a steam inlet and the other valve opens a vent outlet while the trap is filling and as soon as the trap dumps the first valve opens the steam inlet and the second valve closes the vent outlet, while the trap discharges. In this type of trap there must be a swinging-check valve on each side of the trap, in addition to the usual by-pass, to prevent the pressure in the trap, while discharging, from backing up through the inlet and the pressure in the discharge line from backing up into the trap while it is filling. This type of trap will blow steam out through the vent while filling, if the pressure on the inlet side is sufficient, and should not be used, therefore, with such pressures unless the vent is properly piped back into the return to a feed water heater, condenser or to a perforated pipe in the bottom of the receiver to which the trap discharges in such a way as to prevent the escape of the steam that comes in with the condensate and passes through the vent. In the three-valve traps of this type there is an extra valve for closing the discharge while the trap is filling.

High pressure traps should not discharge directly into a vacuum return because of the vapor formed by the re-evaporation of a part of the hot condensation. Fig. 2 shows a method which may be used for disposing of the greater part of the vapor of re-evaporation.

Direct Return Traps

In the general heating plant, where thermostatic traps are installed on the heating units, it becomes necessary to provide a means for returning the water of condensation to the boiler, if a condensation or vacuum pump is not used. When the return main can be kept sufficiently high above the boiler water line for all operating conditions, the water of condensation will flow back by gravity, and no mechanical device is required. But actually this does not work out in practice. It follows, therefore, that a direct return trap is needed for the handling of the condensation even though it may not be called into action except under some operating condition where the pressure differential exceeds the static head provided. The installation of a direct return trap assures safety for such systems, and the operation of the plant under varying conditions.

Direct return traps, sometimes called alternating receivers, may be of the counterbalanced, tilting type, or spring actuated. These consist of a small receiver with an internal float, and when the condensate will not flow into the boiler under pressure, it will feed into the receiver of the trap, and in so doing, raise or tilt the float or mechanism which actuates a steam valve automatically. This admits steam to the receiver, at boiler pressure, and the equalizing of the pressures which follows, allows the water to flow into the boiler. Fig. 3 shows a direct return tilting trap and receiver properly connected for automatically feeding a boiler from a system of returns delivering the condensate to the receiver.

Chapter 11

PIPE, FITTINGS, VALVES AND PIPE WELDING

Pipe; Types of Pipe, Expansion and Contraction: Fittings; Screwed Fittings, Flanged Fittings: Valves; Pressure Requirement: Corrosion: Pipe Welding.

PIPE

THE term *pipe*, while used as a general term to designate any kind of tube for the conveying of fluids, ordinarily refers to pipe made by shaping sheets of metal into cylindrical form and welding the edges together. Pipe made by forming or drawing from a solid billet is termed *seamless tubing* or *seamless pipe*. *Welded pipe* is usually made by either the forge lap-weld or butt-weld process, depending upon the size.

Wrought pipe up to 12 in. in diameter is usually designated by its nominal internal diameter which is slightly different from its actual internal diameter, being considerably less in the smaller sizes than the actual dimension. There are three weights of wrought iron and steel pipe commonly used, known as *standard*, *extra strong*, and *double-extra strong*. Because of the necessity of maintaining the same external diameter in all three weights, for the same nominal size, the added wall thickness is obtained by decreasing the internal diameter.

The term *full weight*, when applied to sizes below 8 in., means that the pipe is up to the nominal weight per foot. When applied to sizes between 8 and 12 in. inclusive, it often indicates that the pipe has the heaviest of the various wall thicknesses listed. In sizes 14 in. and upward pipe is designated by its outside diameter (O.D.) and the wall thickness is specified.

The dimensions of standard and extra strong pipe are given in Tables 1 and 2. The use of double extra strong pipe is limited almost entirely to high pressure hydraulic work.

Types of Pipe

Wrought-Steel Pipe. Because of its low price, the great bulk of wrought pipe used at the present time is of wrought steel. The material used for steel pipe is a mild steel made either by the Bessemer or basic open-hearth process or by the electric furnace.

Wrought-Iron Pipe. The correct definition of wrought iron as suggested by the *International Society for Testing Materials* is "malleable iron which is aggregated from pasty particles without subsequent fusion and contains so little carbon that it does not harden usefully when cooled rapidly."

The chief advantage claimed for wrought iron is to resist corrosion to a greater degree than does steel. This is held to be due to the high degree

TABLE 1. STANDARD WROUGHT PIPE

Table of Standard Dimensions

Size Inches	Diameters		Nominal Thickness Inches	Circumference		Transverse Areas			Length of Pipe per Square Foot of		Nominal Weight per Foot	
	External Inches	Approximate Internal Inches		External Inches	Internal Inches	External Sq. In.	Internal Sq. In.	Metal Sq. In.	External Surface	Internal Surface	Plain Ends	Threaded and Coupled
⅛	0.405	0.269	0.068	1.272	0.845	0.129	0.057	0.072	9.431	14.199	0.244	0.245
¼	0.540	0.364	0.088	1.696	1.144	0.229	0.104	0.125	7.073	10.493	0.424	0.425
⅜	0.675	0.493	0.091	2.121	1.549	0.358	0.191	0.167	5.658	7.747	0.567	0.568
½	0.840	0.622	0.109	2.639	1.954	0.554	0.304	0.250	4.547	6.141	0.850	0.852
¾	1.050	0.824	0.113	3.299	2.589	0.866	0.533	0.333	3.637	4.635	1.130	1.134
1	1.315	1.049	0.133	4.131	3.296	1.358	0.864	0.494	2.904	3.641	1.678	1.684
1¼	1.660	1.380	0.140	5.215	4.335	2.164	1.495	0.669	2.301	2.767	2.272	2.281
1½	1.900	1.610	0.145	5.969	5.058	2.835	2.036	0.799	2.010	2.372	2.717	2.731
2	2.375	2.067	0.154	7.461	6.494	4.430	3.355	1.075	1.608	1.847	3.652	3.678
2½	2.875	2.469	0.203	9.032	7.757	6.492	4.788	1.704	1.328	1.547	5.793	5.819
3	3.500	3.068	0.216	10.996	9.638	9.621	7.393	2.228	1.091	1.245	7.575	7.616
3½	4.000	3.548	0.226	12.566	11.146	12.566	9.886	2.680	0.954	1.076	9.109	9.202
4	4.500	4.026	0.237	14.137	12.648	15.904	12.730	3.174	0.848	0.948	10.790	10.889
5	5.563	5.047	0.258	17.477	15.856	24.306	20.006	4.300	0.686	0.756	14.617	14.810
6	6.625	6.065	0.280	20.813	19.054	34.472	28.891	5.581	0.576	0.629	18.974	19.185
8	8.625	8.071	0.277	27.096	25.356	58.426	51.161	7.265	0.442	0.473	24.696	25.000
8	8.625	7.981	0.322	27.096	25.073	58.426	50.027	8.399	0.442	0.478	28.554	28.809
10	10.750	10.192	0.279	33.772	32.019	90.763	81.585	9.178	0.355	0.374	31.201	32.000
10	10.750	10.136	0.307	33.772	31.843	90.763	80.691	10.072	0.355	0.376	34.240	35.000
10	10.750	10.020	0.365	33.772	31.479	90.763	78.855	11.908	0.355	0.381	40.483	41.132
12	12.750	12.000	0.375	40.055	37.699	127.676	113.097	14.579	0.299	0.318	49.562	50.706

of purity of the iron base and to the purely mechanical resistance to the progress of corrosive action offered by the slag veins. The exact degree of superiority has never been determined.

Identification of Wrought-Iron and Steel Pipe. Wrought-iron pipe is marked at the mill with a spiral line the entire length of each bar, either knurled into the metal or painted in red or other bright color. Otherwise there is little difference in the appearance of wrought-iron and steel pipe but there are several tests which readily identify the materials. The fracture of wrought-iron pipe is ragged, dull gray, and fibrous. By hammering a piece of pipe flat the fracture can easily be observed. The fracture of steel is even, bright and crystalline. Wrought-iron pipe, when threads are cut on it, gives a crumbled chip, due to the fibrous structure. Steel pipe, when threaded, gives a long spiral chip. A microscopic examination of polished and etched specimens is an infallible test. The presence of slag in the wrought iron is unmistakable, while the steel is almost without slag.

Seamless Pipe. Steel pipe or *tubing* without the lap or butt weld is frequently used for high-pressure work. Its advantages are its somewhat greater strength, permitting the use of a thinner wall, and in the small sizes its freedom from the tendency of welded pipe to split at the weld occasionally when bent. Furthermore, the inherent physical properties of the steel used in its manufacture are somewhat better and a variety of combinations of carbon content and heat treatment are available.

Seamless pipe is made by either of two different processes, depending upon the size. The piercing process is used in the smaller sizes and the cupping process is sometimes used for tubing of 6 to 8 in. diameter.

Cast Ferrous Pipe. There are now available several types of cast ferrous metal pipe made of a good grade of cast iron with additions of nickel, chromium, etc. This pipe is available in sizes from 1½ in. to 6 in. and standard lengths of 5 or 6 ft with external and internal diameters closely approximating those of extra strong wrought pipe. Cast ferrous pipe may be had coupled, bevelled for welding or ends plain or grooved for the several types of couplings. It is readily cut, and threaded, as well as welded. The fact that it is readily welded enables the manufacturers to supply the pipe in any lengths practical for handling.

Alloy Metal Pipe. Steel pipe bearing a small alloy of copper is somewhat more resistant to corrosion than plain steel pipe. It is recommended usually for atmospheric corrosive conditions, *i.e.*, for corrosion caused by alternate exposure to air and water.

Expansion and Contraction

The proper provision for the expansion and contraction of piping must be made in all cases where water, steam, or gas is to be used at high temperatures, and is usually accomplished by directional changes, long sweep bends or expansion joints. In instances where it is impracticable to install the piping to obtain the required flexibility by directional changes, it may be advantageous to insert expansion bends in the line. Such expansion bends may be (1) a complete unit such as the expansion *U*-bend, the double-offset expansion *U*-bend, or the circle bend (Fig. 1); (2) a built-up bend composed of several of the smaller curved pieces illustrated in Fig. 1;

TABLE 2. EXTRA STRONG WROUGHT PIPE

Table of Standard Dimensions

Size Inches	Diameters		Nominal Thickness Inches	Circumference		Transverse Area			Length of Pipe per Square Foot of		Length of Pipe Containing One Cubic Foot Feet	Nominal Weight per Foot Plain Ends Pounds
	External Inches	Approximate Internal Inches		External Inches	Internal Inches	External Sq. In.	Internal Sq. In.	Metal Sq. In.	External Surface	Internal Surface		
⅛	0.405	0.215	0.095	1.272	0.675	0.129	0.036	0.093	9.431	17.766	3966.392	0.314
¼	0.540	0.302	0.119	1.696	0.949	0.229	0.072	0.157	7.073	12.648	2010.290	0.535
⅜	0.675	0.423	0.126	2.121	1.329	0.358	0.141	0.217	5.658	9.030	1024.689	0.738
½	0.840	0.546	0.147	2.639	1.715	0.554	0.234	0.320	4.547	6.995	615.017	1.087
¾	1.050	0.742	0.154	3.299	2.331	0.866	0.433	0.433	3.637	5.147	333.016	1.473
1	1.315	0.957	0.179	4.131	3.007	1.358	0.719	0.639	2.904	3.991	200.193	2.171
1¼	1.660	1.278	0.191	5.215	4.015	2.164	1.283	0.881	2.301	2.988	112.256	2.996
1½	1.900	1.500	0.200	5.969	4.712	2.835	1.767	1.068	2.010	2.546	81.487	3.631
2	2.375	1.939	0.218	7.461	6.092	4.430	2.953	1.477	1.608	1.969	48.766	5.022
2½	2.875	2.323	0.276	9.032	7.298	6.492	4.238	2.254	1.328	1.644	33.976	7.661
3	3.500	2.900	0.300	10.996	9.111	9.621	6.605	3.016	1.091	1.317	21.801	10.252
3½	4.000	3.364	0.318	12.566	10.568	12.566	8.888	3.678	0.954	1.135	16.202	12.505
4	4.500	3.826	0.337	14.137	12.020	15.904	11.497	4.407	0.848	0.998	12.525	14.983
5	5.563	4.813	0.375	17.477	15.120	24.306	18.194	6.112	0.686	0.793	7.915	20.778
6	6.625	5.761	0.432	20.813	18.099	34.472	26.067	8.405	0.576	0.663	5.524	28.573
8	8.625	7.625	0.500	27.096	23.955	58.426	45.663	12.763	0.442	0.500	3.154	43.388
10	10.750	9.750	0.500	33.772	30.631	90.763	74.662	16.101	0.355	0.391	1.929	54.735
12	12.750	11.750	0.500	40.055	36.914	127.676	108.434	19.242	0.299	0.325	1.328	65.415

(3) a combination of straight pieces with such curved pieces or cast ells;
(4) a so-called *square* bend made up entirely of straight pieces, cast ells, etc.

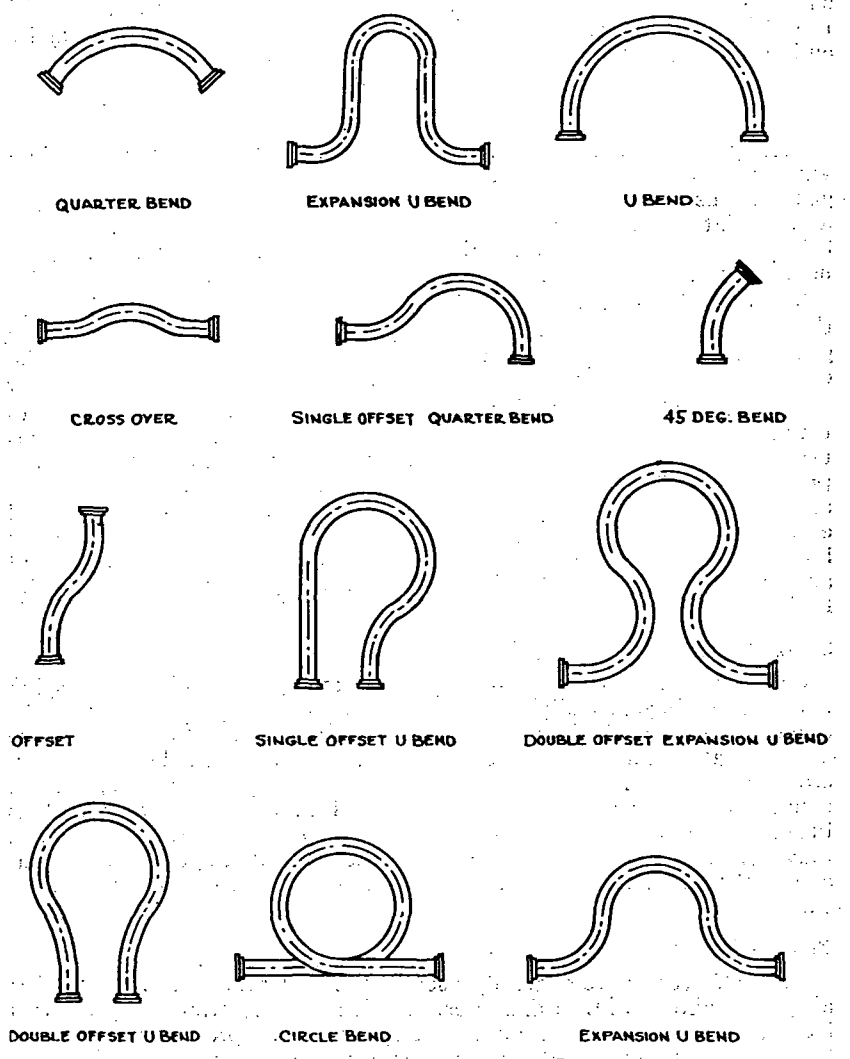


FIG. 1. COMMON TYPES OF PIPE BENDS

In designing any system of steam or hot water piping the expansion for each straight run should be calculated and allowed for.

All risers must be anchored and safeguarded so that the difference in length when hot from the length when cold shall not disarrange the normal and orderly provisions for drainage of the branches.

It is especially necessary with light-weight radiators so to anchor and so to give freedom for expansion of the piping that no strain therefrom shall be allowed to distort the radiators. When expansion strains from the pipes are permitted to reach these light metal heaters they usually emit sounds of distress which are exceedingly troublesome.

FITTINGS

Fittings for joining the separate lengths of pipe together are made in a variety of forms, and are either screwed or flanged; the former being generally used for the smaller sizes of pipe up to and including 3½ in., and the latter for the larger sizes, 4 in. and above. Screwed fittings of large size as well as flanged fittings of small size are also made and are used for certain classes of work at the proper pressure.

The material used for fittings is generally cast iron, but in addition to this malleable iron, steel and steel alloys are also used, as well as various grades of brass or bronze. The material to be used depends on the character of the service and the pressure.

As in the case of pipe, there are several weights of fittings manufactured, designed to be used with pipe of corresponding grade. These variations in weights are known as (1) low-pressure fittings for steam working pressures of 25 lb (cast-iron flanged only, sizes 4 in. and larger), (2) standard fittings for saturated steam working pressures of 125 lb, and extra heavy fittings for saturated steam working pressures of 250 lb. The latter fittings are suitable for cold water working pressures of 350 lb and are usually tested to twice the steam working pressure, or 500 lb cold hydrostatic.

Screwed Fittings

Screwed fittings include nipples or short pieces of pipe of varying lengths; couplings, usually of wrought iron only; elbows for turning angles of either 45 deg or 90 deg; return bends, which may be of either the close or open pattern, and may be cast with either a back or side outlet; tees; crosses; laterals or *Y* branches; and a variety of plugs, bushings, caps, lock-nuts, flanges and reducing fittings. Reducing fittings as well as bushings, both of which are used in changing from one pipe size to another, may have the smaller connection tapped eccentrically to permit free drainage of the water of condensation in steam lines or free escape of air in water lines.

Flanged Fittings

Flanged fittings are generally used in the best practice for connecting all piping above 6 in. in diameter. While screwed fittings may be used for the larger sizes and are satisfactory under the proper working conditions, it will be found difficult either to make or to break the joints in these large sizes.

The dimensions of elbows, tees and crosses for 125 lb cast-iron screwed fittings are given in Table 3, whereas the dimensions for 125 lb cast-iron flanged fittings are given in Tables 4 and 5.

A special type of joint known as the *Sarlun* joint consists of a lip which is provided for welding to make the joint fluid tight, while mechanical

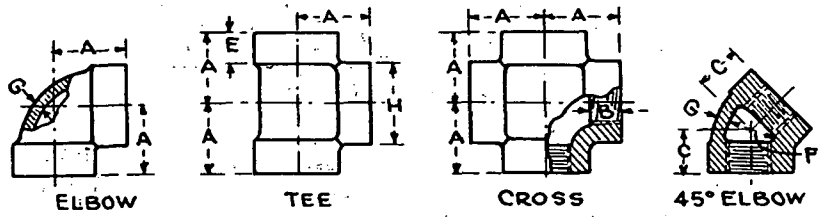
strength is provided by bolted flanges. Another type of pipe joint, the *lap flange*, is made by using loose flanges on lengths of pipe whose ends are lapped to give a bearing surface for a gasket or metal joint.

VALVES

Valves, like fittings, are usually either made with screwed or threaded ends or else are flanged for bolted connection to corresponding flanges on the pipe or fitting, in which case the flange and bolting arrangement should conform with the *American Standard* for flanged fittings of corresponding ratings.

The material used for valves of small size is generally brass or bronze for low pressures and forged steel for high pressures, while in the larger sizes

TABLE 3. DIMENSIONS OF ELBOWS, 45 DEG ELBOWS, TEES, AND CROSSES (STRAIGHT SIZES) FOR 125 LB CAST IRON SCREWED FITTINGS



Nominal Pipe Size	A Center to End, Elbows, Tees and Crosses	C Center to End, 45 Deg Elbows	B Length of Thread Min.	E Width of Band, Min.	F Inside Diameter of Fitting Min.	F Inside Diameter of Fitting Max.	G Metal Thickness, Min.	H Outside Diameter of Band, Min.
¼	0.81	0.73	0.32	0.38	0.540	0.584	0.110	0.93
⅜	0.95	0.80	0.36	0.44	0.675	0.719	0.120	1.12
½	1.12	0.88	0.43	0.50	0.840	0.897	0.130	1.34
¾	1.31	0.98	0.50	0.56	1.050	1.107	0.155	1.63
1	1.50	1.12	0.58	0.62	1.315	1.385	0.170	1.95
1¼	1.75	1.29	0.67	0.69	1.660	1.730	0.185	2.39
1½	1.94	1.43	0.70	0.75	1.900	1.970	0.200	2.68
2	2.25	1.68	0.75	0.84	2.375	2.445	0.220	3.28
2½	2.70	1.95	0.92	0.94	2.875	2.975	0.240	3.86
3	3.08	2.17	0.98	1.00	3.500	3.600	0.260	4.62
3½	3.42	2.39	1.03	1.06	4.000	4.100	0.280	5.20
4	3.79	2.61	1.08	1.12	4.500	4.600	0.310	5.79
5	4.50	3.05	1.18	1.18	5.563	5.663	0.380	7.05
6	5.13	3.46	1.28	1.28	6.625	6.725	0.430	8.28
8	6.56	4.28	1.47	1.47	8.625	8.725	0.550	10.63
10	8.08	5.16	1.68	1.68	10.750	10.850	0.690	13.12
12	9.50	5.97	1.88	1.88	12.750	12.850	0.800	15.47
14 O.D.	10.40	....	2.00	2.00	14.000	14.100	0.880	16.94
16 O.D.	11.82	....	2.20	2.20	16.000	16.100	1.000	19.30

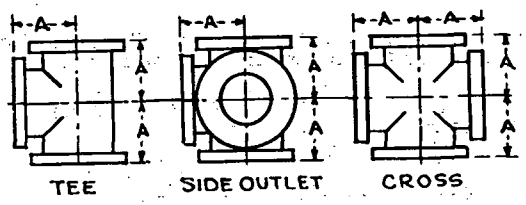
All dimensions given in inches.

either cast-iron, cast-steel or some of the steel alloys are employed. Practically all iron or steel valves intended for steam or water work are bronze-mounted or trimmed, while valves for acids, ammonia and corrosive gases are of iron throughout.

Pressure Requirement

Brass, bronze and iron valves are generally designed for standard or extra heavy service, the former being used up to 125 lb and the latter up to 250 lb saturated steam working pressure, although most manufacturers also make valves for medium pressure up to 175 lb steam working

TABLE 4. DIMENSIONS OF TEES AND CROSSES (STRAIGHT SIZES) FOR 125 LB CAST IRON FLANGED FITTINGS



Nominal Pipe Size a-b	A Center to Face Tees and Crosses b-c	AA Face to Face Tees and Crosses b-c	Diameter of Flange	Thickness of Flange, Min.	Metal Thickness of Body, Min.
1	3½	7	4¼	7/16	7/16
1¼	3¾	7½	4⅝	½	7/16
1½	4	8	5	9/16	7/16
2	4½	9	6	⅝	7/16
2½	5	10	7	11/16	7/16
3	5½	11	7½	¾	7/16
3½	6	12	8½	13/16	7/16
4	6½	13	9	15/16	½
5	7½	15	10	15/16	½
6	8	16	11	1	9/16
8	9	18	13½	1⅛	⅝
10	11	22	16	1 3/16	¾
12	12	24	19	1¼	13/16
14 O.D.	14	28	21	1⅜	⅞
16 O.D.	15	30	23½	1 7/16	1
18 O.D.	16½	33	25	1 9/16	1 1/16
20 O.D.	18	36	27½	1 11/16	1⅛
24 O.D.	22	44	32	1⅞	1¼
30 O.D.	25	50	38¾	2⅛	1 7/16
36 O.D.	28	56	46	2⅜	1⅝
42 O.D.	31	62	53	2⅝	1 13/16
48 O.D.	34	68	59½	2¾	2

All dimensions given in inches.

aSize of all fittings listed indicates nominal inside diameter of port.

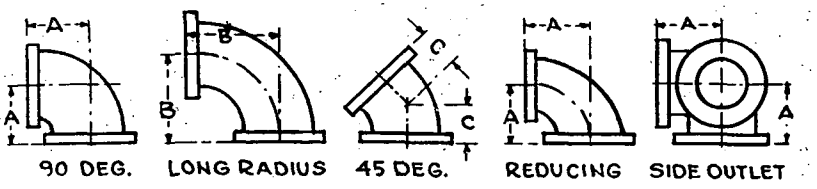
bTees, side outlet tees, and crosses, 16 in. and smaller, reducing on the outlet, have the same dimensions center to face, and face to face as straight size fittings, corresponding to the size of the larger opening. Sizes 18 in. and larger, reducing on the outlet, are made in two lengths, depending on the size of the outlet.

cTees and crosses, reducing on run only, carry same dimensions center to face and face to face as a straight size fitting of the larger opening.

pressure and cast-iron flanged valves for working pressures up to 25 lb steam. In practically all cases these valves are tested at a cold water pressure of twice the steam pressure, and may be used on cold water lines with a pressure 40 per cent in excess of the allowable rated steam pressure. Some manufacturers rate their standard valves at 150 lb steam working pressure instead of 125 lb. The more common types are gate valves or straightway valves, globe valves, angle valves, check valves and automatic valves, such as reducing and back-pressure valves.

A special class of valves is required for controlling the steam and hot water supply to radiators. These valves are of brass, usually of the angle

TABLE 5. DIMENSIONS OF ELBOWS FOR 125 LB CAST-IRON FLANGED FITTINGS



Nominal Pipe Size a	A Center to Face Elbow b-c-d	B Center to Face Long Radius Elbow b-c-d	C Center to Face 45 Deg Elbow c	Diameter of Flange	Thickness of Flange, Min.	Metal Thickness of Body, Min.
1	3½	5	1¾	4¼	7/16	7/16
1¼	3¾	5½	2	4⅝	½	7/16
1½	4	6	2¼	5	9/16	7/16
2	4½	6½	2½	6	⅝	7/16
2½	5	7	3	7	11/16	7/16
3	5½	7¾	3	7½	¾	7/16
3½	6	8½	3½	8½	13/16	7/16
4	6½	9	4	9	15/16	½
5	7½	10¼	4½	10	15/16	½
6	8	11½	5	11	1	9/16
8	9	14	5½	13½	1⅛	⅝
10	11	16½	6½	16	1 3/16	¾
12	12	19	7½	19	1¼	13/16
14 O.D.	14	21½	7½	21	1⅜	⅞
16 O.D.	15	24	8	23½	1 7/16	1
18 O.D.	16½	26½	8½	25	1 9/16	1 1/16
20 O.D.	18	29	9½	27½	1 11/16	1⅛
24 O.D.	22	34	11	32	1⅞	1¼
30 O.D.	25	41½	15	38¾	2⅛	1 7/16
36 O.D.	28	49	18	46	2⅜	1⅝
42 O.D.	31	56½	21	53	2⅝	1 13/16
48 O.D.	34	64	24	59½	2¾	2

All dimensions given in inches.

aSize of all fittings listed indicates nominal inside diameter of port.

bReducing elbows and side outlet elbows carry same dimensions center to face as straight size elbows, corresponding to the size of the larger opening.

cSpecial degree elbows, ranging from 1 to 45 deg, inclusive, have the same center to face dimensions given in 45 deg elbows and those over 45 deg and up to 90 deg inclusive, shall have the same center to face dimensions given for 90 deg elbows. The angle designation of an elbow is its deflection from straight line flow and is the angle between the flange faces.

dSide outlet elbows shall have all openings on intersecting center-lines.

type, modified to suit the service requirements, and are often arranged with graduated heads and lever handles in order to indicate the relative opening of the valve port in any position.

CORROSION

The electrolytic theory of corrosion, as formulated in 1903 by Dr. Whitney, led to the development of certain protective methods for closed water systems, which are based on the removal of dissolved oxygen from the water. Careful experiments in various research laboratories have demonstrated that the amount of corrosion found in such systems is almost directly proportional to the amount of oxygen in solution, and varies with the temperature and rate of flow. The composition of the water also has a bearing on the rate of attack.

All reliable data on this subject indicate that the composition of the iron—*i.e.*, the varying amounts of carbon, phosphorous, manganese, sulphur, silicon, copper, etc., usually found in wrought iron and soft steel—makes very little difference in the amount or character of corrosion under water, although under atmospheric exposure the influence of composition is more marked. Corrosion is stimulated by scale adhering to the iron surface, by electric currents from external sources, by acids carried in solution or as gases, by solids that break down in water, by strains due to un-uniform or inadequate annealing and by contact between dissimilar materials.

The best way to deal with a corrosive water supply is to treat it at its source. In practice, oxygen removal has been accomplished in two ways, (1) by de-aerating the water mechanically and (2) by fixing the free oxygen by chemical combination. Suitable apparatus for this purpose is now on the market. Corrosive action may be retarded by the use of a metal which is electro-positive to that to be protected, such as zinc to protect iron; by the effective neutralization of acid or alkaline contents; by the elimination of un-uniformity in the materials used; and through the exercise of care in counteracting the effects of stray electric currents.

The introduction into piping systems of various chemical compounds, usually for forming a protective coating of thin deposit has apparently been rewarded with some success. Non-ferrous piping may deteriorate rapidly unless selected with due regard to the service conditions to which it will be subjected. The composition and micro-structure are items of special importance. Electrolysis set up by joining copper alloys to iron must be guarded against.

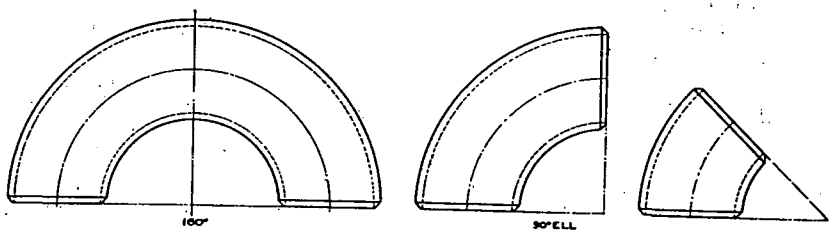
Piping exposed to elements or buried in the ground is quite successfully protected by coatings of the asphaltic type, usually applied hot. These coatings are often reinforced with fabric wrappings. Galvanizing by the hot-dip process and painting with specially prepared mixtures also afford satisfactory protective safeguards.

PIPE WELDING

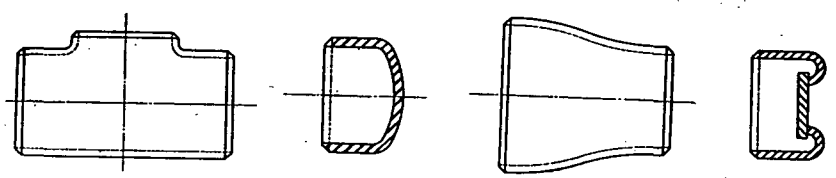
Arc welding and oxy-acetylene welding are used with equal success in piping work. Since "the weld is only as good as the welder," care should be exercised in the selection of the operator. Obviously an operator who

is constantly working at his trade is usually better qualified than one who uses the torch or arc only at intervals. Consequently a separate crew or crews must be supplied in most cases. This fact should be considered when comparing the cost of a welded installation with the same installation made with screwed or flanged joints.

To date welded piping has been found practicable and less expensive than piping made with screwed or flanged joints on sizes down to 2 in., provided the job is sufficiently large to warrant the supplying of a skilled



a. TYPICAL SHORT RADIUS ELBOWS



b. TEE *c.* FORGED CAP *d.* CONCENTRIC REDUCER *e.* END CLOSURE



f. WELDING NECK FLANGE *g.* LAP JOINT FLANGED WELDING NECK

FIG. 2. WELDING FITTINGS

mechanic together with the transportation of equipment, etc. Smaller sizes can also be welded to advantage but there must be a relatively greater amount of welding in order to make a favorable cost comparison. The lowest costs can be obtained where the job is sufficiently large to permit the use of separate crews, one to place and line up material and the other to weld the material already properly placed. The less the work of these two crews overlaps, the lower will be the installation costs. With the application of pipe bending and welds all branches and all changes in direction can be made with long-sweep turns, thereby reducing friction at the bends.

Whenever a branch is joined to a main the use of standard tees for

welding will obviously produce the best finished job. If regular welding tees are not used, however, templates should be used for cutting the hole through the wall of the main pipe and for preparing the end of the branch pipe. The branch pipe should not project inside the main but should fit snugly against the main so that with the process of welding no surplus metal will drop into the interior of the main. Any droppings should of course be removed.

When a branch is taken off from a main line and there is very little room for expansion it is good practice to weld in a reinforcing brace between the branch and the main line. This is particularly true on large piping where high temperatures occur.

In changing the direction of the run of pipe it is better to use bends than to use fittings and nipples.

Special manufactured welding fittings as illustrated in Fig. 2 are available. Most of them can be obtained in all regular pipe sizes and frequently lend themselves to economical and practical application.

Welding rods of high grade material should be used on all welds. The more complicated the turn and the more severe the strain and service the better quality the rod must be. Expert workmanship and correct engineering are of no avail if the welding rod is of improper character.

Since welding is a comparatively new industry there is some danger that failures may occur unless great care is taken with the workmanship. The following rules are basic in welding practice and should be followed rigidly:

1. A skilled operator with the torch or arc, should be employed.
2. The proper welding rod and electrode must be supplied.
3. Regular fittings for welding should preferably be used wherever possible. (See Fig. 2).
4. The choice of oxygen-acetylene or electric arc will be governed by the adaptability of each for the particular installation.
5. Templates shall be used for all cuts, with joints which are to be welded fitted closely, prior to starting the welding.
6. Standard welding tools and equipment of recognized make should be used.

A considerable reduction in weight is made where welding is used, due to the elimination of cast fittings and flanges. There is thus an indirect saving resulting from the lighter supports and hangers required.

Maintenance is kept at a minimum with a properly welded installation. This is especially true in concealed or hard-to-get-at places where repairs would be very expensive. Saving of space in cramped quarters is frequently rendered much simpler by welding. For further information on welding, see *Standard Manual on Pipe Welding* published by the *Heating and Piping Contractors National Association.*

Chapter 12

PIPE INSULATION

Heat Transfer through Bare Pipes; Insulation of Hot Water; Low and High Pressure Steam Lines; Insulation for Cold Surfaces; Effect of Air Velocity on Surface Losses; Economic Thickness of Pipe Insulation; Underground Insulation.

THIS chapter contains essential data for estimating the proper thickness of pipe or surface insulation for various conditions. When steam or hot water are conveyed from one part of a building to another, it usually is desirable that the loss of heat from the pipes through which these heating media pass, be reduced to an economic minimum by means of the proper type and thickness of insulation. Pipe insulation is also used to reduce the absorption of heat by cold pipes as well as to prevent condensation on the outer surfaces.

HEAT TRANSFER THROUGH BARE PIPES

Heat losses from horizontal bare iron pipes, based on data obtained from tests conducted at the Mellon Institute, are given in Table 1. These losses are expressed in Btu per hour per linear foot of pipe per degree Fahrenheit difference in temperature between the steam or hot water in the pipe and the air surrounding the pipe. The monetary value of the loss of heat given in Table 1 may be obtained by means of Fig. 1 for various heating system efficiencies, temperature differences and calorific values and costs of coal. To solve a problem, select the proper heat loss coefficient from Table 1 and locate this value on the upper left hand margin of the chart. Then draw lines in the order indicated by the dotted lines, the dollar value of the heat loss per 100 linear feet of pipe per 1000 hours being given on the upper right hand scale. In using this chart, the cost of coal should also include the labor for handling it, boiler room expense, etc.

In order to determine heat losses per linear foot of pipe from known losses per square foot, it is necessary to know the area in square feet per linear foot of pipe. Table 2 gives these areas for various standard pipe sizes while Table 3 gives the area in square feet for flanges and fittings for various standard pipe sizes.

Very often, even where pipes are thoroughly insulated, flanges and fittings are left bare due to the belief that the losses from these parts are not large. However, the fact that a pair of 9-in. standard flanges having an area of 3.00 sq ft would lose, at 100 lb steam pressure, an amount of heat equivalent to more than a ton of coal per year shows the necessity

for insulating such surfaces. Table 3 shows the areas of both standard and extra heavy flanged fittings including the accompanying flanges bolted to the fittings.

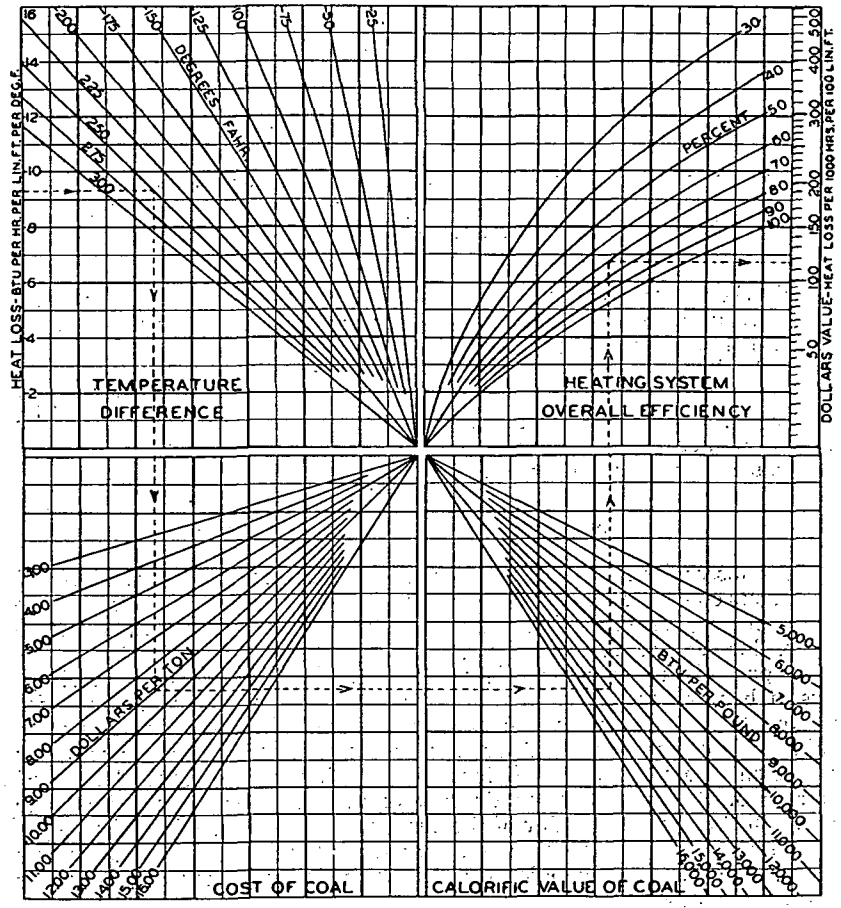


FIG. 1. CHART FOR ESTIMATING DOLLAR VALUE OF HEAT LOSS FROM BARE IRON PIPES. (SEE TABLE 1)[a]

[a]This chart is based on 100 linear feet per 1000 hours. For fractions or multiples of these factors, multiply by proper percentage.

INSULATION OF HOT WATER, AND STEAM LINES

The conductivities of various materials used for insulating steam and hot water pipes are given in Table 4. In this table the conductivities are given as functions of the mean temperatures or the mean of the inner and

outer surface temperatures of the insulations. This method of stating conductivities makes it possible readily to calculate the heat loss through single or compound sections. It should be emphasized that the conductivities given in Table 4 for the various insulations are the average of values obtained from a number of tests made on each type of material, also that all variables due to differences in thickness, pipe sizes, and air

TABLE 1. HEAT LOSSES FROM HORIZONTAL BARE IRON PIPES

Expressed in Btu per linear foot per degree Fahrenheit difference in temperature between the pipe and surrounding still air at 70 F.

NOMINAL PIPE SIZE (INCHES)	HOT WATER				STEAM		
	120 F	150 F	180 F	210 F	227.2 F (5 Lb)	298.7 F (10 Lb)	337.9 F (100 Lb)
	TEMPERATURE DIFFERENCE						
	50 F	80 F	110 F	140 F	157.2 F	228.7 F	267.9 F
½	0.543	0.573	0.605	0.638	0.656	0.742	0.796
¾	0.660	0.690	0.729	0.762	0.781	0.886	0.955
1	0.791	0.829	0.878	0.920	0.953	1.084	1.166
1¼	0.979	1.02	1.087	1.15	1.184	1.345	1.450
1½	1.09	1.15	1.220	1.29	1.335	1.520	1.640
2	1.34	1.40	1.491	1.58	1.637	1.866	2.015
2½	1.58	1.67	1.778	1.87	1.937	2.215	2.388
3	1.88	1.99	2.100	2.22	2.301	2.641	2.853
3½	2.13	2.24	2.380	2.51	2.585	2.972	3.215
4	2.36	2.50	2.650	2.78	2.873	3.312	3.582
4½	2.60	2.75	2.920	3.08	3.170	3.655	3.956
5	2.87	3.02	3.200	3.38	3.493	4.030	4.368
6	3.39	3.56	3.775	4.01	4.115	4.755	5.153
8	4.32	4.55	5.050	5.14	5.270	6.120	6.635
9	4.80	5.05	5.350	5.71	5.885	6.824	7.400
12	6.25	6.62	6.995	7.46	7.670	8.900	9.670

TABLE 2. RADIATING SURFACE PER LINEAR FOOT OF PIPE

NOMINAL PIPE SIZE (INCHES)	SURFACE AREA (SQ FT)	NOMINAL PIPE SIZE (INCHES)	SURFACE AREA (SQ FT)	NOMINAL PIPE SIZE (INCHES)	SURFACE AREA (SQ FT)
½	0.22	2	0.622	5	1.456
¾	0.275	2½	0.753	6	1.734
1	0.344	3	0.917	8	2.257
1¼	0.435	3½	1.047	9	2.519
1½	0.498	4	1.178	12	3.338

conditions are eliminated. Individual manufacturer's materials will, of course, vary in conductivity to some extent from these values.

The heat losses through six of the types of insulation given in Table 4 for 1, 1½ and 2-in. thick materials, and for temperatures commonly encountered in engineering practice can be obtained from Tables 5 to 10, inclusive. The loss through other thicknesses of the materials, and for other hot water or steam temperature conditions may be obtained by interpolation. The heat loss coefficients given in Tables 5 to 10 were

based on the conductivities in Table 4 and were computed from data given in Chapter 22 of THE GUIDE, 1931, in the following manner:

Example 1. Determine the coefficient of transmission (U) in Btu per hour per square foot of pipe surface through a 1-in. thickness of magnesia insulation on a 4-in. pipe. The temperature of the pipe is 210 F and the surrounding air temperature is 70 F.

TABLE 3. AREAS OF FLANGED FITTINGS, SQUARE FEET[a]

NOMINAL PIPE SIZE (INCHES)	FLANGED COUPLING		90 DEG. ELL		LONG RADIUS ELL		TEE		CROSS	
	Standard	Extra Heavy	Standard	Extra Heavy	Standard	Extra Heavy	Standard	Extra Heavy	Standard	Extra Heavy
1	0.320	0.438	0.795	1.015	0.892	1.083	1.235	1.575	1.622	2.07
1¼	0.383	0.510	0.957	1.098	1.084	1.340	1.481	1.925	1.943	2.53
1½	0.477	0.727	1.174	1.332	1.337	1.874	1.815	2.68	2.38	3.54
2	0.672	0.848	1.65	2.01	1.84	2.16	2.54	3.09	3.32	4.06
2½	0.841	1.107	2.09	2.57	2.32	2.76	3.21	4.05	4.19	5.17
3	0.945	1.484	2.38	3.49	2.68	3.74	3.66	5.33	4.77	6.95
3½	1.122	1.644	2.98	3.96	3.28	4.28	4.48	6.04	5.83	7.89
4	1.344	1.914	3.53	4.64	3.96	4.99	5.41	7.07	7.03	9.24
4½	1.474	2.04	3.95	5.02	4.43	5.46	6.07	7.72	7.87	10.07
5	1.622	2.18	4.44	5.47	5.00	6.02	6.81	8.52	8.82	10.97
6	1.82	2.78	5.13	6.99	5.99	7.76	7.84	10.64	10.08	13.75
8	2.41	3.77	6.98	9.76	8.56	11.09	10.55	14.74	13.44	18.97
9	3.00	4.44	8.71	11.44	10.57	13.17	13.18	17.23	16.78	22.10
12	4.41	6.71	13.08	17.73	16.35	18.76	19.67	26.65	24.87	34.11

[a]Including areas of accompanying flanges bolted to the fitting.

TABLE 4. CONDUCTIVITIES (k) OF VARIOUS TYPES OF INSULATING MATERIALS FOR MEDIUM AND HIGH TEMPERATURE PIPES[a]

	MEAN TEMPERATURE				
	100 F	200 F	300 F	400 F	500 F
85 per cent Magnesia Type	0.425	0.465	0.505	0.550	0.590
Corrugated Asbestos Type (4 Plies per 1 in. thick)	0.530	0.650	0.770	0.890	
Corrugated Asbestos Type (8 Plies per 1 in. thick)	0.480	0.555	0.630	0.705	
Laminated Asbestos Type (30–40 Laminations per 1 in. thick)	0.360	0.415	0.470	0.525	0.585
Laminated Asbestos Type (20 Laminations per 1 in. thick)	0.545	0.605	0.665	0.725	0.785
Rock Wool Type	0.350	0.410	0.470	0.530	0.590
High Temperature Type (Diatomaceous Earth and Asbestos)	0.515	0.545	0.575	0.605	0.635
Brown Asbestos Type (Felted Fibre)	0.600	0.640	0.675	0.715	0.750

[a]R. H. Heilman, *Mechanical Engineering*, Vol. 46 (1924), p. 593.

Solution. The heat loss coefficient for a 1-in. thickness of pipe insulation for a temperature difference of 140 deg (from Fig. 5, Chapter 22, THE GUIDE, 1931) is 0.367 Btu per hour per square foot per degree Fahrenheit difference in temperature. The factor for magnesia covering at a temperature difference of 140 deg is 1.214 (by interpolation from Table 7, Chapter 22, THE GUIDE, 1931). The coefficient of transmission is therefore 0.367 × 1.214 or 0.446. (See Table 5).

TABLE 5. COEFFICIENTS OF TRANSMISSION (U) FOR PIPES INSULATED WITH 85 PER CENT MAGNESIA TYPE INSULATION

These coefficients are expressed in Btu per hour per square foot of pipe surface per degree Fahrenheit difference in temperature between pipe and surrounding still air at 70 F

THICKNESS OF INSULATION (INCHES)	NOMINAL PIPE SIZE (INCHES)	HOT WATER				STEAM		
		120 F	150 F	180 F	210 F	227.2 F (5 Lb)	298.7 F (10 Lb)	337.9 F (100 Lb)
		TEMPERATURE DIFFERENCE						
		50 F	80 F	110 F	140 F	157.2 F	228.7 F	267.9 F
1	½	0.744	0.754	0.764	0.774	0.779	0.802	0.814
	¾	0.672	0.681	0.689	0.697	0.701	0.721	0.731
	1	0.613	0.621	0.629	0.637	0.641	0.659	0.670
	1¼	0.562	0.570	0.577	0.585	0.589	0.606	0.617
	1½	0.532	0.539	0.546	0.553	0.557	0.573	0.582
	2	0.500	0.506	0.512	0.519	0.523	0.538	0.547
	2½	0.475	0.481	0.487	0.493	0.497	0.512	0.520
	3	0.455	0.461	0.467	0.474	0.477	0.492	0.500
	3½	0.441	0.447	0.452	0.458	0.462	0.475	0.483
	4	0.429	0.435	0.441	0.446	0.449	0.463	0.471
	4½	0.420	0.425	0.431	0.437	0.440	0.453	0.460
	5	0.411	0.416	0.422	0.427	0.430	0.443	0.450
	6	0.402	0.408	0.413	0.419	0.422	0.435	0.442
	8	0.387	0.392	0.397	0.403	0.405	0.418	0.425
	9	0.380	0.385	0.390	0.395	0.398	0.410	0.417
	12	0.369	0.374	0.378	0.383	0.386	0.398	0.405
1½	½	0.617	0.625	0.633	0.642	0.646	0.665	0.676
	¾	0.550	0.558	0.566	0.573	0.577	0.596	0.606
	1	0.496	0.503	0.511	0.518	0.522	0.540	0.549
	1¼	0.453	0.459	0.465	0.472	0.475	0.490	0.498
	1½	0.424	0.430	0.436	0.442	0.445	0.459	0.467
	2	0.394	0.400	0.405	0.410	0.413	0.427	0.434
	2½	0.371	0.376	0.382	0.386	0.389	0.401	0.408
	3	0.352	0.357	0.362	0.367	0.370	0.380	0.387
	3½	0.339	0.343	0.347	0.351	0.354	0.364	0.370
	4	0.328	0.333	0.337	0.341	0.343	0.353	0.359
	4½	0.320	0.324	0.328	0.332	0.334	0.343	0.350
	5	0.312	0.316	0.320	0.324	0.326	0.336	0.342
	6	0.303	0.307	0.311	0.315	0.318	0.328	0.333
	8	0.287	0.291	0.295	0.299	0.301	0.311	0.316
	9	0.280	0.284	0.288	0.292	0.294	0.303	0.308
	12	0.272	0.275	0.279	0.283	0.285	0.294	0.299
2	½	0.543	0.551	0.558	0.565	0.569	0.587	0.597
	¾	0.484	0.490	0.497	0.503	0.507	0.523	0.532
	1	0.433	0.439	0.445	0.451	0.454	0.467	0.476
	1¼	0.393	0.398	0.403	0.409	0.412	0.424	0.432
	1½	0.365	0.370	0.376	0.381	0.384	0.397	0.402
	2	0.338	0.343	0.347	0.351	0.354	0.364	0.370
	2½	0.316	0.320	0.324	0.328	0.331	0.341	0.347
	3	0.297	0.301	0.305	0.309	0.312	0.321	0.326
	3½	0.284	0.288	0.292	0.295	0.297	0.306	0.311
	4	0.275	0.278	0.282	0.285	0.287	0.296	0.301
	4½	0.266	0.270	0.273	0.276	0.278	0.286	0.290
	5	0.258	0.262	0.265	0.268	0.270	0.278	0.283
	6	0.250	0.254	0.257	0.260	0.262	0.270	0.274
	8	0.236	0.239	0.242	0.245	0.247	0.255	0.258
	9	0.228	0.231	0.234	0.237	0.239	0.246	0.250
	12	0.219	0.222	0.225	0.228	0.230	0.237	0.240

Table 6. Coefficients of Transmission (U) for Pipes Insulated with Corrugated Asbestos Type Insulation (4 Plies Per Inch Thickness)

These coefficients are expressed in Btu per hour per square foot of pipe surface per degree Fahrenheit difference in temperature between pipe and surrounding still air at 70 F

Thickness of Insulation (Inches)	Nominal Pipe Size (Inches)	Hot Water				Steam		
		120 F	150 F	180 F	210 F	227.2 F (5 Lb)	298.7 F (10 Lb)	337.9 F (100 Lb)
		Temperature Difference						
		50 F	80 F	110 F	140 F	157.2 F	228.7 F	267.9 F
1	½	0.890	0.919	0.949	0.978	0.995	1.065	1.106
	¾	0.803	0.829	0.857	0.883	0.898	0.961	0.997
	1	0.731	0.756	0.780	0.804	0.818	0.876	0.909
	1¼	0.671	0.693	0.716	0.738	0.751	0.804	0.834
	1½	0.635	0.656	0.677	0.698	0.710	0.760	0.788
	2	0.595	0.615	0.635	0.656	0.667	0.715	0.742
	2½	0.567	0.586	0.605	0.624	0.635	0.680	0.705
	3	0.544	0.562	0.580	0.598	0.608	0.652	0.677
	3½	0.527	0.544	0.561	0.578	0.588	0.631	0.654
	4	0.513	0.530	0.548	0.565	0.575	0.616	0.639
	4½	0.502	0.518	0.535	0.551	0.561	0.601	0.624
	5	0.490	0.507	0.523	0.539	0.549	0.588	0.611
	6	0.480	0.496	0.512	0.528	0.538	0.577	0.599
	8	0.462	0.477	0.493	0.508	0.517	0.554	0.575
	9	0.453	0.468	0.483	0.498	0.507	0.544	0.564
	12	0.441	0.456	0.470	0.485	0.493	0.529	0.550
1½	½	0.737	0.762	0.787	0.812	0.826	0.884	0.918
	¾	0.657	0.679	0.702	0.725	0.737	0.790	0.820
	1	0.594	0.614	0.634	0.654	0.666	0.713	0.740
	1¼	0.542	0.559	0.577	0.596	0.606	0.649	0.673
	1½	0.507	0.524	0.541	0.558	0.568	0.609	0.632
	2	0.471	0.487	0.503	0.519	0.528	0.565	0.587
	2½	0.443	0.458	0.473	0.488	0.497	0.533	0.553
	3	0.421	0.435	0.449	0.463	0.472	0.506	0.525
	3½	0.403	0.417	0.430	0.443	0.451	0.483	0.502
	4	0.393	0.405	0.418	0.432	0.439	0.471	0.489
	4½	0.383	0.394	0.407	0.420	0.428	0.460	0.476
	5	0.372	0.384	0.397	0.409	0.417	0.447	0.463
	6	0.362	0.374	0.387	0.399	0.406	0.436	0.452
	8	0.343	0.354	0.366	0.378	0.385	0.413	0.429
	9	0.334	0.345	0.357	0.368	0.375	0.403	0.419
	12	0.323	0.334	0.346	0.357	0.364	0.391	0.407
2	½	0.648	0.670	0.692	0.713	0.726	0.779	0.810
	¾	0.578	0.598	0.617	0.637	0.648	0.694	0.720
	1	0.518	0.535	0.552	0.570	0.580	0.622	0.645
	1¼	0.469	0.485	0.501	0.517	0.527	0.566	0.587
	1½	0.438	0.452	0.467	0.481	0.490	0.526	0.545
	2	0.404	0.417	0.430	0.444	0.452	0.483	0.502
	2½	0.379	0.391	0.403	0.415	0.422	0.451	0.466
	3	0.356	0.367	0.378	0.390	0.397	0.425	0.440
	3½	0.339	0.350	0.361	0.373	0.380	0.406	0.421
	4	0.328	0.339	0.350	0.360	0.367	0.392	0.406
	4½	0.318	0.328	0.339	0.350	0.357	0.381	0.395
	5	0.308	0.318	0.329	0.340	0.346	0.370	0.384
	6	0.299	0.309	0.319	0.329	0.335	0.358	0.371
	8	0.282	0.291	0.301	0.310	0.315	0.336	0.349
	9	0.273	0.282	0.291	0.300	0.305	0.325	0.338
	12	0.263	0.272	0.280	0.289	0.294	0.314	0.325

Table 7. Coefficients of Transmission (U) for Pipes Insulated with Corrugated Asbestos Type Insulation (8 Plies Per Inch Thickness)

These coefficients are expressed in Btu per hour per square foot of pipe surface per degree Fahrenheit difference in temperature between pipe and surrounding still air at 70 F

Thickness of Insulation (Inches)	Nominal Pipe Size (Inches)	Hot Water				Steam		
		120 F	150 F	180 F	210 F	227.2 F (5 Lb)	298.7 F (10 Lb)	337.9 F (100 Lb)
		Temperature Difference						
		50 F	80 F	110 F	140 F	157.2 F	228.7 F	267.9 F
1	½	0.801	0.820	0.838	0.857	0.868	0.913	0.939
	¾	0.723	0.739	0.756	0.773	0.783	0.824	0.847
	1	0.658	0.673	0.688	0.704	0.713	0.751	0.772
	1¼	0.606	0.619	0.633	0.647	0.655	0.688	0.707
	1½	0.573	0.586	0.599	0.612	0.619	0.652	0.670
	2	0.538	0.550	0.562	0.575	0.581	0.612	0.629
	2½	0.511	0.523	0.534	0.546	0.553	0.582	0.599
	3	0.489	0.501	0.512	0.524	0.531	0.558	0.575
	3½	0.474	0.485	0.496	0.507	0.514	0.542	0.557
	4	0.461	0.472	0.482	0.493	0.500	0.527	0.542
	4½	0.451	0.462	0.472	0.482	0.489	0.515	0.530
	5	0.442	0.452	0.462	0.473	0.479	0.505	0.520
	6	0.432	0.442	0.452	0.463	0.468	0.493	0.508
	8	0.416	0.426	0.436	0.446	0.451	0.475	0.489
	9	0.408	0.418	0.427	0.437	0.442	0.466	0.480
	12	0.397	0.406	0.415	0.424	0.429	0.452	0.466
1½	½	0.664	0.679	0.695	0.711	0.720	0.759	0.780
	¾	0.593	0.607	0.621	0.636	0.643	0.677	0.697
	1	0.535	0.547	0.560	0.573	0.580	0.611	0.629
	1¼	0.488	0.499	0.510	0.522	0.528	0.556	0.572
	1½	0.457	0.467	0.478	0.490	0.496	0.522	0.537
	2	0.425	0.434	0.444	0.455	0.460	0.485	0.499
	2½	0.399	0.408	0.418	0.428	0.434	0.457	0.471
	3	0.378	0.387	0.396	0.405	0.411	0.433	0.446
	3½	0.363	0.371	0.380	0.388	0.393	0.415	0.427
	4	0.353	0.361	0.369	0.378	0.383	0.403	0.415
	4½	0.343	0.351	0.360	0.368	0.373	0.393	0.404
	5	0.334	0.342	0.350	0.358	0.363	0.383	0.394
	6	0.325	0.333	0.341	0.349	0.353	0.373	0.383
	8	0.309	0.316	0.324	0.332	0.336	0.355	0.365
	9	0.301	0.309	0.316	0.324	0.328	0.346	0.356
	12	0.291	0.298	0.306	0.313	0.317	0.335	0.344
2	½	0.585	0.599	0.613	0.627	0.635	0.668	0.688
	¾	0.520	0.533	0.545	0.558	0.565	0.595	0.612
	1	0.465	0.476	0.487	0.498	0.504	0.532	0.547
	1¼	0.422	0.432	0.442	0.452	0.458	0.483	0.497
	1½	0.394	0.403	0.412	0.422	0.427	0.450	0.462
	2	0.364	0.372	0.380	0.388	0.393	0.415	0.427
	2½	0.339	0.347	0.355	0.363	0.367	0.387	0.398
	3	0.319	0.327	0.334	0.342	0.346	0.365	0.375
	3½	0.304	0.311	0.318	0.326	0.330	0.349	0.358
	4	0.295	0.302	0.308	0.315	0.319	0.336	0.345
	4½	0.285	0.292	0.299	0.306	0.310	0.327	0.336
	5	0.278	0.284	0.290	0.297	0.301	0.317	0.326
	6	0.269	0.275	0.282	0.288	0.292	0.307	0.315
	8	0.253	0.259	0.265	0.270	0.273	0.288	0.296
	9	0.244	0.250	0.256	0.262	0.265	0.280	0.287
	12	0.236	0.241	0.247	0.253	0.256	0.270	0.277

TABLE 8. COEFFICIENTS OF TRANSMISSION (U) FOR PIPES INSULATED WITH LAMINATED ASBESTOS TYPE INSULATION (30 TO 40 LAMINATIONS PER INCH THICKNESS)

These coefficients are expressed in Btu per hour per square foot of pipe surface per degree Fahrenheit difference in temperature between pipe and surrounding still air at 70 F

Thickness of Insulation (Inches)	Nominal Pipe Size (Inches)	Hot Water				Steam		
		120 F	150 F	180 F	210 F	227.2 F (5 Lb)	298.7 F (10 Lb)	337.9 F (100 Lb)
		Temperature Difference						
		50 F	80 F	110 F	140 F	157.2 F	228.7 F	267.9 F
1	½	0.605	0.620	0.635	0.650	0.658	0.695	0.716
	¾	0.546	0.560	0.573	0.586	0.594	0.627	0.645
	1	0.498	0.510	0.522	0.534	0.541	0.570	0.587
	1¼	0.457	0.468	0.480	0.491	0.497	0.525	0.540
	1½	0.432	0.442	0.453	0.464	0.470	0.496	0.511
	2	0.406	0.416	0.426	0.437	0.442	0.467	0.481
	2½	0.385	0.395	0.405	0.415	0.420	0.443	0.457
	3	0.370	0.379	0.389	0.398	0.403	0.425	0.438
	3½	0.359	0.367	0.376	0.385	0.390	0.413	0.426
	4	0.349	0.358	0.366	0.375	0.380	0.402	0.414
	4½	0.341	0.350	0.359	0.367	0.372	0.393	0.405
	5	0.334	0.342	0.351	0.359	0.364	0.384	0.395
	6	0.327	0.335	0.343	0.351	0.356	0.376	0.387
	8	0.314	0.322	0.330	0.338	0.343	0.362	0.373
	9	0.308	0.316	0.325	0.333	0.336	0.355	0.366
	12	0.301	0.308	0.316	0.324	0.328	0.346	0.356
1½	½	0.502	0.514	0.526	0.539	0.546	0.577	0.595
	¾	0.450	0.461	0.473	0.484	0.490	0.517	0.532
	1	0.405	0.415	0.426	0.436	0.442	0.466	0.480
	1¼	0.369	0.378	0.387	0.396	0.401	0.423	0.435
	1½	0.343	0.352	0.361	0.370	0.375	0.397	0.409
	2	0.321	0.329	0.337	0.345	0.350	0.369	0.380
	2½	0.301	0.309	0.317	0.324	0.330	0.348	0.358
	3	0.286	0.293	0.301	0.308	0.313	0.330	0.340
	3½	0.274	0.281	0.288	0.295	0.300	0.316	0.326
	4	0.267	0.273	0.280	0.287	0.291	0.307	0.317
	4½	0.259	0.266	0.272	0.279	0.283	0.299	0.308
	5	0.253	0.260	0.266	0.272	0.276	0.291	0.300
	6	0.247	0.253	0.260	0.266	0.269	0.284	0.293
	8	0.234	0.240	0.246	0.252	0.255	0.270	0.279
	9	0.227	0.233	0.239	0.245	0.249	0.263	0.271
	12	0.221	0.227	0.232	0.238	0.241	0.255	0.263
2	½	0.442	0.453	0.464	0.475	0.481	0.508	0.523
	¾	0.392	0.402	0.412	0.422	0.428	0.452	0.465
	1	0.352	0.360	0.369	0.378	0.383	0.405	0.417
	1¼	0.319	0.327	0.335	0.343	0.348	0.367	0.379
	1½	0.297	0.304	0.311	0.319	0.323	0.341	0.352
	2	0.274	0.280	0.287	0.294	0.298	0.314	0.324
	2½	0.256	0.262	0.269	0.275	0.279	0.293	0.302
	3	0.243	0.249	0.254	0.260	0.264	0.277	0.285
	3½	0.231	0.236	0.242	0.248	0.251	0.265	0.273
	4	0.223	0.228	0.234	0.240	0.243	0.257	0.265
	4½	0.216	0.222	0.227	0.233	0.236	0.249	0.256
	5	0.210	0.215	0.220	0.225	0.228	0.241	0.248
	6	0.203	0.208	0.213	0.218	0.221	0.233	0.240
	8	0.191	0.196	0.201	0.206	0.209	0.220	0.227
	9	0.185	0.190	0.195	0.200	0.203	0.214	0.220
	12	0.178	0.183	0.187	0.192	0.195	0.205	0.210

TABLE 9. COEFFICIENTS OF TRANSMISSION (U) FOR PIPES INSULATED WITH LAMINATED ASBESTOS TYPE INSULATION (APPROXIMATELY 20 LAMINATIONS PER INCH THICKNESS)

These coefficients are expressed in Btu per hour per square foot of pipe surface per degree Fahrenheit difference in temperature between pipe and surrounding still air at 70 F

Thickness of Insulation (Inches)	Nominal Pipe Size (Inches)	Hot Water				Steam		
		120 F	150 F	180 F	210 F	227.2 F (5 Lb)	298.7 F (10 Lb)	337.9 F (100 Lb)
		Temperature Difference						
		50 F	80 F	110 F	140 F	157.2 F	228.7 F	267.9 F
1	½	0.910	0.925	0.940	0.956	0.964	1.001	1.022
	¾	0.823	0.836	0.850	0.863	0.871	0.902	0.921
	1	0.748	0.760	0.773	0.785	0.792	0.823	0.840
	1¼	0.686	0.698	0.710	0.721	0.728	0.756	0.771
	1½	0.649	0.659	0.671	0.682	0.688	0.716	0.731
	2	0.610	0.620	0.630	0.640	0.647	0.671	0.685
	2½	0.581	0.590	0.600	0.609	0.615	0.638	0.651
	3	0.558	0.567	0.576	0.585	0.591	0.613	0.626
	3½	0.539	0.548	0.557	0.566	0.571	0.592	0.604
	4	0.524	0.532	0.541	0.551	0.556	0.577	0.589
	4½	0.514	0.522	0.530	0.539	0.544	0.564	0.575
	5	0.503	0.511	0.519	0.528	0.533	0.553	0.565
	6	0.492	0.500	0.509	0.517	0.522	0.542	0.553
	8	0.473	0.480	0.488	0.497	0.502	0.521	0.532
	9	0.463	0.471	0.478	0.486	0.491	0.510	0.520
	12	0.452	0.459	0.467	0.475	0.478	0.497	0.507
1½	½	0.755	0.767	0.780	0.793	0.800	0.831	0.848
	¾	0.674	0.685	0.697	0.708	0.715	0.743	0.759
	1	0.607	0.618	0.628	0.639	0.645	0.670	0.684
	1¼	0.553	0.562	0.572	0.581	0.587	0.610	0.622
	1½	0.517	0.527	0.536	0.545	0.550	0.572	0.584
	2	0.481	0.490	0.499	0.508	0.513	0.535	0.547
	2½	0.453	0.460	0.469	0.477	0.481	0.500	0.511
	3	0.429	0.436	0.444	0.452	0.456	0.475	0.485
	3½	0.412	0.419	0.427	0.434	0.438	0.456	0.465
	4	0.400	0.407	0.415	0.422	0.426	0.443	0.453
	4½	0.390	0.396	0.402	0.409	0.413	0.429	0.437
	5	0.380	0.386	0.393	0.400	0.403	0.418	0.427
	6	0.369	0.375	0.382	0.389	0.392	0.408	0.417
	8	0.351	0.358	0.364	0.370	0.374	0.388	0.397
	9	0.342	0.349	0.355	0.361	0.364	0.378	0.387
	12	0.332	0.338	0.344	0.350	0.353	0.367	0.375
2	½	0.664	0.675	0.687	0.698	0.704	0.732	0.747
	¾	0.591	0.601	0.611	0.621	0.627	0.652	0.665
	1	0.529	0.538	0.547	0.557	0.562	0.584	0.597
	1¼	0.480	0.488	0.497	0.505	0.510	0.529	0.540
	1½	0.445	0.453	0.462	0.470	0.475	0.494	0.504
	2	0.412	0.420	0.427	0.434	0.438	0.455	0.464
	2½	0.385	0.392	0.398	0.405	0.409	0.425	0.434
	3	0.364	0.370	0.376	0.382	0.385	0.400	0.408
	3½	0.346	0.352	0.358	0.365	0.368	0.382	0.390
	4	0.336	0.342	0.348	0.354	0.357	0.371	0.378
	4½	0.325	0.332	0.338	0.343	0.346	0.360	0.367
	5	0.316	0.322	0.327	0.333	0.336	0.349	0.356
	6	0.306	0.312	0.317	0.323	0.326	0.338	0.345
	8	0.288	0.293	0.298	0.303	0.306	0.317	0.324
	9	0.280	0.284	0.289	0.294	0.297	0.307	0.313
	12	0.269	0.274	0.278	0.283	0.286	0.296	0.302

TABLE 10. COEFFICIENTS OF TRANSMISSION (*U*) FOR PIPES INSULATED WITH ROCK WOOL TYPE INSULATION

These coefficients are expressed in Btu per hour per square foot of pipe surface per degree Fahrenheit difference in temperature between pipe and surrounding still air at 70 F

Thickness of Insulation (Inches)	Nominal Pipe Size (Inches)	Hot Water				Steam		
		120 F	150 F	180 F	210 F	227.2 F (5 Lb)	298.7 F (10 Lb)	337.9 F (100 Lb)
		Temperature Difference						
		50 F	80 F	110 F	140 F	157.2 F	228.7 F	267.9 F
1	½	0.631	0.644	0.658	0.672	0.680	0.712	0.730
	¾	0.569	0.581	0.593	0.606	0.613	0.642	0.659
	1	0.518	0.529	0.541	0.552	0.559	0.585	0.600
	1¼	0.476	0.486	0.497	0.507	0.513	0.537	0.551
	1½	0.450	0.460	0.470	0.480	0.485	0.508	0.522
	2	0.422	0.431	0.441	0.450	0.456	0.478	0.490
	2½	0.402	0.411	0.420	0.428	0.434	0.455	0.466
	3	0.385	0.394	0.402	0.411	0.415	0.435	0.446
	3½	0.373	0.381	0.389	0.398	0.402	0.421	0.432
	4	0.363	0.371	0.379	0.387	0.392	0.411	0.422
	4½	0.355	0.363	0.371	0.379	0.383	0.402	0.413
	5	0.348	0.356	0.364	0.371	0.376	0.394	0.404
	6	0.341	0.348	0.356	0.363	0.368	0.386	0.396
	8	0.327	0.335	0.342	0.349	0.353	0.372	0.381
	9	0.321	0.328	0.335	0.342	0.347	0.365	0.374
	12	0.313	0.320	0.327	0.334	0.338	0.355	0.364
1½	½	0.523	0.534	0.545	0.556	0.563	0.590	0.606
	¾	0.468	0.477	0.487	0.497	0.503	0.528	0.542
	1	0.421	0.430	0.440	0.449	0.455	0.477	0.490
	1¼	0.383	0.391	0.399	0.407	0.412	0.433	0.444
	1½	0.359	0.366	0.375	0.383	0.387	0.407	0.419
	2	0.333	0.340	0.348	0.356	0.360	0.378	0.389
	2½	0.314	0.320	0.327	0.335	0.339	0.355	0.365
	3	0.296	0.302	0.310	0.317	0.321	0.337	0.347
	3½	0.286	0.291	0.298	0.304	0.307	0.323	0.332
	4	0.278	0.284	0.290	0.296	0.300	0.315	0.323
	4½	0.270	0.276	0.282	0.287	0.291	0.305	0.313
	5	0.263	0.269	0.275	0.280	0.284	0.298	0.305
	6	0.257	0.262	0.267	0.273	0.277	0.290	0.297
	8	0.244	0.249	0.254	0.260	0.263	0.276	0.283
	9	0.238	0.243	0.248	0.254	0.257	0.270	0.277
	12	0.230	0.234	0.239	0.245	0.247	0.260	0.267
2	½	0.461	0.471	0.481	0.491	0.496	0.520	0.534
	¾	0.409	0.418	0.427	0.436	0.441	0.463	0.475
	1	0.366	0.374	0.382	0.390	0.395	0.415	0.427
	1¼	0.333	0.340	0.347	0.355	0.359	0.377	0.387
	1½	0.310	0.316	0.323	0.330	0.334	0.351	0.360
	2	0.286	0.292	0.298	0.304	0.308	0.323	0.331
	2½	0.268	0.274	0.279	0.285	0.289	0.302	0.310
	3	0.252	0.257	0.262	0.268	0.272	0.284	0.292
	3½	0.241	0.246	0.251	0.257	0.260	0.272	0.280
	4	0.232	0.237	0.242	0.247	0.250	0.262	0.269
	4½	0.225	0.230	0.235	0.240	0.243	0.255	0.262
	5	0.218	0.223	0.228	0.233	0.236	0.247	0.253
	6	0.213	0.217	0.221	0.226	0.228	0.239	0.245
	8	0.200	0.204	0.208	0.213	0.215	0.225	0.231
	9	0.193	0.197	0.201	0.205	0.207	0.218	0.224
	12	0.185	0.190	0.194	0.198	0.200	0.210	0.216

Example 2. Determine the total heat loss for a period of 30 days through a 1-in. (4 ply) thickness of corrugated asbestos insulation on 100 ft of 3-in. pipe carrying steam at 5 lb pressure, and with surrounding air at 60 F. Also determine percentage of heat saving over bare pipe loss.

Solution. Difference in temperature between pipe and surrounding air = 227.2 − 60 or 167.2 deg. From Table 6 the coefficients of transmission for 1-in. corrugated asbestos (4 ply) are 0.608 and 0.652 Btu per hour per square foot per degree temperature difference at temperature differences of 157.2 deg and 228.7 deg, respectively. The difference is 0.044 Btu per hour per square foot per degree temperature difference for a temperature difference of 71.5 deg. For a temperature difference of 167.2 deg (10 deg higher than 157.2 deg) the coefficient of transmission is then $0.608 + \left(\frac{10}{71.5} \times 0.044\right)$, or 0.614 Btu per hour per square foot per degree temperature difference. From Table 2 the area per linear foot of 3-in. pipe is 0.917 sq ft. The total heat loss is therefore 0.917 × 0.614 × 167.2 × 100 (linear feet) × 720 (hours) = 6,779,700 Btu.

From Table 1, and in the same manner it is determined that the loss through an uninsulated 3-in. pipe for the same conditions will be 28,266,100 Btu. The saving due to insulation is 21,486,300 Btu or 76 per cent of the bare pipe loss.

INSULATION FOR COLD SURFACES

Surfaces maintained at low temperatures should be insulated so as to retard the flow of heat from the outside into the low temperature area and to prevent the formation of condensation and of frost if the temperatures are low enough, as well as to prevent corrosion, induced by the presence of condensed moisture on metal surfaces. Materials commonly used for insulating pipes and surfaces at low temperatures are cork, rock cork, hair felt and other felted or fibrous non-absorbent materials. Thermal conductivities of low temperature insulating materials are given in Chapter 3.

Insulating materials are available commercially to meet varying temperature gradients. For example, the thickness of insulation for ice water is approximately 1½-in. if the temperature in the line is not lower than 25 F; the thickness of insulation for brine is approximately 2½ in. where the temperature ranges from 0 deg to 25 F; and the thickness of insulation where the brine temperature ranges from −30 F to zero degrees is approximately 4 in.

Prevention of Condensation on Cold Pipes

In some cases the prevention of condensation rather than the conservation of heat is the governing factor in determining the thickness of insulation required. Fig. 2 may be used for determining the thickness of any material of known conductivity which should be used to prevent condensation on pipes and flat metallic surfaces. The surface resistances used for calculating the family of curves in Fig. 2 are based on the results of tests made on canvas-covered pipe insulation surfaces at Mellon Institute. However, it has been found that the resistance for asphaltic and roofing surfaces is practically the same as for canvas surfaces so that the curves given may be followed with no alteration on account of the surfaces commonly used. (See discussion of surface transfer of heat in Chapter 3).

Moisture will be deposited on a surface whenever its temperature falls to that of the dew-point. The maximum permissible temperature drop is indicated on Fig. 2 at the point where the guide line passes through the horizontal scale at the left center of the chart. This temperature drop

represents the difference between the dry-bulb temperature and the dew-point temperature for the conditions involved. (See discussion of condensation in Chapter 3).

Insulation to Prevent Freezing of Water in Pipes

Insulation will retard the freezing of water in pipes. With a certain amount of circulation, or even without circulation, if the air remains at a

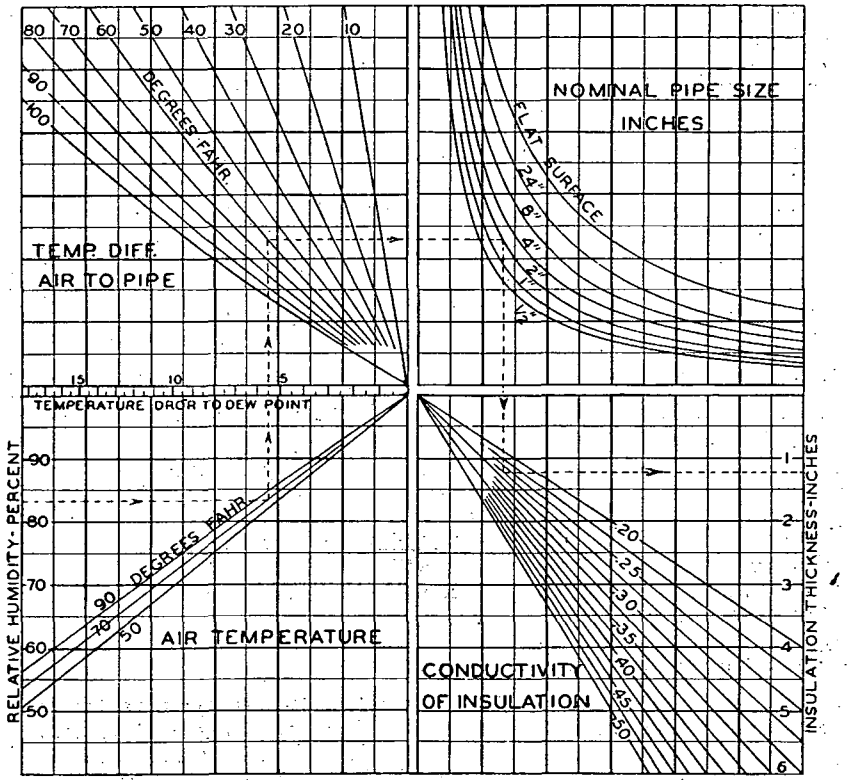
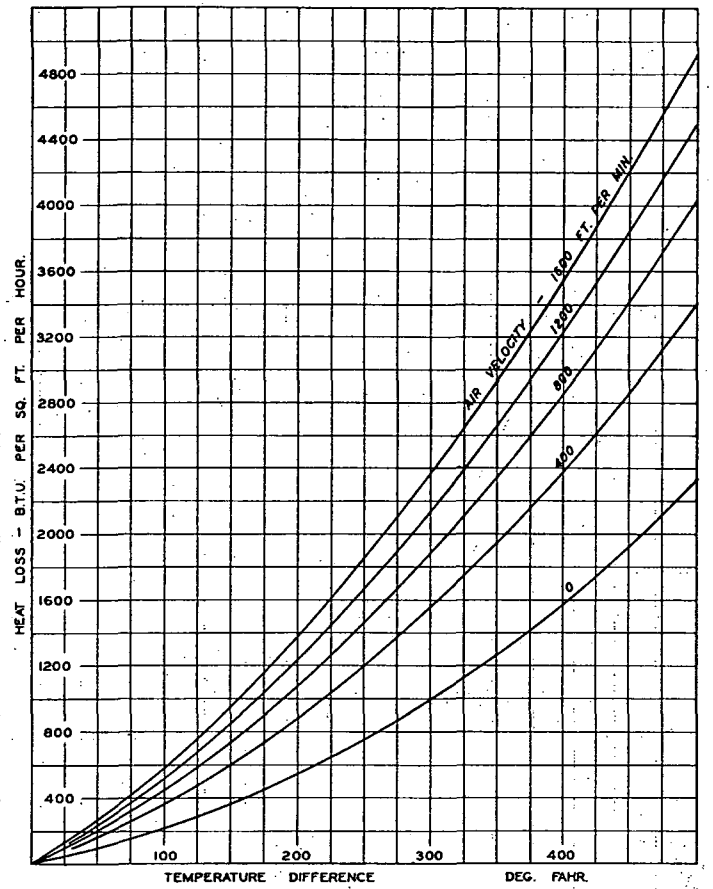


FIG. 2. THICKNESS OF PIPE INSULATION TO PREVENT SWEATING[a]

[a]Solve problems by drawing lines as indicated by dotted line, entering chart at lower left hand scale.

low temperature for only a short period, freezing may be prevented. Still water in pipes may be prevented from freezing by inserting a heating medium inside the insulation surrounding the pipe. No amount of insulation, however, will prevent water in pipes from freezing where there is no circulation or where there is only a small amount of circulation in the pipe, if the outside temperature remains below the freezing point for a sufficient length of time. Pipes carrying water and which may be sub-

jected to severe conditions of temperature are insulated with insulations such as hair felt or cork. The insulation is applied in layers of approximately 1-in. thickness, securely bound in place on the pipe and finished on the outside with a waterproof jacket.

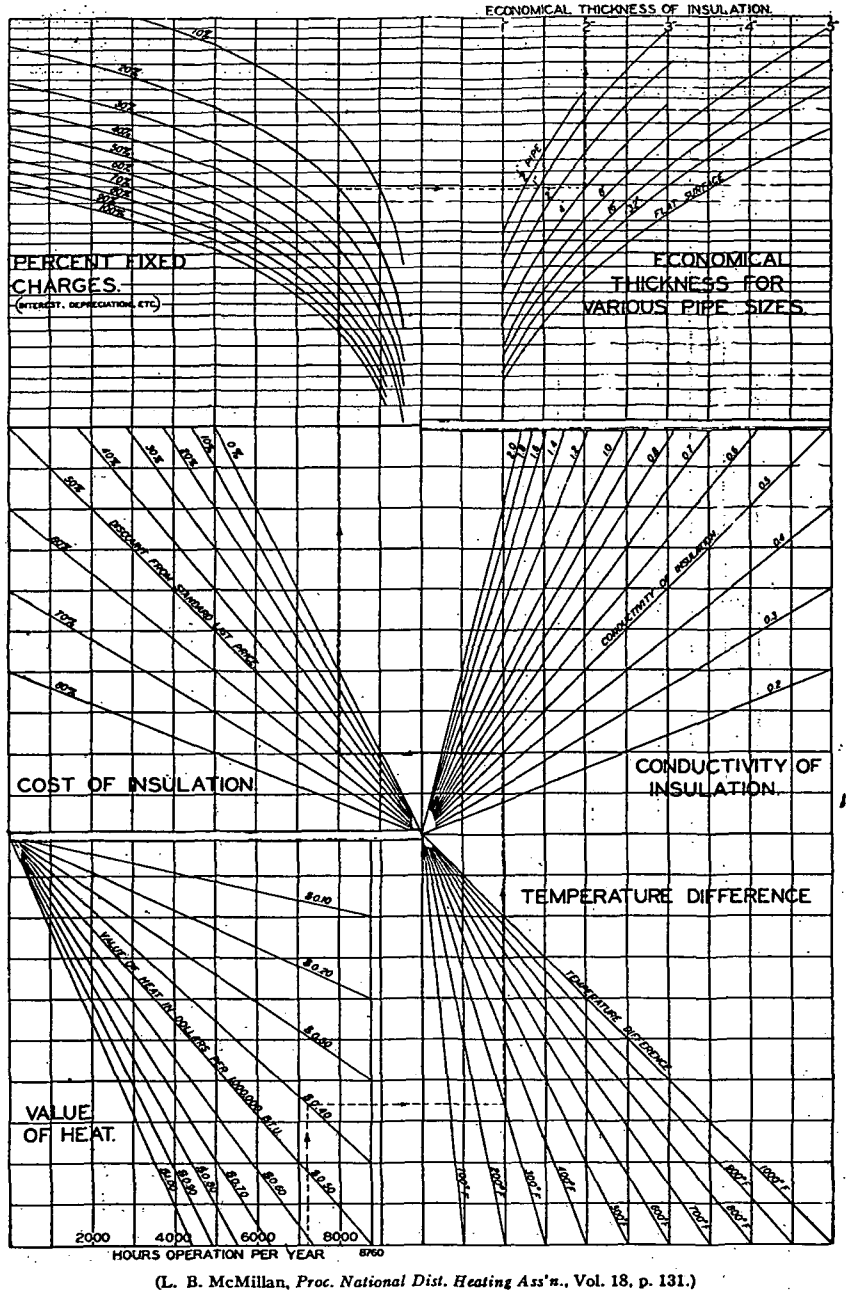


(L. B. McMillan, *Iron and Steel Engineer, July 1925.*)

FIG. 3. HEAT LOSSES FROM SURFACES EXPOSED TO VARIOUS AIR VELOCITIES

EFFECT OF AIR VELOCITY ON SURFACE LOSSES

The rate of heat loss from a surface maintained at constant temperature is greatly increased by air circulation over the surface. Fig. 3 is based on Langmuir's equations (*Trans. Am. Electro-Chem. Soc.*, Vol. 23). Other investigators have shown even greater increases in rates of heat loss from bare surfaces due to air velocity.



(L. B. McMillan, *Proc. National Dist. Heating Ass'n.*, Vol. 18, p. 131.)

FIG. 4. CHART FOR DETERMINING ECONOMICAL THICKNESS OF INSULATION

In the case of well-insulated surfaces the increases in losses due to air velocity are very small as compared with increases shown for bare surfaces, because of the fact that air flowing over the surface of the insulation can increase only the rate of heat transfer from surface to air, and cannot change the internal resistance to heat flow inherent in the insulation itself. The maximum increase in loss due to air velocity ranges from about 30 per cent in the case of 1 in. thick insulation, to about 10 per cent in the case of 3 in. thick insulation, provided that the insulation is thoroughly sealed so that air can flow only over the surface.

If the conditions are such that the air may circulate through cracks and crevices in the insulation, the increases may be far greater than those given. Therefore, it is essential that insulation be sealed as tightly as possible. Pipe insulation out-of-doors should be provided with a weather-proof jacket, and other outdoor insulation should be thoroughly weather-proofed.

TABLE 11. THICKNESSES OF INSULATION ORDINARILY USED INDOORS[a]

STEAM PRESSURES (LB GAGE) OR CONDITION	STEAM TEMPERATURES DEGREES FAHRENHEIT	THICKNESS OF INSULATION		
		Pipes Larger Than 4 In.	Pipes 2 In. to 4 In.	Pipes ½ In. to 1½ In.
0 to 25	212 to 267	1 in.	1 in.	1 in.
25 to 100	267 to 338	1½ in.	1 in.	1 in.
100 to 200	338 to 388	2 in.	1½ in.	1 in.
Low Superheat	388 to 500	2½ in.	2 in.	1½ in.
Medium Superheat	500 to 600	3 in.	2½ in.	2 in.
High Superheat	600 to 700	3½ in.	3 in.	2 in.

[a]All piping located outdoors or exposed to weather is ordinarily insulated to a thickness ½ in. greater than shown in this table, and covered with a waterproof jacket.

ECONOMIC THICKNESS OF PIPE INSULATION

Table 11 shows the thicknesses of insulation which ordinarily are used for various temperature conditions. Where a thorough analysis of economic thickness is desired, this may be accomplished through the use of the chart, Fig. 4.

The dotted line on the chart illustrates its use in solving a typical example. In using the chart, start with the scale at the left bottom margin representing the given number of hours of operation per year; then proceed vertically to the line representing the given value of heat; thence horizontally, to the right, to the line representing the given temperature difference; thence vertically to the line representing the conductivity of the given material; thence horizontally, to the left, to the line representing the given discount on that material; thence vertically to the curve representing the required per cent return on the investment; thence horizontally, to the right, to the curve representing the given pipe size; thence vertically to the scale at the top right margin where the economical thickness may be read off directly. The dotted line on the chart illustrates its use in solving a typical example.

Underground Insulation

It is impossible to determine accurately the economic thickness of insulation to use for an underground installation owing to the many variables which are present such as depth of line, conductivity of ground, moisture conditions, etc. However, it is considered good practice to insulate underground lines with approximately ½ in. less thickness of insulation than for above ground installations under similar operating conditions.

It is necessary to keep the insulation absolutely dry if the efficiency is to be maintained, therefore, precautions should be taken thoroughly to weather-proof the insulation and to provide a drainage system for the water which may get into the conduit.

Chapter 13

DOMESTIC WATER REQUIREMENTS AND PIPE SIZES

Errors to be Avoided; Sizing of Mains and Risers; Sizing Mains and Headers; Sizing of Branch Pipes; Storage Tanks; Hot Water Tanks and Heaters; Hot Water Temperature; Additional Boiler Capacity.

THE duties of the heating engineer frequently include the design and layout of the water supply piping for buildings. Unlike heating and ventilating layouts, there are practically no definite data for estimating the quantity of water likely to be consumed or the probable rate of water flow at any particular moment.

Metered results in one building often show two or three times the metered amount in another building of the same size and with the same type of tenants. In hotels, one riser will often have an almost constant flow that may never be reached by another at peak load. In office buildings, the women's toilets show a far greater daily consumption than those of the men, yet at no time will they approach the hourly consumption of the men's toilet during the first hour of the day. This condition has led to a multiplicity of rules of practice which vary as much as the data used. All must of necessity be based on an assumed rate of consumption and on an assumed probability of simultaneous use, and while the formulae employed may have been derived on sound technical bases the assumptions are often in error.

To arrive at a safe standard, a similar set of hospital, hotel and apartment risers and headers was submitted to several leading architects, engineers and plumbing contractors for pipe sizing. From these a composite layout was made with corrections in the sections where untoward results had occurred in existing installations and from the composite plan the rules of procedure given in this chapter were formulated.

ERRORS TO BE AVOIDED

One of the most common causes of failure of domestic water supply systems is excessive loss of pressure in the mains or risers. An excessive pressure drop in the cold water riser may allow hot water to cross into the cold water piping. Cases have occurred where there was not only a total loss of pressure but a negative pressure was created, resulting in the siphoning of polluted water from bowls or basins through submerged faucets back into the supply pipes. This pressure drop is not always due to restricted risers but often may be due to over-size branches discharging at a much higher rate than that which the riser was designed to carry.

Care should be taken sufficiently to throttle the branches especially at points of high pressure so that the discharge will approximate the amounts given in Table 1.

Unless the flow of water is throttled properly, broken fittings may result from excessive water hammer in addition to draining the pressure in the riser. The throttling should preferably be done by pipe sizing

TABLE 1. BRANCH PIPE SIZES AND QUANTITIES FOR VARIOUS FIXTURES

TYPE OF FIXTURE	PIPE SIZE (IN.)	DESIRED DISCHARGE (GPM)	PROBABLE DISCHARGE (GPM)
Lavatory	½	4	5
Bath	¾	15	14
Shower, Rain Head	½	8	5
Shower, Needle	1	30	28
Tank, Urinal	½	6	5
Tank, W. C.	½	8	5
Urinal Flush Valve	¾	30	14
Urinal Flush Valve	1	30	28
W. C. Flush Valve	1	30	28
W. C. Flush Valve	1¼	30	49
Slop Sink, etc	1	15	14

TABLE 2. EQUIVALENT PIPE SIZES[a]

(Number of ½-in. pipes accommodated by a single pipe at the same friction loss per unit of length based on $D^{5.2}$ using nominal sizes)

PIPE DIAMETER	CAPACITY OR FACTOR VALUE
½	1
¾	2.7
1	5.5
1¼	9.7
1½	15.3
2	32
2½	55
3	86.5
3½	127
4	178
5	310
6	490
8	1000

[a]The nominal size of pipe was used in the preparation of this table on account of the fact that the flow in several existing installations approached the values in the third column of Table 1 and which values follow closely along the estimated values of $D^{5.2}$ when the nominal sizes are taken.

rather than by means of control valves, since the latter concentrate all the resistance at one point which, with the necessary high velocity, causes a hissing, noisy system. To avoid the water hammer, air chambers should be installed just before the fixtures, or a pressure-reducing or flow-regulating valve should be installed on the branch.

Failure to consider the friction consumed by the meter has been the cause of unsatisfactory operation of the system in many cases. The

friction loss through the meter is sometimes as much as that throughout the remainder of the system. Its value can always be obtained from the makers of the particular meter used.

SIZING OF MAINS AND RISERS

The uncertainty of the flow in the risers leaves some uncertainty as to the pressure that will prevail at any branch take-off and precludes the sizing of the branch pipe with any degree of precision. This has led to the adoption of fixed sizes for the various fixtures. These sizes, together with the rate of flow desirable for the fixture and the probable amount of discharge that will result with the average length of branch, are given in Table 1. The discharge quantities which were taken from the equivalent values for the various diameters given in Table 2, follow closely the flow

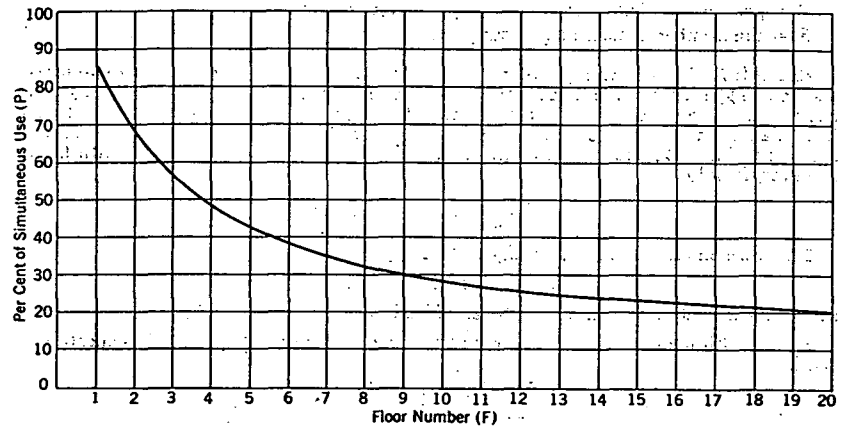


FIG. 1. CHART SHOWING RELATION BETWEEN FLOOR NUMBER AND PER CENT OF SIMULTANEOUS USE OF INSTALLED FIXTURES FOR PROPORTIONING MAINS, RISERS, AND HEADERS. (THE FLOOR NUMBER IS TAKEN AS THE FLOOR NEAREST THE GROUND FOR DOWN-FEED SYSTEMS, AND THE HIGHEST FLOOR FOR UP-FEED SYSTEMS)

through a pipe with an equivalent length of 25 ft for a friction loss of 30 lb per square inch.

It is well to keep the following points in mind while designing the water supply piping:

1. Liberal sizing of mains and risers is advisable.
2. Liberal sizing of the branches may cause trouble.
3. When liberal sized branches are used the risers, mains and tanks must be increased accordingly.
4. With proper care the risers and mains need not be made so large as to make the cost excessive.
5. To base the design on an *assumed* probability of simultaneous use may be dangerous.

Probability of Simultaneous Use

The risers and mains must be sized to accommodate the discharge from all the branches with due consideration to the probability of simultaneous

use. The assumed percentage of simultaneous use varies greatly among designers of water supply systems. Even a precise mathematical calculation as to its value must be based on an assumption of the probable number of times the fixture is used per unit of time. To arrive at a safe practical value of the probability an analysis of the composite layout was made which shows the flow following closely along the curve shown in Fig. 1, the probability being almost 100 per cent at the last floor supplied and diminishing to a minimum of 10 per cent.

The following equation may be written to fit the curve of Fig. 1:

$$P = \frac{224}{F + 2} + 10 \qquad (1)$$

where

P = per cent of simultaneous use (expressed as a whole number).
F = the number of floors being supplied.

Example 1. For a riser supplying two bath rooms on each floor, each bath room fitted with one 1¼-in. flushometer connection, one ¾-in. bath and one ½-in. lavatory connection, the rate of flow for each room if all fixtures were opened simultaneously as taken from Table 1 would be 68 gpm, and for each floor, 136 gpm. For the fifth floor the amount will be 5 × 136 = 680 gpm. The probable simultaneous use at the fifth floor, however, is only:

$$\frac{224}{5 + 2} + 10 = 42 \text{ per cent}$$

and the riser must therefore be designed to carry

$$0.42 \times 680 \text{ gpm} = 286 \text{ gpm}$$

at whatever friction loss the conditions will allow. (See Example 2).

At the 10th floor supplied, the amount flowing at some one time may be expected to reach:

$$10 \times 136 \times \left(\frac{224}{10 + 2} + 10\right) \text{ per cent} = 394 \text{ gpm}$$

In a 10-story building with 22 similar risers the main would be required to supply:

$$\frac{224}{(10 \times 22) + 2} + 10 = 11 \text{ per cent of the total fixture supply.}$$

Formula 1 is based on the number of floors in the building and therefore only applies when the distribution of fixtures on each floor is equal, or nearly equal. Where the fixtures are unequally distributed a percentage of maximum simultaneous use must be estimated for the fixtures on each level and on each portion of the riser, this percentage grading from 100 per cent for the first two fixtures on the end of each branch down to a minimum of about 25 per cent where 500 or more fixtures are installed. The number of gallons per minute used by all the fixtures supplied by a branch or riser at any particular point multiplied by this estimated percentage of maximum use will then give the maximum probable number of gallons per minute passing through the pipe at this point, and the pipe may then be sized on the basis of the friction drop allowable for the conditions involved. Special percentages of maximum simultaneous use must be developed for gang showers, batteries of lavatories for industrial work, and other groups of fixtures where an unusual maximum demand may exist during certain specified hours.

TABLE 3. NUMBER OF ½-IN. PIPES ACCOMMODATED BY A SINGLE PIPE IN THE AVERAGE TYPE BUILDING WITH ALLOWANCE FOR SIMULTANEOUS USE

PIPE DIAMETER (IN.)	NUMBER OF ½ IN. PIPES	PIPE DIAMETER (IN.)	NUMBER OF ½ IN. PIPES
1	3 to 5	3½	431 to 700
1¼	6 to 11	4	701 to 1200
1½	12 to 44	5	1201 to 2400
2	45 to 100	6	2401 to 5000
2½	101 to 220	8	5000 up
3	221 to 430		

Due to a lack of variety in commercial sizes it is not possible to change the size of the riser at each floor. When an increased size is first used the friction loss per unit of length must of necessity be less than the predetermined amount but will increase as the floors are added until it is approximately an equal amount in excess of the loss desired when the size must again be increased. The average loss through the section will be near that desired.

To facilitate the design, the equivalent number of smaller pipe supplied by each large pipe at its location in the composite layout was determined as shown in Table 3. For convenience these values are all referred to the equivalent in ½ in. pipes as specified in Table 2. It should be noted that Table 3 allows for the diversity factor or per cent of simultaneous use.

Example 2. Fig. 2 shows the piping layout of the upper half of a 22-story structure which is typical of office, hotel, club and apartment risers. Taking riser No. 1, the outlets on each floor consist of two 1¼-in. flushometer valve connections, two ¾-in. connections for bath, and two ½-in. connections for the lavatories.

The total factor value for the cold water riser as taken from Table 2 is:

2 × 9.7 = 19.4 for flushometers
2 × 2.7 = 5.4 for baths
2 × 1 = 2.0 for lavatories

Total for each floor 26.8 pipe equivalents

Thus with the first floor supplied (the 12th story in this case) the riser must supply

TABLE 4. AMOUNT OF WATER IN GALLONS PER MINUTE WHICH WILL FLOW THROUGH VARIOUS SIZED PIPES FOR VARIOUS PRESSURE DROPS

FRICTION PRESSURE DROP POUNDS PER SQUARE INCH PER 100-FT. RUN	PIPE SIZES IN INCHES									
	¾	1	1¼	1½	2	2½	3	3½	4	5
5	5.4	11	19	30	62	109	171	252	353	610
7	6.4	13	23	36	74	129	203	298	418	720
10	7.6	15	27	43	88	154	242	357	499	862
20	10.8	22	38	61	125	218	343	504	706	1221
30	13.2	27	47	76	153	267	420	618	864	1500
40	15.0	31	54	86	176	308	485	714	998	1725
50	17.0	35	60	96	197	345	542	800	1115	1930
75	21.0	43	74	117	242	423	665	978	1365	2370
100	24.0	49	85	136	278	485	769	1130	1578	
125	27.0	55	96	152	311	544	858	1260	1765	
150	30.0	60	105	166	341	598	939	1380	1930	

26.8, ½-in. fixtures, the riser of the 2nd floor supplied must accommodate 53.6 fixtures, the 3rd, 80.4, etc. These values are shown in Fig. 2. By referring to Table 3 the pipe sizes may be determined readily and are as shown in Fig. 2. The hot water riser will

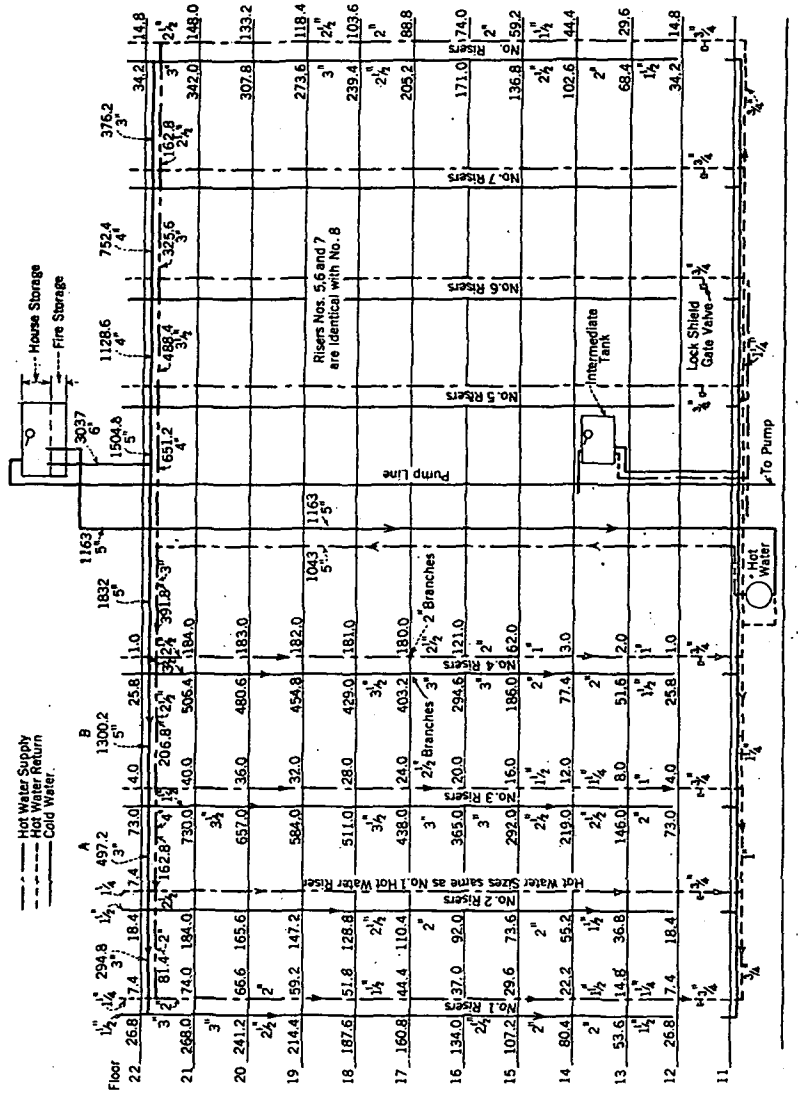


FIG. 2. PIPE SIZES AND QUANTITIES OF WATER FOR WATER SUPPLY PIPING PROBLEM. (SEE EXAMPLE 2)

supply the baths and lavatories only and has a value of 7.4 for each floor. The riser is sized accordingly. Riser No. 2 is similar to Riser No. 1 except that only 1-in. pipe has been used for the flushometer connections. The discharge to the flushometer valve will be at a lower rate and will take a correspondingly smaller riser. The cold water factor per floor is now 18.4.

The class of fixtures per floor and their fixture value for the various risers of Fig. 2 are as follows:

Riser No. 1

2 W. C. flushometers (1¼-in. connections)	19.4
2 Baths (¾-in. connections)	5.4
2 Lavatories (½-in. connections)	2.0
Fixture value per floor (cold water)	26.8
Fixture value per floor (hot water)	7.4

Riser No. 2

2 W. C. flushometers (1-in. connections)	11.0
2 Baths (¾-in. connections)	5.4
2 Lavatories (½-in. connections)	5.0
Fixture value per floor (cold water)	18.4
Fixture value per floor (hot water)	7.4

Riser No. 3

6 W. C.	58.2
4 Urinals	10.8
4 Lavatories	4.0
Fixture value (cold water)	73.0
Fixture value (hot water)	4.0

Riser No. 4

12th, 13th, 14th and 18th to 22nd floors.

2 W. C.	19.4
2 Urinals	5.4
1 Lavatory	1.0
Fixture value (cold water)	25.8
Fixture value (hot water)	1.0

15th, 16th and 17th floors

6 Rain Head Showers	6.0
6 Needle Showers	33.0
4 W. C. (1¼-in.)	38.8
4 Urinals (¾-in.)	10.8
3 Lavatories	3.0
Fixture value (cold water)	91.8
Allowance (see p. 212)	17.0
Fixture value used	108.6
Fixture value (hot water)	42.0
Allowance (see p. 212)	17.0
Fixture value used	59.0

Risers 5, 6, 7 and 8

2 W. C.	19.4
2 Baths	5.4
2 Lavatories	2.0
2 Sinks	2.0
2 Laundries (¾-in.)	5.4
Fixture value (cold water)	34.2
Fixture value (hot water)	14.8

The method is simple but special cases arise where engineering judgment must be exercised. Attention is called to the difference in design between risers Nos. 3 and 4. On the cold water riser No. 3, there are 6 water closets, 4 urinals and 4 lavatories with a combined fixture value of 73.0 per floor. As the time consumed in flushing is small the diversity factor will be the same as for other risers of the system and the regular method may be followed. On the cold water riser No. 4, however, the 12th, 13th, 14th and the 18th to the 22nd floors have 2 water closets, 2 urinals and 1 lavatory with a fixture value of 25.8 per floor and the 15th, 16th and 17th floors each have 6 rain head showers, 6 needle showers, 4 water closets, 4 urinals and 3 lavatories. The water closets, urinals and lavatories would have the usual diversity of use, but if it is suspected that the showers will have periods when they will be crowded and in almost constant use it will be necessary to make the branch almost full size and, of course, the riser correspondingly larger. The factor values that will follow the usual diversity are:

4 W. C.	= 38.8
4 Urinals	= 10.8
3 Lavatories	= 3.0
Total	52.6

The unusual factors are:

6 Rain head showers	= 6.0
6 Needle showers	= 33.0
Total	39.0

Since the showers must be given an almost full supply, the pipe size to supply them must be taken from Table 2 which indicates a pipe slightly larger than a 2-in. pipe. If the size had been taken from Table 3, a 1½-in. pipe would have been indicated. Adopting the 2-in. pipe instead of the 1½-in., the value to be used in the diversity table must be increased by the difference in the carrying capacity of the two pipes as taken from Table 2. This is:

$$32.0 - 15.3 = 16.7 \text{ or, roughly, } 17.0$$

The fixture value for the floor should then be taken as:

$$52.6 + 39.0 + 17.0 = 108.6$$

and according to Table 3, the diversity table, a 2½-in. branch pipe should be used. The fixture value of 108.6 is then added to size the riser for the 16th and 17th floors as shown in Fig. 2. A similar increase is made for the hot water riser.

SIZING MAINS AND HEADERS

To size the headers for either the hot or cold water, it is only necessary to total the values for all the risers that they supply and take the pipe size from Table 3 as was done in sizing the risers themselves. Thus at *A* (Fig. 2) the size is found to be a 3½-in. pipe, and at *B* the fixture value falls close to the dividing line between the 4-in. and 5-in. pipes. If the roof tank is at a high elevation giving considerable pressure the 4-in. pipe

might be sufficient. If there is but a small initial pressure it might be advisable to use the larger size.

To determine the loss of pressure that may occur at this point where the supply for 3 risers to 11 floors each is flowing, consider this point as the 33rd floor, and by the use of Formula 1, the percentage of flow at some peak moment is found to be:

$$\frac{224}{33 + 2} + 10 = 17 \text{ per cent}$$

of the actual total fixtures supplied. The total number of fixture equivalents at this point is 1300 and a flow may therefore be expected at some time sufficient to supply:

$0.17 \times 1300 = 221$ fixtures, which at 5 gpm per fixture amounts to:

$$5 \times 221 = 1105 \text{ gpm.}$$

Table 4 gives the amount of water in gallons per minute which will flow through various pipes for various pressure drops. By referring to this table it is found that the friction loss for 1105 gpm through a 4-in. pipe is nearly 50 lb per square inch per 100 linear feet of pipe while through a 5-in. pipe it is approximately only 15 lb per square inch. It will therefore be advisable to adopt the 5-in. size. This method may be conveniently used to design up-feed systems feeding from city pressures. (See Example 3).

In the drop line from the tank to the hot water heater and the riser from the heater to the distributing header on the 21st floor there are approximately 200 linear feet of pipe. If the friction loss through this length of pipe is too great, there will be too large a difference in the pressures at the cold and hot water fixtures on the different floors. All the hot water for the 8 risers feeding 11 floors each, or 88 floors in all, and supplying 1043 fixtures (½-in.) must flow through it. Owing to the diversity factor, the maximum expected flow at some time will be:

$$1043 \text{ fix.} \times 5 \text{ gal} \times \left(\frac{224}{88 + 2} + 10\right) \text{ per cent} = 652 \text{ gpm}$$

From Table 4, it is found that this amount will create a pressure drop of approximately 5 lb per square inch per 100 ft of 5-in. pipe.

Attention is called to the fact that the headers on the 21st floor are made to supply the 22nd floor fixtures by means of up-feed branches. Similarly, the headers on the 10th floor feed the fixtures on the 11th. This provides an outlet for any air that may be trapped in the piping. Again, the hot water risers are connected to a return header for gravity circulation. These are of ¾-in. pipe and there is no necessity for a larger connection. The headers are then sized for the number of risers they are to accommodate as taken from Table 2. At each ¾-in. connection to the header, however, it is well to install a lock-shield gate valve which may be adjusted to equalize the circulation.

SIZING OF BRANCH PIPES

Most valves will deliver the quantity stated in Table 1 with a pressure of 6 lb per square inch at the valve. This does not mean the static pres-

sure but the pressure that may exist while the water is flowing. For example, if the static pressure were 15 lb per square inch at the branch take-off the branch piping should be made to consume 9 lb in friction. If a pressure of 40 lb existed the branch should consume 34 lb in friction. The exact existing pressure can never be known owing to the uncertainty of the amount of flow. The average length of a branch is approximately 15 ft which, with the fitting resistance, gives an equivalent length of about 25 ft. With the size of tapping used as given in Table 1, the loss in a branch is approximately 8 lb per square inch when delivering the amount specified in the same table. If the actual length of the branch should then exceed 30 ft or if the pressure available is less than 15 lb per square inch, the branches should be made one size larger than those specified in Table 1.

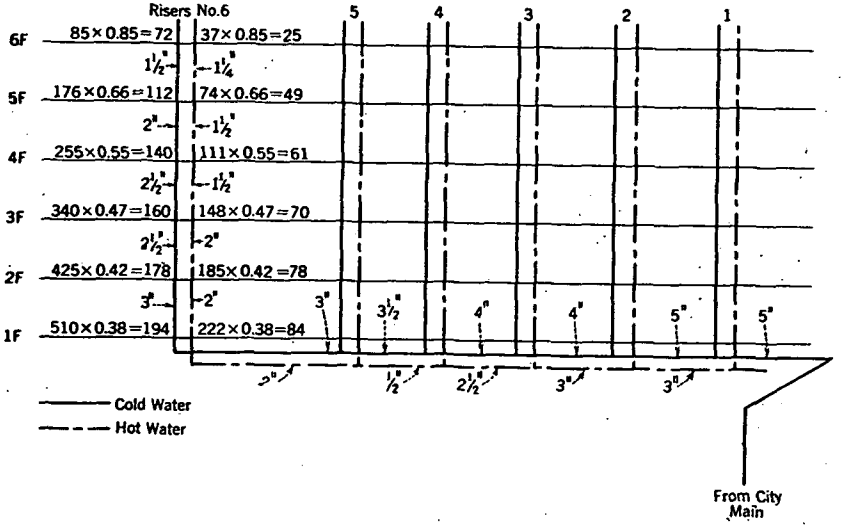


FIG. 3. UP-FEED RISERS FOR A SIX-STORY APARTMENT HOUSE

Example 3. To design an up-feed system as fed from city pressure, assume a 6-story apartment consisting of 6 risers as shown in Fig. 3 and assume that the pressure in the main is 70 lb per square inch. The static pressure for 60 ft of head is about 26 lb per square inch leaving but 44 lb for friction. The next consideration is the friction consumed by the meter. In this case it is taken at 15 lb leaving 29 lb still available. Allowing 6 lb at the fixture and 8 lb loss through the branches, leaves 15 lb still available for friction through the piping. With 60 ft of actual length in the risers and allowing 50 per cent for fitting resistances gives about 90 ft of equivalent length of pipe. The allowable loss per 100 ft, if most of the friction were taken in the risers, would be:

$$\frac{15 \text{ lb}}{0.90} = 16 \text{ lb per square inch}$$

It is advisable to design the headers with as small a loss as possible so that the pressure at the remote riser is almost the same as at the others. The fixture value for the cold water at each floor is 17.1 which is equal to 85 gal per floor, and is obtained as follows:

1 Water closet (1¼-in.)	=	9.7
1 Bath (¾-in.)	=	2.7
1 Lavatory (½-in.)	=	1.0
1 Kitchen sink (½-in.)	=	1.0
1 Laundry (¾-in)	=	2.7
Total cold water	=	17.1 fixtures × 5 = 85 gal
Total hot water	=	7.4 fixtures × 5 = 37 gal

Calculating the per cent of flow by means of Formula 1, the amount flowing at each floor is determined as shown on riser No. 6 of Fig. 3. The pipe sizes can then be determined from Table 4 so that the friction does not exceed the available amount of 16 lb per square inch per 100 linear feet of pipe. Thus on the 3rd floor the riser at some time must carry 160 gpm. From Table 4 it will be found that the friction through a 2½-in. pipe for this amount is about 10 lb per square inch per 100 ft of pipe while through a 2-in. pipe the loss is over 30 lb per square inch. A 2½-in. riser must then be used at this point. The sizes at the other floors are similarly determined. The sizes of the mains are also similarly determined but, as already stated, with less friction drop. Thus the main between the 4th and 5th riser which supplies Risers Nos. 5 and 6 or 12 floors, the per cent of flow at some one time may reach:

$$\frac{224}{12+2} + 10 = 25 \text{ per cent, which is equal to:}$$

$$85 \times 12 \times 0.25 = 255 \text{ gpm}$$

From Table 4 it will be found that a 3½-in. pipe will accommodate this with a loss of but 5 lb per square inch.

STORAGE TANKS

In the selection of storage tanks the rules of practice vary greatly. A generally accepted assumption is that simultaneous use of the fixtures will take place once each hour. The simultaneous flow per minute is thus taken as one hour's storage, which is a purely empirical rule but one which seems to meet most demands. In the case of Fig. 2 there are 3337 cold water and 1043 hot water fixtures making a total of 4380 fixtures. By means of Formula 1 it is found that the per cent of simultaneous use for the 8 cold water and 8 hot water risers supplying 11 floors each, or 176 floors in all, is about 11 per cent giving a simultaneous use of 482 fixtures. At a 5-gal-per-fixture value this gives 2410 gal which is taken as one hour's supply. A five-hour storage capacity would then demand a 10,000-gal tank, and a 10-hour storage, one of 20,000 gal capacity. The latter size would be the better practice insuring service during prolonged pump repairs. These figures do not include the fire or stand pipe storage which must be governed by the prevailing code.

HOT WATER TANKS AND HEATERS

The fixture method is probably as rational as any for determining the capacity of the tank and heater, allowing a safety factor of two to meet the trend of prevailing practice, which is equivalent to taking the peak load flow per minute as a half-hour supply. In the case of Fig. 2 this gives an hourly requirement of:

$$5 \text{ gal} \times 1043 \text{ fixtures} \times \left(\frac{224}{88+2} + 10\right) \text{per cent} \times 2 = 1300 \text{ gal}$$

Two 750-gal tanks with a heating capacity of 750 gal per hour each would

probably be adopted in the average practice, but a 1000-gal tank with a heating capacity of 1000 gal per hour should suffice.

In apartment house work it is customary to allow a heating capacity of 10 gal per hour for each apartment with but one bath, and 15 gal per hour for those with two bath rooms. In the case of Fig. 3 with 36 apartments this calls for a heating capacity of 360 gal per hour although the storage might be made greater. Some designers prefer a greater storage but this is a matter of choice. Using the fixture method for Fig. 3 the heating capacity would be:

$$7.4 \times 36 \text{ apts} \times 5 \text{ gal} \times \left(\frac{224}{36+2} + 10\right) \text{per cent} \times 2 = 426 \text{ gal}$$

In the case of one and two family houses where the demand may sometimes approach 100 per cent, the old rule of allowing a hot water storage of 30 gal and a heating capacity of 10 gal per hour per family is still a good practical one.

HOT WATER TEMPERATURE

There is usually no necessity of maintaining the domestic hot water temperature above 140 F when used only for bath or manual cleansing operations. A water temperature of 105 F makes a hot bath and while the hands may be plunged into water with a temperature of 120 F, a sustained immersion would be impossible. Mechanical dish washers and laundry machines, however, need a temperature higher than 140 F, and when such equipment is to be supplied in conjunction with hot water for personal use it is advisable to employ two separate tanks. Thermostatic regulating control should be used wherever possible.

ADDITIONAL BOILER CAPACITY

If the burden of the hot water requirement is added to the house heating boiler care must be taken to make certain that the capacity of the boiler is sufficient to meet the increased demand. To heat one gallon of water 120 deg requires about 1000 Btu which is approximately equal to 4 sq ft of equivalent heating surface (240 Btu per square foot). If the maximum hourly demand is heated in one hour, the capacity of the boiler or heater should be increased by 4 sq ft (+) for each gallon heated. If sufficient storage capacity is provided, the additional boiler capacity required is correspondingly reduced.

In houses with chimney heights of approximately 40 ft it is unsafe to expect that more than 5 lb of coal can be burned per hour on one square foot of grate. Allowing 8000 Btu available per pound of coal gives 40,000 Btu per square foot of grate. One square foot of grate surface may therefore be allowed for each 40 gal of water to be heated. This does not mean for each 40 gal of storage but for each 40 gal of hourly demand. In the higher type of buildings where the hourly coal consumption in the heating boiler may be much greater than 5 lb of coal per hour the grate area may be correspondingly reduced.

Chapter 14

HEATING BOILERS

Classification; Furnace Design; Heating Surface; Boiler Output; Equivalent Evaporation; Efficiency; Testing; Rating; Selection of Boilers; Pipe Connections; Smoke Breeching and Chimney Connections; Preparing Boilers for Service; Water Line in Steam Boilers; Water Gage Glass Fittings and Cocks; Correcting Unsatisfactory Operation; Protection of Boilers; Cleaning Boilers.

OF the various types and grades of boilers available, experience shows that most of them are capable of practically the same evaporation per pound of fuel, provided they are designed with the same proportions of heating and grate surface and are operated under similar conditions. They differ, however, with respect to space occupied, weight, capacity, first cost, and adaptability to particular conditions of operation and location.

As affecting fuel economy the boiler equipment is one of the most important parts of the heating system. It matters little how elaborate, modern, or well designed the boiler may be, skill, good judgment, and continued vigilance are required on the part of the operator to secure the best efficiency.

CLASSIFICATION

Boilers for steam and hot water heating systems are of two general types, namely (1) cast-iron sectional boilers, and (2) steel boilers of the fire-tube or water-tube type.

Cast-Iron Boilers

Cast-iron boilers may be of round pattern with circular grate and horizontal *pancake* sections joined by push nipples and tie rods, or of rectangular pattern with vertical sections. The latter type may be either of outside header construction where each section is independent of the other and water and steam connections are made through these headers, or assembled with push nipples and tie rods.

Cast-iron boilers usually are shipped knocked down to facilitate handling at place of installation where assembly is made. Generally they fit into small spaces, have a low water line and are low in first cost. In most cases they are limited to working pressures of 15 lb for steam and 30 lb for hot water. Special types are built for hot water supply which will withstand higher local water pressures.

Steel Boilers

Steel heating boilers may be classified as (1) horizontal return tubular (H.R.T.) boilers, (2) portable (self contained) firebox boilers with either water tubes or fire tubes and (3) water-tube boilers of the power type.

The H.R.T. boiler is the oldest type and consists of a horizontal cylindrical shell with fire tubes, enclosed in brickwork to form the furnace and combustion chamber. All heating surfaces and the interior of the boiler are accessible for both cleaning and inspection. Horizontal return tubular boilers should be suspended from structural columns and beams independent of the brick setting.

Portable firebox boilers are the more generally used type of steel heating boilers, their outstanding characteristic being the water-jacketed firebox which eliminates virtually all brickwork. They are shipped in one piece from the factory and come to the job ready for immediate hook-up to piping. They may be of welded or riveted construction and have either water or fire tubes. Manufacturers' catalogs usually list heating surface as well as grate area. The elimination of brickwork also makes this type the most compact of steel boilers as well as the lowest in first cost.

Water-tube boilers. For large heating loads water-tube boilers are quite frequently used. They usually require more head room than other types of boilers but require considerably less floor space and make possible a much higher rate of evaporation per square foot of heating surface, with proper setting, baffling and draft. Water-tube boilers used for heating purposes are brick set, supported on structural steel columns and with the brick setting encased in an insulated steel housing to prevent air infiltration and to minimize heat losses. For large heating loads at a high rate of evaporation, such boilers should be operated at pressures above 15 lb per square inch with a pressure reducing valve on the connection to the heating main.

The tubes of a water-tube boiler may be baffled vertically or horizontally for directing the flow of hot gases over the tubes. In choosing between the two, the matter of heat absorption is of prime importance with flexibility and cost of maintenance of secondary consideration. Investigations by the U. S. Bureau of Mines show that[1]:

1. A boiler in which the heating surface is arranged to give long gas passages of small cross-section will be more efficient than a boiler in which the gas passages are short and of larger cross-section.
2. The efficiency of a water-tube boiler increases as the free area between individual tubes decreases and as the length of the gas pass increases.
3. By inserting baffles so that the heating surface is arranged in series with respect to the gas flow, the boiler efficiency will be increased.

Dead pockets develop in the gas travel due to eddy currents and short circuiting which make parts of the heating surface inactive. Baffling which will minimize such pockets and the inactive heating surface will of course increase the capacity and efficiency.

Magazine Feed Boilers

A special type of boiler has been developed for the burning of small sizes of anthracite known as the *magazine feed boiler*. These are built of

[1]See *U. S. Bureau of Mines Bulletin No. 18*, The Transmission of Heat into Steam Boilers.

both cast-iron and steel, and have a large fuel carrying capacity which results in longer firing periods than would be the case with the standard types using buckwheat sizes of coal. Special attention must be given to insure adequate draft and proper chimney sizes and connections.

Smokeless Boilers

Smokeless combustion of the more volatile bituminous coals may be obtained by the use of down-draft furnaces, dutch-oven furnaces, specially-designed ignition arches and mechanical stokers. See Chapter 16, Fuels, and Chapter 17, Mechanical Stokers.

Hot Water Supply Boilers

Boilers for hot water supply are classified as direct, if the water heated passes through the boiler, and as indirect, if the water heated does not come in contact with the water or steam in the boiler.

Direct heaters are built to operate at the pressures found in city supply mains and are tested at pressures from 200 to 300 lb per square inch. The life of direct heaters depends almost entirely on the scale-making properties of the water supplied. If water temperatures are maintained below 140 F the life of the heater will be much longer than if higher temperatures are used, owing to decreased scale formation and minimized corrosion below 140 F. Direct water heaters in some cases are designed to burn refuse and garbage.

Indirect heaters generally consist of steam boilers in connection with heat exchangers of coil or tube heaters which transmit the heat from the steam to the water. This type of installation costs more than a direct system, but has the following advantages:

1. The boiler operates at low pressure. Water hammer and cold water shocks are not transmitted to the boiler.
2. The boiler is protected from scale and corrosion.
3. The scale is formed in the heat exchanger in which the parts to which the scale is attached can be cleaned or replaced. The accumulation of scale does not affect efficiency although it will affect the capacity of the heat exchanger.
4. Water hammer due to formation of steam is minimized especially if the steam supply to the heater is under automatic control.
5. Discoloration of water may be prevented if the water supply comes in contact only with non-ferrous metal.

Construction Code

All boilers for low pressure heating of whatever type, and of cast-iron or steel construction, are generally built in accordance with the Rules for the Construction of Low Pressure Heating Boilers of the *A.S.M.E.* Boiler Construction Code and such boilers are universally accepted by authorities except in Massachusetts and Canada where local codes prevail. Under the *A.S.M.E.* Code, boilers may be operated at a working pressure of 15 lb for steam and 30 lb for hot water heating. Steel boilers under this Code may also be built for 160 lb water pressure when the temperature of the water in the boiler does not exceed 250 F. Steel boilers of the riveted type may also be built under the *A.S.M.E.* Power Boiler Construction Code or local codes, for higher operating pressures with the same external dimensions as low pressure boilers.

FURNACE DESIGN

Good efficiency and proper boiler performance are dependent on correct furnace design embodying sufficient volume for burning the particular fuel at hand, for permitting of thorough mixing of air and gases, for permitting a velocity low enough to allow sufficient time for combustion to take place and for permitting the maintenance of a sufficiently high temperature to produce combustion.

Proper and efficient combustion depends on a furnace volume so designed as to permit sufficient time for proper mixing and one that can at the same time be maintained at a temperature high enough to produce complete burning of all of the volatile gases. If the air and products of combustion do not thoroughly mix, stratification is likely to develop. In the burning of liquid or powdered fuel, the air should be so introduced as to set up a turbulent action in order that the small atomized particles may be entirely surrounded with air for supporting combustion.

Combustion must take place before the gases are cooled by the boiler heating surface, and the volume of the furnace must be sufficient for this purpose. The brick-set boiler is particularly convenient in this respect since almost any desired furnace volume may be obtained. The furnace temperature must be maintained sufficiently high to produce complete combustion, thus resulting in a higher CO_2 content and the absence of CO. Hydrocarbon gases ignite at temperatures varying from 1000 to 1500 F. A higher unburned gas content will result from a furnace having a small combustion space than from one having a large combustion space. The efficiency obtained from the large combustion space will therefore be higher. For further information on furnace design, see p. 280.

BOILER HEATING SURFACE

Boiler heating surface essentially is that surface which is exposed to fire or hot gases of combustion on one side and water or steam on the other side. In fire-tube and water-tube boilers most of the heating surface is in the tubes.

In horizontal return tubular boilers the bottom half of the shell and heads up to point where the setting corbels in, is effective heating surface. Likewise in a water-tube boiler the bottom side of the shell and the inner side of the tube headers provide active heating surface.

In the past, a heating surface area of 10 to 12 sq ft was required per boiler horsepower, based on the observation that the rate of evaporation of water at the most economical fuel consumption was about 3 lb of water per square foot of boiler heating surface. In modern boiler design, rates of evaporation from 4½ to 6 lb of water are practical with a small loss in economy which is justified by the reduction in investment in boilers and boiler space. Such rates of evaporation are, of course, only possible with boilers set with adequate furnace volume to permit complete combustion, and with means for directing the gas passage so that all heating surface is contacted. Adequate provision for the burning of the fuel and for the draft necessary to support combustion, are also required.

BOILER OUTPUT

The output of a *power* boiler is stated in terms of *boiler horsepower*. A boiler horsepower (*A.S.M.E.* standard) is equal to the evaporation of 34.5 lb of water per hour *from and at 212 F;* that is, a boiler receiving the feed water at 212 F must furnish the necessary heat to generate 34.5 lb of steam at this temperature and atmospheric pressure from water at the same temperature and pressure per hour. In other words, the boiler must supply the latent heat of vaporization (971.7 Btu) to each pound of water to develop steam at atmospheric pressure (14.7 lb per square inch, absolute) or it must furnish $971.7 \times 34.5 = 33{,}523.7$ Btu per hour to the water per boiler horsepower. Therefore, one boiler horsepower = 33,523.7 Btu per hour. The horsepower developed by a boiler in operation is determined by first finding the Btu received per hour by the water and steam from the boiler and dividing this quantity by the Btu equivalent of one boiler horsepower.

The output of *heating* boilers is usually stated in terms of *Btu per hour* or equivalent heating surface (radiation). Since one square foot of equivalent heating surface (steam) has an emission of 240 Btu per hour, a boiler horsepower is equal to about 140 sq ft of equivalent steam heating surface. It is common practice to allow one boiler horsepower for each 100 sq ft of equivalent steam heating surface (radiation), the additional 40 sq ft being intended to provide for secondary losses from mains, risers and returns.

EQUIVALENT EVAPORATION

It is customary to reduce the actual evaporation of a boiler to a standard set of conditions in order to make comparisons. This standard is the amount of water that would have been evaporated into dry steam *from and at 212 F* for the same heat expenditure. In practice, the feed water is usually below this temperature and the evaporation actually takes place at some higher temperature than 212 F. Hence, to find the rate of equivalent evaporation it is necessary to make use of the following relation:

$$E = FP \tag{1}$$

The *factor of evaporation* (F) is the ratio of the heat required to generate one pound of steam for the given condition (at the boiler pressure and temperature and feed-water temperature) to the amount of heat required to generate one pound of dry steam *from and at 212 F*. Therefore:

$$F = \frac{h_w + x h_{fg} - h_f}{971.7} \text{ (for wet steam)} \tag{2}$$

$$= \frac{h - h_f}{971.7} \text{ (for dry steam)} \tag{3}$$

$$= \frac{h + c\,(t_s - t)}{971.7} \text{ (for superheated steam)} \tag{4}$$

where

c = mean specific heat of superheated steam for the given range of temperature and pressure.
E = equivalent evaporation *from and at 212 F* in pounds per pound of fuel burned.
F = factor of evaporation.

h = total heat above 32 F per pound of steam leaving the boiler.
h_f = heat content of the feed water above 32 F.
h_{fg} = latent heat of vaporization.
h_w = heat in the water above 32 F corresponding to the temperature and pressure at which steam is generated.
P = actual evaporation in pounds per pound of fuel burned.
t = temperature of saturated steam corresponding to the pressure, degrees Fahrenheit.
t_s = actual temperature of the steam if superheated, degrees Fahrenheit.
x = quality of steam, pounds of dry steam per pound of mixture.
971.7 = latent heat of steam corresponding to a temperature of 212 F. (Goodenough)

Example 1. A boiler generates 1000 lb of 98 per cent quality steam per hour. Absolute pressure = 100 lb. Temperature of feedwater = 100 F. What is the equivalent evaporation *from and at 212 F?*

Solution. The heat content of the feedwater above 32 F = $h_f = 100 - 32 = 68$ Btu. $h_w = 297.9$ (see Steam Tables). $h_{fg} = 890.5$ (see Steam Tables). $x = 0.98$. Substituting in Formula 2:

$$F = \frac{297.9 + 0.98 \times 890.5 - 68}{971.7}$$

$$= 1.137$$

$$P = FP = 1.137 \times 1000 = 1137 \text{ lb per hour.}$$

BOILER EFFICIENCY

The term *efficiency* when applied to steam boiler performance, ordinarily refers to the overall efficiency of the grate, furnace and boiler when solid fuels are used. It is obviously unfair to charge against the boiler the unconsumed fuel that drops through the grate and becomes mixed with the ashes. It is difficult, however, to separate the efficiency of the boiler and furnace from the grate efficiency, and as the user must pay for any such loss it is customary, unless otherwise noted, to state the combined efficiency rather than separate efficiencies.

It is recommended that when the term *efficiency* is used for guarantees of boiler performance it be clearly defined in the proposal as follows:

Solid Fuels. The efficiency of the *boiler* alone is the ratio of the heat absorbed by the water and steam in the boiler per pound of combustible burned on the grate to the calorific value of one pound of combustible as fired. The *combined* efficiency of *boiler, furnace and grate* is the ratio of the heat absorbed by the water and steam in the boiler per pound of fuel as fired to the calorific value of one pound of fuel as fired.

Liquid Fuels. The *combined* efficiency of boiler, furnace and burner is the ratio of the heat absorbed by the water and steam in the boiler per pound of fuel to the calorific value of one pound of fuel.

BOILER TESTING

Accurate evaporative and water-heating tests on heating boilers must be run before they can be given a rating. The Society has adopted two solid fuel testing codes and one oil fuel testing code. A.S.H.V.E. Codes 1 and 2, which are known as the Standard and Short Form Heat Balance Codes for Testing Low-Pressure Steam Heating Solid Fuel Boilers

(revision of June, 1929), are intended to provide a standard method for conducting and reporting tests to determine the heat efficiency and performance characteristics. Code No. 3 which is known as A.S.H.V.E. Performance Test Code for Steam Heating Solid Fuel Boilers (edition of 1929) is intended to be used with the A.S.H.V.E. Code for Rating Steam Heating Solid Fuel Hand-Fired Boilers. (See A.S.H.V.E. TRANSACTIONS, Vol. 36, 1930). The object of this testing code is to specify the tests to be conducted and to provide a standard method for conducting and reporting tests to determine the efficiencies and performance of the boiler. The proposed Code for Testing Steam Heating Boilers Burning Oil Fuel (edition of March, 1931), is intended to provide a standard method for conducting and reporting tests to determine the heating efficiency and performance characteristics when oil fuel is used with steam heating boilers.

BOILER RATINGS

Solid Fuel Burning Boilers

The use of boilers having ratings which are in accordance with the provisions of the A.S.H.V.E. Code for Rating Steam Heating Solid Fuel Hand-Fired Boilers, is recommended.

A method sometimes used for estimating the approximate reasonable output of a boiler where more accurate and reliable test data are not available, is as follows:

The output in Btu is obtained by multiplying together the square feet of grate surface by an assumed rate of combustion (in pounds of coal per square foot of grate per hour) by the Btu value of the fuel (per pound) by the efficiency of the boiler (at the load and rate of combustion assumed).

This gives an approximate rating. For data on rates of combustion, see Table 1, also Chapter 15, Chimneys, and Chapter 16, Fuels.

Oil-Fired Boilers

The output of a boiler with oil fuel will depend upon the combined efficiency of the boiler and burner and the quantity of oil that can be burned properly within the space provided in the boiler. Data on this subject are contained in a report of investigations made at Yale University in cooperation with the A.S.H.V.E. Research Laboratory, entitled Study of Performance Characteristics of Oil Burners and Low Pressure Heating Boilers by L. E. Seeley and E. J. Tavanlar. (See *Heating, Piping and Air Conditioning*, May, 1931).

Gas-Fired Boilers

The rating of gas boilers, in contrast to that of coal boilers is a comparatively simple matter. The following conditions of rating established by the *American Gas Association* have been generally accepted:

1. The boiler must deliver rated output without chimney connection.
2. There must be no carbon monoxide formed when the gas pressure in service line is normal, 50 per cent below normal, or 50 per cent above normal.
3. The boiler must have an efficiency of at least 75 per cent at rated output.
4. Gas pressure drop in all valves and fittings must not exceed 1 in. of water.

The maximum Btu input or gas that can be burned may be determined by the manufacturer but is checked by the *American Gas Association* laboratory before being approved. An arbitrary efficiency of 80 per cent is assumed in computing the output rating from the Btu input.

The actual Btu delivered by any gas boiler when burning gas at the rated Btu input will vary from the *A.G.A.* output rating in the direct proportion of the actual efficiency with the gas being burned to the assumed efficiency of 80 per cent.

Rating of Steel Boilers

The *Steel Heating Boiler Institute* suggests a single number dimensional rating in the *S.H.B.I.* Code for the Rating of Low Pressure Heating Boilers. (See Rating of Heating Boilers by Their Physical Characteristics, by C. E. Bronson, A.S.H.V.E. TRANSACTIONS, Vol. 36, 1930).

TABLE 1. PRACTICAL COMBUSTION RATES FOR RELATIVELY SMALL COAL-FIRED HEATING BOILERS OPERATING ON NATURAL DRAFT OF FROM ¼ IN. TO ½ IN. WATER[a]

SQ. FT. GRATE	KIND OF COAL	LB. OF COAL PER SQ. FT. GRATE PER HOUR
Up to 4	No. 1 Buckwheat Anthracite	3
5 to 9	No. 1 Buckwheat Anthracite	3½
10 " 14	No. 1 Buckwheat Anthracite	4
15 " 19	No. 1 Buckwheat Anthracite	4½
20 " 25	No. 1 Buckwheat Anthracite	5
Up to 9	Anthracite Pea	5
10 to 19	Anthracite Pea	5½
20 " 25	Anthracite Pea	6
Up to 4	Anthracite Nut and Larger	5
5 to 9	Anthracite Nut and Larger	6
10 " 14	Anthracite Nut and Larger	7
15 " 19	Anthracite Nut and Larger	8
20 " 25	Anthracite Nut and Larger	9
Up to 4	Bituminous	4
5 to 14	Bituminous	7
15 and above	Bituminous	10

[a]Steel boilers usually have higher combustion rates for grate areas exceeding 15 sq ft than those indicated in this table.

SELECTION OF BOILERS

The character of the load, the space available, the fuels to be used and the adaptability to changes in fuels, are some of the important factors determining the type of boiler or boilers to be selected. The size and nature of the load determines the number of boilers conducive to greatest economy. A boiler installation that will permit carrying the peak heating load on an overload and make possible the carrying of normal load at, or near, rating results in maximum economy and flexibility and reduces the first cost to a minimum. Selecting boilers for carrying peak loads on overloads is only advisable in the case of horizontal return tubular boilers and water-tube boilers and the amount of overload advisable is then dependent on the character of furnace and setting.

Selection of Solid Fuel Boilers

The estimated connected load of the boiler or boilers is the sum of the following items (1) to (4), which are taken from the A.S.H.V.E. Code of Minimum Requirements for the Heating and Ventilation of Buildings:

1. The estimated heat emission in Btu per hour of the connected radiation (direct, indirect or blast) to be installed, as previously determined by calculations given in Chapters 2, 3 and 4 of THE GUIDE.
2. The estimated maximum heat in Btu per hour required to supply water heaters or other apparatus to be connected to the boiler.
3. The estimated heat emission in Btu per hour of the piping connecting the radiation and other apparatus to the boiler.
4. The estimated increase in the normal load in Btu per hour due to starting up cold radiation, etc. This percentage of increase to be based on the sum of items (1), (2) and (3) shall not be assumed less than the following:

Sum of (1), (2) and (3):

Up to 100,000 Btu add 65 per cent.
100,000 to 200,000 Btu add 60 per cent.
200,000 to 600,000 Btu add 55 per cent.
600,000 to 1,200,000 Btu add 50 per cent.
1,200,000 to 1,800,000 Btu add 45 per cent.
Above 1,800,000 Btu add 40 per cent.

Other things to be considered are:

5. The kind and amount of attention available. Attention is least skillful and least frequent for owner-operated residence installations and generally increases in skill as well as frequency as size of boiler increases. Local fuels and types of firing service must be considered carefully in this connection.
6. The kind of fuel to be used, including size and characteristics.
7. Size and height of the available chimney.

The boiler performance data may be obtained from A.S.H.V.E. Performance Test Code for Steam Heating Solid Fuel Boilers (Code No. 3). The boiler or boilers should be capable of supplying at the boiler outlets the total Btu per hour as calculated from items (1) to (4), inclusive, when the following conditions of operation are stated specifically:

A. Steam Boilers:

1. Gage pressure in pounds per square inch.
2. Assumed temperature of returns in degrees Fahrenheit.
3. Description of fuel to be employed with calorific value per pound of dry fuel stated (state size, etc., if solid fuel is to be employed).
4. Firing period for solid fuel.
5. Inside dimensions and height of chimney to which boiler or boilers are to be connected, and to which no other openings are to be provided except the cleanout.

B. Hot Water Boilers:

1. Temperature of water leaving boiler outlets in degrees Fahrenheit.
2. Assumed temperature of return water entering boiler in degrees Fahrenheit.
3. Description of fuel to be employed with calorific value per pound of dry fuel stated (state size, etc., if solid fuel is to be employed).
4. Firing period for solid fuel.
5. Inside dimensions and height of chimney above the grate to which *boiler* or *boilers* are to be connected and to which no other openings are to be provided except the cleanout.

As it will usually be found that several boilers will meet the specifications, the final selection of the boiler may be influenced by other considerations some of which are:

1. Dimensions of boiler.
2. Durability under service.
3. Convenience in firing and cleaning.
4. Adaptability to changes in fuel and kind of attention.

In large installations, the use of several smaller boiler units instead of one larger one will obtain greater flexibility and economy by permitting the operation, at the best efficiency, of the required number of units according to the heat requirements.

Selection of Boilers for Oil Fuel

The boiler or boilers to be installed shall be capable of supplying at the boiler outlets the total Btu per hour as computed by the method outlined under the heading *Selection of Solid Fuel Boilers*. The oil burner to be installed shall have a capacity to burn, with efficient combustion, the quantity of the oil it is proposed to employ per hour sufficient to develop the boiler output required.

Where test data are not available for the contemplated combination of boiler and oil burner, economical performance may be obtained by selecting a boiler in which the heat absorbed per square foot of boiler heating surface at the maximum continuous output is approximately 4,000 Btu per hour. It should be ascertained that the burner selected has sufficient combustion space to permit the burning of the required quantity of the available oil fuel.

Selection of Gas-Fired Boilers

Experience with gas-fired boilers, which are rated on Btu output and which can only slightly exceed the rated output, but which require no chimney draft, has shown that a continuous output capacity of 25 per cent in excess of the normal heat loss of radiation, plus piping, is ample for all direct radiator installations. This corresponds to an output of 40 to 60 per cent in excess of the normal heat loss of the radiation, depending upon the proportion of piping to radiation.

Gas-fired boilers rated according to the *American Gas Association* method, and which therefore have *A.G.A.* ratings are selected in the majority of direct-radiator installations, according to the table of selection factors given in Table 1 of Chapter 19.

SPACE FOR AND LOCATION OF BOILERS

Boiler rooms should, if possible, be situated at a central point with respect to the building and should be designed for a maximum of natural light. The space in front of the boilers should be sufficient for firing, stoking, ash removal and cleaning or renewal of flues, and should be at least 3 ft greater than the length of the boiler firebox.

A space of at least 3 ft should be allowed on at least one side of every boiler for convenience of erection and for accessibility to the various dampers, cleanouts and trimmings. The space at the rear of the boiler

should be ample for the chimney connection and for cleanouts and with large boilers the rear clearance should be at least 3 ft in width.

The boiler room height should be sufficient for location of boiler accessories and for proper installation of piping. In general the ceiling height for small steam boilers should be at least 3½ ft above the normal boiler water line. With vapor heating especially the height above the boiler water line is of vital importance.

When steel boilers are used, space should be provided for the removal and replacement of tubes.

PIPE CONNECTIONS

The pipe connections which must be made to both steam boilers and hot-water heaters are:

1. Steam or flow connections from the top.
2. Return connections to the bottom.
3. Blow-off or drain connections.
4. Cold water connections for filling.

The *steam or flow connections* and also the *return connections* must be carefully designed to provide for expansion of the piping, as well as of proper size and number so as to give low outlet velocities, and uniform distribution of the return water over the boiler heating surfaces. The velocity of flow through the outlets of low pressure steam heating boilers should not exceed 15 ft. per second if entrainment of moisture is to be prevented, as with higher velocities the steam leaving the boiler may carry water with it.

Blow-off or drain connections should be made near the boiler and so arranged that the entire system may be drained of water by opening the drain cock. In the case of two or more boilers separate blow-off connections must be provided for each boiler on the boiler side of the stop valve on the main return connection.

Water service connections must be provided for both steam and water boilers, for refilling and for the addition of make up water to boilers. This connection is usually of galvanized iron pipe, and is made to the return main near the boiler or boilers. The heating contractor is required to run this line to the nearest water service main, in which the plumber has left a plugged tee.

For further data on pipe connections for steam and hot-water heating systems, see Chapters 8 and 9.

SMOKE BREECHING AND CHIMNEY CONNECTIONS

Connections from the boiler outlet to the chimney should be air-tight and as short and direct as possible, preference being given to long radius and 45 deg, instead of 90 deg bends. The bend at the entrance to the chimney should not project beyond the inside of the chimney and it should be pointed up from the inside of the chimney.

Where a battery of boilers is connected into a breeching each boiler should be provided with a tight damper. The breeching for a battery of boilers should not be reduced in size as it goes to the more remote

boilers. Good connections made to a good chimney will usually result in a rapid response by the boilers to demands for heat.

PREPARING BOILERS FOR SERVICE

The directions of the boiler manufacturer always should be read before the assembly or installation of any boiler is started, even though the contractor may be familiar with the boiler. All joints requiring boiler putty or cement, which cannot be reached after assembly is complete, must be finished as the assembly progresses.

Nuts or tie rods of sectional cast-iron boilers always must be drawn up and then loosened about one thread to allow for expansion of the boiler when hot. The nuts should be just a little more than hand-tight when the boiler is at its operating temperature.

Flow piping connections should be full size of the manufacturers outlet and preferably should be vertical from the outlets to the maximum height available above the boiler. A large tall outlet pipe and a low outlet velocity are of great value in separating the steam from the water; especially if the boiler has accumulated grease and other foreign matter.

Maximum steam velocities of from 20 to 25 ft per second at the boiler outlet are recommended.

The outlets from steam boilers should be placed as remotely as possible from the areas of the water surface at which steam separation is most violent.

There is usually some advantage to be obtained with low-pressure steam boilers by installing a large drip connection back to the boiler below the water line, from a point as near as practicable to the steam outlet.

WATER LINE IN STEAM BOILERS

Enough water only should be added to heating boilers to keep the water line at the height established by the manufacturer. Raising the water to a higher level may result in carrying over of water with the steam. Water from small steam heating systems should not be lost by leakage or withdrawn to serve as hot water supply as the fresh water required to make up the loss may introduce scale-forming or corrosive matter. On the other hand the occasional addition of new scale-forming water under some conditions may prevent excessive corrosion or pitting of the boiler interior.

WATER GAGE GLASS FITTINGS AND COCKS

Each boiler should have at least one water gage glass and two or more gage cocks located within the range of the visible length of the glass. The water glass fittings or gage cocks may be connected direct to the boiler but it is preferable to mount them on a water column. No connections, except for combustion regulator, drains or steam gages, should be placed on the pipes connecting the water column and the boiler. The steam pipe should drain toward the water column; the water pipe should drain toward the boiler. If the water column is fitted with a low water alarm, the alarm should operate before the level reaches a line not less

than two inches above the lowest permissible water level, usually at the center of the lower gage cock.

CORRECTING UNSATISFACTORY OPERATION

A complaint regarding boiler operation generally will be found to be due to one of the following:

1. *The boiler fails to deliver enough heat.* The cause of this condition may be: (*a*) poor draft; (*b*) poor fuel; (*c*) inferior attention or firing; (*d*) boiler too small; (*e*) improper piping; (*f*) improper arrangement of sections; (*g*) heating surfaces may be covered with soot and (*h*) insufficient radiation installed.

2. *The water line is unsteady.* The cause of this condition may be: (*a*) grease and dirt in boiler; (*b*) water column connected to a very active section and, therefore, may not be showing actual water level in boiler, (*c*) boiler operating at excessive output.

3. *Water disappears from gage glass.* This may be caused by: (*a*) priming due to grease and dirt in boiler; (*b*) too great pressure difference between supply and return piping causing water to back into return; (*c*) valve closed in return line; (*d*) connection of bottom of water column into a very active section or thin waterway; (*e*) improper connections between boilers in battery permitting boiler with excess pressure to push water into boiler with lower pressure.

4. *Water is carried over into steam main.* This may be caused by: (*a*) grease and dirt in boiler; (*b*) insufficient steam dome or too small steam liberating area; (*c*) outlet connections of too small area; (*d*) excessive rate of output; (*e*) water level carried higher than specified.

5. *Boiler is slow in response to operation of dampers.* This may be due to: (*a*) poor draft due to air leaks into chimney or breeching; (*b*) inferior fuel; (*c*) inferior attention; (*d*) accumulation of clinker on grate; (*e*) boiler too small for the load.

6. *Boiler requires too frequent cleaning of flues.* This may be due to: (*a*) poor draft; (*b*) smoky combustion; (*c*) too low a rate of combustion; (*d*) too much excess air in firebox causing chilling of gases.

7. *Boiler smokes through fire door.* This may be due to: (*a*) defective draft in chimney or incorrect setting of dampers; (*b*) air leaks into boiler or breeching; (*c*) gas outlet from firebox plugged with fuel; (*d*) dirty or clogged flues; (*e*) improper reduction in breeching size.

For further information on this subject, refer to the subject of Trouble Shooting treated in Chapter 40.

PROTECTION OF BOILERS

The following physical precautions should be taken in all installations to prevent damage to the boiler:

1. There should be provided proper and convenient drainage connections for use if the boiler is not in operation during freezing weather.

2. Strains on the boiler due to movement of piping during expansion should be prevented by suitable anchoring of piping and by proper provision for pipe expansion and contraction.

3. Direct impingement of too intense local heat upon any part of the boiler surface, as with oil burners, should be avoided by protecting the surface with firebrick or other insulating material.

4. Condensation must flow back to the boiler as rapidly and uniformly as possible. Return connections should prevent the water from backing out of the boiler.

5. Automatic boiler feeders and low water cut-off devices which shut off the source of heat if the water in the boiler falls below a safe level are both recommended for boilers fired with oil or gas. In apartment or commercial buildings where the boiler attendant is frequently absent from the boiler room an electric signal should be attached to the

alarm to ring a bell or buzzer or flash a light in the janitor's quarters or where it will receive his attention.

CLEANING STEAM BOILERS

The grease used to lubricate the cutting tools during erection of new piping systems serves as a carrier for sand and dirt, with the result that a scum of fine particles and grease accumulates on the surface of the water in all new boilers, while heavier particles may settle to the bottom of the boiler and form sludge. These impurities have a tendency to cause foaming, preventing the generation of steam and causing an unsteady water line. Hence, the boiler should be blown off within about one week after it has been placed in operation. This blowing off should be done with the boiler under fire, and should be repeated until a steady water line and clean gage glass result. The scum is best removed through an outlet at the surface of the water.

CLEANING FLUES

All boilers are provided with flue clean-out openings through which the heating surface can be reached by means of brushes or scrapers. Flues of solid fuel boilers should be cleaned often to keep the surfaces free of soot or ash. Gas boiler flues and burners should be cleaned at least once a year. Oil burning boiler flues should be examined periodically to determine when cleaning is necessary.

CARE OF IDLE HEATING BOILERS

During summer months damage is frequently done to heating boilers and is often more serious than during the period of operation. This is due chiefly to corrosion following the combination of sulphur from the fuel with the moisture in the cellar air. At the end of the heating season the following precautions should be taken:

1. All heating surfaces should be cleaned thoroughly and if the boiler is of steel the heating surfaces should be given a coating of lubricating oil on the fire side.
2. All machined surfaces should be coated with oil or grease.
3. Connections to the chimney should be cleaned and in case of small boilers the pipe should be placed in a dry place after cleaning.
4. If there is much moisture in the boiler room, it is advisable to drain the boiler to prevent condensation of moisture on the surfaces when the boiler temperature becomes lower than the dew point. In steel boilers kerosene poured on the surface of the water will form a protecting film over the inside surface as the water is drained out.
5. When the boiler room is comparatively dry, in the case of cast-iron boilers, the water level should be raised into the steam riser to exclude air from the boiler. A hot water system usually is left filled to the expansion tank.
6. The grates and ashpit should be cleaned.

Chapter 15

DRAFT AND CHIMNEYS

Draft; Types of Draft Systems; Natural and Mechanical Draft Systems; Performance of Natural Draft Chimneys; Economical Chimney Sizes; General Draft Equation and Draft Losses, Construction of Chimneys; Smoke Test.

DRAFT

AIR is fed to the fuel during the process of combustion through the medium of a draft. Draft, in general, may be defined as the pressure difference between the atmospheric pressure and that at any part of the installation through which the gases flow. Since a pressure difference implies a head, draft then is a static force. While no element of motion is inferred, yet motion in the form of circulation of gases throughout the entire boiler plant installation is the direct result of draft. This motion is due to the pressure difference, or unbalanced pressure, which compels the gases to flow.

TYPES OF DRAFT SYSTEMS

Draft-producing systems may be classified into four distinct types according to the type of pressure transformer used and the type of draft created, *viz:* (1) Natural draft systems, (2) Venturi draft systems, (3) Induced draft systems, and (4) Forced draft systems.

In *natural draft systems*, the pressure difference is created by means of a natural draft chimney and a thermal difference. Natural draft results in a suction and is therefore a negative pressure. Natural draft systems operate with gases whose temperature is always relatively hot.

In *Venturi draft systems*, the pressure difference is created by means of a Venturi chimney together with either a small fan or a small blower. Venturi draft results in a suction and, like natural draft, is a negative pressure. Venturi draft systems likewise operate with gases whose temperature is always relatively hot.

In *induced draft systems*, the pressure difference is created by means of an induced draft fan. Induced draft, like natural and Venturi draft, is a negative pressure. Induced draft systems also operate with gases whose temperature is always relatively hot.

In *forced draft systems*, the pressure difference is created by means of a forced draft fan. Forced draft results in a plenum and is therefore a positive pressure. Forced draft systems ordinarily operate with relatively cool outside air, although in recent years some installations of this type have been designed to operate with pre-heated air.

NATURAL AND MECHANICAL DRAFT SYSTEMS

Draft is often classified into two kinds according to whether it is created thermally or artificially, *viz:* (1) Natural or thermal draft, and (2) Artificial or mechanical draft.

Natural draft is the difference in pressure produced by the difference in weight between the relatively hot gases inside a natural draft chimney and an equivalent column of the cooler outside air, or atmosphere. Natural draft, in other words, is an unbalanced pressure produced thermally by a natural draft chimney as the pressure transformer and a temperature difference. The intensity of natural draft depends, for the most part, upon the height of the chimney above the grate bar level and also the temperature difference between the chimney gases and the atmosphere. Natural draft tends to produce a vacuum and is, therefore, a type of draft by aspiration.

Artificial draft, or mechanical draft, as it is more commonly called, is a difference in pressure produced either directly or indirectly by a forced draft fan, an induced draft fan or a Venturi chimney as the pressure transformer. The intensity of mechanical draft is dependent for the most part upon the size of the fan and the speed at which it is operated. The element of temperature does not enter into the creation of mechanical draft and therefore its intensity, unlike natural draft, is independent of the temperature of the gases and the atmosphere. Mechanical draft includes the induced and Venturi types of draft systems in which the pressure difference is the result of a suction and also the forced draft system in which the pressure difference is the result of a blowing. Mechanical draft systems tend to produce a vacuum or a plenum, according as the system used in its production creates a pressure difference below, or above, atmospheric pressure, respectively. A mechanical draft system may be used either in conjunction with, or as an adjunct to, a natural draft system.

A typical natural draft system consists essentially of a relatively tall chimney built of steel, brick or reinforced concrete, operating with the relatively hot gases which have passed through the boilers and accessories and from which all of the heat has not been extracted. Hot gases are an essential element in the operation of a natural-draft system. The results obtained by natural-draft systems are identical with those obtained by induced and Venturi-draft systems, the only difference in the systems being in the type of pressure transformer used in creating the pressure difference. Natural draft systems are self-operating and, unlike induced and Venturi systems, require no power to operate the system in order to produce the pressure difference and maintain a gas flow.

A natural-draft chimney performs the two-fold service of assisting in the creation of draft by aspiration and also of discharging the gases at an elevation sufficient to prevent them from becoming a nuisance. Hence the two duties of a natural draft chimney are: (1) Draft creation and (2) Gas disposal. The chimney is the pressure transformer and the draft is the result of the thermal difference.

Natural draft is quite advantageous in installations where the total loss of draft due to resistances is relatively low and also in plants which have practically a constant load and the boilers are seldom operated above their

normal rating. Natural draft systems have been, and are still being, employed in the operation of large plants during the periods when the boilers are operated only up to their normal rating. When the rate of operation is increased above their normal rating, some form of mechanical draft is employed as an auxiliary to overcome the increased resistances or draft losses. Natural-draft systems are used almost exclusively in the smaller size plants where the amount of gases generated is relatively small and it would be expensive to install and operate a mechanical draft system.

The principal advantages of natural draft systems may be summarized as follows: (1) Simplicity, (2) Reliability, (3) Freedom from mechanical parts, (4) Low cost of maintenance, (5) Relatively long life, (6) Relatively low depreciation, and (7) No power required to operate. The principal disadvantages are: (1) Lack of flexibility, (2) Irregularity, (3) Affected by surroundings, and (4) Affected by temperature changes.

PERFORMANCE OF NATURAL DRAFT CHIMNEYS

In order to analyze the performance of a natural draft chimney, it is advantageous to compare its general operating characteristics with those of a centrifugal pump and also a centrifugally-induced draft fan, there being a close similarity between the three. Figs. 1, 2 and 3 show the general operating characteristics of a typical centrifugally-induced draft fan, a typical centrifugal pump, and a typical natural draft chimney, respectively. The draft-capacity curve of the chimney corresponds to the head-capacity curve of the pump and also the dynamic-head capacity of the fan; the efficiency curve of the chimney to the efficiency curves of the pump and fan; and the gas horse-power curve of the chimney to the brake horse-power curves of the pump and fan.

Theoretical Draft; Available Draft

When the gases in the chimney are stationary, the draft created is termed the *theoretical draft.* When the gases are flowing, the theoretical intensity is diminished by the draft loss due to friction, the difference between the two being termed the *available draft.* The general equation for the available draft intensity of a natural draft chimney with a circular section is as follows:

$$D_a = 2.96HB_o\left(\frac{W_o}{T_o} - \frac{W_c}{T_c}\right) - \frac{0.00126W^2T_cfL}{D^5B_oW_c} \qquad (1)$$

where

D_a = available draft, inches of water.

H = height of chimney above grate bars, feet.

B_o = barometric pressure corresponding to altitude, inches of mercury.

W_o = unit weight of a cubic foot of air at 0 deg Fahrenheit and sea level atmospheric pressure, pounds per cubic foot.

W_c = unit weight of a cubic foot of chimney gases at 0 deg Fahrenheit and sea level atmospheric pressure, pounds per cubic foot.

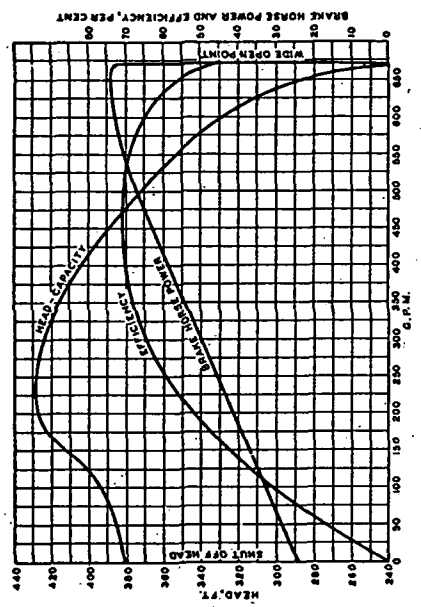


FIG. 2. OPERATING CHARACTERISTICS OF TYPICAL CENTRIFUGAL PUMP

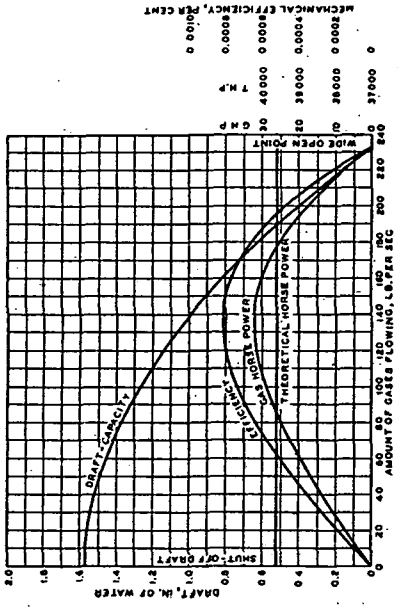


FIG. 3. OPERATING CHARACTERISTICS OF TYPICAL NATURAL DRAFT CHIMNEY

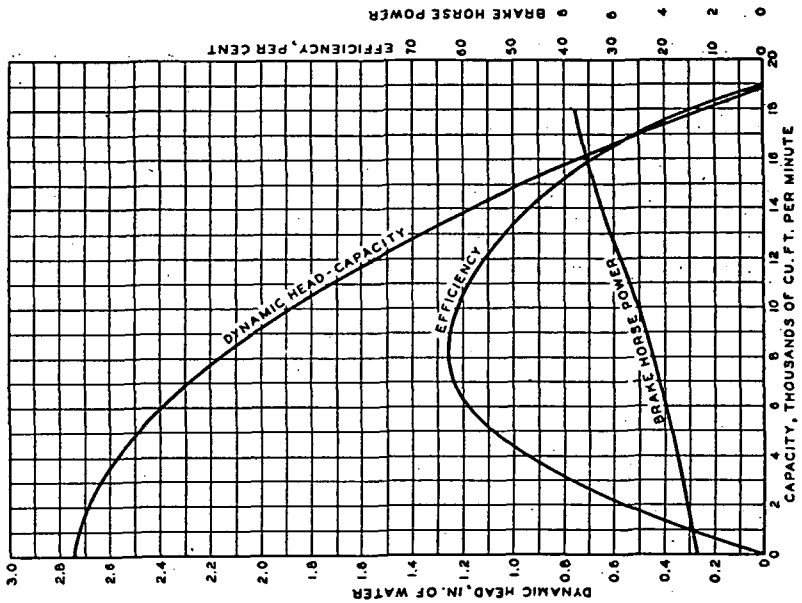


FIG. 1. GENERAL OPERATING CHARACTERISTICS OF TYPICAL INDUCED DRAFT FAN

T_o = absolute temperature of atmosphere, degrees Fahrenheit.

T_c = absolute temperature of chimney gases, degrees Fahrenheit.

W = amount of gases generated in the combustion chamber of the boiler and passing through the chimney, pounds per second.

f = coefficient of friction.

L = length of friction duct of the chimney, feet.

D = minimum diameter of chimney, feet.

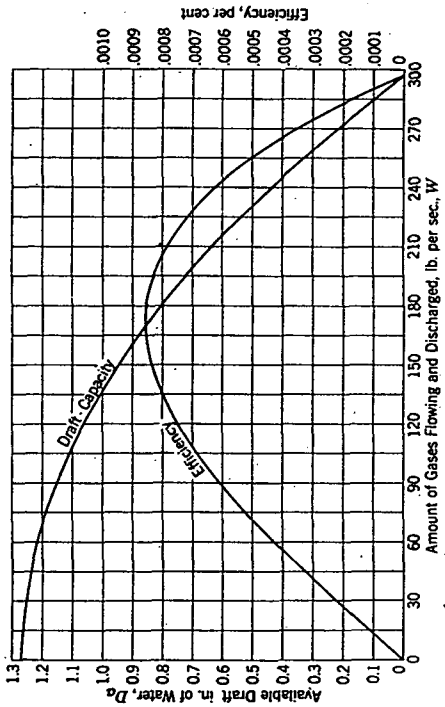


FIG. 4. TYPICAL SET OF OPERATING CHARACTERISTICS OF A NATURAL DRAFT CHIMNEY

The first term of the right hand expression of Equation 1 represents the theoretical draft intensity and the second term, the loss due to friction.

Example 1. Determine the available draft of a natural draft chimney 200 ft in height and 10 ft in diameter operating under the following conditions: atmospheric temperature, 62 F; chimney gas temperature, 500 F; sea level atmospheric pressure, B_o = 29.92 in. of mercury; atmospheric and chimney gas density, 0.0863 and 0.09, respectively; coefficient of friction, 0.016; length of friction duct, 200 ft; and discharging 100 lb of gases per second.

Substituting these values in Equation 1 and reducing:

$$D_a = 2.96 \times 200 \times 29.92 \times \left(\frac{0.0863}{522} - \frac{0.09}{960}\right) - \frac{0.00126 \times 100^2 \times 960 \times 0.016 \times 200}{10^5 \times 29.92 \times 0.09}$$

$$= 1.27 - 0.14 = 1.13 \text{ in.}$$

Fig. 4 shows the variation in the available draft of a typical 200 ft by 10 ft chimney operating under the general conditions noted in Example 1. When the chimney is under static conditions and no gases are flowing, the available draft is equal to 1.27 in. of water, the theoretical intensity. As the amount of gases flowing increases, the available intensity decreases until it becomes zero at a gas flow of 297 lb per second at which point the draft loss due to friction is equal to the theoretical intensity. The draft-capacity curve corresponds to the head-capacity curve of centrifugal pump characteristics and the dynamic-head-capacity curve of a fan. The point of maximum draft and zero capacity is called shut-off draft, or point of impending delivery, and corresponds to the point of shut-off head of a centrifugal pump. The point of zero draft and maximum capacity is called the wide open point and corresponds to the wide open point of a centrifugal pump. A set of operating characteristics may be developed for any size chimney operating under any set of conditions by substituting the proper values in Equation 1 and then plotting the results in the manner shown in Fig. 4.

Energy Output and Input

The efficiency of a natural draft chimney is the thermodynamical ratio of the energy output to the energy input. The energy output is the total work done by the chimney in moving the gases and corresponds to the water horsepower of a centrifugal pump, or the total work done by a fan in moving the gases. The energy input is equal to the theoretical amount of power generated by the chimney and corresponds to the power input of the driving unit of a centrifugal pump or a fan. The thermodynamical efficiency is given by the equation:

$$E_t = \frac{K_a W D_a}{A\sqrt{H}} \qquad (2)$$

where

K_a = a constant depending upon the temperature of the gases, the atmospheric temperature, the elevation of the plant, and the density and specific heat of the gases. For average operating conditions, $K_a = 0.0065$.

Fig. 4 shows the variation in the efficiency of the chimney under consideration for the operating conditions noted. This curve rises from zero at shut-off draft to a maximum for a certain draft and its corresponding capacity and then drops again to zero at the wide open point. The point of maximum efficiency is located by the point on the draft-capacity curve equal to two-thirds of the theoretical draft intensity. In Example 1 the maximum efficiency is at an available draft intensity of ⅔ (1.27) = 0.85 in. of water and the corresponding capacity of 175 lb per second.

Efficiency Curve of Natural Draft Chimney

The efficiency curve of a natural draft chimney corresponds to the efficiency curves of a centrifugal pump and a fan and serves the same general use in that it locates the region of most economical operation. In substituting the values for the various factors in Equation 1, care should be exercised that the selections be as near the actual conditions as is practically possible. The following notes will serve as a guide for these selections:

1. The *barometric pressure* varies inversely as the altitude of the plant above sea level. Fig. 5 gives the barometric pressure corresponding to various elevations as computed from the equation:

$$E_1 = 62{,}737 \log \frac{29.92}{B_o} \qquad (3)$$

where

E_1 = altitude of plant above sea level, feet.

Roughly speaking, the barometric pressure decreases approximately 0.1 in. of mercury per 100 ft increase in elevation.

2. The *unit weight of a cubic foot* of chimney gases at 0 deg Fahrenheit and sea level barometric pressure is given by the equation:

$$W_c = 0.131 CO_2 + 0.095\, O_2 + 0.083\, N_2 \qquad (4)$$

in which CO_2, O_2 and N_2 represent the percentages of the parts by weight of the carbon dioxide, oxygen and nitrogen content, respectively, of the gas analysis. For ordinary operating conditions, the value of W_c may be assumed at 0.09.

3. The *atmospheric temperature* is the actual observed temperature of the outside air at the time the analysis of the operating chimney is made. The mean atmospheric temperature in the temperate zone is approximately 62 F.

4. The *chimney gas temperature* does not vary appreciably from the gas temperature as it leaves the breeching and enters the chimney. For average operating conditions, the chimney gas temperature will vary between 500 F and 650 F except in the case when economizers and recuperators are used when the temperature will vary between 300 F and 450 F. If a chimney has been properly constructed, properly lined and has no air infiltration due to open joints, the temperature of the gases throughout the chimney will not differ appreciably from the foregoing figures. In most up-to-date heating plants, the temperature may be read from instruments or ascertained from a pyrometer.

5. The *coefficient of friction* between the chimney gases and a sooted surface has been found to be approximately 0.016. This factor, of course, will be much less for a new unlined steel stack than for a brick or brick-lined chimney, but in time the inside surface of all chimneys regardless of the material of which they are constructed becomes covered with a layer of soot and the coefficient of friction should be the same for all types of chimneys.

6. The *length of the friction duct* is the vertical distance between the bottom of the breeching opening and the top of the chimney. Ordinarily this distance is approximately equal to the height of the chimney above the grate level.

7. The *amount of gases flowing and being discharged* is, of course, equal to the amount of gases generated in the combustion chamber of the boiler. The total products of combustion may be computed from the equation:

$$W = \frac{C_g G W_{tp}}{3600} \qquad (5)$$

where

C_g = pounds of fuel burned per square foot of grate surface per hour.
G = total grate surface of boilers, square feet.
W_{tp} = total weight of products of combustion per pound of fuel.

Fig. 6 is a typical chimney performance chart giving the available draft intensities for various amounts of gases flowing and sizes of chimney. This chart is based on an atmospheric temperature of 62 F, a chimney gas temperature of 500 F, a unit chimney gas weight of 0.09 lb per cubic foot, sea level atmospheric pressure, a coefficient of friction of 0.016 and a friction duct length equal to the height of the chimney above the grate level. These curves may be used for general operating conditions. For specific operating conditions, a new chart should be constructed from Equation 1.

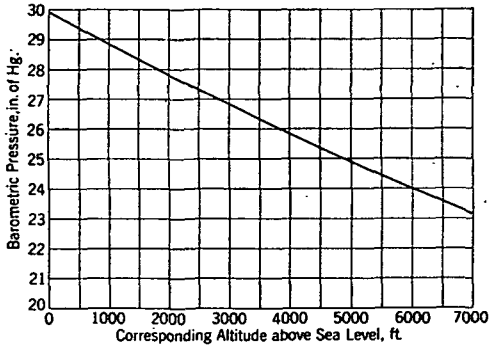


FIG. 5. RELATION BETWEEN BAROMETRIC PRESSURE AND ALTITUDE

ECONOMICAL CHIMNEY SIZES

It has been the usual custom, and still is to a lamentably great extent, to select the required size of a natural-draft chimney from a table of chimney sizes based only on boiler horsepowers. After the ultimate horsepower of the projected plant had been determined, the chimney size in the table corresponding to this figure was then selected as the proper size required. Generally, no further attempt was made to determine if the height thus selected was sufficient to help create the required draft demanded by the entire installation, or the diameter sufficiently large to enable the chimney quickly, efficiently and economically to dispose of the gases. Since the operating characteristics of a natural draft chimney are similar in all respects to those of a centrifugal pump, or a centrifugal fan, it is no more possible to select a proper size chimney from such a table, even with correction factors appended, than it is to select the proper size pump, or fan, from tables based only on the amount of water or gases to be delivered. Just as it is necessary to know the total dynamic head against which a pump and a fan are to operate, so it is necessary to know the total required draft against which the chimney is to operate.

The required diameter and height of a natural-draft chimney is given by the following equations:

$$H = \frac{D_r}{2.96B_o\left(\frac{W_o}{T_o} - \frac{W_c}{T_c}\right) - \frac{0.184fW_cB_oV^2}{T_cD}} \qquad (6)$$

$$D = 0.288\sqrt{\frac{WT_c}{B_oW_cV}} \qquad (7)$$

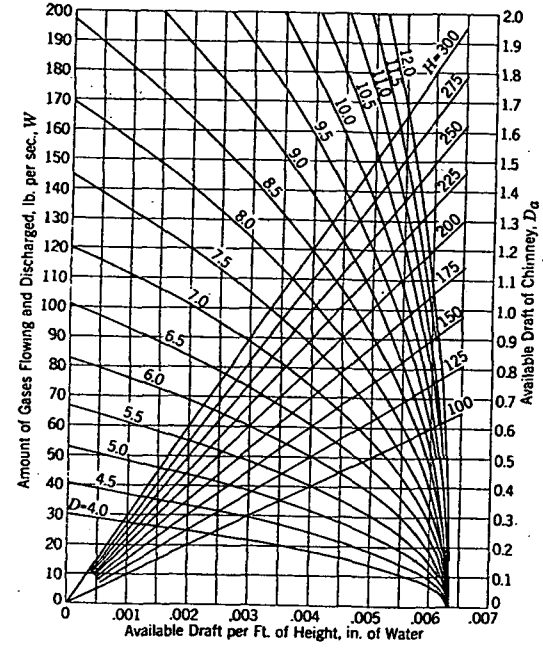


FIG. 6. CHIMNEY PERFORMANCE CHART

where

H = required height of chimney above grate bar level, feet.
D = required minimum diameter of chimney, feet.
V = chimney gas velocity, feet per second.
D_r = total required draft demanded by the entire installation outside of the chimney, inches of water.

Equations 6 and 7 give the required size of a natural-draft chimney with all of the operating factors taken into consideration. Values for all of the factors with the exception of the chimney gas velocity may be either observed or computed. It is, of course, necessary to assume an arbitrary value for the velocity in order to arrive at some definite size. For any one set of operating conditions there will be as many sizes of chimney as there are values of reasonable velocities to assume. Of the number of sizes

corresponding to the various assumed velocities, there is one size which will cost least. Since the cost of a chimney structure, regardless of the kind of material used in the construction, varies as the volume of material in the structure, the cost criterion then may be represented by the approximate equation:

$$Q = \pi t H D \tag{8}$$

where

Q = volume of material, cubic feet.
t = average wall thickness, feet.

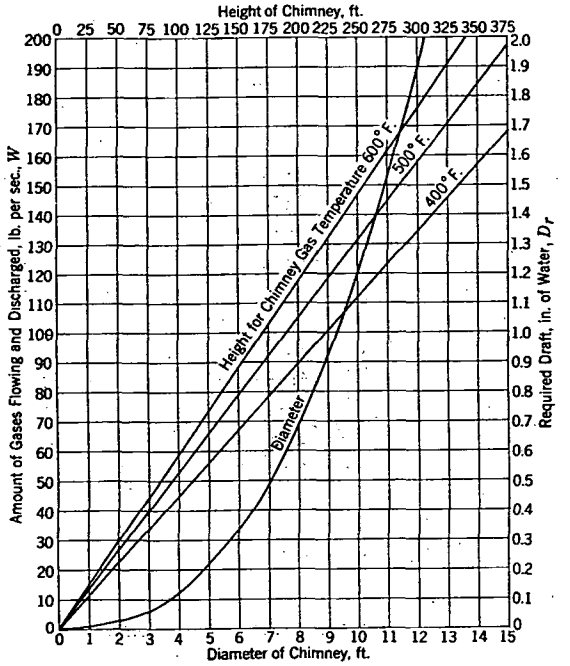


FIG. 7. ECONOMICAL CHIMNEY SIZES

For all practical purposes, the value of πt may be taken as a constant regardless of the size of the structure. Hence, in general, the volume, and consequently the cost, of a chimney structure may be based on the factor HD as a criterion. Therefore, the value of the chimney gas velocity which will result in the least value of HD for any one set of operating conditions will produce a structure whose cost will be least and, as a result, will be the most economical to use.

The problem at hand is to deduce an equation for the chimney gas velocity which will result in a combination of a height and a diameter whose product HD will be least. The solution is obtained by equating the product of Equations 3 and 4 to HD, differentiating this product with

respect to V and equating the resulting expression to zero. This procedure results in the following expression:

$$V_e = \left(\frac{0.772 T_c \left(\frac{W_o}{T_o} - \frac{W_c}{T_c} \right) \sqrt{\frac{W T_c}{B_o W_c}}}{f W_c} \right)^{2/5} \tag{9}$$

where

V_e = economical chimney gas velocity, feet per second.

Equation 9 gives the economical velocity of the chimney gases for any set of operating conditions and represents the velocity which will result in a chimney the size of which will cost less than that of any other size as determined by any other velocity for the same operating conditions. After the value of the economical velocity has been determined, the corresponding height and diameter can then be determined from Equations 6 and 7, respectively, and the economical size will then be attained. Equations 6, 7 and 9 may be simplified considerably for average operating conditions in an average size steam plant by assuming the following conditions:

Average chimney gas temperature, 500 F	$T_c = 960$
Mean atmospheric temperature, 62 F	$T_o = 522$
Average coefficient of friction, 0.016	$f = 0.016$
Average chimney gas density, 0.09	$W_c = 0.09$
Sea level elevation with barometer of 29.92	$B_o = 29.92$

Substituting these values in Equations 2, 3 and 5, respectively, and reducing:

$$V_e = 13.7 W^{1/5} \tag{10}$$

$$D = 1.5 W^{2/5} \tag{11}$$

$$H = 190 D_r \tag{12}$$

Fig. 7 gives the economical chimney sizes for various amounts of gases flowing and required draft intensities as computed from Equations 10, 11 and 12, and are based on the operating factors used in reducing Equations 6, 7 and 9 to their simpler form. The sizes shown by the curves in the chart should be used for general operating conditions only, or for installations where the required data necessary for an exact determination are difficult or impossible to secure. Whenever it is possible to secure accurate data, or the anticipated operating conditions are fairly well known, the required size should be determined from Equations 6, 7 and 9.

The recommended minimum inside dimensions and heights of chimneys for small and medium size installations are given in Table 1, which is taken from the A.S.H.V.E. Code of Minimum Requirements for the Heating and Ventilation of Buildings (edition of 1929).

GENERAL DRAFT EQUATION AND DRAFT LOSSES

The general draft equation for a steam producing plant may be stated as follows:

$$D_t - h_f = h_F + h_B + h_{Br} + h_V + h_{Bd} + h_C + h_O + h_E + h_R \tag{13}$$

where

D_t = theoretical draft intensity created by pressure transformer, inches of water.
h_f = draft loss due to friction in pressure transformer, inches of water.
h_F = draft loss through the fuel bed, inches of water.
h_B = draft loss through the boiler and setting, inches of water.
h_{Br} = draft loss through the breeching, inches of water.
h_V = draft loss due to velocity, inches of water.
h_{Bd} = draft loss due to bends, inches of water.
h_C = draft loss due to contraction of opening, inches of water.
h_O = draft loss due to enlargement of opening, inches of water.
h_E = draft loss through the economizer, inches of water.
h_R = draft loss through recuperators and regenerators, inches of water.

The left hand member of Equation 13 represents the total amount of available draft created by the pressure transformer, that is, the natural draft chimney, Venturi chimney, or fan, and is equal to the theoretical intensity less the internal losses incidental to operation. The right hand member represents the sum of all of the various losses of draft throughout the entire boiler plant installation outside of the pressure transformer itself. The left hand member expresses the available intensity and is

TABLE 1. RECOMMENDED MINIMUM CHIMNEY SIZES FOR HEATING BOILERS AND FURNACES†

Warm Air Furnace Capacity in Sq. In. of Leader Pipe	Steam Boiler Capacity Sq. Ft. of Radiation	Hot Water Heater Capacity Sq. Ft. of Radiation	Nominal Dimensions of Fire Clay Lining in Inches	Rectangular Flue		Round Flue		Height in Ft. Above Grate
				Actual Inside Dimensions of Fire Clay Lining in Inches	Actual Area Sq. In.	Inside Diameter of Lining in Inches	Actual Area Sq. In.	
790	590	973	8½ x 13	7 x 11½	81			35
1000	690	1,140				10	79	
	900	1,490	13 x 13	11¼ x 11¼	127			
	900	1,490	8½ x 18	6¾ x 16¼	110			
	1,100	1,820				12	113	40
	1,700	2,800	13 x 18	11¼ x 16¼	183			
	1,940	3,200				15	177	
	2,130	3,520	18 x 18	15¾ x 15¾	248			
	2,480	4,090	20 x 20	17¼ x 17¼	298			45
	3,150	5,200				18	254	50
	4,300	7,100				20	314	
	4,600	7,590	20 x 24	17 x 21	357			
	5,000	8,250	24 x 24	21 x 21	441			55
	5,570	9,190		24 x 24*	576			60
	5,580	9,200				22	380	
	6,980	11,500				24	452	65
	7,270	12,000		24 x 28*	672			
	8,700	14,400		28 x 28*	784			
	9,380	15,500				27	573	
	10,150	16,750		30 x 30*	900			
	10,470	17,250		28 x 32*	896			

*Dimensions are for unlined rectangular flues.

†This table is taken from the A.S.H.V.E. Code of Minimum Requirements for the Heating and Ventilation of Buildings (Edition of 1929).

analogous to the head developed by a centrifugal pump in a water works system while the right hand member expresses the required draft intensity and is analogous to the total dynamic head in a water works system. For a general circulation of gases, then

$$D_a = D_r \tag{14}$$

where

D_a = available draft intensity, inches of water.
D_r = required draft, inches of water

The *draft loss through the fuel bed* (h_F) or the amount of draft required to effect a given or required rate of combustion, varies between wide limits and represents the greater portion of the required draft. In coal-fired

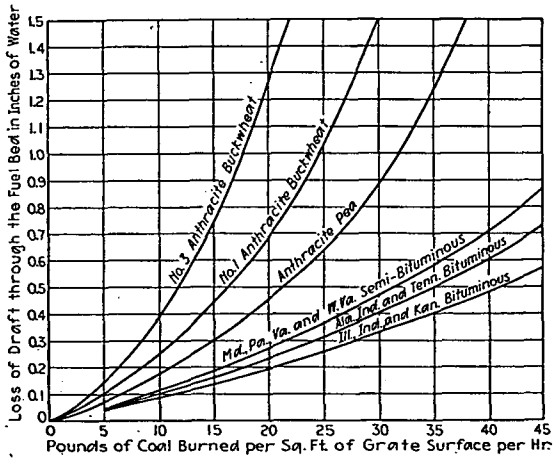


FIG. 8. DRAFT REQUIRED AT DIFFERENT RATES OF COMBUSTION FOR VARIOUS KINDS OF COAL

installations, the draft loss through the fuel bed is dependent upon the following factors:

1. Character and condition of the fuel, clean or dirty.
2. Percentage of ash in the fuel.
3. Volume of interstices in the fuel bed, coarseness of fuel.
4. Thickness of the fuel bed, rate of combustion.
5. Type of grate or stoker used.
6. Efficiency of combustion.

There is a certain intensity of draft with which the best results will be obtained for every kind of coal and rate of combustion. Fig. 8 gives the intensity of draft, or the vacuum in the combustion chamber required to burn various kinds of coal at various rates of combustion. Expressed in other words, these curves represent the amount of draft required to force the necessary amount of air through the fuel bed in order to effect various

rates of combustion. It will be noted that the amount of draft increases as the percentage of volatile matter diminishes, being comparatively low for the lower grades of bituminous coals and highest for the high grades and small sizes of anthracites. Also, when the interstices of the coal are large and the particles are not well broken up, as with bituminous coals, much less draft is required than when the particles are small and are well broken up as with bituminous slack and the small sizes of anthracites. In general, the draft loss through the fuel bed increases as follows:

1. The percentage of volatile matter diminishes.
2. The percentage of fixed carbon increases.
3. The thickness of the bed increases.
4. The percentage of ash increases.
5. The volume of the interstices diminishes.

In making the preliminary assumptions for the draft loss through the fuel bed, due allowances should be made for a possible future change in the grade of fuel to be burned and also in the rate of combustion. A value should be selected for this loss which will represent not only the highest rate of combustion which will be encountered, but also the grade of coal which has the greatest resistance through the fuel bed and which may be burned at a later date.

In powdered-fuel and oil-fired installations, there will be no draft loss through the fuel bed since there is none and, consequently, this factor becomes zero in the general draft equation. All other factors being constant, the height of the chimney in installations of this character will be less than the height in coal-fired installations and in the case of mechanical draft installations the driving units need not be as large since the head against which the fan is to operate is not as great in the former as in the latter.

The *draft loss through the boiler and setting* (h_B) also varies between wide limits and, in general, depends upon the following factors:

1. Type of boiler.
2. Size of boiler.
3. Rate of operation.
4. Arrangement of tubes.
5. Arrangement of baffles.
6. Type of grate.
7. Design of brickwork setting.
8. Excess air admitted.
9. Location of entrance into breeching.

Curves showing the draft loss through the boiler are usually based on the load or quantity of gases passing through the boiler, expressed in terms of percentage of normal rate of operation. Owing to the great variety of boilers of different designs and the various schemes of baffling, it is impossible to group together a set of curves for the draft loss through the boiler which may even be used generally. It is therefore necessary to secure this information from the manufacturer of the particular type of boiler and baffle arrangement under consideration.

When a boiler is installed and in operation, the draft loss depends upon the amount of gases flowing through it. This, in turn, depends upon the

proportion of excess air admitted for combustion. The amount of excess air is measured by the CO_2 content; the less the amount of CO_2, the greater the amount of excess air and hence the greater the draft loss.

The loss of draft through the boiler will vary directly as the size of the boiler and the length of the gas passages within. The loss also varies as the number of tubes high, but not in a direct ratio inasmuch as the loss due to the reversal of flow at the ends of the baffles remains constant regardless of the height of the boiler. The arrangement of the tubes, whether the gases flow parallel to or at right angles to, the tubes, has an appreciable effect on the loss. The arrangement of the baffles influences the draft loss greatly, the loss through a boiler with five passes being greater than the loss through one of three or four passes. A poor design and a rough condition of the brickwork will increase the loss greatly, whereas a proper design and a smooth condition will keep the loss to a minimum. The loss through the boiler will be less when the breeching entrance is located at or near the top of the boiler than when it is located at or near the bottom since the gases have a shorter distance to travel in the former instance.

The *draft loss through the breeching* (h_{Br}) is given by the general equation:

$$h_{Br} = \frac{0.000194 W^2 T_c f L}{A^2 B_o W_c C_{br}} \qquad (15)$$

where

W = the amount of gases flowing, pounds per second.
T_c = absolute temperature of breeching gases, degrees Fahrenheit.
f = coefficient of friction.
L = length of breeching, feet.
A = area of breeching, square feet.
B_o = atmospheric pressure corresponding to altitude, inches of mercury.
W_c = weight of a cubic foot of breeching gases at 0 deg F and sea level atmospheric pressure, pounds per cubic foot.
C_{br} = hydraulic radius of breeching section.

It has been the general custom to *lump off* the intensity of the breeching loss at 0.10 in. of water per 100 ft of breeching length regardless of its size or shape or the amount and temperature of the gases flowing through it. This practice is hazardous and has no more foundation in fact than that of determining the friction head in a water works system without taking into consideration the size of the pipe or the amount of water flowing through it. When the length of the breeching is relatively short, any variation in any one of the factors in the equation will have no appreciable effect on the draft loss. However, when the breeching is relatively long, the draft loss is affected greatly by the various factors, particularly by the size and shape as well as by the weight of gases flowing.

The *draft loss due to velocity* (h_V) is given by the equation

$$h_V = \frac{0.000194 W^2 T_c}{A^2 B_o W_c} \qquad (16)$$

and represents the amount of draft required to accelerate the gases from zero velocity to the velocity at which the gases are flowing, or in other

words, from a static gas condition of zero flow to the amount of gases flowing throughout the installation. This loss corresponds to the velocity head in water works systems.

The *draft loss due to bends* (h_{Bd}) is equivalent to the loss due to the velocity head for a 90-deg bend. In changing direction of flow, the gas velocity decreases to zero with a loss of velocity head and then increases to its proper value at the expense of a loss in pressure head, the net result being a loss in pressure head equal to the velocity head at the bend. This loss is given by the equation:

$$h_{Bd} = \frac{0.000194 W^2 T_c}{A^2 B_o W_c} \tag{17}$$

The friction at a right-angle bend is sometimes expressed as the equivalent of a straight length of flue of a certain length for a certain diameter, similar to the procedure used in estimating the loss due to bends in piping systems conducting water. Most flues, however, particularly breechings, are built square or rectangular in section and no general equation based on the shape of the flue can be conveniently expressed.

The *draft loss due to sudden contraction of an area* (h_C) is given by the equation:

$$h_C = \frac{0.000194 K_C W^2 T_c}{A_s^2 B_o W_c} \tag{18}$$

where

K_C = coefficient of sudden contraction based on $\frac{A_s}{A_1}$, the ratio of the areas of the smaller to the larger section.

A_s = area of the smaller section.

When the flue or passage through which the gases flow is suddenly contracted, a considerable portion of the static head in the larger section is converted into velocity head and a draft loss of some consequence, particularly in a short breeching, takes place. A sudden contraction should always be avoided where possible. At times, however, due to obstructions or limited head-room, it is necessary to alter the size of the breeching but a sudden contraction may be avoided by gradually decreasing the area over a length of several feet.

The *draft loss due to a sudden enlargement of an area* (h_O) is given by the equation:

$$h_O = \frac{0.000194 K_O W^2 T_c}{A_s^2 B_o W_c} \tag{19}$$

where

K_O = coefficient of sudden enlargement based on $\frac{A_s}{A_1}$, the ratio of the areas of the smaller to the larger section.

When the flue or passage through which the gases flow is suddenly enlarged, a portion of the velocity head is converted into static head in the larger section and, like the loss due to sudden contraction, a loss of some

consequence, particularly in short breechings, takes place. A sudden enlargement in a breeching may be avoided by gradually increasing the area over a length of several feet. In large masonry chimneys, the area of the flue at the region of the breeching entrance is considerably larger than the area of the breeching at the chimney and a sudden enlargement exists.

The *draft loss through the economizer* (h_E) should be obtained from the manufacturer but for general purposes may be computed from the following general equation:

$$h_E = \frac{6.6 W_n^2 N T_c}{10^{12}} \tag{20}$$

where

W_n = pounds of gases flowing per hour per linear foot of pipe in each economizer section.

N = number of economizer sections.

An economizer in a steam plant affects the draft in two ways, (1) Offers a resistance to the flow of gases, and (2) Lowers the average chimney gas temperature thereby decreasing the available intensity. In the case of a natural draft installation, both of these factors result in a relative increase in the height of the chimney and, in the case of a large plant, may add as much as 20 to 30 ft to the height. The decrease in the temperature of the gases after they have passed through the economizer has an extremely important effect on the performance of a natural draft chimney and also a fan.

The *draft loss through recuperators and regenerators* (h_R) is generally relatively small and may be disregarded. However, when it is evident that these losses are of some consequence, the friction loss through the regenerator may be calculated from Equation 15 and the losses due to sudden contraction and expansion from Equations 18 and 19, respectively.

CONSTRUCTION OF CHIMNEYS

For general data on the construction of chimneys reference should be made to the Standard Ordinance for Chimney Construction of the *National Board of Fire Underwriters*. Briefly summarized, these provisions are as follows for heating boilers and furnaces:

The construction, location, height and area of the chimney to which a heating boiler or warm-air furnace is connected affect the operation of the entire heating system. Most residence chimneys are built of brick and may be either lined or unlined, but in either case the ***walls must be air-tight*** and there should be ***only one smoke opening*** into the chimney. Cleanout, if provided, must be ***absolutely air-tight*** when closed.

The walls of brick chimneys shall be not less than 3¾ in. thick (width of a standard size brick) and shall be lined with fire-clay flue lining. Fire-clay flue linings shall be manufactured from suitable refractory clay, either natural or compounded, and shall be adapted to withstand high temperatures and the action of flue gases. They shall be of standard commercial thickness, but not less than ¾ in. All fire-clay flue linings shall meet the standard specification of the *Eastern Clay Products Association*. The flue sections shall be set in special mortar, and shall have the joints struck smooth on the inside. The masonry shall be built around each section of lining as it is placed, and all spaces between masonry and linings shall be completely filled with mortar. No broken flue lining shall be used. Flue lining shall start at least 4 in. below the bottom of smoke-

pipe intakes of flues, and shall be continued the entire heights of the flues and project at least 4 in. above chimney top to allow for a 2 in. projection of lining. The wash or splay shall be formed of a rich cement mortar. To improve the draft the wash surface should be concave wherever practical.

Flue lining may be omitted in brick chimneys, provided the walls of the chimneys are not less than 8 in. thick, and that the inner course shall be a refractory clay brick. All brickwork shall be laid in spread mortar, with all joints push-filled. Exposed joints both inside and outside shall be struck smooth. No plaster lining shall be permitted.

Chimneys shall extend at least 3 ft above flat roofs and 2 ft above the ridges of peak roofs when such flat roofs or peaks are within 30 ft of the chimney. The chimney shall be high enough so that the wind from any direction shall not strike the top of the chimney from an angle above the horizontal. The chimney shall be properly capped with stone, terra cotta, concrete, cast-iron, or other approved material; but no such cap or coping shall decrease the flue area.

There shall be but one connection to the flue to which the boiler or furnace smoke-pipe is attached. The boiler or furnace smoke-pipe shall be thoroughly grouted into the chimney and shall not project beyond the inner surface of the flue lining.

The size or area of flue lining or of brick flue for warm-air furnaces depends on height of chimney and capacity of heating system. For chimneys not less than 35 ft in height above grate line, the net internal dimensions of lining should be at least 7 x 11½ in. for a total leader pipe area up to 790 sq in. Above 790 and up to 1,000 sq in. of leader pipe area the lining should be at least 11¼ x 11¼ in. inside. In case of brick flues not less than 35 ft in height with no linings, the internal dimensions should be at least 8 x 12 in. up to 790 sq in. of leader area, and at least 12 x 12 in. for leader capacities up to 1,000 sq in. Chimneys under 35 ft in height are unsatisfactory in operation and hence should be avoided.

SMOKE TEST

The chimney flue must be smoke tight and shall be subjected to a smoke test by the mason contractor in the presence of the architect or his representative, after the mortar has thoroughly hardened.

The method of conducting this test shall be as follows: With a good fire in the boiler or furnace, or in the base of the chimney, put about a square yard of tar paper on the fire. As soon as smoke appears at the top of the chimney close the top of the flue with a piece of old carpet or wet newspapers held down by a weighted board. Keep the tar paper burning in the firepot for five minutes. The architect or his representative shall sign an acceptance in triplicate, stating that the chimney was tight under the foregoing test, and shall give one copy to the mason contractor, one copy to the heating contractor and one copy to the owner.

Chapter 16

FUELS

Solid Fuels; Liquid Fuels; Gaseous Fuels; Fuel Required for Heating; Relative Cost of Heating with Different Fuels.

FUELS are divided into three classes, namely, solid, liquid and gaseous. Those most commonly used for heating purposes are coal and high temperature coke, light and medium oils, and natural and manufactured gas as supplied by the local gas companies.

SOLID FUELS

Coal, because of its abundance and low price, has been the most commonly used fuel; it gradually replaced wood as coal mines were opened and transportation facilities increased. The use of coke has increased rapidly in recent years. According to estimates of the U. S. Bureau of Mines, the coal and coke used for heating purposes in 1928 were:

Anthracite	46 to 56 million tons
Bituminous	56 to 77 million tons
Cokes	7¾ million tons

All coal originated from vegetation in swampy places. This vegetation decayed as it fell and built up in successive layers, in time forming peat which in turn became lignite and then under the influence of pressure and heat gradually changed into coals of higher carbon content. In America the coals in the East have generally developed further than those in the West. As the coals are less developed their moisture and oxygen content increase and their heating value decreases.

Kinds of Coal

The complex composition of coal makes it difficult to classify it into clear-cut types. Its chemical composition is some indication but coals having the same chemical analysis may have distinctly different burning characteristics. Users are mainly interested in the available heat per pound of coal, in the handling and storing properties, and in the burning characteristics. A description of the relationship between the qualities of coals and these characteristics requires considerable space; a treatment applicable to heating boilers is given in U. S. Bureau of Mines *Bulletin* 276.

Fig. 1 illustrates the distribution of the kinds of coal by States and shows the average calorific values and the ash and moisture contents of a limited number purchased on the open market. Five hundred tests in a small domestic boiler were made with these coals by the U. S. Bureau

of Mines and the lower curves show the averages of the pounds of water evaporated per pound of coal under similar and normally good operating conditions.

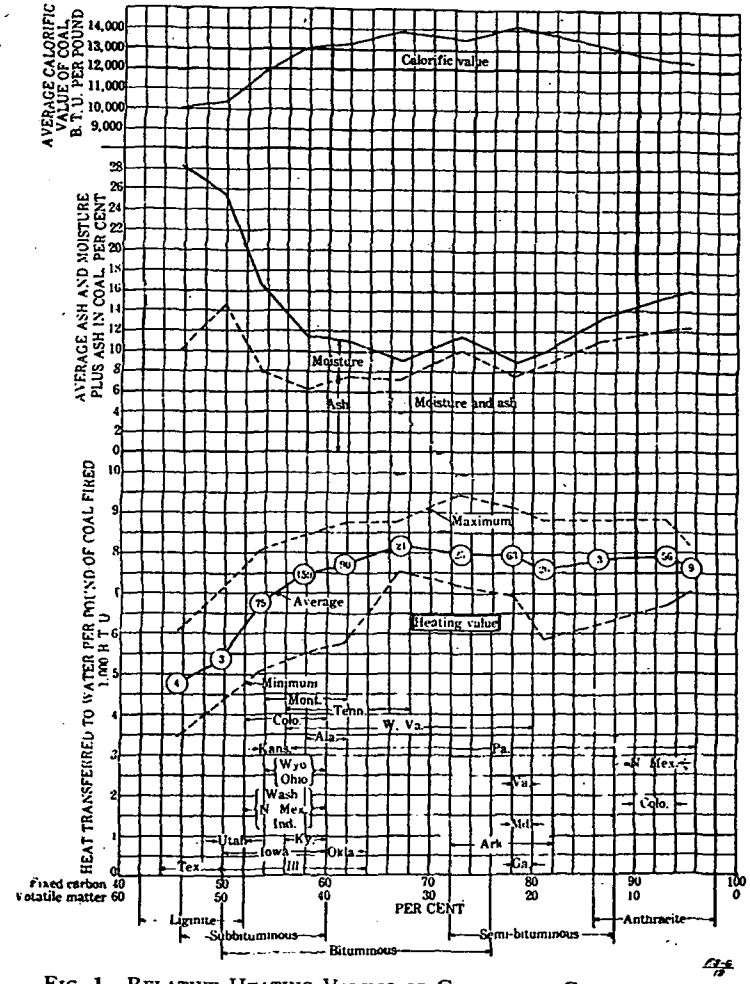


FIG. 1. RELATIVE HEATING VALUES OF COALS WITH CORRESPONDING CALORIFIC VALUES AND PER CENT OF MOISTURE AND ASH

A brief description of the kinds of fuels is given in the following paragraphs, but it should be recognized that there are no distinct lines of demarcation between the kinds and that they graduate into each other:

Anthracite is a clean, dense, hard coal which creates very little dust in handling. It is comparatively hard to ignite but burns freely when well started. It is non-caking, burns with a short flame, creates very little smoke, burns uniformly and the fuel beds

require little attention between firings. It is capable of giving a high efficiency in the common types of hand-fired furnaces.

Semi-anthracite has a higher volatile content than anthracite, is not as hard and ignites somewhat more easily; otherwise its properties are similar to those of anthracite.

Semi-bituminous coal is soft and friable, and fines and dust are created by handling. It ignites somewhat slowly and burns with a medium length of flame. Its caking properties increase as the volatile matter increases, but the coke formed is relatively weak. Having only half the volatile matter-content of the more abundant bituminous coals it can be burned with less production of smoke, and is sometimes called *smokeless coal*.

The term bituminous coal covers a large range of coals, and includes many types having distinctly different composition, properties and burning characteristics. The coals range from the high-grade bituminous coals of the East to the poorer coals of the West. Their caking properties range from coals which completely melt, to those from which the volatile and tars are distilled without change of shape, so that they are classed as non-caking or free-burning. Most bituminous coals are strong and non-friable enough to permit of the screened sizes being delivered free from fines. In general, they ignite easily, burn freely; the length of flame varies with different coals, but it is long. Much smoke and soot are possible and are difficult to reduce to reasonable amounts at low rates of burning.

Sub-bituminous coals occur in the Western States; they are high in moisture when mined and tend to break up as they dry or when exposed to the weather; they are liable to ignite spontaneously when piled or stored. They ignite easily and quickly and have a medium length flame, are non-caking and free-burning; the lumps tend to break into small pieces if poked; very little smoke and soot are formed.

Lignite is of woody structure, very high in moisture as mined, and of low heating value; it is clean to handle. It has a greater tendency than the sub-bituminous coals to disintegrate as it dries, and also is more liable to spontaneous ignition. Freshly mined lignite, because of its high moisture, ignites slowly. It is non-caking. The char left after the moisture and volatile matter are driven off burns very easily, like charcoal. The lumps tend to break up in the fuel bed and pieces of char falling into the ash pit continue to burn. Very little smoke or soot is formed.

Coke

Coke is produced by the distillation of the volatile matter from coal. The type of coke depends on the coal, or mixture of coals used, the temperatures and time of distillation and, to some extent, on the type of retort or oven; coke is also produced as a residue from the destructive distillation of oil.

High-temperature cokes. Coke as usually available is of the high-temperature type, and contains between 1 and 2 per cent volatile matter. High-temperature cokes are subdivided into *beehive coke* of which comparatively little is now sold for domestic use, *by-product coke*, which covers the greater part of the coke sold, and *gas-house coke*. The differences between these three cokes are relatively small; their denseness and hardness decrease and friability increases in the order named. In general, the lighter and more friable cokes ignite and burn the more easily.

Low-temperature cokes are produced at lower coking temperatures, and only a portion of the volatile matter is distilled off. Cokes as made by various processes under development have contained from 10 to 15 per cent volatile matter. In general, these cokes ignite and burn more readily than high-temperature cokes. The properties of various low-temperature cokes may differ more than various high-temperature cokes because of the differences in the quantities of volatile matter and because some may be light and others are briquetted.

The sale of *petroleum coke* for domestic furnaces has been small and is generally confined to the Middle West. They vary in the amount of volatile matter they contain, but all have the common property of a very low ash content, which necessitates the use of refractory pieces to protect the grates from being burned.

Air Required for Burning Solid Fuels

In order to obtain perfect combustion a definite amount of air is required for each pound of fuel fired. A deficiency of air supply will result

in combustible products passing to the stack unburned. An excess of air absorbs heat from the products of combustion and results in a greater loss of sensible heat to the stack.

Total Air Required. The theoretical amount of air required per pound of fuel for perfect combustion is dependent upon the analysis of the fuel; however, for estimating purposes the theoretical air required for different grades of fuel may roughly be taken from Table 1. An excess of about 50 per cent over the theoretical amount is considered good practice under usual operating conditions.

The amount of excess air, based upon the laws of combustion, can be determined by its relation to the percentage of CO_2 (carbon dioxide) in the products of combustion. This relationship is shown by the curves

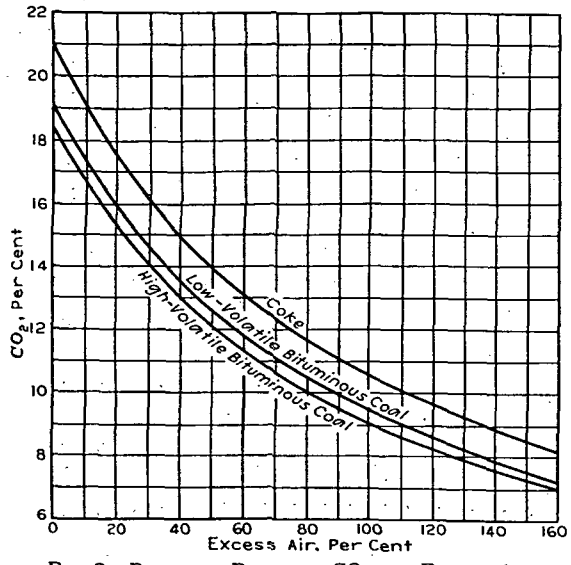


FIG. 2. RELATION BETWEEN CO_2 AND EXCESS AIR IN GASES OF COMBUSTION

(Fig. 2) for high and low volatile coals and for coke. In hand-fired furnaces with long periods between firings the combustion goes through a cycle in each period and the quantity of excess air present varies.

Secondary Air. The division of the total into primary and secondary air necessary to produce the same rate of burning and the same excess air depends on a number of factors which include size of fuel, depth of fuel

TABLE 1. POUNDS OF AIR PER POUND OF FUEL AS FIRED

ANTHRACITE	COKE	SEMI-BITUMINOUS	BITUMINOUS	LIGNITE
9.6	11.2	11.2	10.3	6.2

bed and diameter of fire pot. The ratio of the secondary to the primary air increases with decrease in the size of the fuel pieces, with increase in the depth of the fuel bed, and with increase in the area of the fire pot; the ratio also increases with increase in rate of burning.

Size of the fuel is a very important factor in fixing the quantity of secondary air required for non-caking coals. With caking coals it is not so important because small pieces fuse together and form large lumps. Fortunately a smaller size fuel gives more resistance to air flow through the fuel bed and thus automatically a larger draft above the fuel bed, which thus draws in more secondary air for the same slot openings. In spite of this, a small size fuel requires a larger opening of the door slots; for a certain size for each fuel no slot opening is required, and for larger sizes too much excess air gets through the fuel bed.

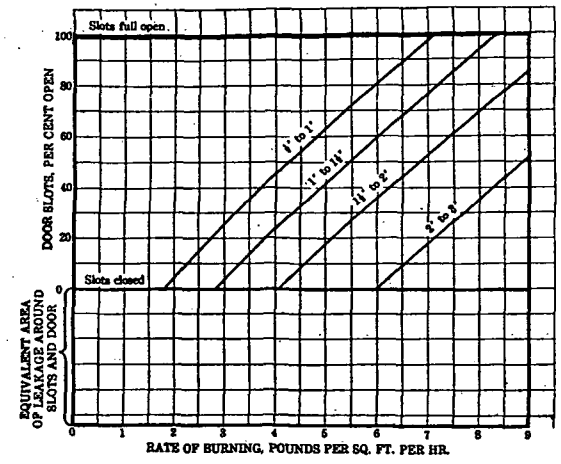


FIG. 3. RELATIVE AMOUNT OF FIRE DOOR SLOT OPENING REQUIRED IN A GIVEN FURNACE TO GIVE EQUALLY GOOD COMBUSTION FOR HIGH TEMPERATURE COKE OF VARIOUS SIZES WHEN BURNED AT VARIOUS RATES

It is impossible to establish a single rule for the correct slot opening for all types and sizes of fuels and for all rates of burning. Furthermore, the size of slot opening is dependent on whether the ashpit damper is open or closed. It is better to have too much than too little secondary air; the opening is too small if there is a puff of flame when the firing door is opened.

Fig. 3 taken from the U. S. Bureau of Mines, Report of Investigations No. 2980, shows the relationship of the slot opening, for a domestic furnace, to the size of coke and the rate of burning; these openings are with the ashpit damper wide open, and would be less if the available draft permits of it being partly closed. The same openings are satisfactory for anthracite.

Bituminous coals require a large amount of secondary air during the period subsequent to a firing, to consume the gases and to reduce the

smoke. The smoke produced is a good indicator, and that opening is best which reduces the smoke to a minimum. Too much secondary air will cool the gases below the ignition point, and prove harmful instead of beneficial.

The following suggestions will be helpful:

1. In cold weather, with high combustion rates, the secondary air damper should be half open all the time.
2. In very mild weather, with a very low combustion rate, the secondary air damper should be closed all the time.
3. For temperatures between very mild and very cold, the secondary air damper should be in an intermediate position.
4. For ordinary house operation, secondary air is needed after each firing for about one hour.

Draft Required for Burning Solid Fuels

The draft required to effect a given rate of burning the fuel as measured at the smokehood is dependent on the following factors:

1. Kind and size of fuel.
2. Combustion rate per square foot of grate area per hour.
3. Thickness of fuel bed.
4. Type and amount of ash and clinker accumulation.
5. Amount of excess air present in the gases.
6. Resistance offered by the boiler passes to the flow of the gases.
7. Accumulation of soot in the passes.

Insufficient draft will necessitate additional manipulation of the fuel bed and more frequent cleanings to keep its resistance down. Insufficient draft also restricts the control by adjustment of the dampers.

The quantity of excess air present has a marked effect on the draft required to produce a given rate of burning, and it is often possible to produce a higher rate by increasing the thickness of the fuel bed. Fig. 4 shows the relations for the same rate of burning between the draft required and the CO_2 content of the gases for a large and a small boiler.

Combustion of Anthracite Coal

An anthracite coal fire should never be poked, as this serves to bring ash to the surface of the fuel bed, where it melts into clinker.

Grate size anthracite coal is suitable for large grates and for a fuel depth of 20 in. or more. The air spaces are large; the amount of surface in contact with the air is small; and consequently combustion is slow. Lumps of rock or slate, being large, may cause trouble in shaking the grate. On grates 25 in. and under, the fire is likely to go out easily with this fuel, unless mixed with small size coal for reducing the air spaces.

Egg size is suitable for large firepots (grates 25 in. and over) if the fuel can be fired at least 20 in. deep. The air spaces between the pieces of coal are large and normal combustion is slower than with the next smaller size coal. Pieces of rock and slate sometimes may be large enough to cause some trouble in shaking the grate. For best results this coal should be fired deep.

Stove size coal is the popular size of anthracite fuel for most boilers

and furnaces used for heating buildings. It is small enough to burn well on 17 in. grates, but large enough so that the draft loss through the fuel bed is not too great. The only instructions needed for burning this type of fuel are:

The grate should be shaken before each firing; the fire should never be poked from the top; the fuel should be fired deeply and uniformly.

Chestnut size coal is in demand for firepots up to 20 in. in diameter, especially those in which the fuel cannot be fired over 15 in. deep. The

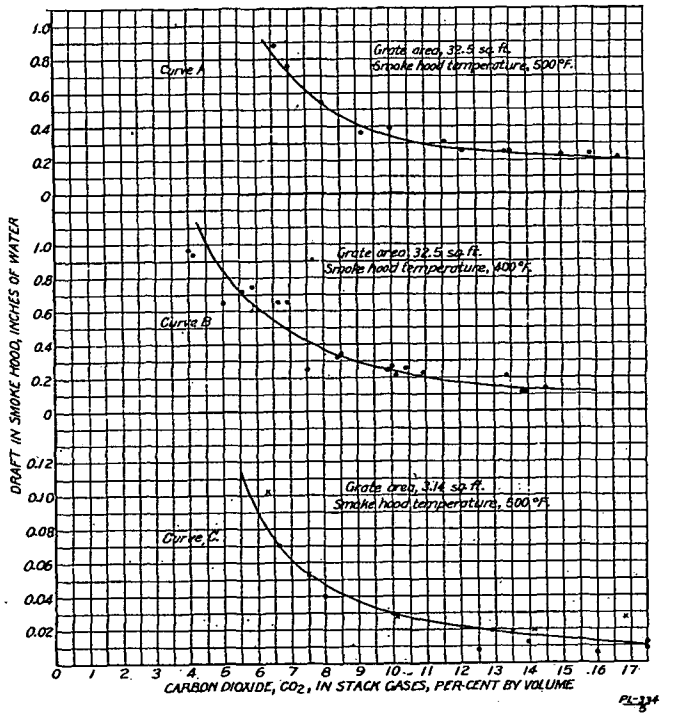


FIG. 4. RELATION BETWEEN DRAFT IN SMOKE HOOD AND PER CENT CO_2 IN FLUE GASES WITH A CONSTANT FLUE GAS TEMPERATURE

percentage of ash is usually higher than in stove coal, but the pieces of rock and slate are small and do not interfere with the shaking of the grates.

Pea size coal is often an economical fuel to burn. It is relatively low in price. When fired carefully, pea coal can be burned on standard grates. It is well to have a small amount of a larger fuel on hand when building new fires, or when filling holes in the fuel bed. Care should be taken to shake the grates only until the first bright coals begin to fall through the grates. The fuel bed, after a new fire has been built, should be increased in thickness by the addition of small charges until at least

level with the sill of the fire door. This keeps a bed of ignited coal in readiness against the time when a sudden demand for heat shall be made on the heater. When firing, the bright fuel should either be pulled forward or pushed to the back of the firepot, leaving a hollow in which to throw the fresh fuel and leaving a portion of the glowing coal exposed, to ignite the gases rising from the fuel; otherwise a gas explosion may occur.

Pea size coal requires a strong draft and therefore the best results generally will be obtained by keeping the choke damper open, the cold-air check closed and by controlling the fire with the air-inlet damper only. Pea size can also be fired in layers with stove or egg size anthracite and used in this manner will reduce the fuel costs and attention required.

Buckwheat size coal requires much the same attention as pea size coal, except that the smaller size of the fuel makes it more difficult to burn on ordinary grates. Even greater care must be taken in shaking the grates than with pea coal on account of the danger of the fuel falling through the grate. A good draft is required and consequently the fire is best controlled by the air-inlet damper only. Where frequent attention can be given and where there is not a big heat demand, this fuel is frequently burned without the aid of any special equipment.

In general it will be found more satisfactory with buckwheat coal to maintain a uniform heat output and consequently to keep the system warm all the time, rather than to allow the system to cool off at times and then to attempt to burn the fuel at a high rate while warming up. A uniform low fire will minimize the clinker formation and keep the clinker in an easily broken up condition so that it readily can be shaken through the grate.

Forced draft and special grates or retorts frequently are used with this fuel for best results.

No. 2 Buckwheat anthracite, or rice size, is used only with forced draft equipment on mechanical stokers. No. 3 Buckwheat anthracite, or barley, has no application in domestic heating.

Combustion of Bituminous Coal

Bituminous coal should never be fired over the entire fuel bed at one time. A portion of the glowing fuel should always be left exposed to ignite the gases leaving the fresh charge.

Air should be admitted over the fire through a special secondary air device, or through a slide in the fire door or by opening the fire door slightly. If the quantity of air admitted is too great the gases will be cooled below the ignition temperature and will fail to burn. The fireman can judge the quantity of air to admit by noting when the air supplied is just sufficient to make the gases burn rapidly and smokelessly above the fuel bed.

The red fuel in the firebox, before firing, excepting only a shallow layer of coke on the grate, should be pushed to one side or forward or backward to form a hollow in which to throw the fresh fuel. (Some manufacturers recommend that all red fuel be pushed to the rear of the firebox and that the fresh fuel be fired directly on the grate and allowed to ignite from the top. The object of this is to reduce the early rapid distillation

of gases and to reduce the quantity of secondary air required for smokeless combustion).

It is well to have the bright fuel in the firebox so placed that the gases from the freshly fired fuel, mixed with the air over the fuel bed, pass over the bed of bright fuel on the way to the flues. The bed of bright fuel then supplies the heat to raise the mixture of air and gas to the ignition temperature, thereby causing the gaseous matter to burn and preventing the formation of smoke.

The fuel bed should be carried as deep as the size of fuel and the available draft permit, in order to have as much coked fuel as possible for pushing to the rear of the firebox at the time of firing. A deep fuel bed obtains the longest firing intervals.

If the coal is of the caking kind the fresh charge will fuse into one solid mass which can be broken up with the stoking bar and leveled from 20 min. to one hour after firing, depending on the temperature of the firebox. Care should be exercised when stoking not to bring the bar up to the surface of the fuel as this will tend to bring ash into the high temperature zone at the top of the fire, where it will melt and form clinker. The stoking bar should be kept as near the grate as possible and should be raised only enough to break up the fuel. With fuels requiring stoking it may not be necessary to shake the grates, as the ash is usually dislodged during stoking.

The output obtained from any heater with bituminous coal will usually exceed that obtainable with anthracite, since soft coal burns more rapidly than hard coal and with less draft. Soft coal, however, will require frequent attention to the fuel bed, because it burns unevenly, even though the fuel bed may be level, forming holes in the fire which admit too much air, chilling the gases over the fuel bed and reducing the available draft.

Combustion of Semi-Bituminous Coal

Semi-bituminous coal is fired like bituminous coal and because of its caking characteristics requires practically the same attention. The *Pocahontas Operators Association* recommends the central cone method of firing in which the coal is heaped on to the center of the bed, forming a cone the top of which should be level with the middle of the firing door. This allows the larger lumps to fall to the sides, and the fines remain in the center and are coked. The poking should be limited to breaking down the coke without stirring and to gently rocking the grates. It is recommended to keep the slides in the firing door closed as the thinner fuel bed around the sides allows enough air to get through.

Combustion of Coke

Coke is a very desirable fuel and usually will give satisfaction as soon as the user learns how to control the fire. Coke ignites and burns very rapidly with less draft than anthracite coal. In order to control the air admitted to the fuel it is very important that all openings or leaks into the ashpit be closed tightly. A coke fire responds more rapidly than an anthracite fire to the opening of the dampers. This is an advantage in warming up the system, but it also makes it necessary to watch the

dampers more closely in order to prevent the fire from burning too rapidly. A deep fuel bed always should be maintained when burning coke. The grates should be shaken only slightly in mild weather and should only be shaken until the first red particles drop from the grates in cold weather. Since coke weighs only about half as much as anthracite coal per cubic foot, and therefore only about half as much can be put in the firepot, it will be necessary to fire oftener; but during the greater part of the heating season this will not be an item of importance. The best size of coke for general use is that which passes over a 1 in. screen and through a 1½ in. screen; for small firepots where the fuel depth is not over 20 in. For large firepots where the fuel can be fired over 20 in. deep, coke which passes over a 1 in. screen and through a 3 in. screen can be used but a uniform size of coke is always more satisfactory. Large sizes of coke should be either mixed with fine sizes or should be broken up before using.

Hand Firing

Hand firing is the oldest and the most widely used method of burning coal for heating purposes. To keep the fuel bed in proper condition where hand firing is used, the following general rules should be observed:

1. Remove ash from fuel bed by shaking the grates whenever fresh fuel is fired. This removes ash from the fire, enables the air to reach the fuel and does away with the formation of clinker (which is melted ash).
2. Supply the boiler with a deep bed of fuel. Nothing is gained by attempting to fire a small amount of fuel. A deep bed of fuel secures the most economical results.
3. Remove ash from ashpit at least once daily. Never allow ash to accumulate up to the grates. If the ash prevents the air from passing through, the grate bars will burn out and much clinker trouble will be experienced.

The principal requirements for a *hand-fired furnace* are that it shall have enough grate area and combustion space. The amount of grate area required is dependent upon the desired combustion rate, recommendations for which are given for various kinds of coal in Table 1, Chapter 14.

The furnace volume is influenced by the kind of coal used. Bituminous coals on account of their long-flaming characteristic require more space in which completely to burn the gases of combustion than do the coals low in volatile matter. For burning high volatile coals provision should be made for mixing the combustible gases thoroughly so that combustion is complete before the gases come in contact with the relatively cool heating surfaces. An abrupt change in the direction of flow tends to mix more thoroughly the gases of combustion.

Hand-fired furnaces may be classed as follows: Up-draft, smokeless arch (inverted bridge wall) and down-draft furnaces.

The *up-draft* furnace is the usual type provided in heating boilers and is used generally with all kinds of coal. While it is suitable for use with anthracite, coke, and semi-bituminous coal, the up-draft furnace is decidedly inadequate for burning bituminous coals from a standpoint of economy.

The *smokeless arch* is an inverted baffle placed in the ordinary up-draft furnace toward the rear. Its purpose is to aid in mixing the gases of combustion. By the aid of the smokeless arch, high volatile coals can be

Table 2. Standard Anthracite Specifications Approved and Adopted by the Anthracite Institute

	Test Mesh (Round) Inches	Oversize Maximum (Per Cent)	Undersize	
			Maximum (Per Cent)	Minimum (Per Cent)
Broken	Through 4⅜	5		
	Over 3¼		15	7½
Egg	Through 3¼	5		
	Over 2 7/16		15	7½
Stove	Through 2 7/16	5		
	Over 1⅝		15	7½
Nut	Through 1⅝	5		
	Over 1 3/16		15	7½
Pea	Through 13/16	10		
	Over 9/16		15	7½
Buck	Through 9/16	10		
	Over 5/16		15	7½
Rice	Through 5/16	10		
	Over 3/16		15	7½
Barley	Through 3/16	10		
	Over 3/32		20	10

burned with practically no smoke at moderate rates of combustion, provided the firing of the coal and the manipulation of the fuel bed are done correctly.

The *down-draft* furnace (originally known as the Hawley down-draft furnace) consists of an upper grate of water tubes located above the usual rocking grate. The draft draws down through the upper grate and up through the lower grate. Coal is fired above the fuel bed on the upper grate and after the ash and some coke have been worked down on the lower grate a lively fire is maintained on both grates. The volatile gases pass down through the upper fuel bed and become highly heated as they meet in the combustion chamber between the grates, with the heated excess air from the lower fuel bed.

Mechanical Stoker Firing

For information on mechanical stokers, refer to Chapter 17.

Sizes of Solid Fuels

There is no general standardization of the sizes of coal and coke. The size of anthracite is standardized as per Table 2. The nomenclature generally used in the Illinois and Mid-Western field is given in Table 3.

Storage Space for Coal

The storage space required for coal or coke is dependent upon the frequency of fuel purchases during the heating season, as well as upon the rate at which the fuel is burned.

In general, the size of the storage space can be determined on the basis of burning 3½ tons of coal or coke per heating season per 100 sq ft of attached equivalent heating surface, based on a heat emission of 240 Btu per square foot. Anthracite coal weighs approximately 52.5 lb per cubic foot; bituminous, 45 lb per cubic foot; and coke, 28 lb per cubic foot.

Dustless Coal

The practice of treating the more friable coals to allay the dust they create is increasing. The coal is sprayed with a solution of calcium chloride or a mixture of calcium and magnesium chlorides. Both these salts are very hygroscopic and their moisture under normal atmospheric conditions keeps the surface of the coal damp, thus reducing the dust during delivery and in the cellar, and obviating the necessity of sprinkling the coal in the bin.

The coal is sometimes treated at the mine but more usually by the local distributor just before delivery. The solution is sprayed under high pressure, using from 2 to 4 gal or from 5 to 10 lb of the salt per ton of coal, depending on its friability and size.

LIQUID FUELS

Oil is used in *domestic* heating largely because it can be supplied automatically as required with practically no attention, and because there is no residue to be removed by hand. Cleanliness is also a factor, as is

TABLE 3. COAL NOMENCLATURE USED IN MID-WESTERN FIELD

NAME OF COAL	SIZE, INCHES	
	Through	Over
Lump	.....	6
Furnace	6	3
Small Egg	3	2
Stove	2	1¼
Chestnut	1¼	¾
Pea	¾	¼
Slack, or No. 5	¼	.....

ability to provide an ample supply of domestic water through the summer with the same burner and boiler that heats the home.

Quality and certainty of local oil supply rapidly are ceasing to be factors, owing to general acceptance of uniform oil fuel specifications, and the growing tendency for coal dealers to sell oil fuel. Few heating plants are beyond a reasonable delivery distance from a reliable source of at least three grades of oil, which simplifies the problem of selection of burner type.

Specifications for Liquid Fuels

Uniform oil specifications were prepared in 1929 by the *American Oil Burner Association,* in cooperation with the *American Petroleum Institute,* the U. S. Bureau of Standards, the *American Society for Testing Materials* and other interested organizations. Oil fuels were classified into six groups, as indicated by Table 4. When these specifications were prepared, it was generally accepted that the first three grades were adapted to domestic use, while the last three were suitable only for commercial and industrial burners. This differentiation has not proved stable, and today domestic installations are using Nos. 4 and 5 of the so-called *heavy-oil* group. Several

burners adapted to domestic use have recently been listed for automatic operation with No. 5, or even No. 6, oil. Usually oils No. 5 or 6 require preheating for proper operation, but where conditions are favorable, the former can be used without the equipment that this entails.

There has been a definite trend toward the heavier oils for domestic use during the last five or six years. For the first few years following the introduction of intermittent burners, the so-called *furnace oils* (now known as Nos. 1 and 2) were commonly used because of the ease with which they could be atomized and the general freedom from carbon, dirt and *muck.* As the result of extensive research, burners today are operating in domestic heating plants using oil that, a few years ago, would have been called unfit for such use.

Trend to Lower Grades of Oil

There are two reasons for the trend to lower grades of oil. While the lighter oils contain slightly more heat units per pound, the weight per gallon increases more rapidly than the decrease in heat units per pound and oil is bought by the gallon. As a consequence, while a No. 1 oil may contain 137,000 Btu per gallon, oil No. 5 may test 149,000 Btu per gallon, or 9 per cent more. Usually there is a differential of 3¢ to 4¢ between the No. 1 and No. 5 oils, so that the economy of buying the heavier fuels is apparent; there remains the economic utilization of the heat content of the heavier oils.

Cost and Delivery of Oil

The cost of oil fuel also is dependent upon the amount that can be delivered at one time, and the method of delivery. Common practice has split the delivery truck tank handling oils for domestic use into compartments of 400 to 500-gal capacity, and these *unit dumps* are made the basis of price. Where a truck can be connected to a storage-tank *fill* and the oil quickly discharged by pump, the price obviously can be less than where a smaller quantity must be drawn off in 5-gal cans and poured. For similar reasons an installation that can be supplied from a tank car on a siding provides for a lower unit fuel cost than where the oil must be trucked, even in the large truck tanks holding 2,000 gal or more that are used for distributing the heavier oils.

Oil Storage Tanks

Storage tanks have become standardized in size and are installed either in the basement or buried outside of the house. A code for the construction and installation of these tanks has been developed by the *National Board of Fire Underwriters* and should be strictly followed. Local regulations may modify this code. In small homes, where oil delivery is a matter of a few hours, the 275-gal inside tank has become standard. This must be installed at least 10 ft from the boiler, and should be set upon steel legs, well above the basement floor. These 275-gal tanks are built in such shape that they can be carried through an ordinary door frame. There is a growing tendency to couple two of these tanks together with a three-way valve so that oil can be drawn only from one tank at a time. This provides an oil storage equivalent to nearly five or six tons of coal at low cost for tankage and installation. Outside tanks are com-

TABLE 4. COMMERCIAL STANDARD FUEL OIL SPECIFICATIONS

A. Detailed Requirements for Domestic Fuel Oils

GRADE OF OIL	APPROX. B.T.U. PER GAL.	FLASH POINT, MIN. MAX.	WATER AND SEDIMENT, MAXIMUM	[a] POUR POINT, MAXIMUM	DISTILLATION TEST		VISCOSITY MAXIMUM
					10% point, maximum	End point, maximum	
No. 1 Light Domestic Fuel Oil A light distillate oil for use in burners requiring a high grade fuel.	139,000	110°F 165°F or legal	0.05%	15°F	420°F	600°F	
					10% point, maximum	90% point, maximum	
No. 2 Medium Domestic Fuel Oil A medium distillate oil for use in burners requiring a high grade fuel.	141,000	125°F 190°F or legal	0.05%	15°F	440°F	620°F	
					10% point, maximum	90% point, maximum	
No. 3 Heavy Domestic Fuel Oil A distillate fuel oil for use in burners where a low viscosity oil is required.	143,400	150°F 200°F or legal	0.1%	15°F	460°F	675°F	Saybolt Universal at 100°F 55 seconds

[a]Lower or higher pour points may be specified whenever required by conditions of storage and use. However. these specifications shall not require a pour point less than 0 deg. fahr. under any conditions.

B. Detailed Requirements for Industrial Fuel Oils

GRADE OF OIL	APPROX. B.T.U. PER GAL.	FLASH POINT, MIN. MAX.	WATER AND SEDIMENT, MAXIMUM	POUR POINT, MAXIMUM	VISCOSITY, MAXIMUM
No. 4. Light Industrial Fuel Oil An oil known to the trade as a light fuel oil for use in burners where a low viscosity industrial fuel oil is required.	144,500	150°F. See Note [b]	1.0%	See Note [c]	Saybolt Universal at 100°F 125 seconds
No. 5 Medium Industrial Fuel Oil Same as Federal Specifications Board Specification for Bunker Oil "B" for burners adapted to the use of industrial fuel oil of medium viscosity.	146,000	150°F	1.0%		Saybolt Furol at 122°F 100 seconds
No. 6 Heavy Industrial Fuel Oil Same as Federal Specifications Board Specification for Bunker Oil "C" for burners adapted to oil of high viscosity.	150,000	150°F	Water sediment 1.75% 0.25%		Saybolt Furol at 122°F 300 seconds

[b]Whenever required. as for example in burners with automatic ignition, a maximum flash point may be specified. However, these specifications shall not require a flash point less than 250 deg. fahr. under any conditions.

[c]Pour point may be specified whenever required by conditions of storage and use. However, these specifications shall not require a pour point less than 15 deg. fahr. under any conditions.

monly of 550-gal, 1000-gal and 1500-gal capacities, and the proper size is largely a matter of local conditions. Usually liquid fuel can be bought in 500-gal *dumps* or 1000-gal *dumps* at a saving of ½¢ to 1¢ over the price for deliveries of lots under 500 gal. The annual saving easily can be estimated and can be used to determine the desirability of the larger and more expensive tank. Another factor is the ease with which oil can be obtained. In and near the larger centers oil trucks are passing many homes daily, and there is not the necessity for maintaining a large reserve that exists where the home is in a rural district with the possibility of material delay due to distance from fuel station or road conditions.

Copper tubing, varying in diameter from ½ in. to 1 in. is coming into use for connecting the burner and tank. The essential advantage is that a single length can be used, practically eliminating the possibility of air or oil leakage, the former perhaps, of more importance than the latter. Newly developed and extremely rugged compression fittings are used at the ends of the tubing. The cost of using this tubing is approximately the same as where iron pipe is used, the difference in material cost of the copper being neutralized by the reduced labor cost.

Oil Burners

For information on oil burners, refer to Chapter 18.

GASEOUS FUELS

Gas is a desirable fuel because of the ease with which it can be handled and controlled, but its use has been limited on account of its higher cost. Gaseous fuels are broadly divided into *natural* and *manufactured*.

When gas is burned a large amount of water vapor is produced as one of the products of combustion. This ordinarily escapes up the chimney, carrying away with it a certain amount of heat. However, when the heat value of gas is determined in an ordinary calorimeter, this water vapor is condensed and the latent heat of vaporization that is given up during the condensation is reported as a portion of the heat value of the gas. The heat value so determined is termed the *gross* or *higher* heat value and this is what is ordinarily meant when the heat value of gas is specified. The heat that is reclaimed by the condensation of the water vapor amounts to about 10 per cent of the total heat value. It is impractical to utilize the entire higher heat value of the gas in any house-heating appliance, because to do so it would be necessary to cool the products of combustion down below their dew-point, which is ordinarily in the neighborhood of 130 F.

Natural Gas is becoming increasingly available, and is also being used to enrich manufactured gas, with or without undergoing treatment to render it best suited for that purpose. Table 5 shows typical values for the three main fields, although that from any one field varies materially.

Manufactured Gas. Table 5 also lists the more common manufactured gas as made by various processes. Manufactured gas as distributed is usually a combination of certain proportions of gases produced by two or more processes and is often designated as *city gas*. Most states have legislation which controls the distribution and fixes a minimum limit to the heat content. This gross or high calorific value usually ranges between

520 and 545 Btu per cubic foot, with an average of 535. A given heat value may be maintained and yet leave considerable latitude in the composition so that as distributed the composition is not necessarily the same in different districts, nor at successive times in the same district. There are limits to the variation allowable, because the specific gravity of the gas depends on the composition, and too great a change in the specific

TABLE 5. REPRESENTATIVE PROPERTIES OF GASEOUS FUELS, BASED ON GAS AT 60 F

GAS	BTU PER CU FT		SPECIFIC GRAVITY, AIR = 1.00	AIR REQUIRED FOR COMBUSTION, (CU FT)	PRODUCTS OF COMBUSTION				THEORETICAL FLAME TEMPERATURE, (DEG FAHR)
					CUBIC FEET			PER CENT CO_2 DRY BASIS	
	HIGH (GROSS)	LOW (NET)			CO_2	H_2O	TOTAL WITH N_2		
Natural gas—Mid-Continental	967	873	0.57	9.17	0.97	1.92	10.2	11.7	3580
Natural gas—Ohio	1130	1025	0.65	10.70	1.17	2.16	11.8	12.1	3600
Natural gas—Pennsylvania	1232	1120	0.71	11.70	1.30	2.29	12.9	12.3	3620
Retort coal gas	575	510	0.42	5.00	0.50	1.21	5.7	11.2	3665
Coke oven gas	588	521	0.42	5.19	0.51	1.25	5.9	11.0	3660
Carburetted water gas	536	496	0.65	4.37	0.74	0.75	5.0	17.2	3815
Blue water gas	308	281	0.53	2.26	0.46	0.51	2.8	22.3	3800
Anthracite producer gas	134	124	0.85	1.05	0.33	0.19	1.9	19.0	3000
Bituminous producer gas	150	140	0.86	1.24	0.35	0.19	2.0	19.0	3160
Oil gas	575	510	0.35	4.91	0.47	1.21	5.6	10.7	3725

gravity necessitates a change in the adjustment of the burners of small appliances.

Combustion of Gaseous Fuels

Table 5 shows that a large proportion of the products of combustion when gas is burned, may consist of water vapor, and that the greater the proportion of water vapor, the lower the maximum attainable CO_2 by gas analysis. The table also shows that a low calorific value does not necessarily mean a low flame temperature since, for example, natural gas has a theoretical flame temperature of 3600 F and blue water gas of 3800 F, although it has a calorific value less than one-third that of natural gas.

The quantity of air given in Table 5 is that required for theoretical combustion, but with a properly designed and installed burner, the excess air can be kept low. The division of the air into primary and secondary is a matter of burner design and the pressure of gas available, and also of the type of flame desired. All the air can be made primary, and by proper pre-mixing of the gas and air the flame can be made short.

Gas Heating Appliances

For information on gas heating appliances, refer to Chapter 19.

FUEL REQUIRED FOR HEATING[1]

An estimate of the fuel which will be required for a heating season requires a knowledge of the total heat requirements of the building and an assumption of the average efficiency of utilization of the fuel. The accuracy of the estimate will depend on the ability to predict these values and on the care taken in making allowances for factors of operation not covered by the general formula. The fuel requirements are given by the following general equation:

$$F = \frac{H \times (t - t_a) \times N}{(t - t_o) \times C \times E} \qquad (1)$$

where

F = quality of fuel required for a heating season.
N = number of hours of heating season corresponding to average temperature, t_a.
t = inside temperature, degrees Fahrenheit.
t_a = average outside temperature, degrees Fahrenheit.
t_o = outside design temperature, degrees Fahrenheit.
H = calculated heat loss of building based on outside temperature of t_o, Btu per hour.
C = Calorific value of one unit of fuel, the unit being the same as that on which F is based.
E = efficiency of utilization of fuel, per cent.

Hourly Heat Loss, *H*

The hourly heat loss (H) is equal to the sum of the transmission losses (H_t) and the infiltration losses (H_i) of the various rooms or spaces to be heated and the total equivalent heating surface required is equal to $\frac{H}{240}$ sq ft. In estimating the fuel consumption of a building of more than one room divided by walls or partitions, it is not correct to use the calculated heat loss of the building without making the proper allowance for the fact that the heating load at any time does not involve the sum of the infiltration losses of all of the heated spaces of the building but only part of the infiltration losses. This is explained in Chapter 4.

It is sufficiently accurate in most cases to consider only half of the total infiltration losses of a building having interior walls and partitions, and the value of H in Equation 1 would, under these conditions, be equal to $H_t + \frac{H_i}{2}$. If a building has no interior walls or partitions, whatever air enters through the cracks on the windward side must leave through the cracks on the leeward side, and only half of the total crack should be used in computing the infiltration for each side and end of the building. Under these conditions it is sufficiently accurate to use the total calculated heat loss (H) for the building.

[1]For further information on this subject see Estimating Fuel Consumption, by Paul D. Close, *Heating, Piping and Air Conditioning*, May, 1931.

Of course, where the required heating surface is estimated by empirical or rule-of-thumb methods, refinements in approximating fuel consumption are not warranted, but rule-of-thumb methods often lead to unsatisfactory results and should be avoided in heating work where more accurate methods are available. It should be emphasized that the value of H in Equation 1 is the total heat loss of the building after making the proper allowance for infiltration.

Calorific Values and Heating Efficiencies

The calorific values of fuel oils and gas can be ascertained with reasonable accuracy. The values for various grades of oil are given in Table 4. The calorific value of gas can always be obtained from the local utility company. Values for natural gas are given in Table 5; manufactured gas usually has a calorific value of about 535. Coals have a larger range and may vary for the same type of coal, depending on its ash content. For general purposes where specific data are lacking, values can be taken from the top curve of Fig. 1.

To decide on the correct efficiency to use is a more difficult matter, particularly if the estimate is being made without a full knowledge of the equipment for burning the fuel and the care the furnace will receive. Efficiencies usually are given in the catalogs of manufacturers of furnaces and boilers, but these values are obtained under test conditions and do not allow for poor attendance, defects in installation or poor draft. On the other hand, such efficiencies assume that all the heat radiated from the outside of the heaters or casings as sensible heat of the flue gases is lost, whereas, if the heater is installed in the building being heated, a considerable portion of these losses may help to heat the building; how much of this it is legitimate to use in increasing the value of E will depend on whether H included the heat losses in the cellar, and on the construction of the chimney. Except for an interior chimney, the heat transferred through the chimney wall to the building will be very small. Chimney allowances should be greater for lower test efficiencies. Thus an insulated furnace will give a high efficiency on test but will not heat the cellar. A modern gas furnace will have a high efficiency with a correspondingly low flue gas temperature and hence there will be very little heat from the flue pipe.

For great exactitude the value for E should take care of inefficiency in the heat distribution in the building because of such losses as excessive heating of the walls behind the radiators and excessive stratification. It is preferable, however, to include these losses in the value of H, and to limit E to the fuel burning equipment.

Automatic fuel burning equipment whether for coal, oil or gas, will tend to save fuel and will therefore produce a higher efficiency, if thermostatically controlled, but on the other hand, automatic equipment tends to make the householder prolong his heating season and to maintain a higher temperature in the house in the early fall and late spring.

Allowance for Non-Heating Periods

Obviously, the theoretical fuel consumption will be reduced considerably by not operating the heating plant at night or during other

periods. Allowance for this may be made in either of two ways: (1) by estimating the average inside temperature (t) or (2) by arbitrarily assuming a certain reduction in the fuel consumption.

The first procedure is, of course, the more accurate. If, for example, the daytime temperature is to be 70 F, and the temperature from 12 midnight to 6 A.M. is to be maintained by thermostatic control at 50 F, then the average daily inside temperature (t) will be $\frac{18 \times 70 + 6 \times 50}{24}$ or 65 F. Strictly speaking, this average inside temperature would only apply when the outside night temperature averages below 50 F, but this fact usually is not of sufficient importance to warrant consideration. If the average outside temperature during the heating season is 30 F, the fuel saving would be approximately $100 \times \frac{70 - 65}{70 - 30}$ or 12.5 per cent. In this case, the additional saving in fuel due to the cooling of the air and structural materials to 50 F would be offset by the heating-up load in the morning.

As to the second procedure, it may be arbitrarily assumed that a saving in the fuel consumption of from 10 to 30 per cent (depending on conditions) will result if the heat is shut off after working hours, and the building heated to the required temperature during the period of occupancy each day. This, of course, is a general statement and wherever possible, the average temperature should be estimated from the proportionate lengths of the occupancy and non-occupancy periods and the corresponding temperatures for these periods. Any deviation from the assumed inside temperature will result in a variation in the fuel consumption.

Heat Required to Warm Building

The heat required to warm the cold building and contents is a factor to be considered. Under certain conditions, the cooling of the structure and contents will, to some extent, compensate for the heat required to rewarm the building. For example, if the building is under thermostatic control and the day and night temperatures are say 70 F and 50 F, respectively, there will be a period during which no heat will be called for while the building is cooling to 50 F and the saving resulting therefrom will correspond to the additional heat required to bring the building and contents back to the daytime temperature. If in estimating the fuel consumption the average daily inside temperature is based on the proper day and night temperatures and periods, the heat required to warm the structure may be neglected.

Where irregular conditions are involved it may be desirable to actually calculate the heat required to warm the building structure and contents for the number of times during the heating season the heating plant would not be in operation and to add this quantity to the fuel required for the number of hours during which the building is heated. The greater the heat capacity of the structure the greater will be the relative importance of this item. For structures of low heat capacity, such as frame buildings, this factor usually may be neglected.

Example 1. A small factory building located in Philadelphia is to be heated to 60 F between the hours of 7 A.M. and 7 P.M., and to 50 F during the remaining hours. The calculated hourly heat loss, based on a design temperature of − 6 F, is 500,000 Btu. If

coal having a calorific value of 12,500 Btu per pound is fired, and the over-all heating efficiency is assumed to be 60 per cent, how many tons of coal will be required for a normal heating season, neglecting other heat sources, and any loss of heat through open windows?

Solution. Since there are no partitions in this building, the entire heat loss is considered. The average outside temperature during the heating season (t_a) is 41.9 F (see Table 3, Chapter 2); $t = 60$ F; $N = 5040$; $H = 500{,}000$; $(t - t_o) = 66$ F; $C = 12{,}500$; $E = 0.60$. Substituting these values in Equation 1 and dividing by 2000 to change to tons:

$$F = \frac{500{,}000 \times 18.1 \times 5040}{66 \times 12{,}500 \times 0.60 \times 2000} = 46 \text{ tons of coal}$$

Inasmuch as the building will be heated to 50 F at night, the average inside temperature (at the breathing line) will be 55 F, and the percentage saving will be $\frac{60 - 55}{60 - 41.9} = 0.276$ or 27.6 per cent. The net fuel consumption will therefore be $46 - 0.276 \times 46$ or 33.3 tons.

Other Factors

There are many factors which would be likely to affect the theoretical fuel requirements of a building such as the opening of windows, abnormal inside temperatures, other heat sources, sun effect, wind, rain, etc. In many cases it is difficult accurately to evaluate these factors, particularly in the case of open windows and the results are correspondingly less accurate. The degree of refinement of the calculations should, of course, be consistent with the conditions involved. If the heat loss from the boiler and piping does not warm the building or is not included in H, the proper allowance should be made. In selecting a boiler, this allowance is frequently assumed to be 25 per cent of the total heat loss of the building, but in estimating fuel requirements, the more accurate procedure of computing the pipe and boiler losses should be used, unless this item is likely to be outweighed by other less tangible factors.

Where temperature control is installed the fuel consumption can obviously be predetermined with greater accuracy than where no such control has been provided. In fact the calculated requirements agree to a remarkable extent in many cases with the actual fuel consumption. This has been particularly true of gas-fired installations, with which effective temperature regulation usually is possible.

Where other heat sources are available it quite often is possible accurately to allow for the reduction in the fuel consumption resulting therefrom. These sources include the heat supplied by persons, lights, motors and machinery, and should also be ascertained in the case of theaters, assembly halls and industrial plants. (See Chapter 2). In many cases these heat sources should not be allowed to affect the size of the installation of heating equipment, although they may have a marked effect upon the fuel consumption. In residences this factor usually may be entirely neglected.

Degree-Day Method

A very useful unit for estimating fuel consumption, particularly for residences, is the degree-day. (See definition in Chapter 1). Degree-days for various cities in the United States and Canada are given in Table 6. The term degree-day originated in the gas industry and was later standardized by the *American Gas Association*.

TABLE 6. DEGREE-DAYS FOR CITIES IN THE UNITED STATES AND CANADA

Col. A State	Col. B City	Col. C Degree-Days	Col. A State	Col. B City	Col. C Degree-Days
Ala.	Mobile	1,439	Nev.	Tonapah	6,069
	Birmingham	2,527		Winnemucca	6,266
Ariz.	Phoenix	1,446	N. H.	Concord	7,335
	Flagstaff	10,913	N. J.	Atlantic City	5,250
Ark.	Hot Springs	2,665	N. Y.	Albany	6,542
	Little Rock	2,861		Buffalo	6,750
Cal.	San Francisco	3,450		New York	5,348
	Los Angeles	1,517	N. M.	Santa Fe	6,064
Colo.	Denver	5,880	N. C.	Raleigh	3,287
	Grand Junction	5,570		Wilmington	2,493
Conn.	New Haven	6,039	N. D.	Bismark	8,498
D. C.	Washington	4,562		Grand Forks	9,724
Fla.	Jacksonville	1,080	Ohio	Cleveland	6,096
Ga.	Atlanta	2,880		Columbus	5,426
	Savannah	1,517	Okla.	Oklahoma City	3,827
Idaho	Lewiston	4,924	Ore.	Portland	4,449
	Pocatello	6,459		Salem	4,629
Ill.	Chicago	6,300	Pa.	Philadelphia	4,950
	Springfield	5,495		Pittsburgh	5,327
Ind.	Indianapolis	5,331	R. I.	Providence	6,111
	Evansville	3,355	S. C.	Charleston	1,770
Iowa	Dubuque	6,744		Columbus	2,600
	Des Moines	6,464	S. D.	Pierre	7,213
Kans.	Topeka	5,282		Sioux Falls	7,683
	Dodge City	5,035	Tenn.	Knoxville	3,517
Ky.	Louisville	4,366		Nashville	3,550
La.	New Orleans	1,044	Texas	El Paso	1,912
	Shreveport	2,097		Galveston	1,050
Me.	Eastport	8,676		San Antonio	1,362
	Portland	7,267	Utah	Salt Lake City	5,358
Md.	Baltimore	4,591		Logan	6,750
Mass.	Boston	6,055	Vt.	Burlington	8,123
Mich.	Alpena	8,319	Va.	Richmond	3,789
	Detroit	6,202		Lynchburg	3,849
	Marquette	8,866		Danville	3,316
Minn.	Duluth	9,650		Norfolk	3,349
	Minneapolis	7,953	Wash.	Seattle	5,156
Miss.	Jackson	1,920		Spokane	6,085
Mo.	St. Joseph	5,289	W. Va.	Elkins	5,813
	St. Louis	4,583		Parkersburg	4,884
	Springfield	4,650	Wis.	Green Bay	8,201
Mont.	Billings	6,983		La Crosse	7,309
	Havre	8,608		Milwaukee	7,366
Nebr.	Lincoln	6,231	Wyo.	Sheridan	8,113
	North Platte	6,479		Cheyenne	7,360

Col. A Province	Col. B City	Col. C Degree-Days	Col. A Province	Col. B City	Col. C Degree-Days
B. C.	Victoria	5,777	Ont.	Toronto	7,732
	Vancouver	5,976	Que.	Montreal	8,705
	Kamloops	6,724		Quebec	8,628
Alb.	Medicine Hat	8,152	N. B.	Fredericton	9,099
Sask.	Qu Appelle	11,261	N. S.	Yarmouth	7,694
Man.	Winnipeg	11,166	P. E. I.	Charlottetown	8,485
Ont.	Port Arthur	10,803			

The base of 65 F is used for an inside temperature of 70 F. This base was chosen because it was demonstrated, by means of data collected from numerous installations, that 65 F usually is the maximum temperature at which fuel is burned to supply heat for a residence.[2] It was also found that the fuel consumed varied almost directly with the difference between 65 F and the outside temperature.

If the inside temperature were maintained at 70 F throughout the 24 hours of the day, then the base of 65 F would probably be in error. It must be borne in mind, however, that although the temperature head is the difference between the inside temperature of say 70 F, and the outside temperature, a lower temperature than 70 F will usually be maintained at night and the base of 65 F will therefore allow for this condition. As already indicated, a temperature of 50 F from midnight to 6 A.M. will reduce the 24-hour average from 70 to 65 F. It is important to note that the degree-day applies specifically to an inside temperature of 70 F, which is the usual temperature for residences, and it should also be noted that allowance is automatically made for the lower night-time temperature, although this allowance is constant for any given locality.

In Equation 1, the quantity $(t - t_a) \times N$ is equivalent to the number of degree-days (D) in a heating season multiplied by 24, when the average daily value of t is 65 F. Therefore

$$(t - t_a) \times N = 24\ D \qquad (2)$$

Substituting the value of $(t - t_a) \times N$ from Equation 2 in Equation 1, the following general formula for an average daily inside temperature of 65 F, which is approximately equivalent to an inside daytime temperature of 70 F for residences, is obtained:

$$F_d = \frac{24\ HD}{(t - t_o) \times C \times E} \qquad (3)$$

Example 2. The calculated hourly heat loss of a residence located in Chicago is 127,000 Btu, which includes 28,000 Btu for infiltration. The design temperatures are − 8 F and 70 F. The normal heating season is assumed to be 210 days (5,040 hours) and the average temperature during this period is 36.4 F (see Table 3, Chapter 2). The building is to be heated with oil fuel having a calorific value of 141,000 Btu per gallon. The heating efficiency is assumed to be 70 per cent. Thermostatic control is to be used and a temperature of 55 F is to be maintained from 11 P.M. to 7 A.M. How many gallons of oil will be required during a normal heating season if the loss of heat through open windows is neglected?

Solution. The maximum hourly heat loss will be $127{,}000 - \frac{28{,}000}{2} = 113{,}000$ Btu $= H$. Substituting the proper values in Equation 1:

$$F = \frac{113{,}000 \times (70 - 36.4) \times 5040}{141{,}000 \times 0.70 \times [70 - (-8)]} = 2490 \text{ gal of oil}$$

The average inside temperature will be $\frac{70 \times 16 + 55 \times 8}{24} = 65$ F

and the fuel saving due to this fact will be $\frac{70 - 65}{70 - 36.4} = 0.149$ or 14.9 per cent

[2]See also Iso-degree-day map and charts developed by P. E. Fansler for coal, oil and gas.

Hence, the net fuel consumption will be $2490 - 0.149 \times 2490 = 2120$ gal.

The normal number of degree-days for Chicago is 6300. Substituting in Equation 3 and solving by the degree-day method:

$$F = \frac{113{,}000 \times 6300 \times 24}{78 \times 141{,}000 \times 0.70} = 2220 \text{ gal of oil}$$

No allowance need be made for the average temperature of 65 F since this is taken care of by the selection of a base of 65 F for the degree-day, as already explained. It will be noted that the two methods check within 5 per cent in this case. If the average daily inside temperature in the first solution had been 66.4 F instead of 65 F, the two methods would have checked exactly.

Industrial Degree-Day

Since the standard degree-day is intended for an inside temperature of 70 F, it is particularly convenient for solving residence problems. Where the design temperature differs greatly from 70 F, the standard degree-day cannot be accurately applied. Consequently, the industrial degree-day[3] has been developed and values have been derived for two bases, namely 55 F and 45 F, intended for inside temperatures of 60 F and 50 F, respectively.

There is a considerable spread, however, between these three bases, and consequently there would be an appreciable error if the actual basis to be used in a certain case would be approximately midway between any two of the three bases for which degree-day values are at present available. Since the correction cannot be made on a proportionate basis, it would be more accurate in the majority of cases involving inside temperatures other than 70, 60 or 50, to apply Equation 1.

Rough Approximations of Fuel Requirements

It is sometimes desirable to obtain a rough approximation of the annual fuel consumption. Such approximations may be obtained by using unit factors based on the fuel requirements per square foot (or per 100 sq ft) of *radiation* or per 1000 cu ft of space. Steam consumption factors for various types of buildings for New York City are given in Chapter 22 under the heading, Steam per Square Foot of Heating Surface.

Fig. 5 may also be used for rough approximations of coal and oil requirements. It should be noted that this figure is given in terms of the fuel consumption per 1000 degree-days per 100 sq ft of equivalent heating surface (steam) based on an emission of 240 Btu per square foot. Unless the *radiation* is calculated with reasonable accuracy, unit factors will be of little value even for rough approximations, since it is obvious that such *radiation* requirements must bear some relationship to the actual heating requirements of the building.

Example 3. Estimate the approximate coal consumption for a building located in New York City in which the calculated heating surface requirements (steam) are 1000 sq ft based on design temperatures of zero and 70 F.

Solution. From Fig. 5, the fuel consumption for a design temperature of zero is 0.53 ton per 1000 degree-days per 100 sq ft of heating surface. Since there are 5348 degree-days in New York City in a normal heating season, the fuel consumption will be approximately $0.53 \times 5.348 \times 100 = 284$ tons.

[3]See *Heating and Ventilating* Degree-Day Handbook.

Fig. 6 is taken from the 3rd edition of Industrial Gas Series on House Heating, published by the *American Gas Association*, and indicates the average gas consumption per degree-day for various heat contents. While the fuel consumption in individual cases may vary somewhat from the curve values, these average values are sufficiently accurate for estimating purposes and give very satisfactory results.

The value generally used in the manufactured gas industry for residences is 0.21 cu ft per degree-day per square foot of equivalent steam *radiation* (240 Btu) based on the theoretical requirements. A correction for warmer climates is necessary and it is customary to gradually increase

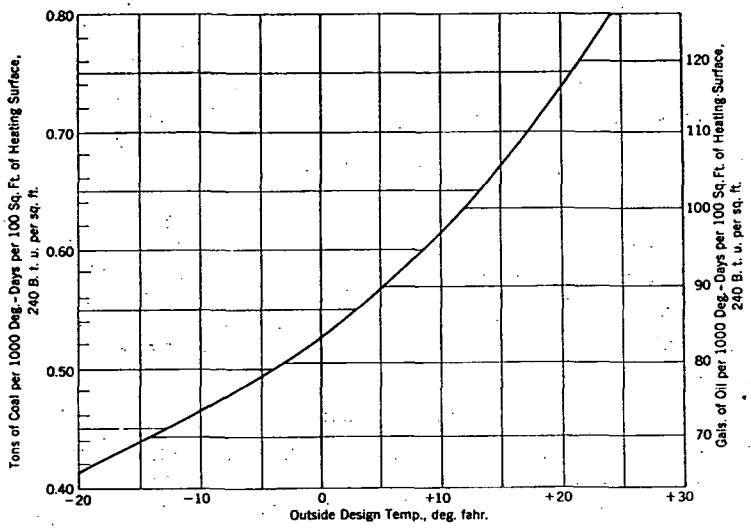


FIG. 5. CURVE FOR OBTAINING ROUGH APPROXIMATION OF ANNUAL FUEL CONSUMPTION IN TONS OF COAL OR GALLONS OF OIL PER 1000 DEGREE-DAYS PER 100 SQ FT OF EQUIVALENT STEAM HEATING SURFACE[a]

[a]This curve is based on heating efficiencies of 60 and 70 per cent for coal and oil respectively, a calorific value of coal of 13,000 Btu per pound, a calorific value of oil of 141,000 Btu per gallon, an inside temperature of 70 F, and an emission of 240 Btu per equivalent square foot of heating surface (steam), and does not allow for unusual factors which would affect the fuel consumption, such as open windows, week-end shutdowns, etc. For hot water, divide the result obtained by means of this chart by 1.6.

the fuel consumption below 3,000 degree-days to about 20 per cent more at 1,000 degree-days.

For hot water or warm air the fuel consumption is about 0.19 cu ft per degree-day per square foot of equivalent steam *radiation*, that is, per 240 Btu per hour. The actual requirements likewise increase with hot water or warm air systems as the number of degree-days decreases below 3,000. For larger installations, that is, 1,000 sq ft of theoretical *radiation* and above, there is an increase in efficiency, and a consequent decrease in the fuel consumption per degree-day per square foot of heating surface.

Heat to Warm Air for Ventilation Requirements

The preceding discussion on fuel consumption has dealt with the heating requirements of the building irrespective of any air that may be introduced for ventilation purposes, other than the normal infiltration of outside air. The heat required for warming air brought into the building for ventilation may be estimated from data given in Chapters 4 and 24.

RELATIVE COST OF HEATING WITH DIFFERENT FUELS

A comparison of the relative cost of heating with different fuels can only be made with even a fair degree of accuracy when there is a full knowledge of the equipment which will be used with each fuel, and the

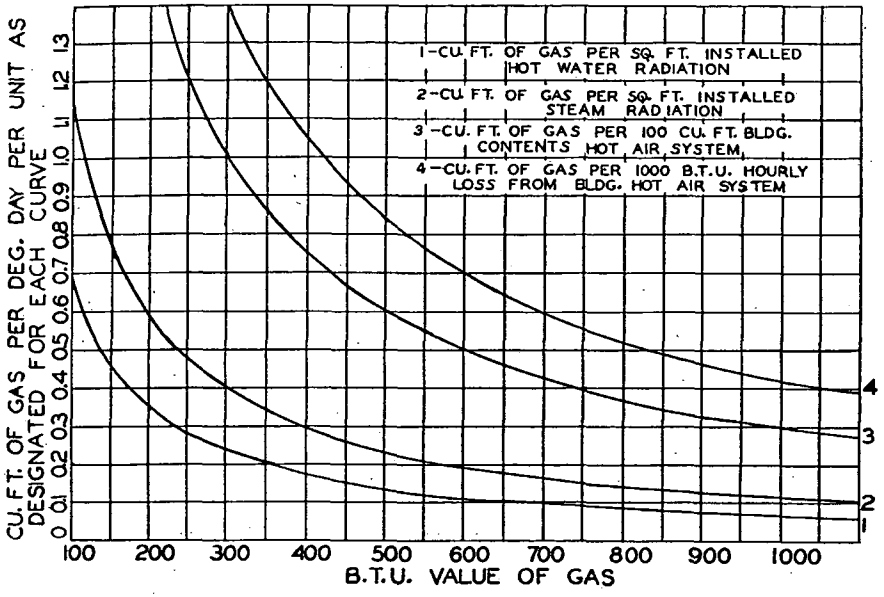


FIG. 6. CHART GIVING GAS REQUIREMENTS PER DEGREE-DAY FOR VARIOUS CALORIFIC VALUES OF GAS AND FOR DIFFERENT HEATING SYSTEMS[a]

[a]This chart is based on an inside temperature of 70 F and an outside temperature of zero. If the *radiation* is installed on the basis of any other temperature difference, multiply the result obtained from this chart by 70, and divide by the actual temperature difference.

efficiency with which each will be operated. When proposing to substitute one fuel for another, the yearly cost with the fuel being used can be obtained, and the accuracy of the comparison will depend on the care taken in estimating the quantity that will be required with the new fuel and the equipment which will be used.

A convenient basis for comparison of various fuels is the cost per million Btu, and the following formulæ may be used for obtaining comparisons on this basis:

Coal

$$X = \frac{500 \times c}{C_o \times E_c} \qquad (4)$$

where

X = cost of heating with coal in dollars per million Btu.
c = cost of coal in dollars per ton.
C_o = calorific value of coal, Btu per pound.
E_c = over-all or house efficiency for coal, expressed as a decimal.

Example 4. If coal having a calorific value of 13,000 Btu per pound costs $10.00 per ton, the cost per million Btu, assuming an efficiency of 60 per cent, will be:

$$X = \frac{500 \times 10}{13{,}000 \times 0.60} = \$0.64$$

Oil

$$Y = \frac{1{,}000{,}000 \times p}{C_o \times W \times E_o} \qquad (5)$$

where

Y = cost of oil in dollars per million Btu.
p = cost of oil in dollars per gallon.
C_o = calorific value of oil, Btu per pound.
W = weight of oil per gallon, pounds.
E_o = over-all or house efficiency for oil, expressed as a decimal.

Example 5. If oil having a calorific value of 141,000 Btu per gallon ($C_o \times W$) costs 10¢ ($0.10) per gallon, the cost per million Btu, assuming an efficiency of 70 per cent, will be:

$$Y = \frac{1{,}000{,}000 \times 0.10}{141{,}000 \times 0.70} = \$1.01$$

Gas

$$Z = \frac{1000g}{C_g \times E_g} \qquad (6)$$

where

Z = cost of heating with gas in dollars per million Btu.
g = average cost of gas, including demand and commodity charges, dollars per thousand cubic feet.
C_g = calorific value of gas, Btu per cubic foot.
E_g = over-all or house efficiency for gas, expressed as a decimal.

Example 6. If manufactured gas, having a calorific value of 535 Btu per cubic foot, costs $1.00 per thousand cubic feet, the cost per million Btu, assuming an efficiency of 80 per cent, will be:

$$Z = \frac{1000 \times 1.00}{535 \times 0.80} = \$2.33$$

Chapter 17

MECHANICAL STOKERS

Classification According to Construction and Operation: Overfeed Flat Grate Stokers; Overfeed Inclined Grate Stokers; Underfeed Side Cleaning Stokers; Underfeed Rear Cleaning Stokers; Classification According to Uses: Domestic Stokers; Small Industrial Stokers; Large Industrial Stokers; Power Type Stokers; Furnace Design.

ASSUMING the same intelligence in handling the fire, coal can be burned more efficiently on a mechanical stoker than on any kind of hand fired grate. This does not necessarily mean that a stoker installation may be more economical because the amount of coal burned may be so small or the cost of the installation so high, that the savings with stokers may not be sufficient to pay for the investment. The operation of burning coal involves uniformity in stoking, proper distribution over the fuel bed, admission of air as required to all parts of the fuel bed and disposal of the ash. The handling of the volatile gas is largely a matter of furnace design but since this gas forms a considerable portion of the heating value of the coal, it may also be said that the proper handling of this gas is a function of firing. All mechanical stokers must provide means of taking care of these several functions in order fully to serve their purpose.

CLASSIFICATION BASED ON CONSTRUCTION AND OPERATION

Stokers may be divided into four types according to their construction and operation, namely, (1) overfeed flat grate, (2) overfeed inclined grate, (3) underfeed side cleaning type, and (4) underfeed rear cleaning type.

Overfeed Flat Grate Stokers

This type is represented by the various chain grate stokers. These stokers receive fuel at the front of the grate in a layer of uniform thickness and move it back horizontally to the rear of the furnace. Air is supplied under the moving grate to carry on combustion at a sufficient rate to complete the burning of the coal near the rear of the furnace. The ash is carried over the back end of the stoker into an ashpit beneath. This type of stoker is suitable for small sizes of anthracite or coke breeze and also for bituminous coals the clinker forming characteristics of which make it desirable to burn the fuel without disturbing it. This type of stoker invariably requires the use of an arch over the front of the stoker to maintain ignition of the incoming fuel and to maintain the volatile at a temperature suitable for combustion. Frequently, a rear combustion arch is required to maintain ignition until the fuel is fully consumed.

Overfeed Inclined Grate Stokers

In general the combustion principle is similar to the flat grate stoker, but this stoker is provided with rocking grates set on an incline to advance the fuel during combustion. Also this type is provided with an ash plate where ash is accumulated and from which it is dumped periodically. This type of stoker is suitable for all types of coking fuels but preferably for those of low volatile content. Its grate action has the tendency to keep the fuel bed well broken up thereby allowing for free passage of air. Because of its agitating effect on the fuel it is not so desirable for badly clinkering coals. Furthermore, it should usually be provided with a front arch to care for the volatile gas.

Underfeed Side Cleaning Stokers

In this type, the fuel is fed in at the front of the furnace to one or more retorts, is advanced away from the retort as combustion progresses while finally the ash is disposed of at the sides. This type of stoker is suitable for all coking coals while in the smaller sizes it is suitable for small sizes of anthracites. In this type of stoker the fuel is delivered to a retort beneath the fire and is raised into the fire. During this process the volatile gas is released, is mixed with air, and passes through the fire where it is burned. The ash may be continuously discharged as in the small stoker or may be accumulated on a dump plate and periodically discharged. This stoker requires no arch as it automatically provides for the combustion of the volatile gas.

Underfeed Rear Cleaning Stokers

This type carries on combustion in much the same manner as the side cleaning type, but consists of several retorts placed side by side and filling up the furnace width, while the ash disposal is at the rear. In principle, its operation is the same as the side cleaning underfeed.

CLASSIFICATION ACCORDING TO USES

Stokers may also be classified according to their uses as (1) domestic, (2) small industrial, (3) large industrial, and (4) power.

Domestic Stokers

This field includes sizes up to 2500 sq ft of radiation. A common type of stoker in this class consists of a round retort having tuyeres at the top where all of the air for combustion is admitted. Coal is fed from a storage hopper outside of the boiler by means of a worm into the bottom of this retort and beneath the fire. The equipment includes a blower which is driven by the same motor that drives the stoker.

Some domestic stokers are provided with automatic grate shaking mechanism together with screw conveyers for removing the ash from the ashpit and depositing it in an ash receptacle outside the boiler. Certain types can also be provided with a coal conveyer which takes coal from the storage bin and maintains a full hopper at the stoker. They may feed coal to the furnace either intermittently or with a continuous flow regulated automatically to suit conditions. Where the boiler is provided with indirect coils for heating the domestic hot water, the stoker may be so

arranged that it can be used the entire year to maintain a continuous hot water supply.

Small Industrial Stokers

The sizes included in this field range from 2500 sq ft of radiation to 125 boiler horsepower. This class is used extensively for heating plants in apartments, hotels, etc., and also for small industrial plants such as laundries, bakeries, creameries, etc. The various stokers in this class differ materially in their design, although the majority are of the underfeed type. The principal exception is an overfeed type having step action grates in a horizontal plane and so arranged that they are alternately moving and stationary, and are designed to advance the fuel during combustion to an ash plate at the rear.

All of the stokers are provided with a coal hopper outside of the boiler. In the underfeed types, the coal feed from this hopper to the furnace may be accomplished by a continuously revolving worm or by an intermittent plunger. The drive for the coal feed may be an electric motor, or a steam or hydraulic cylinder. With an electric motor, the connection between the driver and the coal feed may be through a variable speed gear train which provides two or more speeds for the coal feed; or it may be through a simple gear train and a variable speed driver for the change in speed of the coal feed; or a simple gear train with a coal feed having an adjustment for varying the travel of the feeding device. With a steam or hydraulic cylinder, the power piston is connected directly to the coal feeding plunger.

The stokers in this class vary also in their retort design. It is customary in the worm-feed type to use a short retort in order that the unsupported length of worm within the retort may not be too weak for continuous service. In this type the retort is placed approximately in the middle of the furnace and is provided with tuyere openings at the top on all sides. In the plunger-feed type the retort extends from the inside of the front wall entirely to the rear wall or to within a short distance of the rear wall. This type of retort has tuyeres on the sides and at the rear.

This class of stokers also differs in the grate surface surrounding the retort. In many of the worm-feed stokers this grate is entirely a dead plate on which the fuel rests while combustion is completed. In the dead-plate type, all of the air for combustion is furnished by the tuyeres at the retort. Because of this, combustion is well advanced over the retort so that it may easily be completed by the air which percolates through the fuel bed. With the dead-plate type of grate the ash is removed through the fire doors and it is therefore, desirable that the fuel used shall be one in which the ash is readily reduced to a clinker at the furnace temperature, in order that it may be removed with the least disturbance of the fuel bed.

In other stokers in this class, the grates outside of the retort are air-admitting and shaking grates. These grates permit a large part of the ash to be shaken into the ash pit beneath, while the clinkers are removed through the fire doors. With this type of grate, the main air chamber extends only under the retort while the side grates receive air by natural draft from the ash pit.

In still other stokers of this class, the main air chamber extends beyond the retort and is covered with fuel-bearing, air-supplying grates. With

this type of grate, the fuel is supplied with air from the main air chamber throughout combustion. Also with this type of grate, dump plates are provided beyond the grates where the ash accumulates and from which it can be dropped periodically into the ash pit beneath.

Stokers in this class are compactly built in order that they may fit into standard heating boilers and still leave room for sufficient combustion space above the grates. The height of the grate is approximately the same as that of the ordinary grates of boilers, so that it is usually possible to install such stokers with but minor changes in the existing equipment. In some districts, there are statutory regulations governing such settings.

These stokers vary in furnace dimensions from 30 in. square to approximately 66 in. square. The capacity of the stokers is measured by the amount of coal that can be burned per hour. In general, manufacturers recommend that, for continuous operation, the coal burning rate shall not exceed 25 lb of coal per square foot of grate per hour, while for short peaks this rate may be increased to 30 lb per hour. Although these stokers were designed to burn bituminous coal, they can also be used to burn the small sizes of anthracite but at a somewhat lower rate. It is often customary to have the janitor or some other attendant care for the boiler as one of his duties. Under these conditions the heating plant does not receive the same careful attention as it would if a man devoted his entire attention to the fire. With periodic hand-firing, the boiler is operated inefficiently much of the time. With a stoker, the boiler is operated at the rate that the conditions require so long as there is coal in the hopper. With hand firing, it is customary to use the more expensive sizes of fuel, while with a stoker the smaller sizes are used at a considerable saving in the cost per ton. Because the stoker responds promptly to automatic regulation, it is possible to maintain a reasonably constant standard. Also because of the fact that the stoker feeds the fuel regularly and in small quantities without losses due to opening doors, etc., it must of necessity be more efficient than hand firing. This increase in efficiency depends entirely on conditions, with a minimum of about 10 per cent and a maximum of about 25 per cent.

Large Industrial Stokers

These stokers cover the field from 125 boiler horsepower to 300 boiler horsepower and are suitable for the heating plants of large schools, hotels, hospitals, or other large institutions as well as industrial plants. This class is served both by overfeed stokers and by underfeed stokers. The overfeed stokers are in general, of three types, (1) the chain grate, (2) the rear cleaning inclined grate, and (3) the center cleaning inclined grate or V type.

Stokers of this type are usually operated by natural draft, although in some cases conditions permit the operation of forced draft under the grates. With most fuels, it is not advisable to operate overfeed grates at too high a combustion rate because of the greater difficulty of cleaning and the higher maintenance, but where the fuel is free burning and has a high ash fusion temperature, the combustion rate is not so restricted. The operation of the chain grates and the rear cleaning type of inclined grates has already been described.

The V-type stoker is practically obsolete although many are still in

operation. In this stoker, the grates are inclined downward from both sides of the furnace to a low point at the middle where there is either a dump plate for periodic disposal of the ash or rotary ash gate for continuous discharge of ash. In this stoker, the fuel is fed into a hopper at the top of the grate on each side of the furnace and advanced down the grates to the center where the refuse is accumulated. This stoker is always provided with a combustion arch over the entire furnace for the purpose of assuring thorough combustion of the solid fuel and providing a furnace temperature sufficiently high to burn the volatile gases. Because of this high furnace temperature and because so little of the boiler surface is exposed to the fire to assist in carrying off the heat by radiation, this stoker is characterized by severe clinkering in the ash area. With all types of overfeed stokers, the most desirable installations are in boilers which are operated with comparatively uniform loads and moderate rates of combustion, since, even with good combustion arches, fluctuating loads or high combustion rates result in free volatile gas and this in turn means smoke.

The underfeed stokers in this class were the first of the type to be developed as at the time of their development very few large boilers were in use. The stokers are not so varied in design as those in the smaller class although in principle they are much the same. Practically all of them are of the plunger coal feed type with retorts extending the entire length of the furnace, with air supplying grates adjacent to the retorts, and with manually-operated dump plates at the sides of the furnace. The coal feeding plunger is operated by a steam or electric driver through a reduction gearing, or by a steam or hydraulic piston connected directly to the coal feeding plunger.

These stokers are heavily built and designed to operate continually at high boiler ratings with a minimum amount of attention. Because of the fact that all volatile gas must pass through the fire before reaching the combustion chamber, these stokers will operate smokelessly under ordinary conditions. Also because of the fact that these stokers are always provided with forced draft, they are the most desirable type for fluctuating loads or high boiler ratings.

In the design of the grates for supporting the fuel between the retort and the ash plates, the stokers differ in providing for movement of the fuel during combustion. Some stokers are designed with fixed grates of sufficient angle to provide for this movement as the bed is agitated by the incoming fuel, while others have alternate moving and stationary bars in this area and provide for this movement mechanically. In either type, with proper operation, all refuse will be deposited at the dump plate. Another difference in these stokers is that some makes use a single air chamber under the whole grate area thus having the same air pressure under the ignition area as under the rest of the grate, while others have a divided air chamber using the full air pressure under the ignition area and a reduced air pressure under the remainder of the grate. These stokers vary in size from approximately 5 ft square to a maximum of 8½ ft square.

Power Type Stokers

In general, this field comprises all boilers over 300 boiler horsepower and involves only a small percentage of the heating plants. These stokers are

usually of the underfeed type with multiple retorts and either side cleaning or rear cleaning. In the side cleaning type there may be as many as three retorts in the furnace and the stoker functions in the same manner as has been described for the single retort. This stoker is usually limited in length to approximately 8½ ft while the width may be as great as 10½ ft. In the rear cleaning stokers the number of retorts and the dimensions of the furnace are practically unlimited.

FURNACE DESIGN

The complete combustion of coal involves the combination of the various elements of the coal with the oxygen of the air into such compounds as are no longer effected by oxygen even at the furnace temperature. The chemical reactions which take place during this process are very rapid and take place principally within the fuel bed. However, a considerable volume of gas escapes from the surface of the fire in an active state and must be mixed with air in the furnace chamber before coming in contact with the comparatively cool surfaces of the boiler and being sufficiently reduced in temperature to become inert. It is obvious, therefore, that the design of the furnace is equally as important as the selection of the proper stoker. A certain amount of carbon monoxide formed by the breaking down of the solid fuel may escape from the surface of the fire but this is readily reduced to carbon dioxide within a short distance above the fire. This accounts for the fact that anthracite coal, with its low volatile content, can be completely burned with a small combustion chamber. The difficult portion of the fuel is the volatile constituent. To properly care for this, the following three factors must be given careful consideration in the furnace design:

1. The distance from the fuel bed to the boiler must be such that sufficient time shall be allowed for the combustion of this gas before it comes in contact with the boiler, as otherwise it will pass off as unburned gas and as smoke. This distance will vary with different types of stokers, as for instance, in an overfeed stoker all of the volatile must be burned in the combustion chamber, and, therefore, a greater distance must be allowed than for an underfeed stoker where a considerable portion of gas is burned while passing through the fire. Also the greater the percentage of gas in the coal the greater must be the travel. And finally the design of the boiler will affect this distance, since in certain types the gas travels directly upward to the boiler while in others it travels toward the rear and thus has a longer travel before cooling.

2. The volume of the combustion chamber must be sufficient to permit room for the mixing of gas and air. This condition is more or less interlocked with the first condition and is usually satisfied if the first condition is met.

3. The area of boiler heating surface exposed to the fire must not be so great that the radiant heat of the fire absorbed by the boiler will be such that the furnace temperature will be reduced sufficiently to slow up the combustion process. From the standpoint of the fire, the boiler surface exposed to the fire constitutes a cooling surface and it is quite possible to have enough surface exposed to cause a comparatively low temperature furnace, and, therefore, an inefficient one. A customary rule-of-thumb method of figuring furnace volume is to allow one cubic foot of space per boiler horsepower developed which means a heat release in the furnace of approximately 50,000 Btu per cubic foot of furnace. This, obviously, is not an entirely satisfactory method because of the wide difference in the percentage of volatile contained in different coals. It is recommended, therefore, that the furnace volume shall be based on the volatile constituent and shall be sufficient to give a heat release of approximately 15,000 to 18,000 Btu per cubic foot of furnace volume based on volatile only.

Chapter 18

OIL BURNERS

Domestic Burners; Atomization; Air for Combustion; Ignition; Temperature Control; Protective Devices; Intermittent and High-Low Operation; Boilers for Domestic Oil Burners; Installation; Adjustment of Burner; Service: Commercial Oil Burners; Oil Pumps; Boiler Settings.

AN *oil burner* is primarily a device for preparing oil fuel for combustion. While this is true with most industrial and commercial types of burners it is only partially true with the domestic oil burner. The function of some domestic oil burners is merely to prepare the fuel and air for combustion in combination with automatic operation. There are, however, many types of domestic oil burners in which a considerable portion of the combustion takes place in an integral part of the burner. There is also the type in which the combustion is started and controlled within the burner, the major part of the combustion taking place in the combustion chamber.

There is no line of demarcation between burners used for domestic and commercial or industrial purposes; in some cases homes are heated with units that are miniatures of burners used to fire large heating or power boilers or even marine boilers; in other instances distinctive burner types have been developed to meet requirements in one particular field.

Various classifications can be made to group burners according to different bases, such as:

1*A*. *Atmospheric.*	Utilizes natural chimney draft to provide combustion air
1*B*. *Mechanical Draft*	Electric-motor-driven fan or blower provides air supply, or
2*A*. *Vaporizing.*	Oil distilled on hot surface or in hot *cracking chamber*
2*B*. *Atomizing.*	Oil is thrown from rotating cup or disc, or is blown or forced through orifice, or otherwise broken up into minute globules as an aid to vaporization, or
3*A*. *Luminous.*	Referring to the property of the flame by which it emits proportionately a large amount of radiant energy.
3*B*. *Non-luminous.*	Producing a Bunsen-type flame with little radiant power, or

4*A*. *Mechanical atomizing.* Oil is broken up by mechanical means.

4*B*. *Pressure atomizing*. Oil under pressure is forced through an orifice.

4*C*. *Steam atomizing*. Describing the method of breaking up the oil by means of steam jet.

DOMESTIC BURNERS

The foregoing classifications are flexible and are used merely as a convenience. Homes are heated successfully with burners of each type except the steam atomizing, and with many modifications of each.

Atomization

The purpose of atomization is greatly to increase the surface area of a given quantity of oil in order to accelerate the change from the liquid state (in which oil cannot burn) to the gaseous or vaporous state, in which state it is one of the elementary fuels, gaseous hydrocarbon. This conversion is largely accomplished through the action of radiant heat energy upon the flying globules of oil, and the tremendously increased surface provided aids gasification. While the average domestic burner may consume two or three gallons of fuel an hour, the larger sizes handle up to 50 gal an hour.

Atomization is commonly accomplished by throwing the oil, in a thin film, from the periphery of a rapidly rotating cup or disc, which may be either vertical or horizontal, or by forcing it through a small orifice. Other methods of atomization are used with equal success, and the method of atomization usually is less of a factor in burner efficiency than that of procuring an intimate mixture of the gas with the necessary air for combustion.

Air for Combustion

Air for combustion usually is supplied by a motor-driven fan, several types being in common use. Electric motors varying from $\frac{1}{20}$ hp to $\frac{1}{3}$ hp are used and are started and stopped by the control mechanism. In most cases, they are direct-coupled to the fan as well as to a gear or lobe pump for drawing the oil from the storage tank, and in some cases, to a pump for forcing the oil through the nozzle.

All of the air required for combustion can be supplied by the blower, or else only the *primary* air can be supplied under pressure and provision made so that the remainder will be drawn into the combustion chamber by the natural draft developed by the chimney or by an injector-like action of the primary air. In any event there should be definite control of the quantity of air as well as of the rate of oil supply. Some method of draft regulation is advisable in order to secure proper air regulation. It is necessary to supply more air than is actually required for complete combustion of the oil, but the amount of excess air should be reduced to the lowest workable minimum. Laboratory tests frequently show 25 per cent to 50 per cent more air than is required for combustion, yet field tests indicate that the average burner operates with from 50 per cent to 125 per cent excess air, with a corresponding reduction in the efficiency of the burner. Many domestic burners are extremes of simplicity, the only moving parts being the motor armature with a shaft and direct-connected fan and pump set.

Ignition

The necessity for certain ignition under adverse conditions, when the line voltage is low or the oil is cold is paramount, and this phase of burner design and operation has been given the closest attention, as faulty ignition is more to be feared than improper operation, once the flame is established.

When a burner is operating intermittently under the control of a thermostat, some positive form of ignition is required to function every time there is a call for heat. There are two sources of heat for this initial ignition, an electric spark or the equivalent and a gas flame. Each has its advantages and many combinations have been developed. In *straight electric* ignition, a small transformer converts the line voltage to about 20,000 volts, or sufficient to jump a short gap, the resulting spark directly initiating combustion. In *straight gas* ignition, a gas pilot, properly located, provides the necessary heat.

The gas pilot either may be fixed so as to flame and burn constantly, or a tiny gas flame can be provided with an electric gas valve arranged to admit considerably more gas during the starting period, thus producing a much larger flame. A combination of electric and gas ignition is so arranged that the spark ignites the gas which in turn ignites the oil, the entire ignition system being operative only for a definite period when the thermostat is calling for the burner to start.

Electric ignition on the early burners was limited to those using the higher grades of fuel, gas being required for the commercial burners. Developments in electric ignition, particularly along the line of heated coils or plates, have made this method of ignition desirable.

Temperature Control

Domestic oil burners are controlled directly from the change in temperature of a designated control room (usually the living room, dining room or hall), and/or by temperature or pressure variations in the boiler. Provision may be made for heating domestic water through exchange heaters attached to the boiler, in which water is maintained at a fixed temperature or steam at a set pressure during the entire year. The flow of water or steam to the radiators is controlled by electrically-operated valves, which remain closed during warm weather and open (through the functioning of the room thermosat) when heat is required in the house. The room thermostat either causes heat to be produced by starting the burner when the room temperature drops to a predetermined point or closes the circuit of the motor operating a valve in the flow line of the heating system, the motor opening the water or steam valve and permitting water or steam immediately to flow to the radiators. When the flow in a water heating system is sluggish, the room thermostat also can start the motor of a circulation pump, thereby decreasing the time required to bring the room temperature up to the desired point.

Oil-burner installations put in only a few years ago were simplified to the extent of having a single control element—the room thermostat—that started and stopped the burner. The modern installation provides, in addition, electrical devices inter-wired with the control system to both insure against malfunctioning and to guard against troubles brought on by the characteristics of the heating plant.

One control system provides an instrument actuated by two temperature bulbs, one placed in the outdoor air and the other in a designated part of the heating system. The control is actuated by both bulbs and is designed to maintain the heating medium at a variable temperature to suit the variations in outdoor temperature, the lower the outdoor temperature the higher the temperature of the heating medium.

Protective Devices

Owing to the comparative intensity of heat production with a burner, a boiler with limited water storage above the crown sheet might pass steam to the radiator system so rapidly, at starting, that the sheet would be uncovered, with probable damage to the boiler structure. A low-water safety can be so wired into the system that the burner will be stopped before the water level is reduced to the danger point, or a boiler feed can be installed to add water to the boiler to maintain a safe level, instead of stopping the burner. Either or both should form part of a first-class installation.

Again, with either steam or water systems, the burner control can be inter-wired with a thermostatic device having its temperature element introduced into the boiler near the top, its function being to limit the maximum temperature of water or pressure of steam so the burner will be shut off before dangerous temperatures or pressures are reached. Windows of the room in which the thermostat is located are sometimes opened to *air out* the house in the morning, and if they are not closed promptly, the burner will operate continuously and possibly develop temperature and pressure conditions that might be detrimental to the boiler. This is where the safety device can be used to offset the carelessness of the human being.

Intermittent and High-Low Operation

While the greater number of burners operate on the intermittent principle, some are designed to function on either of two extremes, a *high* and a *low* flame, under thermostatic control, thus getting away from the need of ignition devices. Others go a step further and operate with a flame that can be modulated between high and low extremes, provision being made to maintain the desired air-oil ratio for each step. The intermittent burner is better adapted to Fall and Spring conditions when, during an entire week, there is necessity for burning only eight or ten gallons of oil, and the minimum rate of the continuous burner might indicate a consumption of three or four times that amount. On the other hand, during severe weather, the intermittent burner might require a setting producing heat at a much higher rate than the boiler could absorb, while the continuous burner would generate heat at about one-third of that rate and hence permit the boiler to show a higher efficiency during that period. The two types would probably give about the same results for the entire heating season. A limitation of the high-low flame and of the graduated flame type burners is that there is a limit to the minimum size flame which can be maintained. In many instances the low flame is not less than 20 per cent of the high flame which means that the burner would overheat the building in very mild weather. Such a condition would require that the burner be stopped manually and started manually in mild weather.

In selecting a graduated flame burner, the purchaser should be satisfied that the low flame can be reduced to the required degree. This factor is frequently a very important one and may have a decided bearing on the fuel consumption.

Boilers for Domestic Oil Burners[1]

Boilers used with domestic installations may be those designed for solid fuel or those designed for liquid fuel. The latter are coming to the fore with great rapidity as they usually have greatly increased secondary surface. Many are of copper or steel tube design. Increased efficiencies of 5 per cent to 15 per cent are often obtainable with boilers designed especially for liquid fuel.

It is possible to go to extremes in providing secondary surface sufficient to reduce flue temperatures to the order of 250 F to 300 F, with the result that the added resistance through the flues may necessitate the use of a booster fan to insure sufficient draft. It is difficult to obtain satisfactory efficiencies with boilers having little or no secondary surfaces, where the hot products of combustion pass almost immediately from the combustion chamber to the flue; in fact a high efficiency is unlikely with any fuel under such conditions, and the intermittent burner is especially at a disadvantage because of its characteristic development of heat at a high rate while it is operating.

It is essential that the flame produced by an oil burner, especially where it is strongly luminous, be kept from contact with the water-backed surfaces of the combustion chamber, and to this end bricking or its equivalent must be provided in most cases. Where a burner fires through the ash-pit doorframe bricking must protect the unbacked surfaces of the ash pit. The same fire bricking constitutes the actual combustion chamber for the burner flame, and materially increases the combustion volume for a given boiler.

Many burners of the *rotary* or *spinner* type are so installed that the flame forms a disc or ring just above the grate level. Usually formed hearths are placed on the grate, providing a refractory surface underneath the flame. Where these hearths are factory-formed, or made up on the job with special templates, the burner operation should conform closely to that for which it was designed in order to obtain maximum efficiency. Refractories play an important part in the proper functioning of the burner, especially when the rate of fuel consumption is high, and many unsatisfactory installations have been brought to a high state of efficiency by rebricking.

Installation

The intelligence and care with which a burner is installed largely determine the satisfaction that will result from its operation. Two plans for the installation of burners are in general use. In the first, the dealer makes all installations. In the other, sales agencies function only to make sales, and the installation for as many as twenty such sales offices is done by a centrally located, usually factory controlled, installation force.

[1]For additional information on this subject, refer to Study of Performance Characteristics of Oil Burners and Low-Pressure Heating Boilers, by L. E. Seeley and E. J. Tavanlar (*Heating, Piping and Air Conditioning*, May 1931, p. 419).

Some burners are adjusted for oil rate by means of a blind needle valve that can only be operated with a special wrench; others by changing the size of the orifice; others by a combination of orifice size and pressure. In any event, changes in the firing rate, involving careful air and draft adjustment to match the oil rate, should only be made by a trained man, preferably with the aid of an Orsat test set so that the degree of combustion efficiency can be determined. It is practically impossible to set a burner flame by eye, although that has been general practice in the past. The industry is turning to the Orsat and, as a result, more domestic burners are operating at from 9 per cent to 12 per cent CO_2, representing a higher efficiency combustion than at 5 per cent to 8 per cent, as frequently is the case where the burner is adjusted by eye.

It is essential that the basement, or at least that portion used as a boiler room, be open to the outside air, in order that sufficient air be available for combustion. Frequently a case of poor operation will be found where a test with a draft gage made by inserting the tube through the keyhole of the outer door will show that there is a partial vacuum in the basement when the burner is running, all of the combustion air coming through the keyhole and minute cracks. A simple remedy is to cut an inch from the bottom of the outer door.

Service and Adjustment of Burner

In order to achieve satisfactory heating at the lowest cost, careful consideration should be given to oil, air and draft adjustment. The oil adjustment should be determined from the total heat requirements to be met. The heat loss of the building plus an allowance for piping plus 20 to 25 per cent for pick-up establishes the maximum output required from the boiler. Fig. 1 indicates the oil required in gallons. Piping allowances will usually vary between 25 and 10 per cent, decreasing with an increase in the size of the building.

With the oil rate thus fixed, the air and draft should be set to give efficient combustion (that is, 10 to 12 per cent CO_2). The furnace draft should be set reasonably low and should be maintained constant by means of an automatic draft regulator. Without this the air supply will fluctuate, causing uneven performance. A check should be made to insure that ignition will be satisfactory under all conditions. An oil burner of the continuous type might dispense with all or part of the pick-up allowance due to the nature of its operation. Careful adjustment will provide ample heat output under all conditions, will minimize the load on the boiler and will establish the most favorable conditions for intermittent operation.

An essential element in the satisfactory operation of domestic oil burners is the provision for maintenance and service for the burners. What might be called *emergency service* for mechanical or electrical failure of the burner has rapidly diminished during the last few years until a level has been reached where groups of 100 to 1000 burners in a community consistently will require an average of not more than one call per burner per heating season. Maintenance service is coming into general practice where, for a fixed annual payment, regular inspection is made of the burner, and faulty operation corrected before the burner becomes inoperative. This service may contemplate entire overhauling of the burner during the Summer,

and may include annual cleaning of the boiler flues with a specially designed vacuum cleaner.

COMMERCIAL OIL BURNERS

Liquid fuels are used for heating apartment buildings, hotels, public and office buildings, schools, churches, hospitals, department stores, as well as industrial plants of all kinds. Contrary to domestic heating, convenience seldom is a dominating factor, the actual net cost of heat production usually controlling the selection of fuel. Some of the largest office buildings have been using oil for many years. Many department stores have found that floor space in basements and sub-basements can be used

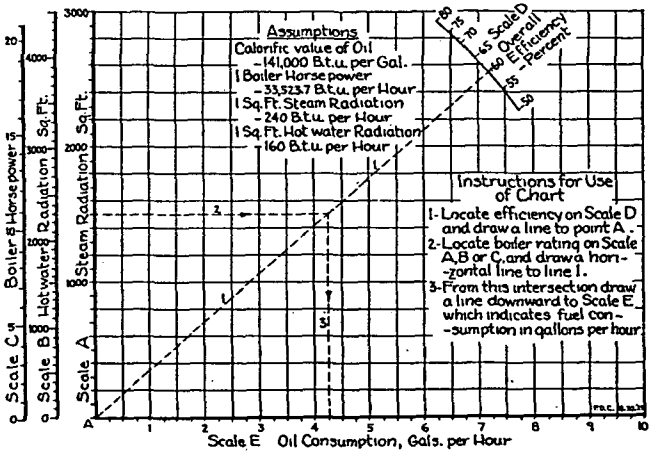


FIG. 1. FULL LOAD RATE OF OIL CONSUMPTION FOR HEATING BOILERS

to better advantage for merchandising wares, and credit the heat producing department with this saving.

Wherever possible, the boiler plant should be so arranged that either oil or solid fuel can be used at will, permitting the management to take advantage of changes in fuel costs if any occur. Each case should be considered solely in the light of local conditions and prices.

Burners for commercial heating may be either large models of types used in domestic heating, or special types developed to meet the conditions imposed by the boilers involved. Generally speaking, such burners are of the mechanical or pressure atomizing types, the former using rotating cups producing a horizontal torch-like flame. As much as 350 gal of oil per hour can be burned in these units, and frequently they are arranged in multiple on the boiler face, from two to five burners to each boiler.

The larger installations are nearly always started with a hand torch, and are manually controlled, but the use of automatic control is increasing and completely automatic burners are now available to burn the two

heaviest grades of oil. Nearly all of the smaller installations, in schools, churches, apartment houses and the like, are full automatic.

Because of the viscosity of the heavier oils, it is customary to heat them before transferring by truck tank. It also has been common practice to preheat the oil between the storage tank and the burner, as an aid to movement of the oil as well as to atomization. This heating is accomplished by heat-transfer coils, using water or steam from the heating boiler, and heating the oil to within 30 deg of its flash point.

Oil Pumps

Unlike the domestic burner, units for large commercial applications frequently consist of atomizing nozzles or cups mounted on the boiler front with the necessary air regulators, the pumps for handling the oil and the blowers for air supply being mounted in sets adjacent to the boilers. In such cases, one pump set can serve several burner units, and common prudence dictates the installation of spare or reserve pump sets. Pre-heaters and other essential auxiliary equipment also should be installed in duplicate.

Boiler Settings

As the volume of space available for combustion is the determining factor in oil consumption, it is general practice to remove grates and extend the combustion chamber downward to include or even exceed the ash-pit volume; in new installations the boiler should be raised to make added volume available. Approximately 1 cu ft of combustion volume should be provided for every developed boiler horsepower, and in this volume, from 1.5 to 2 lb of oil can properly be combusted. This corresponds to a maximum liberation of about 38,000 Btu per cubic foot per hour. There are indications that at times much higher fuel rates may be satisfactory. This in turn suggests that the value of 38,000 Btu per cubic foot per hour should be used with reasonable judgment. For best results, care should be taken to keep the gas velocity below 40 ft per second. Where checkerwork of brick is used to provide secondary air, good practice calls for about 1 sq in. of opening for each pound of oil fired per hour. Such checkerwork is best adapted to flat flames, or to conical flames that can be spread over the floor of the combustion chamber. The proper bricking of a large or even medium sized boiler for oil firing is important and frequently it is advisable to consult an authority on this subject. The essential in combustion chamber design is to provide against flame impingement upon either metallic or fire-brick surfaces. Manufacturers of oil burners usually have available detailed plans for adapting their burner to various types of boilers, and such information should be utilized.

Chapter 19

GAS HEATING APPLIANCES

Gas-Designed Heating Systems; Steam, Hot-Water and Vapor Boilers; Warm Air Furnaces; Warm Air Floor Furnaces; Unit Heaters; Space Heaters; Garage Heaters: Conversion Heating Systems: Selection of Gas Boilers: Ratings: Control Features.

THE increased use of gas for house heating purposes has resulted in the production of such a large number of different types of gas-heating systems and appliances, that today there is probably a greater variety of them than there is for any other kind of fuel.

Gas-fired heating systems may be classified as follows:

I. Gas-Designed Heating Systems.
   - A. Central Heating Plants.
     1. Steam, hot water, and vapor boilers.
     2. Warm Air Furnaces.
   - B. Unit Heating Systems.
     1. Warm air floor furnaces.
     2. Industrial unit heaters.
     3. Space heaters.
        a. Parlor furnaces or circulators.
        b. Steam, hot water, and warm air radiators.
        c. Radiant heaters, wall heaters, etc.
     4. Garage heaters.

II. Conversion Heating Systems.
   - A. Central Heating Plants.
     1. Steam, hot water and vapor boilers.
     2. Warm air basement furnaces.

The majority of these systems are supplied with either automatic or manual control. Central heating plants, for example, whether gas designed or conversion systems, may be equipped with room temperature control, push button control, or manual control.

Although no exact rules can be prescribed as to the field best covered by each of the foregoing systems, each installation will have problems pointing more or less directly to some particular type of heating equipment.

GAS-DESIGNED HEATING SYSTEMS

Steam, Hot Water, and Vapor Boilers

Gas boilers have assumed a well-defined individuality. The usual boiler is sectional in construction with a number of independent burners placed

beneath the sections. In most boilers each section has its own burner. In all cases the sections are placed quite closely together; much closer than would be possible when burning a soot-forming fuel. The effort of the designer is always to break the hot gas up into thin streams, so that all particles of the heat-carrying gases can come as closely as possible to the heat-absorbing surfaces. Because there is no fuel bed resistance and because the gas company supplies the motive power to draw in the air necessary for combustion (in the form of the initial gas pressure), draft losses through gas boilers are low.

Either snap action or throttling control is available for gas boiler operation. This is especially advantageous in straight steam systems because steam pressures can be maintained at desired points, while at the same time complete cut-off of gas is possible when the thermostat calls for it.

Warm Air Furnaces

There are two general classes of gas-fired warm air furnaces, the gravity system which depends upon the natural tendency of heated air to rise, providing the proper circulation of heated air into the room, and the mechanical circulation system by which the air to be heated is forced through or drawn through the furnace by means of a fan.

Warm air furnaces are variously constructed of cast iron, sheet metal and combinations of the two materials. If sheet metal is used, it must be of such a character that it will have the maximum resistance to the corrosive effect of the products of combustion. With some varieties of manufactured gases, this effect is quite pronounced. Warm air furnaces are obtainable in sizes from those sufficient to heat the largest residence down to sizes applicable to a single room. The practice of installing a number of separate furnaces to heat individual rooms is peculiar to mild climates, such as that of southern California. Small furnaces, frequently controlled by electrical valves actuated by push-buttons in the room above, are often installed to heat rooms where heat may be desired for an hour or so each day. These furnaces are used also for heating groups of rooms in larger residences. In a system of this type each furnace should supply a group of rooms in which the heating requirements for each room in the group are similar as far as the period of heating and temperature to be maintained are concerned. Bedroom suites, living and dining rooms, etc., usually present excellent possibilities for this type of unit heating.

The same fundamental principle of design that is followed in the construction of boilers, that is, breaking the hot gas up into fine streams, so that all particles are brought as close as possible to the heating surface, is equally applicable to the design of warm air furnaces. The desirability of using an appliance designed for gas, when gas is to be the fuel, applies even more strongly to furnaces than to boilers.

Codes for proportioning warm air heating plants, such as that formulated by the *National Warm Air Heating Association* (see note p. 93), are equally applicable to gas furnaces and coal furnaces. Recirculation should always be practiced with gas-fired warm air furnaces. It not only aids in heating, but is essential to economy. Where fans are used in connection with warm air furnaces for residence heating, it is well to

have the control of the fan and of the gas so coordinated that there will be sufficient delay between the turning on of the gas and the starting of the fan, to prevent blasts of cold air being blown into the heated rooms. An additional thermostat in the air duct easily may be arranged to accomplish this.

Warm Air Floor Furnaces

Warm air floor furnaces are well adapted for heating first floors, or where heat is required in only one or two rooms. A number may be used to provide heat for the entire building where all rooms are on the ground floor, thus giving the heating system flexibility as any number of rooms may be heated without heating the others. With the usual type the register is installed in the floor, the heating element and gas piping being suspended below. Air is taken downward between the two sheets of the double casing and discharged upward over the heating surfaces and into the room. The appliance is controlled from the room to be heated by means of a control lever located near the edge of the register. The handle of the control is removable as a precaution against accidental turning on or off of the gas to the furnace.

Industrial Unit Heaters

A recent development in gas burning equipment is the direct-fired industrial unit heater. These heaters are of the warm air type and are equipped either with fans or with blowers which cause the air to pass over the heating surfaces at a fairly high velocity and then direct the warm air in to the space to be heated in such a way as to give a positive distribution of the heated air. As is the case with the steam fed unit heaters, the gas fired appliances may be used for heating stores, shops, warehouses, etc. They usually are suspended in the space to be heated and in most instances leave the entire floor and wall area free for commercial use. Partial or complete automatic control also may be secured on appliances of this type.

Space Heaters

As indicated by the foregoing classification, there are many types of space heaters. Appliances of this kind are generally used for auxiliary heating, but may be, and are in many cases, installed for furnishing heat to entire buildings. Space heaters are quite extensively used for house heating in milder climates such as exist in the South and Southwest. With the exception of wall heaters, they are portable, and can be easily removed and stored during the summer season. Although they should be connected with solid piping it is sometimes desirable to connect them with flexible gas tubing in which case a gas shut-off on the heater is not permitted, and only *A.G.A.* approved tubing should be used.

Parlor furnaces or *circulators* are usually constructed to resemble a cabinet radio. They heat the room entirely by convection, *i.e.* the cold air of the room is drawn in near the base and passes up inside the jacket around a drum or heating section, and out of the heater at or near the top. These heaters cause a continuous circulation of the air in the room during the time they are in operation. The burner or burners are located in the

base at the bottom of an enclosed combustion chamber. The products of combustion pass up around baffles within the heating element or drum, and out the flue at the back near the top. They are well adapted not only for residence room heating but also for stores, offices, etc.

Radiant heaters make admirable auxiliary heating appliances to be used during the occasional cool days at the beginning and end of the heating season when heat is desired in some particular room for an hour or two. The radiant heater gives off a considerable portion of its heat in the form of radiant energy emitted by an incandescent refractory that is heated by a Bunsen flame. They are made in numerous shapes and designs and in sizes ranging from two to fourteen or more radiants. Some have sheet-iron bodies finished in enamel or brass while others have cast-iron or brass frames with heavy fire clay bodies. An atmospheric burner is supported near the center of the base, usually by set screws at each end. Others have a group of small atmospheric burners supported on a manifold attached to the base. Most radiant heaters are supported on legs and are portable; however, there are also types which are encased in a jacket which fits into the wall with a grilled front, similar to the ordinary wall register. Others are encased in frames which fit into fireplaces.

Gas-fired steam and hot water radiators are popular types of room heating appliances. They provide an economical form of heating apparatus for intermittently heated spaces such as stores, small churches and some types of offices and apartments. They are made in a larger variety of shapes and sizes and are similar in appearance to the ordinary steam or hot water radiator connected to a basement boiler. A separate combustion chamber is provided in the base of each radiator and is usually fitted with a one-piece burner. They may be secured in either the vented or unvented types, and with steam pressure, thermostatic or room temperature controls.

Warm air radiators are similar in appearance to the steam or hot water radiators. They are usually constructed of pressed steel or sheet metal hollow sections. The hot products of combustion circulate through the sections and are discharged out a flue or into the room, depending upon whether the radiator is of the vented or unvented type.

Luminous flame reflector heaters reflect the radiation from the flames themselves into the room from a polished metal surface. They usually operate with a yellow flame since all of the air for combustion is mixed with the gas as it is being burned.

Probably the nearest approach to the wood fire in appearance is made by the *gas log*. The base and burner assembly are similar to the construction used in radiant heaters. The logs are usually constructed of fire clay and may be secured in a variety of imitation wood designs. When in operation they closely resemble burning logs.

The *coal basket*, which is another popular design of fire place heater, usually has a cast-iron base and frame with a burner assembly similar to the ordinary radiant heater. Fire-clay radiant elements resembling lumps of coal are placed in the frame and supported above the flames. The hot gases passing up around the elements cause them to glow, thus resembling a glowing coal fire.

Garage Heaters

Garage heaters are usually similar in construction to the cabinet circulator space heaters, except that safety screens are provided over all openings into the combustion chamber to prevent any possibility of explosion from gasoline fumes or other gases which might be ignited by an open flame. They are usually provided with automatic room temperature controls and are well suited for heating either residence or commercial garages.

CONVERSION HEATING SYSTEMS

Residence heating with gas through the use of conversion burners installed in coal-designed boilers and furnaces represents a common type of gas-fired house heating system, especially in natural gas territories. In many conversion burners radiants or refractories are employed to convert some of the energy in the gas to radiant heat. Others are of the blast type with luminous flames, operating without refractories. In each case an attempt is made to transfer the majority of the heat from the gas to the medium to be heated within the fire pot itself because of the low heat transfer that takes place in the flue passages.

Many conversion units are equipped with sheet metal secondary air ducts which are inserted through the ash pit door. The duct is equipped with automatic air controls which open when the burners are operating and close when the gas supply is turned off. This prevents a large share of the circulation of cold air through the combustion space of the appliance when not in operation. By means of this duct the air necessary for proper combustion is supplied directly to the burner, therefore making it possible to reduce the amount of excess air passing through the combustion chamber.

Conversion units are made in many sizes both round and rectangular to fit different types and makes of boilers and furnaces. They may be secured with manual, push button, or room temperature control.

SELECTION OF GAS BOILERS

While gas-burning equipment can be and usually is so installed as to be completely automatic, maintaining the temperature of rooms at a predetermined and set figure, there are in use installations which are manually controlled. Under such control the temperature variations are considerable because the human body does not react as readily to temperature changes as does a thermostat, and a greater boiler output is required quickly to regain comfortable temperatures. Experience has shown that in order to effectively overcome the starting load and losses in piping, a manually-controlled gas boiler should have an output as much as 100 per cent greater than the equivalent standard cast-iron column radiation which it is expected to serve.

Boilers under thermostatic control, however, are not subject to such severe pick-up or starting loads. Consequently, it is possible to use much lower selection or safety factors. A gas-fired boiler under thermostatic control is so sensitive to variations in room temperatures, pressure of

steam, or temperature of water, that in most cases a factor of 25 per cent is eminently sufficient for pick-up load.

The factor to be allowed for loss of heat from piping, however, must vary somewhat, the proportionate amount of piping installed being considerably greater for small installations than for large ones. Consequently, a selection factor for thermostatically controlled boilers must be variable. Table 1 gives selection factors to be added to the installed steam radiation under thermostatic control. They have been established by experience and are recommended by the *American Gas Association*.

Appliances used for heating with gas should bear the Approval Seal of the *American Gas Association* Testing Laboratory. Installations should be made in accordance with the recommendations shown in the publications of that Association.

RATINGS FOR GAS HEATING APPLIANCES

Since a gas appliance has a heat-generating capacity that can be predicted accurately to within 1 or 2 per cent, and since this capacity is not

TABLE 1. SELECTION FACTORS FOR GAS BOILERS

EQUIVALENT CAST IRON STEAM RADIATION (SQUARE FEET OF 240 BTU EACH)	SELECTION FACTOR (PER CENT)
500	56.0
800	54.0
1,200	51.0
1,600	48.0
2,000	45.0
3,000	42.5
4,000 and over	40.0

affected by such things as condition of fuel bed and soot accumulation, makers of these appliances have an opportunity to rate their product in exact terms. Consequently all makers give their product an hourly Btu output rating. This is the amount of heat that is available at the outlet of a boiler in the form of steam or hot water, or at the bonnet of the furnace in the form of warm air. The output rating is in turn based upon the Btu input rating which has been approved by the *American Gas Association* Testing Laboratory and upon an arbitrary efficiency which has been assigned by that Association.

In the case of boilers, the rating can be put in terms of square feet of equivalent direct radiation by dividing it by 240 for steam, and 150[1] for water. This gives what is called the *American Gas Association* rating, and is the manner in which all appliances approved by the *American Gas Association* Laboratory are rated. To use these ratings it is only necessary to increase the calculated heat loss or the equivalent direct radiation load by an appropriate amount for starting and piping, and to select the boiler or furnace with the proper rating.

[1]A value of 160 for the heat-emission of hot-water radiators is used by many engineers. The actual heat emission, however, depends on the temperature of the water and of the surrounding air. See Chapters 6 and 8.

It might be stated at this point that the rating given by the *American Gas Association* Laboratory is not only a safe rating when considered from the standpoint of capacity, but is also a safe rating when considered from the standpoint of physical safety to the owner or caretaker. The rating that is placed upon an appliance is limited by the amount of gas that can be burned without the production of harmful amounts of carbon monoxide. This same limitation applies to all classes of gas-consuming heating appliances that are tested and approved by the Laboratory. Gas boilers are available with ratings up to 14,000 sq ft of steam, while furnaces with ratings up to about 500,000 Btu per hour are available.

CONTROL FEATURES

One feature of the piping installation that adds to the satisfactory service rendered by gas boilers is provision for adequate and rapid venting of the air from steam heating systems. If air leaks into the steam distribution system during the period that the gas is turned off, and then vents out slowly when the thermostat calls for heat, the result will be a further cooling of the premises between the time that the thermostat calls for heat and the time that steam reaches the radiators. A freely venting steam or vapor system gives maximum economy and minimum temperature variation. When gas boilers are attached to existing heating plants, it is good practice to check the effectiveness of the venting devices and if necessary, replace them with more effective ones that will prevent the return of air into the heating system, and also to check the tightness of the piping.

On account of the ease and effectiveness with which the fuel can be controlled, gas-burning appliances are particularly adaptable to full automatic control. Standard equipment on a steam boiler generally includes provision for control through a room temperature thermostat, a steam pressure regulator and either a device by means of which the water in the boiler is automatically maintained at the proper level or a device which shuts off the gas in the event that the water level becomes too low. Practically all gas boilers are or may be equipped with automatic safety pilots which shut off the gas if the pilot flame is too low.

Water boilers are adapted to operation under thermostatic room temperature control and are also provided with water temperature control equipment. Warm air furnaces can be under the control of thermostats in the spaces being heated, as well as thermostats located in the heat ducts for the purpose of preventing unpleasantly hot air reaching the heated spaces. Variations in the pressure under which the gas is supplied to the appliance are controlled by means of a gas-pressure regulator. This is an essential part of practically all makes of gas-burning heating appliances, in fact a gas-pressure regulator is required by the *American Gas Association* on all approved gas boilers, warm air furnaces (except floor furnaces) and unit heaters.

CROSS-CONNECTING COAL AND GAS BOILERS

Frequently, when a coal boiler is already installed in a home, it is expedient to leave the coal boiler in place, and to cross-connect the gas boiler with it. Where gas heating is new to the community, it pro-

duces a more secure feeling in the customer's mind when putting in gas-fired house-heating equipment, if he knows that he can burn coal at any time he may desire.

For steam or vapor installations, it is desirable to have the water line in both boilers at the same level so that if desired the gas boiler may automatically take up the load if the fire in the coal boiler goes out.

CHIMNEYS FOR GAS FIRED APPLIANCES

The burning of gas differs from the burning of coal in that the force which supplies the air for combustion of the gas comes largely from the pressure of the gas in the supply pipe, whereas air is supplied to a bed of burning coal by the force of the chimney draft. If, with a coal-burning boiler, the draft is poor, or if the chimney is stopped, the fire is smothered and the combustion rate reduced. In a gas boiler or furnace such a condition would interfere with the combustion of the gas, but the gas would continue to pass to the burners and the resulting incomplete combustion would produce a dangerous condition. In order to prevent incomplete combustion from insufficient draft, all gas-fired boilers and furnaces should have a back-draft diverter in the flue connection to the chimney.

A study of the drawing of a typical back draft diverter will make it plain that a stoppage in the chimney will cause the combustion products to come out into the boiler room, but there will be no interference with the complete combustion of the gas. Another feature in the construction of the back-draft diverter is that a down draft from the chimney will have practically no effect upon the combustion of the gas, due to the baffle deflecting the draft into the boiler room.

As is the case with the complete combustion of almost all fuels, the products of combustion for gas are carbon dioxide (CO_2) and water vapor with just a trace of sulphur trioxide (SO_3). Sulphur usually burns to the trioxide in the presence of an iron oxide catalyst. The volume of water vapor in the flue products is about twice the volume of the carbon dioxide when coke oven or natural gas is burned. Because of the large quantity of water vapor which is formed by the burning of gas, it is quite important that all gas-fired central heating plants be connected to a chimney having a good draft. Lack of chimney draft causes stagnation of the products of combustion in the chimney and results in the condensation of a large amount of the water vapor. A good chimney draft draws air into the chimney through the openings in the back-draft diverter, lowers the dew-point of the mixture, and reduces the tendency of the water vapor to condense.

A chimney for a gas-fired boiler or furnace should be constructed in accordance with the principles applicable to other boilers. Where the wall forming a smoke flue is made up of less than an 8 in. thickness of brick, concrete or stone, a burnt fire clay flue tile lining should be used. Care should be used that the lengths of flue tile meet properly with no openings at the joints. Cement mortar should be used for the entire chimney.

Chapter 20

HEATING WITH ELECTRICITY

Advantages of Electric Heating; Types of Electric Heaters; Off-Peak Electric Thermal Storage Systems; Cost Comparisons; Insulation Required; Heat Equivalents of Electricity.

THE use of electricity as a direct heating medium, employing so-called space or radiant heaters, is confined largely to mild climates, or to localities where electric rates are low. Direct electrical heaters take energy co-incidentally with the heater requirements, which means that the load usually comes directly on the power station's peaks. The thermal storage system uses off-peak electrical energy for which commercially economical rates are now being made available. Therefore, this off-peak form of electrical heating is becoming practicable in many northern climates as well as in milder climates. In some cases electricity is used as a supplementary means of heating such as in industrial plants for the heating of remote spaces.

ADVANTAGES OF ELECTRIC HEATING

The following are some of the important advantages of electric heating:

1. Accurate regulation of room temperatures.
2. Simplicity of operation.
3. Freedom from the dangers attending the presence of a flame.
4. Freedom from handling and disposition of resulting products of combustion.
5. Reliability of source of supply.
6. Maximum efficiency of conversion of the energy into usefulness.
7. Cleanliness.
8. Minimum maintenance and reconditioning.
9. Efficient servicing and supervision by public utility at low cost.

From the foregoing items it is apparent that electricity embraces all the requirements of an ideal heating agent, excepting low cost. Consequently, where electrical energy is sufficiently low in cost, it is being used more or less for heating buildings.

TYPES OF ELECTRIC HEATERS

The various commercial types of electric heaters may be classified as follows:

1. DIRECT HEATERS

   a. Radiant Type. For quick intermittent heating. The heating

element operates at a relatively high temperature, and the heat transfer is principally by radiation.

b. Convection Type. For continuous heating. The heating element operates at a relatively low temperature and the heat transfer is mainly by air currents.

c. Contact Type. Electric strip heaters placed in direct contact by clamping to objects to be heated. They may be used to prevent freezing of pipes and tanks.

2. INDIRECT HEATERS

a. Hot Water or Steam Radiators. Electric immersion units (1) to heat water in radiators, or (2) to generate steam. Each radiator is a separate unit connected to the electric wiring system.

b. Central Heating Plant Using Instantaneous Heating. (1) Air heated by passing directly over electric heating elements, and then circulated by a duct system to the spaces to be heated. (2) Steam generated in electric boiler at times and in quantities required by the heating demand. (3) Water heated to the temperatures and in quantities required for the heating demand.

c. Central Heating Plant Using Thermal Storage. This is described in the following paragraphs and is applicable to warm air, hot water and steam heating.

OFF-PEAK ELECTRIC THERMAL STORAGE SYSTEMS

With electrical heating systems which take electrical energy coincidentally with the building heating demands, the load may come on during the power company's peaks and, therefore, such a load must be served at a rate carrying peak load investment costs. A system of electrical heating utilizing a thermal storage principle permits taking energy from the power system at off-peak periods when the energy can be sold at the lowest price. On this basis, rates of 1¢ and less per kilowatt-hour can be established, thus making electrical heating using thermal storage compare favorably in many cases with manufactured gas, and also with other fuels in certain localities when the service rendered is evaluated.

The off-peak load is not only favorable to the customer, but it is attractive to the power company. It increases many fold the potential sale of electrical energy to domestic customers. In addition, this type of load is corrective for the power company's load and power factors. A widespread appreciation of these facts has taken place in the past two years, as evidenced by the large number of rates being filed for the sale of off-peak energy. These rates vary from 1.5¢ per kilowatt-hour to less than 1¢ per kilowatt-hour. The early installations of off-peak storage heaters in this country were more or less custom built with consequent high cost. However, with increased use and improvements in design and erection of this equipment, standardized units are now available.

In the off-peak storage system, the water in an insulated storage tank

is heated during hours designated by the power company, and the stored heat is used under thermostatic control as required by the building. During the charging period, the storage tank absorbs heat and also smooths out the peak demands of the building, so that a lower connected load is required than for a non-storage system. Charging periods ranging from 12 to 20 hours are being used depending upon the characteristics of the utility's load curve.

Types of Off-Peak Systems

The following types of off-peak heating systems are in use:

1. Hot water with gravity circulation.
2. Hot water with forced circulation.
3. Warm air utilizing forced circulation.
4. Unit heaters utilizing hot water as the heating medium.
5. Warm air utilizing stored heat in connection with waste heat.

The essential parts of all types of off-peak storage systems are:

1. Heavily insulated storage tank.
2. Immersion heating elements.
3. Automatic charging control.
4. Heat distributing system.
5. Automatic room temperature control.

The insulated storage tank, the heating elements and the charging control are practically identical for all types of off-peak systems. Only the heat distributing system and the room temperature control differ to any extent.

The size of the storage tank is based upon the heat losses of the building, the heating schedule, the hours of heating from storage, and allowance for heating-up. The space required for the tank is usually less than that allowed for coal storage with a coal-fired system. In new buildings and where openings permit, factory fabricated tanks are used. Otherwise, the tanks are welded electrically at the final location.

The immersion heating elements are inserted directly into the tank. Automatic charging control is obtained by the use of a synchronous time switch and a tank thermostat, which open and close the main magnetic switch supplying current to the heating elements.

Hot Water Systems

In hot water systems, the storage tank supplies hot water to standard heating units (radiators or convectors) installed in the building. The water in the storage tank is heated to approximately 250 F. In the system using gravity circulation, the temperature of the hot water supplied to the heating units is varied by the action of a mixing valve under control of the room thermostat. In larger installations, the circulation is obtained by means of a pump under thermostatic control. In this case, the temperature of the water supplied to the heating units is regulated by mixing the proper amount of return water with the 250 F water from the storage tank through a suitable by-pass.

Warm Air System

The warm air system makes use of extended heating surface and a plenum chamber assembly (*i.e.*, a central fan system) which is usually installed in the basement alongside the storage tank. The warm air supply ducts are run in the usual manner from the top of the plenum chamber to the registers in the rooms. The return air is brought back through cold air ducts to the inlet side of the fan or blower depending on the size of the installation. Temperature regulation is obtained by thermostatic control of the blower and the valve admitting hot water to the heating units.

With forced air circulation, it is possible to use small ducts and such shapes as will accommodate themselves architecturally to the structure of the house which, of course, cannot usually be done with warm air where the circulation is obtained by natural convection alone. Improved temperature regulation and more uniform air temperature from floor to ceiling can be obtained in this manner. Air cleaning and humidifying apparatus is readily incorporated in the system.

Off-Peak Systems for Industrial Buildings

For substations and certain types of industrial buildings, the electric storage heater is used to supply hot water to unit heaters placed in various parts of the building. Certain sections of the building, such as offices and rooms which are partitioned off from the larger areas, may be heated by ducts leading from indirect heating units supplied with hot water in parallel with the unit heaters.

Still another application is the use of waste heat in conjunction with electric storage heat. In this application, heating units are installed in the waste heat ducts, which supply waste heat from the losses of synchronous condensers and other apparatus. When the waste heat does not provide sufficient heating, the air temperature is boosted by supplying the proper amount of hot water from the storage tank to the heating units. Controls are provided, which not only make the entire operation automatic, but insure the maximum amount of heating from the waste heat source.

Seasonal Power Consumption

There are a number of inherent characteristics of off-peak electric heating which give economies in heat consumption. With the storage tank and basement piping properly insulated, very little heat is given off in the basement. Rapid heating-up in the morning is obtained from storage with no reduction in efficiency of the heater. Further savings are obtained due to constant room temperature and elimination of periods of overheating.

Electric Water Heating

Electric water heating is made quite generally applicable by the use of the off-peak storage method. The low off-peak energy rates introduced by power companies make the cost of electric water heating comparable to manufactured gas in many districts. Automatic storage type electric water heaters, operated off-peak, are not limited in size. Domestic hot

water demands, ranging from 30 to 200 gal per day, can be met as well as applications requiring several thousand gallons per day.

COST COMPARISONS

Cost comparisons between various fuels and electricity for house heating should be made on a heat unit basis, giving due consideration in each case to efficiency. A rate of 1 cent per kilowatt-hour is equivalent to a cost of about $3.00 per 1,000,000 Btu, assuming a transmission loss through the wiring system of 2 per cent. A comparison between the cost of heating with electricity and the cost of heating with coal, oil or gas may be made by referring to Chapter 16.

INSULATION REQUIRED

The importance of insulation, weatherstripping, double windows or storm sash for electrically heated houses cannot be over-emphasized. If electrical energy had no value, there would be no object in reducing the heat losses of a building, at least from the standpoint of heat economy. On the other hand, the more costly the heat, whether produced from electrical energy or fuel combustion, the greater the thickness of insulation required. It is therefore important that the walls and roof of a building to be heated with electrical energy be well insulated, and that the windows be equipped with storm sash and weatherstrips.

The thickness of insulation for buildings heated with electricity (Y_e) for any assumed over-all investment return, may be estimated from the following formula (heating efficiency assumed 100 per cent):

$$Y_e = \frac{eUN\,(t - t_a)}{34.15 \times r \times z} - \frac{k}{U} \qquad (1)$$

where

e = cost of electrical energy, cents per kilowatt hour.
U = coefficient of transmission of uninsulated wall or roof, Btu per hour per square foot per degree Fahrenheit.
N = number of hours during heating season.
t = inside temperature.
t_a = average outside temperature during heating season of N hours.
r = return on investment.
z = installed cost of insulation, cents per square foot per inch thickness.
34.15 = a constant derived from the heat equivalent of electricity.

Example. The electrical energy (e) for a building to be heated by electricity costs 1¢ per kilowatt hour. The coefficient of transmission of the uninsulated wall (U) is 0.25. If the minimum acceptable return on the investment (r) is 20 per cent and the installed cost of the insulation is 9¢, how much insulation will be required? The building is located in Philadelphia, Pa. Assume $N = 5040$, $t = 70$, and $k = 0.30$.

Solution. The average outside temperature during the heating season (t_a) in Philadelphia is 41.9 F. Substituting the proper values in equation 1:

$$Y_e = \frac{1 \times 0.25 \times 5040 \times (70 - 41.9)}{34.15 \times 20 \times 9} - \frac{0.30}{0.25} = 4.5 \text{ in.}$$

For an efficiency lower than 100 per cent, the thickness required would be correspondingly greater.

HEAT EQUIVALENTS OF ELECTRICITY

The relation between electrical energy and heat and power is given by the following equations:

1 horsepower = 746 watts.
= 33,000 ft lb per min

1 Btu = 777.64 ft lb

1 horsepower-hour = $\frac{33{,}000 \times 60}{777.64}$ = 2,546 Btu per hour.

1 watt-hour = $\frac{2{,}546}{746}$ = 3.415 Btu per hour.

1 kilowatt (kw) = 1,000 watts.
= $\frac{3{,}415}{160}$ = 21.3 sq ft of hot water radiation based on a heat emission of 160 Btu per square foot.
= $\frac{3{,}415}{240}$ = 14.2 sq ft equivalent of steam radiation, based on a heat emission of 240 Btu per square foot.

Chapter 21

HEATING WITH EXHAUST STEAM

Adjustment Between Heating Loads and Exhaust Steam; Heating Load and Amount of Exhaust Steam Available; Procedure for Making Analysis; Re-Heated Exhaust Steam.

LARGE industrial plants, hotels and office buildings still find it profitable to maintain their individual power plants if care is taken in the utilization of the exhaust steam, especially for heating purposes.

The exhaust steam may be circulated directly through the radiators, heaters, air heaters, humidifiers or other elements of a heating, or of a heating and ventilating system or it may be used for heating water which in turn may be circulated through similar elements of a hot water heating system. It may also be used for domestic hot water heating.

Frequently there is a fluctuating load on the power or electric generating apparatus which in turn produces fluctuating quantities of exhaust steam. The quantity of steam required for heating is also variable. These two variables do not, as a rule, coincide so that the total quantity of exhaust steam produced may be either a certain percentage less or a certain percentage more than the total quantity of steam required for heating, or for heating and ventilating either during the heating season or throughout the year. These relations change throughout the day and night and throughout the seasons of the year.

There are also wide variations in the heating requirements due to changes in weather conditions and wide variations in the exhaust produced due to such changes as in the demands for lighting on dark or light days, for elevator power during rush or slack periods, for air conditioning on good or bad days and for many other variables in the demands for power or light, depending on the character of building and its operating requirements.

ADJUSTMENT BETWEEN HEATING LOADS AND EXHAUST STEAM

The way in which the quantities of exhaust steam produced and the quantities of steam required during the various intervals of time throughout the year coincide will determine how much may be used, how much must be thrown away and how much live steam must be used to supplement the exhaust steam deficit, unless some means is adopted for adjusting the supply to the demand.

One method of making this adjustment is to store exhaust steam or its equivalent in heat, when it is in excess of the demand and feed this to the system when the exhaust being produced is below the demand. Hot

water accumulators may be used for this purpose by storing heat in water to be fed to the boilers, in water to be used for domestic hot water service, in water to be used in a hot water heating system, in water to be used for process work, or for some combination of these purposes.

Another method is to adjust the quantity of exhaust produced somewhat in concordance with the heating demand. A bleeder turbine from which the exhaust may be taken for the lower heating demands and additional higher pressure steam from its successive stages as this demand goes up is frequently a satisfactory solution for a case where the normal exhaust is deficient. If such a turbine is also arranged to run condensing under various controllable degrees of vacuum and arrangements are made for either circulating the exhaust through the heating system under various pressures above and below atmospheric pressure or for similarly using the exhaust for heating water, such an arrangement may adjust the exhaust to a wide variation of heating demands.

With such an arrangement, the exhaust supply may be automatically adjusted to the demand by having automatic control of the vacuum in the turbine from an outdoor thermostat operating on the flow of cooling water on the condenser and remote control valves in the bleeder steam supplies controlled from the same or a coordinate thermostat. This arrangement has certain advantages over that in which exhaust steam is discharged to the atmosphere when it is in excess of the demand and where live steam at boiler pressure is used to make up the deficit when the exhaust is insufficient. For example, the condensing of the excess exhaust steam increases the efficiency of the turbine so that the total heat rejected to the condenser is less than would otherwise be thrown away, while the use of the bleeder steam conserves heat by allowing a certain amount of power to be generated from this steam before it is fed to the heating system.

A modification of this method of adjustment, especially as between the heating and non-heating seasons, is to use engines or turbines which may be run condensing throughout the non-heating season and non-condensing throughout the heating season. Another modification is to have non-condensing engines or turbines for use during the heating season and low pressure exhaust condensing turbines for using the exhaust steam from these during the non-heating season. This latter arrangement affords a high efficiency since each unit operates under conditions for which it may be best designed. The low pressure turbine in this case may even be made a bleeder turbine and be arranged to operate on various degrees of vacuum with automatic control as previously stated. While this arrangement of units generally shows a high overall economy there is some disadvantage in installing condensing units which have to be frequently started up or shut down and by-passed and hence a straight bleeder turbine is frequently used as a matter of simplicity.

Still another method is to adjust the heating demand so that it will balance as nearly as possible the exhaust heat produced. The use of hand operated or automatic remote control sectional, or zone, regulating valves for separately controlling the various sides and vertical sections of a building in accordance with the exposures, wind velocities, sunshine, etc., the use of automatic temperature control, fractional distribution of steam, distribution of steam under varying degrees of vacuum and the use of

forced hot water with temperature control, all tend to keep the demand commensurate with the actual weather requirements, thereby reducing the maximum demand and at the same time the amount of fluctuation by supplying heat only where it is needed.

HEATING LOAD AND AMOUNT OF EXHAUST STEAM AVAILABLE

In all of these adjustments the question of relative economies and the cost to produce them must necessarily enter into the problem. The efficiencies of engines and turbines vary with the types, sizes, speeds, load conditions and with the steam pressure, temperature, back pressure or vacuum under which they operate. Actual guaranteed water rates for the units and conditions to be employed on any particular operation should be obtained from several reputable makers before endeavoring to estimate the exhaust.

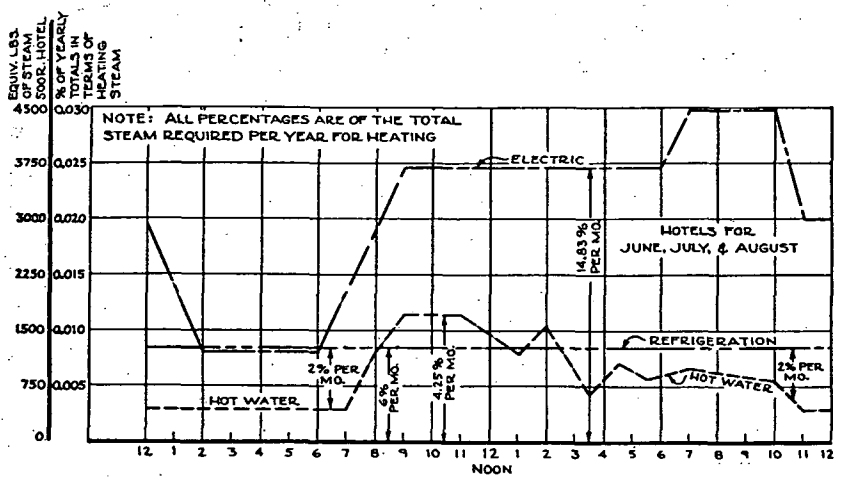


FIG. 1. HOTEL LOAD CURVE FOR JUNE, JULY AND AUGUST

Load conditions and heating requirements must then be computed for the various hours of the day and night and for the various days of the year. Generally, a 24-hour day load and heating requirement chart for each of the four seasons of the year will be sufficient although in many cases the load may be different for some days of each week and of course over holidays and other non-operating periods.

Typical load curves are shown by Figs. 1, 2 and 3. In the hotel diagram (Fig. 1) it will be noted that the steam required for generating the refrigeration power is shown separately and is not included in the steam required to generate the remaining electric current or power. This is for the purpose of comparing it with the hot water load, which it practically equals in all of these charts. For this reason the refrigerating apparatus in this class of building may frequently be steam driven and the exhaust thus produced be used with good economy for heating the domestic hot water even where the remainder of the electric current is purchased

from the outside and steam or hot water direct from the boiler plant is used for heating.

PROCEDURE FOR MAKING ANALYSIS

In making an analysis of any particular operation it is necessary to develop charts similar to Figs. 1, 2 and 3. The total steam required

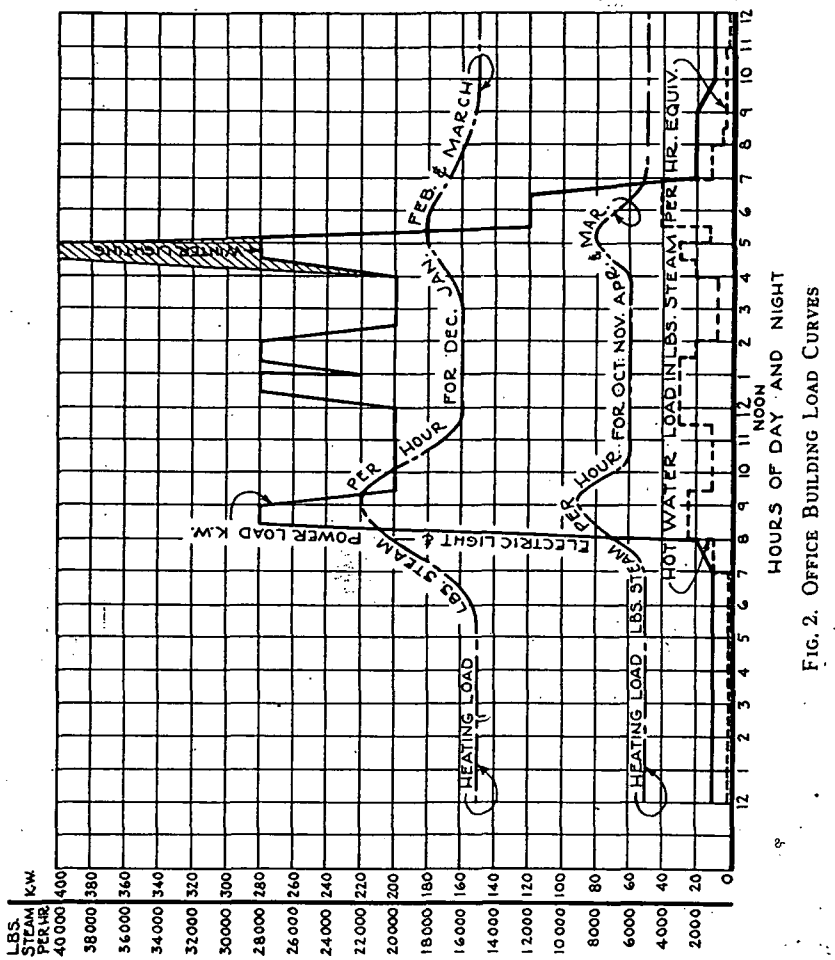


FIG. 2. OFFICE BUILDING LOAD CURVES

for heating per square foot of direct radiation, or its equivalent, per season, for different classes of buildings will be found on p. 325, Chapter 22, District Heating. Of the total steam required for any particular service, the following percentages of the whole may be apportioned to the various months of the heating season in the colder climates: January,

20 per cent; February, 20 per cent; March, 15 per cent; April, 10 per cent; May, 5 per cent; October, 6 per cent; November, 8 per cent; December, 16 per cent.

To determine the amount of exhaust steam available, it is necessary first to develop electric current or power load curves and from these to estimate the amounts of steam used during various periods. Fig. 4 gives the ideal water rate for engines or turbines working under different initial pressure and back pressure or vacuum conditions, with corrections for superheat in the initial steam. Table 1 gives the factors by which ideal water rates may be multiplied to obtain average expected water rates

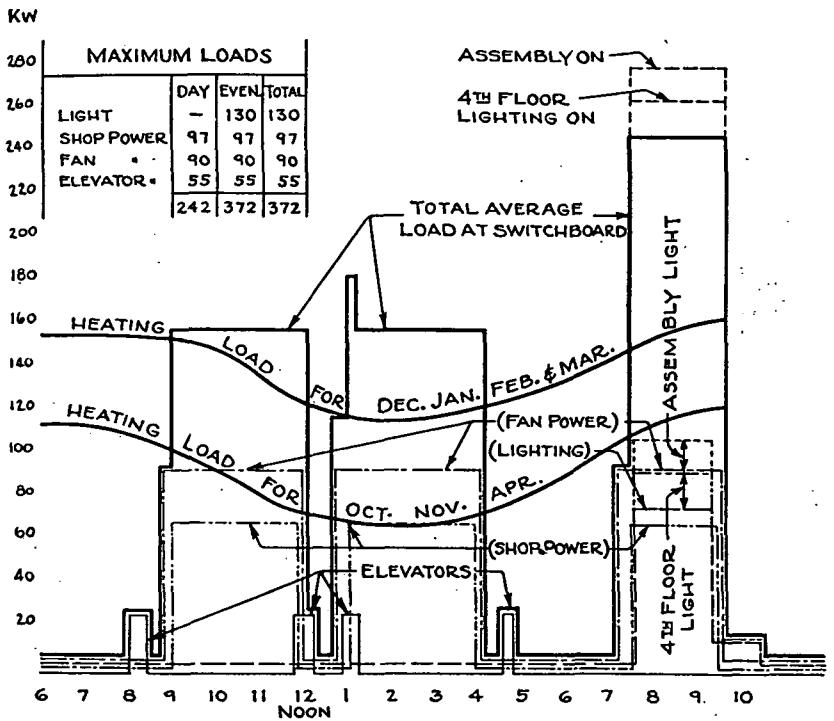


FIG. 3. HIGH SCHOOL LOAD CURVES

for engines and turbines of various capacities when operating under full load conditions. Table 2 gives the factors by which the actual water rates under full load operating conditions should be multiplied to obtain expected water rates under various load conditions. From the load curves and these tables it is a simple matter to develop curves showing the steam required by the electric generating or power units.

The next step is to determine the amount of heat available in this steam for heating, etc., after it has passed through the generating units. This can be done by deducting the heat transferred into work, plus that lost by radiation from the heat in the steam entering the generating units.

TABLE 1. APPROXIMATE FULL LOAD EFFICIENCIES FOR NON-CONDENSING ENGINE AND MULTI-STAGE IMPULSE TURBO-GENERATORS—GEARED TYPE

RATED CAPACITY AT FULL LOAD KW	MECHANICAL EFFICIENCIES OF ENGINE UNITS	MECHANICAL EFFICIENCIES OF TURBINE UNITS	BRAKE POTENTIAL EFFICIENCY RATIO OF TURBINES	[a]FACTORS FOR CONVERTING IDEAL WATER RATES TO ACTUAL WATER RATES (FOR TURBINES ONLY)	GENERATOR EFFICIENCIES AT FULL LOAD
100	0.900	0.930	0.45	2.22	0.932
200	0.905	0.935	0.50	2.00	0.934
300	0.910	0.940	0.54	1.85	0.936
400	0.915	0.942	0.58	1.74	0.938
500	0.920	0.945	0.61	1.64	0.940
600	0.925	0.947	0.64	1.56	0.942
750	0.930	0.950	0.65	1.54	0.944
1000	0.935	0.952	0.67	1.49	0.945
1250	0.940	0.955	0.67	1.49	0.947
1500	0.945	0.957	0.67	1.49	0.950
2000	0.950	0.960	0.68	1.45	0.954
CONDENSING TURBINES					
500		0.950	0.68	1.45	0.940
600		0.952	0.69	1.44	0.942
750		0.954	0.70	1.43	0.944
1000		0.956	0.70	1.43	0.945
1250		0.958	0.70	1.43	0.947
1500		0.960	0.70	1.43	0.950
2000		0.960	0.70	1.43	0.954

	(FOR NON-CONDENSING ENGINES ONLY)
Single valve automatic engine units up to 400 kw	1.64
Four valve automatic engine units up to 400 kw	1.42
Unaflow engine units up to 400 kw	1.20

[a]These factors are for indicated engine or brake turbine loads and do not take into account the mechanical efficiency of engine units or generator efficiencies for either engine or turbine units; but do include the mechanical efficiency of turbines.

TABLE 2. FACTORS BY WHICH TO MULTIPLY ACTUAL WATER RATES AT FULL LOAD TO OBTAIN ESTIMATED WATER RATES AT FRACTIONAL LOADS ON NON-CONDENSING ENGINE AND TURBINE-DRIVEN ELECTRIC GENERATING UNITS[b]

SIZE AND KIND OF UNIT	LOAD			
	¼	½	¾	Full
Single valve engines up to 400 kw	1.32	1.09	1.03	1.00
Four valve engines up to 400 kw	1.30	1.08	1.03	1.00
Unaflow engines up to 400 kw	1.10	1.02	0.980	1.00
Geared turbines up to 600 kw	1.57	1.25	1.05	1.00
Geared turbines 600 to 2000 kw	1.50	1.20	1.04	1.00

[b]These values are for indicated or brake loads and do not take into account variations in generator efficiencies under various load conditions. Generator efficiencies vary from 85 per cent at one quarter load to 95 per cent at full load.

Since 2546 Btu per hour = one horsepower-hour and 3415 Btu per hour = one kilowatt-hour the heat extracted in performing work per pound of steam used may be obtained by dividing these figures by the water rates of the units per indicated horsepower hour or per kilowatt hour, respectively, of work done by the steam. From 1 per cent to 2 per cent may be deducted for radiation and other heat losses, depending upon the size of unit.

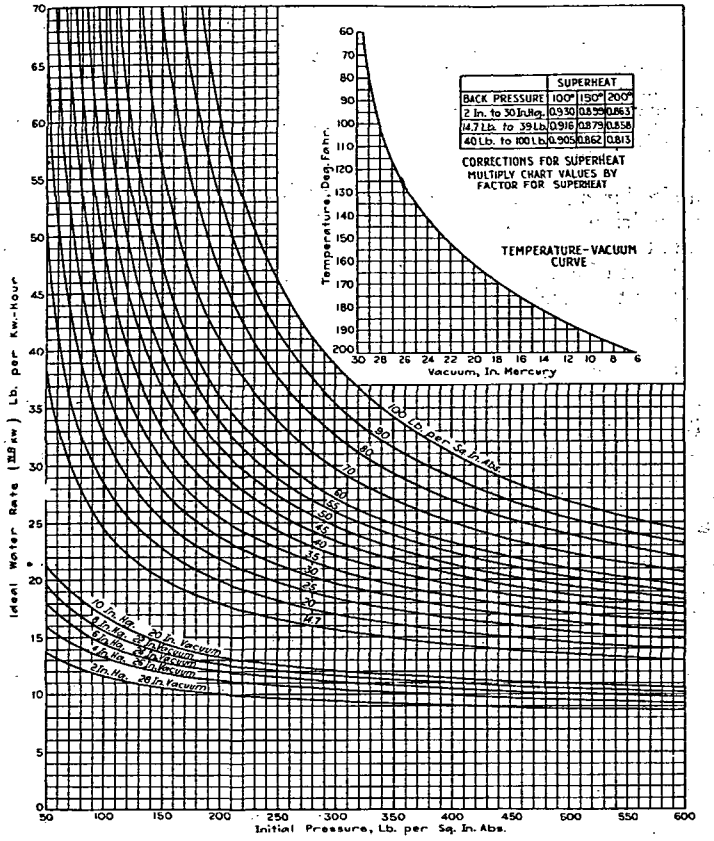


FIG. 4. IDEAL WATER RATE PER KILOWATT HOUR WITH DRY SATURATED STEAM FOR VARIOUS INITIAL PRESSURES AND BACK PRESSURES[ab]

[a]For ideal water rate per indicated horsepower hour, divide these values by 1.34.
[b]From Power from Process and Space Heating Steam, by L. A. Harding (A.S.H.V.E. TRANSACTIONS, Vol. 36, 1930).

Example 1. A 200-kw turbine is operating on saturated steam at 150 lb gage pressure and consuming 40 lb of steam per kilowatt hour delivered, at full load. Determine the heat available in the exhaust for heating.

Solution. The mechanical efficiency of the turbine is 0.935 and the efficiency of the generator is 0.934 (See Table 1), giving a combined efficiency of $0.935 \times 0.934 = 0.873$ which would mean $40 \times 0.873 = 34.92$ lb per kilowatt hour of external work actually done by the steam. The total heat of the steam under the conditions as fed to the turbine is 1195 Btu per pound.

The heat extracted in external work $= \frac{3415}{34.92} = 97.74$ Btu per pound of steam. To this add 1½ per cent for heat lost by radiation, or $97.74 + 1.47 = 99.21$ Btu which is the total heat loss per pound of steam in passing through the turbine. This leaves $1195 - 99.21 = 1095.79$ Btu in each pound of the exhaust.

If the exhaust is to be used and condensed at atmospheric pressure there will be a further deduction of 180 Btu per pound for the heat of the liquid at this pressure. This leaves $1095.79 - 180 = 915.79$ Btu per pound of steam fed to the turbine as being available in the exhaust for heating at atmospheric pressure.

In a similar manner the heat available per pound in the exhaust from an engine driven unit for heating may be estimated by dividing the heat equivalent per unit of work by the number of pounds of steam fed to the unit per unit of actual external work done, adding to this from 1 per cent to 2 per cent for radiation, and subtracting this sum from the total heat in a pound of the steam as fed to the unit and then subtracting from this remainder the heat per pound in the condensate or rejected steam leaving the heating system.

In the case of an engine driven unit, the heat equivalent of a horsepower hour (2546 Btu) should be divided by the water rate per indicated horsepower. If the water rate is given per kilowatt hour delivered by the generator, this may be reduced to pounds per indicated horsepower hour by dividing by 1.34 and multiplying by the mechanical efficiency of the unit and the efficiency of the generator.

Example 2. A 200-kw engine-driven unit operates under the same conditions as the turbine unit in the preceding example, and delivers one kilowatt-hour on 37.8 lb of water.

The mechanical efficiency of the unit is 0.905 and the efficiency of the generator is 0.934 (See Table 1). The water rate per indicated horsepower is therefore

$$\frac{37.8}{1.34} \times 0.905 \times 0.934 = \frac{37.8}{1.34} \times 0.845 = 23.84$$

The heat equivalent of the external work done per pound of steam is $\frac{2546}{23.84} = 106.79$ Btu. To this add 1½ per cent for radiation, or $106.79 + 1.60 = 108.39$ Btu which is the total heat lost per pound of steam in passing through the engine. Deduct this from the total heat per pound in the steam fed to the engine, or $1195 - 108.39 = 1086.61$.

RE-HEATED EXHAUST STEAM

Installations have been made recently where exhaust steam is re-heated and its temperature raised before being distributed. This re-heating and drying-out process is accomplished by passing the exhaust steam through a closed heater where high-pressure, high-temperature steam is present on the closed side. Usually this high-pressure, high-temperature steam is on its way between the stages of a turbine or a compound engine. The effect of pre-heating the exhaust steam is to increase its range of distribution.

For additional information on this subject, see Utilization of Waste Heat, by Perry West (*Heating, Piping and Air Conditioning*, November, 1930).

Chapter 22

DISTRICT HEATING

Underground Steam Piping; Selection of Pipe Sizes; Provision for Expansion; Capacity of Returns with Various Grades; Pipe Conduits; Pipe Tunnels; Service Connections; Steam per Square Foot of Heating Surface; Fluid Meters and Metering.

THIS chapter deals with those phases of district heating which frequently fall within the province of the heating engineer. Data and information are included for solving incidental problems in connection with institutions and factories and for the design of building heating systems which are to be supplied with purchased steam. A complete district heating installation should not be attempted without a thorough study of the entire problem by men competent and experienced in that industry. The Handbook and other publications of the *National District Heating Association*, and the references at the end of this chapter should be consulted.

UNDERGROUND STEAM PIPING

The methods used in district heating work for the distribution of steam are applicable to any problem involving the supply of steam to a group of buildings. The first step is to establish the route of the pipes and in this matter the local conditions so fully control the layout that little can be said regarding it.

Having established the route of the pipes, the next step is to calculate the pipe sizes. In district heating work it is common practice to design the piping system on the basis of pressure drop. The initial pressure and the minimum permissible terminal pressure are specified and the pipe sizes are so chosen that the required amount of steam, with suitable allowances for future increases, will be transmitted without exceeding this pressure drop. The steam velocity is therefore almost disregarded and may reach a very high figure. Velocities of 35,000 fpm are not considered high. By the use of this method the pipe sizes are kept to a minimum with consequent savings in investment.

The steam flowing through any section of the piping can be computed from a study of the requirements of the several buildings served. In general a condensation rate of 0.25 lb per hour per square foot of equivalent heating surface is a safe figure. This allows for line condensation which, however, is a small part of the total at times of maximum load. Any unusual requirements such as those for process steam should be individually calculated.

The steam requirements for water heating should be taken into account, but in most types of buildings this load will be relatively small compared with the heating load and will seldom occur at the time of the heating peak. Unusual features such as large heaters for swimming pools should not be overlooked.

The pressure at which the steam is to be distributed will depend, in part, upon whether or not it has been passed through electrical generating units. If it has , the pressure will be considerably lower than if live steam, direct from the boilers, is used. The advantages of low pressure distribution (2 to 30 lb per square inch) are (1) smaller heat loss from the pipes (2) less trouble with traps and valves and (3) simpler problems in pressure reduction at the buildings. With distribution pressures not exceeding 40 lb per square inch there is little danger even if the full distribution pressure should build up in the radiators through the faulty operation of a reducing valve; but with pressures higher than this a second reducing valve or some form of emergency relief is usually desirable to prevent excessive pressures in the radiators. The advantages of high pressure distribution are (1) smaller pipe sizes and (2) greater adaptability of the steam to various operations other than building heating.

The different kinds of apparatus which frequently must be served require various minimum pressures. Kitchen equipment requires from 5 to 15 lb per square inch, the higher pressures being necessary for apparatus in which water is boiled, such as stock kettles and coffee urns. An increased amount of heating surface, which is easily obtained in some kinds of apparatus, results in quicker and more satisfactory operation at low pressures. For laundry equipment, particularly the mangle, a pressure of 75 lb per square inch is usually demanded although 30 lb per square inch is sufficient if the mangle is equipped with a large number of rolls and if a slow rate of operation is permissible. Pressing machines and hospital sterilizers require about 50 lb per square inch.

SELECTION OF PIPE SIZES

The lengths of pipe, steam quantities and initial and terminal pressures having been chosen the pipe sizes can readily be calculated by means of the Unwin pressure drop formula. This formula, which gives pressure drops slightly larger than actual test results, is as follows:

$$P = \frac{0.0001306\ W^2 L \left(1 + \frac{3.6}{d}\right)}{y d^5} \qquad (1)$$

where

P = pressure drop, pounds per square inch.
W = weight of steam flowing, pounds per minute.
L = length of pipe, feet.
d = inside diameter of pipe, inches.
y = average density of steam, pounds per cubic foot.

This formula is similar to the Babcock formula given in Table 1, Chapter 9.

PROVISION FOR EXPANSION

The linear expansion of the pipe can be determined from Table 1. The elongation values in this table were computed from the following formula:

$$L_t = L_o \left[1 + a\left(\frac{t - 32}{1000}\right) + b\left(\frac{t - 32}{1000}\right)^2\right] \qquad (2)$$

where

L_t = length at temperature t deg F, feet.
L_o = length at 32 F, feet.
t = final temperature, degrees Fahrenheit.
a and b are constants as follows:

METAL	a	b
Cast-Iron	0.005441	0.001747
Steel	0.006212	0.001623
Wrought-Iron	0.006503	0.001622
Copper	0.009278	0.001244

In selecting expansion fittings it is well to allow a margin of 25 per cent between the computed expansion and the actual allowable travel of the expansion fitting to provide for inaccuracies in assembling, etc. Table 2 gives the dimensions of expansion offsets and bends required to take care of different amounts of expansion. For additional information on this subject, refer to Chapter 11.

CAPACITY OF RETURNS WITH VARIOUS GRADES

In general return lines when installed follow the contour of the land, and Table 3 gives sizes of return pipes for various grades. It is evident that at points where the grade is great, smaller pipes can be installed.

PIPE CONDUITS

Conduits for steam pipes buried underground should be reasonably water-proof, able to withstand earth loads and take care of the expansion and contraction of the piping without strain or stress on the couplings, also without affecting the installation or conduit. Expansion of the piping must be carefully controlled by means of anchors and expansion joints or bends so that the pipes can never come in contact with the conduit. Anchors can be anchor fittings or U-shaped steel straps which partially encircle the pipes and are firmly bolted to a short length of structural steel set in concrete.

In laying out conduits of this type the following points should be borne in mind:

1. An expansion joint offset or bend should be placed between each two anchors.

2. If the distance between buildings is 150 ft or less and the steam line contains high-pressure steam, it may be anchored in the basement of one building and allowed to expand into the basement of the second building. If the steam line contains low-

pressure steam (up to 4 lb pressure), this method may be used if buildings are 250 ft or less apart.

3. If the distance between buildings is between 150 ft and 300 ft and the steam line contains high-pressure steam, the lines should be anchored midway between the buildings and allowed to expand into the basements of both buildings. If the steam line contains low-pressure steam this method may be used if buildings are between 250 ft and 600 ft apart. *No manhole is required at the anchor, and a blind pit is all that is necessary.*

TABLE 1. THERMAL EXPANSION OF PIPE IN INCHES PER 100 FEET[a]

(For superheated steam and other fluids refer to temperature column)

SATURATED STEAM			ELONGATION IN INCHES PER 100 FT FROM −20 F UP				SATURATED STEAM		ELONGATION IN INCHES PER 100 FT FROM −20 F UP			
Vacuum Inches of Hg.	Pressure Pounds per Square Inch Gage	Temperature Degrees Fahrenheit	Cast-Iron Pipe	Steel Pipe	Wrought Iron Pipe	Copper Pipe	Pressure Pounds per Square Inch Gage	Temperature Degrees Fahrenheit	Cast-Iron Pipe	Steel Pipe	Wrought Iron Pipe	Copper Pipe
		−20	0	0	0	0	664.3	500	3.847	4.296	4.477	6.110
		0	0.127	0.145	0.152	0.204	795.3	520	4.020	4.487	4.677	6.352
		20	0.255	0.293	0.306	0.442	945.3	540	4.190	4.670	4.866	6.614
		40	0.390	0.430	0.465	0.655	1115.3	560	4.365	4.860	5.057	6.850
29.39		60	0.518	0.593	0.620	0.888	1308.3	580	4.541	5.051	5.268	7.123
28.89		80	0.649	0.725	0.780	1.100	1525.3	600	4.725	5.247	5.455	7.388
27.99		100	0.787	0.898	0.939	1.338	1768.3	620	4.896	5.437	5.660	7.636
26.48		120	0.926	1.055	1.110	1.570	2041.3	640	5.082	5.627	5.850	7.893
24.04		140	1.051	1.209	1.265	1.794	2346.3	660	5.260	5.831	6.067	8.153
20.27		160	1.200	1.368	1.427	2.008	2705	680	5.442	6.020	6.260	8.400
14.63		180	1.345	1.528	1.597	2.255	3080	700	5.629	6.229	6.481	8.676
6.45		200	1.495	1.691	1.778	2.500		720	5.808	6.425	6.673	8.912
	2.5	220	1.634	1.852	1.936	2.720		740	6.006	6.635	6.899	9.203
	10.3	240	1.780	2.020	2.110	2.960		760	6.200	6.833	7.100	9.460
	20.7	260	1.931	2.183	2.279	3.189		780	6.389	7.046	7.314	9.736
	34.5	280	2.085	2.350	2.465	3.422		800	6.587	7.250	7.508	9.992
	52.3	300	2.233	2.519	2.630	3.665		820	6.779	7.464	7.757	10.272
	74.9	320	2.395	2.690	2.800	3.900		840	6.970	7.662	7.952	10.512
	103.3	340	2.543	2.862	2.988	4.145		860	7.176	7.888	8.195	10.814
	138.3	360	2.700	3.029	3.175	4.380		880	7.375	8.098	8.400	11.175
	180.9	380	2.859	3.211	3.350	4.628		900	7.579	8.313	8.639	11.360
	232.4	400	3.008	3.375	3.521	4.870		920	7.795	8.545	8.867	11.625
	293.7	420	3.182	3.566	3.720	5.118		940	7.989	8.755	9.089	11.911
	366.1	440	3.345	3.740	3.900	5.358		960	8.200	8.975	9.300	12.180
	451.3	460	3.511	3.929	4.096	5.612		980	8.406	9.196	9.547	12.473
	550.3	480	3.683	4.100	4.280	5.855		1000	8.617	9.421	9.776	12.747

[a]From *Piping Handbook*, by Walker and Crocker. This table gives the expansion from −20 F to the temperature in question. To obtain the amount of expansion between any two temperatures take the difference between the figures in the table for those temperatures. For example, if a steel pipe is installed at a temperature of 60 F and is to operate at 300 F, the expansion would be 2.519 − 0.593 = 1.926 in.

4. For longer lines, manholes must be located according to judgment and depending upon the expansion value of the type of expansion joint or bend that is used. The minimum number of manholes will be required when an expansion bend or an anchor with double expansion joint is placed in each manhole and the pipes are anchored midway between manholes.

5. A proper hydrostatic test should be applied to the piping before the top of the conduit is applied and before application of insulation. The pressure used in this test should be greater than the pressure used in service, and should be not less than 100 lb per square inch in any case.

The styles and construction of conduits commonly used may be classified as follows. Some of the more common forms are illustrated in Fig. 1.

Wood Casing. The pipe is enclosed in a cylindrical casing usually having a wall 4 in. thick and built of segments which are bound together by a wire wrapped spirally around the casing. The casing is lined with bright tin and coated with asphaltum. The pipe is supported on rollers carried in a bracket which fits into the casing. The lengths of casing are tightly fitted together with a male and female joint. This form of conduit is illustrated in Fig. 1 at *A*. The casing rests on a bed of crushed stone with tile drains laid below. The tile drains are of 4-in. field tile or vitrified sewer tile, laid with open joints.

Filler Type: The pipes are supported on expansion rollers properly supported from the conduit or independent masonry base. The pipes are protected by a split-tile conduit, and the entire space between the pipes and the tile is filled with an insulating filler. Thus the pipes are nested and the insulation between them and the tile effectively prevents circulation of air. The conduit is placed on a bed of gravel or crushed rock from 4 to 6 in. thick, which is extended upward so as to come about 2 in. above the

TABLE 2. LENGTH OF EXPANSION OFFSETS AND BENDS FOR PROPER EXPANSION OF PIPE

TOTAL EXPANSION IN INCHES[a]	FEET OF PIPE AND OFFSET OR U-BEND FOR DIFFERENT DIAMETERS OF PIPE									
	2"	3"	4"	5"	6"	8"	10"	12"	14"	16"
1	11	13	15	17	19	21	23	25	27	30
2	15	18	21	23	26	29	32	35	38	42
3	18	22	26	29	32	36	40	43	48	52
4	21	26	30	34	37	42	47	50	56	58
5	24	30	34	38	41	47	53	57	63	65
6	27	33	37	41	45	52	58	63	69	71
7	30	36	40	44	48	56	62	68	74	----
8	32	39	43	47	52	60	66	72	----	----

[a]This column shows the total expansion the offset will take care of without a cold strain. Although some engineers allow an increase of 40 per cent in the allowable expansion if the pipe is given a suitable initial cold strain when made up, it is regarded as better practice not to allow for it.

The length of pipe in the expansion piece should be the same whether in the form of a single right-angle offset or double offset or U-Bend.

The lengths of arms figured for 12,000 lb. per square inch tension for wrought iron pipe. If steel pipe is used this is good for 16,000 lb. per inch so that the arm will take care of ⅓ more expansion.

parting lines of the tile. A tile underdrain is placed beneath the conduit throughout the entire length and is connected to sewers or to some other point of free discharge. At *B* and *D* in Fig. 1 are shown two forms of tile conduit of the filler type.

Insulated Tile Type: The insulating material is molded to the inside of a split-tile conduit. The pipes are supported on expansion rollers usually. The space between the pipes and the insulating conduit lining may also be filled with an insulating filler. The conduit insulation, piping and earth load are supported by the base drain. A few inches of gravel or crushed rock are placed about the conduit and the base drain.

Sectional Insulation Type (Tile Conduit): Each pipe is insulated in the usual way with any desired type of sectional pipe insulation over which is placed a standard water-proof jacket with cemented joints. The pipes are enclosed in a split-tile conduit which is placed on a bed of crushed rock or gravel from 4 to 6 in. thick. This gravel bed is extended upward so as to come about 2 in. above the parting lines of the tile. Underdrains are sometimes omitted where this type is used; any water which seeps into the conduit being allowed to flow down the bottom of the conduit to the nearest manhole. Drains are laid from the floor of each manhole to some point of free discharge. The pipes are supported on roller frames and these, according to the type of conduit used, are either supported by the conduit itself or have their lower parts set in concrete, thus supporting the pipes independent of the conduit.

Sectional Insulation Type (Tile or Concrete Trench): A type of construction frequently used in city streets, where service connections are required at frequent intervals, the pipes are insulated as described in the preceding paragraph, and are enclosed in a box or trench made either entirely of concrete, or with concrete bottom and specially constructed tile sides and tops. The pipes are supported on roller frames secured in the concrete. At *C* and *E*, Fig. 1, are shown two tile conduits using sectional insulation. In these particular designs the space surrounding the pipe is filled partially or wholly with a loose insulating material. The use of loose material in addition to the sectional insulation is, of course, optional and is only justifiable where high pressure steam is used. The conduit shown at *F* is of a similar type and has the advantage of being made entirely of concrete and other common materials.

Sectional Insulation Type (Bituminized Fibre Conduit): Each pipe is individually insulated and encased in a bituminized fibre conduit. The insulating material is 85 per cent carbonate of magnesia sectional pipe covering, applied in the usual manner as on overhead pipes, except that bands are omitted. After every fifth section of magnesia covering there is applied a short, hollow section of very hard asbestos material in the

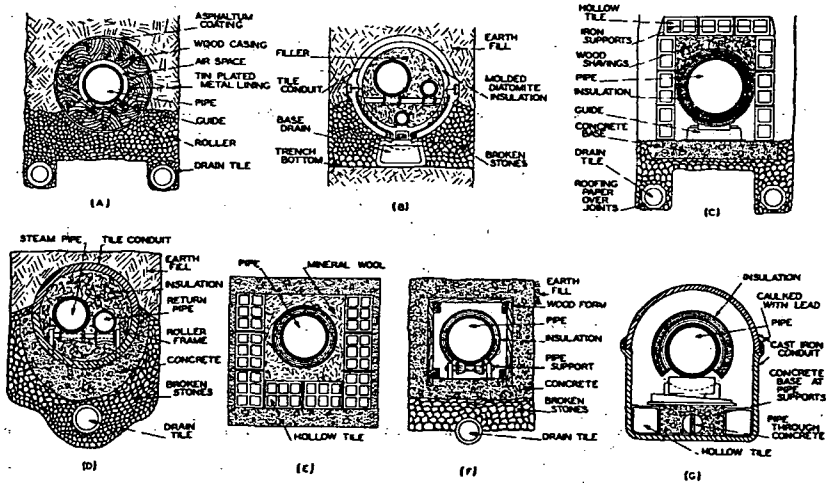


FIG. 1. CONSTRUCTION DETAILS OF CONDUITS COMMONLY USED

bottom portion of which rests a grooved-iron plate carrying ball-bearings upon which the pipe rides when expanding or contracting. This short expansion section is of the same outside diameter as the adjacent 85 per cent magnesia covering. Over the pipe covering and expansion device there are placed two layers of bituminized fibre conduit with all joints staggered and the surface of each conduit, finished with liquid cement. Conduits are placed on a bed of crushed rock or gravel, approximately 6 in. deep, and this is extended upward to about the center line of the conduit when trench is backfilled. Underdrains leading to points of free discharge are placed in the gravel or crushed rock beds.

Special Water Tight Designs. It is occasionally necessary to install pipes in a very wet ground, which calls for special construction. The ordinary tile or concrete conduit is not absolutely water tight even when laid with the utmost care. The conduit shown at *G*, Fig. 1, is of cast-iron with lead-calked joints and is water tight if properly laid. It is obviously expensive and is justified only in exceptional cases. A reasonably satisfactory construction in wet ground is the concrete or tile conduit with a waterproof jacket enclosing the pipe and its insulation, and with the interior of the conduit carefully drained to a manhole or sump having an automatic pump. It is useless to install external drain tile when the conduit is actually submerged.

PIPE TUNNELS

Where steam heating lines are installed in tunnels large enough to provide walking space, the pipes are supported by means of hangers or roller frames on brackets or frame racks at the side or sides of the tunnel. The pipes are insulated with sectional pipe insulation over which is placed a sewed-on painted canvas jacket or a jacket of asphalt saturated asbestos water-proofing felt. The tunnel itself is usually built of concrete or brick and water-proofed on the outside with membrane water-proofing.

On account of their relatively high first cost as compared with smaller conduits, walking tunnels are sometimes not installed where provision for the heating lines is the only consideration, but only where required to accommodate miscellaneous other services, such as for underground passage between buildings.

TABLE 3. CAPACITY OF RETURNS FOR UNDERGROUND DISTRIBUTION SYSTEMS IN POUNDS OF CONDENSATE PER HOUR

SIZES OF PIPE IN.	PITCH OF PIPE PER 100 FT.						
	6″	1′	2′	3′	5′	10′	20′
1	448	998	1890	2240	3490	5490	7490
1¼	1740	2490	3990	4880	6480	9480	13500
1½	2700	4190	5740	7480	9480	14500	20900
2	4980	7380	10700	13900	16900	24900	36900
3	13900	22500	30900	37400	50400	74800	105000
4	30900	44800	64800	79700	105000	154000	229000
5	54800	79800	120000	144800	195000	294000	418000
6	90000	138000	187000	237000	312000	449000	.....
8	190000	277000	404000	508000	660000	938000	.....
10	344000	498000	724000	900000	1190000	.....	.....
12	555000	798000	1148000	1499000	1990000	.....	.....

[a]Size of pipe should be increased if same carries any steam.

SERVICE CONNECTIONS

Most district heating companies enforce certain regulations regarding the consumer's installation, partly to safeguard their own interests but principally to insure satisfactory and economical service to the consumer. There are certain fundamental principles that should be followed in the design of a building heating system which is to be supplied from street mains. Although some of these apply to any building, they have been demonstrated to be especially important when steam is purchased.

1. Provision should be made for conveniently shutting off the steam supply at night and at other times when heat is not needed.

It has been thoroughly demonstrated that a considerable amount of heat can be saved by shutting off steam at night. Although there is, in some cases, an increased consumption of heat when steam is again turned on in the morning, there is a large net saving which may be explained by the fact that the lower inside temperature maintained during the night obviously results in lower heat loss from the building, and less heat need therefore be supplied.

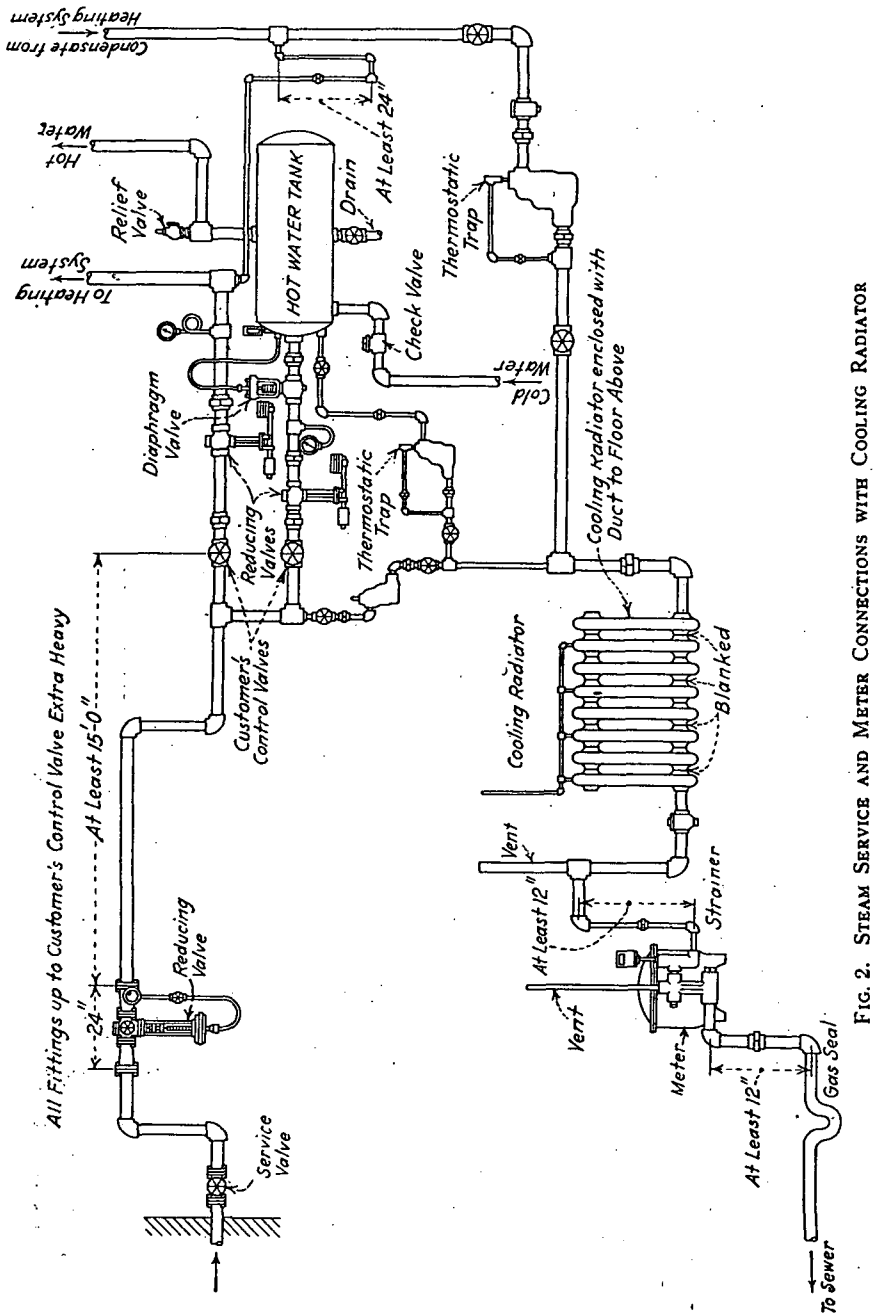


FIG. 2. STEAM SERVICE AND METER CONNECTIONS WITH COOLING RADIATOR

Steam can be entirely shut off at night in most buildings even in very cold weather without endangering plumbing. It is necessary, however, to have an ample amount of heating surface so that the building can be quickly warmed in the morning. Where the hours of occupancy differ in various parts of the building, it is good practice to install separate supply pipes to the different parts. For example, in an office building with stores or a restaurant on the first floor which are open in the evening, a separate main supplying the first floor will permit the steam to be shut off from the remainder of the building in the late afternoon. The division of the building into zones each with a separately controlled heat supply is sometimes desirable, as it permits the heat to be adjusted according to variations in sunshine, wind, etc.

2. Residual heat in the condensation should not be wasted.

This heat may be salvaged by means of a cooling radiator as illustrated in Fig. 2 or, as is more frequently done, by a heat exchanger which preheats the water used for lavatory purposes, as in Fig. 3. Figs. 2 and 3 show the practice of a Boston utility as to the service and meter connections. Fig. 4 shows a typical installation for service from the system of a New York utility.

The condensation from the heating system, after leaving the trap, passes through the preheater on its way to the meter. The supply to the hot water heater passes through the preheater, absorbing heat from the condensation. If the hot water system in the building is of the recirculating type the recirculating connection should be tied in *between* the preheater and the water heater proper, not at the preheater inlet, because the recirculated hot water is itself at a high temperature. The number of square feet of heating surface in the preheater should be approximately equal to one per cent of the equivalent square feet of heating surface in the building.

Because of the lack of coincidence between the heating system load and the hot water demand, a greater amount of heat can be extracted from the condensation if storage capacity is provided for the preheated water. Frequently a type of preheater is used in which the coils are submerged in a storage tank.

3. Heat supply should be graduated according to variations in the outside temperature.

This may be done in several ways as by the use of thermostats of various types or by orifice systems as described in Chapter 9. Another method which is very simple is the use of an ordinary vacuum return line system in which the pressure in the radiators is varied between a high vacuum and a few pounds pressure thus producing some control over the heat output. One form of control which appears to be well suited for controlling district steam service to a building is the weather compensating thermostat. It regulates the steam supply automatically according to the outdoor temperature and gives frequent short intervals of intermittent steam supply, and at the same time insures delivery of steam to all the radiators. Another form of regulation, known as the time-limit control, is sometimes employed for regulating the steam supply from the central station main to the building.

Such a control provides an intermittent supply of steam to the radiation

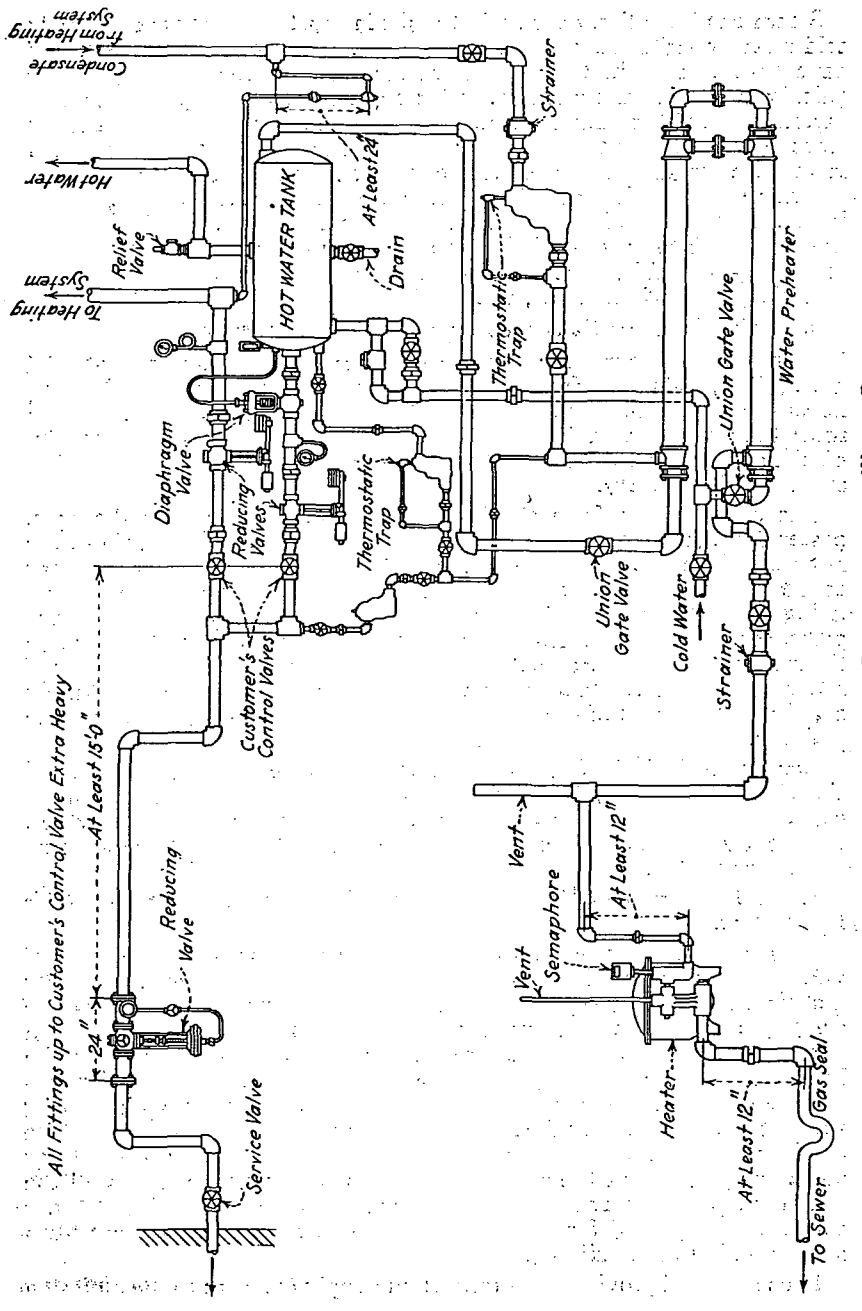


FIG. 3. STEAM SERVICE AND METER CONNECTIONS WITH WATER PREHEATER

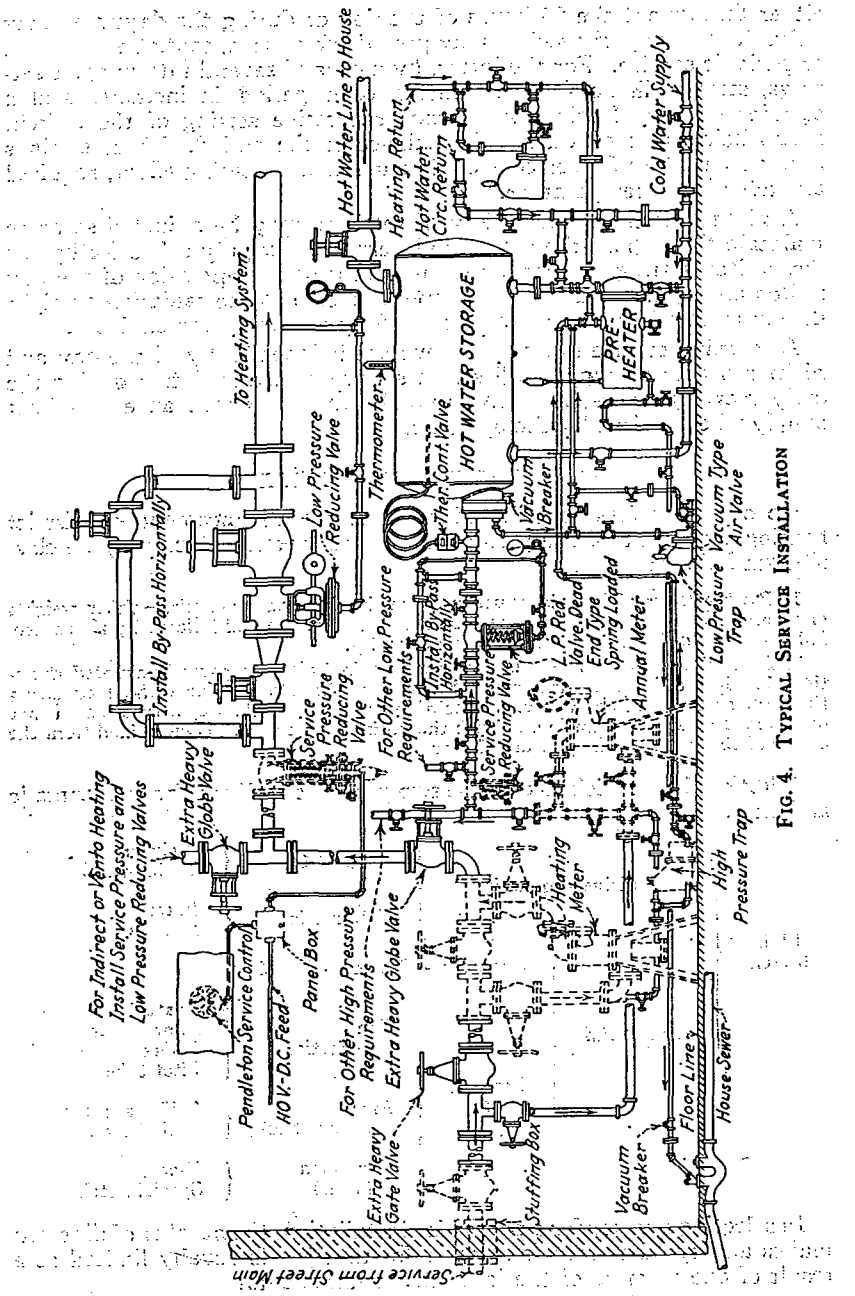


FIG. 4. TYPICAL SERVICE INSTALLATION

either throughout the 24 hours of the day or during the daytime hours only. The setting of a switch may provide no service, continuous service, or periodic service. For the latter, by means of several intermittent settings, steam will be supplied during each period in increments of a certain number of minutes for each successive setting of the switch, steam being shut off during the balance of the period. These settings afford from 15 to 80 per cent of that maximum heating effect, required on days of zero temperature.

A night switch with a variety of settings, may be adjusted so as to maintain throughout the night the intermittent supply called for by the day switch setting, or may be set to interrupt the operation of the day switch and entirely cut off the supply of steam to the radiation at night during certain hours which are selected by the operating engineer.

A morning service switch may operate independently of the day and night switches to supply full steam service to the radiation during the early morning hours, 6.00 A.M. to 9.00 A.M., or afford an excess heat supply when desired by the operator.

FLUID METERS AND METERING

No one thing has contributed more to the advancement of district heating than that of the perfection of fluid meters, which may be classified as follows:

1. *Positive Meters:* The fluid passes in successive isolated quantities—either weights or volumes. These quantities are separated from the stream and isolated by alternately filling and emptying containers of known capacity.

2. *Differential Meters:* The fluid does not pass in isolated separately-counted quantities but in a continuous stream which may flow through the line without actuating the primary device of the meter. In the differential meter, the quantity of flow is not determined by simple counting, as with the positive meter, but is determined from the action of the steam on the primary element.

Additional subdivisions of these two general classifications can be made as follows:

- Fluid Meters
  - Positive - quantity
    - Weighing
      - Weighers
      - Tilting trap
    - Volumetric
      - Rotary
      - Bellows
  - Differential
    - Quantity - Current - Turbine
    - Rate of flow
      - Head (Kinetic)
        - Venturi
        - Flow nozzle
        - Orifice
        - Pitot tube
      - Area (Geometric)
        - Orifice and plug
        - Cylinder and piston
      - Head area (Weir)
        - V-notch
        - Special notch

In selecting a meter for a particular installation, the number of different makes and types of meters suitable for that job is usually limited as a result of one or more of the following requirements:

1. Its use in a new or an old installation.
2. Type of rate to be used in charging for the service.
3. Location of the meter.
4. Large or small quantity to be measured.
5. Temporary or permanent installation.
6. Cleanliness of the fluid to be measured.
7. Temperature of the fluid to be measured.
8. Accuracy expected.
9. Nature of flow: Turbulent, pulsating or steady.
10. Cost.
    - (*a*) Purchase price.
    - (*b*) Installation cost.
    - (*c*) Calibration cost.
    - (*d*) Maintenance cost.
11. Servicing facilities of the manufacturer.

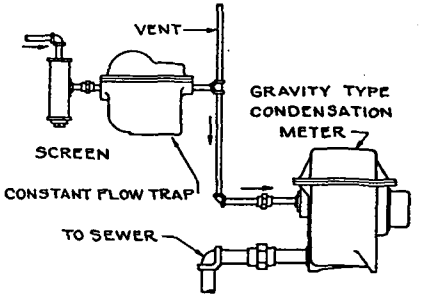


FIG. 5. TYPICAL GRAVITY INSTALLATION OF CONDENSATION METER

12. Pressure at which fluid is to be metered.
13. Type of record desired as to indicating, recording or totalizing.
14. Stocking of repair parts.
15. Use of open jets where steam is to be metered.
16. Metering to be done by one meter or by a combination of meters.
17. Use as a check meter.
18. Its facilities for determining or recording information other than flow.

The majority of the meters used by district heating companies for the sale of steam to their customers are of either the condensation or flow meter type.

Condensation Meters

The condensation meter is a popular type for use on small and medium sized installations, where all of the condensate can be brought to a common point for metering purposes. Its simplicity of design, ease in testing, accuracy at all loads, low cost and adaptability to low pressure distribution has made it standard equipment with many heating companies.

Two types of condensation meters are in general use; the *tilting bucket* meter and the *revolving drum* or *rotor* meter of which there are several makes on the market.

Condensation meters should not be operated under pressure. They are made for either gravity or vacuum installation. Continuous flow traps and vented receivers ahead of gravity type meters are desirable. A typical gravity installation for a condensation meter is shown in Fig. 5, while Fig. 6 is a gravity installation using a vented receiver ahead of the meter. Fig. 7 shows a vacuum installation without a master trap. The pipe discharge from the meter should be of ample size and pitched so as to rapidly remove the condensate from the meter. It is advisable to follow the instructions of the meter manufacturer in installing a meter as the successful operation of any meter depends upon its being properly connected.

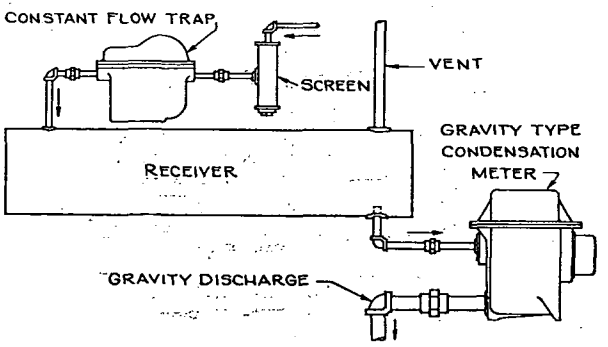


FIG. 6. GRAVITY INSTALLATION FOR CONDENSATION METER USING VENTED RECEIVERS

Flow Meters

Steam flow meters are available in many types and combinations as indicated in the subdivision of fluid meters on page 322.

The *orifice and plug* meter is one in which the steam flow varies directly as the area of the orifice. The vertical lift of the plug, which is proportional to the flow, is transmitted by means of a lever to an indicator and to a pencil arm which records the flow on a strip chart. The total flow over a given period is obtained by plani-metering the area on the chart and applying the meter constant.

Flow meters using an orifice, venturi tube, flow nozzle, or Pitot tube as the primary device are made by a number of manufacturers and can be obtained in either the mechanical or electrically operated type. The electric flow meter makes it possible to locate the instruments at some distance from the primary element which is not always possible with the mechanical flow meter.

Flow meters employing the orifice, venturi tube, flow nozzle or Pitot tube should be so selected as to keep the lower operating range of the

load above 20 per cent of the capacity of the meter. This is desirable for accuracy as the differential pressure at light loads is too small to properly actuate the meter. A few general points to be considered in installing a meter of this type are as follows:

1. It is desirable to place the differential medium in a horizontal pipe in preference to a vertical one where either location is available.
2. Reservoirs should always be on the same level and installed in accordance with the instructions of the meter company.
3. The meter body should be placed at a lower level than that of the pressure differential medium. Special instructions are furnished where the meter body is above.
4. Meter piping should be kept free from leaks.
5. Sludge should not be permitted to collect in the meter body.

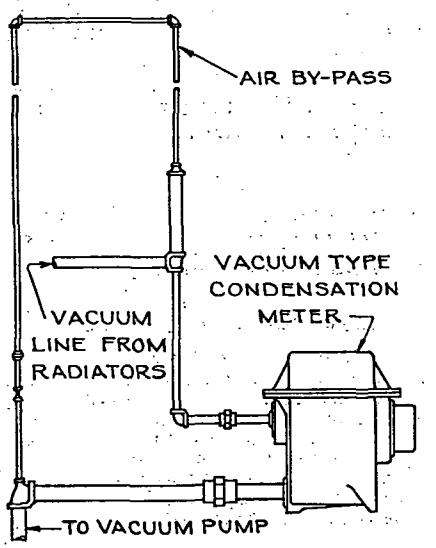


FIG. 7. VACUUM CONDENSATION METER INSTALLATION WITHOUT MASTER TRAP

6. The meter body and meter piping should be kept from freezing temperatures.
7. It is best not to connect a meter body to more than one service.
8. Special instructions are furnished for metering a turbulent or pulsating flow.

STEAM PER SQUARE FOOT OF HEATING SURFACE

The following factors are used in New York City for the different classes of buildings listed. The factors are based on maintaining an inside temperature of 70 F for certain hours with a minimum outside temperature of 0 deg F, and an average of 43 F for the heating season of eight months (October 1 to June 1). In this group are six types of buildings:

For manufacturing or commercial loft type where steam is used to heat the premises during the day hours to maintain 65 to 68 F from 9 A.M. to 5 P.M. No Sunday or holiday use and no night use. *Factor:* 325 lb per square foot of heating surface per season.

For office buildings using steam during daylight hours only to maintain 70 F from 9 A.M. to 6 P.M. for approximately 240 days (heating season). No night use. *Factor:* 400 lb per square foot of heating surface per season.

For office buildings using steam during day hours and at night when required to 7, 8 and 9 P.M. (customary where there are stock brokers or banking offices), 240 days. *Factor:* 500 lb per square foot of heating surface per season.

For residences of the block type (not detached) where high-class heating service is required somewhat similar to apartment buildings. *Factor:* 550 lb per square foot of heating surface per season.

For apartment houses where high-class heating service is required. (Steam off at midnight). *Factor:* 650 lb per square foot of heating surface per season.

For hotels (commercial type) where very high-class service is required; 24-hour service. *Factor:* 800 lb per square foot of heating surface per season.

By assuming one square foot of equivalent heating surface for each 100 cu ft of space heated, which seems a fair ratio in New York City, it is possible roughly to estimate the steam required per cubic foot of space, information which is often more easily obtained than the square feet of heating surface. Considerable additional data on the heating requirements of various types of buildings in a number of cities may be found in the Handbook of the *National District Heating Association.*

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Chapter 23

AUTOMATIC TEMPERATURE CONTROL

Thermostats; Temperature Control Systems; Heating Plant Control; Zone Control; Control of Humidity; Industrial Process Control.

WHENEVER the maximum installed capacity of heating, ventilating and air conditioning equipment is not required, some method of limiting or controlling the output is desirable. This chapter contains information relative to the principles of operation of automatic temperature control systems, as well as data pertaining to the various devices available for the design of such systems. Additional information on this subject will be found in other chapters. Various types of control devices and systems are described in the Catalog Data Section of THE GUIDE.

Controls are applied for the following reasons:

1. To maintain conditions required for human comfort and efficiency.
2. To maintain conditions required for industrial processes.
3. To obtain economy in operation.
4. To provide necessary safety measures.

The proper operation of all control systems depends on the selection of the correct type of control instrument, as well as on its correct application within the complete system.

THERMOSTATS

Automatic control of temperature requires the use of an instrument known as a *thermostat* which responds to a change in temperature. Although there are many types of thermostats, the basic principles of operation of practically all types are included in the following classifications:

1. The *diaphragm* type (Fig. 1) which, by means of an expanding liquid or gas within a diaphragm or bellows, furnishes motion; and this motion may be mechanically transmitted in proportion to the rise and fall of temperatures surrounding the diaphragm.

2. The *direct-expansion* type (Fig. 2) which operates by direct expansion and contraction of a substance which has a high coefficient of expansion such as hard rubber. The slight movement of the thermostatic element usually must be multiplied through a system of levers.

3. The bi-metallic type (Fig. 3-a, b and c) which is actuated by means of two intimately attached metals having dissimilar coefficients of expansion. This type is inherently more sensitive to temperature changes than the diaphragm or direct expansion types, but lacks the necessary force to cause motion of the controlled equipment and must be used with compressed air, electric current or other source of power. The sensitive element may take any one of a number of forms, the most common being the

straight strip, the circular strip, the spiral and the helix. Fig. 3-a shows the straight strip used in a compressed air thermostat, Fig. 3-b shows the spiral used in a mercury tube type of thermostat, and Fig. 3-c shows the curved strip used in an open contact thermostat.

Direct-Acting and Indirect-Acting Thermostats

Thermostats may control directly, or indirectly, the equipment which regulates the supply of heat and are frequently classified on this basis as follows:

Direct-Acting or Self-Contained Thermostats. These instruments have sufficient power in themselves to actuate the controlling devices. They may be subdivided

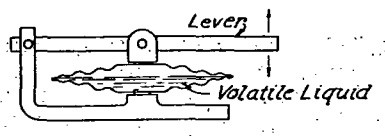


FIG. 1. DIAPHRAGM TYPE THERMOSTAT

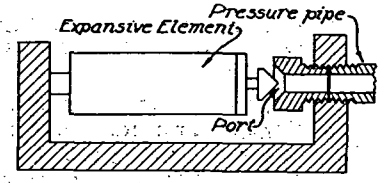


FIG. 2. DIRECT EXPANSION TYPE THERMOSTAT

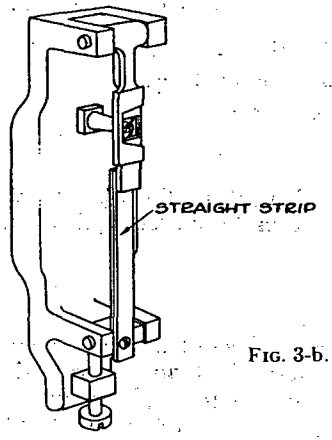


FIG. 3-a. STRAIGHT STRIP BI-METALLIC TYPE THERMOSTAT

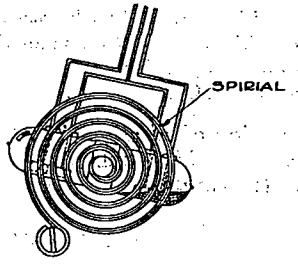


FIG. 3-b. SPIRAL BI-METALLIC TYPE THERMOSTAT

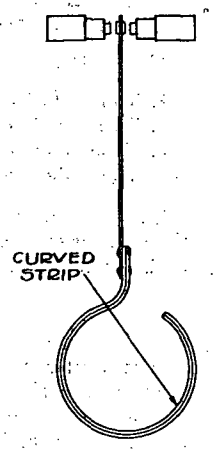


FIG. 3-c. CURVED STRIP BI-METALLIC TYPE THERMOSTAT

further into two groups: (1) those in which the sensitive element and the controlling device are in one body, the power from the thermostat being transmitted by a system of levers; and (2) those in which the sensitive element and the controlling device are separated, the power from the thermostat being transmitted through a capillary tube.

The expansion or volatilization of a fluid actuates a diaphragm which transmits its motion to a valve or damper. The small movement of the diaphragm may, if necessary, be multiplied and transmitted by mechanical means, such as a system of levers, or by liquid pressure in order to produce sufficient movement of the damper or valve. This thermostat is inherently intermediate acting since the expansion or volatilization of the fluid and movement of the diaphragm is proportional to the change in temperature.

There are many types of thermostatic radiator valves which come in the first group. In general they maintain some temperature at their location which bears a relation to the room temperature. Since these control devices are inherently intermediate acting, they should not be used on one-pipe systems because a partially closed valve will not allow the condensation to leave the radiator.

Fig. 4 shows the operation of a self-contained thermostat in connection with a hot water storage tank whereby the supply of steam to the tank is controlled directly by the temperature of the water in the tank. Fig. 5 shows the use of a self-contained thermostat on a hot water tank with vacuum return.

Indirect Acting Thermostats. These instruments do not have sufficient power to operate the controlling devices, but function to control the external source of power which in turn operates the valves and dampers. There are two distinct groups of these instruments, the *compressed air* and the *electric*.

Essentially the compressed air thermostat consists of a hole or leak port which is opened or closed by means of the thermostatic element. This port communicates with a diaphragm which in turn controls the supply of compressed air reaching the valve or

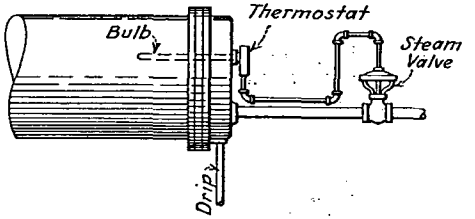


FIG. 4. SELF-CONTAINED THERMOSTAT IN HOT WATER STORAGE TANK

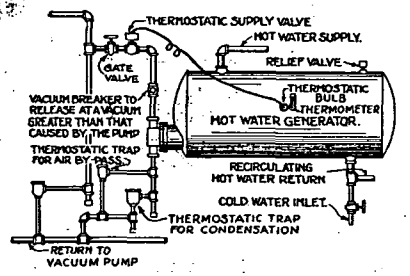


FIG. 5. SELF-CONTAINED THERMOSTAT ON HOT WATER TANK WITH VACUUM RETURN

damper operator. The instrument regulates the flow of the compressed air to and from the controlled devices. There are two classes of these instruments, one of which allows the air pressure to build up or be released instantly and is called the positive or snap-acting type; and the other which allows the compressed air to be maintained at any intermediate pressure called the intermediate or gradual-acting type.

The electric thermostat makes or breaks one or more electric circuits. In other words it amounts to an automatically operated switch which opens and closes circuits in response to the change in temperature. The controlled devices may be constructed to be positive or gradual acting.

There are many models of all of these thermostats which may be generally grouped as follows:

1. *Room Thermostats.* All thermostats which are designed to be used in a room to control the temperature within that area.

2. *Duct Thermostats.* These instruments are constructed so that the thermostatic element is in the air duct or chamber and the remainder of the instrument is on the outside of the duct. This type of thermostat is generally used to control the temperature of the air in various parts of ventilating and air conditioning systems.

3. *Two-Temperature Thermostats.* These instruments are used when it is desired to control at two distinct temperatures at different periods by means of a single thermostat. For example, a temperature of approximately 70 F may be desired during the day, while

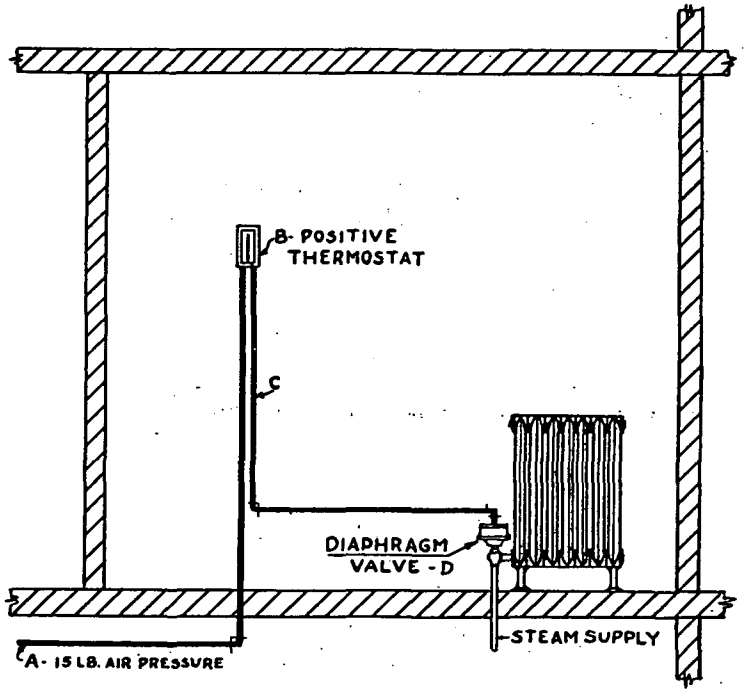


FIG. 6. CONTROL OF DIRECT RADIATOR WITH POSITIVE THERMOSTAT

some lower temperature is satisfactory during the night. Shifting from the high to the low temperature may be accomplished at some remote point by means of a clock or a manual switch.

4. *Clock Thermostats.* These instruments are arranged with clock mechanisms to maintain predetermined temperatures at predetermined hours, such as a low night temperature which may be automatically increased at a certain hour to the proper day temperature.

5. *Weather Compensating Thermostats.* These instruments control the temperature of a building with respect to the outdoor temperature. Two thermostatic elements, one of which is placed outdoors and the other attached to a radiator, are arranged so as to operate the supply of heat in conjunction with each other. The temperature of the radiator is thus decreased as the weather temperature rises. This system may control the temperature of hot water, the pressure on a steam boiler, the volume of steam supplied from outside the building, the amount of gas or oil fuel consumed or the operating rate of a coal stoker.

TEMPERATURE CONTROL SYSTEMS

The foregoing discussion has concerned the sensitive element of the thermostat and its work. The following pertains to the types of control used for (1) direct radiators, (2) unit heaters, (3) unit ventilators, and (4) central fan systems.

Direct Radiators

The control of rooms heated by direct radiators may be accomplished in several different ways. The problem is to control the heating units located at one or more points in or adjacent to the room. The circulation of air is not rapid, and the rate of temperature change usually is slow. The types of controls commonly used are: *first*, the direct-acting radiator valves with the thermostatic element at the valve, or at some adjacent point in the room and connected to the valve by means of a capillary tube; and *second*, the indirect-acting thermostat controlling either air or electri-

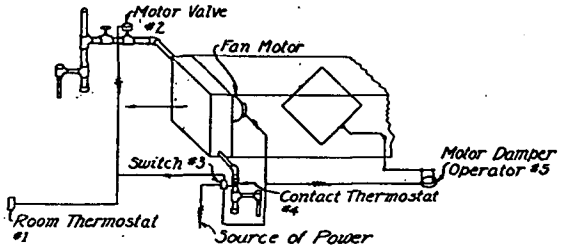


FIG. 7. ARRANGEMENT OF AUTOMATIC CONTROL FOR A UNIT HEATER

cally operated valves. Fig. 6 shows a radiator controlled by an indirect-acting thermostat.

Unit Heaters

Unit heaters present a different problem of control because the circulation within the room usually is different than with direct radiators. The simplest control is a thermostat which, directly or indirectly, will stop and start the fan motor to maintain the desired temperature, heat being supplied to the unit whether the fan is running or not. A more complete control is obtained if the valve on the heating coil is closed when the fan motor is stopped, and opened when the motor is started.

Fig. 7 shows an efficient control for a unit heater, taking into consideration all the factors which may arise. The room thermostat No. 1 calls for heat and passes electric current to motor valve No. 2, which operates, admitting steam to the heater. The same impulse from thermostat No. 1 also seeks to operate switch No. 3 and so to cause operation of the fan motor, but is prevented by contact thermostat No. 4 coiled around the return pipe of the heater. Thus unless the heater is warm its fan cannot operate and the ensuing cold drafts are avoided. As soon as the contact thermostat No. 4 becomes warm it permits operation of switch No. 3, starting the fan motor, and where desired also permits the motor

damper operator No. 5 to open the intake damper from outside. The fan always stops and the damper always closes when the heater is cold.

For additional information on the control of unit heaters, refer to Chapter 35.

Unit Ventilators

The unit ventilator presents a different control problem than the unit heater. Generally this type of unit draws its supply of air from the outside, heats it, and introduces this air into the room under control. There are many types of unit ventilators on the market. Some have a mixing damper by which the temperature of the air entering the room may be

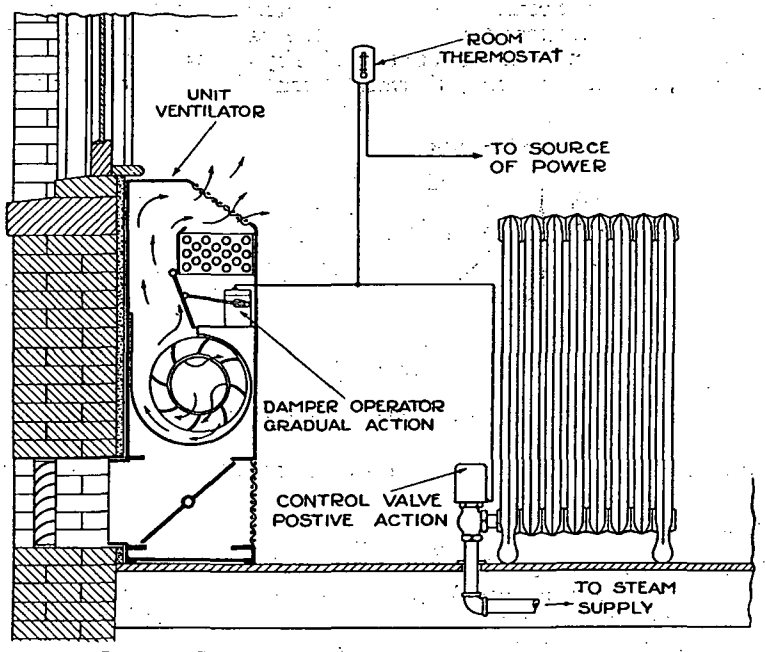


Fig. 8. Control of Unit Ventilator and Radiator

varied, others have valves for this purpose, and still others use a combination of the two. Regardless of the construction of the machine, the essential requirement is that the temperature of the air delivered to the room should change slowly and remain as near room temperature as possible. Frequently direct radiators are used in conjunction with the unit ventilators to supply additional heat in extremely cold weather or for quickly heating-up the room.

The four general types of control for unit ventilators are as follows:

1. A damper operator, the supply of power to which is controlled by a room thermostat, is attached to the mixing damper. When the thermostat calls for heat, the damper is moved to a position which forces more air through the heating unit and thus increases

the amount of heat supplied to the room. This action must be gradual so that the air temperature may be changed slowly to prevent the drafty condition caused by supplying first hot and then cold air.

2. In mild weather the heating unit frequently supplies sufficient heat to cause overheating of the room, even though all of the air is by-passed around the heating unit. To avoid this fault a valve is placed on the heating unit to close the steam supply when the damper is by-passing all of the air. This valve is used in addition to the damper operator explained in the foregoing paragraph.

3. In some unit ventilators one or more heating units and no mixing damper are used. A gradual-acting valve on each heating unit controls the supply of steam to the unit to give the proper amount of heat required to maintain the desired room temperature. A thermostat to govern each valve may be installed in the room or one thermostat may be used for all valves.

4. Another type of unit ventilator is arranged so that all recirculated air passes through the heating unit and the outside air is introduced into the room for cooling purposes only. The outside air damper and the recirculated air damper are interlocked

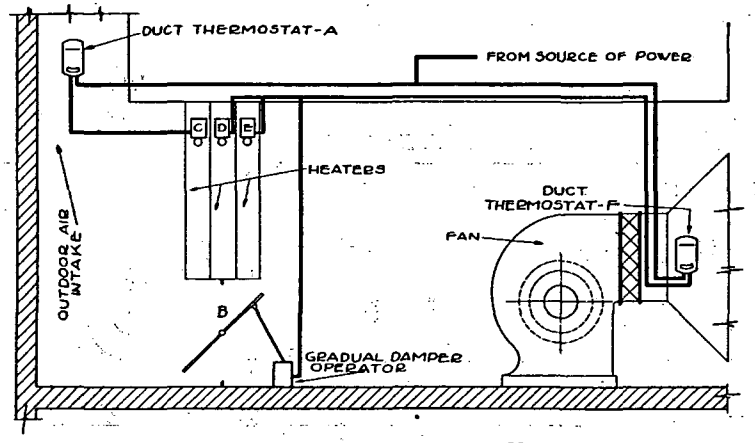


Fig. 9. Control of a Split System of Ventilation

so that one damper operator will control them. In addition a valve operator is placed on the heating unit. Both of the operators should be gradual to avoid drafty conditions. When the thermostat calls for heat, the damper operator slowly closes the outside air damper and opens the recirculating damper simultaneously; if this does not meet the demand, the valve on the heating unit opens until the room temperature reaches the desired point.

Fig. 8 shows a unit ventilator which may or may not be used in conjunction with a direct radiator. It is generally considered advisable to shut off the steam to the direct heating surface, if any, first, so that the control system will allow the unit ventilator to supply the full heating requirement where possible. For additional information on the control of unit ventilators, refer to Chapter 36.

Central Fan Systems

The numerous types of central fan systems present many control problems. In general they all have one point in common, namely that the temperature change may be very fast due to rapid circulation.

System for Ventilating Only (Split System). Fig. 9 shows an accepted

control for ventilating systems. Thermostat *A* located in the outside air duct set just above freezing, controls a valve *C* on the first heating coil. This valve is either completely open or completely closed. The by-pass damper *B* and the other two valves *D* and *E* are controlled by a duct thermostat *F* located in the discharge duct from the fan. If the temperature of the air surrounding the thermostat *F* increases, the damper is moved to admit more cold air. Should this not reduce the temperature sufficiently, the valves on the heating coil will be closed gradually and in sequence until the correct temperature is reached. The opening or closing of the damper *B* and the valves *D* and *E* must be gradual or there will be a wide fluctuation in air temperature.

In ventilating systems it is customary to supply air to the ventilated spaces at an inlet temperature approximately equal to the temperature maintained in the rooms. The radiators therefore are designed to take

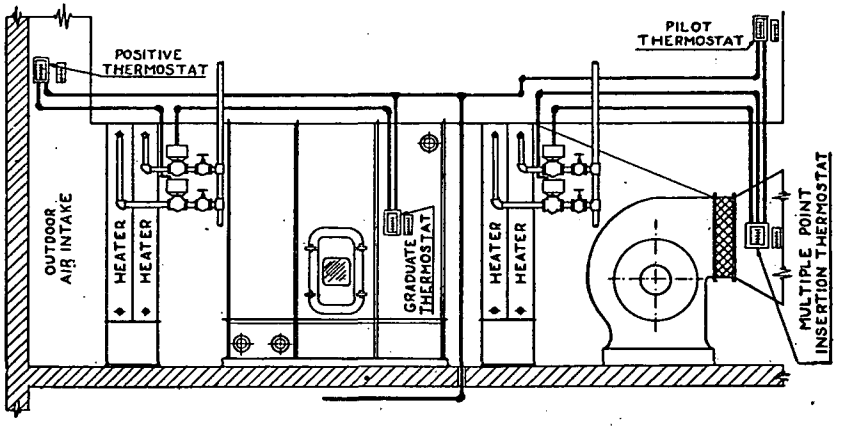


FIG. 10. USE OF PILOT THERMOSTAT ON VENTILATING SYSTEM WITH AIR WASHER

care of all the heat losses from the room. Hence, in order to maintain controlled room temperatures it is further necessary to use room thermostats governing control valves placed on the radiators. With this type of central fan system it is possible to ventilate a large number of rooms by means of one fan.

In some installations, such as in theaters or auditoriums, it is difficult to install sufficient direct heating surface to offset the heat losses from the room. Also there are installations where a short heat-up period is allowed before occupancy of the room, and it is advisable to use the entire heating capacity of the ventilating system for this purpose. Systems of this type have, in addition to the control described in Fig. 9, a pilot thermostat located in the room to be heated or in the path of air withdrawn from that room. This thermostat is set for the temperature required in the ventilated space and controls the supply of power to the thermostat *F* located in the fan discharge controlling the damper *B* and the heating units *D* and *E*.

When the temperature of the air in the room is below the setting of the pilot thermostat, the control is such that the by-pass damper *B* is closed and the valves on the heating coils are open. Thus the maximum heating capacity is available to bring the room temperature to the desired point. When the room temperature reaches the setting of the pilot thermostat, the control of the air temperature is returned to the thermostat *F* in the fan discharge. The fan discharge thermostat, therefore, serves as a minimum temperature control and prevents introduction of air at temperatures which would produce drafts or faulty air distribution. Accurate control of room temperature is accomplished in this manner, but the system can not well be used where more than one room is supplied with air from a single fan.

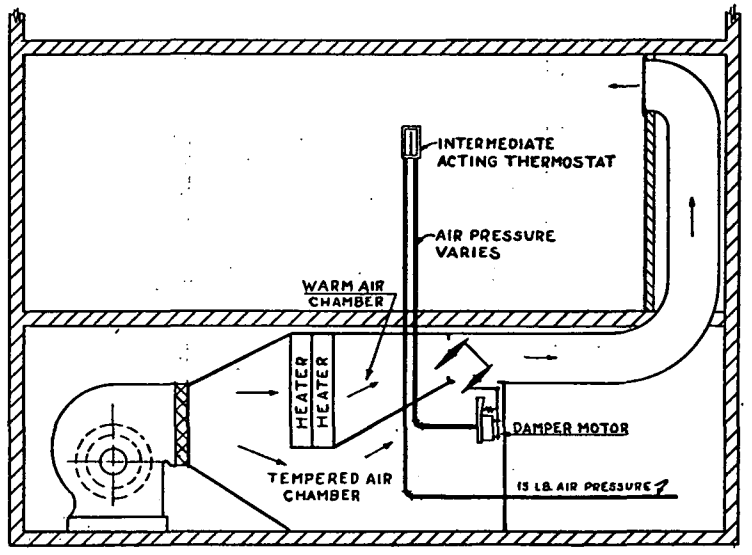


FIG. 11. CONTROL OF MIXING DAMPERS WITH INTERMEDIATE ACTING THERMOSTAT

In central fan systems, air washers are often used and in such cases, due to the effect of temperatures on humidity, additional control is required. Fig. 10 shows such an arrangement with control of the second tempering heating unit from the air washer temperature and with the usual control of the first tempering heating unit from the outside temperature. This permits the air to be kept cool while passing through the washer so that too much moisture will not be absorbed. Fig. 10 also shows control of the re-heating units from a duct thermostat in the fan discharge and the application of a pilot thermostat to a system of this sort.

Combined Systems. There are various central fan systems which are used for both heating and ventilating. They are usually arranged with tempering heating units, automatically controlled to provide a minimum temperature for ventilating only, and additional heating units to supply

the heating requirements. Fig. 11 shows a type of system which has the reheating units located in the fan room. Tempered air at about 70 F is supplied to the fan and may be further heated by the reheating units or pass into the tempered air chamber. A room thermostat controls a gradual-acting damper operator on the double mixing damper in the warm and tempered air chambers. When the thermostat calls for heat, the damper operator moves the dampers so that more air is taken from the warm air chamber. It is essential that the double mixing damper be moved slowly to prevent alternate blasts of hot and cold air from being supplied to the room.

Outside Air, Recirculating and Vent Dampers. In all types of plenum systems, the outside air damper is usually opened and closed by a damper operator. This operator may be controlled from a switch in the engi-

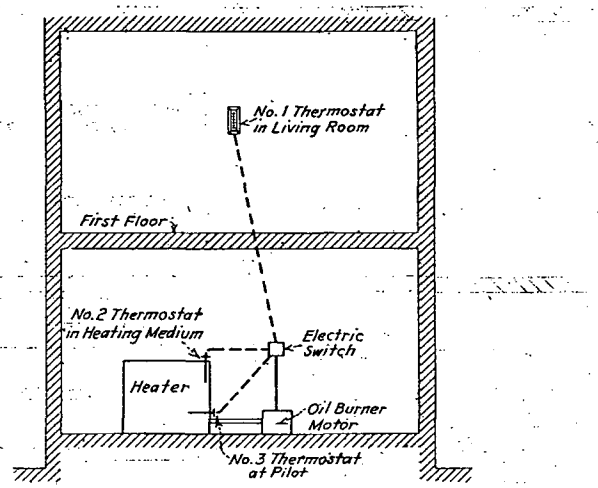


FIG. 12. ELECTRIC THERMOSTAT APPLIED TO OIL FIRED HEATING SYSTEM

neer's room or it may be operated by a relay in the fan motor circuit. When the ventilating fan is started, the relay causes the damper operator to open the outside air damper.

Recirculating dampers and vent dampers may also be opened and closed by means of damper operators controlled from remote locations. Generally these damper operators are positive acting and are either completely opened or closed. However, in some cases where part outside air and part recirculated air is used, it is advantageous to use damper operators which have a certain number of definite positions. With this type of operator it would be possible to use 75 per cent outside air and 25 per cent recirculated air, or any other proportions which might be predetermined. These damper operators are controlled from switches generally mechanically interlocked so that the total opening of the two dampers is 100 per cent.

CONTROL OF SMALL HEATING PLANTS

In small buildings the heating plant may be controlled by a single thermostat located in a key room in the building, instead of each room having its own control.

The most common control for a hand fired furnace or boiler consists of a room thermostat and a furnace regulator of some type. The thermostat should be located in a representative room; never, of course, near the chimney or heat flue, too close to a radiator, nor in a drafty hallway, and preferably on an inside wall. The regulator is attached to the draft and check dampers of the furnace. When the temperature of the air surrounding the thermostat drops, the thermostat causes the furnace regulator to open the draft and close the check damper. As soon as the room comes up to temperature, the draft is closed and the check damper opened. With this arrangement on hot water heating systems it is

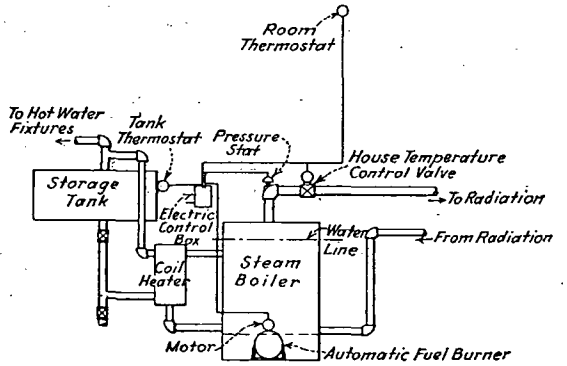


FIG. 13. TYPICAL ARRANGEMENT OF STEAM OR VAPOR SYSTEM WITH TWO THERMOSTATS CONTROLLING AUTOMATIC FUEL BURNER USED FOR HOUSE HEATING AND WATER HEATING

advisable to install an immersion thermostat in the boiler. This thermostat should be connected with the room thermostat so that both must call for heat before the draft is opened, but either one may cause the draft to be closed. On warm air systems it is advisable to use a bonnet thermostat and on steam heating systems a pressure limiting device, in series, in each case, with the room thermostat. If the temperature of the heating medium becomes too high, the drafts will be closed even though the room thermostat continues to call for heat.

It is essential that automatic temperature control be used with oil burners, gas burners, and stokers to aid economical operation. There are many types of burners and many types of control, but there are some points common to all. First, a room thermostat is located in a key position in the building to maintain a given temperature at that point. Safety devices are installed in connection with this thermostat so that a failure of the ignition, power, or fuel supply, will shut the system down. The same limit controls as recommended for coal burning should be used.

Fig. 12 illustrates diagrammatically the essentials of an oil burner control circuit. Three thermostats are employed as shown in the illustration. Thermostat No. 1 will stop the burner when the room temperature is too high and No. 2 will stop the burner when the temperature of the heating medium exceeds the setting of thermostat No. 2. Both temperatures must be below their respective thermostat settings to start the burner. Thermostat No. 3 responds to the flame temperatures and in conjunction with the control switch acts as a safety to stop the burner if the latter fails to ignite or burn properly as demanded by thermostats Nos. 1 and 2.

Steam and hot water heating plants are often used to provide heat for the domestic hot water supply as well as for heating the building. Fig. 13 illustrates one such system. The burner control is similar to that shown in Fig. 12 except that either the room thermostat or the tank thermostat may cause the opening of the valves in the mains which supply them and start the fuel burner, but the burner will not stop unless both thermostats have closed their valves or the steam pressure shall have reached that allowed by the pressurestat. Much the same control is applied to gas burners and automatic coal stokers.

ZONE CONTROL

Zone control is a step between a single thermostat and individual room temperature control. The building is first divided into sections or zones which may have quite different heat requirements. With this method of control:

First: The zoning should be done with reference to the compass, since the north and west quarters in most localities require considerably more heat during the heating season than do the south and east quarters.

Second: Most large office buildings have more or less space occupied by merchants, and some by clubs, restaurants, etc., which have short hours of occupancy. Much can be accomplished in zoning with reference to the kind of occupancy of space.

INDUSTRIAL PROCESS CONTROL

There are many industrial processes requiring automatic temperature and humidity regulation. The control equipment operates on the same principles that have been described, but is often specially designed for each particular process. Each installation, or the installation for each process, is likely to be a problem peculiar to that process.

Chapter 24

VENTILATION OF PUBLIC BUILDINGS

Ventilation Systems; Objects of Ventilation; Air Quantities; Exhaust Openings; Other Factors Affecting Ventilation; Recirculation; Inside Temperatures; Drafts; Psychological Aspects; Heat Required for Ventilation; School Room Ventilation.

THE original meaning of the word *ventilation* was merely that of air change; *to ventilate* meant to displace the air within a building or other enclosure, by outside or unvitiated air. However, as the art of creating and maintaining satisfactory conditions indoors has progressed, ventilation has come to mean more than the mere displacement of air, and as far as humans are concerned, involves the maintenance of conditions considered essential to the comfort and health of the occupants, which is usually termed air conditioning, and which is treated in Chapter 28. The present chapter is devoted to a discussion of the ventilation of public buildings in the original sense of air change.

VENTILATING SYSTEMS

Ventilating systems are classified as *natural* and *mechanical* according to the motive forces by which air change is brought about. Information concerning the design of mechanical exhaust systems of ventilation for industrial buildings is given in Chapter 25. Natural ventilation is treated in Chapter 26. Central fan systems of heating and/or ventilation for public and industrial buildings are covered in Chapter 31, whereas unit ventilators for schools and public buildings are discussed in Chapter 36. When, in the case of mechanical ventilation, the heating is accomplished with radiators separate from the ventilating equipment, it is called a *split* system. If the ventilating equipment also provides for the heating, it is a *combined* system.

OBJECTS OF VENTILATION

The primary objects of ventilation are (1) to supply the necessary oxygen for respiration, (2) to remove odors, (3) to remove toxic, poisonous or harmful substances, and (4) to remove the heat and moisture given off by the occupants and the heat given off by power and lighting equipment, particularly in warm weather.

Air for Respiration. A comparatively small quantity of air is required to take care of the needs of the lungs. An adult at rest breathes about 0.25 cu ft of air per minute and exhales about 0.01 cu ft of CO_2 in the same period, or at the rate of 0.6 cu ft per hour, thus removing about 4 per cent of the oxygen from the air actually breathed. This does not necessarily

indicate the effect on the air in the room occupied. The same air may be rebreathed for a considerable time without apparent harmful effects. However, the average carbon dioxide content of a room should at no time during occupancy be permitted to exceed 16 parts in 10,000 parts of air.

Removal of Odors. Body odors are repulsive and offensive and should be removed by the ventilating system. Odors such as come from cooking, tobacco smoking, toilet and locker rooms and laundries, even though they may eventually become tolerable and unnoticeable, should be minimized.

Removal of Harmful Substances. The removal of harmful or injurious substances from various sources of contamination is frequently of considerable importance. Exhaust systems for dust and refuse created in industrial operations are treated in Chapter 25.

Heat and Moisture. Whenever human beings are present in closed quarters the products of respiration from the lungs, together with the heat and water vapor from the skin are given off directly into the surrounding air. A comparatively large quantity of air is required for this purpose.

In a crowded place of assemblage the heat given off by the occupants, together with that given off by the lighting and power equipment, may be more than the normal heat loss through the structure even in winter under cold climatic conditions. A typical case for winter might show about 300 Btu of body heat, plus 100 Btu per person from light, etc., being given up to the building against about 200 Btu heat loss from the building, per person per hour. This would mean that 200 Btu per person must be carried away by the ventilating system.

It may be that the moisture given off by occupants or by processes will increase the relative humidity to such an extent as to cause discomfort to occupants or interfere with the processes, due to condensation; and the ventilation system must provide for such conditions.

AIR QUANTITIES

There are three standards upon which air quantities may be based, namely (1) bodily heat removal, (2) maintenance of natural ionic content, and (3) elimination of body odors and bacteria.

The most logical basis is that of bodily heat removal in which the temperature rise of the air due to the addition of heat from the bodies of occupants, disregarding other sources of heat, does not exceed a predetermined number of degrees when the full volume available is taken from the outside. Each person at rest gives off about 5 Btu of sensible heat per minute at 70 F. This is sufficient to raise 277 cu ft of air one degree per minute. If a 10-deg rise is allowable, then 27.7 or say 28 cfm per person would be required. If other heat sources are considered, the quantity of air required would be more than 28 cfm. This apparently justifies the *arbitrary assumption* of 30 cfm per person which has been used for many years and which is probably satisfactory for ordinary air change requirements where the removal of bodily heat is the primary consideration.

The air quantities given in Table 1 are stated in terms of square feet of floor area and are based on the 30-cfm-per-person assumption with

allowance for the maximum density with which the ventilated spaces would be occupied. For air conditioning problems a more exact determination should be made in accordance with the data given in Chapter 28. Body odors can be removed with as low as 7½ cfm per person, whereas between 7½ and 10 cfm per person is usually ample for chemical requirements.

Natural ventilation is usually permissible when the following requirements are met:

1. At least 50 sq ft of floor area for each occupant of the room.
2. At least 500 cu ft of air space for each occupant of the room.
3. Effective openings in windows and/or skylights equal to at least 5 per cent of the floor area.

TABLE 1. QUANTITY OF AIR REQUIRED FOR VENTILATION BASED ON SQUARE FEET OF FLOOR SPACE

TYPE OF BUILDING	ROOM	CU. FT. OF AIR PER MINUTE PER SQUARE FOOT OF FLOOR AREA
SCHOOLS	Classrooms	2.0
	Assembly Rooms	1.5
	Gymnasia	1.5
	Picture Machine Booths	1.5
	Dining Rooms	1.5
	Kitchens	2.0
	Corridors	0.5
	Wardrobes and Lockers	2.0
	Toilet, Bath, etc.	2.0
THEATERS	Seating Spaces	2.0
	Toilets, etc.	2.0
	Picture Machine Booths	2.0
HOTELS	Assembly Rooms	2.0
	Dining Rooms	1.5
	Kitchens	4.0
HOSPITALS	Wards	1.0
	Dining Rooms	1.5
	Toilets	2.0
	Kitchens	4.0

In all other cases, a positive means of ventilation should be provided which will introduce into the space or spaces of occupancy at least 0.6 cu ft of air per minute for each square foot of floor area or 30 cu ft of air per minute for each occupant (whichever is the greater). Each such positive ventilating system should be capable of taking the full quantity of air to be circulated from an outside uncontaminated source and of venting, discharging or exhausting a corresponding quantity of room air to the outside.

Special Requirements

The air supply and exhaust for toilets and chemical laboratories should be entirely separate from any other air supply or exhaust system, and should remove at least 2 cu ft of air per minute for each square foot of floor area or at least ⅙ of the volume of the space every minute (which-

ever is the greater) during occupancy. Likewise, locker rooms, wardrobes, shower rooms and swimming pools should be provided with at least 2 cu ft of air per minute for each square foot of floor area.

The air supply or exhaust for kitchens should be entirely separate from any other supply or exhaust system and should remove at least 2 cu ft for occasionally used kitchens and 4 cu ft for commercial kitchens for each square foot of floor area every minute during occupancy and use. This air removal volume should be not less than a complete air change every ten minutes for occasionally used kitchens and a complete air change every five minutes for commercial kitchens.

In some codes for compulsory ventilation of rooms a credit is allowed for the air which may leak in or out through openings such as operatable windows and doors. It is conceivable that if there are many such openings, properly located so as to permit air movement from them across the room, no other ventilation need be supplied. There are, of course, many rooms which have operatable closures on these openings but which have all of the openings on but one side, and which therefore are not as effective for ventilating purposes as when they are on opposite sides of the room.

There are openings having closures of such types as to be unsatisfactory for ventilating purposes, particularly windows having center pivots vertically above each other so that sun shades are constantly involved, and through which the rain and snow may enter when opened only a trifle. Openings in skylights are not satisfactory unless they are used in connection with windows and doors and should be given no credit against the air change requirement unless they are in rooms which have accredited side wall openings.

EXHAUST OPENINGS

Outlets from buildings should never *look* out through a vertical wall, because in the winter the wind is likely to stop or reduce greatly the outflow of the much lighter warm rejected air. Outlets from low buildings will reverse and will cause trouble if close to a more lofty building, despite the presence of fans in the circuit, since the wind when blowing against the wall will *mushroom* in all directions and often will create a pressure sufficient to prevent egress of air. The most effective ventilation outlet is an open-top chimney, as many ventilator hoods interpose resistance to air flow roughly proportional to their effectiveness in keeping out rain and snow.

OTHER FACTORS AFFECTING VENTILATION

The location and the type of heat-losing and heat-gaining surfaces in a room affect the ventilation of the room, since heating units cause local up-drafts and open windows and cool walls cause down-drafts. Rooms which have ceiling radiators usually have cool floors, if no mechanical circulation is provided. Mechanical ventilation therefore reduces stratification in such cases.

RECIRCULATION

The saving in operating costs obtainable by recirculation of the air in ventilation systems, while very considerable, must not be obtained at the

expense of air quality. At no time during occupancy should there be taken from out of doors less than 10 cu ft of air per minute for each occupant. The percentage of recirculated air may be varied to suit the seasonal changes so as to conserve heat in winter and refrigeration in summer. Where recirculation is employed the problem is primarily one of air conditioning, because of the necessity for controlling the physical properties and quality of the air.

Toilets and similar rooms and all kitchens in buildings using recirculation should be separately, mechanically ventilated, with the exhaust in excess of the supply, in order to prevent objectionable odors from diffusing into other parts of the building. This air removal may in many cases be sufficient to insure an adequate replacement of outside air to the general recirculating system. For additional information on recirculation, refer to Chapter 28.

DRAFTS

Air velocities that are noticeable may be a very serious menace to health under certain conditions. The air coming in contact with the occupants of a room should not exceed a velocity of 50 fpm as measured with a Kata thermometer.

When using an upward system of air supply, as through floor mushrooms, or an air supply from the side, so as to bring the incoming air directly into contact with the occupant, drafts may result from the introduction of air at temperatures slightly cooler than the average room temperature. For this reason, the downward system of air distribution is more often used in large and densely occupied places of assemblage. (See Chapter 32). The air should be brought in at a point high enough to permit of its being diffused before coming into contact with the occupants. Under such conditions the temperature difference may be considerably greater with a resulting decrease in volume of air handled.

HEAT REQUIRED FOR VENTILATION

The heat required to warm the outside air introduced for ventilation purposes (H_v) must be added to the normal heat losses of the building and may be determined by means of the following basic formula:

$$H_v = 0.24(t - t_o)\, W_v$$

where

0.24 = specific heat of air at constant pressure.
t = room temperature.
t_o = outside temperature.
W_v = weight of air to be introduced per hour in pounds = $Q_v d$
Q_v = volume of air to be introduced, cubic feet per hour.
d = density of air = 0.075 at 70 F.

Example. A building in which the temperature to be maintained is 70 F, requires 10,000 cfm. If the outside temperature is − 10 F, how much heat will be required to warm the air introduced for ventilation purposes to the room temperature?

Solution. $Q_v = 10{,}000 \times 60 = 600{,}000$ cfh. $d = 0.075$. $W_v = 0.075 \times 600{,}000 = 45{,}000$ lb. $t = 70$ F. $t_o = -10$ F. $H_v = 0.24 \times [70 - (-10)] \times 45{,}000 = 865{,}000$ Btu per hour.

SCHOOL ROOM VENTILATION[1]

The entire field of ventilation presents no more important problem than the adequate and satisfactory ventilation of the average school room occupied for approximately six hours of the day by a class of 40 pupils and a teacher. Any attempt to place the responsibility for the control and regulation of the heating and ventilating system on the teacher is of dubious value, when it is considered that, with constantly changing outside temperatures and winds, no possible adjustment of window openings can be correct for any length of time even for a given room. Considering the building as a whole, it is apparent that rooms on the windward side are always subjected to pressure, while those on the leeward side are subjected to suction whenever an appreciable wind is blowing. Outside air will readily enter the open windows of the former rooms, but inside air will pass out of the open windows of the latter rooms, so that open window ventilation under windy weather conditions can be applied to only one-half of the building at best. The leeward half has to take the *drift* of the air from the rooms of the other half.

It would appear that a mechanical system designed on the basis of the present knowledge of the essential factors as outlined in Chapter 28 is, in most cases, the best present solution of this problem, if complete and positive automatic control of the proper air conditions in a school room is to be accomplished.

Studies of school room ventilation made by the New York State Commission on Ventilation[2] (1913-17) and continued by the New York Commission on Ventilation[3, 4, 5, 6] (1926-29) originally attributed differences in the rate of incidence of respiratory illness to the kind of ventilating systems used. However, a later report,[7] which includes studies of the influences of previously uncompensated variables such as race, age, sex, social and economic status, distance pupils had to walk to school, and the inability of various observers to diagnose respiratory diseases consistently, announces the important conclusion that respiratory illness does not constitute a satisfactory criterion for judging the effects of air conditions on the health of school children.

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[1] *See School Room Ventilation*, by A. C. Willard, *Heating, Piping and Air Conditioning*, September, 1929.

[2] *Ventilation, Report of the New York State Commission on Ventilation*, 1923.

[3] *Effects of Mechanical and Natural Ventilation on the Health of School Children*, by T. J. Duffield (A.S.H.-V.E. TRANSACTIONS, Vol. 34, 1928).

[4] *A Study of Ventilation and Respiratory Illness in Syracuse Schools*, with an Analysis of Factors Affecting Criteria Used, by Rufus Cole, et al (*The American Journal of Hygiene*, Vol. 12, 1930, p. 196).

[5] *A Study of Ventilation and Respiratory Illness in Syracuse Schools;* Rate of Air Flow and Room Temperature in Relation to the Health of School Children, by Rufus Cole, et al (*American Journal of Hygiene*, Vol. 12, 1930, p. 215).

[6] *A Study of Ventilation and Respiratory Illness in New York Schools; Comparison of Window-Gravity Ventilation and of Unit Fan Ventilation with Varying Air Flow*, by Rufus Cole, et al (*Ibid.*, Vol. 13, 1931, p. 235).

[7] *The Principles of School Ventilation—A Review of Recent Experimental Work and the Consensus of Scientific Opinion at the Present Time*, by T. J. Duffield (*The Aerologist*, April, 1930).

Chapter 25

VENTILATION OF INDUSTRIAL BUILDINGS; EXHAUST SYSTEMS

Requirements of Efficient System; Design of Exhaust Systems; Typical Layout and Calculations; Selecting the Fan; Collectors; Design of Hoods; Conveyor Pipes; Maintenance of System; Clothing Factory Pressing Rooms; Cold Storage Warehouses; Lacquer Spray Booths.

VENTILATION (air change) as applied to industrial buildings, factories, etc., is used mainly for the purpose of removing excessive heat, objectionable odors and injurious substances. Data concerning the deleterious effects on the human body of these factors are given in Chapter 28. The removal of heat frequently is accomplished by means of natural ventilation (see Chapter 26), although in many cases mechanical means are necessary. The removal of injurious substances usually is obtained by mechanical exhaust systems.

When air conditioning is applied to industrial buildings, it is done so in most cases to control some manufacturing process as outlined in Chapter 29, but occasionally it is used solely to maintain conditions considered essential to the comfort, health and efficiency of the workmen. It often happens, however, that the conditions best suited to a certain manufacturing process are also ideal from the standpoint of comfort and efficiency.

This chapter contains information on mechanical exhaust and collecting systems. The exhausted air and refuse is, of course, replaced by an equal amount of *fresh* air through openings in the building construction. If the exhaust system efficiently removes the objectionable substances, the air which replaces the exhausted air, if it comes from an uncontaminated source, is more than sufficient, in most cases, to adequately ventilate the building.

TYPES OF EXHAUST SYSTEMS

There are two general arrangements, the central and the group systems. In the central system a single or double fan is located near the center of the shop with a piping system radiating to the various machines to be served. In the group system, which is sometimes employed where the machines to be served are widely scattered, small individual exhaust fans are located at the center of the machine groups. The group arrangement has the advantage of flexibility.

Exhaust systems are also classified by the means employed to collect dust or other material handled. The dust or refuse may be collected and

controlled by enclosing hoods, open hoods, inward air leakage or by exhausting the general air of the room.

With some classes of machinery it is not feasible to closely hood the machines and in these cases open hoods over or adjacent to the machines are provided to collect as much as possible of the dust and fumes. This class includes such machines as rubber mills, package filling machinery, sand blast, crushers, forges, pickling tanks, melting furnaces, and the unloading points of various types of conveyors.

The open hoods should be placed as close to the source of dust or fumes as possible, with due regard to the movements of the operator. When the hood has to be placed at some distance above the machine it should be large enough to encompass an area of considerable extent as diffusion is usually quite rapid.

Consideration must also be given to the natural movement of the fumes. For those that are lighter than air the hood should be over or above the machine and where a heavy vapor or dust-laden air at ordinary temperature is to be removed, horizontal or floor connections are required. If it is attempted to remove heavy dust such as lead oxides by an overhead hood the conditions may be worse than if no exhaust were used at all, owing to the rising air current carrying the dust up through the breathing zones. The principle to keep in mind in all cases is to take advantage of the natural tendency of the material to move upward or downward.

In another class of operation the main object is to prevent the escape of dust into the surrounding atmosphere, the removal of some dust from the machine or enclosure being merely incidental. The dust-creating apparatus is enclosed within a housing which is made as tight as practicable, and sufficient suction is applied to the enclosure to maintain an inward air leakage, thus preventing escape of the dust. While the exhaust system is only required to handle the air which leaks in through the crevices and openings in the enclosure, yet in many installations leakages are very high and great care is required to obtain satisfactory results with a system of this kind. The inward-leakage principle is utilized for controlling dust in the operating of tumbling barrels, grinding, screening, elevating and similar processes.

Certain dust and fume producing operations are best carried on by isolating the process in a separate compartment or room and then applying general ventilation to this space. The compartment or room in which the work is performed should be as small as is consistent with convenience in handling the work. The ventilating system should be designed so that a strong current of clean air is drawn across the operator, and away from him toward the work, where the dust is picked up and carried from the room.

REQUIREMENTS OF EFFICIENT SYSTEM

The most important requirements of an efficient exhaust and collecting system are as follows:

1. Fans, collectors, hoods, and ducts should be of adequate size.
2. Air volume and velocities should be adequate for the work to be accomplished.

3. The exhaust hoods should not interfere with the operation of the machine or with access to its working parts.
4. The system should not increase the fire hazard.
5. The system should not increase the dust explosion hazard.
6. Where power is expensive, it should do the required work with a minimum power consumption.
7. In cold climates, it should not remove any more air than necessary from the building.
8. Where power is comparatively cheap, first cost should be low, even if the power required to operate is slightly higher.

DESIGN OF EXHAUST SYSTEMS

The first step in designing systems employing hoods to trap the material is to determine the number and size of the connections for each individual machine. At this point the designer's past experience is of great value, as, while it is possible to set certain general standards, yet in actual practice the sizes are considerably affected by the local conditions which the layout man finds in the field, and he bases the pipe sizes and hoods on his judgment, being guided by his experience and the general practice.

The size of hoods and connections are determined by the size and type of machines or apparatus to be handled by the exhaust system, by the kind of material worked, by the duty of the machines and by other local conditions. It is impracticable to lay down any general rules for determining size connections for the various types of machines and Tables 1 to 3, giving sizes as used in some of the common industries are only intended to serve as a general guide. Under certain favorable conditions smaller connections may be supplied.

Open bottom exhaust hoods of the canopy type, where it is impractical to enclose completely the point of origin of the dust or fumes, should extend over the machine or operation at least 12 in. in every direction if the hood is not elevated more than 2 ft. For each additional 2 ft of elevation, the size of the hood should be increased at least 12 in. in all directions.

It is desirable to make the area of the connecting pipe not less than one-fifteenth of the total hood area.

In systems employing inward air leakages the area of connections must be proportional to total leakage area in the enclosing housing.

Tumbling barrels have connections ranging from 4 to 8 in., bucket conveyors 6 to 12 in., and screening machines 6 to 10 in.

In general room exhaust, large connections should be provided so that the air may be handled at low velocity and with a minimum power consumption.

Air Velocities Required

After having determined on the proportions of the exhaust system as regards hoods and connections it is then necessary to choose the air velocity or suction at the hood connections; suction at the hood connections being a measure of the air velocity at that point.

The air velocity required is dependent upon the specific gravity of the material, the fineness of the particles, and their physical characteristics.

TABLE 1. SIZE OF CONNECTIONS FOR WOOD-WORKING MACHINERY

TYPE OF MACHINE	DIAMETER OF CONNECTIONS IN INCHES
Circular Saws, 12-in. diam.	4
Circular Saws, 12-24-in. diam.	5
Circular Saws, 24-40-in. diam.	6
Band Saws, Blade under 2 in. wide	4
Band Saws, Blade 2-3 in. wide	5
Band Saws, Blade 3-4 in. wide	6
Band Saws, Blade 4-5 in. wide	7
Band Saws, Blade 5-6 in. wide	8
Small Mortisers	6
Single End Tenoners	6
Double End Tenoners	7
Double End, Double Head Tenoners	10
Planers, Matchers, Moulders, Stickers, Jointers, etc.—	
With Knives, 6-10 in.	5–6
With Knives, 10-20 in.	6–8
With Knives, 20-30 in.	6–10
Shapers, Light Work	4–5
Shapers, Heavy Work	8
Belt Sander, Belt less than 6 in. wide	5
Belt Sander, Belt 6-10 in. wide	6
Belt Sander, Belt 10-14 in. wide	7
Drum Sander, 24 in.	5
Drum Sander, 30 in.	6
Drum Sander, 36 in.	7
Drum Sander, 48 in.	8
Drum Sander, over 48 in.	10
Disc Sander, 24 in. diam.	5
Disc Sander, 26-36 in. diam.	6
Disc Sander, 36-48 in. diam.	7
Arm Sander	4

TABLE 2. SIZE OF CONNECTIONS FOR GRINDING AND BUFFING WHEELS

DIAMETER OF WHEELS	MAX. GRINDING SURFACE SQ. IN.	MIN. DIAM. OF BRANCH PIPES IN INCHES
Grinding—		
6 in. or less, not over 1 in. thick	19	3
7 in. to 9 in., inclusive, not over 1½ in. thick	43	3½
10 in. to 16 in., " " " 2 in. "	101	4
17 in. to 19 in., " " " 3 in. "	180	4½
20 in. to 24 in., " " " 4 in. "	302	5
25 in. to 30 in., " " " 5 in. "	472	6
Buffing—		
6 in. or less, not over 1 in. thick	19	3½
7 in. to 12 in., inclusive, not over 1½ in. thick	57	4
13 in. to 16 in., " " " 2 in. "	101	4½
17 in. to 20 in., " " " 3 in. "	189	5
21 in. to 27 in., " " " 4 in. "	338	6
27 in. to 33 in., " " " 5 in. "	518	7

Certain materials such as grease wools, silk waste, salt, and other hydroscopic substances are difficult to handle due to the tendency to deposit in the conveyor pipes.

While the velocity in the system should be sufficiently high to insure the removal of the material, it should be kept as low as practicable since any higher velocity requires the use of unnecessary power. With a fixed system or orifice the power increases as the cube of the increase in velocity; or for the same quantity of air and material handled, inversely as the fifth power of the diameter of round ducts.

Velocities commonly employed are: 2,500 to 3,000 fpm for light dusts, cotton, shavings and sawdust from dry wood, and similar substances. Heavy dusts, wool, shavings and sawdust from wet wood, rags, waste paper and similar materials, 3,000 to 4,000 fpm. Lead dust, hog waste, pulp chips, etc., 4,000 to 6,000 fpm.

TABLE 3. SUCTION PRESSURES REQUIRED AT HOODS FOR CONNECTIONS OF USUAL PROPORTIONS

	STATIC SUCTION IN INCHES OF WATER
Exhausting from grinding and buffing wheels	2
Exhausting from tumbling barrels	2
Exhausting from wood-working machinery—light duty	2
Exhausting from wood-working machinery—heavy duty	2–4
Shoe machinery exhaust	2–3
Exhausting from rubber manufacturing processes	2
Flint grinding exhaust	2
Exhausting from pottery processes	2
Lead dust and fume exhaust	2–4
Fur and felt machinery exhaust	2–3
Exhausting from textile machinery	2–3
Exhausting from elevating and crushing machinery	2
Conveying bulky and heavy materials	3–5

In choosing the pipe sizes consideration must be given to the manner in which the machines will be operated, as in case a considerable number of machines, all discharging into one main, should be shut off at the same time, the velocity in the main might easily be lowered to the point where it would not be sufficient to carry the material from the machines still in operation, and thus result in clogging the pipes. Accordingly, it is sometimes desirable to use velocities higher than the minimum to allow a factor of safety to cover this contingency.

In some states codes have been issued specifying suctions to be maintained for the more common dusts. A suction standard should always be considered in conjunction with the shape of hood, and size connection, as these factors together determine the volume of air exhausted and its velocity, which in turn are a measure of the effectiveness of the exhaust system.

Volume of Air

The volume of air of standard density taken into the system at each connection is given by the formula:

$$Q = 4{,}000\, A\, f \sqrt{i} \qquad (1)$$

where

Q = cubic feet of air per minute.
A = area of connection in square feet.
f = orifice or restriction coefficient.
i = static suction measured in inches of water.

The orifice coefficient f is dependent upon the shape and construction of the hood and will range from 60 to 90 per cent. An average value is 70 per cent.

TABLE 4. CUBIC FEET OF AIR HANDLED PER MINUTE THROUGH AVERAGE COLLECTING HOODS

Based on Coefficient of Orifice of 0.71 with 10 Per Cent Added for Leakage

DIAMETER OF CONNECTION PIPE IN.	MAINTAINED SUCTION—IN. WATER GAGE						
	1	1½	2	2½	3	4	5
1½	38	47	54	61	67	76	86
2	68	84	97	108	118	136	153
2½	107	131	161	168	185	214	238
3	153	188	217	243	266	306	343
3½	209	256	296	330	362	418	466
4	273	334	386	431	473	546	609
4½	345	423	488	546	598	690	775
5	427	523	605	676	741	854	955
6	614	751	867	970	1062	1228	1373
7	835	1023	1181	1322	1448	1670	1870
8	1092	1337	1546	1727	1892	2184	2440
9	1381	1694	1953	2184	2387	2762	3091
10	1705	2090	2409	2695	2959	3410	3806

Knowing the suction at each hood and the diameter of each connection, the volume of air passing up each branch can be taken from Table 4. The sum of all these volumes gives the total volume to be handled by the exhaust fan.

Size of Pipes

Common practice is to provide a main suction pipe having an area 20 to 25 per cent in excess of the sum of the areas of the branches entering it between the point in question and the dead end of the main. Similarly the discharge pipe leading from the fan outlet to the collector is frequently made the same diameter as the large end of the main suction pipe. The reason for this increase in size is that a considerable power saving results from the lower air velocity. However, there is no technical reason why mains should be a certain percentage greater area than the sum of the

connections, and still lower power consumption can be obtained by using larger branches and mains of equal area. While the rule of thumb method of determining size of mains works very well in many cases, yet it is always desirable to figure the mains and branches of the proper size to give the velocity which has been found best suited to the work to be done.

In certain special cases where explosive or poisonous dusts such as aluminum buffings, grain dust, powdered sugar, or lead dust are handled, increasing the size of the mains unduly would introduce a serious hazard.

TABLE 5. FRICTIONAL RESISTANCE OF STRAIGHT CONVEYOR PIPE

To Flow of Air Per 100 Feet of Pipe

VEL. OF AIR IN FT. PER MIN.	LOSS OF PRESSURE IN INCHES FOR GIVEN DIAMETER PIPE						
	4″	5″	6″	7″	8″	10″	12″
2000	1.92	1.53	1.28	1.09	0.962	0.770	0.640
2200	2.32	1.85	1.55	1.32	1.16	0.932	0.778
2400	2.77	2.22	1.84	1.58	1.39	1.01	0.924
2600	3.26	2.60	2.17	1.86	1.63	1.30	1.08
2800	3.76	3.01	2.52	2.15	1.89	1.51	1.26
3000	4.33	3.46	2.88	2.47	2.08	1.73	1.44
3200	4.93	3.94	3.28	2.82	2.47	1.97	1.64
3400	5.56	4.45	3.71	3.18	2.78	2.22	1.85
3600	6.23	4.98	4.15	3.56	3.12	2.49	2.08
3800	6.95	5.55	4.62	3.97	3.48	2.78	2.32
4000	7.69	6.15	5.13	4.40	3.85	3.08	2.57
4200	8.48	6.78	5.65	4.85	4.25	3.49	2.83
4400	9.26	7.41	6.18	5.30	4.63	3.71	3.09
4800	11.05	8.85	7.38	6.32	5.55	4.43	3.69
5200	13.00	10.50	8.66	7.44	6.50	5.21	4.34
5600	15.25	12.05	10.05	8.61	7.55	6.03	5.05
6000	17.30	13.85	11.52	9.89	8.66	6.92	5.76
	14″	16″	18″	20″	22″	24″	30″
2000	0.550	0.482	0.428	0.385	0.350	0.320	0.257
2200	0.655	0.582	0.578	0.465	0.423	0.388	0.310
2400	0.790	0.693	0.617	0.553	0.504	0.462	0.369
2600	0.930	0.810	0.722	0.650	0.590	0.542	0.434
2800	1.07	0.932	0.838	0.754	0.685	0.628	0.503
3000	1.24	1.08	0.961	0.865	0.788	0.722	0.577
3200	1.41	1.23	1.09	0.985	0.895	0.820	0.657
3400	1.59	1.43	1.24	1.11	1.01	0.925	0.742
3600	1.78	1.56	1.38	1.25	1.13	1.04	0.832
3800	1.99	1.74	1.54	1.39	1.26	1.16	0.926
4000	2.20	1.92	1.71	1.54	1.40	1.28	1.03
4200	2.43	2.12	1.88	1.70	1.54	1.42	1.13
4400	2.66	2.33	2.06	1.85	1.68	1.54	1.24
4800	3.17	2.77	2.46	2.22	2.02	1.85	1.48
5200	3.72	3.25	2.89	2.61	2.36	2.16	1.75
5600	4.32	3.78	3.35	3.02	2.74	2.52	2.01
6000	4.95	4.33	3.85	3.46	3.14	2.89	2.31

FRICTIONAL RESISTANCE OF ELBOWS

Elbows having a throat radius equal to the pipe diameter set up a resistance equivalent to a section of straight pipe approximately 10 diameters long. With a throat radius of 1½ times the diameter the resistance is about the same as seven diameters of straight pipe.

TABLE 6. DIAMETERS OF BRANCH PIPES AND CALCULATIONS OF MAIN FOR TYPICAL EXHAUST SYSTEM ILLUSTRATED IN FIG. 1

MACHINE	DIAMETER OF BRANCH PIPES	AREA SQ. INCHES	TOTAL LOAD AREA SQ. INCHES	TOTAL LOAD AREA SQ. INCHES + 25%	SECTION OF MAIN	DIAMETER OF MAIN IN EVEN INCHES
Rip Saw	5 in.	19.6	19.6	25	*B*	6 in.
Cut-off Saw	4 in.	12.6	32.2	40	*C*	7 in.
Band Saw	5 in.	19.6	51.8	65	*D*	9 in.
Planer Top Connection	6 in.	28.3	80.1	100		
Planer Bottom Connection	6 in.	28.3	108.4	135	*E & F*	13 in.

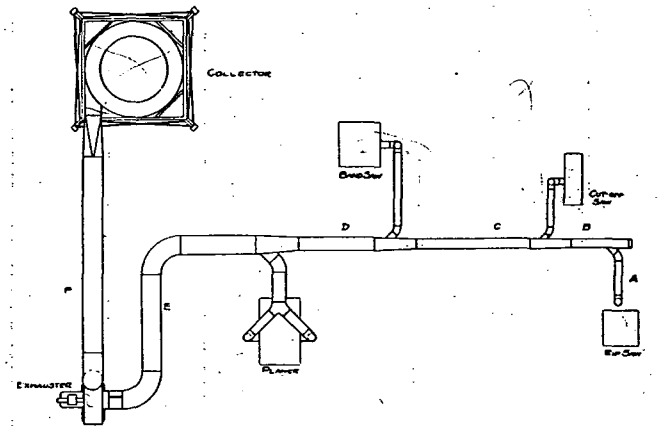


FIG. 1. TYPICAL EXHAUST SYSTEM

TABLE 7. DETAILS OF CALCULATION OF FRICTION OF PIPING SYSTEM ILLUSTRATED IN FIG. 1

SECTION OF PIPING	EFFECTIVE LENGTH OF PIPE TAKEN AS:	DIAMETER OF PIPE IN INCHES	AREA OF PIPE IN SQ. FT.	CFM	VELOCITY OF AIR FLOW, FEET PER MINUTE	FRICTION PER 100 FT. OF LENGTH	PIPE FRICTION
A	20 ft.	5	0.136	605	4450	7.4	1.48
B	10 ft.	6	0.195	605	3100	3.1	0.31
C	10 ft.	7	0.267	991	3700	3.8	0.38
D	15 ft.	9	0.442	1,596	3600	2.8	0.42
E	20 ft.	13	0.922	3,330	3600	2.0	0.40
F	25 ft.	13	0.922	3,330	3600	2.0	0.50
TOTAL pipe friction							3.49

Resistance of System

The maintained resistance of the exhaust system is composed of three factors: (1) loss through the hoods; (2) collector drop; and (3) friction drop in the pipes.

The loss through the hoods is usually assumed to be equal to the suction maintained at the hoods. The collector drop in inches of water is given roughly by Equation 2, but where possible the resistance of the particular collector to be used should be ascertained from the manufacturer as these resistances differ quite widely.

$$\text{Drop} = C\left(\frac{V}{1{,}000}\right)^2 \qquad (2)$$

where

C = a constant which depends upon the type of collector and ranges from 0.065 to 0.145.

V = velocity in feet per minute of air entering the collector.

Friction drop in the pipes must be computed for each section where there is a change in area or in velocity. Find the velocities in each section of pipe starting with the branch most remote from the fan. The friction drop for these sections can be determined by reference to Table 5. Total friction loss in the piping system is the friction drop in the most remote branch plus the drop in the various sections of the main, plus the drop in the discharge pipe.

TYPICAL LAYOUT AND CALCULATIONS

To illustrate the method of laying out and calculating the elements of an exhaust system, assume a small wood-working shop, having one 16 in. diameter rip saw, one 12 in. diameter cut-off saw, one band saw with 2 in. blades, and one planer with 10 in. knives, and with the general arrangement of the machines and exhaust system as shown in Fig. 1.

First, determine the sizes to be used for the branch connection to the hoods. These sizes can be taken from Table 1 giving due consideration to the type and size of machines as well as the class of work handled. (See Table 6).

The next step is to determine the size of the main, which varies in diameter, increasing from its dead end towards the fan, as necessitated by the branch pipes entering it. Its exact diameter at any point is determined according to the following rule:

The area of the main at any point should be 20 per cent to 25 per cent in excess of the sum of the areas of the branches entering it between the point in question and the dead end of the main. Floor sweeps, if equipped with efficient blast gates, need not be included in computing the area of the main.

According to Table 3, 2 in. suction at the hoods is suitable for exhausting from wood-working machinery where the duty is light, as would be the case in this problem. The volume of air to be handled by the system is determined from Table 4.

1 to 5 in. connection, 2 in. suction, (from Table 4) 605 × 1 equals	605 cfm
1 to 4 in. connection, 2 in. suction, (from Table 4) 386 × 1 equals	386 cfm
1 to 5 in. connection, 2 in. suction, (from Table 4) 605 × 1 equals	605 cfm
2 to 6 in. connection, 2 in. suction, (from Table 4) 867 × 2 equals	1,734 cfm
TOTAL	3,330 cfm

The next step in the calculations is to determine the maintained resistance of the system, which corresponds to the static pressure that the exhaust fan must produce to obtain the proper volume of air and suction at the hoods.

This maintained resistance is composed of the following elements:

1. Loss through the hoods. This is usually assumed as equal to the suction maintained at the hoods, in this problem 2 in.

2. Frictional resistance or loss in piping system. This is a function of the pipe diameter and the velocity of flow and accordingly it is necessary to compute the friction for each section and to add the components together.

3. Pressure drop or loss through the collector. For an exhaust system such as the one under consideration it is customary to choose a collector having an inlet of the same, or slightly greater, diameter than the main discharge pipe leading to the collector.

The friction per 100 ft of length for various pipe diameters and velocities can be read from Table 5.

The friction for intermediate pipe sizes not given in the table can be computed from the table values, from the relation that the friction in two pipes, the velocity remaining constant, is inversely proportional to the ratio of the diameters. This can be written:

$$z_2 = z_1 \frac{d_1}{d_2} \qquad (3)$$

z_1 = friction in pipe of d_1 diameter.
z_2 = friction in pipe of d_2 diameter.

The total pipe friction is calculated to be 3.49 in. of water. The individual steps in the calculation are given in Table 7.

The effective length of pipe is determined by adding to the actual length a sum to compensate for the effect of elbows as given in the note at the bottom of Table 5.

In this problem the main discharge pipe is 13 in. in diameter and a collector having a 14 in. inlet is selected. The area of the collector inlet is 1.069 sq ft.

Velocity at collector inlet:

$$V = \frac{3{,}330}{1.069} = 3{,}120$$

$$\text{Collector Drop} = C\left(\frac{V}{1{,}000}\right)^2$$

$$= 0.145\left(\frac{3{,}120}{1{,}000}\right)^2 = 1.4 \text{ in. of water.}$$

The total resistance of the system as indicated in Table 8 is 6.89 in. of water. Therefore an exhaust fan to handle 3,330 cfm at 7 in. static pressure will be required.

TABLE 8. TOTAL RESISTANCE OF THE SYSTEM SHOWN IN FIG. 1

1. Loss at hoods	2.00 in. of water
2. Loss through piping	3.49 in. of water
3. Loss at collector	1.40 in. of water
TOTAL resistance of system	6.89 in. of water

SELECTING THE FAN

The usual types of ventilating fans are unsuitable for exhaust systems which are required to handle materials such as shavings, sawdust, emery dust, etc. Higher pressures are required than in ventilating work and in addition housings and blast wheel must be so constructed that the materials handled do not deposit in them. While the fans used in different exhaust systems are more or less of the same general type, modifications are frequently necessary to fit them for handling such materials as long shavings, strips of paper, cotton, pulverized coal, etc.

Where considerable quantities of explosive dust or inflammable materials pass through the exhaust fan, the blast wheel should be constructed of brass composition, copper or other soft metal and in all cases ample clearance should be provided between blast wheels and housings.

Where stringy or fibrous material is to be handled through the fan, a fan wheel especially designed for that purpose should be employed.

For further data on the selection of fans, see Chapter 34.

COLLECTORS

The most common method of separating the dust and other materials from the air is to pass the mixture through a centrifugal or "cyclone" collector. In this type of collector the mixture of the air and material is introduced on a tangent, near the cylindrical top of the collector, and the whirling motion sets up a centrifugal action causing the comparatively heavy materials suspended in the air to be thrown against the side of the separator, from which position it spirals down to the tail piece, while the air escapes through the stack at the center of the collector.

For most systems, the inlet size of the collector may be the same as the diameter in inches of the main pipe leading to it. The larger the collector within certain limits the better will be the separation, and the less will be the back pressure on the fan and the power consumed.

Special construction is sometimes required for fine dust, also some blowpipe manufacturers use a special type of collector for furnace feed, the object being to deliver the material to furnaces as uniformly as possible.

When more than one fan delivers into a single collector a back pressure valve is required to prevent one fan blowing back through the other in case the second fan should stop for any reason.

In most plants, where wood refuse is used for fuel, it is delivered by gravity directly from the collector to the furnace. The discharge pipe leading from the bottom of the collector is divided and the junction is furnished with a switch or valve so arranged that when the material comes too fast for the fires it can be diverted into a reserve bin.

The furnace feeder should be hinged where it is attached to the lower end of the discharge pipe, in order that it may be disconnected from the furnace when the fan is shut down. Also great care must be taken to provide an absolutely tight switch. Otherwise, when discharging refuse to the storage bin, fine sawdust will sift through this valve and settle in the furnace feed pipe, and, in case the fireman has neglected to disconnect the feeder from the furnace, the flame may flash back, following this train of fine sawdust, into the collector.

Other forms of collectors or separators are: settling chambers, cloth screen and bag collectors, bag houses, air washers and electric precipitators. For further information on this subject, refer to Chapter 38.

DESIGN OF HOODS

If the material to be moved is already in motion, as are the chips thrown off from wood-working machines, the hoods should be arranged in the path of the particles so that the velocity of the particles assists the air in carrying the material to the throat of the hood.

Hoods should be arranged to draw dust and fumes away from the face of the operator. They should be placed as close as possible to the source of dust or waste material and wherever practical, the hoods should entirely enclose the dust producing operation.

Hoods are usually constructed of galvanized sheet iron or other equally substantial and durable material. The material should be heavy enough to withstand the abrasive action of the dust and refuse. The hoods should be of sufficient mechanical strength to keep their shape and should be well braced and substantially supported. Galvanized iron used should never be lighter than No. 22 gage.

If acid or corrosive fumes are present heavy material painted with acid resisting paint should be used, or the hoods may be made of non-corrosive material. The exposed edges of all sheet metal hoods should be bound with wire or band iron, not only to give the necessary stiffness, but also to prevent the operator from being cut by the raw edges of the sheets.

CONVEYOR PIPES

The conveyor pipes leading from the hoods to the fan and thence to the collector are commonly made of galvanized iron, the gage of which varies from No. 24 to 14, depending upon the diameter. The piping should be free from dents, fins and projections on which refuse might catch.

All permanent circular joints should be lap-jointed, riveted and soldered, and all longitudinal joints either grooved and locked or riveted and soldered. Circular laps should be in the direction of the flow, and piping installed out-of-doors should not have the longitudinal laps at the bottom. Every change in pipe size should be made with an eccentric taper flat on the bottom, the taper to be at least 5 in. long for each inch change in diameter. All pipes passing through roofs should be equipped with collars so arranged as to prevent water leaking into the building.

The main trunks and branch pipes should be as short and straight as possible, strongly supported, and with the dead ends capped to permit

inspection and cleaning. All branch pipes should join the main at an acute angle, the junction being at the side or top and never at the bottom of the main. Branch pipes should not join the main pipes at points such that the material from one branch tends to enter the branch on the opposite side of the main.

Cleanout openings having suitable covers should be placed in the main and branch pipes so that every part of the system can be easily reached in case the system clogs. Either a large cleanout door should be placed in the main suction pipe near the fan inlet, or a detachable section of pipe, held in place by lug bands, may be provided.

Elbows should be made at least two gages heavier than straight pipe of the same diameter, the better to enable them to withstand the additional wear caused by changing the direction of flow. They should preferably have a throat radius of at least one and one-half times the diameter of the pipe.

Every pipe should be kept open and unobstructed throughout its entire length, and no fixed screen should be placed in it, although the use of a trap at the junction of the hood and branch pipe is permissible, provided it is not allowed to fill up completely.

The passing of pipes through fire-walls should be avoided wherever possible, and sweep-up connections should be so arranged that foreign material cannot be easily introduced into them.

MAINTENANCE OF SYSTEM

Because of its simplicity the exhaust system usually receives but little attention once it is installed; however, to obtain the best results, it should be inspected at suitable intervals and necessary adjustments made.

The exhaust fan should be given proper attention the same as any other high-speed machine. It should be kept in proper alignment and tightly bolted to its foundation.

Suction hoods, which have been removed to adjust the machines, should be replaced as soon as the adjustments are completed.

Never start a machine with the blast gate closed, as the slight air leakage past the blast gate may draw material into the pipe and clog it.

Disconnect furnace feeders from the furnaces when not in operation, and do not overload the system by ill-advised additions.

CLOTHING FACTORY PRESSING ROOMS

In the men's garment manufacturing industry there are used large batteries of clothes pressing machines.

These usually have large heated areas filled with high pressure steam, and the heaters and the piping which serves them and the jets of steam used on some of the machines for direct application to the cloth, bring about a man-cooling problem of considerable extent. The following solution has been found reasonably satisfactory for use during warm weather:

1. Mechanical exhaust ventilation of about 2,000 cu ft per minute per machine, with gravity inlets through ducts, doors, windows, etc.

2. Mechanical supply ventilation taking air from out-of-doors, delivered horizontally directly toward the face and breast of each operative through an adjustable nozzle of about one-half square foot area at a velocity of about 800 fpm. This nozzle should be about 2 ft from the man.

3. The inlet to the mechanical supply ducts should be taken if possible from the north or shady side of the building, or from a shaded court, never from above a sunny black roof, since the normal out-door air will gain considerable heat when drawn into the building over such a surface.

COLD STORAGE WAREHOUSES

Fruit and vegetables are alive until they begin to decay and if they are to remain alive and well they must be given an ample supply of air and favorable humidity conditions. Conclusive demonstration has been made of the necessity of controlled ventilation for rooms in which fruit and vegetables are stored, even though the temperature in such rooms may be kept very low. It is possible to obtain well developed proprietary systems of ventilation for cold storage warehouses, and as the volume of air to be changed may be comparatively small, the cost for extra refrigeration due to ventilation is trifling, and often is more than compensated for by the improved interior air circulation and the elimination of air-stratification.

Warehouses for fruit storage where no refrigeration is employed should have many doors and windows, which may be opened during the night in warm weather, and closed during the day. The product should be piled in such manner as to allow very free air circulation between the cases and around them. Fans for driving new air quickly through and around the cases often are employed to good advantage.

LACQUER SPRAY BOOTHS

In general there must be an exhaust fan which will provide an air velocity of at least 150 fpm through the opening into the hood from the room. It is preferable in installations of this type to use a pressure fan with an inductor-jet or nozzle so that the carried-away lacquer does not enter the fan at all. It is proper to make the exhaust duct in the vicinity of the booth of such type that accumulations of paint may be removed when they begin to clog the air ways.

In many automobile body spray booths the ducts for exhausting from the spray hood will range from 30 to 48 in. in diameter. A 30 in. duct usually requires about 2 hp for the fan, which maintains on the 5 in. nozzle pipe, pressure equal to a column of water about 7 in. high. For a 48 in. duct the fan requires about 5 hp and the pressure is 10 in. of water on a 6½ in. nozzle pipe. There are proprietary systems of this type.

Chapter 26

NATURAL VENTILATION

Motive Forces; Means of Effecting Natural Ventilation; Roof Ventilators; Application of Natural Ventilation.

VENTILATION systems may be classified as *natural* and *mechanical*. Natural systems are those which employ natural forces *only* to bring about the desired air change, whereas mechanical systems are those in which air motion is obtained by mechanical means. For data on mechanical systems of ventilation, see Chapters 25 and 31.

Factory or industrial buildings are usually ventilated by natural forces, and most commonly by means of windows arranged in side walls and in monitors of some form. The vast amount of opening made available by operative sash gives opportunity for tremendously great air movements, even with forces of but slight intensity. Roof ventilators are used on buildings of all kinds, particularly where fumes and gases are produced.

Dwelling houses depend almost entirely upon natural forces for ventilation, occasionally by means of roof ventilators, but almost always by windows. Natural ventilation has an important application in dairy stables and other buildings housing live stock.

MOTIVE FORCES IN NATURAL VENTILATION

The natural forces available for the displacement of air in buildings are the wind and the difference of temperature of the air inside and outside the building. The arrangement and control of ventilating openings should be such that the two forces act cooperatively and not in opposition.

The magnitudes of the forces of wind and temperature difference are variable in amount and beyond the control of man. However, their effect in producing ventilation may be graduated from the maximum as desired, by a proper control of the amount of ventilating openings and their disposition about a building. Natural ventilation finds its best application in buildings of the industrial type, which are usually open throughout from floor to roof, and in which enormous ventilating areas can be made available both in side walls and roof.

Wind Action[1]

The wind operates to produce regions of pressure or suction about the exterior of a building as compared with the conditions that would exist in these regions if the air were still. The principal effects of the wind when blowing directly against one face of a building are illustrated in Fig. 1. The

[1]See *Airation of Industrial Buildings*, by W. C. Randall (A.S.H.V.E. TRANSACTIONS, Vol. 34, 1928).

maximum intensity of pressure at point C is approximately given by the following equation:

$$P_w = 0.00048M^2 \quad (1)$$

where P_w is pressure in inches of water, and M is velocity of wind in miles per hour. The mean pressure over the windward face is somewhat less, being, perhaps, 75 per cent of the maximum.

The maximum suction occurs at point B at roof and sides, and in magnitude is about three-quarters of the maximum pressure as given by

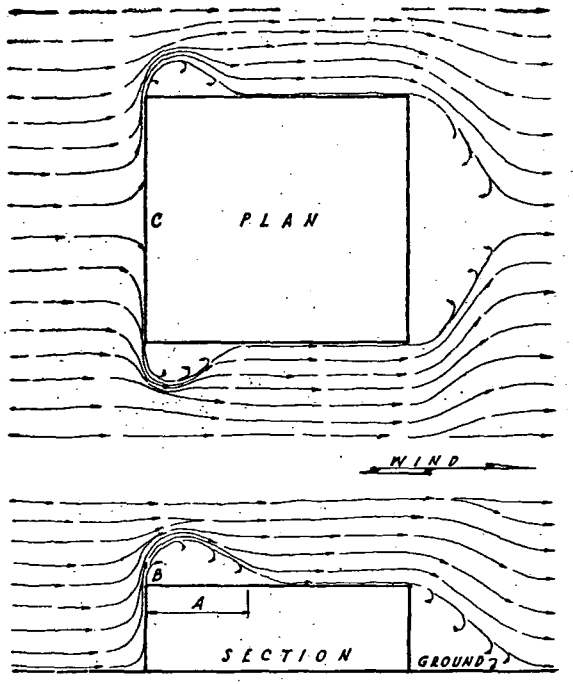


FIG. 1. THE JUMP OF WIND FROM WINDWARD FACE OF BUILDING. (*A*—LENGTH OF SUCTION AREA; *B*—POINT OF MAXIMUM INTENSITY OF SUCTION; *C*—POINT OF MAXIMUM PRESSURE)

equation 1. The distance A, measuring the extent of the suction regions on sidewalls and roof, caused by the leap, or splash, of the wind from the windward face, seems to be determined by the height and width of the windward face, and is independent of the wind velocity. The intensity of the suction diminishes from the maximum at B to zero at the point where the stream lines again flow parallel to the surfaces of the building.

Maximum effect of the wind in producing ventilation can be obtained by providing openings in the windward face for ingress of air and in the leeward face, or in sidewalls and roof near the leeward face, for egress of air, in which case the air moves through the building in the same general

direction as the wind; or, with no openings in the windward face, but with openings provided in the suction regions in sidewalls and roof near the windward face for egress of air, and openings in the leeward end, or in sidewalls near the leeward end for ingress of air, in which case the air movement within the building is in a direction opposite to that of the wind. A knowledge of these facts and their application will often result in a better layout of operations and processes, and even in a more favorable orientation of a building with respect to the prevailing direction of the wind, so that heat and objectionable fumes may be removed more advantageously from an industrial building.

Where the wind comes at an angle to the building, the same general rules apply. The mean pressure of the wind on the oblique faces may be considered as being approximately equivalent to the normal component of the wind, except that when the wind's direction is within 15 or 20 deg of parallelism, the splash from the corner begins to appear, and there will then be suction near the windward corner.

Temperature Difference

Excess temperature inside a building over that outside tends to produce flow as in a chimney. The total head or force arising from this cause is given approximately by equation 2.

$$p_t = 0.000028mD \quad (2)$$

where p_t is the total force or head in inches of water; m is the vertical distance between inlet openings below and outlet openings above; and D is the temperature difference.

The total force or head is consumed in forcing the air in at inlet openings, through the building, and out at the outlet openings. The force required to move the air through the building is usually negligible, so that the total head may be considered as being consumed at inlet and outlet openings. The part of the total head consumed in forcing the air to flow through the lower or inlet opening will be manifested as an excess of outside pressure over inside pressure at that level; while at the upper or outlet opening, the part of the total head consumed in forcing the air out will be manifested as a pressure inside, greater than outside. Thus the lower part of the building inside will be in a state of partial vacuum with respect to the outside, while the upper part will be in a state of pressure. At some point between the levels of the two openings, the pressure state is neutral, and no flow will take place through an opening at that level. This level is called the *neutral zone*.[2]

Relation between Head and Flow

The relation between head or pressure difference on the two sides of an opening, and the velocity that will be created thereby, is given approximately by equation 3.

$$V = 4{,}000\sqrt{p} \quad (3)$$

where V = velocity in feet per minute through an opening, and p is the

[2] See *The Neutral Zone in Ventilation*, by J. E. Emswiler (A.S.H.V.E. TRANSACTIONS, Vol. 32, 1926; also p. 77, Chapter 4).

pressure difference, in inches of water, existing at that opening from any causes or combination of causes.

With V known, the flow, Q, at the opening can then be easily computed by the familiar relation.

$$Q = AVC \qquad (4)$$

where Q is the flow in cubic feet per minute; A is the area in square feet, and C is a coefficient.

For openings such as result from swinging or sliding windows and doors, where the aperture is essentially an orifice, the value of C will be about 0.60.

It would be comparatively easy to calculate flow through an opening, if the pressure difference could be determined. However, so many factors participate in the general action that it is very difficult to evaluate a pressure difference arising from a given wind velocity and temperature. The difficulty is further augmented by the fact that the pressure difference is likely to have a different value for every different opening or group of openings of a building.

NATURAL VENTILATION METHODS

Ventilation by the use of natural forces is produced by means of openings of various kinds between the interior and exterior of a building. These may consist of:

1. Windows (or doors) representing apertures in walls or roofs.
2. Roof ventilators of the unit type designed to develop an inductive force when acted upon by the wind.
3. Roof ventilators of the continuous type providing a ridge opening throughout the length of the building, but not particularly designed to develop an inductive force.
4. Stacks or shafts providing communication between localized interior points and a region above the roof.

Windows have the advantage of transmitting light, as well as providing ventilating area when open. Their movable parts are arranged to open in various ways; they may open by sliding as in the ordinary double-hung, wood window; by tilting on horizontal pivots at or near the center; or by swinging on pivots at top or bottom. Whatever the form and type of window used the thing of essential importance in ventilation is the amount of clear area that can be made available. The motive head to produce flow through windows is almost entirely dependent upon the distribution of those motive forces in and about a building, as discussed under wind and temperature difference. A pivoted window, projecting out from the plane of the wall is bound to impose some obstructive influence upon such air currents as exist in that particular vicinity, and may result in the production of some localized pressure or suction that will influence flow there, and to that degree, one type of window might give more or less active ventilation than another. But, speaking generally, the motive head causing flow through a window is determined by the forces of wind and temperature difference existing there, and not by the kind of window, except in so far as the kind of window establishes the area of opening.

Windows may be arranged for individual operation, or they may be

grouped in long runs, as in factory buildings. Those used in office buildings may have deflecting devices at the sills for avoiding direct draft upon occupants, or a bottom pivoted ventilator, arranged to swing in at the top, may serve the same purpose.

ROOF VENTILATORS

A roof ventilator consists of a structure built up around a roof opening in such a way as to cause the wind to *induce* a suction in the vicinity of the opening, and so create an outflow. Since roof ventilators are

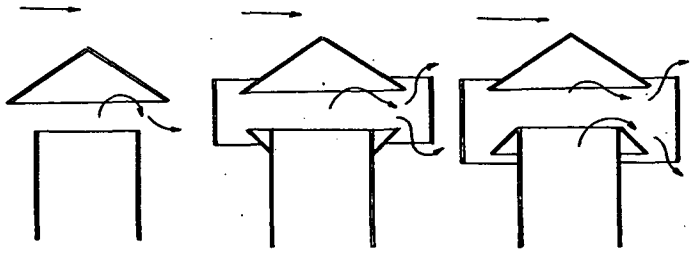


FIG. 2 FIG. 3 FIG. 4

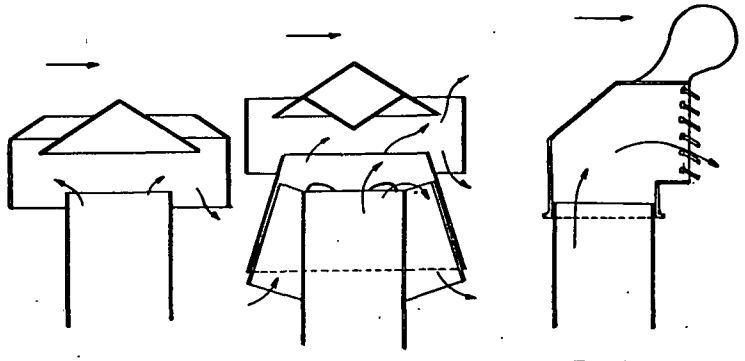


FIG. 5 FIG. 6 FIG. 7

VARIOUS STYLES OF ROOF VENTILATORS

intended for installation on roofs of buildings, and function as outflow openings only, they constitute but a part of a ventilating system, and attention must be given to the provision of openings for inflow. It is evident that such ventilators could not function even in the strongest wind, and with the maximum temperature difference, without inlet openings. Often such ventilators must depend upon infiltration only for inflow. Inlet openings of about twice the area of the roof ventilators should be provided where natural ventilation is used. Dampers should be installed in ventilators with adequate and accessible operating mechanism.

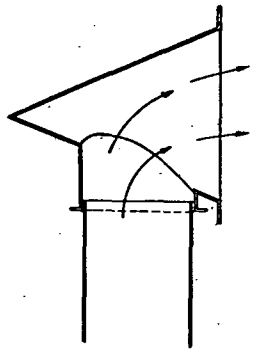


FIG. 8

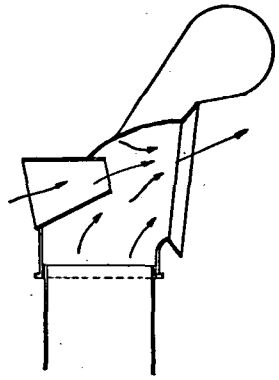


FIG. 9

ROTARY VENTILATORS

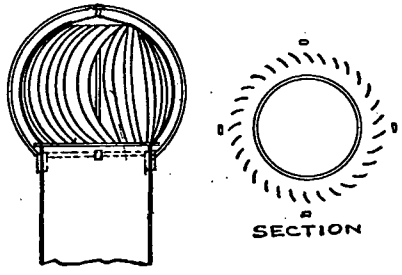


FIG. 10
AIR-TURBINE VENTILATOR

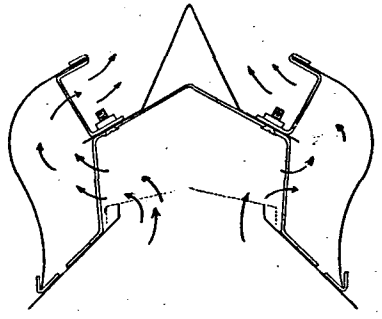


FIG. 11. CONTINUOUS TYPE ROOF VENTILATOR

In considering roof ventilators, as already described in this chapter, the general action of the wind upon the building, should be kept in mind.

A ventilator located within the region indicated by *A* in Fig. 1, will not contribute any inductive effect because in this region there is little or no wind. The ventilator opening will function, but will function in the same way as would a window in that locality, because of the resultant effect of the suction produced by the wind acting upon the building, and by whatever temperature differences prevail.

Roof ventilators are effective if placed in the wind-flow, no matter what the direction of the wind. On the other hand, if ventilators do not stand in the path of the wind, and depend only upon the same forces for producing flow as do windows or any other plain opening, they are at a disadvantage because of the greater resistance of their more complex passages.

Types of Roof Ventilators

The simplest form of roof ventilator is the *stationary* type shown in Fig. 2 and consists of an outlet pipe with a conical hood above it. The addition of a storm band, as shown in Figs. 3, 4, and 5, gives an increased protection against the entrance of rain or snow. The storm band, if placed so close to the cones as to restrict the outflow of air, interferes with ventilation. On the other hand, if the openings are made large enough to permit free egress of the inside air, the storm band increases the ventilation by better utilizing the wind velocity to produce suction.

A further development of the latter principle is the *siphon* ventilator, as illustrated in Fig. 6, in which siphons or ducts are introduced for the particular purpose of producing suction.

In the swiveling or *rotary* ventilators, typified by Figs. 7 and 8, a freely rotating cowl is used. A wind vane is provided for keeping the opening facing away from the direction of the wind. This type allows free egress of the inside air (unless the outlet is made unduly small). Its action depends chiefly upon the suction produced by the wind on the leeward side of the ventilator.

In the *induction* or *ejector* type of ventilator, which is also of the swiveling or rotary type, Fig. 9, the kinetic energy of the wind is intended to create a suction inside the cowl as well as outside.

Resistance to flow of air in the ventilator is caused by: (1) restricted outlet openings, or (2) many turns or changes of the direction of the air flow. As regards the first item, this depends entirely upon the proportions, and not upon the type; some of the stationary ventilators have smaller, and others have larger outlet area than some cowl ventilators of the same nominal size. Regarding the second item, the swiveling cowl ventilators offer less resistance than the stationary type, in that the direction of air flow is changed as little as possible.

Unless swiveling ventilators move very freely, the opening, at times, faces towards the wind so that ventilation produced by temperature difference is much reduced, or wholly counteracted. In that case, snow and rain may blow in. The rumbling or creaking noise caused by a hard turning swivel ventilator also is very unpleasant. These troubles are, of course, eliminated in well-designed ventilators, but must be kept in mind.

In Fig. 10 is shown a rotary or *air-turbine* ventilator, which rotates continuously under the action of the wind, the motion being produced by the difference of wind pressure on the convex and concave sides of the vanes. This type of ventilator must be very carefully designed if it is to be leak-proof, and if the noises and impact forces, due to ice accumulating on the vanes in the winter are to be eliminated.

The *continuous type of roof ventilator* is illustrated in Fig. 11. It furnishes a continuous opening in the roof throughout the length of the building, and is in effect a ridge louvre or monitor. It is stated that the high temperature of the air immediately beneath the sheathing, resulting from exposure of the roof to the sun's rays, induces a powerful convective effect along the pitched roof toward the opening which offers a direct avenue of escape, whereas in the unit type of ventilator, the free egress of the air is confined to definite points along the roof, and the natural upward flow is diverted with some loss, to a longitudinal movement. These ventilators are expected to function by the force of temperature difference alone, and have no external features designed to generate a suction by the action of the wind. The absence of a conspicuous external structure makes this type of ventilator particularly suitable for certain types of buildings.

Stacks are really chimneys and utilize both the inductive effect of the wind and the force of temperature difference (the so-called *gravity* action). While their openings projecting above the roof are not provided with any special construction for developing suction by the action of the wind, the plain vertical opening is nevertheless almost as efficient in this respect as any roof ventilator, and like the roof ventilator, the stack outlet should be located so that the wind may act upon it from any direction.

By means of stacks, even multi-story buildings of the school or office type, may be supplied with adequate air change. With little or no wind, chimney effect or temperature difference will produce inflow equally through windows in all sides of the building. With wind, the inductive force at the top of ventilating shafts is more powerful than that on the leeward side of the building, so that air is drawn in through leeward openings by a combination of the forces of wind and temperature difference. On the windward side, the direct forcing pressure of the wind is of course added to the temperature difference effect. Thus forces are available for causing inflow at practically every window of a building of this kind. Adequacy of stack size must be provided, and it must of course be recognized that the motive forces are not of the same intensity at all openings.

Selection of Roof Ventilators

While the average efficiency of one class of roof ventilators will be higher or lower than the average efficiency of another class, this does not in any way determine the capacity of individual ventilators, as ventilators of the same class and, which from a casual observation appear to be the same, may have entirely different characteristics, due to the fact that some of the fundamentals have been overlooked or changed in one or the other.

The principles which should be followed in the selection of roof ventilators are:

A—Stationary Ventilators.

1. A head sufficiently large to produce a large low-pressure area on the side opposite the wind, and to give an area of outlet for the air leaving the head large enough to obviate undue resistance to flow. At the same time the head should not be so large as to be unwieldy in handling or to be structurally weak when erected.
2. A storm band on stationary non-siphoning ventilators should be sufficiently wide and so placed as to prevent the entrance of external air into the ventilator head.
3. If the ventilator is a siphoning type, additional outlet air space must be provided in the head in order not to restrict the air passage from the exhaust pipe.

B—Rotary Ventilators.

1. A flaring outlet from a rotary ventilator will give a better exhaust than a straight outlet.
2. Practically frictionless and noiseless turning of the ventilator head, when the wind direction changes. The head should turn at very low wind velocities.
3. Smallest possible change of direction of the air ascending from the building and least possible resistance to its egress by louvres or other obstructions at the outlet opening.

C—All Ventilators.

1. Freest possible outlet for the air from the building, with large areas and smallest possible change of direction of the air flow.
2. Freedom from down drafts and from entrance of rain or snow.
3. Freedom from being rendered inoperative by collection of snow or formation of ice on ventilator.

Capacities of Roof Ventilators

The variety of factors affecting capacity makes it essential for the user of ventilators to exercise great care in respect to the item of capacity. All comparisons of capacity must be referred to a given dimension, namely the throat area, corresponding to the nominal size of the ventilator.

Careful tests of ventilators of various types have been made by reliable investigators, and the reader is referred to their work for information on capacities. See TRANSACTIONS, A. S. H. V. E., Vol. 27, 1921, p. 67; Vol. 28, 1922, p. 189; and Vol. 29, 1923, p. 39. Also Bulletin No. 14, Engineering Experiment Station, Kansas State Agricultural College.

Conservative figures for the best types of ventilators now on the market,

under conditions of unrestricted flow of air to the ventilator, are given by the equation:

$$Q = A \times \left[\frac{36 \times \sqrt{H \times (t_i - t_o)}}{6 + V} + 20 \times V \right] \quad (5)$$

where

Q = cubic feet of air exhausted per hour through a ventilator having a free area at the throat of A square inches, mounted on a roof at a height of H feet from the center of the ventilator outlet to the inlet opening of the building, and with a wind velocity of V miles per hour, and average temperature t_i inside t_o outside.

High class ventilators, for instance those of the ejector type, will, under favorable conditions, discharge continuously 25 per cent more air than these conservative figures indicate. Capacities are lower, on the other hand, if ventilators of lower efficiency are used, or if the flow of air into or through the building is restricted, or if the ventilator is not exposed to the free sweep of the wind. Tests occasionally show considerably higher discharge rates over short periods of time. These abnormally high results are produced by the action of the wind upon certain openings of the building; they are not due to the ventilator itself, and cannot be depended upon for continuous ventilation if the direction of the wind changes. In the smaller sizes of ventilators (12 in. or less in throat diameter) the air discharge per square inch of cross-sectional area is reduced, on account of the frictional resistance and, in the rotary types, on account of reduction of free area by the supports, bearings, etc.

Example 1.—What is the capacity of an 18-in. ventilator, located 35 ft above the inlet openings, with 6 mph wind velocity, 50 F outside temperature, 68 F inside temperature?

Answer.—$A = 0.7854 \times (18)^2 = 255$ sq. in.

$$Q = 255 \times \left[\frac{36 \times \sqrt{35 \times (68 - 50)}}{6 + 6} + 20 \times 6 \right] = 50{,}000 \text{ cfh, average capacity under these conditions.}$$

The air supply required based on square feet of floor space is given in Chapter 24, and the number of the renewals of air contents per hour is given in Chapter 4.

To obtain effective, uniform ventilation and avoid local drafts, the ventilators should not be placed more than 30 ft apart; 20 ft apart is a good average. It is best, although not absolutely necessary, to locate the ventilator at the ridge of the roof, unless the building exceeds 40 ft in width, in which case two rows of smaller ventilators should be used. Where the building to be ventilated is surrounded by higher buildings which obstruct air currents, it is desirable to extend the ventilators above the buildings by mounting them on stacks.

Example 2.—A foundry building is 40 ft wide, 200 ft long, with an average height of 40 ft; the ventilators are to be mounted at the ridge of the roof, at a height of 55 ft above the floor. What number and size of ventilators are required?

Answer.—In this case, ventilation is especially necessary in summer. The air in the building should not be over 10 F warmer than the outside air. The wind velocity may be as low as 4 miles per hour. Spacing the ventilators, tentatively, 25 ft apart, 8 ventilators would be required. Under average conditions, 10 air renewals per hour are sufficient. If the foundry is small and cramped, and pouring takes place over a large section of the floor space, 15 or more air renewals per hour may be needed. On the basis of 10 renewals per hour, the capacity of each ventilator must be:

$$Q = \frac{10 \times (200 \text{ ft} \times 40 \text{ ft} \times 40 \text{ ft})}{8} = 400{,}000 \text{ cfh.}$$

The discharge per square inch of throat area under these conditions is;

$$\left[\frac{36 \times \sqrt{55 \times 10 \text{ deg}}}{6 + 4 \text{ mi. per hr.}} + 20 \times 4 \text{ mi. per hr.} \right] = 165 \text{ cfh of air.}$$

The required throat area per ventilator is

$$\frac{400{,}000}{165} = 2420 \text{ sq in.}$$

if there is no resistance and no wind pressure.

The diameter is $\sqrt{\frac{2420}{0.7854}} = 55.5$ in. Standard sizes are 54 in. and 60 in. Either eight—54-in. or else seven—60-in. ventilators could be used, spaced respectively 25 ft or 28 ft apart.

The foregoing is based on the use of high class ventilators. If ventilators of lower efficiency are used, or if the air flow into the building is restricted (as in winter) larger ventilators may be required.

APPLICATION OF NATURAL VENTILATION

General Rules

Although it is practically impossible to predetermine accurately the pressure difference at each individual ventilating opening, from fundamental data of wind velocity, wind direction, temperature difference, building dimensions and disposition of openings, in most cases merely a general knowledge of how the forces of wind and temperature difference act, what their maximum magnitudes are, and how they are disposed in and about a building, will be helpful in planning ventilation. The following simple rules are suggested:

1. In an industrial building where furnaces, that give off heat and fumes, are to be installed, it is better to locate them in the end of the building exposed to the prevailing wind. The strong suction effect of the wind at the roof near the windward end will then cooperate with temperature difference, to provide for the most active and satisfactory removal of the heat and gas laden air.

2. In case it is impossible to locate furnaces in the windward end, that part of the building in which they are to be located should be built higher than the rest, so that the wind, in splashing therefrom will create a suction. The additional height also increases the effect of temperature difference to cooperate with the wind.

3. In the use of monitors, windows on the windward side should usually be kept closed, since, if they are open, the inflow tendency of the wind counteracts the outflow tendency of temperature difference. Openings on the leeward side of the monitor result in cooperation of wind and temperature difference.

4. In order that the force of temperature difference may operate to maximum advantage, the vertical distance between inlet and outlet openings should be as great as possible. Openings in the vicinity of the neutral zone are less effective for ventilation.

5. In order that temperature difference may produce a motive force, there must be vertical distance between openings. That is, if there are a number of openings available in a building, but all are at the same level, there will be no motive head produced by temperature difference, no matter how great that difference might be.

6. In the design of window ventilated buildings, where the direction of the wind is quite constant and dependable, the orientation of the building together with amount and grouping of ventilation opening can be readily arranged to take full advantage of the force of the wind. On the other hand, where the direction of the wind is quite variable, it may be stated as a general principle that windows should be arranged in sidewalls and monitors so that there will be approximately equal area on all sides. Thus, no matter what the wind's direction, there will always be some openings directly exposed to the pressure force of the wind, and others opposed to a suction force, and effective movement through the building will be assured.

It is entirely possible to calculate, with a fair degree of accuracy, the air changes in a factory building for various conditions of wind and temperature difference, and to plan a schedule of control of ventilator openings that will give adequate ventilation under all conditions. The natural forces of wind and temperature difference are active at all times, and must be reckoned with even in a mechanically ventilated building, unless the construction is air tight, which may be considered an impossibility.

Control of natural ventilation depends upon hand regulation, which may be applied in two ways, *first*, by the selection of appropriate localities about the building at which to make openings, with regard to direction of the wind, and *second*, by regulation of the amount of opening, which is accomplished by window operative devices, dampers, or louvers. Control may be effected by the regulation of either inlet or outlet openings, or both and for satisfactory results needs careful study and close attention.

Dairy Barn Ventilation[1]

The following are the salient requirements of dairy barn ventilation:

1. For good ventilation, there should be provided about 3,500 cu ft of fresh air per hour per 1,000 lb of live stock weight.

2. A strong convective circulation is generated by the heat from the bodies of the stock, causing an upward movement toward the ceiling, about them, and a consequent downward movement at the walls.

3. Intake openings should be located in the walls near the ceiling so that incoming cold air, falling toward the floor, will accentuate the convective action induced by the heat within.

4. Outlet openings seem to function merely as exhaust ports, to relieve the interior pressure, and appear to have little influence on the direction of air currents. Hence, the spacing or distribution of outlet openings is rather immaterial, so long as the required aggregate area is provided. Area of outlet openings should be about one-third greater than intake.

5. It is better to take the air out at the floor than at the ceiling, since by the former there appears to be a larger volume of warm air held in the stable, which contributes to better temperature control.

6. The active circulation resulting from the down-flowing cold air entering at openings in the walls near the ceiling, cooperating with the convective action induced by the heat of the animals, effectually prevents condensation and keeps the air fresh and odorless.

Although the foregoing statements were derived from a study of dairy stables, it will be found that some of them are general in their application.

[1]For additional information on this subject, refer to paper, entitled, *Dairy Stable Ventilation*, by F. L. Fairbanks (A.S.H.V.E. TRANSACTIONS, Vol. 34, 1928).

Chapter 27

PRINCIPLES OF AIR CONDITIONING

Air and Water Vapor; Vapor Pressure and Dalton's Law; Humidity; Wet, Dry-Bulb and Dew-Point Temperatures; Relation of Dew-Point to Relative Humidity; Temperature of Evaporation; Temperature of Adiabatic Saturation; Psychrometric Chart; Calculation of Vapor Pressure; Total Heat; Rate of Evaporation.

AIR conditioning in its broadest sense is the practice of simultaneously controlling two or more of the physical or chemical properties of air. In the development of air conditioning, however, the term has been more generally associated with the control of temperature and humidity, which are the two most important physical properties of air bearing on the comfort and health of man and on industrial processes.

Air conditioning may be used to maintain conditions most suitable for the comfort and health of man (see Chapter 28) or to control some of the physical properties of materials in the process of manufacture (see Chapter 29). The usual requirement in air conditioning as applied to processing hygroscopic materials is to maintain a definite moisture content of the product. In some cases, however, it is desired to control merely a definite moisture content of the air. In problems involving human comfort, it is necessary to maintain certain limiting or desirable effective temperatures[1] which depend upon the experimentally-determined relationships of wet- and dry-bulb temperatures and air motion.

AIR AND WATER VAPOR

Air is a mixture of a number of gases and water vapor. The percentage of the gases contained in air remains relatively constant, and is usually given no consideration by the air-conditioning engineer. The percentage of moisture mixed with air varies over wide limits, and this percentage affects the health and feeling of warmth of man, and the behavior of many materials in the process of manufacture.

Air is said to be *saturated* at a certain temperature when it has mixed with it the maximum possible amount of water vapor at that temperature. The amount of vapor a given space will hold is independent of the presence of air. It is dependent entirely on, and increases with, the temperature.

VAPOR PRESSURE AND DALTON'S LAW

The vapor pressure of water also depends upon its temperature. According to *Dalton's Law of Gaseous Mixtures*, each gas or vapor in a

[1]For definition of effective temperature, refer to Chapter 1.

mixture, at a given temperature, contributes to the observed pressure the same amount that it would have exerted by itself at the same temperature had no other gas or vapor been present. If p = the observed pressure of the mixture and p_1, p_2, p_3, etc. = the pressure of the gases or vapors corresponding to the observed temperature, then

$$p = p_1 + p_2 + p_3, \text{ etc.} \quad (1)$$

Pressures of saturated water vapor and other properties for various temperatures are given in Table 1.

HUMIDITY

Humidity is the moisture or water vapor mixed with the air in the atmosphere. Absolute humidity is the weight of water vapor per unit of space and is usually expressed as grains or pounds per cubic foot at a given temperature and percentage of saturation (1 lb = 7000 grains). *Relative humidity* is the ratio of the weight of water vapor in a given space as compared to the weight which the same space is capable of containing when fully saturated at the same temperature, and is usually expressed as a percentage. It is the ratio of the absolute humidity for the given condition involved to the absolute humidity at saturation for the corresponding dry-bulb temperature. When air is unsaturated, the vapor pressure is lower than the maximum corresponding to the temperature of the mixture. The ratio of such unsaturated vapor pressure to the vapor pressure of the mixture when saturated is also the relative humidity. That is:

$$rh = \frac{e}{e_t} = \frac{D}{D_t} \text{ (approximately)} \quad (2)$$

where e and D are the pressure and density of the vapor in the air, and e_t and D_t are the saturation pressure and density respectively of the vapor corresponding to the temperature t of the mixture.

WET, DRY-BULB AND DEW-POINT TEMPERATURES

The quantity of moisture mixed with the air under different conditions of temperature and saturation is usually determined by means of some form of instrument in which a dry-bulb and a wet-bulb thermometer are used. *Dry-bulb* temperature is the temperature of the air as determined by an ordinary dry-bulb mercury thermometer. *Wet-bulb* temperature is the temperature as determined by a similar thermometer, except with its bulb encased in a fine mesh fabric bag moistened with clean water and whirled through the air until the temperature depression due to the cooling effect of evaporation from the moistened bag reaches equilibrium. Wet-bulb temperature corresponds to that which a thoroughly wet body will attain if the air passes over it for a sufficient length of time and with a high enough velocity.

Air is usually deficient in water vapor; that is, it is unsaturated. Therefore, the water vapor exists at a temperature above that of saturation, or is superheated. If the pressure is above atmospheric (14.7 lb per

square inch) the vapor is superheated steam; if the pressure is below atmospheric, it is superheated vapor.

If an unsaturated mixture of air and water vapor be cooled without the removal of any moisture pressure, it will ultimately become saturated. The temperature at which saturation is obtained for a given weight of water vapor is termed the *dew-point* temperature. Any further cooling beyond this temperature will result in a precipitation of moisture from the mixture, that is, condensation.

Table 1 gives the pressure of saturated vapor, the weight of saturated vapor, as well as the volume in cubic feet of one pound of dry air and air saturated, also the sensible heat content above 0 deg F of one pound of dry air, and the latent heat of the vapor required to saturate one pound of dry air, for various dry-bulb temperatures. If the weight of unsaturated water vapor of a mixture is known, the dew-point temperature may be ascertained from Table 1 by noting the temperature corresponding to saturation for this weight. The data in Table 1 may be conveniently used for solving humidifying and cooling problems.

Example 1. Humidifying Air. Air is to be maintained at 70 F with a relative humidity of 40 per cent when the outside air is at 0 deg F, with a relative humidity of 70 per cent. Find the weight of water vapor per pound of dry air to be added by the air washer, the temperature of the saturated air leaving the washer, and the heat required to bring the air to this condition.

Referring to Table 1, one pound of air at 70 F, if saturated contains 0.01578 lb of water vapor; hence with 40 per cent humidity it contains $0.40 \times 0.01578 = 0.006312$ lb. One pound of air at 0 deg F contains 0.000781 lb of vapor when saturated and $0.70 \times 0.000781 = 0.000547$ lb when the humidity is 70 per cent. The water vapor to be added per pound of dry air is therefore $0.006312 - 0.000547 = 0.005765$ lb. By inspection it is found that air at 45 F completely saturated contains the same weight of vapor, namely, 0.00631 lb, as air at 70 F with 40 per cent humidity; hence the air should leave the washer at 45 F. The heat content of air at 0 deg F and 70 per cent humidity is $0 + 0.70 \times 0.964 = 0.675$ Btu per pound and the heat content of 1 lb of air at 45 F with the vapor required to saturate it is 17.59 Btu. The heat required for the process per pound of dry air is therefore approximately $17.59 - 0.675 = 16.92$ Btu.

Example 2. Cooling. Air enters a washer at 84 F with a relative humidity of 50 per cent and is to be cooled to 54 F. Find the dew-point temperature, weight of vapor condensed and heat removed per pound of dry air.

At 84 F, 1 lb of air contains 0.02547 lb of water vapor when saturated and therefore $0.50 \times 0.02547 = 0.01274$ lb with 50 per cent humidity (see Table 1). At 64 F saturated air contains the same weight of water vapor; hence the dew-point is 64 F. At 54 F, 1 lb of air, if saturated, contains 0.00887 lb of vapor. Hence, in cooling from 64 F to 54 F the weight of vapor removed is $0.01274 - 0.00887 = 0.00387$ lb. The heat content of the air in the initial state (84 F, 50 per cent humidity) is $20.29 + 0.50 \times 26.62 = 33.60$ Btu, and the heat content of 1 lb of dry air at 54 F, with vapor required to saturate it, is 22.45 Btu. The difference is $33.60 - 22.45 = 11.15$ Btu. A slight correction may be made for the heat removed in cooling the water, due to condensation between 64 F and 54 F. At 64 F condensation begins, at 54 F 0.00387 lb has been condensed; hence the heat that must be removed from the water is approximately $\frac{1}{2} \times 0.00387 \times 10 = 0.019$ Btu. Adding this to 11.15 Btu, the heat removed per pound of dry air during the process is 11.17 Btu.

RELATION BETWEEN DRY-BULB, WET-BULB AND DEW-POINT TEMPERATURES

As previously stated, the dew-point temperature represents the saturation temperature for a given quantity of moisture. When the temperature has been reduced to the dew-point, the wet- and dry-bulb

TABLE 1. MIXTURES OF AIR AND SATURATED WATER VAPOR[a]

TEMP., °F.	[b]PRESSURE OF SATURATED VAPOR		WEIGHT OF SATURATED VAPOR				VOLUME IN CU. FT.		HEAT CONTENT IN B.T.U. OF 1 LB. OF DRY AIR ABOVE 0 °F.	LATENT HEAT OF VAPOR, B.T.U.	[c]HEAT CONTENT IN B.T.U. OF 1 LB. OF DRY AIR WITH VAPOR TO SATURATE IT
	In. of Hg.	Lb. per Sq. In.	per Cu. Ft.		per lb. of Dry Air		of 1 lb. of Dry Air	of 1 lb. of Dry Air + Vapor to saturate it			
			Pounds	Grains	Pounds	Grains					
0	0.0375	0.0184	0.0000674	0.472	0.000781	5.47	11.58	11.59	0.0	0.964	0.964
2	.0417	.0204	.0000746	.522	.000869	6.08	11.63	11.65	0.482	1.071	1.553
4	.0462	.0227	.0000823	.576	.000963	6.74	11.68	11.70	0.964	1.186	2.150
6	.0512	.0252	.0000909	.636	.001067	7.47	11.73	11.75	1.446	1.313	2.759
8	.0567	.0279	.0001001	.701	.001183	8.28	11.78	11.80	1.928	1.455	3.383
10	0.0628	0.0308	0.0001103	0.772	0.001309	9.16	11.83	11.86	2.411	1.608	4.019
12	.0694	.0341	.000121	.850	.001447	10.13	11.88	11.91	2.893	1.776	4.669
14	.0766	.0376	.000134	.935	.001599	11.19	11.94	11.97	3.375	1.961	5.336
16	.0846	.0415	.000147	1.028	.001764	12.35	11.99	12.02	3.858	2.162	6.020
18	.0932	.0458	.000161	1.128	.001946	13.62	12.04	12.08	4.340	2.383	6.723
20	0.1027	0.0504	0.000177	1.237	0.002144	15.01	12.09	12.13	4.823	2.623	7.446
22	.1130	.0555	.000194	1.356	.002360	16.52	12.14	12.19	5.305	2.885	8.190
24	.1242	.0610	.000212	1.485	.002596	18.17	12.19	12.24	5.787	3.170	8.957
26	.1365	.0670	.000232	1.625	.002854	19.98	12.24	12.30	6.270	3.482	9.752
28	.1499	.0736	.000254	1.776	.003134	21.94	12.29	12.35	6.752	3.821	10.573
30	0.1646	0.0809	0.000278	1.943	0.003444	24.11	12.34	12.41	7.234	4.195	11.429
32	.1806	.0887	.000303	2.124	.003782	26.47	12.39	12.47	7.716	4.058	11.783
33	.1880	.0923	.000315	2.206	.003938	27.57	12.41	12.49	7.96	4.22	12.18
34	.1957	.0961	.000327	2.292	.004100	28.70	12.44	12.52	8.20	4.40	12.60
35	0.2036	0.1000	0.000340	2.380	0.004268	29.88	12.47	12.55	8.44	4.57	13.02
36	.2119	.1041	.000353	2.471	.004442	31.09	12.49	12.58	8.68	4.76	13.44
37	.2204	.1083	.000367	2.566	.004622	32.35	12.52	12.61	8.93	4.95	13.87
38	.2292	.1126	.000381	2.663	.004809	33.66	12.54	12.64	9.17	5.14	14.31
39	.2384	.1171	.000395	2.764	.005002	35.01	12.57	12.67	9.41	5.35	14.76
40	0.2478	0.1217	0.000410	2.868	0.005202	36.41	12.59	12.70	9.65	5.56	15.21
41	.2576	.1266	.000425	2.976	.005410	37.87	12.62	12.73	9.89	5.78	15.67
42	.2678	.1315	.000441	3.087	.005625	39.38	12.64	12.76	10.14	6.01	16.14
43	.2783	.1367	.000457	3.201	.005848	40.93	12.67	12.79	10.38	6.24	16.62
44	.2891	.1420	.000474	3.319	.006078	42.55	12.69	12.82	10.62	6.48	17.10

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[b]Below 32 F the pressure of saturated vapor in contact with ice is given.
[c]Values in this column do not include the heat of the liquid. Below 32 F the heat of sublimation of ice is included.

TABLE 1. MIXTURES OF AIR AND SATURATED WATER VAPOR[a] (CONTINUED)

TEMP., °F.	PRESSURE OF SATURATED VAPOR		WEIGHT OF SATURATED VAPOR				VOLUME IN CU. FT.		HEAT CONTENT IN B.T.U. OF 1 LB. OF DRY AIR ABOVE 0 °F.	LATENT HEAT OF VAPOR, B.T.U.	[b]HEAT CONTENT IN B.T.U. OF 1 LB. OF DRY AIR WITH VAPOR TO SATURATE IT
	In. of Hg.	Lb. per Sq. In.	per Cu. Ft.		per lb. of Dry Air		of 1 lb. of Dry Air	of 1 lb. of Dry Air + Vapor to saturate it			
			Pounds	Grains	Pounds	Grains					
45	0.3003	0.1475	0.000492	3.442	0.00632	44.21	12.72	12.85	10.86	6.73	17.59
46	.3120	.1532	.000510	3.568	.00656	45.94	12.74	12.88	11.10	6.99	18.09
47	.3240	.1591	.000528	3.698	.00682	47.73	12.77	12.91	11.34	7.26	18.60
48	.3364	.1652	.000547	3.832	.00708	49.58	12.79	12.94	11.58	7.54	19.12
49	.3492	.1715	.000567	3.970	.00736	51.49	12.82	12.97	11.83	7.83	19.65
50	0.3624	0.1780	0.000588	4.113	0.00764	53.47	12.84	13.00	12.07	8.12	20.19
51	.3761	.1848	.000609	4.260	.00793	55.52	12.87	13.03	12.31	8.43	20.74
52	.3903	.1917	.000630	4.411	.00823	57.64	12.89	13.07	12.55	8.75	21.30
53	.4049	.1989	.000653	4.568	.00855	59.83	12.92	13.10	12.79	9.08	21.87
54	.4200	.2063	.000676	4.729	.00887	62.09	12.95	13.13	13.03	9.41	22.45
55	0.4356	0.2140	0.000699	4.895	0.00920	64.43	12.97	13.16	13.28	9.76	23.04
56	.4517	.2219	.000724	5.066	.00955	66.85	13.00	13.20	13.52	10.13	23.64
57	.4684	.2300	.000749	5.242	.00991	69.35	13.02	13.23	13.76	10.50	24.25
58	.4855	.2384	.000775	5.424	.01028	71.93	13.05	13.26	14.00	10.89	24.88
59	.5032	.2471	.000802	5.611	.01066	74.60	13.07	13.30	14.24	11.28	25.52
60	0.5214	0.2561	0.000829	5.804	0.01105	77.3	13.10	13.33	14.48	11.69	26.18
61	.5403	.2654	.000858	6.003	.01146	80.2	13.12	13.36	14.72	12.12	26.84
62	.5597	.2749	.000887	6.208	.01188	83.2	13.15	13.40	14.97	12.56	27.52
63	.5798	.2848	.000917	6.418	.01231	86.2	13.17	13.43	15.21	13.01	28.22
64	.6005	.2949	.000948	6.633	.01276	89.3	13.20	13.47	15.45	13.48	28.93
65	0.6218	0.3054	0.000979	6.855	0.01323	92.6	13.22	13.50	15.69	13.96	29.65
66	.6438	.3162	.001012	7.084	.01370	95.9	13.25	13.54	15.93	14.46	30.39
67	.6664	.3273	.001046	7.320	.01420	99.4	13.27	13.58	16.18	14.97	31.15
68	.6898	.3388	.001080	7.563	.01471	103.0	13.30	13.61	16.42	15.50	31.92
69	.7139	.3506	.001116	7.813	.01524	106.6	13.32	13.65	16.66	16.05	32.71
70	0.7386	0.3628	0.001153	8.069	0.01578	110.5	13.35	13.69	16.90	16.61	33.51
71	.7642	.3754	.001190	8.332	.01634	114.4	13.38	13.73	17.14	17.19	34.33
72	.7906	.3883	.001229	8.603	.01692	118.4	13.40	13.76	17.38	17.79	35.17
73	.8177	.4016	.001269	8.882	.01751	122.6	13.43	13.80	17.63	18.41	36.03
74	.8456	.4153	.001310	9.168	.01813	126.9	13.45	13.84	17.87	19.05	36.91

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[b]Values in this column do not include the heat of the liquid.

TABLE 1. MIXTURES OF AIR AND SATURATED WATER VAPOR[a] (CONTINUED)

Temp., °F.	Pressure of Saturated Vapor		Weight of Saturated Vapor				Volume in Cu. Ft.		Heat Content in B.T.U. of 1 lb. of Dry Air Above 0 °F.	Latent Heat of Vapor, B.T.U.	[b]Heat Content in B.T.U. of 1 lb. of Dry Air with Vapor to Saturate It
			per Cu. Ft.		per lb. of Dry Air						
	In. of Hg.	Lb. per Sq. In.	Pounds	Grains	Pounds	Grains	of 1 lb. of Dry Air	of 1 lb. of Dry Air + Vapor to saturate it			
75	0.8744	0.4295	0.001352	9.46	0.01877	131.4	13.48	13.88	18.11	19.71	37.81
76	.9040	.4440	.001395	9.76	.01942	135.9	13.50	13.92	18.35	20.38	38.73
77	.9345	.4590	.001439	10.07	.02010	140.7	13.53	13.96	18.59	21.08	39.67
78	.9658	.4744	.001485	10.39	.02080	145.6	13.55	14.00	18.84	21.80	40.64
79	.9981	.4903	.001532	10.72	.02152	150.6	13.58	14.05	19.08	22.55	41.63
80	1.0314	0.5066	0.001580	11.06	0.02226	155.8	13.60	14.09	19.32	23.31	42.64
81	1.0656	.5234	.001629	11.40	.02303	161.2	13.63	14.13	19.56	24.11	43.67
82	1.1008	.5406	.001680	11.76	.02381	166.7	13.65	14.17	19.80	24.92	44.72
83	1.1370	.5584	.001732	12.12	.02463	172.4	13.68	14.22	20.04	25.76	45.80
84	1.174	.5767	.001786	12.50	.02547	178.3	13.70	14.26	20.29	26.62	46.91
85	1.212	0.5955	0.001841	12.89	0.02634	184.4	13.73	14.31	20.53	27.51	48.04
86	1.251	.6148	.001897	13.28	.02723	190.6	13.75	14.35	20.77	28.43	49.20
87	1.292	.6347	.001955	13.68	.02815	197.0	13.78	14.40	21.01	29.38	50.39
88	1.334	.6551	.002014	14.10	.02910	203.7	13.80	14.45	21.25	30.35	51.61
89	1.377	.6761	.002075	14.53	.03008	210.6	13.83	14.50	21.50	31.36	52.86
90	1.421	0.6977	0.002137	14.96	0.03109	217.6	13.86	14.55	21.74	32.39	54.13
91	1.466	.7200	.002201	15.41	.03213	224.9	13.88	14.60	21.98	33.46	55.44
92	1.512	.7427	.002267	15.87	.03320	232.4	13.91	14.65	22.22	34.59	56.78
93	1.560	.7660	.002334	16.34	.03430	240.1	13.93	14.70	22.46	35.69	58.15
94	1.609	.7901	.002403	16.82	.03544	247.1	13.96	14.75	22.71	36.86	59.56
95	1.659	0.8148	0.002474	17.32	0.03662	256.3	13.98	14.80	22.95	38.06	61.01
96	1.710	.8401	.002546	17.82	.03783	264.8	14.01	14.86	23.19	39.30	62.48
97	1.763	.8662	.002621	18.35	.03908	273.6	14.03	14.91	23.43	40.57	64.00
98	1.818	.8929	.002697	18.88	.04036	282.5	14.06	14.97	23.67	41.88	65.55
99	1.874	.9204	.002775	19.42	.04169	291.8	14.08	15.02	23.91	43.24	67.15
100	1.931	0.9486	0.002855	19.98	0.04305	301.3	14.11	15.08	24.16	44.63	68.79
101	1.990	0.9775	.002937	20.56	.04446	311.2	14.14	15.14	24.40	46.07	70.47
102	2.051	1.0072	.003021	21.15	.04591	321.4	14.16	15.20	24.64	47.54	72.18
103	2.113	1.0376	.003107	21.75	.04741	331.9	14.19	15.26	24.88	49.07	73.95
104	2.176	1.0689	.003195	22.36	.04895	342.7	14.21	15.33	25.13	50.64	75.77

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[b]Values in this column do not include the heat of the liquid.

TABLE 1. MIXTURES OF AIR AND SATURATED WATER VAPOR[a] (CONTINUED)

Temp., °F.	Pressure of Saturated Vapor		Weight of Saturated Vapor				Volume in Cu. Ft.		Heat Content in B.T.U. of 1 lb. of Dry Air Above 0 °F.	Latent Heat of Vapor, B.T.U.	[b]Heat Content in B.T.U. of 1 lb. of Dry Air with Vapor to Saturate It
			per Cu. Ft.		per lb. of Dry Air						
	In. of Hg.	Lb. per Sq. In.	Pounds	Grains	Pounds	Grains	of 1 lb. of Dry Air	of 1 lb. of Dry Air + Vapor to saturate it			
105	2.241	1.1010	0.003285	22.99	0.0505	354	14.24	15.39	25.37	52.26	77.63
106	2.308	1.134	.003377	23.64	.0522	365	14.26	15.46	25.61	53.92	79.53
107	2.377	1.168	.003472	24.30	.0539	377	14.29	15.52	25.85	55.64	81.49
108	2.448	1.202	.003568	24.98	.0556	389	14.31	15.59	26.09	57.41	83.50
109	2.520	1.238	.003667	25.67	.0574	402	14.34	15.66	26.33	59.23	85.57
110	2.594	1.274	0.003769	26.38	0.0593	415	14.36	15.73	26.58	61.11	87.69
111	2.670	1.311	.003873	27.11	.0612	428	14.39	15.80	26.82	63.04	89.86
112	2.748	1.350	.003979	27.85	.0631	442	14.41	15.87	27.06	65.04	92.10
113	2.827	1.389	.004087	28.61	.0652	456	14.44	15.95	27.30	67.10	94.40
114	2.909	1.429	.004198	29.39	.0673	471	14.46	16.02	27.55	69.22	96.77
115	2.993	1.470	0.004312	30.18	0.0694	486	14.49	16.10	27.79	71.40	99.10
116	3.079	1.512	.004428	31.00	.0717	502	14.52	16.18	28.03	73.65	101.68
117	3.167	1.555	.004547	31.83	.0739	518	14.54	16.26	28.27	75.97	104.24
118	3.257	1.600	.004669	32.68	.0763	534	14.57	16.35	28.51	78.36	106.87
119	3.349	1.645	.004793	33.55	.0788	551	14.59	16.43	28.76	80.80	109.56
120	3.444	1.692	0.004920	34.44	0.0813	569	14.62	16.52	29.00	83.37	112.37
125	3.952	1.941	.005599	39.19	.0953	667	14.75	16.99	30.21	97.33	127.54
130	4.523	2.221	.006356	44.49	.1114	780	14.88	17.53	31.42	113.64	145.06
135	5.163	2.536	.007197	50.38	.1305	913	15.00	18.13	32.63	132.71	165.34
140	5.878	2.887	.008130	56.91	.1532	1072	15.13	18.84	33.85	155.37	189.22
145	6.677	3.280	0.00916	64.1	0.1800	1260	15.26	19.64	35.06	182.05	217.1
150	7.566	3.716	.01030	72.1	.2122	1485	15.39	20.60	36.27	214.03	250.3
155	8.554	4.201	.01156	80.9	.2511	1758	15.52	21.73	37.48	252.61	290.1
160	9.649	4.739	.01294	90.6	.2987	2091	15.64	23.09	38.69	299.55	338.2
165	10.860	5.334	.01445	101.1	.3577	2504	15.77	24.75	39.91	357.75	397.7
170	12.20	5.990	0.01611	112.8	0.4324	.....	15.90	26.84	41.12	431.2	472.3
175	13.67	6.71	.01793	125.5	.5290	.....	16.03	29.51	42.33	526.0	568.3
180	15.29	7.51	.01991	139.4	.6577	.....	16.16	33.04	43.55	651.9	695.5
185	17.07	8.38	.02206	154.4	.8359	.....	16.28	37.89	44.76	826.1	870.9
190	19.01	9.34	.02441	170.9	1.0985	.....	16.41	45.00	45.97	1082.3	1128.3
200	23.46	11.53	0.02972	208.0	2.2953	.....	16.67	77.24	48.40	2247.5	2296

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[b]Values in this column do not include the heat of the liquid.

thermometers register exactly the same. For example, air at a dry-bulb temperature of 50 F and a relative humidity of 100 per cent (saturation) will contain 53.47 grains of moisture per pound, under which condition the dry-bulb and wet-bulb thermometers will both register 50 F. If this air is heated, both thermometers will rise, but the wet-bulb temperature will rise more slowly and the relative humidity will be rapidly reduced. The dew-point temperature remains constant at 50 F since any given number of grains of moisture per pound has a fixed and definite dew-point temperature of saturation.

A pound of air at a dry-bulb temperature of 72 F, and a wet-bulb temperature of 59 F contains about 53.4 grains of water vapor. If this air is passed through a fine spray of recirculated water, it will absorb moisture; the dry-bulb temperature will immediately begin to fall, but the wet-bulb temperature will remain constant at 59 F until the dry-bulb temperature has dropped to the wet-bulb temperature, namely, 59 F. As the absorption takes place, the dew-point temperature will gradually rise from 50 F to 59 F, when saturation is obtained. At ordinary temperatures the absorption of one grain of moisture per cubic foot lowers the dry-bulb temperature approximately 8½ deg.

RELATION OF DEW-POINT TO RELATIVE HUMIDITY

A peculiar relationship exists between the dew-point and the relative humidity and this is found most useful in air conditioning work. This is, that for a fixed relative humidity there is substantially a constant difference between the dew-point and the dry-bulb temperature over a considerable temperature range. The following table giving the room temperature, dew-point temperature, and dew-point differentials for 50 per cent relative humidity illustrates this relationship most clearly:

Dry-bulb temperature	65.0	70.0	75.0	80.0	85.0	90.0
Dew-point temperature	45.8	50.5	55.25	59.75	64.25	68.75
Difference between dew-point and dry-bulb temperature	19.2	19.5	19.75	20.25	20.75	21.25

It will be seen from an inspection of this table that the difference between the dew-point temperature and the room temperature is approximately 20 deg throughout this range of dry-bulb temperatures or, to be more exact, the differential increases only 10 per cent for a range of practically 25 deg.

This principle holds true for other humidities and is due to the fact that the pressure of the water vapor practically doubles for every 20 deg through this range.

The approximate relative humidity for any difference between dew-point and dry-bulb temperature may be expressed as:

$$\frac{100}{2^{\frac{t-t_1}{20}}} \qquad (3)$$

where

t_1 = dew-point temperature.

This principle is very useful in determining the available cooling effect obtainable with saturated air when a desired relative humidity is to be maintained in a room, even though there may be a wide variation in room temperature. This problem is one which applies to certain industrial conditions, such as those in cotton mills, tobacco factories, etc., where relatively high humidities are carried and where one of the principal problems is to remove the heat generated by the machinery. It also permits the use of a differential thermostat, responsive to both the room temperature and to the dew-point temperature, to control the relative humidity in the room.

TEMPERATURE OF EVAPORATION

Air may also be saturated adiabatically by being brought into contact with water without the addition or subtraction of external energy. Under this condition water vaporizes into the space occupied by the air, assuming that no heat is available from the water itself. That is, no temperature change takes place in the unvaporized water present, and the heat required for change of state must come from the sensible heat in the air itself, thus resulting in the lowering of its temperature.

The moisture content of the air, therefore, is increased and its temperature is lowered simultaneously, and it is obvious that the increase in latent heat must exactly equal the decrease in the sensible heat of the mixture. Further, this process will go on until the air becomes saturated, when no further exchange between the sensible and latent heat is possible. This final temperature at which adiabatic saturation takes place in any body of air of known temperature and moisture content is known as the *temperature of evaporation* and corresponds to the *wet-bulb* temperature.

TEMPERATURE OF ADIABATIC SATURATION

In order that no heat exchange may take place between the water and the surrounding air, it is necessary that the water shall be introduced at the temperature of evaporation. On the other hand, if free water shall be exposed to a continuous current of air of a given temperature and moisture content, the water will ultimately assume of its own accord this equilibrium temperature of evaporation. It is for this reason that an ordinary thermometer which has its bulb covered by a wetted cloth or otherwise is coated with the water, if protected against outside sources of heat such as radiation and if subjected to a stream of air having a definite temperature and moisture content, will indicate the temperature of adiabatic saturation. This proves the identity between what is termed the *wet-bulb temperature* and the *temperature of adiabatic saturation.*

With the ordinary sling psychrometer which is used in measuring the moisture content of air, however, there is always some radiation present and, if the wet-bulb be not strongly ventilated, the error due to radiation may be considerable. With strong ventilation, however, the radiation effect is usually less than one per cent. This error depends upon the

temperature and velocity of air movement, and the relationship of this error to these factors is shown in a paper entitled *The Temperatures of Evaporation of Water into Air*, presented by W. H. Carrier and D. C.

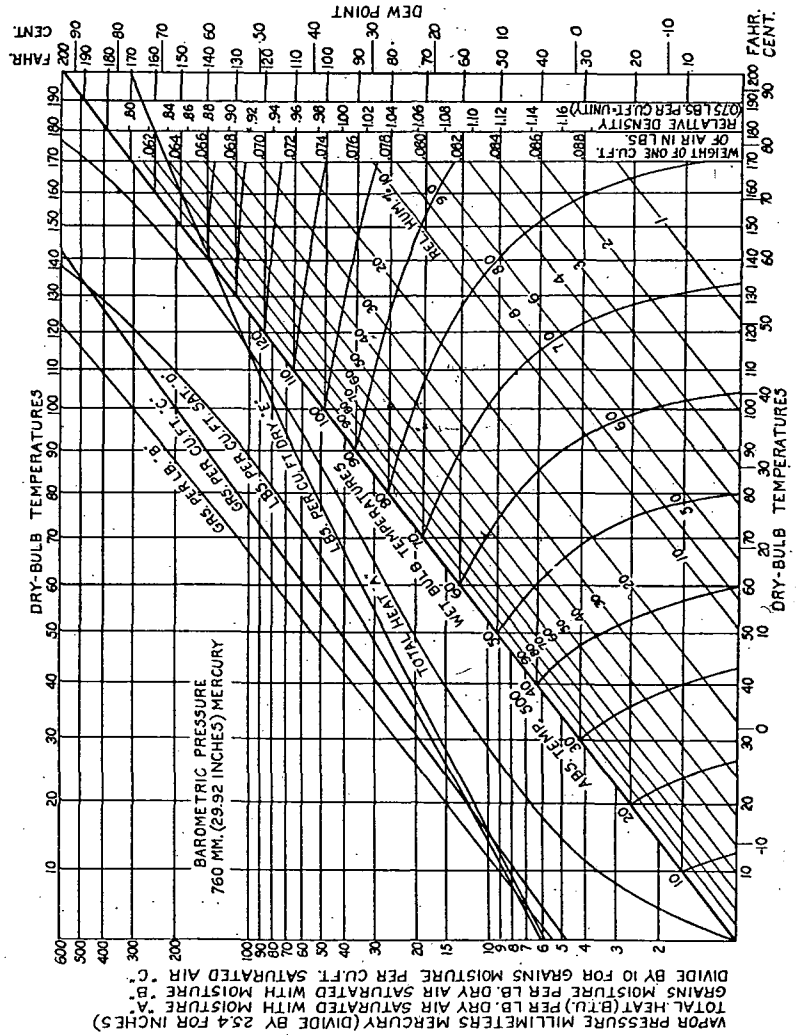


FIG. 1. PSYCHROMETRIC CHART

Lindsay, before the *American Society of Mechanical Engineers* in 1924.

From the foregoing, four fundamental principles in air conditioning may be stated.

1. When dry air is saturated adiabatically the temperature is reduced as the absolute humidity is increased, and the decrease of sensible heat is exactly equal to the simultaneous increase in latent heat due to evaporation.

2. As the moisture content of air is increased adiabatically, the temperature is reduced simultaneously until the air is saturated, when no further heat metamorphosis is possible. This ultimate temperature may be termed the temperature of adiabatic saturation.

3. When an insulated body of water is permitted to evaporate freely in the air, it assumes the temperature of adiabatic saturation of that air and is unaffected by convection, *i.e.*, the true wet-bulb temperature of air is identical with its temperature of adiabatic saturation.

4. The true wet-bulb temperature of the air depends entirely on the total of the sensible and the latent heat in the air and is independent of their relative proportions. In other words, the wet-bulb temperature of the air is constant, providing the total heat of the air is constant.

It will be obvious in considering the foregoing process, that a formula relating the latent heat change to the sensible heat change establishes the relationship of this theoretical wet-bulb temperature to the temperature and moisture of the air. This was first pointed out by W. H. Carrier in the Rational Psychrometric Formula:

$$r' (W' - W) = C_{pa} (t - t') + C_{ps} W (t - t') \qquad (4)$$

in which

$(t - t')$ = the true wet-bulb depression.

$(W' - W)$ = the moisture absorbed per pound of pure air when it is adiabatically saturated from an initial dry-bulb temperature t_o and an initial moisture content W.

C_{pa} = mean specific heat of air at constant pressure between temperature t and t'.

C_{ps} = specific heat of steam at constant pressure between t and t'.

r' = latent heat of evaporation at wet-bulb temperature t'.

Knowing any two of the three important values of t, t' or W, the third may be solved.

This is an exceedingly useful relationship, not only in air conditioning and the drying of materials but in the psychrometry of air or other gases to which it directly applies. It is evident that if the wet-bulb temperature of air of a known dry-bulb temperature but unknown moisture content be determined experimentally with the wet-bulb thermometer, it will be possible to calculate directly the moisture content of that air from the relationship.

PSYCHROMETRIC CHART

The Bulkeley Psychrometric Chart[2] (Fig. 1) shows graphically the relationships expressed in Equation 4. It also gives the grains of moisture per pound of dry air for saturation, the grains of moisture per cubic foot of saturated air, the total heat in Btu per pound of dry air saturated with moisture, and the weight of the dry air in pounds per cubic foot. Fig. 2 shows the procedure to follow in using the Bulkeley Chart. The directrix curves above the saturation line are as follows:

[2]The Bulkeley Psychrometric Chart was presented to the Society in 1926. (See A.S.H.V.E. TRANSACTIONS, Vol. 32, 1926.) Fig. 1 has been reproduced from the original chart but with the secondary cross-section lines omitted.

A is the total heat in Btu contained in the mixture above 0 deg F, and is to be referred to column of figures at left side of chart.

B is the grains of moisture of water vapor contained in each pound of the saturated mixture and is to be referred to the figures at the left side of the chart.

C is the grains of moisture or water vapor per cubic foot of saturated mixture, and is to be referred to the figures at the left side of the chart and divided by ten.

D is the weight in decimal fractions of a pound, of one cubic foot of the saturated mixture, and is referred to the first column of figures to the right of the saturation line between the vertical dry-bulb temperature lines 170 and 180 F. The relative density of the mixture is read in a similar manner from the same curve by the column of figures between the vertical dry-bulb temperature lines 180 and 190 F.

E is similar to *D* but is for dry air, devoid of all moisture or water vapor. For convenience, the approximate absolute temperature of 500 F is given at 40 F on the saturation line for the purpose of calculating volume, weight per cubic foot and relative density at partial saturation.

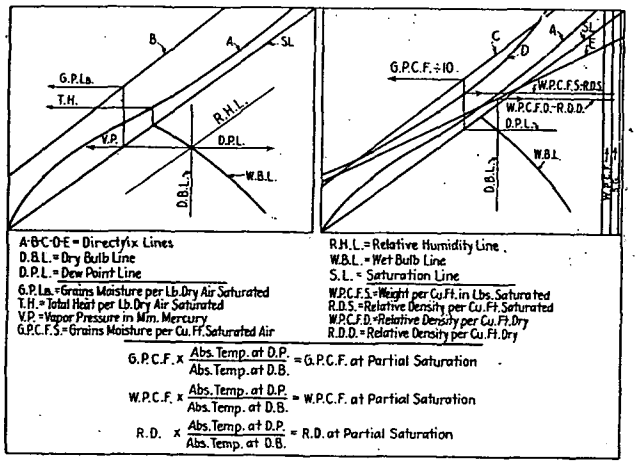


FIG. 2. DIAGRAMS SHOWING PROCEDURE TO FOLLOW IN USING BULKELEY CHART

Examples in Use of Chart (Fig. 1)

Example 3. Relative Humidity: At the intersection of the 78-F wet-bulb line and the 95-F dry-bulb line, the relative humidity is read directly on the straight diagonal lines as 45.7 per cent.

Example 4. Dew-Point: At the intersection of the 78-F wet-bulb line, the dew-point temperature is read directly on the horizontal temperature lines as 70.9 F.

Example 5. Vapor Pressure: At the intersection of the 78-F wet-bulb line and the 95-F dry-bulb line, pass in a horizontal direction to the left of the chart and on the logarithmic scale read the vapor pressure as 19.4 millimeters of mercury. (Divide by 25.4 for inches).

Example 6. Total Heat Above 0 Deg in Mixture per Pound of Dry Air Saturated with Moisture: From where the wet-bulb line joins saturation line, pass in vertical direction on 78-F dry-bulb line to its intersection with curve *A* and on the logarithmic scale at the left of the chart read 40.6 Btu per pound of mixture. The use of this curve to obtain total heat in the mixture at any wet-bulb temperature is a great convenience, as the number of Btu required to heat the mixture and humidify, as well as the refrigeration required to cool and dehumidify the mixture, can be obtained by taking the difference in total heat before and after treatment of the mixture.

Example 7. Grains of Moisture per Pound of Mixture: From 70.9 F dew-point temperature on the saturation line, pass vertically to the intersection with curve *B* and on the logarithmic scale at the left read 114 grains of moisture per pound.

Example 8. Grains of Moisture per Cubic Foot of Mixture, Partially Saturated: From 70.9 F dew-point temperature on the saturation line proceed in a vertical direction to curve *C*, and on the logarithmic scale to the left read 83.3, which divided by 10, gives 8.33 grains. A temperature of 70.9 F is equal to an absolute temperature of 530.9, and 95 F equals 555 F, absolute temperature. Therefore, $\frac{530.9}{555} \times 8.33 = 7.97$ grains per cubic foot of partially saturated mixture.

Example 9. Grains of Moisture per Cubic Foot of Dry Air, Saturated: Starting at the saturation line at the desired temperature, pass in vertical direction to curve *C* and on logarithmic scale, on left, read and divide by 10.

Example 10. Weight per Cubic Foot of Dry Air and Relative Density: From point where, for example, the 70-F vertical dry-bulb line intersects curve *E*, pass to right side and read 0.075 lb; if cubic feet per pound is desired, divide 1 by this amount. The relative density is read immediately to the right as 1.00.

Example 11. Weight per Cubic Foot of Saturated Air and Relative Density: From point where, for example, the 70 F vertical line intersects the curve *D*, pass to the right and read weight per cubic foot as 0.07316 with a relative density of 0.9755 for saturated air at 70 F.

Example 12. Weight per Cubic Foot and Relative Density of Partially Saturated Air: Air at 50 F and a wet-bulb temperature of 46 F is to be heated to 130 F. The wet- and dry-bulb lines intersect at a dew-point temperature of 42 F. Pass to the left where this dew-point line intersects the saturation line and then pass in a vertical direction to where the 42 F dry-bulb line intersects with curve *D*. Then pass directly to the right and read the weight per cubic foot of saturated air at 42 F as 0.07844 and the relative density as 1.046. The absolute temperature at 42 F is 502 F, and at 130 F is 590 F. Therefore, $\frac{502}{590} = 0.851$. The weight of 1 cu ft of air at 50 F dry-bulb and 46 F wet-bulb when heated to 130 F is $0.07844 \times 0.851 = 0.06675$, and the relative density is $1.046 \times 0.851 = 0.89$.

CALCULATION OF VAPOR PRESSURE

A formula has also been derived which will permit the approximate calculation of the vapor pressure from the wet-bulb temperature observation. This is useful particularly in determining relative humidities for conditions other than the standard barometric conditions for which the psychrometric chart is made. The formula for expressing this relationship is:

$$e = e' - \frac{(P - e')\,(t - t')}{2{,}800 - 1.3t'} \qquad (5)$$

where

e = partial pressure of the moisture in the air, which also equals vapor pressure corresponding to the dew point.
e' = the vapor pressure corresponding to saturation at wet-bulb temperature t'.
P = the barometric pressure.
t = dry-bulb temperature in deg fahr.
t' = wet-bulb temperature in deg fahr.

TOTAL HEAT

In cooling and dehumidifying air, it is necessary to take into consideration not only the sensible heat of the air itself but the latent heat of the moisture removed, as in Example 2.

Air at any temperature and moisture content may be considered as having a certain definite total heat in thermal units per unit weight as calculated from some arbitrary base, such as zero moisture and zero temperature. By using the psychrometric chart, on which are given wet-bulb temperatures and corresponding total heats, it is possible to determine the total heat to be removed in the process of dehumidification by subtracting the total heat of the cooled air with its reduced moisture content from that of the air in its initial condition as indicated on the chart.

This process is simplified greatly by taking into account the fourth psychrometric principle, by observing the fact that the wet-bulb temperature of the air may be used as the measure of the total heat which the air contains. Thus, by referring to the chart, having given air of known temperature and known moisture content, a corresponding wet-bulb temperature is obtained. Then, under standard barometric conditions, the quantity desired is determined by reference to the curve of total heat. For example, air at 85½ F with 80 per cent relative humidity has exactly the same total heat as air at 101 F and 40 per cent relative humidity, because in both cases the wet-bulb temperature is 80 F. This wet-bulb temperature represents about the maximum wet-bulb temperature ever encountered in the Temperate Zone under extreme conditions, and is nearly the maximum found in the Tropics. A normal high wet-bulb temperature for the Temperate Zone may be taken at 75 F in calculating requirements for air cooling, as this is seldom exceeded, except for short periods.

RATE OF EVAPORATION

In problems of air conditioning and drying, as well as in other industrial applications of evaporation, such as cooling towers, for example, it is desirable to determine the rate of evaporation. There are two distinct cases of evaporation. The *first* case is that in which the source of heat is primarily from the water itself and in which the air temperature may even be raised. The *second* is that in which the heat for evaporation is obtained entirely from the air itself, in which case the air is cooled and the temperature of the water remains substantially constant at the wet-bulb temperature. Both cases, however, may be reduced to a common basis of calculation. It has been found that the increase in the rate of evaporation is nearly in direct proportion to the increase in the air velocity, and that it is in direct proportion to the difference in vapor pressure between the vapor pressure of the water and the pressure of the vapor in the air.

The general formula covering the experimental data may be expressed as follows:

$$\frac{dw}{dt} = (a + bv)(e' - e) \qquad (6)$$

where

$\frac{dw}{dt}$ = rate of evaporation.
a = the rate of evaporation in still air.
b = the rate of increase with velocity.

e' = the vapor pressure of the liquid.
e = the vapor pressure in the atmosphere.
v = velocity.

The only difference between case *one* and case *two* is that in case *one* the vapor pressure of the liquid is one of the known or assumed factors, being dependent upon the known temperature of the liquid, while in case *two*, e' is the vapor pressure corresponding to the wet-bulb temperature of the air.

This wet-bulb or evaporation temperature is dependent upon the dry-bulb temperature and the moisture content, or upon the total heat of the air as indicated in the previous paragraph.

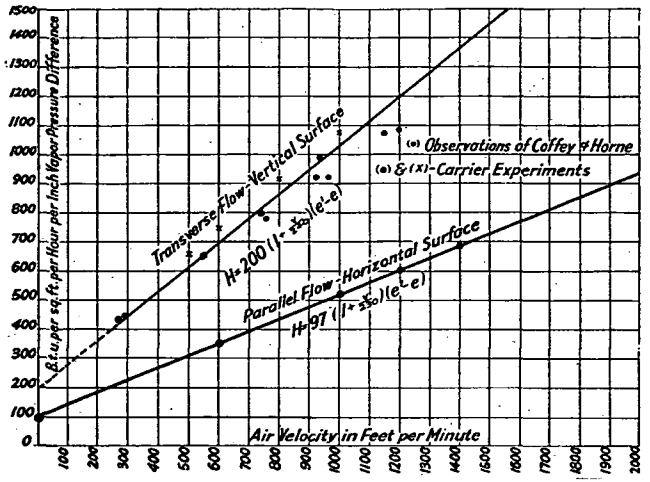


FIG. 3. HEAT TRANSMITTED BY EVAPORATION

The effect of air velocity depends upon whether the flow of air is parallel to the surface or perpendicular to the surface elements. For a flow of air *parallel* to a horizontal surface

$$w = 0.093\left(1 - \frac{v}{230}\right)(e' - e) \quad \text{(approximately)} \qquad (7)$$

where

w = pounds evaporated per square foot per hour.
v = velocity of atmosphere over surfaces in feet per minute.
e' = vapor pressure of the water corresponding to its temperature.
e = vapor pressure in the surrounding atmosphere.

For *transverse* flow, as across a tubular surface, the rate of evaporation is nearly doubled.

These relationships are indicated graphically on the chart, Fig. 3.

Since the difference in vapor pressures is substantially proportional to the difference between the wet- and dry-bulb temperatures (*i.e.*, the wet-

bulb depression) the rate of evaporation is also for case *two* substantially proportionate to the wet-bulb depression.

In case *two*, the rate of sensible heat transfer, from the air to the liquid to produce evaporation is substantially the same as the rate of heat transfer with the same type of surface, without moisture being present, but with the same temperature differences. In other words, the rate of heat transfer depends upon the temperature difference only, whether the surface is wet or not. For example, it has been shown that the rate of heat transfer with air flowing across staggered coils (transverse flow) may be represented by the formula:

$$U_t = \frac{1}{0.0447 + \frac{50.66}{v}} \qquad (8)$$

where

U_t = heat transfer expressed in Btu per hour per square foot per degree difference in temperature between steam and air, for transverse flow.

At a velocity of 400 fpm, $U_t = 5.8$, at a velocity of 800 fpm, $U_t = 9.3$.

Referring to Fig. 3, showing the rate of heat transmission by evaporation for different air velocities, it will be noted that for transverse flow there are 560 Btu per hour per square foot transferred per inch difference of vapor pressure at a velocity of 400 fpm and 910 Btu per hour per square foot per inch difference in vapor pressure at a velocity of 800 fpm. One inch of vapor pressure difference corresponds approximately to 95 deg difference between the wet- and dry-bulb temperature. Dividing by 95, the value of 5.9 Btu per square foot per degree difference in temperature is obtained for a velocity of 400 fpm and 9.55 Btu per square foot for a velocity of 800 fpm.

It will be noted that for these two cases the heat transfer by evaporation per degree difference in temperature corresponds almost exactly with the heat transfer by convection coils. The similarity may be noted by comparing the formula for heat transfer in parallel flow, where

$$U_p = \frac{1}{0.026 + \frac{161}{v}} \qquad (9)$$

with the heat transfer by evaporation with parallel flow. The relationship will be seen to be very close in both cases and would indicate that the heat transfer by evaporation is actually brought about by a process of convection.

The difference in form of the two formulae may be due in part to errors in observation at the higher and lower velocities.

In cooling air and condensing out the moisture therefrom the heat transfer is considerably more rapid than when the air is dry and no moisture is condensed. In general the rate of heat transmission on the air side is increased an amount which is proportionate to the latent heat removed as compared with the sensible heat removed. That is, if the latent heat removed was 50 per cent of the sensible heat removed, then the conductivity of the surface in contact with the air would be increased approximately 50 per cent.

Chapter 28

AIR CONDITIONING IN RELATION TO COMFORT AND HEALTH

Changes in Composition and Vitiation of Air; Heat Regulation in Man; Effects of Adverse Air Conditions; Acclimatization and the Psychologic Factor; Relation of Temperature, Humidity and Air Motion to Sensations of Warmth and Comfort; Optimum Air Conditions for Comfort and Health; Application of Comfort Charts to Air Cooling; Recirculation and the Use of Ozone; Ultra-Violet Radiation and Ionization; Heat and Moisture Given Up by Human Body; Air Pollution in Relation to Comfort and Health; Synthetic Air Chart.

FROM the standpoint of comfort and health, air conditioning may be regarded as the art of maintaining the atmosphere of occupied spaces at a condition best suited to the physiological requirements of the human body. According to the present knowledge of the problem, the requirements consist of maintaining simultaneously the proper temperature, humidity and air movement, and a reasonable air purity with regard to dusts, bacteria and odors.

CHANGES IN COMPOSITION AND VITIATION OF AIR

Under the artificial conditions of indoor life, the air undergoes certain chemical changes and a vitiation which are brought about by the occupants themselves. The oxygen content is somewhat reduced, and the carbon dioxide slightly increased by the respiratory processes. Organic matter, which is usually perceived as odors, is given off from the mouth, skin and clothing. The temperature of the air is increased by the metabolic processes, and the humidity raised by the moisture emitted from the skin and lungs. Moreover, according to latest researches[1], there is a marked decrease in both positive and negative ions in the air of occupied rooms.

Contrary to old theories, the usual changes in oxygen and carbon dioxide are of no physiological concern because they are much too small even under the worst conditions. The amount of carbon dioxide in air is often used in ventilation work as an index of odors of human origin, but the information it affords rarely justifies the labor involved in making the observation. Little is known of the identity and physiological effects of the organic matter given off in the process of respiration. The former belief that the discomfort experienced in confined spaces was due to some

[1] *Changes in Ionic Content in Occupied Rooms Ventilated by Natural and Mechanical Methods*, by C. P. Yaglou, L. C. Benjamin and S. P. Choate (*Heating, Piping and Air Conditioning*, October, 1931).

toxic volatile matter in the expired air is now limited, in the light of numerous researches, to the much less dogmatic view that the presence of such a substance has not been demonstrated. The only fact that does appear certain is that expired and transpired air is odorous and offensive, and it is capable of producing headache, nausea, loss of appetite and a disinclination for physical activity. These reasons alone, whether æsthetic or physiological, are sufficient to warrant adequate air conditioning.

A certain part of the dissemination of disease which occurs in confined spaces is caused by the continuous emission of pathogenic bacteria from infected persons. Infections by droplets from coughing and sneezing constitute a limited mode of transmission in the immediate vicinity of the infected person. Experiments have shown that the mouth spray is a coarse rain which settles down quickly. The contamination is local and the problem is considered to be largely one of contact infection rather than air-borne infection.

The primary factors in air conditioning work, in the absence of any specific contaminating source, are temperature, humidity and air movement. As compared with these physical factors, the chemical factors are, as a general rule, of secondary importance.

HEAT REGULATION IN MAN

The importance of temperature, humidity and air movement arises from the profound influence which these factors exert upon body temperature, comfort and health. Body temperature is a resultant of two factors, (1) heat production and (2) heat loss. The heat resulting from the combustion of food within the body maintains its temperature well above that of the surrounding air. At the same time, heat is constantly lost from the body by radiation, conduction and evaporation. Since, under ordinary conditions, the body temperature is maintained at its normal level of about 98.6 F, the heat production must be balanced by the heat loss. In healthy persons this takes place automatically by the action of the heat regulating mechanism.

According to the general view, special areas in the skin are sensitive to temperature. Nerve courses carry the sense impressions to the brain and the response comes back over another set of nerves, the motor nerves, to the musculature and to all the active tissues in the body, including the endocrine glands. In this way, a two-sided mechanism controls the body temperature by (1) regulation of internal heat production (chemical regulation), and (2) regulation of heat loss by means of automatic variation in the rate of cutaneous circulation and the operation of the sweat glands (physical regulation). The mechanisms of adjustment are complex and little understood at the present time. Coordination of these different mechanisms seems to vary greatly with different air conditions.

In reasonably warm environments (75 F to 80 F), metabolism, or internal heat production, is decreased to some extent, probably by an inhibitory action on heat producing organs, such as the liver. The blood capillaries in the skin become dilated by reflex action of the vasomotor nerves, allowing more blood to flow into the skin, and thus increase its temperature and consequently its heat loss. The increase in peripheral

circulation is at the expense of the internal organs. If this method of cooling is not in itself sufficient, the stimulus is extended to the sweat glands which allow water to pass through the surface of the skin, where it is evaporated. This method of cooling is the most effective of all, as long as the humidity of the air is sufficiently low to allow for evaporation. In high humidities, equally good results may be obtained by increasing the air movement, and hence heat loss by conduction and evaporation.

In cold environments, in order to keep the body warm there is an actual increase in metabolism brought about partly by voluntary muscular contractions (shivering) and partly by an involuntary reflex upon the heat producing organs. The surface blood vessels become constricted and shrink further below the surface, thus increasing the insulating layer and decreasing heat loss. The blood supply to the skin is curtailed by vasomotor shifts to the internal organs, in order to conserve body heat.

EFFECTS OF ADVERSE AIR CONDITIONS

Effects of Heat

Although the human organism is capable of adapting itself to variations in environmental conditions, its ability to maintain heat equilibrium is limited. The heat regulating center fails, for instance, if the external temperature is so abnormally high that bodily heat cannot be eliminated as fast as it is produced. Part of it is retained in the body, causing a rise in skin and deep tissue temperature, an increase in the heart rate, accelerated respiration and the like (see Table 1). In extreme conditions, the metabolic rate is markedly increased owing to the excessive rise in body temperature, and a vicious cycle results which may eventually lead to serious physiologic damage.

Examples of this are met with in unusually hot summer weather and in hot industries where the radiant heat from hot objects renders heat loss from the body by radiation and convection impossible. Consequently, the workers depend entirely on evaporation for the elimination of body

TABLE 1. PHYSIOLOGICAL RESPONSES TO HEAT OF MEN AT REST AND AT WORK[a]

Effective Temp.	Actual Cheek Temp. (Deg Fahr)	Men at Rest			Men at Work 90,000 ft-lb of Work per Hour			
		Rise in Rectal Temp. (Deg Fahr per Hour)	Increase in Pulse Rate (Beats per Min. per Hour)	Approximate Loss in Body Weight by Perspiration (lb per Hr.)	Total Work Accomplished (ft-lb)	Rise in Body Temp. (Deg Fahr per Hr)	Increase in Pulse Rate (Beats per Min. per Hr.)	Approximate Loss in Body Wt. by Perspiration (lb per Hr.)
60	.....	.....	.....	.....	225,000	0.0	6	0.5
70	.....	0.0	0	0.2	225,000	0.1	7	0.6
80	96.1	0.0	0	0.3	209,000	0.3	11	0.8
85	96.6	0.1	1	0.4	190,000	0.6	17	1.1
90	97.0	0.3	4	0.5	153,000	1.2	31	1.5
95	97.6	0.9	15	0.9	102,000	2.3	61	2.0
100	99.6	2.2	40	1.7	67,000	4.0	103[b]	2.7
105	104.7	4.0	83	2.7	49,000	6.0[b]	158[b]	3.5[b]
110	.....	5.9[b]	137[b]	4.0[b]	37,000	8.5[b]	237[b]	4.4[b]

[a]Data by A.S.H.V.E. Research Laboratory.
[b]Computed value from exposures lasting less than one hour.

heat. They stream with perspiration and drink liquids abundantly to replace the loss.

One of the most deleterious effects of high temperatures is that the blood is diverted from the internal organs to the surface capillaries, in order to serve in the process of cooling. This affects the stomach, heart, lungs and other vital organs, and it is believed that the feeling of lassitude and discomfort experienced is due to the anæmic condition of the brain. The stomach loses some of its power to act upon the food, owing to a diminished secretion of gastric juice, and there is a corresponding loss in the antiseptic and antifermentive action which favors the growth of bacteria in the intestinal tract[2]. These are considered to be the potent factors in the increased susceptibility to gastro-intestinal disorders in hot summer weather. The victim may lose appetite and suffer from indigestion, headache and general enervation, which may eventually lead to a premature old age.

In warm atmospheres, particularly during physical work, a considerable amount of chloride is lost from the system through sweating. The loss of this substance may lead to attacks of cramps, unless the salts are replaced in the drinking water. In order to relieve both cramps and fatigue, Moss[3] recommends the addition of 6 grams of sodium chloride and 4 grams of potassium chloride in a gallon of water.

The deleterious physiologic effects of high temperatures exert a powerful influence upon physical activity, accidents, sickness and mortality. Both laboratory and field data show clearly that physical work in warm atmospheres is a great effort, and that production falls progressively as the temperature rises. The incidence of industrial accidents reaches a minimum at about 68 F, increasing above and below that temperature. Sickness and mortality rates increase progressively as the temperature rises.

Effects of Cold

The action of cold on human beings is not well known. Cold affects the human organism in two ways: (1) through its action on the body as a whole, and (2) through its action on the mucous membranes of the upper respiratory tract. Little exact information is available on the latter.

On exposure to cold, the loss of heat is increased considerably and only within certain limits is compensation possible by increased heat production and decreased peripheral circulation. The rectal temperature often rises upon exposure to cold but the pulse rate and skin temperature fall. The blood pressure increases, owing to constriction in the peripheral vessels and to thickening of the blood. The skin subcutaneous tissues and muscles form reservoirs for storing the water which leaves the blood. In extremely cold atmospheres compensation becomes inadequate. The body temperature falls and the reflex irritability of the spinal cord is markedly affected. The organism may finally pass into an unconscious state which ends in death.

[2] *Influence of Effective Temperature upon Bactericidal Action of Gastro-Intestinal Tract*, by Arnold and Brody (*Proceedings Society* Exp. Biol. Med. Vol. 24, 1927, p. 832).

[3] *Some Effects of High Air Temperatures upon the Miner*, by K. N. Moss (*Transactions Institute of Mining Engineers*, Vol. 66, 1924, p. 284).

Cannon[4] showed that excessive loss of heat is associated with increased activity of the adrenal medulla. The extra output of adrenin hastens heat production which protects the organism against cooling. Bast[5] found a degeneration of thyroid and adrenal glands upon exposure to cold, and some physicians believe that the common use of tonics in spring has something to do with the degeneration of the endocrine glands.

Effects of Changes in Temperature

A moderate amount of variability in temperature is known to be beneficial to health, comfort, and the performance of physical and mental work. On the other hand, extreme changes in temperature, such as those experienced in passing from a warm room to the cold air out of doors, appear to be harmful to the tissues of the nose and throat which are the portals for the entry of respiratory diseases.

Experiments show that chilling causes a constriction of the blood vessels of the palate, tonsils and throat, which is accompanied by a fall in the temperature of the tissues. On rewarming, the palate and throat do not always regain their normal temperature and blood supply. This anæmic condition favors bacterial activity and it is believed to play a part in the inception of the common cold and other respiratory diseases.

Sickness records in industries seem to strengthen this belief. The Industrial Fatigue Research Board of England[6] found that in workers exposed to high temperatures and to changes in temperature, namely, steel melters, puddlers, and tin-plate millmen, there is an excess of all sickness, the excess among the puddlers being due chiefly to respiratory diseases and rheumatism. The causative factor was not the heat itself but the sudden changes in temperature to which the workers were exposed. The tin-plate millmen who were not exposed to chills, since they work almost continuously throughout the shift, had no excess of rheumatism and respiratory diseases. On the other hand, the blast-furnacemen, who work mostly in the open, showed more respiratory sickness than the steel workers. This experience in British factories is well in accord with the findings in American industries[7]. According to these data the highest pneumonia death rate is associated with dust, extreme heat, exposure to cold, and to sudden changes in temperature.

ACCLIMATIZATION AND THE PSYCHOLOGIC FACTOR

Acclimatization and the factor of psychology are two important influences in air conditioning which cannot be ignored. The first is man's ability to adapt himself to changes in air conditions; the second is an intangible matter of habit and suggestion.

Some persons regard the unnecessary endurance of cold as a virtue. They believe that the human organism can adapt itself to a wide range of

[4] *Studies on the Condition of Activity of Endocrine Glands*, by W. B. Cannon, A. Guerido, S. W. Britton and E. M. Bright (*American Journal of Physiology*, Vol. 79, 1926, p. 466).

[5] *Studies in Exhaustion Due to Lack of Sleep*, by T. H. Bast, J. S. Supurnaw, B. Lieberman and J. Munro (*American Journal of Physiology*, Vol. 85, 1928, p. 135).

[6] *Fatigue and Efficiency in the Iron and Steel Industry*, by H. M. Vernon (Industrial Fatigue Research Board, *Report* No. 5, 1920, London).

[7] *Iron Foundry Workers Show Highest Percentage of Deaths from Pneumonia* (*Statistical Bulletin*, Metropolitan Life Insurance Company, 1928).

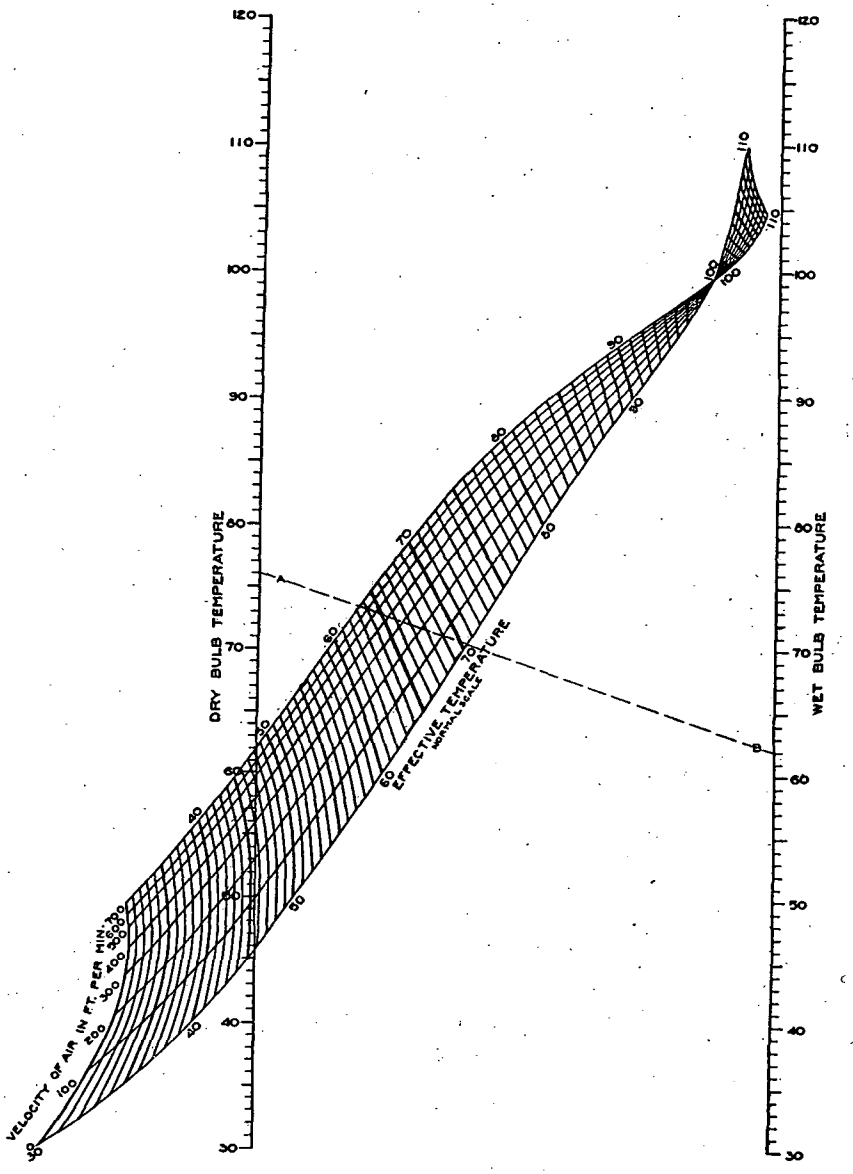


FIG. 1. THERMOMETRIC CHART SHOWING NORMAL SCALE OF EFFECTIVE TEMPERATURE
(Applicable to human beings at rest and normally clothed).

air conditions with no apparent discomfort or injury to health. In the light of the present knowledge of air conditioning these views are not justified. Acclimatization to extreme conditions involves a strain upon the heat regulating system and it interferes with the normal physiologic functions of the human body. Thousands of years in the heat of Africa do not seem to have acclimatized the Negro to a temperature averaging 80 F. The same holds true of northern races with respect to cold, although the effects are mitigated by artificial control. All this seems to indicate that adaptation to a climate averaging between 60 and 75 F is a very primitive trait[8].

In certain individuals the psychologic factor is more powerful than acclimatization. A fresh air fiend may suffer in a room with windows closed regardless of the quality of the air. As a matter of fact, instances are known in which paid subjects refused to stay in a windowless but properly conditioned experimental chamber because the atmosphere felt suffocating to them upon entering the room.

RELATION OF TEMPERATURE, HUMIDITY AND AIR MOTION TO SENSATIONS OF WARMTH AND COMFORT

Temperature, humidity and air motion taken together, determine the feeling of warmth and influence the elimination of body heat. In other words, the temperature sensations of the human body depend not only on the temperature of the surrounding air as registered by a dry-bulb thermometer, but also upon the temperature indicated by a wet-bulb thermometer. Dry air at a relatively high temperature may feel cooler than air of considerably lower temperature with a high moisture content. Air motion makes any moderate condition feel cooler.

On the other hand, in cold environments an increase in humidity produces a cooler sensation. The dividing line at which humidity has no effect upon comfort varies with the air velocity and is about 46 F (dry-bulb) for still air and about 51, 56 and 59 F for air velocities of 100, 300 and 500 fpm respectively.

The Effective Temperature Index

Combinations of temperature, humidity and air movement which produce the same feeling of warmth are called thermo-equivalent conditions. Elaborate experiments made by the A.S.H.V.E. Research Laboratory show that this newly-developed scale of thermo-equivalent conditions not only indicates the sensation of warmth, but also determines the physiological *effects* on the body induced by heat and cold. For this reason, it was called *Effective Temperature* scale or index.

Effective temperature is a relative index of the degree of warmth or cold felt in response to temperature, humidity and air movement. It combines these three factors into a single value. All air conditions which are thermally equivalent to each other have the same effective temperature value. The scale of effective temperatures is based on the degree of warmth and comfort experienced by a healthy individual in pure still air, saturated with moisture and with the surrounding objects at the same

[8] *Civilization and Climate*, by Ellsworth Huntington, *Yale University*, 1924.

temperature as the air. For instance, an air condition has an effective temperature of 65 deg when it induces a sensation of warmth like that experienced in a saturated atmosphere of 65 F in still air.

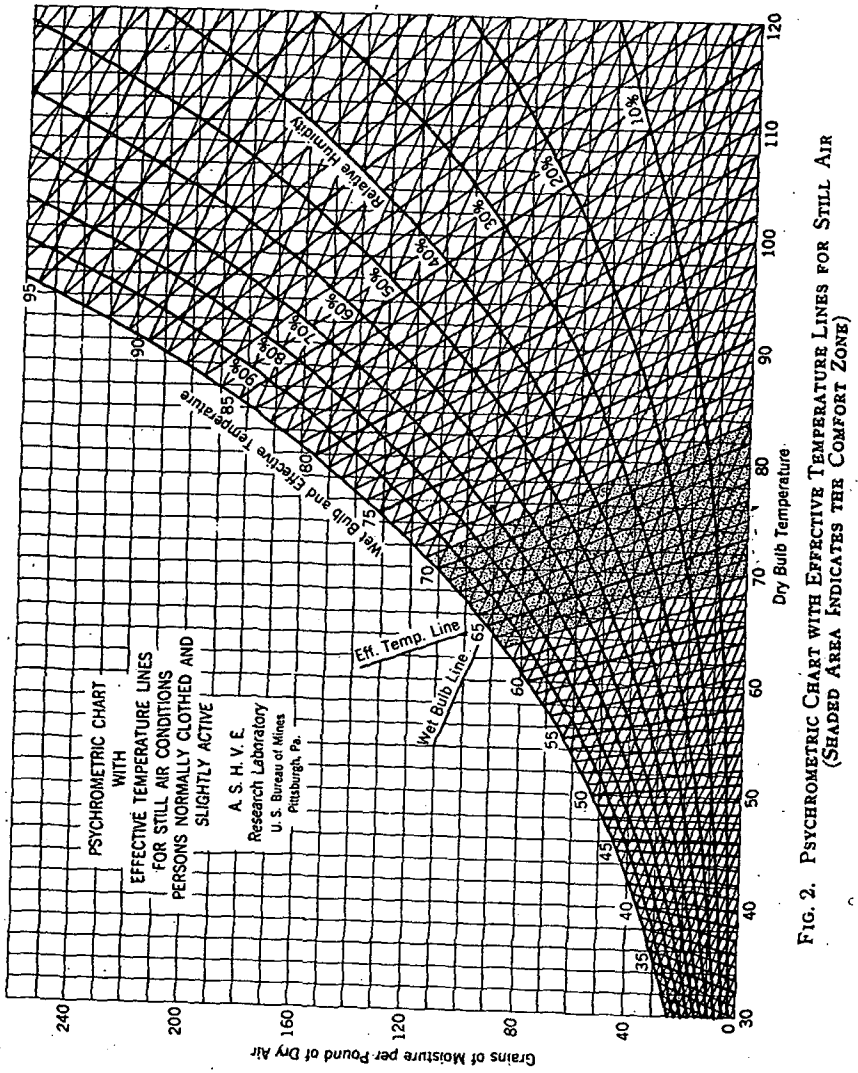


FIG. 2. PSYCHROMETRIC CHART WITH EFFECTIVE TEMPERATURE LINES FOR STILL AIR (SHADED AREA INDICATES THE COMFORT ZONE)

A series of tests has been carried out in the psychometric rooms of the A.S.H.V.E. Research Laboratory, Pittsburgh, in order to determine all the equivalent conditions met with in general air conditioning work. Reports of these studies for both still and moving air are given in A.S.H.-

V.E. TRANSACTIONS, Vols. 27 to 36, inclusive. Fig. 1 shows the results in a single chart (the so-called thermo-metric chart) which applies to persons at rest and normally clothed. The equivalent conditions or effective temperature lines are shown by the short cross-lines.

The difference between the effective temperature for still air and for moving air, of any velocity, represents the cooling resulting from that air velocity.

Example in Use of Chart (Fig. 1)

Example 1. Given dry-bulb and wet-bulb temperatures of 76 F and 62 F, respectively, and an air velocity of 100 fpm, determine: (1) effective temperature of the condition; (2) effective temperature with still air; (3) cooling produced by the movement of the air; (4) velocity necessary to reduce the condition to 66 deg effective temperature.

Solution (*1*). Draw line *AB* through given dry- and wet-bulb temperatures. Its intersection with the 100-ft velocity curve gives 69 deg for the effective temperature of the condition. (2) Follow line *AB* to the right to its intersection with the 0 velocity line, and read 70.4 deg for the effective temperature with still air. (3) The cooling produced by the movement of the air is 70.4 — 69 = 1.4 deg effective temperature. (4) Follow line *AB* to the left until it crosses the 66 deg effective temperature line. Interpolate velocity value of 340 fpm, to which the movement of the air must be increased for maximum comfort.

OPTIMUM AIR CONDITIONS FOR COMFORT AND HEALTH

No single comfort standard can be laid down which would meet every need. There is an inherent individual variation in the sensation of warmth or comfort felt by persons when exposed to an identical atmospheric condition. The state of health, age, sex, clothing, activity, and the degree of acquired adaptation seem to be the important factors affecting the comfort standards.

Since the prolonged effects of temperature, humidity and air movement on health are not known to the same extent as their effects on comfort, the optimum conditions for health may not be identical with those for comfort. On general physiologic grounds, however, the two do not differ greatly since this is in accordance with the efficient operation of the heat regulating mechanism of the body. This belief is strengthened by results of studies on premature infants over a four-year period[9]. By adjusting the temperature and humidity so as to stabilize the body temperature of these infants, the incidence of diarrhœa and mortality was automatically decreased, gains in body weight increased and infections were reduced to a minimum.

Comfort Line and Comfort Zone

That range of effective temperatures over which the majority of people (50 per cent or more) feel comfortable, is called the *comfort zone* and is shown in Fig. 2. That particular effective temperature at which a maximum number of people feel comfortable is called the *comfort line.*

The *winter comfort zone* as determined at the A.S.H.V.E. Laboratory ranges from 63 deg to 71 deg ET. While at rest, 97 per cent of the experimental subjects were found to be comfortable at 66 deg ET and this

[9] *Application of Air Conditioning to Premature Nurseries in Hospitals*, by C. P. Yaglou, Philip Drinker and K. D. Blackfan (A.S.H.V.E. TRANSACTIONS, Vol 36, 1930).

temperature was accepted as the *winter comfort line* or *optimum effective temperature*. These tests were made in 1923 in rooms with wall surface temperatures approximately the same as the room dry-bulb temperature. For walls of large area having unusually low surface temperatures, however, a somewhat higher range of effective temperature is required to compensate for the increased loss of heat from the body by radiation. Although Fig. 2 shows the comfort zone as extending from 0 per cent relative humidity to 100 per cent relative humidity, it is probable that the limits should be 30 per cent and 70 per cent since extreme humidities are not conducive to comfort. Furthermore, 30 per cent to 70 per cent is the approximate range used in the experiments at the A.S.H.V.E. Laboratory.

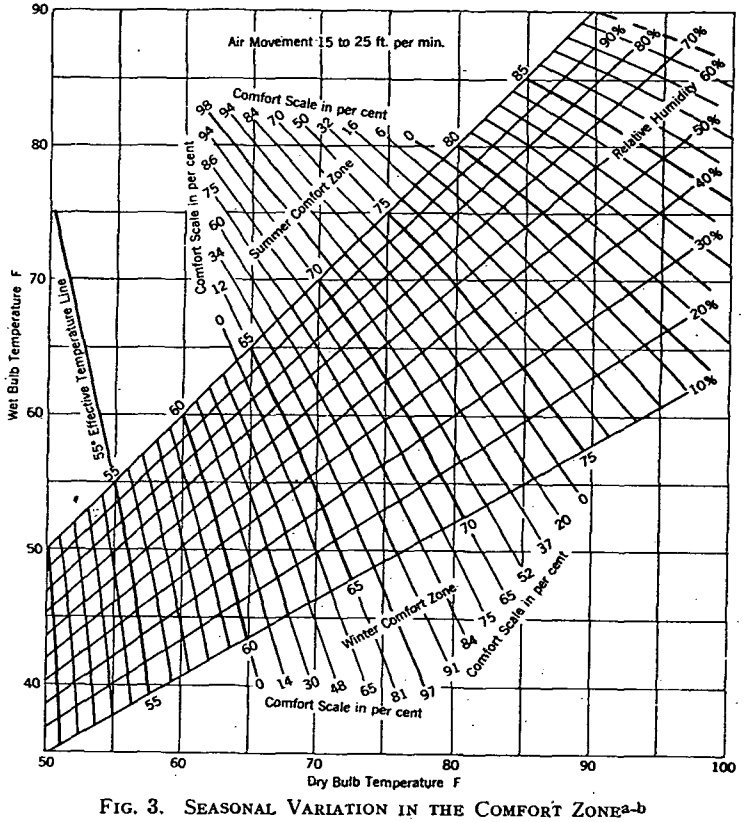


FIG. 3. SEASONAL VARIATION IN THE COMFORT ZONE[a-b]

[a] *Determination of the Comfort Zone*, by F. C. Houghten and C. P. Yaglou (A.S.H.V.E. TRANSACTIONS Vol. 29, 1923).

[b] *The Summer Comfort Zone; Climate and Clothing*, by C. P. Yaglou and Philip Drinker (A.S.H.V.E. TRANSACTIONS, Vol. 35, 1929).

The *summer comfort zone* for men and women in the United States

wearing customary warm weather clothing ranges from about 67 deg to 75 deg ET, based on studies made at the Harvard School of Public Health. The probable optimum effective temperature is 71 deg. These effective temperatures average about 4 deg higher than those found in winter when customary winter clothing was worn. Fig. 3 shows the summer and winter comfort zones superimposed upon the effective temperature chart designed at the A.S.H.V.E. Laboratory[10]. Young men as a general rule prefer conditions in the cool region of the comfort zone, and women and older people in the warm region of the comfort zone.

Crowding the experimental chamber lowered the optimum effective temperature from 70.8 deg when the gross floor area per occupant was 44 sq ft and the air space 380 cu ft to 69.4 deg when the floor area was reduced to 14 sq ft and the air space to 120 cu ft per occupant.

Comfort Chart Examples

Example 2. Given dry-bulb and wet-bulb temperatures of 75 and 68 F, respectively. First, what is the effective temperature? Second, is this condition warmer or cooler than 80 F dry-bulb and 60 F wet-bulb?

Solution. The first condition is given by the intersection of the 75 F dry-bulb line and the 68 F wet-bulb line (Fig. 2). The effective temperature of 72.1 deg is given by the numerical value of the effective temperature line passing through this point and indicated by the scale along the saturation curve. The second condition is given by the intersection of 80 F dry-bulb and 60 F wet-bulb and is 71.8 deg ET. It is therefore 0.3 deg ET cooler than the first condition.

Example 3. Given 76 F dry-bulb and 61 F wet-bulb, how many degrees difference between this condition and the winter comfort line or 66 deg ET?

Solution. The effective temperature for this condition is given by the intersection of the 76-F dry-bulb and 61-F wet-bulb lines and is 70 deg ET, which is 4 deg ET warmer than the comfort line.

Example 4. Given the dry and wet-bulb temperatures in a room 76 and 54 F, respectively. What air velocity will be necessary to make this condition more comfortable, that is, 66 deg ET?

Solution. From Fig. 1 it will be seen that this condition has an effective temperature of 68.0 deg in still air, while an air velocity of 200 fpm gives an effective temperature of 65.7 deg. A velocity of about 160 fpm will give the desired result.

Example 5. Given a condition having dry and wet-bulb temperatures of 90 F and 85 F, respectively. How much cooler will this condition feel if air at a velocity of 300 fpm is supplied instead of still air?

Solution. This condition in still air has an effective temperature of 86.6 deg (Fig. 1) while if the air has a velocity of 300 fpm it will have an effective temperature of 83.8 deg. Cooling of 2.8 deg ET will be produced by the 300-fpm air velocity.

Adaptation to Seasonal Weather

The variation in the comfort zone (Fig. 3) from winter to summer is probably due partly to adaptation to seasonal weather and partly to differences in the clothing worn in the two seasons.

The optimum effective temperature was found to follow the average monthly outdoor temperature more closely than the prevailing outdoor temperature. It remained at approximately the same value in July, August and September, and although the average monthly temperature did not vary much, the prevailing outdoor temperature ranged from 70 F

[10] *The Summer Comfort Zone; Climate and Clothing*, by C. P. Yaglou and Philip Drinker (A.S.H.V.E. TRANSACTIONS, Vol. 35, 1929).

to 99.5 F. A decrease in the optimum temperature became apparent only when the prevailing outdoor temperature fell to 66 F, which is below the customary room temperature in the United States for summer and winter.

The optimum effective temperature for summer (Fig. 3) applies primarily to cases in which the human body has reached thermal equilibrium with the surrounding air. When one enters a room at 71 deg ET on a hot day, one is likely to experience an intense chill or shock. However, after about two hours exposure, this optimum condition will be quite satisfactory for the average person. On account of this acclimatization, a higher plane of summer temperature conditions is required in places of public assembly where the period of occupancy is short, than is required for offices or industrial plants where the period of occupancy is of longer duration. Both summer and winter comfort zones shown in Fig. 3 make proper allowance for adaptation, and they apply to homes, offices, schools and other similar places where people of sedentary habits spend from three to eight or more hours daily.

In theaters and department stores, which are cooled artificially in warm weather, the contrast between outdoor and indoor air conditions becomes the deciding factor in regard to the temperature and humidity to be maintained. The object of cooling theaters in summer is not to reduce the temperature to the optimum degree, but to maintain therein a reasonably comfortable temperature, and at the same time to avoid sensations of chill or of intense heat in entering and leaving the building.

A satisfactory rule of thumb is to add to 72 F one-third of the difference between the outside dry-bulb temperature and 70 F. This will give a moderate difference and eliminate the shock caused by passing from a hot to a cool atmosphere or the reverse. It is also advantageous to keep the theater entrances and lobbies at a temperature between that prevailing out of doors and that in the auditorium. Desirable indoor conditions in summer corresponding to various outdoor temperatures are given in Table 2, Chapter 2. The relative humidity must be lowered so as to give a sense of comfort without chill. For economical reasons the relative humidity in air-conditioned buildings is, as a general rule, maintained too high in summer and too low in winter, whereas for comfort it should be just the opposite. Entirely aside from this requirement, the relative humidity must induce a rate of evaporation which will keep clothing and skin dry. The lower limit in winter is 30 per cent and the upper limit in summer is 60 per cent.

Optimum Humidity

Dry air produces an excessive loss of moisture from the skin and respiratory tract. Owing to the cooling effect of evaporation, higher temperatures are necessary, and this condition leads to discomfort and lassitude. Moist air, on the other hand, interferes with the normal evaporation of moisture from the skin, and again may cause a feeling of oppression and lassitude, especially when the temperature is also high.

Just what the optimum range of humidity is, is a matter of conjecture. There seems to exist a general opinion, supported by some experimental and statistical data, that warm, dry air is less pleasant than air of a

moderate humidity, and that it dries up the mucous membranes in such a way as to increase susceptibility to colds and other respiratory disorders[11], [12], [13].

For the premature infant, a high relative humidity of about 65 per cent is demonstrably beneficial to health and growth[14], and according to Huntington[15], this seems to be the case for adults also. All of these studies indicate that the optimum humidity must always be considered in combination with temperature.

The chief drawback to high indoor humidities is condensation and frosting on the window glass. With an outdoor temperature of 25 F, condensation will occur on a single glass when the relative humidity reaches 30 per cent, and on double glass when the humidity reaches 63 per cent. In zero weather double glazing will allow an indoor humidity of 48 per cent before condensation begins.

Comfort Zone for Men Working

Satisfactory comfort conditions are found to vary from 40 deg to 70 deg ET, depending upon the rate of work and amount of clothing worn. The effective temperatures giving maximum comfort for persons working have been determined by the A.S.H.V.E. Research Laboratory for a rate of work which is considered hard labor. For this degree of work, 50 per cent were fairly comfortable for temperatures ranging from 46 to 64 deg ET, while the greatest percentage found maximum comfort at 53 deg ET. In hot industries, 80 deg ET is considered the upper limit compatible with efficiency, and, whenever possible, this should be reduced to 70 deg ET or less.

Optimum Air Conditions for Infants and Children

The comfort charts (Figs. 2 and 3) apply to adults between 20 and 70 years of age living in the northeastern parts of the United States. For prematurely born infants, the optimum temperature varies from 100 F to 75 F, depending upon the stage of development. The optimum relative humidity for these infants is placed at 65 per cent. No data are yet available on the optimum air conditions for full term infants and young children up to school age. Satisfactory air conditions for these age groups are assumed to vary from 75 F to 68 F with natural indoor humidities. For school children, the studies of the *New York State Commission on Ventilation* place the optimum air conditions at 66 F to 68 F temperature with a moderate humidity (not specified) and a moderate but not excessive amount of air movement (not specified)[16].

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[11] *Reactions of the Nasal Cavity and Post-Nasal Space to Chilling of the Body Surface*, by Mudd, Stuart, et al (*Journal Experimental Medicine*, 1921, Vol. 34, p. 11).

[12] *Reactions of the Nasal Cavity and Post-Nasal Space to Chilling of the Body Surfaces*, by A. Goldman, et al. II Concurrent Study of Bacteriology of Nose and Throat (*Journal Infectious Diseases*, 1921, Vol. 29, p. 151).

[13] *The Etiology of Acute Inflammations of the Nose, Pharynx and Tonsils*, by Mudd, Stuart, et al (Am. Otol., Rinol., and Laryngol, 1921).

[14] *Application of Air Conditioning to Premature Nurseries in Hospitals*, by C. P. Yaglou, Philip Drinker and K. D. Blackfan (A.S.H.V.E. TRANSACTIONS, Vol. 36, 1930).

[15] *Weather and Health*, by Ellsworth Huntington (*Bulletin* of the National Research Council No. 75. The National Academy of Science, Washington, D. C., 1930).

[16] *Ventilation*, Report of the New York State Commission on Ventilation, 1923.

APPLICATION OF COMFORT CHARTS TO AIR COOLING

From a study of the comfort charts it will be evident that there are four fundamental ways of producing effective cooling:

1. The dry-bulb temperature may be lowered by direct cooling or removal of heat.
2. The moisture content of the air may be reduced.
3. Air motion may produce effective cooling except for extremely severe conditions.
4. Evaporation of water without addition or subtraction of heat is accompanied by an increase in moisture content and a fall in dry-bulb temperature along the wet-bulb line resulting in effective cooling.

Take as an example a condition of 92 F dry-bulb and 40 per cent relative humidity having a wet-bulb temperature of 72.8 F and an effective temperature of 81.1 deg. This condition can be made equivalent to 78 deg ET or it can be made to feel 3.1 deg ET cooler by any one of the four fundamental changes mentioned, as follows:

1. By the removal of heat the dry-bulb temperature may be made to fall to 85.5 F (see Fig. 2) along the *90 grain moisture per pound of dry air line or 64.2 F dew-point* line, when the effective temperature will be 78 deg.
2. Without removal of sensible heat or lowering of the dry-bulb temperature, the moisture content may be reduced from 90 to 46 grains per pound of dry air, when the effective temperature will be 78 deg.
3. A 460-ft velocity (see Fig. 1) will change the still-air condition of 81.1 deg ET to 78 deg ET or will give 3.1 deg ET cooling.
4. Evaporation of water at room temperature without addition or removal of heat will cause the point on the chart, Fig. 2, indicated by the condition under consideration to move along the wet-bulb temperature line to the left thereby lowering the dry-bulb temperature and increasing the moisture content. The wet-bulb temperature will remain the same but the effective temperature will be lowered. By adding 14 grains of moisture without heat, the dry-bulb temperature will fall to 83.8 F and the effective temperature will fall to 78 deg.

The best method of producing effective cooling to be employed in any particular case will depend upon accompanying circumstances and should be determined by a competent engineer. Generally, the removal of heat or water vapor or both, by direct cooling or dehumidifying is most effective. Effective cooling by air motion or evaporation of water is relatively much less expensive, but these methods of cooling are limited to certain conditions of temperature and humidity. Cooling by evaporation of water is effective when the air is dry or when there is considerable difference between the wet- and dry-bulb temperature. Cooling by air motion is most effective at low temperatures. When the effective temperature approaches that of the body little or no cooling results and for certain higher temperatures air motion will make an uncomfortable condition even less bearable.

For moderately high temperatures greater effective cooling results from adiabatic saturation and air movement. Take, for example, a condition of 96 F dry-bulb and 80 F wet-bulb having an effective temperature of 85.7 deg. A 300-fpm air velocity will improve this condition by only 2.0 deg ET. Saturation with water vapor will give a condition of 80 F dry-bulb, 80 F wet-bulb and 80 deg ET or 5.7 deg ET improvement. A 300-ft air velocity with this new wet- and dry-bulb temperature will give an effective temperature of 75.6 deg or a total improvement of 10.0 deg.

A good air washer may reduce the temperature of the air passing through it about 70 per cent of the difference between the wet- and dry-bulb temperatures. Its operation would hardly be justified without a water supply having a temperature of 50 F or cooler because of increasing relative humidity with a decreasing temperature. The effectiveness of an air washer will increase in proportion to the dryness of the outside air and the coldness of the water. For additional information on air washers, see Chapter 30.

RECIRCULATION AND THE USE OF OZONE

Recirculation of air to the extent of 50 per cent or more effects a considerable saving in both heating and refrigeration, but as a general rule it impairs the quality of the air by excessive humidity, excessive odors or both. Moreover, recirculation has a tendency to deprive the air of its ionic content[17], but the influence of this factor on comfort and health is at present questionable.

The value of ozone in recirculated air is debatable and not well founded. Numerous researches[18], [19], [20] have shown that ozone in concentrations permissible in air conditioning work (0.1 to 0.5 parts per million parts of air) exerts practically no effect on pathogenic air-borne organisms and it does not destroy odors but it merely masks them by olfactory compensation. It requires at least 13 parts of ozone per million parts of air to influence bacteria[21]. Human beings are injuriously affected by ozone in concentrations of one part or more per million parts of air. This amount will not destroy odors, kill bacteria, nor purify organic matter.

ULTRA-VIOLET RADIATION AND IONIZATION

In spite of rapid advances in air conditioning during the past few years, the secrets of reproducing indoors the natural climatic elements as they exist in open country under ideal weather conditions have not as yet been fully ascertained. Extensive studies have failed to discover the stimulating quality in open country air which is lost when the air is brought indoors, and particularly when it is treated mechanically. Ultra violet light and ionization have been suggested but have not yet been identified.

It is generally recognized that total solar radiation in open air is the greatest curative and a powerful germicidal agent. A critical review of the literature, however, discloses that artificial ultra-violet radiation has little importance in air conditioning, at least for the time being, because it is not known which of the solar rays brings about the cure, and what physiologic processes are involved in their action. With the exception of rickets and certain skin diseases, artificial radiation was found to have no effect on susceptibility, incidence, and resistance to respiratory infections[22],

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[17] *Changes in Ionic Content in Occupied Rooms, Ventilated by Natural and Mechanical Methods*, by C. P. Yaglou, L. C. Benjamin and S. P. Choate (*Heating, Piping and Air Conditioning*, October, 1931).

[18] *Proceedings, Royal Society of London*, by L. Hill and M. Flack (1911, B, Vol. 84, p. 404).

[19] *Jordan and Carlson* (*Journal American Medical Association*, 1931, Vol. 61, p. 1607).

[20] *Konrich* (Ztschr, f. Hyg., 1913, Vol. 73, p. 443).

[21] *Preventive Medicine and Hygiene*, by Milton J. Rosenau.

[22] *Light—Its Photodynamic Activity and Use as a Therapeutic Agent*, by F. W. Schultz, K. W. Stenstrom and E. M. Clausen (Report to the White House Conference on Child Health and Protection, Washington, February, 1931).

no permanent effects on blood and no effect on the general metabolism of human beings.

Ionization, on the other hand, seems to offer a fruitful field for research. Recent experiments[23] show that in occupied rooms there is a marked decrease in both positive and negative small ions. As shown in Fig. 4, the ionic content fell abruptly soon after the occupants assembled to a very low level which was maintained until the occupants left the room. Both positive and negative ions began to rise again as soon as the occupants departed. The problem now is to determine whether such alterations in the electrical quality of air have any significant bearing on comfort and health. If this proves to be the case, some artificial source of ionization must be employed in occupied rooms.

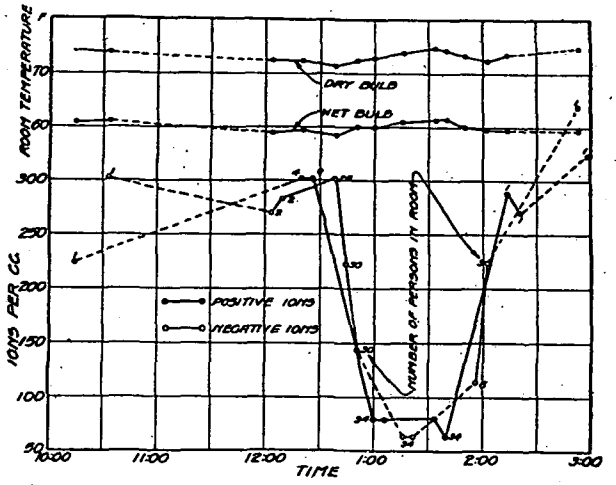


FIG. 4. INFLUENCE OF ROOM OCCUPANCY ON IONIC CONTENT[a]
(CUBICAL CONTENTS OF ROOM, 10,000 CU FT; NUMBER OF OCCUPANTS, 34)

[a]*Changes in Ionic Content in Occupied Rooms, Ventilated by Natural and Mechanical Methods*, by C. P. Yaglou, L. C. Benjamin and S. P. Choate (*Heating, Piping and Air Conditioning*, October, 1931).

HEAT AND MOISTURE GIVEN UP BY HUMAN BODY

In order to solve air conditioning problems involving the human body it is necessary to know the rate at which sensible and latent heat is given up by the body under various conditions of temperature and activity. Research at the A.S.H.V.E. Laboratory[24] has resulted in the data given in Figs. 5, 6, 7 and 8. Table 2 gives the metabolic rates for various degrees of activity.

[23]*Changes in Ionic Content in Occupied Rooms, Ventilated by Natural and Mechanical Methods*, by C. P. Yaglou, L. C. Benjamin and S. P. Choate (*Heating, Piping and Air Conditioning*, October, 1931).

[24]*Heat and Moisture Losses from Men at Work and Application to Air Conditioning Problems*, by F. C. Houghten, W. W. Teague, W. E. Miller and W. P. Yant (*Heating, Piping and Air Conditioning*, June, 1931).

The experimental data from which the curves were drawn indicates that total heat loss does not vary appreciably within the comfort zone range (see Fig. 5). Above or below this range the variation seems to be approximately a function of effective temperature. Sensible and latent heat losses (Figs. 6 and 8) on the other hand, vary greatly within the comfort zone range, the variation following more closely the dry-bulb temperature than any other factor.

Although total heat loss and sensible and latent heat losses are not exact functions of effective and dry-bulb temperature, respectively, for all conditions of humidity and air motion, they are plotted as such in the curves. This is accomplished by approximations not always rigidly accurate, but sufficiently so for application in most practical problems.

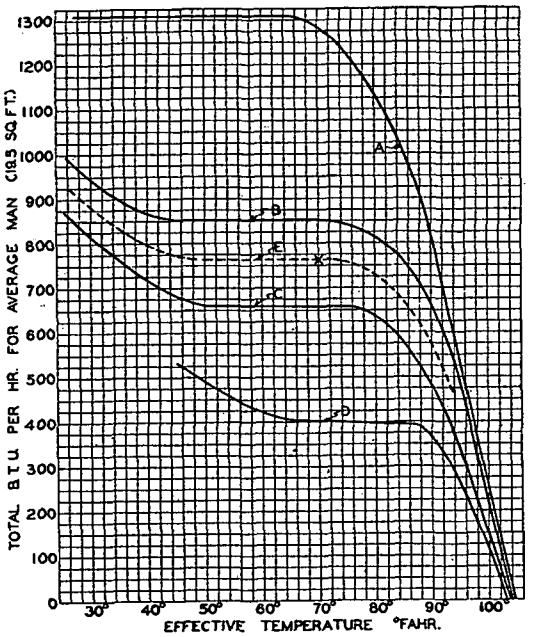


FIG. 5. RELATION BETWEEN TOTAL HEAT LOSS FROM THE HUMAN BODY AND EFFECTIVE TEMPERATURE FOR STILL AIR*

*Curve *A*—Men working, 66,160 ft-lb per hour. Curve *B*—Men working 33,075 ft-lb per hour. Curve *C*—Men working 16,538 ft-lb per hour. Curve *D*—Men seated at rest. Curves *A* and *C* drawn from data at an effective temperature of 70 deg only and extrapolating the relation between curves *B* and *D*, which were drawn from data at many temperatures.

An atmospheric condition resulting in sensible perspiration is to be avoided for good air conditions. Tables 3 and 4 give the approximate effective temperatures at which perspiration is noticeable in different degrees by most individuals for 95 per cent and 20 per cent relative humidity.

In theaters, auditoriums, department stores and other crowded enclosures, the amount of heat and moisture given off by the people is so

large that normal changes in temperature and humidity have relatively little effect on indoor air conditions. The principal object of air conditioning in such places is to remove excessive heat and moisture by supplying a sufficient quantity of properly conditioned air. The indoor air conditions, however, must be varied according to the outside temperature, as already pointed out.

Other Cooling Load Factors

Although the heat and moisture losses from the human body constitute the major portion of the cooling load in most cases where air conditioning

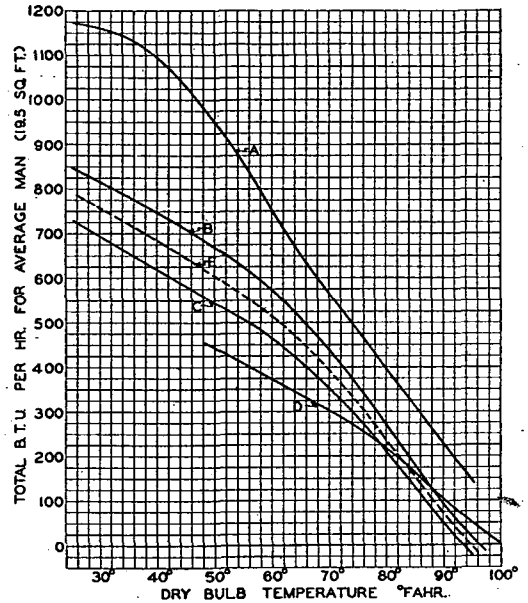


FIG. 6. RELATION BETWEEN SENSIBLE HEAT LOSS FROM THE HUMAN BODY AND DRY-BULB TEMPERATURE FOR STILL AIR*

*Curve *A*—Men working 66,150 ft-lb per hour. Curve *B*—Men working 33,075 ft-lb per hour. Curve *C*—Men working 16,538 ft-lb per hour. Curve *D*—Men seated at rest. Curves *A* and *C* drawn from data at a dry-bulb temperature of 81.3 F only and extrapolating the relation between curves *B* and *D* which were drawn from data at many temperatures.

for comfort and health is provided, other factors also must be considered. These include heat from lights, machinery, processes, etc., as well as the transmission and infiltration of heat through the building structure. The computations for these factors may be made in accordance with data given in Chapter 2.

Allowance must also be made in many cases for sun effect on, and heat capacity of, the building structure, studies of which are now in progress at the A.S.H.V.E. Research Laboratory. Another item to be considered is the radiant heat received by the body from high temperature wall and ceiling surfaces.

Examples Involving Heat and Moisture Losses

Example 6. Assume that the design of an air conditioning system for a theater is to be based on an outdoor dry-bulb temperature of 95 F and a wet-bulb temperature of 78 F with an indoor relative humidity of 50 per cent. A dry-bulb temperature midway between 76 F (the probable optimum for continuous exposure) and 95 F, is selected. This is approximately 85 F. Estimate the sensible and latent heat given up per person.

Solution. The sensible heat, and the moisture given up per person per hour under this condition are obtained from Figs. 6 and 7 by following a vertical line from a dry-bulb temperature of 85 F to Curve *D*, and thence horizontally to the vertical scales. The sensible heat is 165 Btu and the moisture is 1530 grains per person per hour. The latent heat in Btu may be read from Fig. 7 on the vertical scale on the left, or it may be computed by multiplying the moisture loss in pounds by 1040, which is the latent heat of evaporization of water at the temperature of the skin.

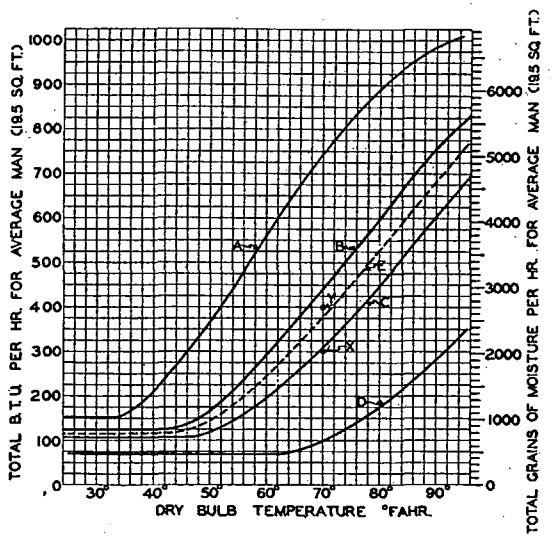


FIG. 7. LATENT HEAT AND MOISTURE LOSS FROM THE HUMAN BODY BY EVAPORATION, IN RELATION TO DRY-BULB TEMPERATURE FOR STILL AIR CONDITIONS*

*Curve *A*—Men working 66,150 ft-lb per hour. Curve *B*—Men working 33,075 ft-lb per hour. Curve *C*—Men working 16,538 ft-lb per hour. Curve *D*—Men seated at rest. Curves *A* and *C* drawn from data at a dry-bulb temperature of 81.3 F only and extrapolating the relation between curves *B* and *D* which were drawn from data at many temperatures.

Example 7. How much sensible heat, how much latent heat and how much water vapor will be added per hour to the atmosphere of an auditorium by an audience of 1000 adults, when the dry- and wet-bulb temperatures are 75 F and 63.5 F, respectively?

Solution. From Curve *D*, Fig. 6, find the sensible heat loss per person for a dry-bulb temperature of 75 F and still air to be 265 Btu per hour. From Fig. 7 find the latent heat loss per person for a dry-bulb temperature of 75 F to be 134 Btu per hour and the moisture added to be 905 grains per hour. Sensible heat = 1,000 × 265 = 265,000 Btu. Latent heat = 1,000 × 134 = 134,000 Btu. Water vapor added per hour to the air in the auditorium = 1,000 × 905 = 905,000 grains or 129 lb.

The sensible and latent heat added to the air may also be found as follows: The effective temperature for dry- and wet-bulb temperatures of 75 F and 63.5 F, respectively, is 70.3 deg. From Curve *D*, Fig. 5 find 403 Btu as the total heat added to the air by a person for an effective temperature of 70.3 deg. From Fig. 8 find the percentage of sensible and latent heat at a dry-bulb temperature of 75 F to be 66.5 per cent and 33.5

per cent. The sensible heat added to the air in the auditorium is 1,000 × 0.665 × 403 = 267,995 Btu per hour. The latent heat added is 1,000 × 0.335 × 403 = 135,005 Btu per hour.

Example 8. If the dry- and wet-bulb temperatures of the auditorium were 85 F and 63 F, respectively, how much heat and moisture would be dissipated to the atmosphere?

Solution. From Figs. 6 and 7, respectively, the sensible and latent heat losses per person for a dry-bulb temperature of 85 F are found to be 164 and 225 Btu per hour.

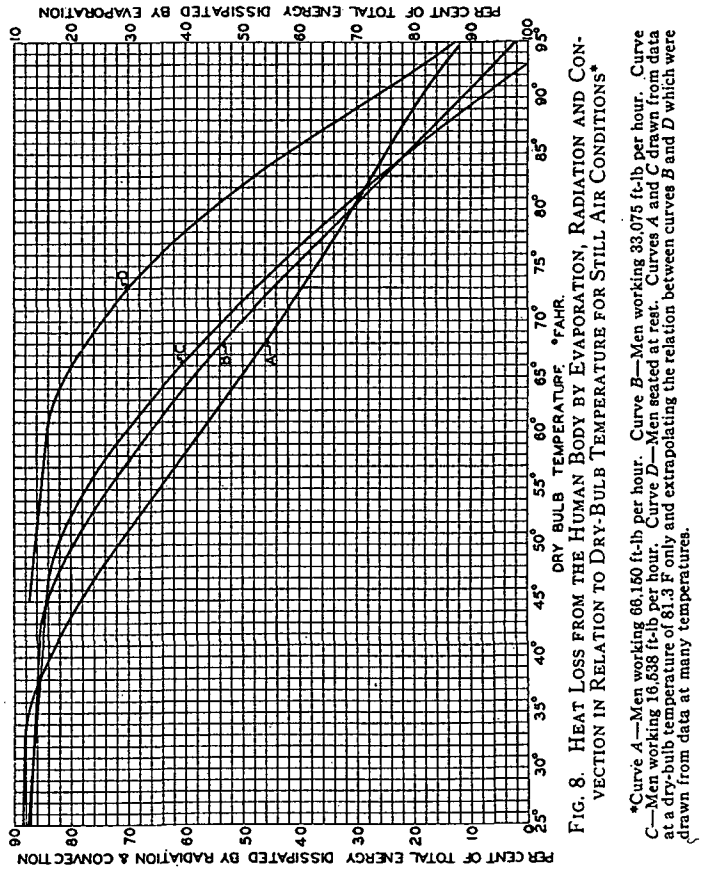


FIG. 8. HEAT LOSS FROM THE HUMAN BODY BY EVAPORATION, RADIATION AND CONVECTION IN RELATION TO DRY-BULB TEMPERATURE FOR STILL AIR CONDITIONS*

*Curve *A*—Men working 66,160 ft-lb per hour. Curve *B*—Men working 33,075 ft-lb per hour. Curve *C*—Men working 16,538 ft-lb per hour. Curve *D*—Men seated at rest. Curves *A* and *C* drawn from data at a dry-bulb temperature of 81.3 F only and extrapolating the relation between curves *B* and *D* which were drawn from data at many temperatures.

The water vapor added to the atmosphere is 1,520 grains per hour. The audience will then add 164,000 Btu sensible heat, 225,000 Btu latent heat and 1,520,000 grains or 217 lb of water vapor to the air in the auditorium per hour.

Examples 7 and 8 demonstrate that while the effective temperature, and hence, the feeling of warmth and rate of total heat loss, does not differ greatly in the two cases, the relative proportion of sensible and latent heat loss is reversed. In order to maintain the air conditions stipulated the air conditioning equipment must remove 61.6 per cent more

sensible heat in Example 7 than in Example 8; and 67.8 per cent more latent heat or water vapor in Example 8 than in Example 7. In Example 7, 66.5 per cent of the total heat loss is sensible while in Example 8 only 42.5 per cent of the total loss is sensible.

Example 9. Neglecting the gain or loss of heat to an auditorium by transmission or infiltration through the walls, windows and doors, how many cubic feet of outside air, with dry- and wet-bulb temperatures of 65 F and 59 F, respectively, (63.1 deg ET) must be supplied per hour to an auditorium containing 1000 people in order that the inside shall not exceed 75 F (dry-bulb) and 65 F (wet-bulb), respectively?

Solution. Figs. 6 and 7 give 265 Btu sensible heat and 905 grains of moisture as the additions per person with a dry-bulb temperature of 75 F in the auditorium. Therefore

TABLE 2. RELATION BETWEEN METABOLIC RATE AND ACTIVITY[a]

ACTIVITY	METABOLIC RATE BTU PER HOUR FOR AVERAGE MAN (19.5 SQ FT SURFACE AREA)	AUTHORITY
Seated at rest	384	Research Laboratory, American Society of Heating and Ventilating Engineers.
Standing at rest	431	Research Laboratory, American Society of Heating and Ventilating Engineers.
Walking 2 mph	761	Average values from (Douglas, Haldane, Henderson and Schneider) and (Henderson and Haggard).
Walking 3 mph	1049	Douglas, Haldane, Henderson and Schneider
Walking 4 mph	1388	Average values from (Douglas, Haldane, Henderson and Schneider) and (Henderson and Haggard)
Walking 5 mph	2530	Douglas, Haldane, Henderson and Schneider
Slow run	2285	Henderson and Haggard
Very severe exercise	2555	Benedict and Carpenter
Maximum exertion	3333 — 4762 +	Henderson and Haggard
Tailor	482	Becker and Hamalainen
Bookbinder	626	Becker and Hamalainen
Shoemaker	661	Becker and Hamalainen
Carpenter	762 — 963	Becker and Hamalainen
Metal Worker	862	Becker and Hamalainen
Painter (of furniture)	876	Becker and Hamalainen
Stonemason	1488	Becker and Hamalainen
Man sawing wood	1797	Becker and Hamalainen

[a]See paper entitled, *Heat and Moisture Losses from Men at Work and Application to Air Conditioning Problems*, by F. C. Houghten, W. W. Teague, W. E. Miller and W. P. Yant (*Heating, Piping and Air Conditioning*, June 1931).

265,000 Btu of sensible heat and 905,000 grains of moisture will be added to the air in the auditorium per hour.

Taking 0.24 as the specific heat of air, 2.4 Btu per pound of air will be required to raise the dry-bulb temperature from 65 to 75 F and $\frac{265{,}000}{2.4}$ = 110,400 lb of air or 110,400 × 13.4 = 1,479,000 cfh of air will be required. This is equivalent to $\frac{1{,}479{,}000}{1000 \times 60}$ = 24.7 cfm per person.

The moisture content of the inside air as taken from a psychrometric chart is 76 grains per pound of dry air and that of the outside condition is 65 grains. The increase in moisture content will therefore be 11 grains per pound of dry air. Hence $\frac{905{,}000}{11.0}$ = 82,300 lb of air at the specified condition will be required. This is equivalent to 82,300 × 13.4 = 1,103,000 cfh of air or $\frac{1{,}103{,}000}{1000 \times 60}$ = 18.4 cfm of air per person.

The higher volume of 24.7 cfm per person will be required to keep the dry-bulb temperature from rising above the 75 F specified. The wet-bulb temperature will therefore not rise to the maximum of 65 F.

Example 10. Assume that a man performs work at a rate equivalent to 50,000 ft-lb per hour, in an atmosphere having a dry-bulb temperature of 70 F. Estimate the sensible and latent heat given off per hour.

Solution. Since the net mechanical efficiency of the human body is about 20 per cent, the increase in metabolism due to work, over the resting metabolism, will be $\frac{50,000}{778^* \times 0.20}$ = 320 Btu per hour. Assuming a resting metabolism of 400 Btu per hour (see Fig. 5), the total metabolism during work will be 400 + 320 = 720 Btu per hour, and the total heat loss $720 - \frac{50,000}{778}$ = 656 Btu per hour approximately. In Fig. 8, follow a vertical line from a dry-bulb temperature of 70 F to a point midway between Curves *A* and *B*. The sensible heat loss is about 46 per cent of the total loss, or 0.46 × 656 = 302 Btu per hour, and the latent heat 54 per cent of the total or 0.54 × 656 = 354 Btu per hour.

*Heat equivalent of mechanical work.

TABLE 3. CONDITION OF SENSIBLE PERSPIRATION FOR PERSONS SEATED AT REST FOR VARIOUS ATMOSPHERIC CONDITIONS[b]

DEGREE OF PERSPIRATION[a]	ATMOSPHERIC CONDITION					
	95 PER CENT R. H.			20 PER CENT R. H.		
	E. T.	D. B.	W. B.	E. T.	D. B.	W. B.
Forehead clammy	73.0	73.6	72.4	75.0	87.0	60.7
Body clammy	73.0	73.6	72.4	75.0	87.0	60.7
Body damp	79.0	79.7	78.4	81.0	97.5	67.5
Beads on forehead	80.0	80.8	79.4	87.0	109.4	75.2
Body wet	84.5	85.4	84.0	86.5	108.5	74.6
Perspiration on forehead runs and drips	88.0	89.0	87.6	94.0	125.2	85.4
Perspiration runs down body	88.5	89.5	88.1	90.0	116.0	79.5

[a]Forty per cent of subjects registered degree of perspiration equal to or greater than indicated.

[b]*Thermal Exchanges* between the Human Body and its Atmospheric Environment, by F. C. Houghten, W. W. Teague, W. E. Miller, W. P. Yant (*American Journal Physiology*, Vol. 88, No. 3, April, 1929, pp. 386–406).

TABLE 4. CONDITION OF SENSIBLE PERSPIRATION FOR PERSONS WORKING AT HARD LABOR FOR VARIOUS ATMOSPHERIC CONDITIONS

DEGREE OF PERSPIRATION[a]	ATMOSPHERIC CONDITION					
	95 Per Cent Relative Humidity			20 Per Cent Relative Humidity		
	E. T.	D. B.	W. B.	E. T.	D. B.	W. B.
Forehead clammy	59.0	59.4	58.3	69.5	80.5	56.5
Body clammy	50.0	50.2	49.3	57.0	61.6	44.2
Body damp	60.0	60.3	59.3	62.5	69.6	49.5
Beads on forehead	68.0	68.5	67.5	76.0	91.0	63.4
Body wet	69.0	69.6	68.5	71.0	82.8	53.0
Perspiration on forehead runs and drips	78.5	79.3	78.0	82.0	100.5	70.2
Perspiration runs down body	79.0	79.8	78.5	81.0	99.8	69.0

[a]Forty per cent of subjects registered degree of perspiration equal to or greater than indicated.

In cases in which the external work is not appreciable, as for instance, in sewing, walking on a level road, and the like, the rate of heat loss will be approximately equal to the total metabolism.

AIR POLLUTION IN RELATION TO COMFORT AND HEALTH

Atmospheric Pollution

Under certain circumstances in which dusts and toxic gases are conspiciously present in the atmosphere, the factor of air purity becomes of utmost importance. Many kinds of dusts and gases are capable of producing profound pathologic effects and damage to property and vegetation. The harmful effects which may result depend largely upon the chemical and physical nature of the impurities, the concentration, length of time, and conditions under which they are breathed.

Aside from specific industrial processes which contaminate the factory atmosphere, the concensus of opinion is that the damage attributed to general atmospheric pollution is, in most instances, greatly exaggerated. The objection is largely economic. There is practically no subjective proof to show that the effect of dust in ordinary air is sufficient to cause demonstrable injury to health by inhalation or by obliteration of the sun's rays. The effects may be slow, cumulative, and insidious in their manifestations, but at present direct evidence is lacking.

Dust-borne bacteria are sometimes held responsible for the transmission of disease organisms through the medium of air, but this is not supported by epidemiologic evidence. Bacteria of the pathogenic variety were found to constitute but a very small proportion of the total dust-borne bacteria[25]. The non-pathogenic bacteria in air are, in general, considered harmless, but it is not known whether continuous inhalation of these organisms may eventually produce harmful effects.

Industrial Air Pollution

In many industrial processes, sufficient amounts of dusts, fumes and vapors are liberated to be injurious to the health of the workers. Some dusts are poisonous (lead, mercury, arsenic, manganese, cadmium, etc.) and some act as irritants (silica, steel, iron, granite, etc.). Certain dusts may produce catarrhal conditions and increase susceptibility to such diseases as bronchitis, pneumonia and tuberculosis. Silicious dust is especially harmful because it has a direct damaging action upon the tissue of the lungs. On the other hand, organic dusts, both animal and vegetable (hair, pollen, textile fibers, etc.), do not seem to affect the lungs at all, although they may cause considerable discomfort to persons sensitive to them by their action on the upper respiratory passages.

Industrial gases and fumes act specifically upon the mucous membranes, the lungs, blood, skin, and eyes. Some of these substances are extremely poisonous and their action sets in after very short exposures, as is true, for example, in the inhalation of carbon monoxide, hydrogen sulphide, ammonia, chlorine, bromine, arsine and cyanogen.

The industrial processes which liberate harmful substances are too

[25]*The Microbic Content of Indoor and Outdoor Air*, by C.-E. A. Winslow and W. W. Browne (*Monthly Weather Review*, Vol. 2, 1914, p. 452).

TABLE 5. TOXICITY OF GASES AND FUMES IN PARTS PER 10,000 PARTS OF AIR[a]

VAPOR OR GAS	RAPIDLY FATAL	MAXIMUM CONCENTRATION FOR FROM ½ TO 1 HOUR	MAXIMUM CONCENTRATION FOR 1 HOUR	MAXIMUM ALLOWABLE FOR PROLONGED EXPOSURE
Carbon monoxide	40	15–20	10	1
Carbon dioxide	800–1000	.....	.....	.....
Hydrocyanic acid	30	1½	½	⅕
Ammonia	50–100	25	3	1
Hydrochloric acid gas	10–20	½	.....	1/10
Chlorine	10	½	.....	1/100
Hydrofluoric acid gas	2	1/10	.....	1/33
Sulphur dioxide	4–5	½–1	.....	1/10
Hydrogen sulphide	10–30	5–7	2–3	1
Carbon bisulphide	.....	11	5	½
Phosphene	20	4–6	1–2	.....
Arsine	2½	½	½	.....
Phosgene	Over ¼	¼	.....	1/100
Nitrous fumes	2½–7½	1–1½	.....	⅛
Benzene	190	.....	31–47	1½–3
Toluene and xylene	190	.....	31–47	.....
Aniline	.....	.....	1–1½	1/10
Nitrobenzene	.....	.....	1/100	1/500
Petrol	243	100–220	.....	.....
Carbon tetrachloride	480	240	40	16
Chloroform	250	140	50	2
Tetrachlorethane	73	.....	.....	1½
Trichlorethylene	370	.....	.....	.....
Methyl chloride	1500–3000	200–400	70	5–10
Methyl bromide	200–400	20–40	10	2
Lead vapor	.....	.....	.....	5–6

[a]Original data compiled by Y. Henderson and H. Haggard. (See *Noxious Gases*, 1927). Data revised by T. M. Legge. (See *Lessons Learned from Industrial Gases and Fumes*, Institute of Chemistry of Great Britain and Ireland, London, 1930).

manifold and the effects too diverse to be considered here. It would suffice to discuss the commonest and most serious with which the ventilating engineer may be confronted, namely, carbon monoxide, lead, and silica. For a more thorough treatise on the subject, refer to books by Hamilton[26], Rosenau[27], and Henderson and Haggard[28].

Carbon monoxide is one of the commonest forms of gas poisoning. It is met with in mines, foundries, coke-oven sheds, garages, and in houses. The poisonous action is due to the fact that the combining power of carbon monoxide with the hæmoglobin of the red blood corpuscles is about 300 times greater than that of oxygen. This stable combination destroys the power of the hæmoglobin to unite with oxygen in the lungs and to supply it to the tissues. The effects are, therefore, due to lack of oxygen and the symptoms are those of anoxemia, namely, dizziness, headaches, sleepiness, fatigue, and in extreme cases, paralysis and death. The dangerous saturation level of the blood with carbon monoxide is about 50 per cent. Even as little as 0.07 per cent in air will render, in half an hour, one quarter of the red corpuscles incapable of uniting with oxygen.

[26]*Industrial Poisons in the United States*, by Alice Hamilton.
[27]*Preventive Medicine and Hygiene*, by Milton J. Rosenau.
[28]*Noxious Gases*, by Y. Henderson and H. Haggard.

One to two parts per 10,000 parts of air is set as a safe limit of pollution which may be breathed for a long time without producing perceptible symptoms.

Silicosis is a chronic disease of the lungs which results from local physio-chemical action of hydrated silica upon the pulmonary tissue causing progressive lumphatic fibrosis and rendering the tissue susceptible to tuberculosis. The disease is slow in evolution, requiring usually a number of years of exposure. It occurs principally among granite workers, sand blasters, metal miners, metal polishers, potters, millstone workers and others.

Studies have shown that dust containing a high percentage of free silica in particles less than 10 microns (1 micron = 0.0004 in.) in size are chiefly responsible for silicosis because only these particles reach the depths of the lungs. Workers exposed to air containing about 15,000,000 or less, dust particles per cubic foot (35 per cent free silica in the form of quartz) under 10 microns in size, showed practically no sickness from tuberculosis. In order to attain this safe concentration, a velocity of 1500 fpm was necessary in the suction hoods[29] intended for dust removal.

Lead poisoning is the most insidious and most frequent of all of the occupational intoxicants. It occurs principally among lead workers and smelters, lead miners, potters, painters, typesetters, stereotypers, plumbers, glass, gold and silver workers. Lead, in practically all forms is a cumulative poison which is absorbed by way of the blood stream, chiefly from the respiratory tract, but also from the digestive tract and from the skin. The effect may be acute or chronic poisoning. The principal symptoms are colic, constipation, anæmia, headache, anorexia, a bluish line along the edges of the gums, rheumatic pains, and in extreme conditions, paralysis, blindness, insanity and death.

It has been found[30] that 2 mg per day is the lowest dose, by inhalation, which in the course of years may result in lead poisoning. Regular inhalation during the usual working hours of air containing less than 0.2 mg of lead per cubic meter does not seem to produce serious lead intoxication in individuals of representative industrial groups[31].

The prevention of industrial hazards from dusts and poisonous gases is largely a ventilation problem, and it consists in keeping the impurities in air down to a safe concentration. At present, there are no accurate standards on which to base the design of the ventilation equipment. Approximate data on the toxicity of various gases and fumes met with in industrial establishments are given in Table 5. The maximum allowable concentrations for prolonged exposure (Column 5) will, perhaps, in the course of weeks, months or years, produce pernicious effects because the experiments cited here were limited in most cases to exposures of not more than a week.

Very little is known concerning the physiologic effects induced by various concentrations of dusts and by various durations of exposure.

[29]*A Study of the Efficiency of Dust Removal Systems in Granite-Cutting Plants*, by J. J. Bloomfield (*Public Health Reports* No. 44, 1929, Vol. 42, p. 2505).
[30]*Lead Poisoning*, by Thomas Morrison Legge (*Journal Royal Society Arts.*, 1929, Vol. 77, p. 1023).
[31]*What is a Dangerous Quantity of Lead Dust in Air*, by C. M. Salls (*Industrial Hygiene Bulletin*, New York State Department of Labor, 1925).

With very few exceptions, ventilation standards for dusts are lacking and the only way to judge the safe concentration is by means of periodic medical examinations of the workers and by routine measurements of dust concentration.

SYNTHETIC AIR CHART

The Synthetic Air Chart designed by E. Vernon Hill[32], was adopted by the Society as a standard for measuring the relative perfection of air conditions maintained in a given space. The results of tests are plotted on a chart, and the perfection of the air conditions as a whole determined on a percentage basis by deducting from 100 per cent perfection the lack of perfection in each of the following six factors:

1. The effective temperature difference, or the amount of variation from the ideal effective temperature.
2. Dust particles per cubic foot.
3. Bacteria.
4. Percentage of freedom from objectionable odors.
5. Carbon dioxide, parts per 10,000.
6. Distribution.

[32]For complete description of the operation of the Synthetic Air Chart, see *Modus Operandi of The Synthetic Air Chart*, by John R. Allen (A.S.H.V.E. TRANSACTIONS, Vol. 26, 1920), and A.S.H.V.E. GUIDE, 1931, p. 411.

Chapter 29

AIR CONDITIONING FOR INDUSTRIAL PROCESSES

Moisture Content and Regain; Conditioning and Drying; Desirable Atmospheric Conditions; General Requirements; Drying and Moisture Control; Comfort Versus Production.

IN the manufacture or processing of hygroscopic materials such as textiles, paper, wood, leather, tobacco, foodstuffs, etc., the temperature and relative humidity of the air have a marked influence upon the rate of production and upon the weight, strength, appearance and general quality of the product. This influence is due to the fact that most materials of vegetable or animal origin, and to a lesser extent minerals in certain forms, take moisture from or give it up to the surrounding air.

In industries where the physical properties of the product affect value, the question of moisture is of special importance. With increase in moisture content, hygroscopic materials ordinarily become softer and more pliable. Economy of manufacturing therefore requires that the moisture content be maintained at a percentage most favorable to rapid and satisfactory manipulation and to a minimum loss of material through breakage. A constant condition is desirable in order that high speed machinery may be adjusted permanently for the desired production with a minimum loss from delays, wastage of raw material and defective product.

In the processing of hygroscopic materials, it is usually necessary to secure a final moisture content suitable for the goods as shipped. Where the goods are sold by weight it is proper that they contain a normal or standard moisture content. Air conditioning is important in certain branches of the chemical industry in controlling the temperature of reaction and facilitating or retarding evaporation. The control of moisture content of air supplied to blast furnaces in the manufacture of pig iron also has proved advantageous.

A few of the industries in which air conditioning plays an important part and the major uses in these industries are as follows:

Automobile. Drying of siccative coatings, manufacture of steel, manufacture of artificial leather, drying of rubber, manufacture of tire fabrics, cementing of inner tubes, conditioning of wooden spokes and other wooden parts, conditioning and manufacturing of all electrical windings in connection with the electrical apparatus and the manufacture of storage battery plates and the rubber containers.

Bakery. Flour storage, yeast and ingredient storage, mixers, fermentation room, make-up room, proof boxes, loaf cooling, wrapping (including paraffin paper), cake mixing and cake icing.

Brewery. Fermentation in vat rooms.

Chemical. Powders (including explosives and baking powder), drying of salts of all kinds, hydroscopic compounds and drugs, glues and gelatines.

Clay Products. Bricks, pottery and ceramics.

Confectionery. Chocolates, bon bons, hard candy, gum drops, marshmallows, caramels, chewing gum and starch and various sugars.

Drugs and Pharmaceuticals. Drugs and pharmaceuticals might also be included under chemicals, but definitely to be added to this group are capsules, hydroscopic colloidal crystals, serums and toxins.

Electrical Goods. Toll cable manufacture, telephone exchanges, winding rooms, lamp manufacture, filament departments.

Films and Film Laboratories. Drying cabinets, printing rooms, perforating rooms, projection assembly rooms, moving picture studios, celluloid and colored photography.

Foods. Bread and cake, cereals, macaroni, meats (cold storage markets), yeast, enzymic products, fruits, including apples and bananas, both for preserving and ripening.

Furs. Fur storage.

Incubators. Human babies, and chickens and similar hatching.

Laboratories. All kinds.

Leather. Drying and processing of hides, skins and manufacture of bags, shoes, findings.

Linoleum. Drying, printing, oil cloth, and linseed oil buildings.

Matches. Storage of raw materials and machine drying and packing.

Minerals. Gold beater rooms, gold and silver leaf manufacturing, metal enamelling, and mottled ware, particularly all cutting on iron.

Paper and Paper Products. Moisture absorption in manufacture, cutting, folding, binding and furnishing bags, including gluing, parchment paper, cellophane containers, paste board containers, paste board bottles and egg containers.

Pearls. Artificial pearls.

Printing, Lithography and Rotogravure. Playing cards, process work, storage, offset work, binding, rollers and ink.

Soap. Crystallizing under the cold process.

Textiles. Cotton: drying, spinning and weaving. Rayon: chemical house, spinning, drying, twisting, reeling, winding, inspection and storage. Silk: storage, twisting and reeling, spinning, weaving, knitting, tin and lead weighting and regain rooms (hosiery and underwear).

Tobacco. Cigarettes: storage, mixing, blending, paper and machine manufacture. Cigars: storage, curing, cleaning, wrapping and packing.

It is apparent that the subject of air conditioning for industrial processes is extensive and greatly involved, and that a detailed treatment is therefore beyond the scope of this book. Volumes have been written on individual phases of it. A few of the salient points of the general subject are covered in this chapter.

MOISTURE CONTENT AND REGAIN

The terms *moisture content and regain* refer to the amount of moisture in hygroscopic materials. *Moisture content* is the more general term and refers either to free moisture (as in a sponge) or to hygroscopic moisture (which varies with atmospheric conditions). It is usually expressed as a percentage of the total weight of material. *Regain* is more specific and refers only to hygroscopic moisture. It is expressed as a percentage of the *bone-dry* weight of material. For example, if a sample of cloth weighing 100.0 grains, is dried to a constant weight of 93.0 grains, the loss in weight, or 7.0 grains, represents the weight of moisture originally contained. This

expressed as a percentage of the total weight (100.0 grains) gives the moisture content or 7 per cent. The regain, which is expressed as a percentage of the bone-dry weight, is $\frac{7.0}{93.0}$ or 7.5 per cent.

The use of the term regain does not necessarily imply that the material as a whole has been completely dried out and has re-absorbed moisture. In the case of certain textiles, for instance, complete drying during manufacturing is avoided as it might appreciably reduce the ability of the material to re-absorb moisture. In measuring moisture it is necessary to dry out a sample so that the loss in weight may be used as a basis for calculating the regain of the whole lot.

The moisture content of an hygroscopic material at any time depends upon the nature of the material and upon the temperature and especially the relative humidity of the air to which it has been exposed. Not only do different materials acquire different percentages of moisture after prolonged exposure to a given atmosphere, but the rate of absorption or drying out varies with the nature of the material, its thickness, density, etc.

Table 1 shows the regain or hygroscopic moisture content of several organic and inorganic materials when in equilibrium at a dry-bulb temperature of 75 F and various relative humidities. The effect of relative-humidity on regain of hygroscopic substances is clearly indicated. The effect of temperature is comparatively unimportant. In the case of cotton, for instance, an increase in temperature of 10 deg has the same effect on regain as a decrease in relative humidity of one per cent. Changes in temperature do, however, affect the rate of absorption or drying. Sudden changes in temperature cause temporary fluctuations in regain even when the relative humidity remains stationary.

CONDITIONING AND DRYING

Exposure of hygroscopic materials to an atmosphere of controlled humidity and temperature for the purpose of establishing a specified moisture condition in the material is called *conditioning.* Where the desired final moisture content is relatively low, the term *drying* is usually used. In any case, control of relative humidity, temperature, air velocity and length of exposure are all of more or less importance.

The conditioning treatment may be undertaken in a special enclosure (conditioning room) or it may be accomplished in the same room and at the same time as some regular manufacturing process. For instance, in the weaving of textiles a high relative humidity is commonly employed to keep the yarn strong and pliable, thus assisting in the weaving process and at the same time leaving the product in a satisfactory condition of regain for commercial reasons.

As a rule, commercial regain standards are specified percentages which by test have been found equivalent to a so-called *standard atmosphere* to which the goods would be in hygroscopic equilibrium after prolonged exposure. Committee D13 on Textiles of the *American Society for Testing Materials* has adopted a relative humidity of 64 to 66 per cent and a temperature of 70 to 80 F as the standard atmosphere for textile testing.

TABLE 1. REGAIN OF HYGROSCOPIC MATERIALS

Moisture Content Expressed in Per Cent of Dry Weight of the Substance at Various Relative Humidities—Temperature, 75 F

CLASSIFICATION	MATERIAL	DESCRIPTION	RELATIVE HUMIDITY—PER CENT									AUTHORITY
			10	20	30	40	50	60	70	80	90	
Natural Textile Fibres	Cotton	Sea Island—Roving	2.5	3.7	4.6	5.5	6.6	7.9	9.5	11.5	14.1	Hartshorne
	Cotton	American—Cloth	2.6	3.7	4.4	5.2	5.9	6.8	8.1	10.0	14.3	Schloesing
	Cotton	Absorbent	4.8	9.0	12.5	15.7	18.5	20.8	22.8	24.3	25.8	Fuwa
	Wool	Australian Merino—Skein	4.7	7.0	8.9	10.8	12.8	14.9	17.2	19.9	23.4	Hartshorne
	Silk	Raw Chevennes—Skein	3.2	5.5	6.9	8.0	8.9	10.2	11.9	14.3	18.8	Schloesing
	Linen	Table Cloth	1.9	2.9	3.6	4.3	5.1	6.1	7.0	8.4	10.2	Atkinson
	Linen	Dry Spun—Yarn	3.6	5.4	6.5	7.3	8.1	8.9	9.8	11.2	13.8	Sommer
	Jute	Average of Several Grades	3.1	5.2	6.9	8.5	10.2	12.2	14.4	17.1	20.2	Storch
	Hemp	Manila and Sisal—Rope	2.7	4.7	6.0	7.2	8.5	9.9	11.6	13.6	15.7	Fuwa
Rayons	Viscose Nitrocellulose Cupramonium	Average Skein	4.0	5.7	6.8	7.9	9.2	10.8	12.4	14.2	16.0	Robertson
	Cellulose Acetate	Fibre	0.8	1.1	1.4	1.9	2.4	3.0	3.6	4.3	5.3	Robertson
Paper	M. F. Newsprint	Wood Pulp—24% Ash	2.1	3.2	4.0	4.7	5.3	6.1	7.2	8.7	10.6	U. S. B. of S.
	H. M. F. Writing	Wood Pulp—3% Ash	3.0	4.2	5.2	6.2	7.2	8.3	9.9	11.9	14.2	U. S. B. of S.
	White Bond	Rag—1% Ash	2.4	3.7	4.7	5.5	6.5	7.5	8.8	10.8	13.2	U. S. B. of S.
	Com. Ledger	75% Rag—1% Ash	3.2	4.2	5.0	5.6	6.2	6.9	8.1	10.3	13.9	U. S. B. of S.
	Kraft Wrapping	Coniferous	3.2	4.6	5.7	6.6	7.6	8.9	10.5	12.6	14.9	U. S. B. of S.
Misc. Organic Materials	Leather	Sole Oak—Tanned	5.0	8.5	11.2	13.6	16.0	18.3	20.6	24.0	29.2	Phelps
	Catgut	Racquet Strings	4.6	7.2	8.6	10.2	12.0	14.3	17.3	19.8	21.7	Fuwa
	Glue	Hide	3.4	4.8	5.8	6.6	7.6	9.0	10.7	11.8	12.5	Fuwa
	Rubber	Solid Tire	0.11	0.21	0.32	0.44	0.54	0.66	0.76	0.88	0.99	Fuwa
	Wood	Timber (Av.)	3.0	4.4	5.9	7.6	9.3	11.3	14.0	17.5	22.0	Forest P. Lab.
	Soap	Ivory	1.9	3.8	5.7	7.6	10.0	12.9	16.1	19.8	23.8	Fuwa
	Tobacco	Cigarette	5.4	8.6	11.0	13.3	16.0	19.5	25.0	33.5	50.0	Ford
Foodstuffs	White Bread		0.5	1.7	3.1	4.5	6.2	8.5	11.1	14.5	19.0	Atkinson
	Crackers		2.1	2.8	3.3	3.9	5.0	6.5	8.3	10.9	14.9	Atkinson
	Macaroni		5.1	7.4	8.8	10.2	11.7	13.7	16.2	19.0	22.1	Atkinson
	Flour		2.6	4.1	5.3	6.5	8.0	9.9	12.4	15.4	19.1	Bailey
	Starch		2.2	3.8	5.2	6.4	7.4	8.3	9.2	10.6	12.7	Atkinson
	Gelatin		0.7	1.6	2.8	3.8	4.9	6.1	7.6	9.3	11.4	Atkinson
Misc. Inorganic Materials	Asbestos Fibre	Finely Div.	0.16	0.24	0.26	0.32	0.41	0.51	0.62	0.73	0.84	Fuwa
	Silica Gel		5.7	9.8	12.7	15.2	17.2	18.8	20.2	21.5	22.6	Fuwa
	Domestic Coke		0.20	0.40	0.61	0.81	1.03	1.24	1.46	1.67	1.89	Selvig
	Activated Charcoal	Steam Activated	7.1	14.3	22.8	26.2	28.3	29.2	30.0	31.1	32.7	Fuwa
	Sulphuric Acid	H_2SO_4	33.0	41.0	47.5	52.5	57.0	61.5	67.0	73.5	82.5	Mason

DESIRABLE ATMOSPHERIC CONDITIONS

The most desirable relative humidity during processing depends upon the product and the nature of the process. As far as the behavior of the material itself and its desired final condition are concerned, each material and process represents a different problem. The best relative humidity may range anywhere from 0 to 100 per cent. Similarly the most desirable temperature may range between wide limits for different materials and treatments. Extremes in either relative humidity or temperature require relatively expensive equipment for maintaining these conditions and controlling them automatically. Also, in departments where people are working, their health, comfort and productive efficiency must be considered. A compromise often is desirable.

It is generally considered that relative humidities below 40 per cent are on the dry side, conducive to low regains, a brittle condition of fibrous materials, prevalence of static electricity and a tendency toward dryness of the skin and membranes of human beings. At the other end of the scale, humidities above 80 per cent are relatively damp, conducive to high regains, extreme softness and pliability.

GENERAL REQUIREMENTS

In general, air conditioning apparatus for industrial purposes must be capable of absorbing heat from various sources such as machinery power, electric lamps, people, sunlight and chemical reaction; of warming or cooling to any desired degree, and of giving or permitting ample air supply at all times. Refrigeration may or may not be required, depending upon natural conditions, the required relative humidity and the maximum permissible temperature. Washing, purifying and recirculating of the air may be desirable. Accurate, sensitive and reliable automatic control of humidity or temperature, or both, is essential in most cases.

The amount of moisture to be added or removed from the air is different for each industrial process. It depends upon the temperature and relative humidity to be maintained, and upon the several factors mentioned in the previous paragraph, also upon outdoor conditions, required rate of air change, amount of material entering or leaving the room per hour and the number of employees. Weather greatly affects the immediate requirements for air conditioning, but the advantages of a favorable climate are usually of secondary importance in modern industrial development.

Most industrial processes require a constant relative humidity so that the quantity of moisture existing naturally in the air must be either increased or lowered. Such industries include the confectionery, rayon, printing and lithographic industries. Others require not only a constant relative humidity but also a uniform temperature. For example, plants containing full fashioned hosiery machines and automatic machines for wrapping chewing gum, food products, confectionery and cigarettes require exact conditions of heat and moisture in order to function satisfactorily without frequent adjustments.

DRYING AND MOISTURE CONTROL

In the manufacturing and processing of many hygroscopic materials there are one or more stages in the process where moisture has to be removed from the material. In the case of products not themselves soluble in water, this is usually accomplished by air drying. In order to avoid injury to the products the rate of moisture removal must be controlled with accuracy in certain stages, while at the end of the drying it may be extremely important to control accurately the final moisture content of the material.

This is true in the manufacture of the various tobacco products, textiles, certain gelatin products including photographic films, lumber, paper, flour and macaroni. In many of these products it is not only necessary to control this final moisture content to insure the desirable qualities of the product itself but to standardize its moisture content from the standpoint of sales value.

COMFORT VERSUS PRODUCTION

In many instances air conditioning is commercially desirable from the standpoint of human comfort rather than primarily for the effect upon the products themselves. Not only is air conditioning for comfort desirable from a humanitarian standpoint, but it is commercially expedient because the worker's skill and efficiency are influenced by his physical well-being. In many cases the output of the worker is greatly increased by the proper control of atmospheric conditions, when normally they would be so unsatisfactory as to reduce to a marked degree the rate and quality of work.

In such industries as the printing and lithographing the quality of the product and the personal comfort of the employees assume almost equal importance. In order to obtain proper register with the application of colors in different processes, a moderate and exact humidity is necessary. In hot, moist weather, and in the absence of machinery for dehumidification and refrigeration, such a condition can be secured only by the use of heat at considerable human discomfort.

In other industries the product is affected by both relative humidity and temperature as in the manufacture of chocolates, chewing gum, cigarettes and machine-made cigars. Here it is necessary to humidify during some parts of the year and to dehumidify and refrigerate at other seasons in order to maintain a uniform condition both of temperature and humidity within the limits permissible by the products. It happens in these instances as in many others that the atmospheric conditions best suited to the products and processes are almost ideal for the health, comfort and efficiency of the workers.

Chapter 30

AIR CONDITIONING APPARATUS

Humidifiers; Air Washers; Dehumidifiers; Refrigerating Machines; Temperature and Humidity Control; Unit Conditioners.

AIR conditioning equipment includes apparatus for providing the necessary heat and moisture exchanges within the room to be conditioned and of the air supplied to the room for ventilation, and automatic devices for governing such apparatus so that temperature and humidity may be controlled within the limits desired. The latter are referred to as controls. Those for controlling temperature are known as thermostats, and those for controlling humidity are known variously as hygrostats, psychrostats, or humidostats.

Apparatus for effecting humidity changes may be divided into two distinct groups:

1. The humidifiers used for the purpose of increasing the moisture content of the air and to produce cooling by evaporation.
2. The dehumidifiers used for the removal of moisture from the air and to produce cooling by contact with water or surfaces at a lower temperature than the air.

HUMIDIFIERS

Humidifiers may be divided into the following general types, according to the method of operation:

1. *Direct:* Spraying into the room.
2. *Indirect:* Introduction of moistened air.
3. *Combined:* Direct and indirect.

INDUSTRIAL TYPE DIRECT HUMIDIFIERS

The industrial type direct humidifier is essentially an apparatus designed to inject a finely divided spray of moisture or water vapor into an enclosure for the purpose of increasing the humidity of the air.

Most industrial humidifying systems consist of locally-distributed units which deliver spray to the room atmosphere to be absorbed by evaporation. The success of such humidifiers depends upon their ability to generate a spray of such a quality and to distribute it in such a manner that evaporation will take place continuously and thoroughly without precipitation upon surrounding objects. Once the spray has been evaporated the resulting vapor diffuses itself uniformly and with great rapidity. The most important consideration therefore is the complete evaporation of the spray.

Evaporation of Spray

The spray delivered by a humidifier must be fog-like, consisting of particles small enough to be evaporated while they still float in the air. The weight of coarse particles and their relatively small surface, would cause them to sink and be deposited upon any object which they happened to touch before evaporation could take place. As the relative humidity rises and the space approaches saturation, the rapidity of the evaporation of the spray decreases. The higher the humidity, the greater the necessity that the spray be fine and be widely and rapidly distributed to avoid precipitation.

Evaporation requires an appreciable amount of time. The particles must be discharged with considerable velocity, and over the widest possible area to stimulate rapid evaporation. The actual evaporative capacity of a humidifier depends upon (1) uniformly fine quality of the spray, (2) effective distribution of spray, and (3) quantity of spray successfully delivered and actually evaporated under typical working conditions. The ability of a direct humidifier to generate a large quantity of spray is of little value unless accompanied by the ability to distribute the spray so widely as to assure successful evaporation.

Spray Generation and Distribution

The methods for generating spray are by atomization, by impact, by centrifugal-hydraulic separation and by centrifugal-mechanical separation.

Atomization: This is commonly accomplished by utilizing a jet of compressed air to *tear* water into particles of spray and distribute it similar to the familiar method used in ordinary nasal atomizers.

Impact: In an early type of humidifier two small streams of water under pressure were directly opposed, one slightly smaller than the other. The impact caused the water to fly into a jet of spray of conical form. This method has been superseded by a simpler equivalent in which a single fine jet of water under pressure impinges directly upon the opposed end of a small round wire. It is this type of nozzle which is widely used in so-called *spray humidifiers* and *high duty humidifiers.*

Centrifugal-hydraulic separation: A jet of water enters a small cylindrical chamber through a tangential port and escapes through an axial port with a rapid rotation which causes it immediately to separate into a cone of spray. This device is most commonly used in the spray chamber of saturated air humidifiers for central station purposes.

Centrifugal-mechanical separation: Water thrown by centrifugal force from the surface of a rapidly revolving disc or brush separates into particles sufficiently small to be utilized in some forms of mechanical humidifiers.

After generating the spray, distribution is effected by (1) air blast, (2) induction or (3) fan propulsion.

Air Blast. In atomizers, the same jet of air which generates the spray propels it through a space sufficient for its diffusion and evaporation.

Induction. The aspirating effect of an impact or centrifugal spray jet is utilized to induce the flow of a current of air through a duct or casing, and the air current is utilized to effect the distribution of the entrained particles of spray in the outer air.

Fan Propulsion. Currents of air generated by fans are utilized to entrain and convey the spray with great force.

Effective Area of Distribution

The size, shape, and direction—the spread—of the jet of spray leaving a humidifier, have an important bearing upon the effective area of distribution. The greater the spread, the greater the evaporative capacity of the unit.

Small Jet, One Direction Only. The spray discharged by an atomizer issues from a single small opening, forming a cone of spray of very small diameter, delivered in one direction only.

Large Jet, One Direction Only. Some types of humidifiers discharge a large cylindrical jet of spray horizontally and in one direction only. This jet being larger than that of the atomizer results in a larger area of distribution and makes possible a correspondingly larger capacity.

Large Jet, All Directions. High duty humidifiers have a large annular outlet from which the spray issues horizontally to all points of the compass at high velocity. This results in the maximum possible area of distribution and thus greatly increases the allowable capacity of the unit.

Because of these differences in the effective area of distribution the atomizer is installed in a relatively large number of units of relatively small capacity, whereas the high duty humidifier is installed in a relatively small number of units of relatively high capacity.

Cooling Effect of Humidifiers

Every pound of water evaporated at 70 F absorbs about 1053 Btu—more than seven times the amount of heat required to melt one pound of ice (144 Btu). Modern humidifiers evaporate several gallons of water in each hour. The heat required to evaporate the spray is withdrawn from the surrounding air which is thereby lowered in temperature. This explains the comfortable and moderate room temperatures found in well-humidified factories in hot weather. The cooling effect of a humidifier is directly proportional to the weight of water which it evaporates.

Effect of Heating the Supply Water

In winter, the cooling effect just described increases the demand for heat. By heating the water supplied to the humidifiers, the desired temperature may be more readily maintained in the building. This practice also increases the rate of evaporation. By thus simultaneously increasing the capacity of the humidifying and the heating systems, a distinct advantage is secured in severe weather, especially on cold mornings.

Atomizing Humidifiers

Atomizing humidifiers are in common use. They are of several different types, all of which rely upon compressed air as the atomizing and distributing agency.

Air is supplied under pressure (ordinarily about 30 lb per square inch) from a centrally located air compressor through main and branch pipe lines to the atomizing units. The air lines on which the units are located are usually horizontal and parallel to water lines which supply water by gravity from a float tank located in the neighborhood of the humidifiers.

Water is maintained at a constant level slightly lower than the outlets of the atomizers themselves. It is drawn constantly to the atomizer by aspiration while compressed air is supplied. When the air supply is cut off by closing a valve, aspiration ceases and the flow of water stops. Supplying water under pressure to atomizers should be avoided because

it incurs the risk of leakage, drip, or coarse spray which cannot be permitted when water is supplied by aspiration.

In the turbo humidifier, the atomizer proper consists of only two parts which can be separated and reassembled without the use of any tool other than a wrench. The parts register in one position only, so that all necessity for adjustment is avoided. The jet of spray has a slight rotation which insures immediate separation of the particles of moisture, thus preventing any tendency toward precipitation. The spray issues from a single outlet in a flat surface so that deposits of lint cannot cause drip or interfere with operation.

High Duty Humidifiers

In the high duty humidifier, water is supplied under high pressure (ordinarily about 150 lb per square inch) through pipe lines from a centrally-located pumping unit. Each humidifier contains a spray generating nozzle of the impact type, located in a cylindrical casing. Below is a drainage pan to provide for the collection and return of unevaporated water which flows through a return pipe to a filter tank, from which it is recirculated. A fan mounted above propels a powerful air current through the humidifier.

The shape and relative positions of the casing and pan are such that only the finest spray escapes. The warm and relatively dry air enters from above, is drawn through the head, charged with moisture, and cooled to the wet-bulb temperature. It escapes from the annular opening below at high velocity in a complete and nearly horizontal circle. The spray is quickly evaporated and the resulting vapor is rapidly and thoroughly diffused.

This effective distribution of fine spray over the maximum possible area insures complete and extremely rapid vaporization even at the highest humidities. The quality of the spray is finer and the evaporative capacity is greater than that of any other type of humidifier suitable for local distribution.

The fan is propelled by a direct-connected electric motor. Different models of this humidifier, all of the same general type, are used for different conditions so that the evaporating capacity and area of distribution may be adapted to the factory requirements.

High duty humidifiers are suspended from factory ceilings and are so located as to insure widespread and uniform circulation and the best possible humidity conditions. Units of exceptionally high capacities are used where the requirements are most severe, and units of smaller capacities are installed in relatively larger numbers when high humidities are required at more moderate temperatures.

The air is thoroughly cleaned during its passage through the humidifier by intimate mixture with the spray. Dust, lint, and bacterial atmospheric impurities are thus precipitated into the drainage pan, passing with the unevaporated water through the return piping to a centrally-located tank. Here all foreign matter is removed by a gravel bed filter and accumulated impurities are rejected to waste by periodical washing and flushing. Fresh water to replace evaporation is constantly added to the purified return water, which is redistributed to the humidifiers by

means of a circulating pump at the necessary pressure. In winter, steam under control of a thermostat is usually admitted to the tank so that the circulated water may be held at any desired temperature.

Occasional flushing of the main filter is necessary to remove accumulations of lint which gradually collect in the humidifier casings. The fan motors require occasional renewal of their oil supply.

Spray Humidifiers

The so-called spray humidifier comprises an impact spray nozzle in a cylindrical casing with a drainage pan below it. The aspirating effect of the spray nozzle induces a moderate air current through the casing which distributes the entrained spray. The general method of circulating and returning the water is similar to that employed for high duty humidifiers. A suitable pump and centrally-located filter tank are required.

The spray type of humidifier and the high duty humidifier have many features of resemblance but the latter because of its finer spray and greater capacity is often considered better adapted for producing the higher humidities which modern practice demands.

Centrifugal Humidifiers

There has always existed a demand for a self-contained humidifier, that is, one having the ability to generate and distribute spray without the use of air compressors, pumps, or other auxiliaries. A humidifier of such characteristics is naturally convenient for a small installation where few heads are required.

These humidifiers are generally of two types. One type operates under low water pressure and evaporates about 20 per cent of the water fed to it; the other maintains a constant level in the bottom of the humidifier and may be arranged to evaporate all the water fed to it. Both types generate spray from water thrown from the surface of a revolving disc in a complete, horizontal circle.

When centrifugal humidifiers are used in laboratories or rooms where little or no dust and lint are present, they may be supplied with water by gravity through a single pipe which maintains water in a pool in the bottom of the pan at a constant level. Such an arrangement is not satisfactory in factories where the air washing action of the humidifier results in the rapid accumulation of precipitated dust, lint, or other impurities in the drainage pan.

Removal of Impurities

In textile mills, the continuous removal of impurities is one of the recognized functions of the modern humidifier. This is accomplished by supplying water through one pipe line and carrying away the unevaporated water and its entrained impurities through another. The drainage water may run to waste if the system is small and the water supply ample and inexpensive. When the cost and quantity of the water require economy, the drainage water may be collected, filtered, and recirculated from a filter tank in which impurities are removed. The purified return water is lifted by a pump to a small reservoir for gravity supply to the humidifiers.

INDIRECT HUMIDIFIERS

Indirect humidifiers are similar in operation to spray-type air washers, except that the water is sprayed directly against the current of incoming air. Such humidifiers comprise a chamber usually 10 ft or more in length, through which the air is drawn at a velocity from 500 to 700 ft per minute. Inside the chamber are placed one or more banks of nozzles distributed over the cross-sectional area of the chamber to produce a uniform spray. These nozzles create a finely divided spray through centrifugal action and require water pressures for effective humidification of from 35 to 45 lb per square inch. At the intake of the humidifying chamber there is provided a set of baffles for distribution of the air and for preventing the spray from escaping from the chamber. At the outlet of the humidifier chamber there is provided an eliminator. This eliminator, consisting of a series of metal baffles, is so designed as to separate all of the free, unevaporated moisture from the humidified air. Thus the air leaving the humidifier is completely saturated, but without any entrainment or unevaporated water particles. Such humidifiers are used only in connection with ventilating systems. They are practically always placed on the inlet side of the ventilating fan. Provision is made for warming the water in winter so that the air may be saturated at a definite temperature. The heating of the water usually is controlled by means of a thermostat placed in the path of the saturated air leaving the humidifier and controlling the heater through which the spray water passes.

In other cases, particularly in industrial work where high humidities are maintained, the control of the dew-point temperature is effected by a thermostat controlling the mixture of outside air and return air from the building by means of fresh and return air dampers at the inlet of the humidifier.

In industrial work the dew-point regulation is effected in winter time by both of these means operating in conjunction. In those installations where all outside air must be employed, it is usual to provide in front of the air washer certain pre-heater coils of sufficient capacity to bring the air to a temperature slightly above the freezing point. In summer time operation, whenever the outside wet-bulb temperature is above the minimum dew-point desired in the building, all outside air supply is taken and it will be observed from the psychrometric principles discussed in Chapter 27 that the air issuing from the humidifier will have been cooled to the wet-bulb temperature of the entering air, provided, of course, that the water is neither heated nor cooled by recirculation, which is usually the case in such installations.

In most manufacturing processes relatively little moisture is added to, or extracted from, the air in the room by the process itself, and as windows and doors are closed, conditions in the room rapidly stabilize to the moisture content of the entering air. Thus, it is possible to control the relative humidity within the room by proportioning the quantity of the air in accordance with the heat sources within the room, such as heat from machinery and the occupants, electric lights, sunlight and outside radiation. The quantity of air to be supplied for each unit of heat thus removed is definitely dependent upon the relative humidity to be carried.

For example, if 50 per cent relative humidity is to be carried in the room the ventilation must be restricted so there shall be a rise of 20 deg between the temperature of the entering air and that of the air in the room itself. Smaller temperature rises would give increased relative humidities. In textile mills, for instance, with the humidities usually carried it is possible to keep the room temperature within about 12 deg of the outside wet-bulb temperature. Inasmuch as the wet-bulb temperature on hot days is usually 15 deg to 25 deg lower than the dry-bulb temperature, the mill temperature will be below the outside temperature and provision has to be made by inward transfer of heat through the walls for the heat thus absorbed. The general layout of such a system of

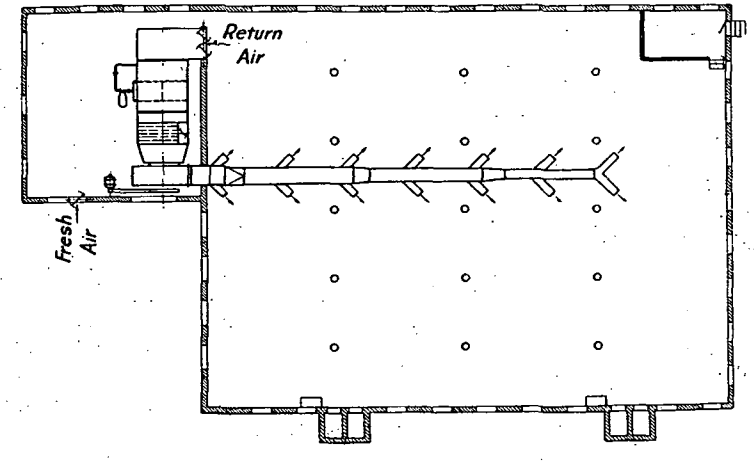


Fig. 1. Layout of a Factory System of Humidification and Air Conditioning

humidification and air conditioning is shown in Fig. 1. Data on the design of central fan systems are given in Chapter 31.

Dew-point control is particularly applicable where there are a number of different departments to be served from one central equipment, and where there is but little change in the moisture content of the air in the room due to moisture changes in the materials processed or due to excessive air leakage from outside.

Another system of control which is used considerably, especially where there is but one room to be controlled from one apparatus and where there may be considerable moisture change in the room itself due to local conditions, is to adjust the dew point at the apparatus, either continuously or intermittently, by means of a hygrostat placed in the room and so connected as to vary either the temperature or quantity of spray water used in the humidifier, or both. This system may be designated as *direct relative humidity control.*

In direct humidity control installations the temperature and humidity

are both under control during the heating season, and in the summer the humidity must be maintained constant, but the temperature must be allowed to rise in accordance with the increase of the wet-bulb temperature above the minimum desired. Temperature variations under mill conditions will be from 75 F to 90 F. Such results are superior from the standpoint of comfort and well-being of the operators than those previously experienced without the control. Automatic humidity control has resulted greatly in increasing the effectiveness of the workers, but the provision of ventilation also has improved greatly the conditions in mills as to dust, lint, and odors. In the spinning of fine cotton yarns, automatic humidity control is of great value in producing an improved product as well as in bettering working conditions. The uniform air motion results in the lowering of the effective temperature with a consequent increase in comfort and efficiency of the workers at temperatures and humidities which are necessarily high because of the requirements of the product. The air motion results also in removing the heat directly and immediately from the point of production on the spinning frame, thus avoiding localized increase of temperature and decrease of relative humidity. In other words, it permits the entire process to be subjected more nearly to the average room conditions. For additional information on the control of humidity and instruments used therefor, refer to page 432.

Where large quantities of power are generated in a limited space and where a comparatively high relative humidity is required, it is often feasible and economical to use a combination of direct and indirect humidification. The indirect humidification provides the desired quantity of ventilation and cooling and the additional direct humidification provides for increase in humidity without interfering with the ventilation or the cooling effected by the indirect system.

In general, it may be stated that direct humidification is most satisfactory where high humidities are desired but where little cooling, ventilation or air motion is required. Therefore, the indirect system is most applicable where either low or high relative humidities are desired with maximum cooling and ventilation effect. For conditions that require an unusually large amount of heat to be absorbed by ventilation, together with the maintenance of high humidities, it is ofttimes preferable to make use of the combination system of indirect and direct humidification. If the indirect system alone were used it would mean an unusually large volume of air to be handled, which might interfere, due to air motion, with production, even though it would result in greater cooling effect. If direct humidification alone were used, no ventilation would be obtained, with consequently higher room temperatures.

Inasmuch as cooling and humidification requirements in summer are much more severe than those in winter, an excess of humidifying and cooling capacity must be provided to meet extreme conditions and this requires automatic control if the best results are to be obtained. Such applications of humidity control may be considered standard practice today in the United States.

The same type of equipment as used in cotton mills largely is applicable to other textile industries, including rayon manufacture and also is applicable to tobacco factories, paper mills and many other buildings.

DEHUMIDIFIERS

In many industries it is as important to control the temperature in summer as in winter and, at the same time, the relative humidity must be controlled both in summer and in winter. To accomplish this the air must be warmed and the humidity must be increased in winter, and the air must be cooled and the moisture content of the air must be reduced in summer, so that both temperature and humidity indoors may be held at a definite point regardless of outside weather conditions, and regardless of conditions within the plant itself.

The design of air distribution equipment and the external appearance of such equipment is the same as described for systems of humidification. The main differences are found in the internal construction of the dehumidifier, in the use of refrigeration or of heat as required for controlling the water temperature, and in differences in the general methods of control.

Dehumidifiers are of two general types. *First*, the spray type in which the water is cooled outside of the spray chamber and then introduced. *Second*, the type in which the refrigerating coils are placed directly in the spray chamber and in which the water is sprayed over this surface, air coming in contact both with the wetted coils and the spray.

The use of refrigerated surfaces for cooling and dehumidifying air has given way almost entirely to the use of the direct spray of cooled water. One of the principal reasons for this change is the high effectiveness of heat transfer between the finely divided spray and the air, which is thereby lowered substantially to the temperature of the leaving water. This efficient heat transfer reduces greatly the temperature head required in refrigeration, and therefore, reduces the size and cost of the refrigerating equipment.

With the spray type of dehumidifier, all the water vapor is condensed from the air to the point of saturation at the temperature corresponding to that of the air leaving the dehumidifier and all free moisture is removed by a series of baffles or eliminators, in the same manner as in the standard air washer. The spraying of water into the air to remove moisture from it might seem paradoxical, except for the application thereto of easily understood laws of physics.

Both types of dehumidifiers have air-distributing baffles at the inlet end and eliminators at the outlet end. The dehumidifier usually is considerably longer than the humidifier and in the spray type there are two or more sets of sprays, some of which may be directed against the air flow.

The object is to obtain a coarser spray and, at the same time, a much larger quantity of cold water per unit of air to be treated, than in the humidifier. Heat absorbing capacity as well as surface must be provided in the spray water. The usual allowable rise in spray water temperature entering and leaving the dehumidifier is from 6 deg F to 10 deg F, and in well-designed dehumidifiers of the spray type the final temperature of the air is substantially identical with the final temperature of the leaving water. This is made possible by the counter-flow effect employed in such apparatus. The air velocities through the dehumidifier usually are lower than those employed in the humidifier, normal velocities being from 400 to 550 fpm through the cross-sectional area.

Greater care must also be taken to obtain the elimination of free water than with the humidifier, as an entrainment beyond the eliminator defeats the purpose of the equipment.

Dehumidifier systems usually are provided with two essential control elements; a dew-point control at the apparatus and a room control. The former maintains a uniform temperature of saturated air leaving the dehumidifier at all times of the year. In summer, in industrial work, this is so constructed as to use nearly all return air, thus reducing the refrigerating load required, while when the wet-bulb temperature outside is below the dew point required within the room the latter is controlled by the dew-point thermostat which brings about a mixture of fresh and return air as required. The room temperature is controlled independently at a definite point above the dew-point or saturation temperature either by a thermostat or by a hygrostat, depending upon whether the more important factor is the temperature or the relative humidity. Frequently the nature of the process is the governing factor in the selection of control. For example, if moisture is given off or taken up by the materials in the process of manufacture, and if the relative humidity is the more important factor, then the hygrostat would be used. The amount of infiltration, which affects both temperature and humidity, may also be the governing factor in the selection of control, and the instrument selected would depend on whether the control of temperature or humidity is the more important. The control operates either with volume dampers controlling the quantity of air introduced, or with valves or dampers which govern the heat output from local heaters such as radiators. Usually the control is a combination of both volume control and of air temperature control.

In installations for auditoriums and theaters the requirements are different from those in factories, since there must be a considerable volume of air circulated in order to provide ventilation and cooling. The moisture content of this air must be relatively constant, but its temperature must be variable. A satisfactory solution of this problem has proved difficult, but special systems of control are now in general use which permit the temperature and humidity of theaters to be controlled independently and at the same time, to be immediately responsive to changes in occupancy. Some of these arrangements are successful in operation without the use of any external heat whatever.

AIR WASHERS

Air washers clean the air by bringing it in contact with a large water area,

1. By passing it through a fine spray,
2. By passing it over wet surfaces, or
3. By passing it both through a spray and over wet surfaces.

By this air cleaning method the dust particles are wetted and discharged with the spray water or retained on the wet surfaces of the eliminator plates. After the air is washed it is freed from entrained water. In addition to air cleaning, the air washer has certain distinct advantages in air conditioning work. A well designed washer is effective in the maintenance of proper temperature and humidity conditions.

The moisture content of air usually is changed when it is passed through water sprays or over wet surfaces. Both the dry and wet-bulb temperatures of the air approach that of the water at which temperature the air tends to become saturated. The moisture content of the air may, therefore, be controlled by controlling the water temperature. By using water at a temperature below the dew-point temperature of the entering air, the washer becomes a dehumidifier; or by heating the water to a temperature above the dew-point of the entering air the humidity or moisture content of the air may be increased. By raising the dry-bulb temperature of the air after leaving the washer, its relative humidity may also be controlled.

Humidifying Efficiency

The humidifying efficiency of any air washer may be expressed as:

$$E = 1 - \frac{\text{Final wet-bulb depression}}{\text{Initial wet-bulb depression}}$$

For example, with an initial wet-bulb depression of 20 deg and a final wet-bulb depression of 5 deg, the humidifying efficiency is:

$$E = 1 - \frac{5 \text{ deg}}{20 \text{ deg}} = 0.75$$

The usual humidifying efficiency of a good air washer is 70 per cent. The humidifying efficiency of air washers of the commonly termed humidifier type should range from 95 to 98 per cent.

Control of Temperature and Humidity

Air washers require a method of control of temperature to prevent freezing by too low an initial temperature, and to prevent over-humidification by too high temperatures of the air coming in contact with the water. There are available one method of hand control and five methods of automatic or semi-automatic control. The method of hand control is by the use of tempering heaters, divided into two or more sections in series, the outer section being turned on by hand whenever the outside temperature approaches freezing and the successive sections being turned on as the temperature drops below freezing. Where two sections are available it is usual to turn on the second section when the outside temperature goes below zero, and to turn on the third section, where necessary at temperatures below zero. The first, or outside section, must always be turned on full in cold weather to prevent freezing of the heaters. The steam supply to the second, or inside section, may be hand-regulated at all temperatures higher than about 10 F.

The five systems of automatic regulation are:

1. The sections of the tempering heater are controlled both by variations in the outside temperature conditions and by an auxiliary control for one inside section from a thermostat located on the discharge side of the air washer. (It is not possible ordinarily to control the temperature of the air entering the washer, except where there is an unusually long tunnel or duct for the thorough mixture of the air leaving the tempering heaters before it comes in contact with the thermostat).

2. By heating the spray water so as to maintain a temperature or dew-point (as the air is then saturated) of the air leaving the washer at between 35 and 40 F. This method does not necessarily require a tempering heater. It is preferable, however, to use one section for the purpose of tempering the air, should the washer be shut down; this to prevent freezing of the water when the apparatus is not in operation. More than one tempering section should never be used, except where temperatures may go considerably below zero; then the tempering sections may be turned on, one at about 20 F, and the second at about 0 deg F. The tempering section may be operated manually or by a thermostat connected with the outside air. The steam supply for water heating should be sufficient to heat and saturate the air at from 10 to 35 F, when water heating is used in conjunction with a tempering section. This is to allow a sufficient margin for safety of operation.

3. By regulating the heat supplied either through tempering sections or through the spray water so that the water in the tank shall be kept well above the freezing point. Inasmuch as the wet-bulb temperature of the air and the water in the tank are but few degrees apart when the water in the tank is not heated directly, this method is a fairly effective and simple one. One permissible variation of this method is to use a thermostat in the air leaving the washer, controlling the dry-bulb temperatures at this point through regulation of the steam supply to the inside tempering section. The wet-bulb temperature of the air is controlled by means of a thermostat in the water leaving the eliminator plates and is held at the desired point by means of adding heat to the spray water. This will control exactly the temperature and relative humidity of the leaving air. Two or more tempering sections are required for this method.

4. The fourth method is desirable where recirculation is used and consists in maintaining the temperature leaving the washer at about 40 F by means of a thermostat located at this point controlling the admixture of fresh and return air through automatically operated dampers. This prevents over-humidification, eliminates danger of freezing, and effects the highest economy in cost, as no steam is required for either tempering or humidifying, except after the air has passed the washer.

5. The fifth method of automatic control is to reheat the air leaving the air washer to a definite thermostatically controlled temperature, and to control the relative humidity of the air by means of a hygrostat which operates either on the tempering sections to heat the air or which controls a water heater for the spray water.

Steam Requirements

Where the spray water is not heated it is necessary that the wet-bulb temperature of the incoming air be above the freezing point; otherwise the eliminator plates will coat with ice and stop up, even if the dry-bulb temperature of the leaving air is above the freezing point. It is necessary to heat zero air to 48 F in order that the wet-bulb temperature may be 35 F. The temperature of the leaving air may then be expected to be approximately 39 F dry-bulb and 35 F wet-bulb, with a dew-point of 31 F. If the humidifying capacity of the washer is 75 per cent the additional heat required to furnish humidification is that indicated by the temperature drop of 9 deg, or 162 Btu per 100 cu ft of air, or one boiler horsepower for every 3400 cu ft of air per minute. These are the minimum requirements for humidification, above those required for heating the air.

REFRIGERATING MACHINES

The refrigerating machine with which the heat is removed from the air consists of three essential parts, the evaporator, the compressor and the condenser. There are, of course, many valves, accessories and devices each peculiar to the several different types of machines and necessary to their proper operation.

In the evaporator, or cooler, a pressure is maintained which causes the

refrigerant to evaporate or boil at a sufficiently low temperature to absorb heat from the water, air or other medium in contact with the cooling surface. Various devices such as separators, accumulators and eliminators are required to remove any entrainment of liquid from the gas leaving the cooler. Liquid refrigerant must be fed to the cooler at the same rate at which it is evaporated so as to maintain an approximately constant level. Various manual and automatic valves are available for this purpose.

Many different types of coolers are available. Probably the earliest design was the open Baudelot which consisted of a number of superimposed pipes over which the water to be cooled flowed from a carefully leveled flooding trough carried just above the uppermost pipe. Drip strips were required to prevent an unnecessary loss by splashing from the pipes. For extremely small tonnages such a cooling surface might be submerged, but with a submerged coil the rate of heat transfer will vary over a wide range, depending upon the agitation of the water.

Where proper protection against freeze-ups can be provided enclosed coolers of either the shell and coil or the shell and tube type may be used to simplify water handling problems. In many cases the loss of considerable static head can be avoided by the use of a closed cooler.

Good practice calls for a drop in water temperature ranging from the minimum of about 6 deg to a maximum of 10 deg, the lesser change in water temperature requiring a correspondingly greater volume to be pumped and carried through pipes. A mean difference between water temperature and refrigerant temperature of 7.5 to 15 deg is satisfactory. The temperature at which heat must be received by the refrigerant is therefore determined by the mean water temperature and the mean effective temperature difference.

Inasmuch as the latent heat per pound of refrigerant is approximately constant within the narrow range of temperature which is utilized in water cooling and the volume of gas per pound of refrigerant increases very rapidly as the temperature and pressure is reduced, the temperature of the refrigerant determines the volume of gas which must be handled by the compressor.

The function performed by the compressor is that of withdrawing the gaseous refrigerant from the cooler and delivering it to the condenser at such a pressure that its heat can be absorbed by water at ordinary temperatures and the gas recondensed into a liquid ready to be returned to the cooler. The construction of condensers follows along the same general lines as that of coolers. The atmospheric type in which the latent heat of a considerable amount of evaporation is added to the sensible heat absorption by the water is almost identical with the Baudelot. Shell and tube condensers are almost identical with the coolers. The double pipe condenser in which the cooling water is passed through the inner of two concentric pipes with the refrigerant in the annular space is quite commonly used. It is important in designing and locating condensers to make adequate provision not only for cleaning but also for the removal and replacement of the tubes or complete sections.

The condenser water must receive and carry away all of the heat absorbed in the cooler, plus the heat equivalent of the power used in driving the compressor, with slight corrections for radiation direct from the com-

pressor and from gas transmission lines between the compressor and the condenser.

HUMIDITY CONTROL INSTRUMENTS

Control of relative humidity of air in buildings is accomplished by the use of instruments termed humidostats, hygrostats and psychrostats, or by the proper combination of a number of thermostats. Humidostats function in a manner similar to that of thermostats and may be used in connection with both electric and compressed air systems. The following are the most commonly used methods of automatically controlling the relative humidity of air:

1. A thermostat is located in or at the outlet of a spray-type air conditioner which maintains a constant saturation temperature of the air leaving the conditioner by varying the temperature of water entering the suction of the pump supplying the spray nozzles, or by varying the temperature of the air entering the conditioner, or both. The temperature of the air entering the conditioner may be varied by use of tempering heaters, or by the proper proportioning of supply and return air entering the conditioner. This thermostat is known as a dew-point thermostat, as it determines the dew-point temperature of the air introduced into the conditioned spaces. A second thermostat in the room, or in the path of the air leaving the room, maintains a constant dry-bulb temperature by varying the amount of sensible heat added to the air leaving the conditioner, or by varying the volume of air introduced into the conditioned spaces. These two thermostats, in combination, control the dry-bulb and dew-point temperatures, which accordingly fix the relative humidity.

2. A wet-bulb thermostat is located in the room, or in the path of the air leaving the room, to maintain a constant wet-bulb temperature by varying the saturation temperature at the air conditioner outlet. A dry-bulb thermostat is located in the room to maintain a constant dry-bulb temperature, which in combination with a constant wet-bulb temperature fixes the relative humidity.

3. A differential thermostat may be used to control relative humidity. This instrument consists of two thermostatic elements, one of which is in the path of the air leaving the conditioner, and the other under the influence of the dry-bulb temperature in the room. Instruments of this kind maintain a constant relative humidity by maintaining a constant difference between the dew-point temperature and dry-bulb temperature in the room.

4. A humidostat which responds directly to changes in humidity may be used to maintain a predetermined relative humidity with constant or with varying temperature. It may do this; by varying the dew-point temperature of air leaving a conditioner; by varying, with dampers, the proportion of moist and dry air; by varying the amount of moisture otherwise added to the air; or by varying the dry-bulb temperature.

Chapter 31

CENTRAL FAN SYSTEMS

Fan-Furnace Heating; Construction of Fan Furnaces; Ratings and Capacities; Arrangement of Heaters; Residence Type Fan Furnaces; Coal-Fired; Oil-Fired; Gas-Fired; Distributing Systems: Fan Steam Heating; Arrangement of Apparatus; Heating Units; Temperature Control: Design of Central Fan Systems.

THE term *central fan system* as used in this chapter refers to any mechanical indirect system of heating, ventilating or air conditioning, in which air is heated or conditioned, and delivered by blowers through a system of ducts to the rooms or spaces for which it is intended. Such systems are adaptable and effective in buildings:

1. Too large for gravity distribution.
2. Where definite atmospheric conditions must be maintained.
3. Where the functions of heating and ventilating (or air conditioning) must be combined.

Much of the equipment used in central fan systems is the subject matter of other chapters. It is the purpose of this chapter to discuss the co-ordinated design. Central fan systems may be classified as: (1) direct fired (fan furnace) or (2) indirect (fan steam). Fan furnaces or the direct-fired type are made in large units for schools and public buildings and in small self-contained units in a single casing for residences and other small buildings. In the indirect type, steam is usually the medium by which heat is transferred from the boiler to the heating units. The heating units are enclosed in a casing which in turn is connected to one or more distributing ducts.

FAN FURNACE HEATING

Among the advantages of fan furnaces are:

1. Quick heating of heater surfaces with quick delivery of heat.
2. Variable air temperatures, quantities and velocities.
3. Simplicity of controls.

Construction of Fan Furnaces

Heaters for fan-furnace systems usually are made of cast iron or of steel. The cast-iron furnaces which are used mainly for large installations such as schools and public buildings, are made in sections which are cemented and then bolted together on the job. The steel furnaces are assembled with welded or riveted joints. Casings are of sheet-metal and angle-iron panel construction with sheet-metal and asbestos linings, or of brick with sheet-metal top deck, insulated. Access doors for inspection

are necessary. There is no connection between the heating elements and the casing except at the front or firing end. Large units have locomotive-type shaking grates, and small units have circular firepots and grates. In large units the dome above the fire is kept 4 ft or more above the normal fire level.

Furnaces for use with fans must incorporate in their design the feature of longest fire travel and maximum surface commensurate with construction economy and durability, and the maximum in heating surface for impingement of the circulating air. The fuel to be used is a factor, anthracite being less desirable than bituminous coal, oil or gas. The use of a high radiation fuel bed is likely to result in overheating and reduced life of the firebox walls. For this reason it is common practice to have the surface adjacent to the fuel lined with cast-iron or fire-clay material. Sometimes these linings are arranged as tuyeres to preheat the air for combustion. Expansion and contraction must be minimized by designing equal thicknesses of metal, by ribbing, long fire travel and sectional construction.

The proper design of the heater hinges largely on the kind of fuel to be burned. Accordingly, various manufacturers are making special units for coal, oil and gas. Each class of fuel requires a distinct type of heater for the highest efficiency and economy obtainable. Briefly the characteristics of a heater to obtain the best efficiency and economy for each of the fuels are as follows:

1. COAL BURNING:
   - *a. Bituminous*—Large, open combustion spaces, and self-cleaning heating surfaces.
   - *b. Anthracite*—Large firebox capacity.
2. OIL BURNING:
   - *a.* Long tortuous fire travel.
   - *b.* Extensive heating surface.
3. GAS BURNING:
   - *a.* Extensive heating surface.
   - *b.* Numerous small flue passages.

A combustion rate of from 5 to 8 lb of coal per square foot of grate per hour is recommended for residential heaters depending upon the ratio of grate surface to heating surface, firing period and available draft. A rate of from 10 to 14 lb is permissible with larger heaters if the available draft is sufficient, and the ratio of grate to heating surface is high. Where oil fuel is used care must be exercised in selecting the proper size and type of burner for the particular type of heater used.

Direct fired heaters should be designed for blow-through installation, that is, the combustion vessel should be under external pressure so that there can be no leakage of the products of combustion into the ventilating system.

Ratings and Capacities of Fan Furnaces

This class of equipment usually is rated in one of three ways, as follows:

1. The temperature rise of the air is listed over a certain range of velocities through the free area of the heater for varying combustion rates, for a certain heating value of the fuel.
2. The volume of air in cubic feet per minute is listed over several temperature rises with the necessary fuel consumption, taking coal of some known heating value as a standard.
3. The Btu imparted to the air is listed for varying combustion rates.

Either of the first two methods is preferable to the third because of the inaccuracies that are apt to creep into the latter, due to the fact that for the same combustion rate on any given heater, the Btu imparted to the air will not remain constant, but will vary with the volume of air passed over the heater.

The capacities of heaters for large commercial and industrial buildings range from 400,000 to 1,800,000 Btu per hour per unit. The capacities of heaters for residences and other small buildings range from 50,000 to 400,000 Btu per hour per unit.

The emission of heat from the heating surface of these furnaces will vary from 2,000 to 3,000 Btu per square foot per hour. The average is about 2,500 Btu. Higher rates of emission may be obtained by increasing the air velocities over the heating surfaces, and the velocity of movement of the combustion gases on the inside of the heating surfaces.

In commercial sizes the ratio of the heating surface to the grate surface will vary from 30 to 1 to 50 to 1. Heavy duty heaters average about 40 to 1 and residential heaters about 20 to 1. For oil or gas extra large heating surface area is required.

The free area through the heaters and resistance to the flow of air at varying velocities are characteristics depending upon the heater in question. The resistance of heaters should not exceed one-half the total static resistance in the system.

Arrangement of Fan Furnace Heaters

Fan-furnace heaters are readily arranged for any combination of one or more heaters in battery. Any variation of the following arrangements may be used (See Figs. 1 to 8, inclusive):

1. Battery of any number of units with one plenum chamber.
2. Separate batteries of heaters with separate fans and plenum chambers.
3. Heaters in battery with separate division casings and louvers at rear for cut off of air supply to each heater.
4. Tempered air in addition to warm air chamber.
   - *a.* By recirculating small portion of heated air back to fan inlet;
   - *b.* By connecting warm air chamber to tempered air chamber with control damper; or
   - *c.* By mixing cold air below heaters to warm air from plenum chamber.
5. Automatic control of temperature by
   - *a.* Controlling quantity of heated air entering room;
   - *b.* Controlling temperature by mixing dampers; or
   - *c.* Controlling temperature by regulation of fuel.

Control of Fan Furnaces

Control of various units of a plant can be easily arranged by electric or pneumatic cut-off dampers. This will provide means of heating por-

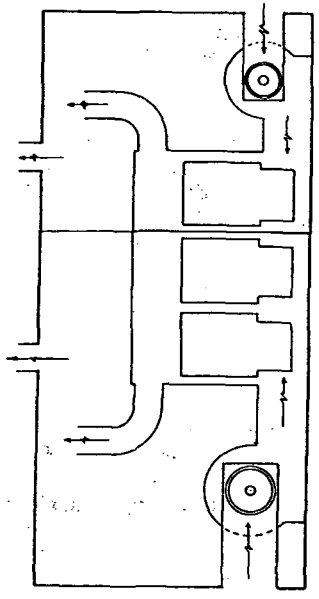


FIG. 2. TWO BATTERIES OF HEATERS AND FANS FOR INDEPENDENT SERVICE USING OUTSIDE AIR AND EXHAUST TO ATMOSPHERE

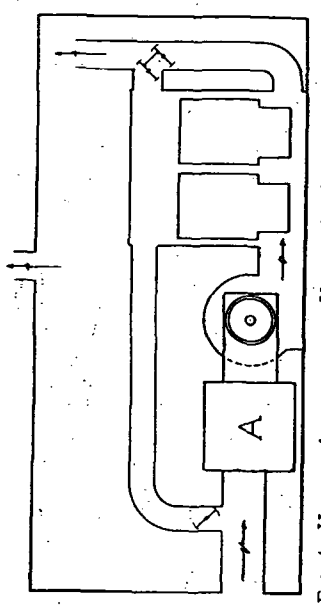


FIG. 4. HEATER ARRANGED FOR USE OF AIR WASHER OR FILTER (A) WITH HEATED AIR TO MIX WITH OUTSIDE AIR FOR TEMPERING, SHOWING MIXING DAMPER FROM WARM AIR AND TEMPERED AIR AND EXHAUST TO ATMOSPHERE

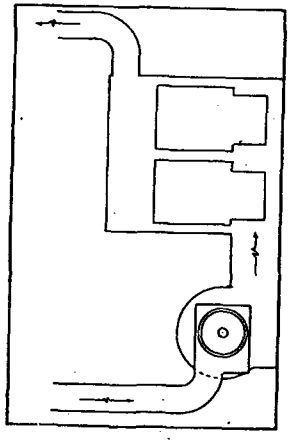


FIG. 1. HEATER ARRANGED FOR COMPLETE RECIRCULATION OF AIR WITH TEMPERATURE CONTROL DIRECT ON HEATER

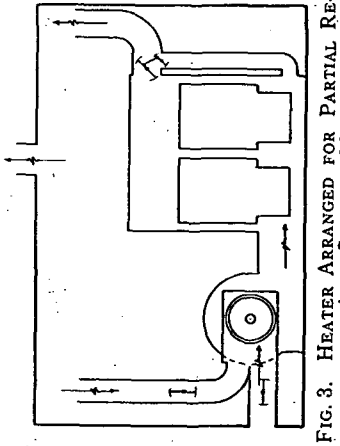


FIG. 3. HEATER ARRANGED FOR PARTIAL RECIRCULATION, ALSO SHOWING MIXING DAMPER FROM WARM AIR AND TEMPERED AIR CHAMBERS, AND PARTIAL EXHAUST TO ATMOSPHERE

tions of the building only. Remote control of outside air dampers working in unison with ventilator dampers where the exhaust outlets are used, will make the operation of the plant easier.

Automatic control of humidity can be secured by means of sprays or by air washers. When air washers are employed it is necessary to introduce a warm-air supply in front of the air washer or to use heated water to prevent freezing when using outside air. Humidifying pans connected to an outside water supply and regulated by a float-valve mechanism frequently are used for humidification. Water sprays may readily be placed at a central source.

For all plants a warm-air plenum chamber thermometer, of extension type, indicating the temperature of the air leaving the heater, is of great assistance for proper operation.

It is desirable to provide the following controls with any type of fuel or draft in addition to the usual house-temperature regulation:

1. A temperature limit control in the warm-air plenum space to prevent overheating.
2. An automatic fan-motor starter governed by a thermostatic switch in the warm-air plenum chamber so that the fan cannot be started until after the heater is sufficiently warmed and which will cause the fan to start as soon as the heater becomes warm.

A gas-burning installation should be fitted with safety devices, such as safety pilot burners and temperature limit controls in the warm-air plenum space operating in conjunction with automatic snap valves in the gas supply lines. These will function to shut off all gas to the burners in the event the pilot burners should be extinguished or if the temperature in the warm-air plenum chamber exceeds any set degree.

Small Fan Furnace and Air Conditioning Systems

The field of fan-furnace heating has been extended to include residences and other small buildings through the development of equipment which incorporates in single units all devices necessary for filtering, for humidifying, for temperature regulation, for forcing a positive delivery of the air. Some manufacturers enclose the heater, fan, filters and humidifier or sprays in a cabinet casing of neat appearance.

The most important characteristics of the fan-furnace system for small buildings are as follows:

1. The registers may be placed in outside walls, or under windows, or at any location above floor line on inside walls, contrary to practice in gravity work.
2. The heater location need not be central, and its location may be determined by proximity to the chimney.
3. Pipes may be of small size and need not be given a slope to aid the flow.
4. Cold-air returns may be placed with a view to securing the most advantageous collection of return air without sacrificing efficiency.
5. Remote rooms may be heated satisfactorily because the system provides a positive delivery of conditioned air to each room.
6. All air may be filtered to remove dust.
7. The fan may be used for circulating air when no fuel is being burned.

Residence-Type Coal-Fired Fan Furnaces

Small size coal-fired fan-furnaces are available. In general these consist of standard warm air furnace parts to which have been added ap-

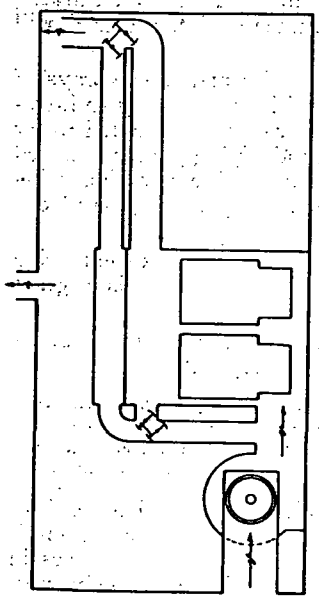


FIG. 6. HEATER ARRANGED TO USE OUTSIDE AIR, WITH TEMPERED AIR CHAMBER ABOVE WARM AIR CHAMBER SHOWING DOUBLE DUCT DISTRIBUTING SYSTEM AND MIXING DAMPERS AT BASE OF RISERS

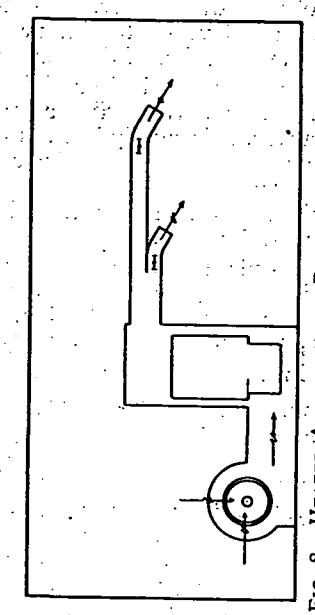


FIG. 8. HEATER ARRANGED FOR RECIRCULATION WITH TRUNK LINE DISTRIBUTING SYSTEM SHOWING TEMPERATURES CONTROL BY AIR VOLUME AT OUTLET, OR DIRECT ON HEATER

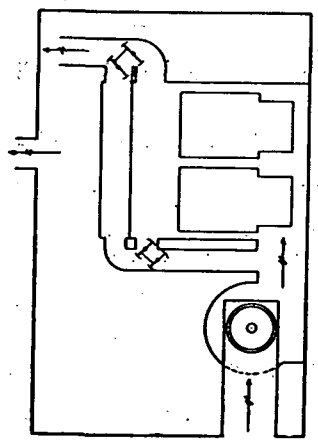


FIG. 5. HEATER ARRANGED TO USE COMPLETE OUTSIDE AIR WITH TEMPERED AIR CHAMBER ABOVE WARM AIR CHAMBER SHOWING MIXING DAMPER TO TEMPER AIR, ALSO MIXING DAMPER TO DUCT FROM WARM AND TEMPERED AIR CHAMBERS

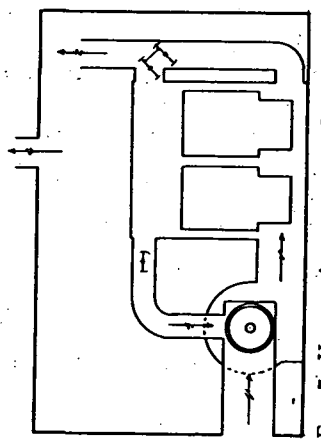


FIG. 7. HEATER ARRANGED FOR OUTSIDE AIR WITH WARM AIR CONNECTION TO FAN INLET TO TEMPER AIR, ALSO MIXING DAMPERS FROM WARM AIR AND TEMPERED AIR CHAMBER

paratus for filtering or spraying, humidifying, and blowing the air. Practically all are provided with by-passes or open fans, so that gravity circulation may be obtained. A few are built in compactly arranged integral casings.

Capacities range from the normal gravity warm-air furnace capacities of 40,000 Btu per square foot of grate per hour to three times as much or 120,000 Btu per square foot grate per hour. The capacity obtained is largely a matter of combustion rate. With an adequate flue draft, combustion rates of 12 to 14 lb per square foot of grate may be obtained, whereas normal gravity operation averages about 4 lb per square foot. Thus, fuel consumption determines the rating of fan furnaces, the quantity of air being a dependent factor. For good efficiencies, velocities through the heater above 500 fpm and combustion rates below 6 lb are necessary.

In obtaining high capacity and efficiency it is the practice to reduce the normal free area of the gravity equipment by inserting baffles which restrict the area and produce high velocity heat transfer. By this process relatively small heaters can be forced to produce high capacities, and there is economy in space, weight and cost.

Tests have shown that unless the fans are capable of producing velocities of 500 fpm through the net area of the casing, there is little value in their use. In other words the fan flow must exceed the gravity flow appreciably if it is to be capable of forcing the capacity to higher limits than can be obtained by gravity. Systems for fan furnace operation should be designed for fan duty. Systems intended for gravity are usually unbalanced by the application of forced circulation.

Residence-Type Oil-Fired Fan Furnaces

Special types of fan furnaces adapted to oil fuel, which include air conditioning apparatus, are also available.

Oil-fired heaters must be equipped with high temperature limit control to cut off the oil burner in case of fan failure. Oil-fired fan furnaces are usually provided with direct acting thermostats connected to the burner for maintaining the proper temperature. A device should be provided to cut off the fan whenever the thermostat cuts off the burners, to prevent overheating of rooms that are thermostatically controlled.

Residence-Type Gas-Fired Fan Furnaces

For gas fuel, high efficiencies have been obtained through the use of large areas of heating surface concentrated in banks of plate heaters through which the air is forced at high velocity. High operating efficiencies, further, are assured through the use of throttling gas valves, which, actuated by thermostats, proportion the consumption of fuel to the demand for heat, and thereby lessen the losses due to excessive flue temperatures and radiation.

When high efficiencies are attained in gas-fired units provision must be made for disposal of the condensation formed in the passages of the heater, and for protecting the surfaces from the corrosive action of the sulphurous or sulphuric acid formed.

In special cases provision must be made for producing a draft in the flue pipe and for protection against the formation of condensation therein.

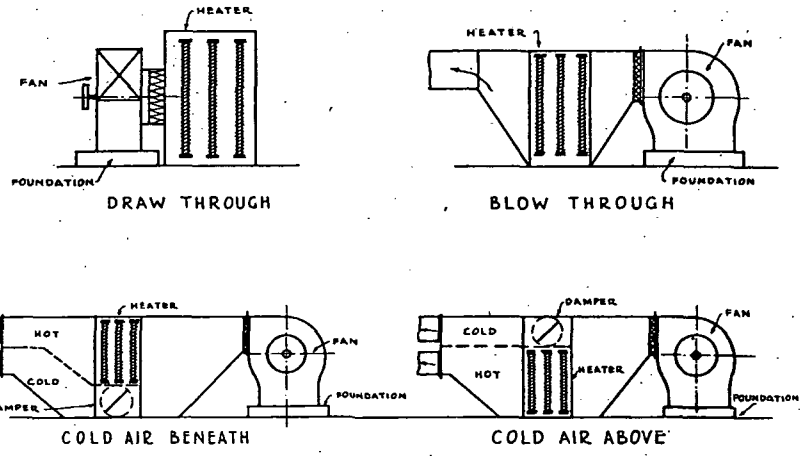


FIG. 9. STANDARD ARRANGEMENTS FOR HEATER AND BY-PASS

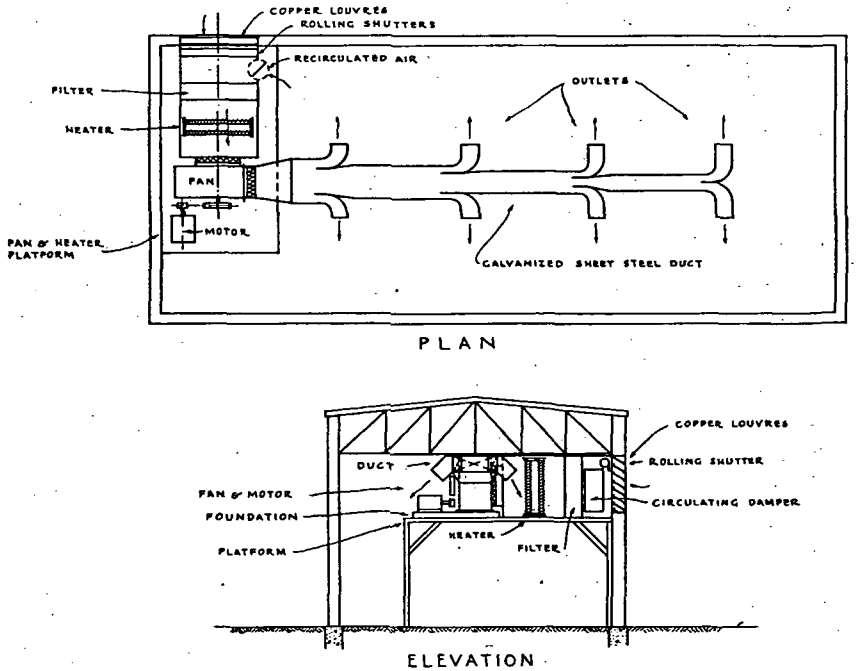


FIG. 10. COMMON ARRANGEMENT OF A FAN STEAM HEATING SYSTEM FOR A SHOP BUILDING

Distributing Systems for Small Installations

Fan-furnaces of this type are adaptable either to trunk line duct systems, to central chambers, or to individual pipe installations, the size and shape of building being the governing factors. The supply of air to individual rooms may be made with small branches, 6 in. and 8 in. diameters being used. These branches and also the main trunk lines may be either round or rectangular. Risers and registers of commercial sizes in use in gravity warm air heating practice are adaptable.

The basic principles of proportioning ducts apply to this system as well as to the larger fan systems. The velocity of air through the ducts depends upon the power furnished by the fan and motor, the limiting factors being economy and quiet operation. Both supply ducts and return air systems should be based upon equal friction throughout the design to assure proper circulation. The following velocities have been found satisfactory:

Over nominal area of registers	200–300 ft per minute
Branches and stacks	400–600 ft per minute
In main ducts of trunk system	500–800 ft per minute
In returns	500–700 ft per minute

With a central distributing system, standardized orifices, calibrated in terms of cubic feet, may be used. In this case all pipes may be the same size and the flow balanced by the orifices. It is desirable where orifices are not used to install equalizing dampers in all runs. Return air openings should provide easy recirculation to the central fan and should be cushioned against noise by sound deadening.

FAN STEAM HEATING

The fan steam or indirect type of central fan system differs only from the essentials of the fan furnace system in the medium for heating and the type of surface. With the central fan steam system it usually is possible to place a fan and heater in an equipment room in close proximity to the boiler room where the supply and return piping can be simplified, and where the operation of the fan and heater can be under the close observation of the engineer. Maintenance costs can also be reduced to a minimum with this type of system.

When the heater is located between the fan and main duct, the combination is termed *blow-through*, and when the fan is installed between the heater and the duct, the arrangement is known as *draw-through*. These two arrangements are shown by Fig. 9. The draw-through combination is more often used for shop and factory installations where compactness is desirable, the blow-through combination being used principally for *hot and cold* systems as installed in schools and public buildings.

Arrangements of Apparatus for Indirect Type

A very common arrangement of the fan steam system of heating is illustrated by Fig. 10. The arrangement consists of a fan, indirect heater unit enclosed by a sheet-metal casing connected with the suction side of the fan, a sheet-metal casing connected to the heater casing run to the outside of the building and provided with an adjustable opening inside

the building for recirculation of the air when desired, and a duct system attached to the fan outlet to convey and distribute the air to various parts of the building to be warmed by the apparatus. The fan is ordinarily motor-driven; there are, however, many cases when a direct-connected steam engine may be used to advantage. In this event the exhaust from the engine can be connected to one or more sections of the heater, depending upon the condensation rate of the engine. The recirculation duct connected with the opening in the suction duct, should be extended to a point as near the floor as possible.

When ventilation is not a requirement or is considered relatively unimportant, as in shop and factory heating, and the number of persons vitiating the air is small compared with the cubical contents of the building or the process does not generate obnoxious gas or vapors, the air may be recirculated, sufficient outside air for ventilation being supplied by infiltration. The amount of heat to be supplied the heater in this case is the same as would be required for a direct radiation installation.

When ventilation is a requirement to be met, an arrangement similar to that shown by Fig. 10 may be employed. Since the amount of air necessary for heating is generally in excess of the amount required for ventilation, considerable fuel economy may be effected by recirculating a portion of the air. In this case only sufficient outside air is drawn into the system to meet the ventilation requirement and the remainder of the air, required for heating, is recirculated. This may be readily effected by an arrangement of ducts and dampers on the suction side of the fan as previously mentioned. If the outside air introduced is to be washed or conditioned the washer or humidifier and tempering coil may be added between the inlet for the recirculated air and the fresh air intake. (See Chapter 30).

The draw-through apparatus is employed on account of its compactness as well as the advantage gained by connecting the fan directly to the duct system. In this case the temperature of the air delivered will be the same to all parts of the building. The blow-through apparatus, Fig. 9, is sometimes used where different temperatures and independent temperature regulation are required for different rooms of the building. Modern practice, however, seems to favor the draw-through system, delivering the air to all rooms at the same temperature, and taking care of varying temperature requirements by the use of booster coils located in the various ducts. The use of the bypass around the heating coils permits the mixture of hot and cold air in any desired proportions, by the use of a mixing damper at the point where the two ducts from the heater, and from the bypass, join to form one duct leading to the room. In the case of public buildings, the fan frequently blows the warm air into a plenum chamber, from which the air ducts radiate to the various rooms of the building; this arrangement is sometimes called the *plenum system*.

Heating Units for Fan Steam Systems

The heating surface for fan steam systems in use at the present time consists either of pipe coils, finned tubes of steel, copper, brass or other metal, cast-iron sections with extended surfaces, or cellular type of heating units. Steam is passed through these heating units and the air to be heated is passed over the exterior heating surface.

In selecting a heater for any particular service, the choice should be based on the desired requirements as follows:

1. Final temperature desired.
2. Loss in air pressure (or friction) through the heater.
3. Velocity through the heater.
4. Free area or face area of heater.
5. Ratio of heating surface to net free (or face) area.
6. Air volume required.
7. Rows deep of pipe, tubes or sections.
8. Amount of heating surface.

Final Temperature Desired. The choice of a heater is largely influenced by the final temperature desired, when the entering air temperature and steam pressure available at the heaters are specified. These data are obtainable from manufacturers' catalogs for various types of heaters.

Loss in Air Pressure (or Friction). The allowable friction through the heater is one of the first factors to be determined in the selection of the apparatus. The velocities of air through various types of heaters will not necessarily be the same, but for any particular job the velocity through the heater should be a secondary consideration and the allowable friction or air pressure loss should be fixed approximately before proceeding with the selection of the heater. The loss in air pressure (or friction) through the heater should not exceed a pre-determined maximum allowable amount for economical operation and for moderate size and first cost of installation.

In public building work, the maximum allowable friction through both tempering coil and reheater coils should never exceed $\frac{5}{8}$ in. of water and it is advisable that the friction be kept considerably lower than this figure if possible. A tempering coil friction ranging from 0.10 to 0.20 in. of water is considered satisfactory. The air pressure loss for reheaters ordinarily ranges from 0.20 to 0.40 in. of water. In factory work, the maximum friction through the heater should never exceed 0.8 in. or 1 in. of water and it is advisable to figure the heaters at lower frictions if possible.

Velocity through Heater. This velocity has generally been given in manufacturers' tables as being measured at 70 F and in most cases refers to the velocity through the net free area of the heater, or through the net space between the pipes, tubes or sections. Although most manufacturers give suitable velocities measured at 70 F, certain manufacturers show velocities measured at 65 F and others indicate velocities measured at the average air temperature through the heater. Many new heaters, however, specify net face areas with corresponding velocities, instead of velocities through net free areas. In either case, manufacturers publish the corresponding friction or air-pressure loss in tables.

Temperature Control of Fan Steam System

Control of the temperature can be accomplished in a simple manner by a single thermostat placed in a suitable position in the heated space and actuating steam valves on the heater sections. A popular method of controlling the temperature is by mixing dampers, permitting the bypassing of a certain amount of air around the heaters and mixing with the

heated air before it is admitted to the areas to be heated. In the operation of such a plant it is important to have the heating coil under entirely separate control from the tempering coil. By *tempering coil* is meant the heater which receives the cold air and raises its temperature to above 32 F. This tempering coil should be either under hand control so that it is entirely *on* when the outside temperature is 35 F or less; or it should be under the control of a snap action thermostat set to come on at 35 F and to insure steam being on the coils at all times that the temperature is below this point. Any control for the heated areas involving steam regulation, should be accomplished by regulating the supply to the reheaters.

DESIGN OF CENTRAL FAN SYSTEMS

The design of a fan steam heating system is in many respects similar to that for a fan-furnace system. As in all problems involving the layout of a heating system, the first step is to calculate the heat losses of the building. If all or a part outside air is to be used, the heat required to warm this incoming air must be added to the heat losses of the building.

The general procedure for the design of all types of central fan systems, whether fan-furnace or fan steam, is as follows:

1. Calculate the heat loss for each room or space to be heated according to the procedure outlined in Chapter 2.
2. Determine volume of air for ventilation or air conditioning by reference to Chapters 24, 27, 28 and 29.
3. Determine temperature of air leaving register outlets or supply outlets. If the system is to function only as a heating system, that is, entirely as a recirculating one, the temperature of the air must be assumed and the values given in Table 1 may be used as a guide.
4. Estimate temperature of air leaving heater. This is the outlet temperature plus the loss in transit in the ducts. For ducts in outside walls or attics, or other exposed

TABLE 1. AIR VELOCITIES AND REGISTER TEMPERATURES

TYPE OF BUILDING	VELOCITIES IN FEET PER MINUTE							REGISTER TEMPERATURE
	Thru Free Area of Heaters	In Horisontal Supply Ducts	In Supply Risers	Into Room	In Vent Outlets	In Vent Risers	In Horisontal Vent Ducts and Recirculating Ducts	
Schools	800 to 1000	800 to 1000	500 to 600	300 to 400	300 to 400	500 to 600	600 to 800	90° to 120°
Churches	800 to 1000	700 to 900	400 to 600	300 to 500	300 to 500	400 to 600	500 to 700	80° to 120°
Auditoriums and Convention Halls	800 to 1000	800 to 1000	500 to 600	300 to 500	300 to 500	500 to 600	600 to 800	80° to 120°
Garages and Industrial Buildings	1000 to 1400	1000 to 1400	600 to 1000	400 to 1000	400 to 600	600 to 1000	800 to 1200	80° to 140°

places, allow 0.25 deg per linear foot of uninsulated duct, and less for ducts in interiors.

5. Calculate weight of air to be circulated.
6. Determine temperature of air entering heater.
7. Determine temperature increase through heater.
8. Calculate heat to be supplied.
9. Calculate fuel requirement and grate areas.
10. Select heater using manufacturers' data and performance curves.
11. Design duct system from data in Chapter 32.
12. Calculate total static pressure of system from data in Chapter 32, and manufacturers' tables. The total static pressure is the sum of the static pressure requirements of all the elements in series in the system.
13. Select fan, motor, and drive, from manufacturers' tables and also Chapter 34.

The foregoing procedure is necessary in any of the following cases which may arise in practice[1], the formulæ applying to either direct-fired or steam systems:

A. The heating of the building is done entirely by means of a central fan system, all of the air being drawn from the outside.

B. Similar to (*A*), except that all of the air is recirculated.

C. A portion of the air is recirculated, and the remainder is drawn in from the outside.

D. Air at the same temperature to be delivered to all the rooms. A constant relative humidity is maintained in the building and all of the air circulated is drawn from outside the building. (Not applicable to the heating of various rooms where individual control of each room is desired).

E. Arrangement similar to (*D*), except that a portion of the air is recirculated.

F. Arrangement of apparatus where individual control of the temperature for each room is required in conjunction with air washer equipment to maintain a constant relative humidity in the rooms. The air washer is provided with a water heater for the spray water, capable of fully saturating the air. It is impossible to maintain the same room temperature throughout the building with a uniform temperature of the air entering the rooms owing to the fact that the weight of air to be delivered to each room is determined and fixed by the ventilating requirements.

In analyzing these cases, the following symbols will be used:

H = heat loss of the room or building, Btu per hour.
H_1 = heat to be supplied to the heater, Btu per hour.
H_2 = heat supplied tempering coil, Btu per hour.
H_3 = heat supplied air washer, Btu per hour.
M = weight of air to be introduced into the room or building, pounds per hour.
M_r = weight of recirculated air, pounds per hour.
M_o = weight of air drawn in from outside, pounds per hour.
t_o = mean temperature of outside air, degrees Fahrenheit.
t = mean air temperature to be maintained in the room or building, degrees Fahrenheit.
t_1 = mean temperature of the air entering the heater.
t_2 = mean temperature of the air leaving the heater.
t_z = temperature loss in the duct system.
t_y = temperature of the air leaving the duct outlets.
0.24 = specific heat of air at constant pressure.
G = grate area, square feet.
C = combustion per hour (pounds of coal, gallons of oil, cubic feet of gas).

[1]See Mechanical Equipment of Buildings by Harding and Willard, Vol. I, revised edition, 1929.

C_1 = combustion rate for coal, pounds of coal per square foot of grate per hour.
E = heater efficiency factor.
F = fuel value per unit of the fuel, Btu.

Case A. (Fig. 2 or 11) All of the air circulated to be drawn from outside the building, in which case $(t_1 - t_o)$.

$$M = \frac{H}{0.24\,(t_y - t)} \tag{1}$$

$$H_1 = 0.24\,(t_2 - t_1)M \tag{2}$$

$$C = \frac{H_1}{F \times E} \tag{3}$$

$$G = \frac{C}{C_1} = \frac{H_1}{F \times E \times C_1} \tag{4}$$

Example. The heat loss H for a certain factory building is 700,000 Btu per hour. The mean inside temperature t to be maintained is 65 F. The assumed outside air temperature t_o is 0 deg; $t_z = 0$ and $t_y = t_2$ and is assumed to be 140 F. Required, M and H_1.

$$M = \frac{700{,}000}{0.24\,(140 - 65)} = 38{,}889 \text{ lb per hour}$$

$$H_1 = 0.24\,(140 - 0)\,38{,}889 = 1{,}305{,}000 \text{ Btu per hour}$$

If a fan furnace is to be employed with gaseous fuel having a calorific value of 530 Btu per cubic foot and if the manufacturers performance efficiency is 0.85:

$$C = \frac{1{,}305{,}000}{530 \times 0.85} = 2880 \text{ cu ft gas per hour}$$

or if coal at 12,000 Btu per pound is used in a furnace that has a performance efficiency of 0.60 at a combustion rate of 7 lb per square foot of grate per hour:

$$G = \frac{1{,}305{,}000}{12{,}000 \times 0.60 \times 7} = 26 \text{ sq ft}$$

Case B. (Fig. 12) All of the air is to be recirculated, in which case $t_1 = t$.

Using the data from the preceding example, $M = 38{,}889$ and from Formula 2

$$H_1 = 0.24\,(140 - 65) \times 38{,}889 = 700{,}000 \text{ Btu per hour}$$

This example illustrates the saving in fuel consumption by the recirculation of the air. The heat to be supplied the apparatus is the same as that required for a direct system of heating and is equal to the heat loss of the building ($H_1 = H$), in the example (700,000 Btu per hour) as compared with 1,305,000 for *Case A*.

Case C. (Fig. 3 or 13) A portion of the air circulated is recirculated air and the remainder, as may be required for ventilating purposes, is drawn in from the outside.

$$M = M_o + M_r = \frac{H}{0.24\,(t_y - t)} \tag{5}$$

The temperature of the resulting mixture of outside and recirculated air entering the heater is:

$$t_1 = \frac{M_o(t_o + 460) + M_r(t + 460)}{M_o + M_r} - 460 \tag{6}$$

Example. Assuming that a positive supply of outside air is required for ventilation at the rate of 1800 cu ft per hour per employee, and assuming 50 employees in the

preceding example, then $M_o = 0.075 \times 50 \times 1800 = 6750$ lb per hour is required, measured at 65 F.

$$M_r = M - M_o = 38{,}889 - 6750 = 32{,}139 \text{ lb.}$$

$$t_1 = \frac{6750\,(460) + 32{,}139\,(65 + 460)}{38{,}889} - 460 = 54 \text{ F.}$$

$$H_1 = 38{,}889 \times 0.24\,(140 - 54) = 802{,}669 \text{ Btu.}$$

The three preceding cases refer to installations in which conditioning the air to maintain certain relative humidity requirements does not enter

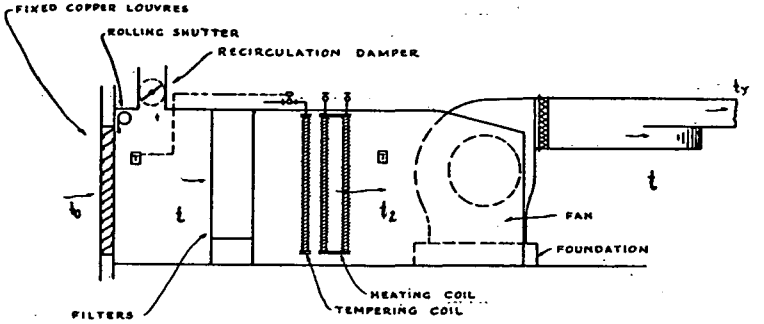


FIG. 11. HEATER AND FAN ARRANGED FOR OUTSIDE AIR CIRCULATION (CASE A)

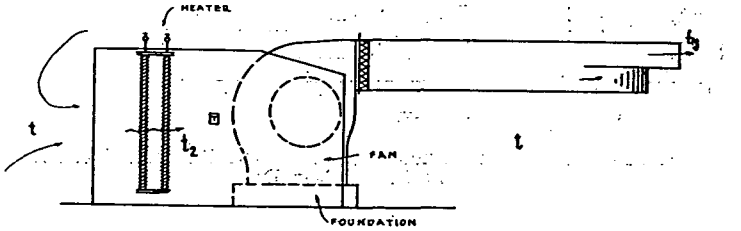


FIG. 12. ARRANGEMENT FOR RECIRCULATION (CASE B)

into the problem, as for example, certain types of industrial installations. In practically all modern public buildings, theaters, schools, and in many industrial installations the ventilating requirements include the provision for air washing and humidifying the air delivered to the various rooms of the structure.

In the following cases it is assumed that in addition to maintaining a mean room temperature t, the heating and ventilating apparatus is required to maintain a constant relative humidity in the rooms.

Case D. (Fig. 4 or 14) The maximum relative humidity that may be maintained within the building without the precipitation of moisture on single glazed sash when the outside temperature is 30 F is approximately 35 per cent. If the inside temperature t is 70 F, 35 per cent relative humidity corresponds to a dew-point temperature of 41 F. (See psychrometric chart, Chapter 27).

The installation shown in Fig. 14 contemplates the use of a tempering coil, air washer provided with a water heater, and a hot-blast heater. The tempering coil, one section

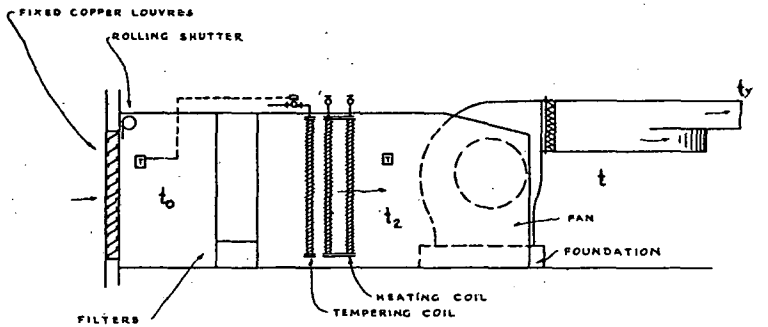


FIG. 13. COMBINATION OF RECIRCULATED AND OUTSIDE AIR (CASE C)

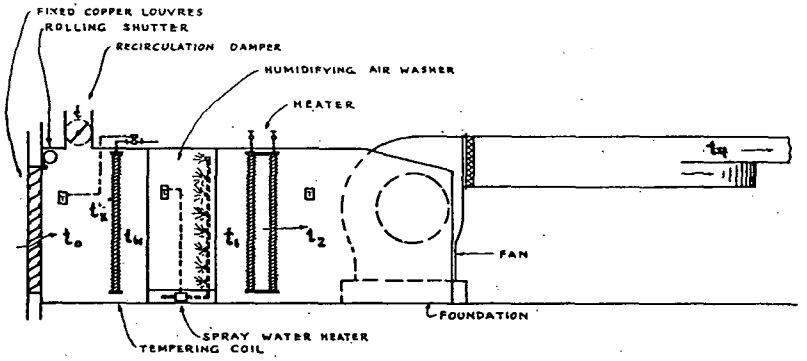


FIG. 14. OUTSIDE AIR CIRCULATED; CONSTANT RELATIVE HUMIDITY IN ROOM (CASE D)

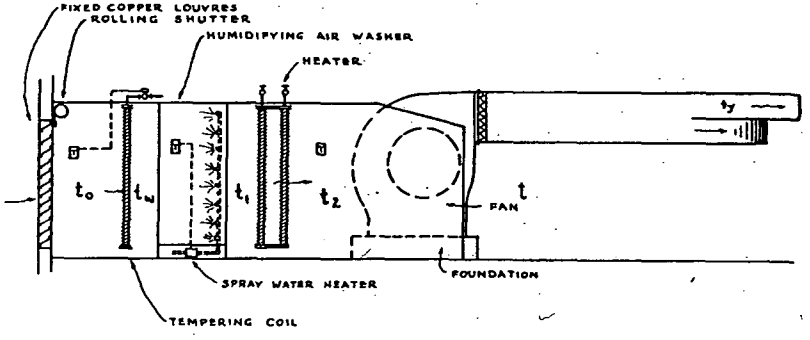


FIG. 15. COMBINATION OF RECIRCULATED AND OUTSIDE AIR; CONSTANT RELATIVE HUMIDITY IN ROOM (CASE E)

in depth, warms the incoming air to approximately 35 F to prevent freezing any of the spray water. The air passing through the spray chamber is saturated and leaves at a temperature of $t_1 = 41$ F.

The heat to be supplied the heater is:

$$H_1 = 0.24\ (t_2 - 41)M \text{ Btu per hour}$$

The heat to be supplied the tempering coil is:

$$H_2 = 0.24\ (35 - t_o)M \text{ Btu per hour}$$

The amount of heat, per pound of air circulated, to be supplied the humidifying washer or humidifier is the difference between the heat content of the assumed dry air entering

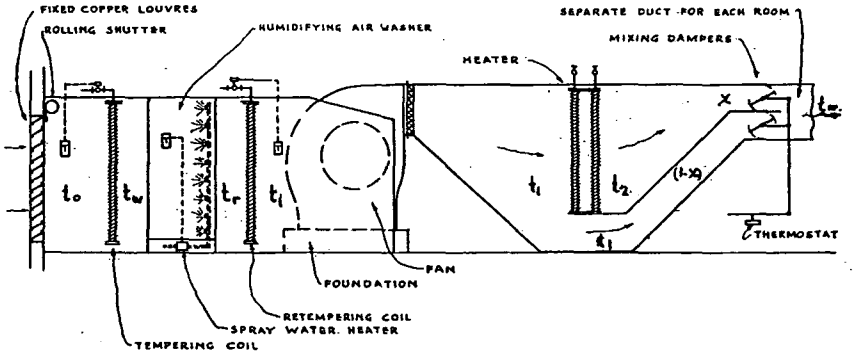


FIG. 16. OUTSIDE AIR CIRCULATED; CONSTANT TEMPERATURE AND RELATIVE HUMIDITY MAINTAINED IN EACH ROOM (CASE F)

the washer at a temperature of $t_w = 35$ F and the leaving saturated air at $t_1 = 41$ F, or

$$15.7 - 8.4 = 7.3 \text{ Btu per pound of dry air}$$

The amount of heat required for the washer is:

$$H_3 = 7.3\ M \text{ Btu per hour}$$

The total amount of heat required by the apparatus is therefore;

$$H_1 + H_2 + H_3 \text{ Btu per hour}$$

If a washer having a *humidifying efficiency* of 67 per cent *without water heater* is employed it will be necessary to heat the outside air drawn into the apparatus by means of a tempering coil to such a temperature that the air in passing through the water sprays will become partially saturated (adiabatically) having a moisture content per pound of air equal to saturated air at 41 F. If the incoming air is warmed by the tempering coil to $t_w = 88$ F (requiring a two-section-depth heater) it will be cooled in the washer to 64 F or $88 - 64 = 24$ deg.

If the *humidifying efficiency* of the washer were 100 per cent, the air would become adiabatically saturated at 52 F or a temperature drop of $88 - 52 = 30$ F. The efficiency of the washer is, however, only 67 per cent, so that the actual temperature drop will be 0.67×36 deg or 24 deg, as used.

The heat to be supplied the heater is in this case $H_1 = 0.24\ (t_2 - 64)M$ Btu per hour, and for the tempering coil is $H_2 = 0.24\ (88 - t_o)M$. The total heat required by the apparatus is $H_1 + H_2$, no heat being supplied to the washer.

Case E. (Fig. 15) The arrangement of the heating and ventilating apparatus is similar

to Case *D* except that a portion of the air is recirculated. All of the air circulated is passed through the washer and heater.

$$M = M_o + M_r = \frac{H}{0.24\ (t_y - t)} \text{ pounds per hour} \qquad (7)$$

M_o is known from the ventilating requirements. Then $M_r = M - M_o$, weight of air recirculated. Assume 35 per cent relative humidity to be maintained in the rooms, which corresponds to a dew-point temperature of 41 F for $t = 70$ F, and a tempering coil to warm the entering outside air from zero to 35 F. The resulting temperature t_x of the mixture of outside and recirculated air entering the tempering coil is:

$$t_x = \frac{M_o\ (35 + 460) + M_r\ (t + 460)}{M} - 460 \qquad (8)$$

A washer supplied with a water heater will raise the temperature of the air passing through from t_w to $t_1 = 41$ F and saturate it at this temperature.

$$H_1 = 0.24\ (t_1 - 41)M, \text{ for heater}$$

$$H_2 = 0.24\ (t_w - t_x)M, \text{ for tempering coil}$$

The heat to be supplied the washer per pound of air passing through the washer is equal to the difference between the heat content of saturated air at a temperature $t_1 = 41$ F (15.7 Btu per pound) and the heat content per pound of the mixture at a temperature of t_w and relative humidity to be calculated.

Assuming the outside air temperature $t_o = 0$, and dry; the inside air temperature $t = 70$ and 35 per cent relative humidity corresponding to 0.00552 lb of moisture per pound of air, there are M pounds containing $0.00552M$ lb moisture or $\frac{M}{0.00552M}$ lb moisture per pound of air entering the washer. Knowing the temperature t_w, the relative humidity is readily determined and the heat content per pound.

Case F. (Fig. 16) The temperature t_y will ordinarily be different for each room. With H and M_o fixed, $0.24\ (t_y - t)\ M_o = H$, or

$$t_y = \frac{H}{0.24\ M_o} + t \qquad (9)$$

In order to provide the proper temperature t_y for each room, the so-called *hot* and *cold* or *double plenum chamber* system is employed. The weight of air drawn in from outside the building is the sum of the values for M_o as determined by the ventilating requirements for each room and is the total weight of air passing through the tempering coil and washer and entering the rooms. Each room is provided with an independent supply duct run to the heater plenum chamber; so that varying amounts of bypassed tempered air and hot air may be mixed to obtain the required temperature (t_y) for each room independently ($t_m = t_y - t_z$). The mixing dampers are ordinarily placed under thermostatic control.

Ducts and Outlets

The design of the duct system should be based on data contained in Chapter 32. The total friction against which the fan must operate is the sum of the resistances of all of the elements of the entire system.

Fans and Motive Power

The selection of fan and motor should be based on data contained in Chapter 34. Centrifugal fans are generally used as they are well adapted for working against the frictional resistance of the system, and reach their maximum efficiency when working against the resistance offered by the average central fan heating system.

Chapter 32

AIR DISTRIBUTION SYSTEMS

Dynamic and Friction Losses; Friction Chart; Proportioning Losses: Design of Ducts; General Rules; Procedure; Air Velocities; Proportioning for Friction; Plenum Chamber and Individual Ducts; Main Trunk Ducts with Branches; Prevention of Noise; Duct Construction: Air Distribution; Stratification and Diffusion; Downward and Upward Air Distribution; Inlets and Outlets; Grilles and Registers; Measurement of Air Flow; Pitot Tubes; Anemometers; Kata Thermometers.

THE laws governing the flow of fluids are based on the assumption that the density remains constant throughout the flow. In considering the flow of a gas such as air, these laws do not strictly hold. The velocity of flow in an air duct of uniform size through which a given weight of air is passing will vary with an increase or decrease in pressure which causes a corresponding decrease or increase in volume.

The flow of air due to large pressure differences is most accurately stated by thermodynamic formulae for air discharge under conditions of adiabatic flow, but such formulae are complicated and the error occasioned by the use of the same formulae that apply to the flow of fluids may be considered negligible when only such pressure differences are involved as occur in ordinary heating and ventilating practice. The pressure difference in this field seldom exceeds more than 2 in. water gage, and it is sufficiently accurate in considering the relations between pressure head and velocity of flow for air in ducts to apply the same formulae as are used for the flow of liquids. The basic formula is:

$$V = 1096.5 \sqrt{\frac{p}{W}} \qquad (1)$$

where

V = velocity in feet per minute.
p = head or pressure in inches of water.
W = weight of air in pounds per cubic foot.

For standard air (70 F, and 29.92 barometer) $W = 0.07495$ lb per cubic foot. Substituting this value in Equation 1:

$$V = 1096.5 \sqrt{\frac{p}{0.07495}} = 4005 \sqrt{p} \qquad (2)$$

An inspection of Equation 1 indicates that temperature affects the velocity of flow by changing the weight per cubic foot of air. Tables 5 and 6 (Chapter 39) give the velocities at various pressures and temperatures.

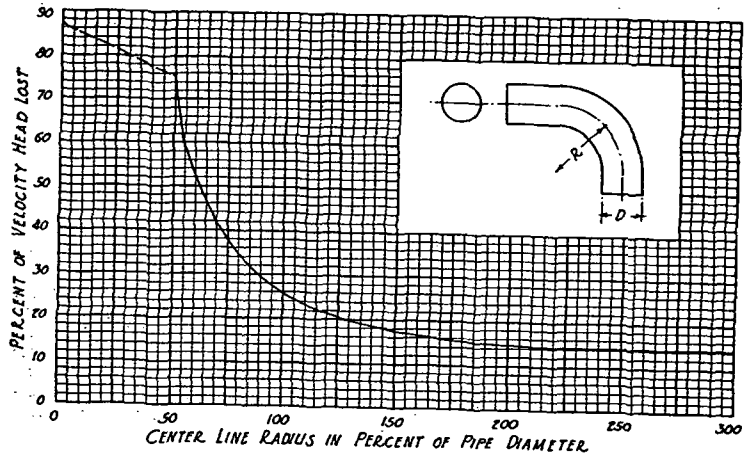


FIG. 1. CURVE SHOWING LOSS OF PRESSURE IN ROUND ELBOWS

PRESSURE LOSSES

The drop in pressure in air distributing systems is due to the *dynamic* losses and the *friction* losses. The friction losses are those due to the friction of the air against the sides of the duct. The dynamic losses are those due to the change in the direction or in the velocity of air flow.

Dynamic Losses

Dynamic losses occur principally at the entrance to the piping, in the elbows, and wherever a change in velocity occurs. The entrance loss is the difference between the actual pressure required to produce flow and the pressure corresponding to the flow produced; it may vary from 0.1 to

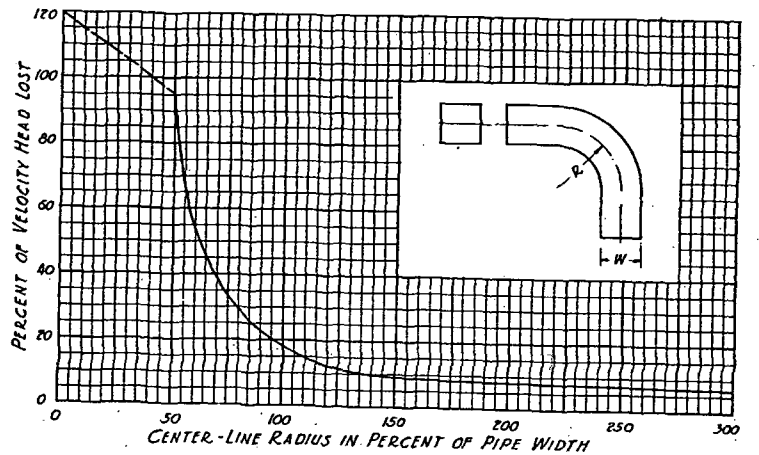


FIG. 2. CURVE SHOWING LOSS OF PRESSURE IN SQUARE ELBOWS

0.5 times the velocity head. The pressure loss in elbows must also be allowed for in the design. It is customary to express dynamic losses in terms of the percentage of the velocity head; in other words, the percentage of that pressure corresponding to the average velocity in the duct which is expressed in terms of inches of water gage. Figs. 1 and 2 show the effect of changing the radius of elbows of square and rectangular section. These charts are based on tests of pipe elbows of ordinary good sheet metal construction. For example, a five-piece round pipe elbow having a centerline radius of one diameter has a loss of about 25 per cent of the velocity head. At a velocity of 2000 fpm the corresponding head is 0.3 in. water gage, and at this velocity the elbow just referred to would cause a pressure drop of 0.075 in. water gage. Experience has shown that good results may be obtained when the radius to the center of the elbow is 1½ times the pipe diameter. The pressure drop will then be approximately 17 per cent of the velocity head for round ducts, and 8 per cent for square ducts. Very little advantage is gained in making elbows with a radius of more than two diameters.

Friction Losses

Friction losses vary directly as the length of the duct, directly as the square of the velocity and inversely as the diameter. Since length is a fixed quantity for any system, the factors subject to modification are the area and the velocity, which determine the relation between the first cost of the duct system and the cost of the power for overcoming friction.

The friction between the moving air and pipe surface causes a loss of head which is numerically equal to the pressure required to maintain a given velocity, and is expressed in the following modification of Fanning's formula:

For round pipe and standard air[1]

$$h_L = f\frac{L}{D}h_v = \frac{L}{CD}\left(\frac{V}{4005}\right)^2 \qquad (3)$$

For rectangular ducts

$$h_L = fL\left(\frac{a+b}{2ab}\right)h_v = \frac{L}{C}\left(\frac{a+b}{2ab}\right)\left(\frac{V}{4005}\right)^2 \qquad (4)$$

where

h_L = loss of head, inches of water.

$h_v = \left(\frac{V}{4005}\right)^2$ = velocity head, inches of water.

V = velocity of air, feet per minute.

L = length of pipe
D = diameter of pipe
a, b = sides of rectangular duct
} all in feet or inches.

f = coefficient of friction.

$C = \frac{L}{f}$ = length of pipe in diameters for one head loss.

For all practical purposes C varies only with the nature of the pipe surface: $C = 60$ for perfectly smooth pipe = 55 for pipe as used in planing

[1]Standard air; 70 F and 29.92 in. barometer.

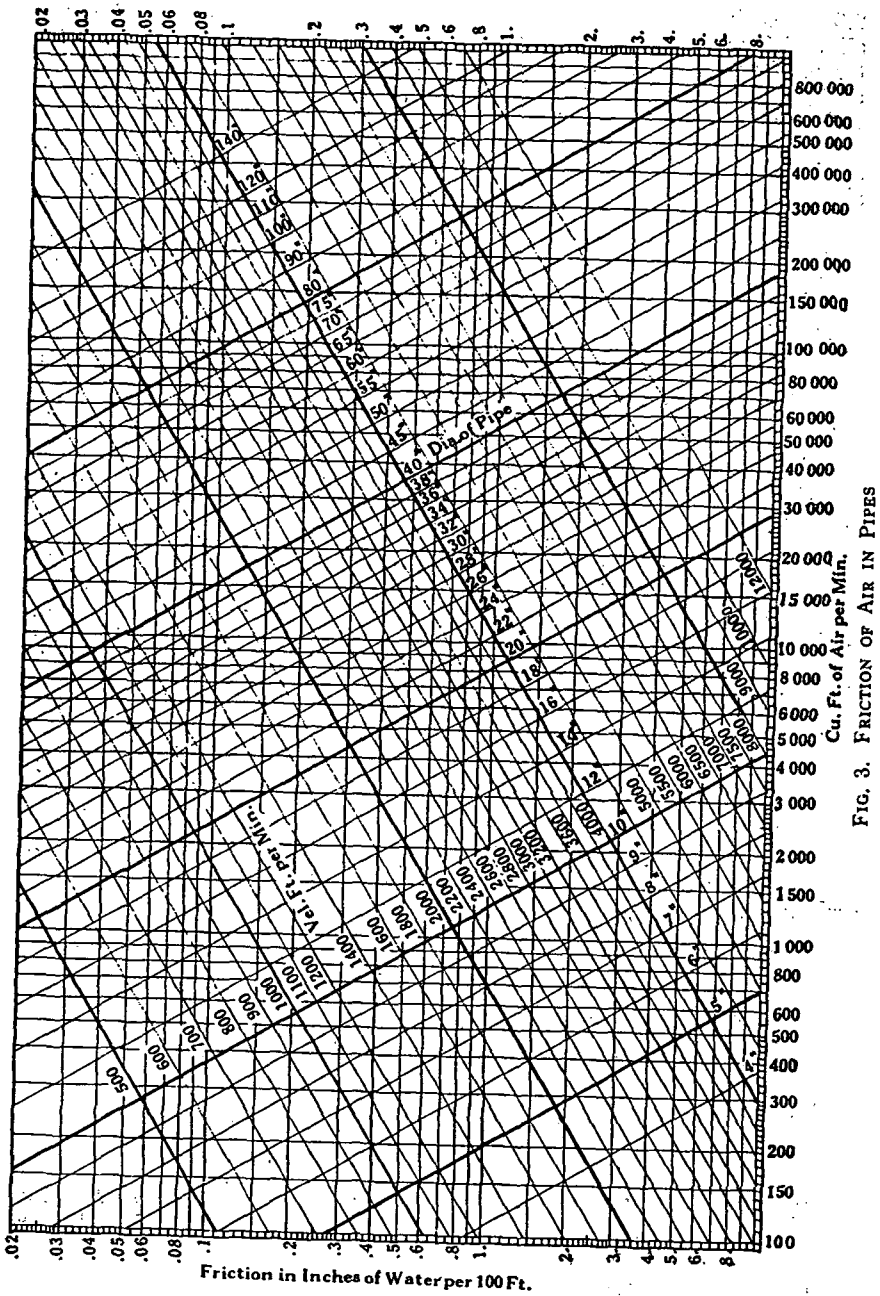


FIG. 3. FRICTION OF AIR IN PIPES

mill exhaust systems = 50 for heating and ventilating ducts = 45 for smooth and 40 for rough conduits of tile, brick or concrete. However, Fritzche states (and numerous tests check very closely) that f varies inversely as the 2/7 power of the pipe diameter, and inversely as the 1/7 power of the velocity, or inversely as the 1/7 power of capacity, which is the same thing. Thus Formula 1 may be revised as follows, based upon a loss of one velocity head (at 2000 fpm) in a length equal to 50 diameters of 24 in. galvanized swedged pipe:

$$h_L = 1.1 \frac{L}{CD^{9/7}} \left(\frac{V}{4005}\right)^{13/7} \tag{5}$$

The preceding formulæ are based on standard air, and for other conditions the friction varies directly as the air density and inversely (approximately) as the absolute temperature. The increase of friction due to increase of air viscosity with increased temperature is small and is generally neglected.

Friction Loss Chart

Fig. 3 is a convenient chart for determining the friction loss for various air quantities in ducts of different size. The general form of this chart is familiar, but it should be noted that it is corrected for changes in the coefficient of friction based on the rule that the coefficient of friction varies inversely as the 2/7 power of the diameter, and inversely as the 1/7 power of the capacity. Fig. 3 is based on a loss of one velocity head (at a velocity of 2000 fpm) in a length equal to 50 diameters of 24-in. round galvanized-iron duct of the usual construction.

Example 1. Assume that it is desired to pass 10,000 cfm of air through 75 ft of 24-in. diameter pipe. Find 10,000 cfm on the right scale of Fig. 3 and move horizontally left to the diagonal line marked 24-in. The other intersecting diagonal shows that the velocity in the pipe is 3200 fpm. Directly below the intersection it is found that the friction per 100 ft is 0.59 in.; then for 75 ft the friction will be $0.75 \times 0.59 = 0.44$ in. In a like manner any two variables may be determined by the intersection of the lines representing the other two variables.

Proportioning the Losses

Other losses of pressure are at the entrance to the duct, through the heating units, air washer, etc. In ordinary practice in ventilation work it is usual to keep the sum of the duct losses ⅓ to ½ and the loss through the heating units at less than ½ of the static pressure. The remainder is then available for producing velocity. In the design of an ideal duct system, all factors should be taken into consideration and the air velocities proportioned so that the resistance will be practically equal in all ducts regardless of length.

DESIGN OF DUCTS

The sizes of ducts and flues for gravity or mechanical circulation of air are usually based on the losses due to friction, and these losses must be kept within the available pressure difference. This pressure difference in mechanical ventilation is that derived from the fan, while in gravity

ventilation the aspirating effect due to the temperature and height of the column of heated air causes the pressure difference.

General Rules

The general rules to be followed in the design of a duct system are:

1. The air should be conveyed as directly as possible at reasonable velocities to obtain the results desired with greatest economy of power, material and space.
2. Sharp elbows and bends should be avoided.
3. The sides of all ducts or flues should be as nearly equal as possible. (In no case should the ratio between long and short sides be greater than 10 to 1).

Procedure for Duct Design

The general procedure for designing a duct system is as follows:

1. Study the plan of the building and draw in roughly the most convenient system of ducts, taking cognizance of the building construction, avoiding all obstructions in steel work, equipment, etc., and at the same time maintaining a simple design.
2. Arrange the positions of duct outlets to insure the proper distribution of heat.
3. Divide the building into zones and proportion the volume of air necessary to supply the heat for each zone.
4. Determine the size of each outlet based on the volume as obtained in the preceding paragraph, for the proper outlet velocity.
5. Calculate the sizes of all main and branch ducts by either of the following two methods:
   a. Velocity Method. Arbitrarily fix the velocity in the various sections, reducing the velocity from the point of leaving the fan to the point of discharge to the room. In this case the pressure loss of each section of the duct is calculated separately and the total loss found by adding together the losses of the various sections.
   b. Friction Pressure Loss Method. Proportion the duct for equal friction pressure loss per foot of length.
6. Calculate the friction for the duct offering the greatest resistance to the flow of air, which resistance represents the static pressure which must be maintained in the fan outlet or in the plenum space to insure distribution of air in the duct system. The duct having the greatest resistance, will usually be that having the longest run, although not necessarily so.

Air Velocities

The following velocities of air are considered standard for public buildings:

1. Through the outside air intakes, 1000 fpm.
2. Through connections to and from heating unit, 1000 to 1200 fpm.
3. Through the main discharge duct, from 1200 to 1600 fpm.
4. In branch ducts, 600 to 1000 and vertical flues 400 to 800 fpm.
5. In registers or grilles, 200 to 400 fpm depending upon the size and location. If diffusers of proper design are used, 25 per cent higher air velocities are permissible.

These duct velocities may safely be increased 20 per cent if first-class construction is used to prevent any breathing, buckling, or vibration. High velocities at one point in the system neutralize the effect of proper design at all other points; hence the importance of splitters in elbows and similar precautions. For industrial buildings noise is seldom considered, and main duct velocities as high as 2800 or 3000 fpm may be used where conditions will permit. For department stores and similar buildings, maximum velocities with good construction and design may be as high

as 2000 or 2200 fpm in main ducts, with suitable reduction in branches and outlets. With these velocities first-class duct construction is essential.

Proportioning the Size for Friction

By means of Figs. 4 and 5 the diameter of branch pipes necessary to carry a given percentage of the total air in the main pipe with the same friction per foot of the length may be determined. These charts, as well as Fig. 3, are based on the assumption that the coefficient of friction varies inversely as the 1/7 power of the capacity.

Example 2. Suppose a 60-in. main pipe is to be used, and it is desired to know the size of branch pipe required to carry 50 per cent of the total air in the main. Find 50 per cent at the left of the chart, move right to the 60-in. diagonal line and note directly above at the top of the chart, that the branch pipe will be 46.5 in. in diameter.

Where rectangular ducts are used it is frequently desirable to know the equivalent diameter of round pipe to carry the same capacity and have the same friction per foot of length. Table 1 gives directly the circular equivalent of rectangular ducts for equal friction and capacity. To obtain the size of rectangular ducts for different capacities, but of the same friction per foot of length, first obtain the equivalent round pipe for equal friction. Thus, if a branch of sufficient size to carry 30 per cent of a 12 x 36-in. pipe is desired, it is found from Table 1 that the main is equivalent to a 22.2 in. diameter round pipe. From Fig. 5, 30 per cent of this is a pipe 14.3 in. in diameter, and referring again to Table 1, the rectangular equivalent branch is a 12 x 14-in., 10 x 17¼-in., or any other desirable combination.

Plenum Chamber and Individual Ducts to Rooms. The following formula may be used to determine the friction loss in terms of the velocity head for a supply system having a plenum chamber and individual ducts to rooms:

$$F = 2\tfrac{1}{2} + \frac{L}{4d} + \frac{N}{5} \qquad (6)$$

where

F = total friction loss in terms of the velocity head.
L = greatest length in feet.
d = diameter of round duct or mean of width and depth if rectangular duct.
N = the number of long radius elbows.

The first term ($2\frac{1}{2}$) is the number of velocity heads lost at the entrance to the duct, at the entrance to vertical flue, and through the riser and register; the second term represents the friction loss in the duct based on one velocity head for 50 diameters, and the third term is derived from the fact that a properly designed elbow has a loss of 20 per cent of the velocity head.

By means of Formula 6, factors for the various ducts are found from which values are assigned for velocities such that the loss in the ducts is not more than one-quarter of the static pressure required, which, for a system of this class, is usually about 1 in. The velocity corresponding to ¼ in. being 2000 fpm, the factor F will give a loss of ¼ in. if $V = \frac{2000}{\sqrt{F}}$.

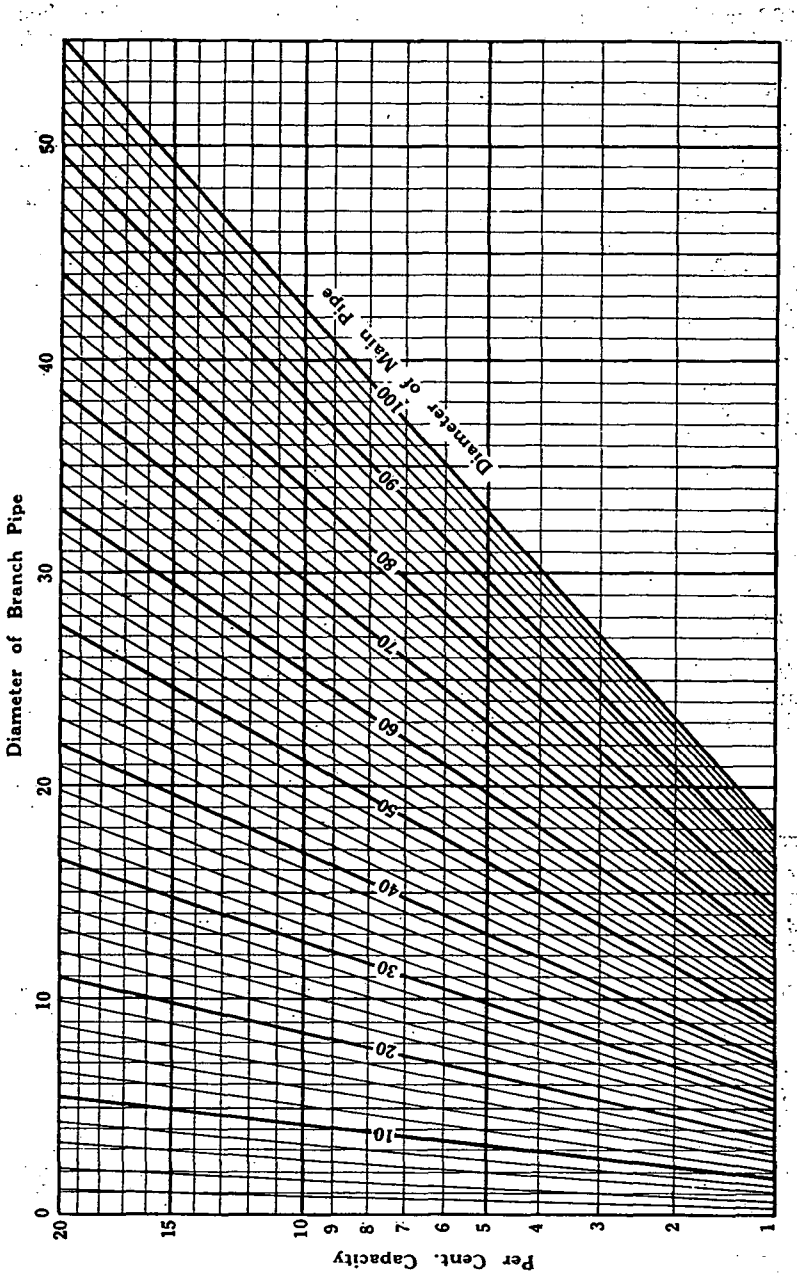


FIG. 4. MAIN AND BRANCH PIPES FOR EQUAL FRICTION PER FOOT OF LENGTH (1 TO 20 PER CENT CAPACITY).

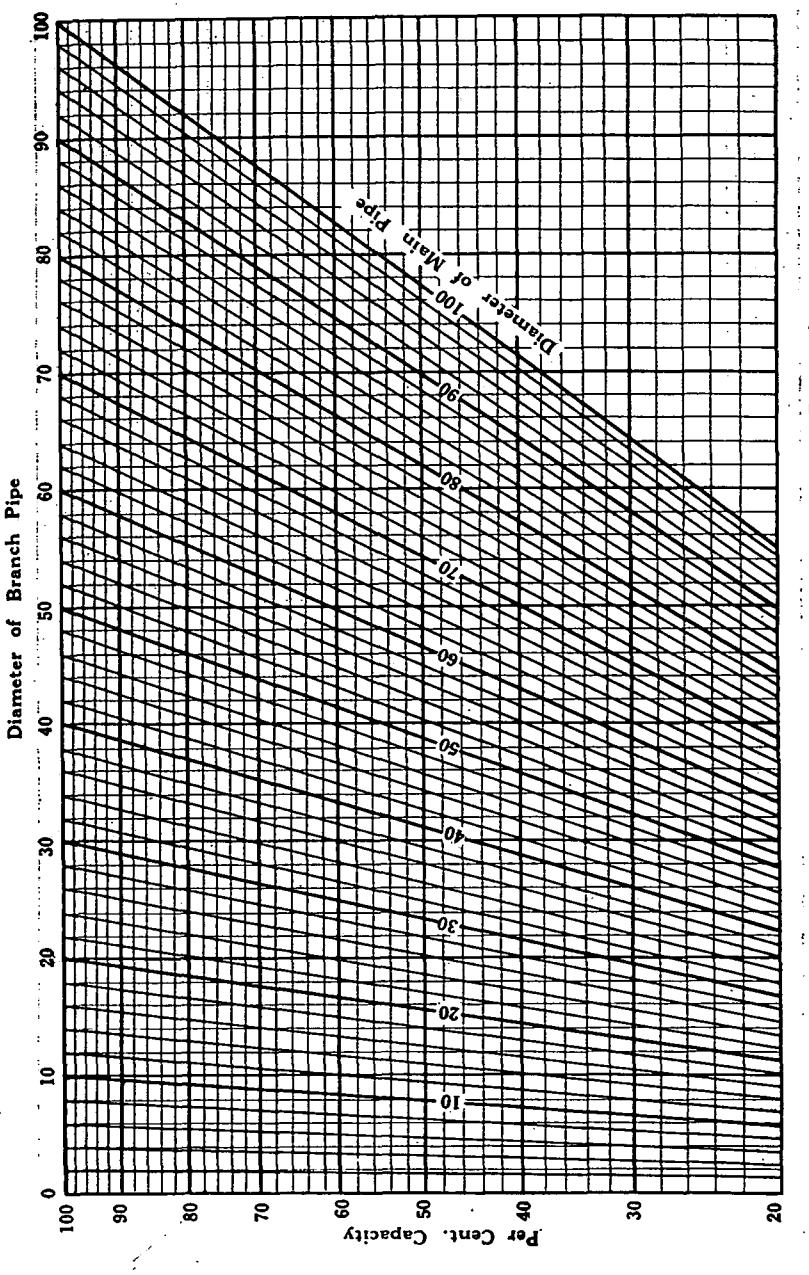


FIG. 5. MAIN AND BRANCH PIPES FOR EQUAL FRICTION PER FOOT OF LENGTH (20 TO 100 PER CENT CAPACITY)

Table 1. Circular Equivalents of Rectangular Ducts for Equal Friction

Side Rectangular Duct	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
8	6.9	7.6	8.2	8.8																
9	7.3	9.0	8.7	9.3	9.9															
10	7.7	8.4	9.2	9.8	10.4	11.0														
11	8.0	8.8	9.6	10.2	10.9	11.5	12.1													
12	8.3	9.2	10.0	10.7	11.4	12.0	12.6	13.2												
13	8.7	9.6	10.4	11.1	11.8	12.5	13.1	13.7	14.3											
14	8.9	9.9	10.8	11.5	12.3	12.9	13.6	14.3	14.9	15.4										
15	9.2	10.2	11.1	11.9	12.7	13.4	14.1	14.7	15.3	16.0	16.5									
16	9.5	10.5	11.4	12.3	13.1	13.8	14.5	15.2	15.8	16.5	17.1	17.6								
17	9.8	10.8	11.8	12.6	13.5	14.2	15.0	15.7	16.3	17.0	17.6	18.2	18.7							
18	10.0	11.1	12.1	13.0	13.8	14.6	15.4	16.1	16.8	17.4	18.1	18.7	19.2	19.8						
19	10.3	11.4	12.4	13.3	14.2	15.0	15.8	16.5	17.2	17.9	18.6	19.2	19.8	20.4	20.9					
20	10.5	11.6	12.7	13.6	14.5	15.4	16.2	17.0	17.6	18.4	19.0	19.7	20.3	20.9	21.5	22.0				
22	11.0	12.1	13.2	14.2	15.2	16.1	16.9	17.8	18.5	19.2	19.9	20.6	21.3	21.9	22.5	23.1	23.6	24.2		
24	11.4	12.6	13.8	14.8	15.8	16.8	17.6	18.5	19.3	20.0	20.8	21.5	22.2	22.8	23.5	24.0	24.7	25.2	25.9	26.4
26	11.8	13.1	14.3	15.4	16.4	17.3	18.3	19.2	20.0	20.8	21.6	22.3	23.0	23.8	24.4	25.1	25.7	26.3	26.9	27.5
28	12.2	13.5	14.8	15.9	17.0	18.0	19.0	19.8	20.7	21.5	22.4	23.1	23.9	24.6	25.3	26.0	26.6	27.3	27.9	28.5
30	12.6	13.9	15.2	16.4	17.5	18.5	19.5	20.5	21.4	22.2	23.1	23.9	24.7	25.4	26.2	26.8	27.5	28.2	28.8	29.5
32	12.9	14.3	15.6	16.9	18.0	19.1	20.1	21.1	22.0	22.9	23.8	24.6	25.4	26.2	27.0	27.7	28.4	29.1	29.8	30.5
34	13.2	14.7	16.1	17.3	18.5	19.6	20.7	21.6	22.6	23.5	24.4	25.3	26.2	26.9	27.7	28.5	29.2	30.0	30.7	31.3
36	13.6	15.1	16.4	17.7	19.0	20.1	21.2	22.2	23.2	24.2	25.1	26.0	26.8	27.7	28.5	29.3	30.0	30.8	31.5	32.2
38	13.9	15.4	16.8	18.2	19.4	20.6	21.7	22.8	23.8	24.8	25.8	26.7	27.5	28.4	29.2	30.0	30.8	31.5	32.3	33.1
40	14.3	15.7	17.2	18.6	19.8	21.1	22.2	23.3	24.4	25.4	26.4	27.3	28.2	29.1	29.9	30.8	31.6	32.4	33.1	33.9
42	14.5	16.1	17.6	19.0	20.3	21.6	22.7	23.8	24.9	25.9	26.9	27.9	28.8	29.8	30.7	31.4	32.2	33.0	33.8	34.5
44	14.8	16.4	18.0	19.4	20.7	22.0	23.1	24.3	25.4	26.5	27.5	28.5	29.5	30.3	31.2	32.1	32.9	33.7	34.5	35.3
46	15.1	16.7	18.4	19.8	21.1	22.4	23.6	24.8	25.9	27.0	28.1	29.1	30.1	31.0	31.9	32.8	33.8	34.6	35.4	36.2
48	15.4	17.0	18.7	20.1	21.5	22.8	24.1	25.2	26.4	27.5	28.6	29.6	30.5	31.6	32.5	33.4	34.3	35.2	36.1	37.0
50	15.7	17.3	19.0	20.4	21.9	23.2	24.5	25.7	26.9	28.0	29.2	30.3	31.3	32.2	33.1	34.1	35.0	35.9	36.8	37.6
52	15.9	17.6	19.2	20.8	22.2	23.6	24.9	26.2	27.4	28.5	29.6	30.7	31.8	32.9	33.8	34.7	35.6	36.5	37.4	38.3
54	16.1	17.9	19.6	21.1	22.6	24.0	25.3	26.6	27.8	29.0	30.1	31.2	32.3	33.4	34.4	35.3	36.3	37.2	38.0	38.9
56	16.3	18.2	19.9	21.5	22.9	24.4	25.7	27.0	28.3	29.5	30.6	31.7	32.8	33.9	34.9	35.9	36.9	37.8	38.7	39.6
58	16.6	18.4	20.2	21.8	23.3	24.7	26.1	27.4	28.7	30.0	31.1	32.2	33.3	34.4	35.4	36.4	37.4	38.4	39.4	40.3
60	16.8	18.7	20.4	22.1	23.6	25.1	26.5	27.8	29.1	30.5	31.6	32.7	33.8	34.9	36.1	37.1	38.1	39.1	40.0	40.9
62	17.0	19.0	20.7	22.4	24.0	25.5	26.9	28.2	29.5	30.9	32.1	33.2	34.3	35.4	36.6	37.7	38.7	39.6	40.6	41.6
64	17.3	19.2	21.0	22.7	24.3	25.9	27.3	28.6	29.9	31.3	32.6	33.7	34.8	35.9	37.1	38.2	39.2	40.2	41.2	42.2
66	17.5	19.5	21.2	23.0	24.6	26.2	27.7	29.0	30.3	31.7	33.0	34.2	35.3	36.4	37.6	38.7	39.8	40.8	41.8	42.8

Table 1. Circular Equivalents of Rectangular Ducts for Equal Friction—(Continued)

Side Rectangular Duct	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	42	44	46	48
26	28.1	28.6																		
28	29.1	29.7	30.2	30.8																
30	30.1	30.7	31.3	31.9	32.5	33.0														
32	31.1	31.7	32.3	32.9	33.5	34.1	34.6	35.2												
34	32.0	32.7	33.3	33.9	34.5	35.1	35.7	36.3	36.8	37.4										
36	32.9	33.7	34.3	34.9	35.5	36.1	36.7	37.3	37.9	38.5	39.1	39.6								
38	33.8	34.6	35.3	35.9	36.5	37.1	37.7	38.4	39.0	39.5	40.1	40.7	41.2	41.8						
40	34.6	35.3	36.0	36.7	37.4	38.0	38.6	39.3	39.9	40.5	41.1	41.7	42.3	42.9	43.4	44.0				
42	35.2	36.0	36.8	37.6	38.3	39.0	39.6	40.3	40.9	41.5	42.1	42.7	43.4	44.0	44.5	45.1	46.2			
44	36.1	36.9	37.7	38.5	39.2	39.9	40.5	41.2	41.8	42.5	43.1	43.7	44.3	44.9	45.5	46.1	47.2	48.4		
46	37.0	37.8	38.5	39.3	40.0	40.8	41.5	42.2	42.9	43.5	44.2	44.8	45.4	46.0	46.6	47.2	48.4	49.5	50.6	
48	37.8	38.5	39.2	40.0	40.8	41.5	42.3	43.0	43.7	44.4	45.0	45.6	46.3	46.9	47.5	48.1	49.3	50.5	51.6	52.8
50	38.4	39.2	40.0	40.8	41.5	42.3	43.0	43.8	44.5	45.2	45.9	46.5	47.1	47.9	48.5	49.1	50.4	51.6	52.9	54.0
52	39.1	40.0	40.8	41.6	42.3	43.1	43.9	44.7	45.4	46.1	46.8	47.5	48.2	48.9	49.5	50.1	51.3	52.5	53.8	55.0
54	39.8	40.7	41.5	42.4	43.2	44.0	44.7	45.5	46.4	47.0	47.6	48.4	49.2	49.9	50.5	51.1	52.3	53.5	54.8	56.0
56	40.4	41.3	42.1	43.0	43.8	44.6	45.4	46.2	46.9	47.7	48.5	49.1	49.9	50.6	51.3	52.0	53.3	54.6	55.9	57.0
58	41.2	42.1	42.9	43.8	44.5	45.4	46.2	47.0	47.8	48.5	49.4	50.0	50.8	51.5	52.2	52.9	54.2	55.5	56.8	58.0
60	41.8	42.7	43.6	44.5	45.4	46.1	46.9	47.8	48.5	49.3	50.1	50.9	51.6	52.3	53.0	53.8	55.0	56.4	57.7	58.9
62	42.5	43.4	44.3	45.1	46.0	46.8	47.6	48.4	49.3	50.0	50.9	51.7	52.4	53.0	53.9	54.5	55.9	57.2	58.5	59.7
64	43.1	44.0	44.9	45.8	46.7	47.5	48.4	49.2	50.0	50.9	51.7	52.4	53.2	53.9	54.7	55.4	56.8	58.1	59.4	60.6
66	43.7	44.7	45.6	46.5	47.3	48.2	49.1	50.0	50.7	51.6	52.4	53.1	53.9	54.7	55.5	56.2	57.6	59.1	60.4	61.6
68	44.4	45.3	46.3	47.2	48.0	48.9	49.7	50.7	51.4	52.2	53.1	53.8	54.6	55.5	56.2	56.9	58.4	59.9	61.3	62.6
70	45.0	46.0	46.9	47.8	48.7	49.5	50.4	51.3	52.0	52.9	53.7	54.5	55.4	56.2	57.0	57.7	59.1	60.6	62.1	63.5
72	45.5	46.5	47.5	48.4	49.3	50.1	51.0	51.9	52.8	53.7	54.6	55.4	56.2	57.0	57.8	58.7	60.0	61.3	63.0	64.5

TABLE 1. CIRCULAR EQUIVALENTS OF RECTANGULAR DUCTS FOR EQUAL FRICTION—(Continued)

Sides Rectangular Duct	50	52	54	56	58	60	62	64	66	68	70	72	74	76	78	80	82	84	86	88
50	55.0																			
52	56.1	57.2																		
54	57.2	58.3	59.4																	
56	58.3	59.4	60.5	61.6	63.8	66.0	68.2	70.4	72.6	74.8	77.0	79.2	81.4	83.6	85.8	88.0	90.2	92.4	94.6	96.8
58	59.3	60.5	61.6	62.7	63.8	64.9	69.3	71.5	73.7	75.9	78.1	80.3	82.5	84.7	86.9	89.1	91.3	93.5	95.7	97.9
60	60.3	61.5	62.7	63.8	64.9	66.0	70.4	72.6	74.8	77.0	79.2	81.4	83.6	85.8	88.0	90.2	92.4	94.6	96.8	99.0
62	61.3	62.5	63.7	64.8	66.0	67.1	71.5	73.7	75.9	78.1	80.3	82.5	84.7	86.9	89.1	91.3	93.5	95.7	97.9	100.1
64	62.2	63.5	64.7	65.9	67.1	68.2	72.6	74.8	77.0	79.2	81.4	83.6	85.8	88.0	90.2	92.4	94.6	96.8	99.0	101.2
66	63.2	64.4	65.7	66.9	68.1	69.3	73.7	75.9	78.1	80.3	82.5	84.7	86.9	89.1	91.3	93.5	95.7	97.9	100.1	102.3
68	64.1	65.4	66.6	67.9	69.1	70.3	74.8	77.0	79.2	81.4	83.6	85.8	88.0	90.2	92.4	94.6	96.8	99.0	101.2	103.4
70	65.0	66.3	67.6	68.8	70.1	71.3	75.9	78.1	80.3	82.5	84.7	86.9	89.1	91.3	93.5	95.7	97.9	100.1	102.3	104.5
72	65.9	67.2	68.5	69.8	71.1	72.3	77.0	79.2	81.4	83.6	85.8	88.0	90.2	92.4	94.6	96.8	99.0	101.2	103.4	105.6
74	66.8	68.1	69.4	70.7	72.0	73.3	78.1	80.3	82.5	84.7	86.9	89.1	91.3	93.5	95.7	97.9	100.1	102.3	104.5	106.7
76	67.6	69.0	70.3	71.6	72.9	74.2	79.2	81.4	83.6	85.8	88.0	90.2	92.4	94.6	96.8	99.0	101.2	103.4	105.6	107.8
78	68.4	69.8	71.2	72.6	73.9	75.2	80.2	82.5	84.7	86.9	89.1	91.3	93.5	95.7	97.9	100.1	102.3	104.5	106.7	108.9
80	69.2	70.7	72.1	73.5	74.8	76.1	81.2	83.4	85.6	87.8	90.0	92.2	94.4	96.6	98.8	101.0	103.2	105.4	107.6	109.8
82	70.1	71.5	73.0	74.4	75.7	77.1	82.2	84.4	86.6	88.8	91.0	93.2	95.4	97.6	99.8	102.0	104.2	106.4	108.6	110.8
84	70.9	72.3	73.8	75.2	76.6	78.0	83.2	85.4	87.6	89.8	92.0	94.2	96.4	98.6	100.8	103.0	105.2	107.4	109.6	111.8
86	71.7	73.2	74.6	76.0	77.4	78.9	84.2	86.4	88.6	90.8	93.0	95.2	97.4	99.6	101.8	104.0	106.2	108.4	110.6	112.8
88	72.5	74.0	75.5	76.8	78.3	79.8	85.2	87.4	89.6	91.8	94.0	96.2	98.4	100.6	102.8	105.0	107.2	109.4	111.6	113.8
90	73.3	74.7	76.3	77.7	79.1	80.6	86.1	88.3	90.5	92.7	94.9	97.1	99.3	101.5	103.7	105.9	108.1	110.3	112.5	114.7
92	74.1	75.5	77.1	78.5	79.9	81.4	87.0	89.2	91.4	93.6	95.8	98.0	100.2	102.4	104.6	106.8	109.0	111.2	113.4	115.6
94	74.8	76.3	77.8	79.3	80.7	82.2	87.8	90.0	92.2	94.4	96.6	98.8	101.0	103.2	105.4	107.6	109.8	112.0	114.2	116.4
96	75.5	77.1	78.7	80.2	81.6	83.0	88.7	90.9	93.1	95.3	97.5	99.7	101.9	104.1	106.3	108.5	110.7	112.9	115.1	117.3

Example 3. If the longest run of pipe is 70 ft, the mean of its two dimensions 25 in. and it has 4 elbows, then $F = 2\frac{1}{2} + \frac{70}{100} + 4/5 = 4$ velocity heads loss in the duct. The velocity which will cause a loss of ¼ in. will then be $V = \frac{2000}{\sqrt{F}} = 1000$ fpm.

Main Trunk Ducts with Branches. A main duct with branches is generally used to convey tempered air for ventilation purposes only. In place of individual ducts a comparatively large main duct supplies air by branches to various rooms with a velocity which may be 2000 fpm at the start and reduced to 400 fpm in the risers, these figures varying according to the nature of the installation. This duct system may be designed so that the loss of pressure in the branches is equalized in a manner similar to that previously described. For each branch a factor may be calculated by Formula 6. It is usually desirable that the loss in each branch approximate 0.1 in., or since the velocity corresponding to 0.1 in. is 1260 fpm, the factor F and the velocity V will give a loss of 0.1 in. if $V = \frac{1260}{\sqrt{F}}$.

Example 4. Table 2 is a schedule for an air distribution system of a typical school (see Figs. 6 to 10 inclusive). The volume of air per minute for classrooms is based on the number of pupils, with an allowance of 30 cfm per pupil. Table 2 shows the volume of air to be delivered to each room, and also gives the dimensions of the risers, the size of the diffusers and the velocities through each.

The total air requirement for the building is 24,050 cfm. To provide a margin for some unavoidable leakage, the total volume should be increased 10 per cent, and this increased volume should be used as the basis for determining the size of the main ducts and branches, although the 10 per cent added may be disregarded in arriving at the size of the risers and diffusers, inasmuch as any leakage will probably have occurred before the air reaches this point.

TABLE 2. AIR SCHEDULE FOR TYPICAL SCHOOL LAYOUT

Room No.	Cubic Content	Dimensions Feet	Sq. Ft. Floor	No. of Pupils	Air Req. per Min.	Size Riser Inches	Velocity (fpm)	Size Diffuser (Inches)	Diffuser Velocity (fpm)
1	7000	26½ x 22 x 12	583	40	1200	16 x 20	540	20 x 30	288
2	7000	26½ x 22 x 12	583	40	1200	16 x 20	540	20 x 30	288
3	7000	26½ x 22 x 12	583	40	1200	16 x 20	540	20 x 30	288
4	7000	26½ x 22 x 12	583	40	1200	16 x 20	540	20 x 30	288
5	7000	26½ x 22 x 12	583	40	1200	16 x 20	540	20 x 30	288
6	7000	26½ x 22 x 12	583	40	1200	16 x 20	540	20 x 30	288
7	8720	33 x 22 x 12	726	50	1500	16 x 24	563	24 x 30	300
8	8720	33 x 22 x 12	726	50	1500	16 x 24	563	24 x 30	300
9	7000	26½ x 22 x 12	583	40	1200	16 x 20	540	20 x 30	288
10	7000	26½ x 22 x 12	583	40	1200	16 x 20	540	20 x 30	288
11	5800	22 x 22 x 12	483	33	990	16 x 16	556	16 x 30	297
12	7000	26½ x 22 x 12	583	40	1200	16 x 20	540	20 x 30	288
13	3360	21½ x 13 x 12	280	20	600	12 x 16	450	16 x 20	270
14	3360	21½ x 13 x 12	280	20	600	12 x 16	450	16 x 20	270
15	17500	54 x 27 x 12	1460	100	3000	2–16 x 24	465	24 x 30	300
16	6480	20 x 27 x 12	540	37	1110	16 x 20	503	20 x 26	289
17	7000	26½ x 22 x 12	583	40	1200	16 x 20	540	20 x 30	288
Audi.	37600	65 x 34 x 17	2220	....	2500	2–16 x 20	565	20 x 30	301
Office	3700	14 x 22 x 12	308	....	250	8 x 12	375	12 x 12	250

Since the plan (Fig. 6) shows a moderately short run of main duct, and with no risers at a considerable distance away, a fan should be selected which will have the required capacity of 26,455 cfm with a maximum velocity over the fan outlet of 1600 fpm. The outlet area should therefore be 16½ sq ft.

From the fan outlet to the main duct, a cone connection is used by means of which a part of the velocity head is transformed into static pressure, which regain, if the reduction in velocity is considerable, may be deducted from the resistance of the system. From a velocity of 1300 fpm in the main duct next to the fan, a gradual reduction is made as indicated on the basement plan (Fig. 6).

Fig. 7 shows an alternate basement plan for underground ducts. Lower velocities are

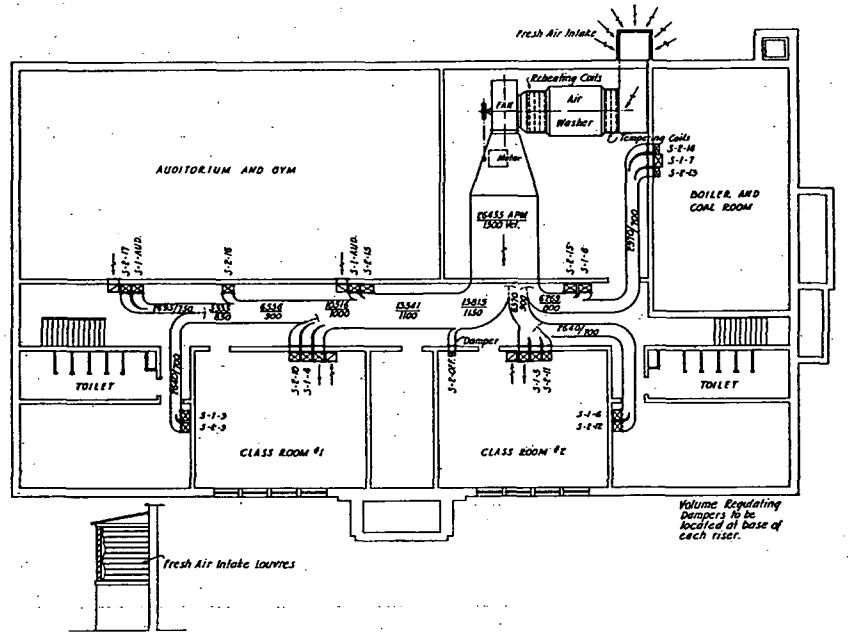


FIG. 6. BASEMENT PLAN METAL DUCT DISTRIBUTION TYPICAL SCHOOL LAYOUT

recommended than with the sheet metal duct system. Concrete ducts are usually made the full width of the corridor, and of uniform depth throughout.

The clear area of the fresh air inlet is based on a velocity of 900 fpm or $\frac{26,455}{900} = 29\frac{1}{2}$ sq ft. The tempering coil will raise the temperature of the incoming air from zero to 32 F with a velocity of 1000 fpm through the clear area. The air washer should have a maximum velocity of 500 fpm, or a clear area of 53 sq ft. The air washer, if provided with humidity control, will raise the temperature from 32 F to saturation at 42 F, which includes the heat required for evaporation; if no humidity control is provided, this heating load must be assumed by the tempering coils. The reheater coil will raise the temperature from 42 F to 70 F. If the system is used for both heating and ventilation, the reheater coil must be of sufficient depth to supply the maximum heat requirements for extreme weather. For more detailed information on tempering coil and air washer control, see Chapter 31, Design of Central Fan Systems.

The friction of the system in inches of water for this typical school is as follows:

	Friction Losses
Outside air intake 900 fpm velocity (1½ heads × 0.051)	0.077 in.
Tempering coil loss (from manufacturers' table)	0.100 in.
Air washer loss (from manufacturers' table)	0.250 in.
Reheater loss (from manufacturers' table)	0.100 in.

Discharge duct friction:

(A length of 50 diameters occasions a friction loss equivalent to one velocity head)

5 diameters of duct at 1300 fpm velocity

$$\left(\frac{5 \text{ diam}}{50} \times 0.106\right) \quad 0.011$$

Elbow at 1150 fpm velocity

$$\left(\frac{10 \text{ diam}}{50} \times 0.083\right) \quad 0.017$$

7 diameters of duct at 1100 fpm velocity

$$\left(\frac{7 \text{ diam}}{50} \times 0.076\right) \quad 0.011$$

2 diameters of duct at 1000 fpm velocity

$$\left(\frac{2 \text{ diam}}{50} \times 0.0625\right) \quad 0.003$$

4 diameters of duct at 900 fpm velocity

$$\left(\frac{4 \text{ diam}}{50} \times 0.051\right) \quad 0.004$$

2 diameters of duct at 850 fpm velocity

$$\left(\frac{2 \text{ diam}}{50} \times 0.045\right) \quad 0.002$$

5 diameters of duct at 700 fpm velocity

$$\left(\frac{5 \text{ diam}}{50} \times 0.0305\right) \quad 0.003$$

2 elbows at 700 fpm velocity

$$\left(\frac{20}{50} \times 0.0305\right) \quad 0.012$$

(Friction loss of one well rounded elbow is equivalent to 10 diameters of straight duct)

15 diameters riser at 540 fpm velocity

$$\left(\frac{15}{50} \times 0.018\right) \quad 0.006$$

2 bad elbows in riser at 540 fpm velocity

$$\left(\frac{60}{50} \times 0.018\right) \quad 0.022$$

(Friction loss of one bad elbow equivalent to 30 diameters of straight duct)

	0.091	0.091
Allowance for regulating damper and diffuser		0.100
Static pressure		0.718 in.

The fan should be selected from manufacturers' ratings which, according to the A.S.H.V.E. Standard Code for the Testing of Centrifugal and Disc Fans, will deliver 26,455 cfm of air at a static pressure of 0.718 in. and which has an outlet area of 16½ sq ft.

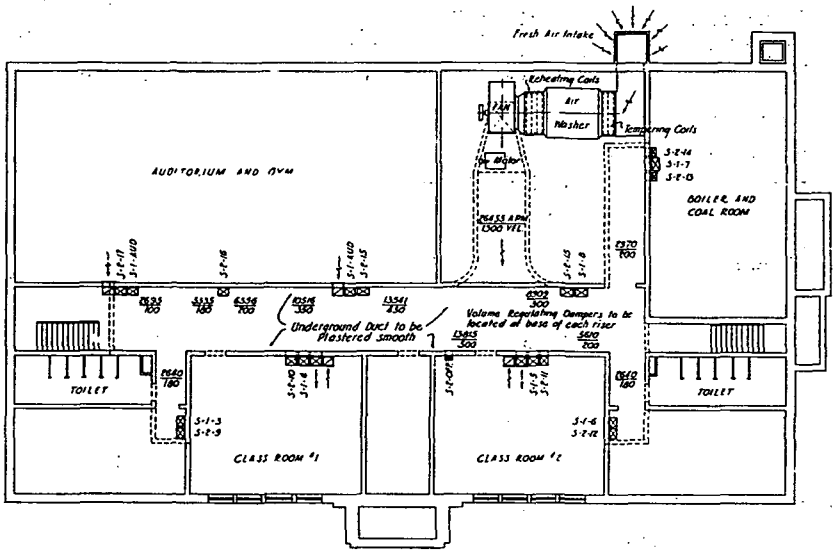


FIG. 7. BASEMENT PLAN CONCRETE DUCT DISTRIBUTION TYPICAL SCHOOL LAYOUT

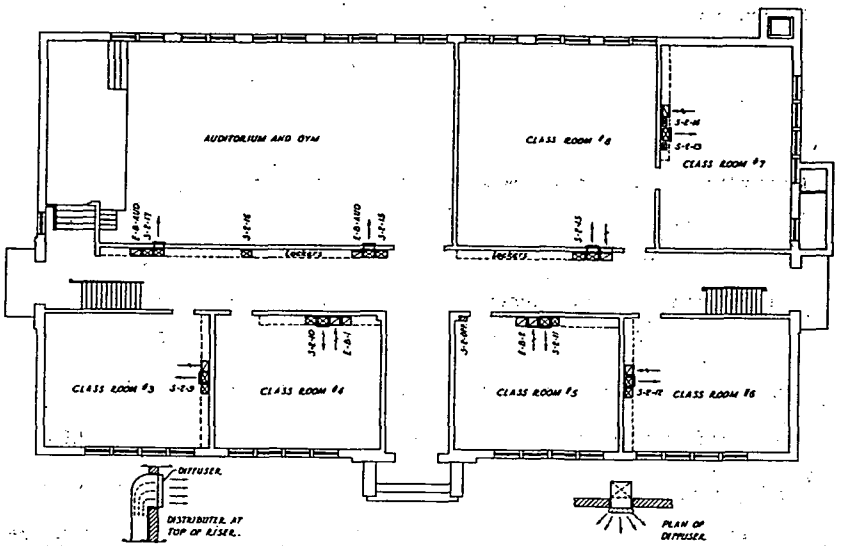


FIG. 8. TYPICAL SCHOOL LAYOUT—FIRST FLOOR PLAN

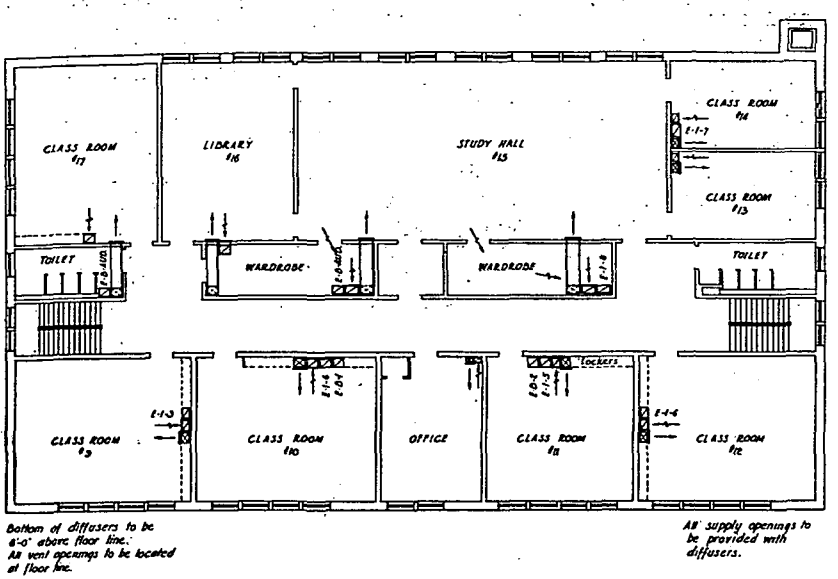


FIG. 9. TYPICAL SCHOOL LAYOUT—SECOND FLOOR PLAN

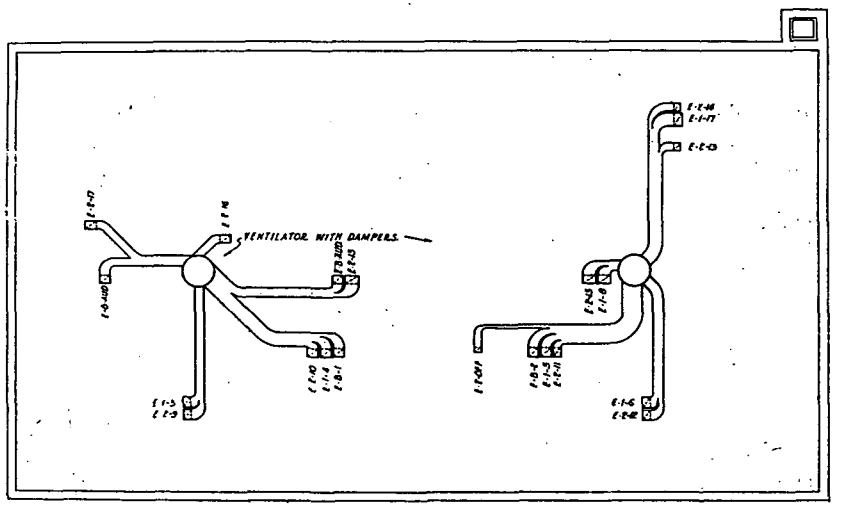


FIG. 10. PLAN OF VENT DUCT IN ATTIC SPACE—TYPICAL SCHOOL LAYOUT

Where there are one or more ducts with branches, the velocity of air in the ducts may be either chosen arbitrarily or calculated for friction losses. When arbitrary values are assigned, a certain amount of dampering should be provided for; this will be small when the method chosen permits a drop in velocity as the quantity of air is reduced.

After the total air quantity and the size of fan are ascertained, the main duct is usually fixed as being at least equal in area to the fan outlet, or perhaps 10 per cent greater. From this main pipe all others are proportioned. For example, if the main duct is 30 in. in diameter, a branch to carry 10 per cent of the total capacity should be 12.7 in. in diameter (see Fig. 4) in order to have the same friction per foot of length, while one carrying one-half the total capacity of a 30-in. main with the same friction loss per foot would be 23.4 in. in diameter. By this method of equalizing

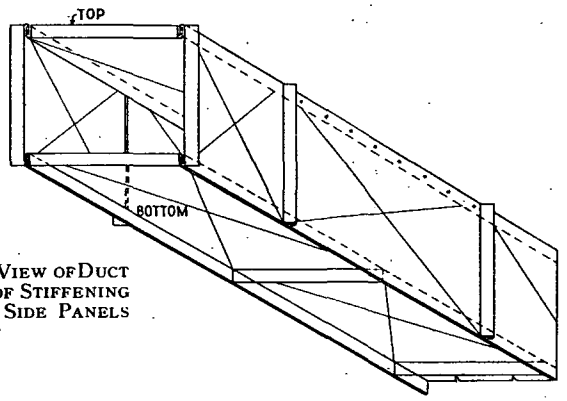


FIG. 11. ISOMETRIC VIEW OF DUCT SHOWING LOCATION OF STIFFENING SEAMS ON TOP AND SIDE PANELS OF DUCT

friction it is unnecessary to consider the resistance of each section of pipe independently, but only to know the distance from the fan outlet to the end of the longest run of pipe, the number and size of elbows, and the diameter and velocity in the largest pipe.

Example 5. If the greatest length of piping in a system is 130 ft with a 26-in. diameter main pipe and one 20-in. elbow, the piping having been designed for equal friction per foot of length, the friction would be the same as for 130 linear feet of 26 in. pipe, or 60 diameters. To this should be added the friction loss in elbows, in this case one 20-in. elbow, which has a loss equivalent to one-fifth of a velocity head or ten diameters of 20-in. pipe. This in turn is $\frac{20}{26} \times 10 = 7.7$ diameters of 26-in. pipe. The total equivalent length of the system will then be 60 + 7.7 or 67.7 diameters. Since 50 diameters is equivalent to one velocity head, the loss is $\frac{67.7}{50} = 1.35$ times the velocity head. If the velocity is, for example. 2200 fpm, corresponding to 0.3 in. pressure, the friction loss of the system will be $1.35 \times 0.3 = 0.405$ in.

Prevention of Noise

Frequently the prevention of sound in a heating or ventilating system imposes more severe restrictions than the prevention of excessive pressure drop. This question is highly involved and requires consideration of

many factors. The air velocities to be used will vary with the standard of construction used in the ducts themselves as well as with the nature of the occupancy and the construction of the building. In general, architects and engineers who leave the details of duct construction to the contractor must, of necessity, design for lower velocities than might be required for

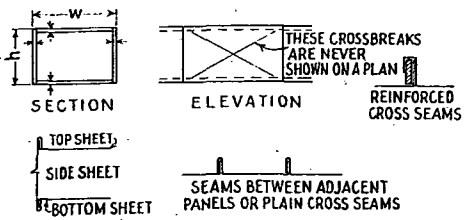


FIG. 12. DETAILS OF SEAMS

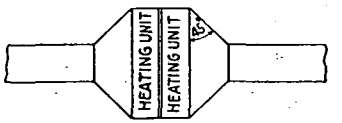


FIG. 13. METHOD OF INSTALLING HEATING UNIT

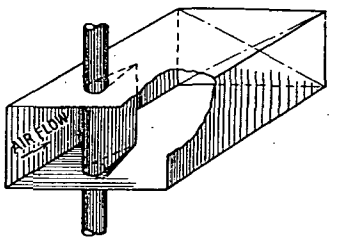


FIG. 14. INSTALLATION OF EASEMENT IN DUCT AROUND OBSTRUCTION

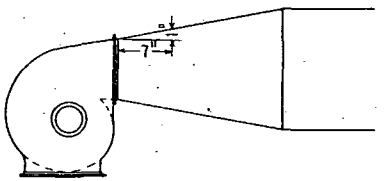


FIG. 15. FAN DISCHARGE CONNECTION

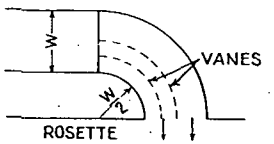


FIG. 16. AIR SPLITTERS INSTALLED IN ELBOW

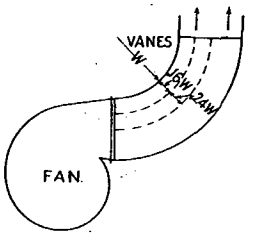


FIG. 17. AIR SPLITTERS INSTALLED IN ELBOW AT FAN DISCHARGE

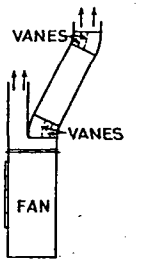


FIG. 18. AIR SPLITTERS IN BRANCH DUCTS AND ELBOWS

quiet operation if proper construction details were always followed. The contractor may be expected to build the ducts by the least expensive methods, and the engineer must anticipate this. For further information on noise reduction, see Chapter 40, General Information.

Details of Duct Construction

If panel construction is used with standing seams or similar reinforcement, and the panels are cross broken to give rigidity, there is less like-

lihood of vibration due to air flow or deflection due to air pressure. Elbows made without splitters and improperly shaped transformation sections produce high local velocities which are the cause of noise in duct work. The use of first-class duct construction with well designed transformation sections and splitters in elbows tends to maintain relatively uniform velocities with decrease in turbulence and in the noise produced.

Figs. 11 to 18 show acceptable construction details for rectangular ducts, elbows, transformation pieces or connections, and air splitters. Other methods are also acceptable, such as the use of angle iron stiffeners for large ducts. Good construction is essential to the elimination of duct noises and for the prevention of a flimsy installation.

Fig. 11 is an isometric view of a duct showing the location of the stiffening seams on the top and side panels. The cross seams should not occur at the same place but should be staggered as indicated. Heating units should be installed as shown in Fig. 13 with the duct connections making an angle of not less than 45 deg, but preferably 60 deg. Fan discharge connections should have a maximum slope of 1 in 7, as indicated in Fig. 15. Whenever a pipe or other obstruction passes through a duct

TABLE 3. RECOMMENDED GAGES FOR RECTANGULAR SHEET METAL DUCT CONSTRUCTION[a]

GAGE	WIDTH OF DUCT	SEAM	REINFORCED SEAM
26	Up to 12 in.		
24	13 in to 30 in.	1	
22	31 in. to 48 in.	1	
22	49 in. to 60 in.	1½	⅛ in. x 1⅜ in.
20	61 in. to 90 in.	1½	⅛ in. x 1⅜ in.

[a]If panels are not cross broken two gages heavier material should be used.

an easement should be placed around the pipe as indicated in Fig. 14. Air splitters should be installed in elbows as shown in Figs. 16 and 17. The recommended gages for rectangular sheet-metal duct construction are given in Table 3.

AIR DISTRIBUTION

Stratification and Diffusion

Air tends to flow parallel with or remain in its particular temperature stratum. If the air supplied by the ventilating system is warmer or cooler than the room air, it will tend to rise or fall. If entering at a fairly high velocity, the velocity will persist for some distance even if contrary to the effect of the temperature difference; if the velocity is high enough a considerable amount of local circulation is induced.

If relatively cool air is introduced through the ceiling of a warm room, there is a tendency for it to drop without much natural diffusion, and likewise warm air introduced near the floor will tend to rise without diffusion if the velocity is low; hence careful attention should be given to the location of air inlets and outlets and the velocity with which air is introduced. Since the effect of introducing air above the room temperature is

radically different from the action when introduced below room temperatures, different treatment is required for cooling systems than for warming.

Downward Air Distribution

The downward system of air distribution which consists of bringing supply air in at the ceiling and taking it away at or near the floor is in common use for auditoriums, theatres, department stores and other large spaces. The natural tendency for heat given off by the occupants to rise and carry with it the products of respiration, makes it impossible to secure proper air distribution by the use of supply openings in the walls or in the floor. Moreover, when cooling is being done the incoming air, even though slightly below the room temperature, produces chilling drafts. The downward system of air distribution often utilizes special devices to effect diffusion of the air in the desired directions and so that it falls uniformly at a low velocity.

Upward Air Distribution

Successful plants are in operation using the upward system of air circulation from hood openings in the floor under each seat, but success with this system is contingent on having a low rate of occupancy so that it is not necessary to use large air volumes or low temperatures.

Location of Inlets and Outlets

For school-rooms, offices and smaller spaces in general, satisfactory locations for the air supply inlet are:

1. Downward discharging grilles in the ceiling.
2. Horizontally discharging diffusers on side of room opposite windows.
3. Upward discharging grilles in the window stools.
4. Upward discharging slots in floor beneath radiators on the outside wall.
5. Upward discharging grilles 3 ft to 4 ft above the floor on outside walls, as with unit ventilators.

The location of exhaust outlets in auditoriums and class rooms vary. With downward distribution mushroom registers in the floor may be used, or side wall registers, or both. In schoolrooms side wall registers connecting with vertical flues are customary, either with gravity or fan exhaust.

If the space has little or no heat loss, the air may be introduced at a temperature very near the room temperature; inlets and outlets may be approximately opposite each other, and the system is likely to be successful whether upward or downward distribution is used, providing the inlet location and air velocities combine to avoid drafts. However, if large glass surfaces or radiators cause disturbance of the air flow, or if there is a considerable amount of heat from the occupants, or if there is a considerable difference between the entering air temperature and the room air temperature, greater care must be taken to insure proper distribution without drafts.

There are no set rules which may be followed implicitly for location of inlets and outlets. It is necessary to keep in mind the nature of the occupancy, the proportions of the space to be ventilated, the heat losses

(or gains in the case of a cooling system), and the effect on air distribution of cold wall and glass surfaces, radiators, lights, and the bodily heat of the occupants.

Uniform Distribution

Where accurate humidity control is required, uniform temperature conditions are very important, because a change in temperature means a change in relative humidity even though the absolute humidity (grains of moisture per pound of air) is constant. For this reason the air must be distributed uniformly, not with respect to floor space, but with respect to the amount of heat to be absorbed in the various portions of the room. The designer of air conditioning systems, particularly for industrial plants, must therefore have fairly exact information as to the distribution and source of heat within the room, or else have means of controlling the temperature or quantity of air supplied to the different sections independently.

In industrial plants the higher duct velocities which are ordinarily employed assist in providing general air movement and uniformity of distribution. The high outlet velocity sets in motion a considerably larger amount of room air. The effectiveness of this action depends on the entering velocity, and where drying processes are involved, high entering velocities are often used for setting in motion large volumes of air and obtaining uniform drying.

Grilles and Registers

The plain lattice grille of cast-iron or pressed steel with from 40 to 60 per cent net clear area is the type generally used in ventilation work, but the recommendations regarding velocities apply also to ornate patterns. Registers are not as generally used in ventilation and air conditioning work as grilles. It has proved more satisfactory and economical to install a damper in the duct leading to the grille. In some instances the deflection caused by the shutters in a register seriously affects distribution.

Where the occupants of the room are close to the registers or grilles, the size should be such that the velocity through them will be from 200 to 400 fpm, depending on the location and kind of installation, as already stated. However, low air velocities induce stratification and where the ceiling height will permit, velocities as high as 800 fpm may be used. The velocity through floor registers should vary between 125 and 175 fpm. Much will depend on the location of grille, the direction of the air flow and the distance it should carry.

MEASUREMENT OF AIR FLOW

The quantity, velocity and pressure of air discharged by a fan or flowing through a duct or grille may be determined by various methods. Those in common use are by Pitot tube, Kata thermometer and anemometer readings, the latter being suitable for low air velocities and being commonly used for measurements at points where the air is not confined in a duct. The use of calibrated nozzles, orifice plates, or Venturi meters are recognized methods, which, however, have little application in connection with ventilation practice.

Pitot Tubes

This usually consists of two tubes, one within the other, which when properly held in the air stream will register the total or impact pressure and the static pressure, respectively. If these tubes are connected to opposite sides of a water column the recorded pressure will be the differential or velocity head. Volume measurements may thus be made in a duct of known area. Pitot tube measurements are preferably used for air velocities exceeding 20 fps. Volumetric determinations from Pitot tube readings must take into account the barometric pressure, temperature and humidity. These factors determine the weight or density of the air.

In general no accurate velocity pressure readings can be taken when the flow of air in ducts is turbulent. To insure accuracy a straight section of duct from 5 to 10 times its own diameter is desirable in order to straighten out the air currents. If it is necessary to take Pitot tube readings in shorter sections of straight duct, the results must be considered subject to some doubt and checked accordingly. For accurate work it is necessary to make a traverse of the duct, dividing its cross section into a number of imaginary equal areas and taking a reading in the center of each, the average of the velocities corresponding to these pressures giving the true velocity in the duct.

Anemometers

These instruments are quite delicate, and when accuracy is required should be frequently calibrated. The ordinary method of taking air velocities over an area is to make a traverse as described in connection with the Pitot tube, the instrument being moved from one section or area to the next at regular intervals so that the total reading is the average velocity of flow for the total elapsed time. The anemometer as usually calibrated reads directly in linear feet. This reading must be divided by the elapsed time in minutes to obtain the velocity in feet per minute.

The following procedure for obtaining anemometer readings is based on research conducted at *Armour Institute of Technology* in cooperation with the A.S.H.V.E. Research Laboratory[b].

Supply Grilles. The surface of the grille should be marked off into a number of equal areas approximately 6 in. square. A 4-in. anemometer should be used and should be held at the center of each section in contact with the grille (or as close as possible), for a period of time sufficient to insure an average reading. In the case of supply grilles, the instrument should always be held with the dial facing the operator. The average of the corrected readings should then be used in the following formula to obtain the flow in cubic feet per minute:

$$cfm = CV\,\frac{A + a}{2} \text{ or } \frac{CVA\,(1 + p)}{2} \qquad (7)$$

where

V = average of corrected anemometer readings in feet per minute.
A = gross area of grille, square feet.
a = net free area of grille, square feet.

[b]Measurement of Flow of Air through Registers and Grilles, by L. E. Davies (*Heating, Piping and Air Conditioning*, January, 1930, and April, 1931).

p = percentage of free area of grille expressed as a decimal.
C = a coefficient that varies with the velocity from grille and may vary slightly with type of grille. (See Table 4).

As the velocity increases, C approaches a constant value, and the highest value shown can be used for all higher velocities with very slight error.

Particular care should be exercised in the case of long, narrow grilles. The nature of the approach sometimes results in a narrow strip along the top or bottom of the grille through which no air will be flowing. This may be detected by holding the anemometer completely out of the air stream and then moving it slowly inward over the grille until the vanes just start to move. The distance which the vanes extend over the grille opening at this moment will indicate the width of the dead strip. Only

TABLE 4. VALUES OF C FOR VARIOUS AIR VELOCITIES[a]

AVERAGE INDICATED VELOCITY, fpm	SUPPLY GRILLES
150	0.952
200	0.957
300	0.967
400	0.977
500	0.985
600	0.992
700	0.998
800	1.000
Factors for average use.....	low velocity.....0.97
	high velocity.....1.00

[a]These coefficients refer to thin lattice work grilles without louvers or dampers.

the remaining portion of the grille should be considered in making the calculations for gross and free area.

Care should also be taken to use the correct free area of the grille, as this is equally as important as the air measurement. The results of tests on grilles of ornamental plaster design are not in as close agreement as those given in Table 4 for thin lattice work grilles without louvers or dampers. It is difficult to measure the free area of ornamental grilles, because the material is much thicker, and since parts of the surface are raised above the general level it is difficult to keep the anemometer in contact. Until tests now under way afford some improved method, the use of an anemometer with ornamental plaster grilles for measurement of air supply is not recommended.

Exhaust Grilles. The surface of the grille should be marked off and readings taken in the same manner as with supply grilles, except that the instrument should be held with the dial facing the grille, and in contact with it. The traverse should be taken at a uniform rate, allowing sufficient time in each space to minimize the percentage of error. In the case of exhaust grilles it is found that the formula

$$cfm = KVA \quad (8)$$

gives more accurate results, *in which*

V = average indicated velocity obtained by the anemometer traverse in contact with grille.
A = gross area of grille, square feet.
K = coefficient determined by experiment.

The value of K in Formula 8 ranges from 0.8 for cast-iron plain lattice design exhaust grilles at a velocity of 150 fpm to 0.82 at 700 fpm. For thin iron grilles of conventional ornamental design, the value of K varies from 0.75 at 150 fpm to 0.834 at 700 fpm. The use of a constant 0.8 would therefore introduce an error which is very slight. It has also been found in the experiments at *Armour Institute of Technology* that tests of exhaust grilles of ornamental plaster design are in much closer agreement than is the case with supply grilles, and the use of the same formula recommended for exhaust grilles of plain lattice design will give results which, while not so accurate, are subject to errors varying from + 11 per cent to − 7 per cent. Formula 8 has the advantage of making it unnecessary to measure the free area, which in the case of grilles of ornamental design is difficult to do.

The flow of air through registers and grilles is of considerable importance, being frequently the only convenient method of measuring the volume of supply air to a room. While duct measurements, if available, are more dependable, grille measurements provide a fairly accurate method, if care is taken in the technique of using the anemometer.

Kata-Thermometer

The Kata-thermometer which was invented by Dr. Leonard Hill of England, can be used advantageously as an anemometer provided the walls and surrounding objects are at or near the room temperature. Especially at low velocities it constitutes a useful instrument for readily detecting drafts.

The instrument is essentially an alcohol thermometer with a bulb approximately ⅝ in. in diameter and ½ in. long with a stem 8 in. long reading from 100 to 95 F, graduated to tenths of a degree. To take readings the bulb is heated in water until the alcohol expands and rises into the top reservoir. It is then thoroughly dried and all traces of moisture are removed. The time in seconds required for the liquid to fall from 100 F to 95 F is recorded with a stop watch and this time is a measure of the rate of cooling.

The dry Kata gives the cooling power by radiation and convection. The wet Kata, which has a cotton lisle wick fitted snugly around the bulb, gives the cooling power by radiation, convection and evaporation. For constant velocities the time of cooling of the dry Kata is a function of the dry-bulb temperature alone, while that of the wet Kata is a function of the wet-bulb temperature regardless of the dry-bulb temperature or the relative humidity.

Due to the comparatively brief time of fall of the wet Kata thermometer, the dry Kata thermometer is far more accurate for measuring air

motion since any probable error in recording the time of fall will only amount to a small fraction of the total period. To calculate the air movement, obtain the dry Kata cooling power (H) in millicalories per second by dividing the Kata factor (F) engraved on the stem by the average time of cooling in seconds. The dry Kata cooling power is then divided by the difference between 36.5 C and the dry-bulb air temperature (Θ) and the velocity in meters per second (V) determined from the following equations:

For velocities above one meter per second

$$\frac{H}{\Theta} = 0.13 + 0.47\sqrt{V} \qquad (9)$$

For velocities below one meter per second

$$\frac{H}{\Theta} = 0.20 + 0.40\sqrt{V} \qquad (10)$$

Chapter 33

AIR CLEANING DEVICES

Requirements of an Air Cleaner; Types of Air Cleaners; Air Washers; Viscous Cell Filters; Viscous Automatic Filters; Dry Air Filters; Dust Removal Efficiency; Recommendations for Air Filter Installations.

EFFICIENT air cleaning devices serve to eliminate air borne impurities which are detrimental to human comfort and well-being and cause extensive property damage. Impurities of the air may be classified as dusts, fumes and smoke.

Dusts are particles which are large and heavy enough to fall with increasing rapidity, due to gravity, in still air. For instance, particles of flying sand or grit, such as are blown on a windy day, the average diameter of which is approximately 0.01 cm (100 microns), may be called dust. The great bulk of harmful impurities in the atmosphere belongs to the class of dusts which include products of combustion such as flue dust, soot and carbon; minerals such as silica dust and cement dust; organic dusts such as decayed animal and vegetable matter, bacteria. Under organic dust might also be included pollens and tree dusts, which are today regarded as causitive agents in hay fever and similar allergic disorders. The size of some of the pollens which are a most frequent cause of these disorders are:

Ragweeds	18 to 24 microns diam.
Timothy Grass, Johnson Grass, etc.	40 to 50 microns diam.
Tree dusts, such as Maple and Oak	36 to 52 microns diam.

Fumes are smaller particles which fall with constant, rather than with increasing, velocity, due to gravity, in still air. The solid particles from atmospheric fog, for instance, are called fumes and have an average diameter of about 0.0014 cm (14 microns).

Smokes are particles which do not settle at all in still air, which diffuse constantly, and which are actuated by the Brownian motion, rather than by gravity. An example of this type would be certain smokes, the average diameter of the particles of which is about 0.0000015 cm (0.015 micron).

REQUIREMENTS OF AN AIR CLEANER

The first attempt at air cleaning for general ventilation work probably was by the use of dry screens. Since ordinary Portland cement passes a screen having 100 mesh to the inch, it is apparent that much dust may pass the finest screen. When a fine screen is moistened, not only the dirt ceases to pass but also the air passages clog so that the filter becomes

ineffective. Fine cloth filters are very effective, except that they also clog rapidly and soon become impervious to air. These considerations led many years ago to the development of the air-washer types of air cleaners which use water. With the advent of the automobile and the increased industrial activities of city life, the character of air impurities changed from one which was soluble in water to soot, carbons, etc., which are almost totally unaffected by water. To meet these conditions various types of viscous and dry filters were developed.

To fulfill the essential requirements of clean air, an air cleaner should:

1. Be efficient in the removal of harmful and objectionable impurities in the air, such as dust, dirt, pollens, bacteria, etc;
2. Be efficient over a considerable range of air velocities;
3. Have a low frictional resistance to air flow;
4. Have a large dust-holding capacity without excessive increase of resistance or have ability to operate so as automatically to keep the resistance constant;
5. Be easy to clean and handle or clean itself automatically; and
6. Leave the air passing through the cleaner, free from entrained moisture or charging liquids used in the cleaner.

Air cleaners are rated as follows:

1. Capacity in cubic feet of air handled per minute.
2. Resistance in inches of water at rated capacity.
3. Percentage of dust removal at rated capacity.

TYPES OF AIR CLEANERS

Air cleaners may be classified as follows:

1. According to principle of air cleaning.
   - a. Air washers.
   - b. Viscous air filters.
     - (1) Unit type.
     - (2) Automatic type.
   - c. Dry air filters.
2. According to application.
   - a. For central fan systems of ventilation and air conditioning. Filters of the automatic or semi-automatic type are usually recommended and are installed in a central plenum chamber.
   - b. For unit ventilators. Filters of viscous unit or dry type; installed at inlet of individual units.
   - c. For window installations. Self-contained units consisting of fan and filter, usually dry type; adapted to be placed in the ordinary window.
   - d. For warm air furnaces. Unit type viscous or dry filters placed in small plenum chamber of warm air house heating systems.
   - e. For compressor and diesel engines. Unit type viscous or dry filters, installed at air intake of compressors and diesel engines.
   - f. For compressed air lines. Unit type viscous or dry filters.

VISCOUS CELL FILTERS

Viscous-coated air filters are distinguished from air washers in that they clean the air without the use of water. Thus the temperature and

moisture content of the air are not changed by passing through a viscous filter.

The principle of air cleaning used in these filters is that of *adhesive impingement.* Dust and dirt in the air, especially soot and carbons, are trapped and retained by successive impingements on oil coated surfaces. While the arrangement of filtering media and the kind of materials used are almost unlimited, there are certain rather definite requirements for a practical commercial filter.

In order to secure maximum efficiency it is necessary to divide the air into innumerable fine streams; the more intimately and freely the air is brought into contact with the viscous-coated media the better the cleaning will be. As the dirt and dust particles are leached out of the air and collected on the adhesive-coated surfaces, additional supplies of viscous liquid are required in order to bind further layers of dirt. For this reason the filter medium in *unit filters* is usually designed to hold, somewhere within the cell, additional supplies of viscous liquid, capable of distribution by capillary attraction.

Investigations in this country and abroad demonstrate that the first impingement of dust laden air on a viscous coated surface removes about 60 per cent of the dust, the next impingement takes 60 per cent of what then remains—that is, 24 per cent—the next impingement removes 9.6 per cent, etc. This tendency to eliminate progressively smaller amounts of dust at each impingement, even though finer dust particles are caught at each successive impingement, has led to progressively packed filter media in practically all unit filters. Such an arrangement provides relatively large spaces for the collection of dirt in the front part of the filter, where the bulk of solids is taken out, without undue increase in resistance, while at the back of the filter the openings are smaller and finer dust particles are removed.

The binding liquid used with viscous filters should have the following properties:

1. Its surface tension should be such as to produce a homogeneous film-like coating on the filter medium.
2. The viscosity should vary only slightly with normal changes of temperature.
3. It should be germicidal in its action to prevent the development of mold spores, bacteria, etc., on the filter media.
4. The liquid should flow freely at low temperatures.
5. Evaporation should not exceed 1 per cent.
6. It should be fireproof.
7. It should be odorless.

The viscous-cell filter takes its name from the manner in which the filter medium is subdivided into small units to facilitate easy handling. Each unit consists of a frame and interchangeable cells. These cells fit into the frame and may be locked in place, a felt gasket assuring airtight contact at all points. An installation is built up of the required number of units, arranged in the form of a wall between the source of dusty air and the supply fan.

The resistance of a unit filter of the adhesive-impingement type depends upon the velocity at which the air is handled and the condition of the unit, that is, whether it is clean or dirty. The resistance of a commercial

unit air filter varies from 1/16 in. to 1/4 in. water gage when clean, depending upon its design, at the rated capacity of 800 cfm. (See Fig. 1). As dust accumulates in any filter of this type, the resistance rises as shown in Fig. 2.

The efficiency of the unit is usually highest after it has accumulated a certain portion of its maximum load of dirt. The dust collected in the cell acts as an efficient medium for the further collection of solids from the air.

In order to maintain a practically constant resistance and air volume a certain number of cells is removed at regular intervals and the dust deposit is cleaned off. The cells are then recharged with the proper viscous liquid and put back in service. By thus progressively cleaning a predetermined number of cells every week—or every month as the case may be—the resistance and consequent air volume can be held at any desired figure.

Under actual operating conditions, one pound of dust represents about

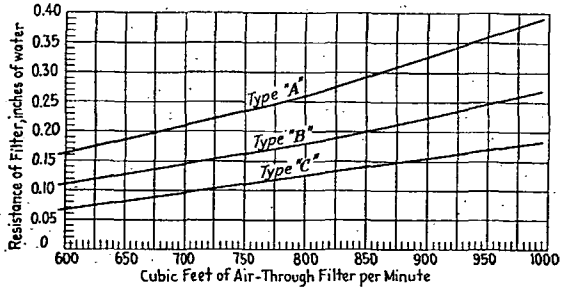


FIG. 1. RESISTANCE TO AIR-FLOW OF A TYPICAL UNIT AIR FILTER

eight weeks of normal service. The resistance of the filter installation shown in Fig. 2, could be held at any point between 0.15 in., the resistance of the clean filter, and 0.27 in., the resistance after accumulating one pound of dust, by cleaning a sufficient number of cells each week to maintain the desired average.

To make sure of proper periodic cleaning of the units the installation of a standard draft gage is recommended. Proper washing, draining and recharging equipment should be installed as convenient to each group of cell filters as possible.

VISCOUS AUTOMATIC FILTERS

The principle of air cleaning used in the viscous automatic filters is the same as in the cell filters. The removal of the accumulated dust, however, is done automatically instead of by hand. The automatic cleaning and recoating of these filters is based on the principle that the viscous fluid itself will perform the cleaning function, thereby eliminating a separate washing agent. The dust collected by the filter thus is deposited finally in the bottom of the viscous fluid reservoir from where it may be removed by different methods, depending on the design of the filter.

There are three general types of automatic filters. They are differentiated from each other according to the process of self-cleaning and renewing of the viscous coating used by each type, as follows:

1. The filter medium has the form of an endless curtain suspended vertically, with its lower portion submerged in a viscous fluid reservoir. The curtain rotates slowly through this bath, thus performing the cleaning and recoating of the filter medium.

2. The filter screen is arranged in the form of shelves or cylinders and the viscous fluid is flushed through all parts of the medium in a direction opposite to the air flow.

3. The filter medium is arranged vertically and is stationary. The viscous fluid is flushed from above over the medium, while the air flow is stopped.

The washing and renewing process in automatic filters usually is intermittent. It is accomplished by an electric motor or by other motive power and is controlled by manual or by automatic timing devices. The operating cycle is of a pre-determined frequency and should be so timed as to insure a constant static pressure drop across the filter. The customary

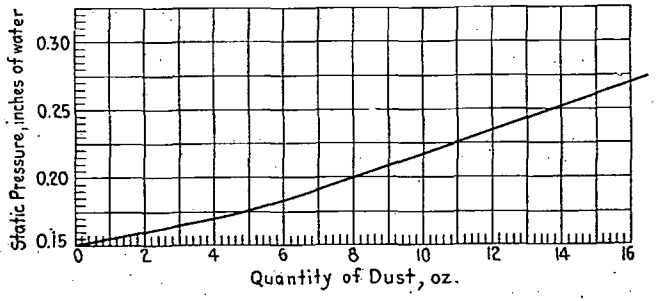


FIG. 2. CHART SHOWING CHANGE IN RESISTANCE DUE TO DUST ACCUMULATION

resistance to air flow is 3/8 in. water gage at an air velocity of 500 fpm, measured at the filter entrance. Automatic viscous filters are made up in units which are delivered either fully assembled or in parts to be assembled at the point of installation.

DRY AIR FILTERS

Dry-air filters, in which dust is impinged upon or filtered through screens made of felt, cloth, cellulose, etc. are available in various types. These filters require no adhesive liquid, but depend on the straining or screening action of the filtering medium.

Dry-air filters are reconditioned by vacuum cleaning or by vibrating the filter sheets. Practically all of the various types of dry filter media have a definite length of useful life depending upon the nature and strength of the texture. Dry filters, as a class, therefore, differ from the all-metal, viscous type in that their filtering media must be replaced periodically.

Because of the close texture of the filtering media used in most of the dry filters, the surface velocity, or velocity of the air entering the media, is considerably lower than in the viscous types and ranges between

10 and 50 fpm, depending on the nature and texture of the sheets. The initial resistance, or the resistance when the filter media are clean, is likewise somewhat lower. The usual practice is to allow the dirt to accumulate on the filtering surface until the resistance has reached a pre-determined maximum. At this point the load of dirt is removed by some mechanical means and the filter thereby reconditioned. A constant resistance such as is obtained with the automatic viscous filters cannot usually be maintained with dry filters. However, an *average* operating resistance results, provided the filter is properly maintained and reconditioned. Dry-air filters usually are made up in units which are assembled in groups in a manner similar to viscous cell filters.

AIR WASHERS

Information on air washers will be found in Chapter 30, Air Conditioning Apparatus.

DUST REMOVAL EFFICIENCY

The efficiency in dust removal of air-cleaning devices can be determined by means of tests made with air at stated capacities and with dust of definite quantity and quality. There are a number of excellent commercial instruments available for this purpose. The percentage of dust removal for commercial air-cleaning devices should range between 80 and 98 per cent, and the minimum removal under such conditions should be specified and guaranteed by the manufacturer.

RECOMMENDATIONS FOR AIR FILTER INSTALLATIONS

1. An air filter should be of ample size for the amount of air it is called upon to handle. An overload of 10 per cent to 15 per cent is regarded as the maximum allowable. When air volume is subject to increase, a larger filter should be installed.
2. Duct connections to and from the filter should change size or shape gradually to insure even air distribution over the entire filter area.
3. Filters should be installed so that the face area is at right angles to the air flow to avoid eddy currents and dead air corners.
4. If space is limited and uniform air distribution difficult to obtain, baffles or diffusers should be provided to distribute air flow equally over the filter area.
5. Sufficient space should be provided in front as well as behind the filter to make it accessible for inspection and service. A distance of two feet may be regarded as the minimum.
6. Access doors of convenient size should be provided in the sheet metal connections leading to and from the filters.
7. All doors on the clean air side should be lined with felt to prevent infiltration of unclean air. All connections and seams of the sheet metal ducts on the clean air side should be as airtight as possible.
8. Electric lights should be installed in the chamber in front of and behind the air filter.
9. Air washers should, whenever possible, be installed between the tempering and heating coils to protect them from extreme cold in winter time.
10. Filters installed close to air inlet should be protected from the weather by suitable louvers, in front of which a large mesh wire screen should be provided.

Chapter 34

FANS AND MOTIVE POWER

Classification of Fans; Characteristic Curves; Selection of Fans; Control; Designation; Arrangement of Drive; Motive Power; Electric Motors.

THE term *fan* is usually applied to equipment used for the purpose of creating air flow by any means, except positive displacement. Compressors or rotary blowers are used where positive displacement is required. In general, fans of all types can be made to perform the same duty, although mechanical difficulties, noise or lack of efficiency may limit the use to one or the other type as outlined under the heading, Selection of Fans.

CLASSIFICATION OF FANS

Fans may be classified according to the direction of air flow as follows:

1. Axial flow (flow parallel with axis).
   a. Disc type.
   b. Propeller type.
2. Radial flow (flow parallel with radius of rotation).
   a. Centrifugal type.
   b. Kinetic type.

Radial-flow fans include steel plate fans, pressure blowers, etc., while the kinetic type includes all the so-called multiblade fans. All the foregoing types have variations which may be obtained by slight modification of the proportions or change in the angularity of the floats. The angularity of the floats determines the speed characteristic of a centrifugal type of fan, the forward curve corresponding to slow speed and the backward curve to high speed operating characteristics.

CHARACTERISTIC CURVES

Characteristic curves of fans are determined by tests performed in accordance with the Standard Code for the Testing of Centrifugal and Disc Fans[1] as adopted by the AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS and the *National Association of Fan Manufacturers*. The results of tests are plotted in different ways; the abscissae may be the ratio of delivery assuming full open discharge as 100 per cent and the ordinates may be static pressure, dynamic pressure, horsepower

[1] A.S.H.V.E. TRANSACTIONS, Vol. 29, 1923 and revised June, 1931.

and efficiency. The illustrations in this chapter are essentially of this type.

For engineering calculations it is found convenient to use the ratio of opening as abscissae and to plot the manometric effects as ordinates. Fig. 1 shows typical curves. In addition to the pressure curves it is customary to plot ratio of horsepower and efficiencies.

Two of the curves are of immediate value to an observer. The *SP/PVP* curve is an index of speed characteristics. The higher the value, the

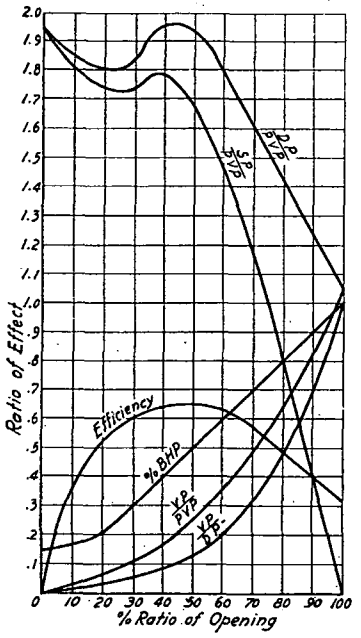


FIG. 1. TYPICAL CURVES SHOWING RELATION OF RATIO OF OPENING TO RATIO OF EFFECT

lower the required operating speed. The brake horsepower percentage curve is an index of variation of power requirement under varying ratios of openings. When the curve is flat, it is referred to as a *self-limiting power characteristic*. The efficiency has the same significance as it has on other mechanical appliances.

Disc and propeller fan characteristics are shown in Fig. 2. These fans, when properly designed, have a satisfactory efficiency at low resistance, comparing favorably in this respect with forward curved blade fans. They are low in cost and are economical in operation. Although this type of fan can operate against considerable resistance, the power increases rapidly and the noise often becomes objectionable, so that they do not always compare favorably with centrifugal fans for such service.

The curves (Fig. 2) show the rapid reduction in capacity and increase

in power as the resistance increases. The low efficiency when overcoming heavy resistance is due to the low speed of the blades near the hub as compared to the relatively high peripheral or tip speed. The air driven by the blade area near the rim can pass back through the less-effective blade area at the hub more easily than it can overcome the duct resistance.

The straight blade (*paddlewheel*) or partial backward curved blade type of fan is practically obsolete for ventilation. Its use is largely confined to such applications as conveyors for material, or for gases containing foreign material, fumes and vapors. The open construction and the few large flat blades of these wheels render them resistant to corrosion and prevent material from collecting on the blades. Fig. 3 shows the characteristic curves. This type of fan has a good efficiency, but the horsepower steadily increases as the static pressure falls off, which requires that the motor be selected with a moderate reserve in horsepower to take care of possible error in calculation of duct resistance.

The *forward curved multiblade fan* is the type most commonly used in heating and ventilating work, as it has a low peripheral speed, a large capacity and is quiet in operation. The point of maximum efficiency for this fan occurs near the point of maximum static pressure. The static pressure drops consistently from the point of maximum efficiency to full open operation. Fig. 4 shows that this type of fan will have a high and low delivery for a given static pressure at constant speed. The power curve rises continually from low to peak capacity, but if reasonable care is exercised in figuring resistance there is no danger of overloading the motor.

Multiblade fans with a forward angle at the heel and a slight backward angle at the tip of the blade have been used for some years in heating and ventilating work with entire satisfaction as to quiet operation. The speed is somewhat higher than that of the forward curved blade, but considerably lower than the regular backward curved types. (See Fig. 5).

The radial tip blade type of fan has an efficiency slightly higher than the forward curved blade type of fan. The horsepower curve indicates that a large reserve in horsepower of the motor is required as with the forward curved blade type of fan. Fig. 6 shows the characteristic curves of this type of fan.

The outstanding characteristics of the *full backward curve multiblade type fan* are the steep pressure curves, the non-overloading power curve, and the high speed. (See Fig. 7). This fan operates at a peripheral speed of approximately 250 per cent of the forward curve multiblade type for like results. The pressure curves begin to drop at very low capacity and continue to fall rapidly to full outlet opening. The steep pressure curves tend to produce constant capacity under changing pressures. Where wide fluctuations occur, the use of this type of fan is desirable to prevent overloading of motors. The maximum power requirement occurs at about the maximum efficiency. Consequently a motor selected to carry the load at this point will be of sufficient capacity to drive the fan over its full range of capacities at a given speed. The high speed of this type makes it adaptable for direct connected electric motor drives. The high speed necessitates heavier construction, and more operating attention and

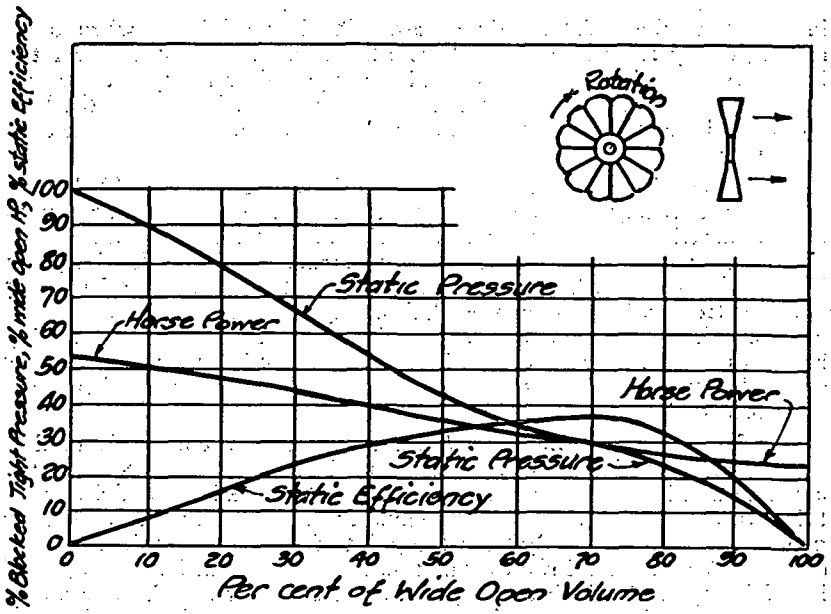


FIG. 2. OPERATING CHARACTERISTICS OF A DISC OR PROPELLER FAN

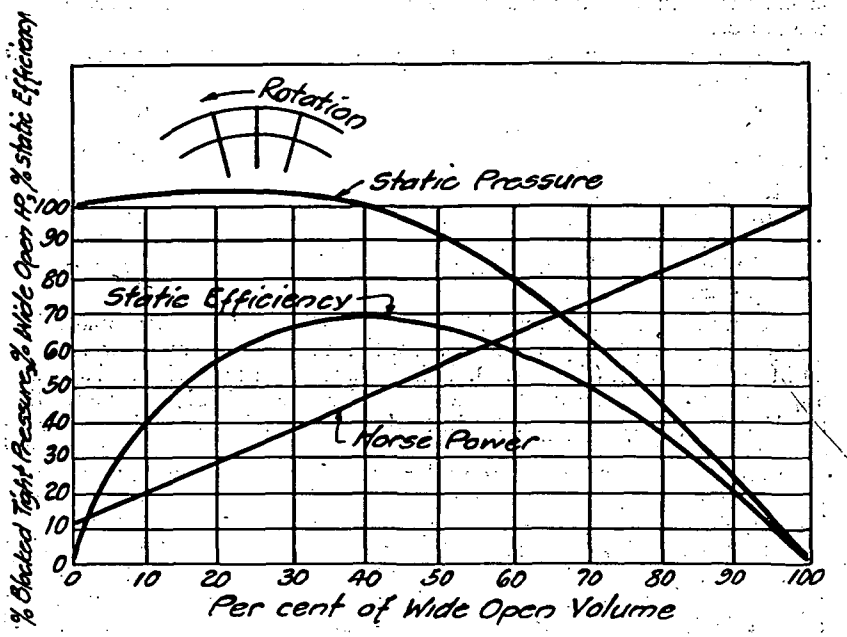


FIG. 3. OPERATING CHARACTERISTICS OF A FAN WITH STRAIGHT BLADES

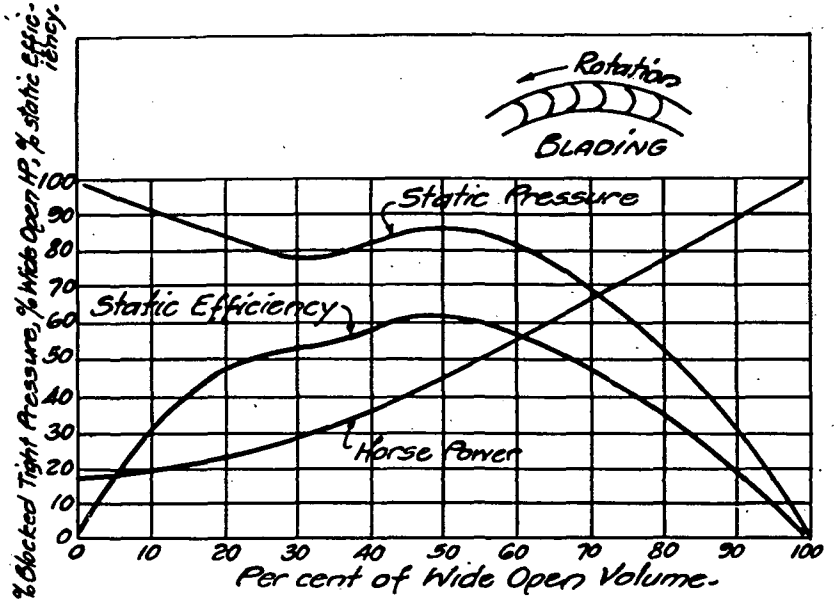


FIG. 4. OPERATING CHARACTERISTICS OF A FAN WITH BLADES CURVED FORWARD

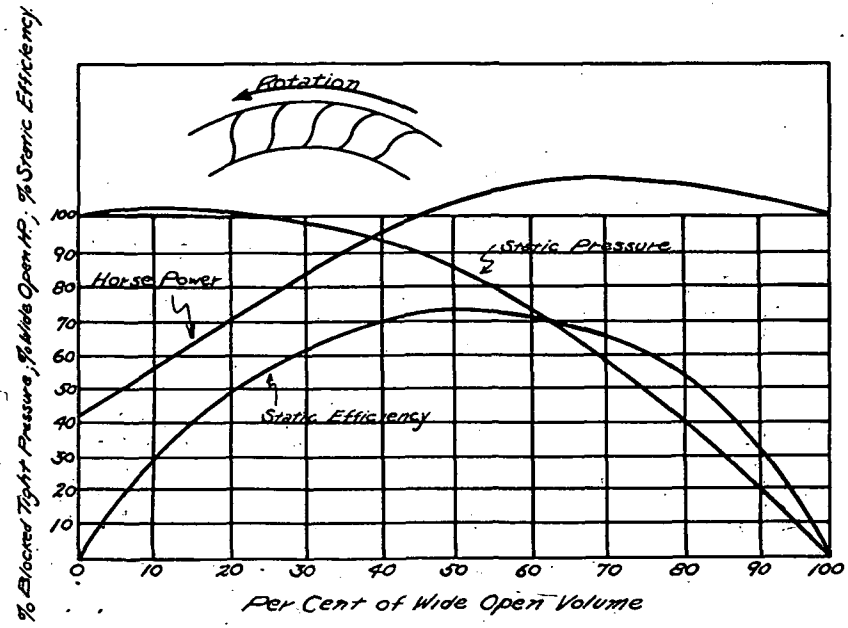


FIG. 5. OPERATING CHARACTERISTICS OF A FAN WITH A DOUBLE CURVED BLADE

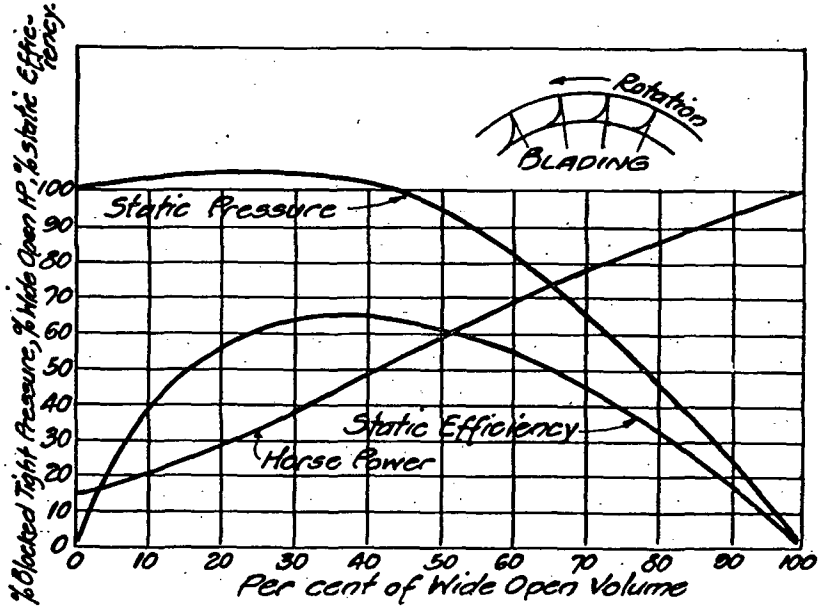


FIG. 6. OPERATING CHARACTERISTICS OF A FAN WITH RADIAL TIE BLADES

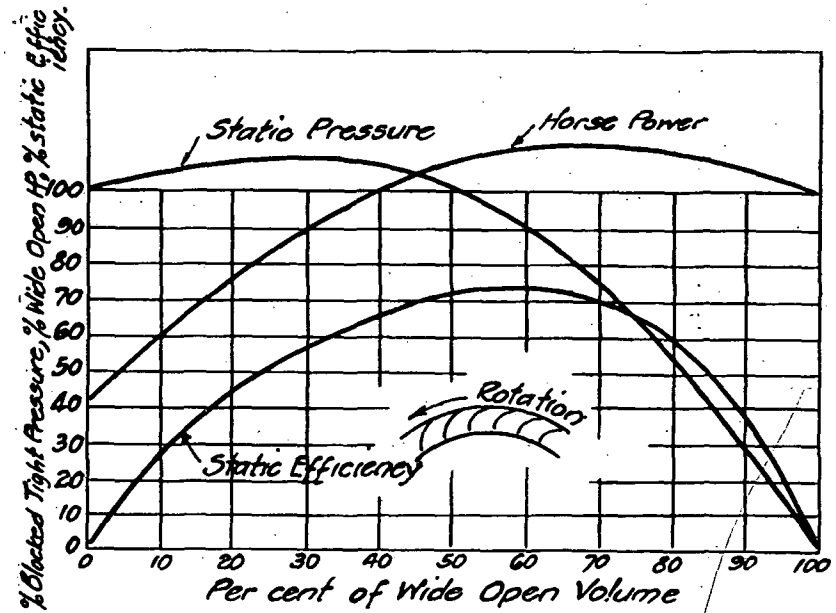


FIG. 7. OPERATING CHARACTERISTICS OF A FAN WITH FULL BACKWARD CURVED BLADES

service is required than for the other type multiblade fans. The dimensional bulk for a given duty often is 150 to 200 per cent that of a forward curve multiblade type fan.

Typical fan performance curves indicating static pressure, static efficiency and horsepower are shown in Fig. 8.

SELECTION OF FANS

Fans for Ventilation

The following information is required to select the proper type of fan:

1. Cubic feet of air per minute to be moved.
2. Static pressure required to move the air through the system.
3. Type of motive power available.
4. Whether fans are to operate singly or in parallel on any one duct.
5. What degree of noise is permissible.
6. Nature of the load, such as variable air quantities or pressures.

Knowing the requirements of the system, the main points to be considered for fan selection are:

1. Efficiency.
2. Reliability of operation.
3. Size and weight.
4. Speed.
5. Noise.
6. Cost.

In order to facilitate the choice of apparatus, the various fan manufacturers supply fan tables or curves which usually show the following factors for each size of fan operating against a wide range of static pressures:

1. Volume of air in cubic feet per minute, (68 F, 50 per cent relative humidity, 0.07488 lb per cubic foot).
2. Outlet velocity.
3. Revolutions per minute.
4. Brake horsepower.
5. Tip or peripheral speed.
6. Static pressure.

The most efficient operating point of the fan is usually shown by either bold or italicized figures in the capacity tables.

Two important factors in selecting fans for ventilating systems are efficiency (which affects the cost of operation) and noise. First cost and space available are secondary. The fans should be selected to operate at maximum efficiency without noise. Noise in a ventilating system is irritating and a cause for complaint. Fans must be selected of proper size in order to reduce it to a minimum. Noise may be caused by other factors than the fan, namely, high velocity in the duct work, unsatisfactory location of the fan room, improper construction of floors and walls and poor installation. Where noise is chargeable directly to the fan, it is caused either by excessive peripheral speeds, or the fan is of insufficient size. It should be remembered, however, that the tip speed required for

a specified capacity and pressure varies with the type of blade, and a tip speed that is excessive for the forward curved type is not necessarily so for the backward or slightly backward type. A noisy fan usually is one which is operated at a point considerably beyond maximum efficiency.

For a given static pressure there is a corresponding outlet velocity and peripheral speed wherein maximum efficiency is obtained. If a fan be selected to operate at this point, the cost of operation and the noise can be held within control.

To aid in selecting fans as near as possible to the point of maximum efficiency, there are listed for each static pressure, corresponding outlet velocities and tip speeds which will give satisfactory results. The proper

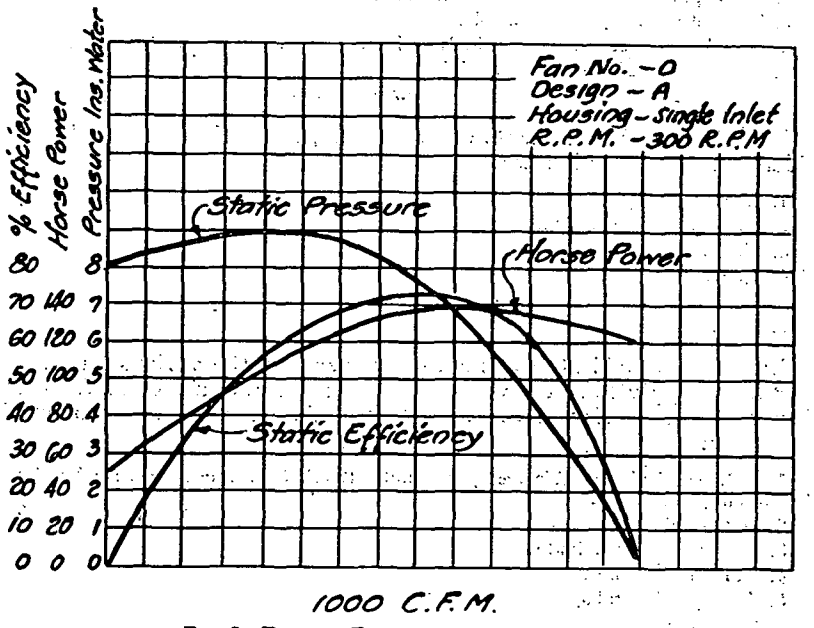


FIG. 8. TYPICAL FAN PERFORMANCE CURVE

tip speed for a given static pressure varies with design of wheel and number of blades or vanes in wheel.

Lower outlet velocities than listed in Table 1 may be used, but care must be exercised when fans of the forward curved type are used to avoid selecting a fan for operation below its useful range.

In exhaust ventilating systems where the air column moves toward the fan, noise due to the higher tip speeds and outlet velocities, will not be so readily transmitted back through the air column to the building. Therefore higher outlet velocities may be used, but this will be at the expense of increased horsepower.

Amply large fans should always be used for both exhaust and supply systems, as there may be and usually is leakage despite the most careful

workmanship, necessitating the delivery of more air at the fans than is exhausted from or supplied through the openings in the various rooms.

Long runs of distributing ducts, heaters, air washers, etc., usually are parts of any ventilating system where high static pressures are needed. Under such conditions it is practicable to select fans with higher outlet velocities and peripheral speeds since the duct system itself will tend to muffle objectionable air sounds.

Fans with low outlet velocities should be used regardless of the static pressure, if connected with short ducts to register faces, on account of noise.

The connection of a fan to a metallic duct system should be made by a canvas or similar flexible material so as to prevent the transmission of fan vibration or noises. Where fans are connected to concrete ducts such as are used in the ventilation of vehicular tunnels, the connection is made direct.

Fans for Drying

Both disc and centrifugal types of fans are used for drying work. Disc fans are well adapted to the removal of moisture-laden air when operating against low resistance and when handling air at low temperatures.

Motors on these fans usually are of the fully-enclosed moisture-proof types so that saturated air or air containing foreign material will not injure the motors.

Unit heaters employing disc or propeller type fans are widely used in the drying field. In drying, disc or propeller fans may be used where not too much duct work is required and where air is to be delivered against pressure, since the noise developed from the high peripheral speed of these fans is not ordinarily objectionable in process work of this nature.

Centrifugal fans or blowers of the multiblade type generally are selected to supply air for drying, as they are capable of delivering large volumes against all pressures with a minimum amount of power.

Belt driven fans usually are to be preferred to direct-connected fans

TABLE 1. GOOD OPERATING VELOCITIES AND TIP SPEEDS FOR FORWARD CURVED MULTIBLADE VENTILATING FANS

Static Pressure In Inches of Water	Outlet Velocity Feet per Minute	Tip Speed Feet per Minute
¼	1000–1100	1520–1700
⅜	1000–1100	1760–1900
½	1000–1200	1970–2150
⅝	1100–1300	2225–2450
¾	1200–1400	2480–2700
⅞	1300–1600	2660–2910
1	1500–1800	2820–3120
1¼	1600–1900	3162–3450
1½	1800–2100	3480–3810
1¾	1900–2200	3760–4205
2	2000–2400	4000–4500
2¼	2200–2600	4250–4740
2½	2300–2600	4475–4970
3	2500–2800	4900–5365

as they make a more flexible and economical unit. Wherever drying is done throughout the year and where air requirements change as the drying conditions change, the drying can be speeded up or reduced through control of the fan capacity. This may be done by changing the fan speed or by varying the outlet area with dampers.

Due to the low speeds of forward curved multiblade or paddle wheel type fans, these can be direct-connected to reciprocating steam engines and the exhaust steam may be used in the heating apparatus. In selecting engine driven fans for drying processes, where a large quantity of exhaust steam is used in the heaters, a smaller fan and greater power consumption may be used, because power economy is not essential under this condition.

Where static pressure in a dryer varies, and where battery operation is required, the full backward curved fan is recommended. This type is well adapted for direct-connected motors of the higher speeds.

Fans for Dust Collecting and Conveying

The application of fans or exhausters for handling refuse, dust, fumes, etc., generated by machine equipment is covered in Chapter 25. Information is given regarding the methods for determining air quantities, velocity required for carrying various materials and method of determining maintained resistance or total static pressure at which the fan is to operate.

The selection of a proper size fan or exhauster is at times governed by the future requirements of the plant. In many instances, additional future capacity is anticipated and should be provided for.

Having determined the necessary volume of air and the maintained resistance or static pressure required, the proper size fan may be selected from the fan manufacturers' performance charts or capacity tables. The fan chosen should be the size that will provide the required ultimate quantities with the minimum power consumption.

FAN CONTROL

Some method of volume control of fans usually is desirable. This may be done by varying the peripheral velocity, or by interposing resistance, as by throttling-dampers. Both methods, since they reduce the volume of air, reduce the power required. In many installations adjustments of volume are desirable during varying hours of the day. In others an increased supply of air in summer over that needed for winter is demanded. Experience is required in deciding whether speed-control or damper-control shall be used for specific cases. Where noise is a factor, it may be exceedingly desirable to reduce the speed at times, while on the other hand, any fan which has its normal speed reduced as much as 50 per cent without *change in resistance* will move only 50 per cent of the air.

DESIGNATION OF FANS[2]

This method of designation will apply to all centrifugal fans, single or double width, and single or double inlet. Do not use the word "hand," but specify "clockwise" or "counter-clockwise."

[2]Recommendations adopted by the *National Association of Fan Manufacturers.*

Facing the driving side of the fan, blower or blast wheel, if the proper direction of rotation is clockwise, the fan, blower or blast wheel will be designated as *clockwise.* If the proper direction of rotation is counter-clockwise, the designation will be *counter-clockwise.* (The driving side of a single inlet fan is considered to be the side opposite the inlet regardless of the actual location of the drive).

The discharge of a fan will be determined by the direction of the line of air discharge and its relation to the fan shaft, as follows:

Bottom Horizontal: If the line of air discharge is horizontal and below the shaft.

Top Horizontal: If the line of air discharge is horizontal and above the shaft.

Up Blast: If the line of air discharge is vertically up.

Down Blast: If the line of air discharge is vertically down.

All intermediate discharges will be indicated as angular discharge as follows:

Either top or bottom angular up discharge or top or bottom angular down discharge, the smallest angle made by the line of air discharge with the horizontal being specified.

ARRANGEMENT OF DRIVE

In order to prevent misunderstandings, which cause delays and losses, the arrangements of fan drives adopted by the *National Association of Fan Manufacturers* and indicated in Fig. 9 are suggested.

GENERAL SUGGESTIONS

Single inlet, single width fans should be selected wherever possible. If double width, double inlet fans are selected, care must be taken that both inlets have the same free area. If one inlet of a *forward curved blade* type of fan is obstructed more than the other, the fan will not operate properly, as one half of the wheel will deliver more air than the other half. The *backward curved* and *double curved* type with backward tip operate satisfactorily in double or in parallel operation.

MOTIVE POWER

It is no easy matter to predetermine the exact resistance to be encountered by a fan, or having determined this resistance, to insure that no changes in construction or operation shall ensue which may increase air resistance, thus requiring more fan speed and power to deliver the required volume, or which may reduce air resistance, thus causing delivery of more air and a consequent increase of power even at constant speed.

It is recommended, therefore, for centrifugal type fans that the rated power to be supplied shall exceed the rated fan power by a liberal margin, when *forward curved* types are used. When *backward* or *double curved* blade types are used, motors with ratings very close to that of the fan horsepower can be employed.

Justification for liberal power provision exists also in the possibility of varying demand due to changes in ventilation requirements, intensity of occupation, weather conditions, etc.

The motive power of fans should be determined in accordance with the Standard Code for the Testing of Centrifugal and Disc Fans, as adopted by the AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS and the *National Association of Fan Manufacturers.*

Fans may be driven by electric motors, steam engines (either horizontal or vertical), gasoline or oil engines and turbines, but as previously stated, the drive most commonly used is the electric motor.

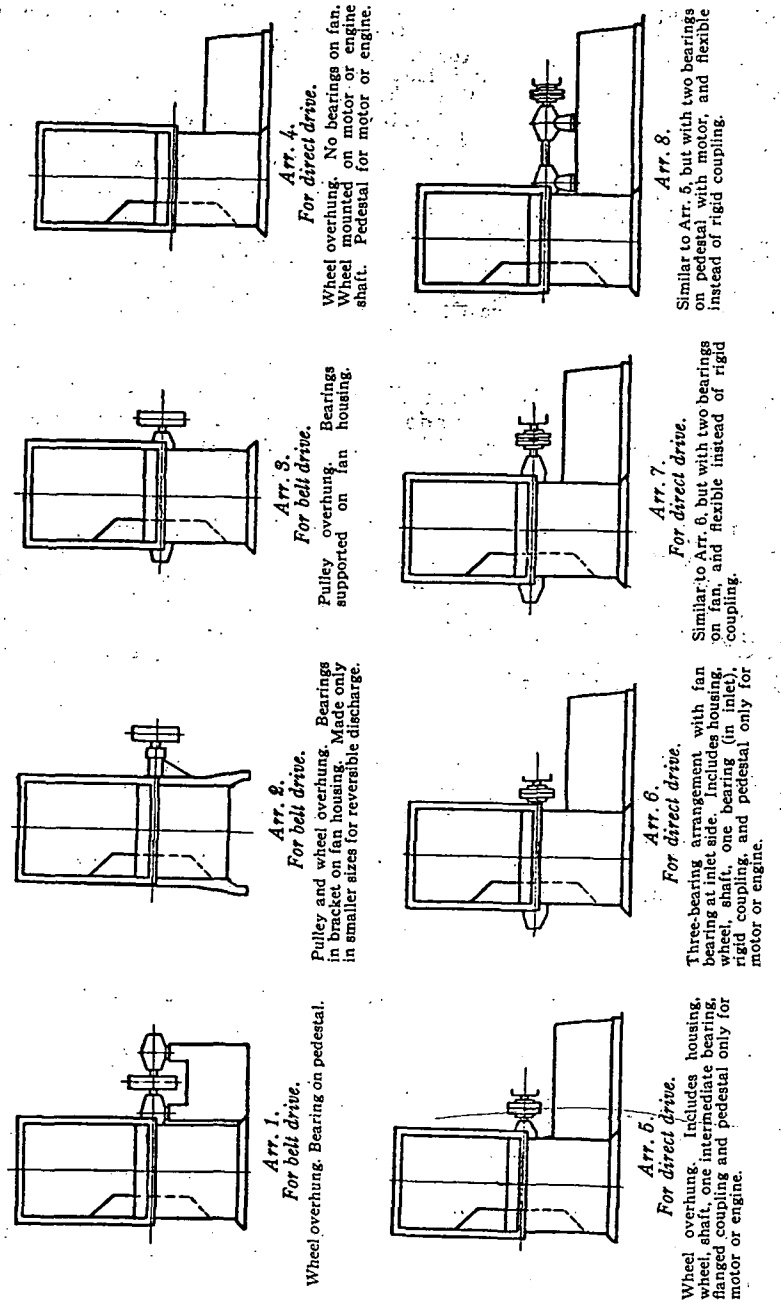


FIG. 9. ARRANGEMENT OF FAN DRIVES

ELECTRIC MOTORS

Electric power is almost the universal solution for fan operation, as electric motor speeds are flexible for adapting to direct-connected fans. Electric motors are readily suited to various types of drives, such as belts, chains or gears.

Each type of electric motor and kind of electric current has its advantages and disadvantages as applied to a fan application.

Direct-connected electric motors usually are very efficient for fan driving because there is no slippage due to belts, and no wear or noise due to chains or gears. There is less maintenance and upkeep to a direct-connected unit, and with an overhung fan wheel on the motor shaft, the usual fan bearings are eliminated.

The disadvantage of a slow-speed direct-connected motor is that it may be unduly large and heavy as well as costly, but this may be offset by the compactness of the unit as a whole due to limited space for fan equipment.

Should anything go wrong with a slow-speed direct-connected motor there may be a considerable delay in securing replacements, as these motors are not usually carried in stock, as is the case with moderately high-speed motors.

If a change of speed is found necessary with a direct-connected motor, it will mean a change of motor, which may necessitate a change in the motor foundation usually built with the fan in such cases. On the other hand, non-direct-connected motors have transmissions subject to wear and slippage, and chains or gears may be noisy with this latter type. However, should a change in speed be necessary where the motor is not direct-connected, changes in speed ratio can easily be accomplished by changing pulleys, sprockets or gears on either the fan or the motor. In the case of a motor breakdown a standard stock motor may easily be substituted.

A type of drive using wedge-shaped rope-like belts, often in multiple, has become very popular recently as it enables the use of high speed motors with slow speed fans. These motors are less expensive and more efficient, and further allow very short belt centers, saving floor space, thus making the fan unit and the motor much more compact than the usual belt drive. The compactness secured by this equipment compares favorably with a direct connected layout. This type of drive is also very quiet in operation, being similar to a conventional belt drive in this respect.

Alternating current motor designs are such that improved operating characteristics are obtained with the higher motor speeds. Efficiencies and power factors are improved over those in effect with slower speed motors, thus showing a considerable saving in power consumption, where some effective speed reducing transmission device to the fan, is installed.

Quietness of operation is more readily obtained with moderately high speed induction motors than with low speed motors, as any slight magnetic unbalance is not as easily heard. Magnetic unbalancing at times causes noises whose repetition and wave length is such as to cause vibrations and harmonics. Amplifications of the noises in other parts of a building

remote from the motor equipment are sometimes found, due to such noises being carried by the steel work, ducts, or piping in the building. There is considerable evidence that these sounds are more easily controlled with higher motor speeds than with lower motor speeds.

Motors which are practically quiet in operation and free from magnetic disturbing noises can be obtained and should always be specified for quietness of operation when used for fan installations in buildings where quietness is a factor.

In the construction of fan and motor foundations where the machinery is mounted on the floor or upon a concrete platform, it is a usual practice to install a layer of cork on top of which is laid or floated the base which carries the apparatus. It is essential that the bolts or lag screws which

TABLE 2. CLASSIFICATION OF MOTORS

GROUP	SUB. DIV.	TYPE	CURRENT	SPEED CHARACTERISTICS	STARTING TORQUE	STARTING CURRENT	APPLICATIONS
A	1	Shunt Wound	d-c	Constant	Medium	High	Fans
	2	Squirrel Cage	a-c	Constant	Medium	High — About six times full load	Fans, Centrifugal Pumps
	3	Synchronous	a-c	Constant	Medium	Starts as Squirrel Cage Motor	Motor Generator Sets, Air Compressors, Fans
	4	Slip Ring or Wound Rotor	a-c	Constant	Heavy	Low	Vacuum Pumps, Air Compressors
	5	Double Squirrel Cage	a-c	Constant	Heavy	Medium	Frequent and Heavy Starting Loads, Pumps, Compressors
B	1	Brush Shifting	a-c	Adjustable	Medium	Low	Stokers, Boiler Fans
	2	Cumulative Comp'd with Shunt Predominance	d-c	Adjustable	Heavy	High	Pumps
	3	Squirrel Cage Poles can be Regrouped	a-c	Multi-Speed	Medium	High	Fans, Ice Machines
C	1	Series	d-c	Variable	Heavy	Low	Fans
	2	Cumulative Comp'd with Series Predominance	d-c	Variable	Heavy	Low	Single Acting Reciprocating Pumps
	3	Slip Ring—Using External Resistance in Secondary	a-c	Variable	Heavy	Low	Fans

fasten the machines to this foundation shall not extend through to the floor. It is wise to fasten curbs to the floor, these presenting insulated surfaces to the machinery foundation and so preventing it from traveling. The general classification of motors used for heating, ventilation and air conditioning is shown in Table 2.

Control for Electric Motors

Very small direct current motors may be started by throwing them directly on the line through a suitable starting switch. The larger sizes require some type of starting rheostat. When speed adjustment is desired, the controller for adjusting the speeds of the motor usually functions also as a starting device.

Alternating current motors of 5 hp and under, usually may be thrown directly on the line. It is good practice to use a starting switch equipped with a thermal overload or inverse time limit overload device. This type of switch provides protection to the motor beyond the power of fuses to supply. Fuses when used necessarily must be large enough to take care of the inrush current which makes them inadequate for protecting the motor under operating conditions. The thermal overload device allows for this inrush and does not function until an overload has become persistent, the time element depending upon the percentage of overload over the rating of the element.

This type of switch is available for manual operation and also is furnished in the magnetic type for remote operation by push-button, or for operation by other types of pilots such as pressure switches and thermostats.

On the standard squirrel cage motors above 5 hp a starting compensator usually is employed to keep the inrush current to within the limits specified by the local power companies. Compensators may be obtained in transformer type and primary resistor type, and usually are furnished for manual operation. They can be secured for remote control also, but are necessarily expensive. However, the new type of high reactance, self-starting motors, may usually be thrown across the line up to 30 hp in size, and still have their inrush current within the limits of the rules of *National Electric Light Association*. With this type of motor a magnetic contactor usually is used. This device may be operated from a remote point by push-button, if desired. These magnetic contactors are furnished usually with thermal overload and no-voltage protection.

For remote operation of motors through magnetic starters, the operating buttons may be located in the engineer's or manager's office, and tell-tale indicating lamps may be wired up with the circuit to indicate whether or not the unit is in operation.

This type of control is very desirable in large buildings where the engineer is to have complete charge of the ventilating system.

Remote or automatic control of the units may be effected also by pneumatic or hydraulic apparatus, or by thermostats or by pressure devices which are provided with electric contacts for starting or stopping the units upon reaching certain conditions.

Variable speed slip ring motors and direct current motors may also be arranged for remote speed control by means of pre-set automatic

regulators, where the operating speed of the motor is set by a dial-switch or regulator (which may be near the fan or at a remote point) and the motor is then automatically controlled at this speed merely by operating the remote control push-button for starting or stopping the equipment.

Arrangements may be made for remote control of fan motors, or for automatic control by influence of temperature. Remote control may be by pneumatic or by hydraulic manipulation as well as by electrical means.

In many large ventilating systems which have heating plants in connection, steam engines are used to operate fans. A medium speed steam engine, exhausting at low pressure into the radiators which heat the building or which warm the air, is a very economical source of power, is quiet in operation, and has a wide range of speed variation. The steam economy of such an engine usually is of little importance, since the engine serves as an auxiliary to the pressure-reducing valve interposed in such cases between the boiler and the radiators.

Internal combustion engines and line shafting are often used for fan driving, requiring clutches or shift-belts with loose pulleys in order to secure proper starting and control.

It is seldom necessary to reduce the speed of ventilating fans more than 50 per cent from the maximum fan speed, but for economical operation on large systems there should be a number of operating speeds between maximum speed and 50 per cent below maximum speed.

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Chapter 35

INDUSTRIAL UNIT HEATERS

Functions; Types; Heating Mediums; Heat to be Supplied; Entering Air Temperature; Delivery Air Temperature; Ratings and Capacities; Arrangement of Heaters; Discharge; Boiler Capacity; Electric Units; Direct Fired Units; Turbine Driven Units; Automatic Control.

THE industrial unit heater is composed of a heating element enclosed by a casing in which a power driven fan or fans are mounted. The fans draw or force air over the heating surface, and discharge it in selected directions. Other auxiliary apparatus such as valves, by-pass dampers, louvers, screens, controls, etc., may or may not be a part of the unit, depending on the type. Generally no ducts are attached either to the outlets or to the inlets, the units being complete in themselves.

The heating and ventilating of factory and industrial buildings is frequently accomplished by means of units which include all the apparatus necessary for providing, directing and controlling the necessary volume of air heated to the proper temperatures for the purpose. Unit heaters usually are placed directly within the room to be heated and have the inherent characteristic of delivering and distributing the air by mechanical impulse. In many buildings this feature results in exceedingly economical and successful heating.

FUNCTIONS OF UNIT HEATERS

Unit heaters are designed to:

1. Circulate the air in the building at a rapid rate.
2. Promote uniformity of temperature and quick heating-up.
3. Direct the heated air so as to accomplish the positive and rapid placing of the heat where it is effective.
4. Reduce the temperature differential between floor and ceiling.
5. Reduce the number of heat emitting units and simplify piping and installation.
6. Increase the capacity of the heating surface by passing the air over it at high velocity.
7. Provide a system by which room temperatures are readily controlled manually or by thermostats.

In addition to their prime function of heating buildings, unit heaters may be adapted to a number of industrial processes, such as drying, curing, etc., with which the use of heated air in rapid circulation with uniform distribution is of particular advantage. They may be used for moisture absorption, such as fog removal in dye-houses or for the prevention of condensation on ceilings or other cold surfaces of buildings in

which process moisture is given off. When such conditions are severe, it is necessary that the heaters draw air from outside in enough volume to provide a rapid air change and that they operate in conjunction with ventilators or fans for exhausting the moisture-laden air. (See discussion of condensation in Chapter 3.)

TYPES OF UNIT HEATERS

There are many types of unit heaters available. Most of them employ heating coils to be supplied with steam or hot water. Some are designed primarily for mounting on the floor, whereas others are designed for suspension overhead. Heating surfaces in the form of pipe coils, non-ferrous tubes or shapes with extended surfaces, cast-iron, and pressed and built-up sections of the cartridge or automotive type are all used in unit heater construction.

Among the unit heaters available are types having from one to four outlets per heater which may be arranged to discharge in selected directions and which will project their heating effect over distances of from 30 to 200 ft from the heater, depending upon the capacity of the heater and upon the design of the fans and outlets. These heaters have been successful when placed as far as 400 ft from each other. This makes it possible to select the heater location best suited to the production layout in factories. There are available propeller fan type heaters of smaller capacity with outlet velocities of from 300 to 800 fpm, and these may be placed from 30 to 100 ft apart.

HEATING MEDIUMS

Unit heaters are made to operate on hot water, or with steam at high or low pressure. When high pressure steam is used, the heater must of course be especially designed for that purpose.

The present day tendency is to use steam at low pressure when the boiler supplies steam for heating purposes only, and when the transmission lines are short. Many industrial plants, however, generate steam at high pressure either for long distance transmission or for process uses. When such high pressure steam is available in sufficient quantity for the peak load, it is economical usually to use high pressure unit heaters. Thus the line pressure may be turned into the units directly without reducing valves and the condensation may be trapped to overhead returns when desired. Smaller coils may be used in high pressure heaters to lessen their cost and to produce a final temperature which will not be too high.

DETERMINING HEAT TO BE SUPPLIED

The heat losses of a building to be equipped with unit heaters are determined in the same manner as for any other heating system, excepting so far as the unit heaters may change the air temperature at the ceiling or at the mean height of the walls. (See Chapter 2).

Unit heaters may be arranged to recirculate the air or to supply warmed air from the outside for ventilation or to make up air exhausted.

If all or a part of the air is to be taken in from out-of-doors, the heat

necessary to warm this air from the outside temperature to the inside temperature must be added to the transmission or other losses. Unit heaters of the number and size needed to furnish the total heat required are then selected from the manufacturers' rating tables, using these ratings at the steam pressure to be used and at the temperature at which the air will enter the heater.

TEMPERATURE OF AIR ENTERING HEATER

For recirculating heaters with intakes at the floor level, use the temperature to be maintained in the room as the temperature of the air entering the heater. Where suspended heaters are used without any intake boxes extending down to the floor level, a higher entering air temperature should be used than that at which the room is to be maintained. With suspended heaters taking in air at some distance above the floor, the temperature variation from floor to ceiling may reach as much as 1½ deg for each foot of elevation during periods when the maximum capacity of the heaters is required. Unit heaters taking in recirculated air at the floor level should maintain temperature differentials of less than 1 deg per foot of elevation when the maximum capacity of the heaters is required. These temperature differences per foot of elevation are less than the corresponding variations per foot of elevation for spaces heated by direct radiation.

DELIVERY AIR TEMPERATURE

A rapid recirculation or turnover of the air in the room makes for fuel economy. This calls for the selection of heaters having a liberal air capacity for the required heat output, which in turn means a relatively low final temperature. Extremely low final temperatures can be had only at the expense of larger heaters and increased power, so that an economic limit is imposed. Contributing conditions vary too widely to permit of a suggested standard, but in general for heating purposes, it is advisable to use a delivery temperature not more than 70 deg above the average room temperature desired.

RATINGS AND CAPACITIES

It is standard practice to rate unit heaters in Btu per hour at a given temperature of air entering the heater and at a given steam pressure maintained on the coil. Steam at 2 lb pressure and air entering at 60 F are used as the standard basis of rating[1]. The capacity of a heater increases as the steam pressure increases, and decreases as the entering air temperature increases. The heat capacity for any condition of steam pressure and entering air temperature may be calculated approximately from any given rating by the use of factors in Tables 1 and 2. Table 1 is for blow-through and Table 2 is for draw-through unit heaters. These tables are accurate within 5 per cent.

The ratings customarily published for unit heaters, apply only for recirculation and free discharge, unless otherwise noted in the rating

[1]See A.S.H.V.E. Standard Code for Testing and Rating Steam Unit Heaters. (A.S.H.V.E. TRANSACTIONS, Vol. 36, 1930).

TABLE 1. CONSTANTS FOR DETERMINING THE CAPACITY OF BLOW-THROUGH TYPE UNIT HEATERS FOR VARIOUS STEAM PRESSURES AND TEMPERATURES OF ENTERING AIR

(Based on Steam Pressure of 2-lb Gage and Entering Air Temperature of 60 F)

Steam Pressure Lb per Sq In.	Temperature of Entering Air											
	−10°	0°	10°	20°	30°	40°	50°	60°	70°	80°	90°	100°
0	1.538	1.446	1.369	1.273	1.191	1.110	1.034	0.956	0.881	0.809	0.739	0.671
2	1.585	1.495	1.405	1.320	1.237	1.155	1.078	**1.000**	0.926	0.853	0.782	0.713
5	1.640	1.550	1.456	1.370	1.289	1.206	1.127	1.050	0.974	0.901	0.829	0.760
10	1.730	1.639	1.545	1.460	1.375	1.290	1.211	1.131	1.056	0.982	0.908	0.838
15	1.799	1.708	1.614	1.525	1.441	1.335	1.275	1.194	1.117	1.043	0.970	0.897
20	1.861	1.769	1.675	1.584	1.498	1.416	1.333	1.251	1.174	1.097	1.024	0.952
30	1.966	1.871	1.775	1.684	1.597	1.509	1.429	1.346	1.266	1.190	1.115	1.042
40	2.058	1.959	1.862	1.771	1.683	1.596	1.511	1.430	1.349	1.270	1.194	1.119
50	2.134	2.035	1.936	1.845	1.755	1.666	1.582	1.498	1.416	1.338	1.262	1.187
60	2.196	2.094	1.997	1.902	1.811	1.725	1.640	1.555	1.472	1.393	1.314	1.239
70	2.256	2.157	2.057	1.961	1.872	1.782	1.696	1.610	1.527	1.447	1.368	1.293
75	2.283	2.183	2.085	1.990	1.896	1.808	1.721	1.635	1.552	1.472	1.392	1.316
80	2.312	2.211	2.112	2.015	1.925	1.836	1.748	1.660	1.577	1.497	1.418	1.342
90	2.361	2.258	2.159	2.063	1.968	1.880	1.792	1.705	1.621	1.541	1.461	1.383
100	2.409	2.307	2.204	2.108	2.015	1.927	1.836	1.749	1.663	1.581	1.502	1.424

Note.—To determine capacity at any steam pressure and entering temperature, multiply constant from table by rated capacity at 60 F entering and 2 lb pressure.

TABLE 2. CONSTANTS FOR DETERMINING THE CAPACITY OF DRAW-THROUGH TYPE UNIT HEATERS FOR VARIOUS STEAM PRESSURES AND TEMPERATURES OF ENTERING AIR

(Based on Steam Pressure of 2-lb Gage and Entering Air Temperature of 60 F)

Steam Pressure Lb per Sq In.	Temperature of Air Entering Heater											
	−10°	0°	10°	20°	30°	40°	50°	60°	70°	80°	90°	100°
0	1.483	1.405	1.329	1.253	1.178	1.105	1.032	0.962	0.892	0.822	0.754	0.688
2	1.520	1.442	1.363	1.290	1.215	1.141	1.069	**1.000**	0.930	0.861	0.792	0.728
5	1.565	1.485	1.410	1.334	1.260	1.187	1.114	1.045	0.975	0.906	0.838	0.771
10	1.637	1.558	1.480	1.403	1.328	1.253	1.182	1.112	1.042	0.973	0.903	0.838
15	1.688	1.610	1.533	1.458	1.382	1.310	1.239	1.168	1.099	1.028	0.960	0.895
20	1.728	1.649	1.572	1.498	1.421	1.350	1.278	1.208	1.138	1.070	1.002	0.936
30	1.803	1.725	1.648	1.572	1.497	1.423	1.352	1.281	1.212	1.145	1.078	1.010
40	1.864	1.787	1.710	1.637	1.563	1.491	1.420	1.350	1.282	1.215	1.148	1.081
50	1.927	1.850	1.773	1.700	1.628	1.554	1.483	1.416	1.347	1.278	1.211	1.145
60	1.973	1.897	1.820	1.748	1.673	1.601	1.531	1.463	1.394	1.325	1.260	1.194
70	2.018	1.943	1.869	1.795	1.722	1.651	1.582	1.512	1.443	1.377	1.310	1.243
75	2.043	1.970	1.895	1.822	1.750	1.680	1.609	1.540	1.471	1.402	1.333	1.268
80	2.064	1.988	1.914	1.841	1.770	1.698	1.629	1.560	1.491	1.422	1.354	1.288
90	2.102	2.028	1.951	1.878	1.804	1.732	1.661	1.590	1.523	1.457	1.387	1.321
100	2.150	2.071	1.994	1.919	1.845	1.770	1.700	1.630	1.560	1.492	1.425	1.359

Note.—To determine capacity at any steam pressure and entering temperature, multiply constant from table by rated capacity at 60 F entering and 2 lb pressure.

tables. If outside air intakes, filters or ducts on the discharge side are used with the heater, proper consideration should be given to the reduction in air and heat capacity that will result because of this added resistance.

The percentage of this reduction in capacity will depend upon the characteristics of the heater and on the type, design and speed of the fans employed, so that no specific percentage of reduction can be assigned for all heaters for a given added resistance. In general, however, disc or propeller fan units will have a larger reduction in capacity than housed fan units for a given added resistance, and a given heater will have a larger reduction in capacity as the fan speed is lowered. When confronted with this problem the ratings under the conditions expected should be secured from the manufacturer.

When steam supplied to the heaters contains superheat, the capacity

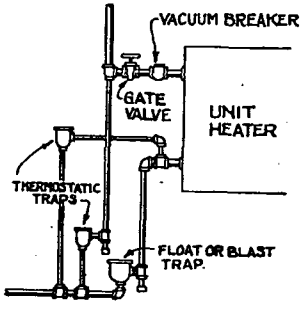


FIG. 1. UNIT HEATER CONNECTIONS WHERE CONDENSATION IS RETURNED TO VACUUM PUMP

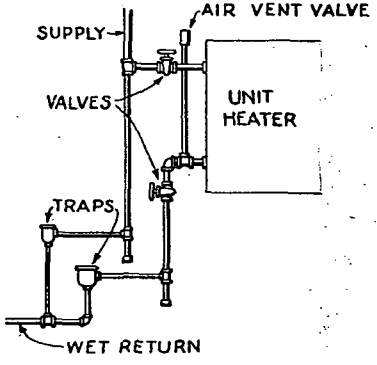


FIG. 2. UNIT HEATER CONNECTIONS WHERE CONDENSATION IS RETURNED TO BOILER THROUGH WET RETURN

of the heater will be but slightly less than with saturated steam at the same pressure. Recent tests indicate that the reduction of capacity from this cause is negligible for superheat up to 50 deg and will not exceed 3½ per cent for any degree of superheat.

Heaters may be distributed through the central portions of a room discharging toward exposed surfaces, or may be spaced around the walls, discharging along the walls and inward as well, when there are considerable roof losses.

In general, it is better to direct the discharge from the unit heaters in such fashion that rotational circulation of the entire room content is set up by the system rather than to have the heaters discharge in random and in counter-directions.

DIRECTION AND LOCATION OF DISCHARGE

Various types and makes of unit heaters are illustrated in the Catalog Section of THE GUIDE. Usually hot blasts of air in working zones are

objectionable, so heaters mounted on the floor should have their discharge outlets above the head line and suspended heaters should be placed in such manner and turned in such direction that the heated air stream will not be objectionable in the working zone. In the interest of economy, however, the elevation of the heater outlet and the direction of discharge should be so arranged that the heated air shall be brought as close to the head line as possible, yet not into the working zone. In general, the higher the elevation of the unit, the greater the volume and velocity required to bring the warm air down to the working zone, and consequently, the lower the required temperature of the air leaving the unit.

BOILER CAPACITY FOR UNIT HEATERS

The capacity of the boiler should be based on the rated capacity of the heaters at the lowest entering air temperature that will occur, plus an allowance for line losses. Ordinarily for recirculating heaters the lowest entering temperature will occur at the beginning of the heating period and is usually taken as 40 F, while for heaters taking air from outdoors the lowest entering temperature will be the extreme outdoor temperature expected in the district. No greater allowance in boiler capacity beyond the calculated heat demand need be added in order to supply unit heaters than for any other type of system.

It is unwise to install a single unit heater as the sole load on any boiler, particularly if the unit heater motor is started and stopped by thermostatic control. The wide and sudden fluctuations of load that occur under such conditions would require closer attendance to the boiler than is usually possible in a small installation. Where oil or gas is used to fire the boiler, it is possible by means of a pressurestat to control the boiler, in response to this rapid fluctuation. In most cases, however, and particularly where the boiler is coal-fired, it is advisable to use two or more smaller heating units instead of one large unit.

Steam pressures below 5 lb can be used with safety for recirculating unit heaters when their coils are designed for the purpose and when proper provision is made for returning the condensate. If heaters are to take in air that may be at a temperature below freezing, however, a steam pressure of not less than 5 lb should be maintained on the heater coils.

QUIETNESS OF OPERATION

In selecting unit heaters, attention should be given to the degree of quietness required for the installation.

No given fan speed may be applied as a measure of relative quietness to fans of different design and proportions. Quietness is a function of type, diameter, blade form and other variables besides speed, and all these must be taken into account. In general small fans may be run at higher motor speeds with equal quietness than large fans.

UNIT HEATER CONNECTIONS

Piping connections for unit heaters are similar to those for other types of fan-blast heaters. Typical connections are shown in Figs. 1, 2 and 3.

One-pipe gravity and vapor systems are not recommended for unit heater work.

On two-pipe gravity, or on pump and receiver systems the return from each unit should be fitted with a heavy duty or blast trap and an air valve should be connected into the return header of each unit. Pressure-drop must be compensated for by elevation of the heater above the water line of the boiler or of the receiver.

On vacuum systems the return from each unit should be fitted with a large capacity trap to discharge the water of condensation and with a thermostatic air valve for eliminating the air, or with a heavy duty trap for handling both the condensation and the air, provided the air finally can be eliminated at some other point in the return system.

On high pressure systems the same kind of traps may be used as with vacuum systems, except that they must be constructed for the pressure used. If the air is to be eliminated at the return header of the unit, a

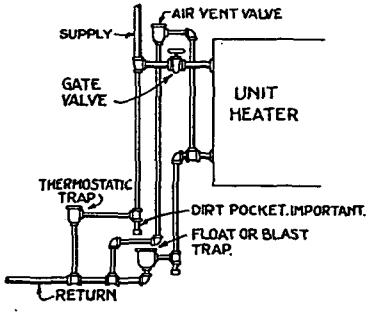


FIG. 3. UNIT HEATER CONNECTIONS WHERE CONDENSATION IS RETURNED TO CONDENSATION PUMP OR HOT WELL

high pressure air valve can be used; otherwise the air may be passed with the condensate through the high-pressure return trap.

The connections for steam and return piping to unit heaters must always be calculated on the basis of the high heat emission or condensation rate of such devices, usually by reducing the heat to be supplied to square feet of equivalent radiation by dividing by 240, and then using the pipe-size tables given in Chapter 9.

ELECTRIC HEATING UNITS

The foregoing discussion relates generally to units in which steam, vapor, or hot water are used as the heating medium. On rare occasions electrical resistances are used as the heating element. These are applied only where electric power is abundant and cheap and where other forms of fuel are scarce and expensive.

DIRECT FIRED UNITS

Where steam or hot water are not available the direct-fired type of heater is sometimes used. The heating element is a warm-air furnace in

which coal, coke, oil or gas is burned directly. This heating element is enclosed in a casing through which a fan maintains a rapid air current by pressure. This type of heater is often used for temporary heat during building construction or where the installation of a steam or hot water plant is for some reason not justified.

TURBINE DRIVEN UNIT HEATERS

Where high pressure steam is available it is sometimes used to drive a steam turbine direct-connected to the unit heater. The exhaust from this turbine, reduced in pressure, is then passed into the heating coil where it is condensed and returned to the boiler.

AUTOMATIC CONTROL

Where automatic temperature control is to be used, there are two classes of units to be considered. One is the standard unit, which has been on the market for many years, and the other is the bypass-type unit, which is a more recent development.

Control of Units Not Having Bypass

There are two general methods of automatic control that may be applied to the unit without bypass. One is to stop and start the unit heater motors individually or in a group by means of a room thermostat. The other is to control the steam supply either to individual units or to a group of units by means of a gradual-acting valve operated from a room thermostat. Where a steam valve control is used, the return system must be equipped with a vacuum pump, as an appreciable pressure difference between supply and return connections necessarily exists when the steam is throttled.

A combination of these two methods is sometimes used wherein the steam supply to the units is cut off completely before the unit heater motor is stopped and is turned on just before the motor is started again. The purpose of this control is to cool off the heater casing and to prevent possible discomfort to persons close to the unit from the radiant heat if steam is left on the coils when the motor is stopped. This is accomplished by two thermostats, one for controlling the motor and the other for controlling the steam valve. With this combination control, there is some possibility of draft complaint, for at times the fans may deliver cool air.

Gradual-acting control of the steam valve should not be applied to heaters with outside air connections unless some protection against freezing is also used. This protection can be accomplished by separating the heater coil into two parts, one of which acts as a tempering coil and is controlled from an outside air thermostat which will keep steam at full pressure on the coil whenever the entering air is below freezing, and which will cut off the steam when the entering air goes above freezing. The main coil is controlled from the room thermostat and is depended upon for temperature regulation. Another method of protection is to immerse in the return condensate a thermostat which controls a positive-acting bypass valve and which will admit additional steam if the temperature of the condensate falls to the freezing point. This is purely a safety device

and assumes that no condition of normal regulation will require enough throttling to make freezing possible. If this were not the case, such a method would not be suitable, as it prevents regulation beyond the point where the bypass valve opens.

As a precaution against allowing the unit heater motors to continue to run if the steam supply fails or is for some reason shut off, either a pressurestat or thermostat in the supply line, or an aqua switch on the return line may be installed to stop the motor when the pressure or temperature in the supply line, or the temperature in the return line drops below a predetermined point.

Control of Bypass-Type Units

The bypass-type units are equipped with a bypass opening and two interconnected dampers, so arranged that all or any portion of the air may be passed through or around the coil without being heated. It is possible to obtain a fair degree of temperature regulation by manually operating the dampers, but with the application of automatic controls, unusually good temperature control is obtained.

There are two types of control applicable to the bypass units. The older method is the *pneumatic* while the newer method is the *electric*. For the former, an air motor is installed on the unit to actuate the dampers. A pneumatic room thermostat is connected by means of small air lines to this air motor as well as to a source of compressed air supply. Should the room temperature tend to rise above the thermostat setting, the position of the dampers will shift to allow more air to be bypassed and less air to be heated through the coil. This produces a lower discharge temperature, which restores the desired temperature condition in the room. Conversely, should the room temperature tend to fall, the damper positions shift, so that less air is bypassed and more air is heated in going through the coil and a greater quantity of heat is supplied to the room.

The electric controls are similar to the pneumatic controls. In place of the air motor, a small reversible electric motor is used, and this is actuated by a room thermostat. When more heat is required, the thermostat makes a contact which causes the motor to shift the damper positions so that less air is bypassed and more air is drawn through the coil. When less heat is required, the thermostat makes another contact which causes the motor to operate in the reverse direction.

Where conditions require, an additional thermostat may be used to stop the fan motor when the bypass damper is wide open and the coil damper tightly closed. Also, an aquastat may be applied to the return line which will stop the fan motor should the steam supply fail.

For additional information on the control of unit heaters, see Chapter 23.

Chapter 36

UNIT VENTILATORS

Apparatus Usually Included; Functions of Unit Ventilators; Split and Combined Systems: Location of Units; Vent Openings; Capacities; Unit Ventilator Calculations.

A UNIT ventilator[1] is primarily a unit heater (see Chapter 35) which uses all or part out-door air for ventilation purposes, and which is provided with means for controlling the temperature of the air delivery. Various types are illustrated in the Catalog Data Section of this issue of THE GUIDE. Unit ventilators are used principally for heating and ventilating schools and public buildings, whereas unit heaters are used mainly for industrial heating.

APPARATUS USUALLY INCLUDED

A unit ventilator must be pleasing in design because it is generally used where it must harmonize with the furniture or with the decorative scheme. It consists usually of a rectangular steel cabinet finished with an enameled surface and containing the following necessary or optional parts:

1. Outside air inlet.
2. Inlet damper for closing the opening to the outside air inlet when the unit is not in use.
3. Adhesive type filters for cleaning the air (optional).
4. A heating element usually of special design and intended for hot water or low pressure steam.
5. Motor and fan assembly.
6. Mixing chamber where warm and cold air streams are brought together. (No mixing chamber is normally provided where sectional type heating units are used).
7. Recirculating damper (optional).
8. Humidifying arrangement[2] (optional).
9. Device for ozonizing air (optional).
10. Discharge grille or diffuser.
11. Temperature control arrangement.

FUNCTIONS OF UNIT VENTILATORS

The primary functions of a unit ventilator are:

1. To supply a given quantity of out-door air for ventilation.
2. To warm the air to approximately the room temperature if the unit is intended for

[1] A roof ventilator is sometimes termed a *unit ventilator*. For information on roof ventilators, see Chapter 26.

[2] If the unit includes provision for control of humidity, it is usually called a *unit conditioner*. See Chapter 37.

ventilation only, or to a higher temperature if it is intended to take care of all or a part of the heat transmission losses from the room.

3. To control the temperature of the air delivered.

4. To deliver air to the room in such a manner that proper distribution is obtained without drafts.

5. To recirculate room air for the purpose of heating when ventilation is unnecessary, or partly recirculate, mixing inside and outside air.

6. To perform all its functions without objectionable noise.

In addition to these functions, unit ventilators frequently are arranged so that the air supplied may be cleaned by means of filters of the adhesive type. If filters are used, the proper allowance must be made for the increased resistance offered to the air flow. Humidifiers in unit ventilators are optional.

1. *Air Supply for Ventilation.* The out-door air supply for ventilation is brought about by motor-driven fan or fans operated at comparatively low speeds and located in the lower part of the cabinet, the back of the cabinet being connected to the outside through rust-proof louvers and screens. Air quantities may be estimated on the basis of data given in Chapter 24. In densely occupied spaces, the usual practice is to allow 30 cfm per person.

2. *Warming Incoming Air.* The air is heated by blowing it through specially designed extended heating surface. The amount of heating surface to be provided in the unit is of course determined by the volume of air to be heated and the temperature range. If the unit is to be used for supplying air for ventilation only, the heating surface must be sufficient to maintain a final air temperature of about 70 F. If the unit is to be used for heating as well as for ventilation, the heating surface must be sufficient to maintain the necessary final air temperature for the conditions involved.

3. *Control of Temperature.* This is accomplished by controlling the temperature of the air discharged from the unit in one of two ways; *first*, by the automatic operation of a mixing damper which controls the relative quantities of air being blown through the heating unit or by-passed around it, and *second*, by dividing the heating unit into two or more sections and controlling (*i.e.*, throttling) the steam so that the proper amount of steam will be supplied to as many sections as required.

The outside air inlet damper and recirculating damper (where one is provided) should be so connected that there will be an uninterrupted supply of air to the fans at all times the unit is in operation. These dampers may be operated by hand or by pneumatic or electric motors controlled from some central point such as the engineer's office, or automatically at the unit itself. Provision should be made for the inlet damper to close automatically whenever the fans are shut down. The temperature of the air from the machine should be regulated automatically by thermostats in the room which control the position of the by-pass dampers below the heating elements, or the number of sections to which steam is supplied. Thermostats for controlling by-pass dampers must be of the intermediate type to hold the dampers in intermediate positions to prevent objectionable drafts. When direct radiators are used in conjunction with unit ventilators the control is usually arranged so as

automatically to open the valves to the direct radiators when the room temperature falls about 2 deg below the setting of the thermostat for the unit ventilator. Another arrangement opens the radiator valve whenever the unit ventilator control reaches the full heating position. Further information on this subject is contained in Chapter 23.

4. *Distribution.* This function is governed by the proper selection and location of the unit. Diffusion and distribution are dependent upon a relatively high velocity air stream discharged in a generally vertical direction, and in order to insure satisfactory diffusion in the room the final temperature of the air discharged from the unit must be kept as low as possible. With a final temperature above 110 F, excessive stratification of the air may be experienced. Troublesome drafts may be eliminated to a large extent if a static pressure is built up in the room, which can be done only if the vent from the room is small.

5. *Recirculation* reduces fuel consumption and aids in heating up rooms. Certain units are designed to recirculate all air at all times, except when the admission of outside air is needed to regulate room temperatures. Under this arrangement, the outside air for ventilating purposes is obtained solely from the infiltration, but the amount thus obtained is ordinarily insufficient to meet legal ventilating requirements. Recirculation is therefore prohibited by ordinance in some communities.

6. *Quiet Operation.* The unit ventilator is generally set close to the occupants of the room where activities are being carried on which preclude the use of noisy equipment. Quiet operation is therefore imperative.

SPLIT AND COMBINED SYSTEMS

In the *split* system shown in Fig. 1, the unit is used primarily for ventilation, delivering the air to the room at very near the room temperature, sufficient separate direct heaters being placed in the room to heat it to the desired temperature, independently of the unit. With the split system the separate direct heaters tend to improve the air circulation and diffusion within the room, since they constantly pull the cold air from the floor, warm it and use it to counteract the window chill.

In some cases the unit ventilator selected may have a capacity more than sufficient to warm the air needed to meet the ventilating requirements, and a corresponding reduction may be made in the amount of direct heating surface installed. The greater the amount of excess capacity of the unit, the more efficient will be the temperature regulation of the room. The split system permits the heating of the room during failure of electric current, since the direct radiators will furnish heat, but it permits a careless operator to avoid operating the ventilating equipment.

The combined system (Figs. 2 and 3) employs the unit ventilator alone, its capacity being sufficient both for ventilation and for supplying the heat loss. Direct heating surface is omitted altogether. It becomes necessary then that the fan be running whenever the room is to be heated and this also gives assurance of ventilation. With the combined system the distribution of the air within the room probably is not as perfect as with the split system, and more drafts will be encountered unless wide and rapid variations in the temperature of the air delivered by the machine

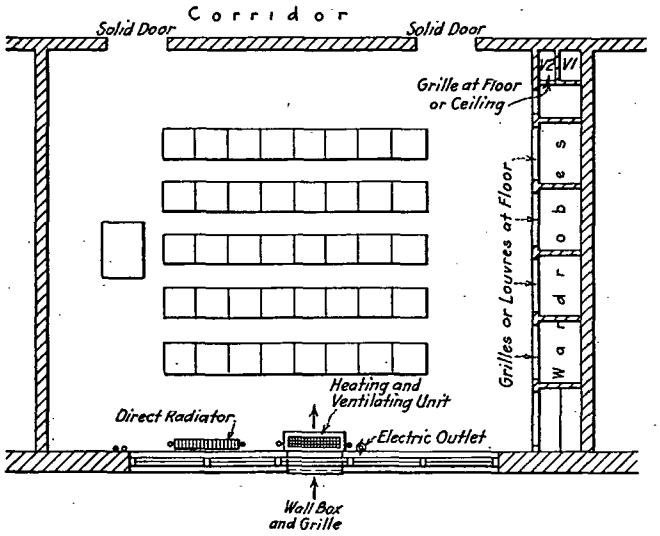


FIG. 1. SPLIT SYSTEM WITH INDIVIDUAL VENT.

are avoided by good temperature control, a positive pressure in the room and the proper discharge velocity. The cost of installation of a combined system is usually less than that of a split system and there is less danger of overheating.

Central fan systems (Chapter 31) as well as unit ventilator systems may be designed for split or combined operation.

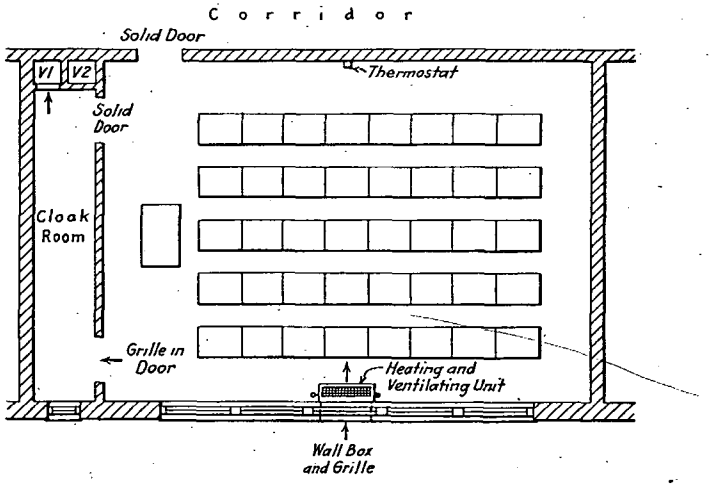


FIG. 2. COMBINED SYSTEM WITH INDIVIDUAL VENT.

LOCATION OF UNITS

The location of the unit ventilator in a room is important. Wherever possible it should be placed centrally on an outside wall. It is difficult to obtain proper air distribution if the unit is erected either on an inside wall or in a corner of the room. Standard units discharge the air stream upward, but for special cases units may be installed to discharge air horizontally. Units may be set away from the wall or partially recessed into the wall to save space without materially affecting the results. The air inlet may enter the cabinet at the back at any point from top to bottom;

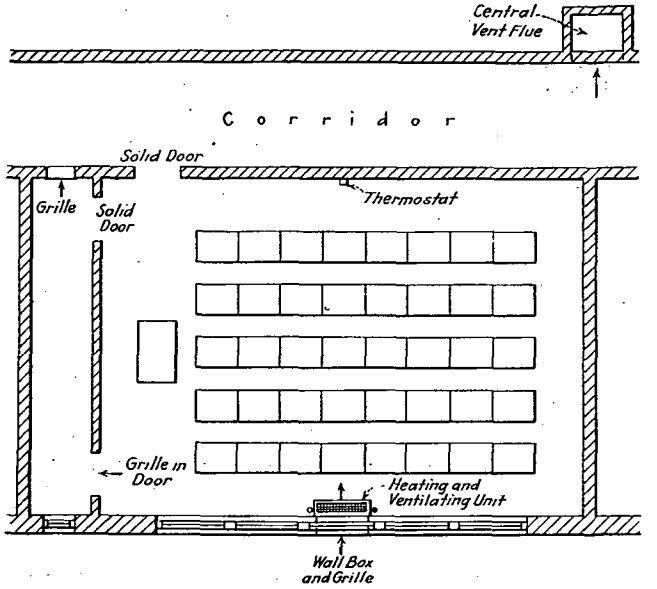


FIG. 3. COMBINED SYSTEM WITH CORRIDOR VENT.

all units, however, should be arranged to operate with free air inlet and free discharge.

VENT OPENINGS

The size and location of the vent outlet is important. In many cases the sizes for public buildings are regulated by law, but the location of the vents generally is left to the discretion of the engineer.

Size of Opening

The best results have been obtained with a velocity through the vent openings nearly equal to that at which the air is introduced into the room, thus maintaining a slight pressure in the room. Calculated velocities at the vent openings of from 600 to 800 fpm produce the best diffusion results from this system.

The cross-sectional area of the vent flue itself may be figured on the

basis of 15 sq in. of flue for each 100 cfm. Thus the vent flue area of a flue for a room equipped with one 1200 cfm unit ventilating machine would be 180 sq in. The area of vent flue opening from the room may be figured on the basis of 25 sq in. per 100 cfm.

Location of Vent

The vent opening should not be placed directly opposite the unit, since the incoming air when introduced at lower than room temperature falls to the floor and moves directly toward this vent opening, causing possible floor drafts and in any event causing failure properly to cool the occupants of the room.

In buildings provided with wardrobes or cloakrooms the vents may be so located that the air shall pass through these spaces, heating and ventilating them with air which otherwise would be passed to the outside without being used to the best advantage. Many State codes for ventilation of public buildings make this arrangement mandatory.

In rooms without wardrobes or cloakrooms the vent flue may be located diagonally opposite the unit, and two such flues generally are desirable, one near each opposite interior corner of the room. This gives the air an opportunity to mix thoroughly with the room air before dropping to the vent opening.

The individual vent flue and the corridor or central vent flue are the methods generally used with unit ventilators. The individual vent flue system (Figs. 1 and 2) provides for separate vent flues from each room. The corridor vent or central vent outlet system (Fig. 3), provides for outlets centrally located to take care of a group of classrooms, the air passing from the classrooms, wardrobe or cloakroom to the corridor, and from the corridor to the central outlets. The grilles between the wardrobes and corridors may be near the ceiling, provided the air leaves the classroom to enter the wardrobes near the floor in the classrooms. A velocity of 800 to 900 fpm may be used for the central outlet from the corridor.

Where the law and the type of building construction will premit, the escaping spent air from the building may circulate throughout the attic on its way out.

CAPACITIES

Unit ventilators are available in air capacities ranging from 450 cfm to 5000 cfm and with corresponding heat capacities (above that required for ventilation purposes based upon an outside temperature of zero and an inside temperature of 70 F) ranging from 125 to 600 sq ft of equivalent direct heating surface. Some manufacturers furnish a unit with several heating capacities for each air capacity thus enabling the engineer to select the unit best adapted to the heating and ventilating load. Typical capacities are given in Table 1.

UNIT VENTILATOR CALCULATIONS

The amount of heat to be supplied by the unit ventilator will depend on the amount of air passed through the unit and the temperature range through which the air is heated. The weight of air (W) to be circulated

per hour is fixed by the ventilating requirements and is frequently assumed to be 30 cfm per occupant (see Chapter 24).

Combined System

If no direct heating surface (radiation) is installed, the combined heating and ventilating requirements must be taken care of by the unit ventilators, and the total heat to be supplied is obtained by means of the following formulæ:

$$H_t = 0.24\ W\ (t_y - t_o) \tag{1}$$

$$W = dQ \tag{2}$$

$$t_y = \frac{H}{0.24W} + t \tag{3}$$

From equations 1, 2 and 3:

$$H_t = H + 0.24\ dQ\ (t - t_o) \tag{4}$$

Example 1. The heat loss of a certain room is 25,000 Btu per hour, and the ventilating requirements are 1000 cfm. If the room temperature is to be 70 F and all air taken from the outside at zero, what will be the total heat demand on the unit if it is required to provide for both the heating and ventilating requirements (combined system).

Solution. $H = 24{,}000$; $d = 0.075$ (at 70 F);
$Q = 1000 \times 60 = 60{,}000$ cfh; $t = 70$ F; $t_o = 0$.

Substituting in equation 4:

$$H_t = 24{,}000 + 0.24 \times 0.075 \times 60{,}000\ (70 - 0) = 99{,}000 \text{ Btu } (+)$$

$$t_y = \frac{24{,}000}{0.24 \times 0.075 \times 60{,}000} + 70 = 92.3 \text{ F}$$

If all of the air is recirculated, the total heat required is of course the same as the heat loss of the room, or

$$H_t = H = 0.24\ W\ (t_y - t) \tag{5}$$

Split System

If the heat loss of the room is to be taken care of by direct heating surface, the unit ventilators will be required to warm the air introduced for the ventilating requirements. Therefore:

$$H_v = 0.24\ W\ (t_y - t_o) \tag{6}$$

TABLE 1. TYPICAL CAPACITIES OF UNIT VENTILATORS FOR AN ENTERING AIR TEMPERATURE OF ZERO.

CUBIC FEET OF AIR PER MINUTE	TOTAL CAPACITY IN SQUARE FEET OF EQUIVALENT DIRECT HEATING SURFACE (RADIATION)	CAPACITY AVAILABLE FOR HEATING THE ROOM IN SQUARE FEET OF EQUIVALENT DIRECT HEATING SURFACE (RADIATION)	FINAL AIR TEMPERATURE (DEG. FAHR.)
600	285	95	105
750	350	115	105
1000	455	150	105
1200	565	190	105
1500	705	235	105

In this case t_y should be equal to or slightly higher than t. If the unit ventilator were of such capacity as to exactly provide for the ventilating requirements, the direct radiation would be selected on the usual basis. However, it is necessary to employ a unit which may not exactly meet the ventilating requirements, since standard units are usually rated in terms of the volume of air that will be delivered at a certain temperature t_y for an initial temperature of t_o. Therefore a certain amount of heat (H_h) may be available from the unit ventilator for heating purposes, as previously stated, and the amount of equivalent direct heating surface may, if desired, be deducted from the amount required for heating the room.

Example 2. Assume the same data as in example 1, for a split system, and select the unit and direct heating surface, making allowance for any excess capacity of the unit above that required to warm the air introduced for ventilation purposes.

Solution. The amount of equivalent direct heating surface required, disregarding the unit ventilator, is equal to $\frac{24{,}000}{240} = 100$ sq ft. A unit having an air capacity of 1050 cfm is selected, the excess heating capacity of this unit for an entering air temperature of zero being 82 sq ft. The theoretical net direct heating surface required with the fan in operation is therefore 18 sq ft. However, it is not likely that this or any other unit contains enough indirect heating surface to heat the average size classroom when the fan is inoperative. The maximum deduction should not exceed 75 sq ft of equivalent direct heating surface, and as previously stated, the best results are obtained when no deduction is made for the excess capacity of the unit.

SYMBOLS USED IN THIS CHAPTER

d = density of air, pounds per cubic foot.
H = heat loss of room, Btu per hour.
H_h = heating capacity of unit ventilator in excess of that required to warm air introduced for the ventilating requirements, Btu per hour.
H_t = total heat requirements for both heating and ventilation, Btu per hour $= H + H_v$.
H_v = heat required to warm air for ventilation, Btu per hour.
Q = volume of air introduced for the ventilating requirements, cubic feet per hour.
t = temperature to be maintained in the room.
t_o = outside temperature.
t_y = temperature of the air leaving the unit.
W = weight of air circulated, pounds per hour.
0.24 = specific heat of air at constant pressure.

Chapter 37

UNIT AIR CONDITIONERS AND COOLERS

Unit Air Conditioners—Advantages and Disadvantages; Description and Operation; Evaporative and Non-Evaporative Cooling; Water Required: Cooling Units—Functions; Types; Cooling Media; Heat Absorption; Temperature of Air Circulated; Ratings and Capacities; Location of Units; Compressor Capacity; Automatic Control; Defrosting.

UNIT AIR CONDITIONERS

THE unit air conditioner is a self-contained apparatus performing the same functions as the larger so-called central station equipment. It may be used for the air conditioning of printing plants, textile mills, candy manufacturing, packing and storage departments, cigar and cigarette making and seasoning departments, bakeries, process rooms necessary in the manufacture of pharmaceuticals and related products, and for any industrial plant or department in which production depends on, or quality is improved by, positive and accurate control over atmospheric conditions.

The unit air conditioner provides for humidification or dehumidification, air washing, heating or cooling, and uniform distribution of air, either with or without ducts, depending on the location of the units. Each unit is a complete air-conditioning plant in itself including spray nozzles, air re-heater, fan, pump, automatic control, etc. They are usually built in graduated standard sizes ranging in capacity up to 10,000 cfm each.

Advantages of Unit Air Conditioners

The principal advantages of such equipment are that the desirable results of the indirect humidification system can be applied to old buildings without installing duct work. Also where manufacturing processes are changed and departments are sub-divided or enlarged the units are easily moved or increased in number to suit the new requirements. Because of their portability they are useful for tenants of rented buildings.

Disadvantages of Unit Air Conditioners

Frequent cleaning and adjustment of controls of air-conditioning units, used where dust and lint occur, may be objectionable. A multiple unit installation, therefore, involves a great deal more attention than does a single unit located in the basement. In dehumidifying plants, especially, the expense of piping required for connection of separate air-conditioning units to the refrigerating apparatus, must be considered. The central station system generally is recommended where more than three unit conditioners are required.

Description and Operation

Unit air conditioners are manufactured in horizontal and vertical types and are thus adjustable to varying space requirements, being floor mounted or suspended. Water, steam and electrical connections are required to prepare them for operation. Electric power requirements generally range from 1 to 7 kw. Fan motors are from ⅛ to 5 hp. Water consumption varies from 40 to 200 gal per 12-hour period, according to the size of unit.

An air-conditioning unit may be so designed that it will draw in air from the room or enclosure in which it is placed or from the outside, or by the aid of mixing dampers, may draw any predetermined mixture of inside and outside air. This entering air passes through one or more spray or mist chambers, in which space moisture is either added to or removed from the air in accordance with the temperature of the air and of the spray water. At the same time the air is washed substantially free of dust and solid matter in this chamber. The air next travels between the customary labyrinth eliminator plates to lose its entrained water. A suitably located fan assembly causes the air to flow over a heating unit before being delivered to the room. A motor-driven centrifugal pump or other means is used to deliver water from the tank built into the base of the unit to the spray heads, mist nozzles or other atomizing apparatus. In some makes of unit air conditioners, other means than spray nozzles are used to produce the required water spray or mist for the transfer of heat from air to water or vice versa. Automatic instruments control the condition of the leaving air by regulating the temperature of the spray water and also by varying the amount of steam supplied to the air heater. Such instruments usually are placed in the path of the return air as it enters the unit to be conditioned, as the entering air is a sample of room air. The spray water can be heated by an ejector or by a closed type heater.

For dehumidifying work cold water may be supplied under automatic control as needed. It usually is found best where refrigeration is used to employ a separate water cooler located in close proximity to the compressors and condensers, rather than to use direct expansion coils or brine coils within the air conditioning units.

Evaporative Cooling

In certain buildings in which a considerable amount of heat is generated by power driven machinery or from other sources involved in the manufacturing operations or during hot seasons when heat is transmitted into the building, evaporative cooling of the air, which occurs in the spray chamber of the unit, is sufficient to reduce the temperature of the air in the conditioned room from 5 to 20 deg below the existing outdoor temperature. Though evaporative cooling is limited according to the relative humidity of the air entering the spray chamber of the unit-cooling and dehumidifying type air conditioner, the general effectiveness contributes to the comfort of the workers and offers an efficient means of utilizing or disposing of the mechanical heat developed by machinery or of that given off from other sources.

Non-Evaporative Cooling

When it is desired to maintain conditions of temperature and humidity below those normally possible to obtain by evaporative cooling it is necessary to supply water to the unit at a temperature below the dew-point or saturation temperature of the entering air. The source of low temperature water may be a well, or the water may be cooled by refrigeration.

Water Required

In the usual practice of air washing, humidifying and evaporative cooling, the water in the tank of the unit is used over and over. It is necessary to replace or make up only that which has been evaporated by the air passing through the unit. A connection is made to the general water supply and by means of a float valve a constant water level is maintained. Under average operating conditions the water evaporated by one unit amounts to about 0.75 lb per minute or between 40 and 50 gal in 12 hours. It is, of course, necessary to drain and flush the water tank periodically according to the amount of dirt washed from the air.

Air Conditioning Capacity

Air conditioning capacity cannot, in general, be calculated on the basis of square feet of floor space or upon the cubical content of a room. It is based, rather, upon the heat to be supplied or absorbed. For instance, one room of 25,000 cu ft may contain machinery giving off 4240 Btu per minute while a room of like volume may contain machinery or heat sources dissipating twice this quantity. Such conditions control the calculation of air conditioning requirements.

Productiveness and Well-Being of Worker

Conditions of humidity and air movement properly adjusted in relation to the air temperature are now recognized by health authorities as of paramount importance to the productiveness and the well-being of workers. In many cases where air conditioning equipment has been installed primarily to control the effect upon materials or upon manufacturing operations, an improvement in the health and efficiency of the employees has been noted.

COOLING UNITS

Product cooling units are usually construed to mean a combination of a cooling coil and fan or blower, erected as a unit and having a common enclosure. A motor, float valve, surge drum, valves and other auxiliary fittings may or may not be a part of the unit, depending upon the type. The fans draw or force air over the cooling surface, and discharge it in selected directions. As a rule outlets are specially designed to accomplish air distribution without the use of ducts. These units are usually placed directly within the room to be cooled.

Functions of Cooling Units

Cooling units are designed to:

1. Circulate the air in the room at a rapid rate.

2. Promote uniformity of temperature distribution.
3. Direct the cooled air positively and rapidly where it is most effective.
4. Reduce the amount of space taken up by cooling apparatus.
5. Provide a system readily responsive to manual or thermostatic control.
6. Increase the capacity of the cooling surface by passing air over it at high velocity.
7. Provide, under favorable temperature conditions, a convenient means of either manual or automatic defrosting of cooling surface.
8. Provide a neat appearing sanitary apparatus for obtaining required temperatures in cold storage rooms.

In addition to their prime function of cooling cold storage rooms, product cooling units have the advantage of air circulation to alleviate condensation occurring on walls and ceilings. In meat prechill rooms they eliminate fog entirely. Outside air intakes are adaptable where the stored product requires ventilation. Apple storage rooms and banana ripening and storage rooms fall in the latter class.

Types of Cooling Units

A common type of product cooling unit is designed for floor mounting and is obtainable in various sizes having two, three or four outlets which may be arranged to discharge in selected directions, thus making it possible to choose a location best suited for air direction for the placing of the product within the room and for piping connections. Cooling units are generally made of steel tubing suitably coated to prevent corrosion, or of aluminum or some alloy.

Where floor space is not available, relatively smaller units of the suspended type may be employed. These units are usually equipped with extended surface coils made either of steel or non-ferrous metal. Where a large amount of moisture must be condensed from the room it is possible to avoid coil frosting by using a floor mounted brine spray unit.

Drip pans collect moisture when cooling surfaces are defrosted. Refrigerants are supplied directly to the interior of the coils in all cases, and the heat from the room is drawn from the air, passing over the cooling surfaces.

Cooling Media

Cooling units are suitable for operation on gaseous refrigerants such as ammonia, methyl chloride, sulphur dioxide, carbon dioxide. Cold water or brine can also be used. The choice of refrigerant is governed by the design and construction of the cooling coil.

Determining Heat to be Absorbed

The heat gain of a room to be equipped with cooling units is determined in the same manner as for any other product cooling system. This consists of direct sunlight gain, radiation gain, infiltration and product load. Where air is brought in from the outside directly through the unit for ventilation purposes, the heat gain necessary to reduce the air from outside temperature to room temperature must be added to the transmission and other gains. Units are then selected from the manufacturers' rating tables. The gains thus far mentioned are sensible heat gains. The latent heat load resulting from moisture precipitation, must also be taken into account in many cases.

Example 1. A fur storage room is to be maintained normally at a temperature of 32 F. At intervals, however, the room is to be lowered to 20 F, which temperature will be maintained for several days, after which 32 F will again be held. What is the cooling load?

The room is located in the basement of an existing building and has no outside exposure. Maximum temperature of rooms surrounding walls and ceilings, 90 F. Floor is on ground. Room has a vestibule entrance. Four lights of 100 watts each will be burning part of the time. No occupants in room except at infrequent intervals. Brine available at a minimum temperature of 10 F.

Size of Room: 25 ft long by 20 ft wide by 9 ft high.
Walls: 6-in. concrete, 4-in. cork and ½-in. plaster finish.
Ceiling: 4-in. concrete, 4-in. cork and ½-in. plaster finish.
Floor: Cinder fill, 6-in. concrete, 4-in. cork, 2-in. concrete.

Solution. The cooling load will be the sum of the following items:

Sunlight gain (Btu per hour)	none
Lights: $4 \times 100 \times \frac{3.4}{4}$ (25 per cent use assumed)	340
Cooling unit motor, ½ hp	1260
Transmission	
Walls: $90 \times 9 \times (90 - 70) \times 0.066$	3742
Ceiling: $20 \times 25 \times (90 - 70) \times 0.067$	2345
Floor: $20 \times 25 \times (90 - 30) \times 0.065$	2275
Infiltration	
$\frac{4500 \times (90 - 20)}{8 \text{ hr} \times 55.2}$	713
Product Load:	
None	
	10675
Safety factor (10 per cent)	1067
Total sensible heat load	11742 Btu per hour

The cooling unit selected must be capable of absorbing 11742 Btu per hour of sensible heat.

Temperature and Volume of Air Circulated

The drop in temperature of the air through a cooling unit is comparatively small, while the volume handled is large. This feature permits of greater heat transfers per unit of surface and a minimum moisture precipitation. Consequently, the temperature difference between the room and discharged air is small, making it of little consequence whether the intake to the unit is located at the floor or at the ceiling.

Example 2. In Example 1, assume that air enters the base of the cooling unit at 20F and leaves outlets at 17 F. This is a 3-deg reduction in temperature. Compute the volume of air in cubic feet per minute that unit must handle.

Solution. The weight of dry air at 17 F is 0.0835 lb per cubic foot. Specific heat = 0.24. Volume of air to be handled per minute =

$$\frac{11742}{60 \times 3 \times 0.24 \times 0.0835} = 3280 \text{ cfm}$$

Therefore, the cooling unit selected should handle not less than 3280 cfm and should have enough coil surface to absorb 11742 Btu per hour when circulating air at 20 F and sufficient 10-F brine supplied to the coils. Unit should be of floor mounted type.

Ratings and Capacities

It is common practice to rate cooling units in Btu per hour at a given temperature of air entering the unit and at a given refrigerant temperature maintained within the coil. This Btu capacity may be either sensible or total heat capacity. Ratings are sometimes expressed as equivalent tons of refrigeration. No standard basis for rating has yet been adopted. The heat capacity for any given condition of room temperature and refrigerant temperature must be obtained from the manufacturers' tables. Ratings are on the basis of a coil flooded with refrigerant and with no frost (or but a light coating) on the coil. Suitable reduction in sensible heat capacity must be made for a heavy coating of frost. In the case of brine or cold water as the refrigerant, suitable correction must be made for the rate of flow through the coil.

Location of Units

The following considerations govern the location of cooling units within a room:

1. Arrangement of product within the room.
2. Air distribution.
3. Number of units required.
4. Convenience of piping connections.

The most important of these is air distribution. Units should be so located as to accomplish equal distribution of air to all parts of the room.

The discharge of cooled air in general should be above the product, in the free space between the ceiling and the product. The travel of the air through the substance cooled back to the inlet of the unit should be at low velocity.

Compressor Capacity

The machines producing refrigeration must be of sufficient capacity to absorb not only the sensible heat gain of the storage room but also the latent heat load which comes of moisture precipitation. The number of hours operation per day will depend entirely upon its capacity with relation to the requirements. It is presumed that the cooling unit capacity has been selected to coincide with the desired operation. It is best practice to choose a compressor which will produce a small temperature difference between the refrigerant and the room, sufficient however to obtain the desired capacity from the cooling unit.

Automatic Control

Cooling units are readily adaptable to thermostatic control. Several arrangements are as follows:

1. Room thermostat in conjunction with a magnetic or motor-operated valve to regulate the flow of refrigerant to coil. Usually the fans operate continuously.
2. Room thermostat to control operation of compressor. Fans operate continuously.
3. Room thermostat to control the operation of the fan motors.
4. Room thermostat to control the operation of fan motor and compressor motor simultaneously.
5. Room thermostat to control operation of the compressor with back pressure control to regulate the fans.

Chapter 38

SMOKE, DUST AND CINDER ABATEMENT

Definitions of Smoke; Dust and Cinders; Nature's Dust Catcher; Dust and Cinder Catchers; Disposal of Dust and Cinders; Testing of Dust and Cinder Catchers; Settling Chambers; Dust and Cinder Traps; Centrifugal Catchers; Electrostatic Precipitators; Gas Scrubbers; Filters.

THE concentration of industrial activity around the large cities of the world has resulted in the pollution of the air above these cities by smoke, dust and cinders. In those areas where large quantities of fuel of various kinds are burned in automobiles and other internal combustion engines and in the furnaces of space-heating and industrial boilers, large quantities of solid material are discharged into the atmosphere at relatively low levels.

The effect of this air pollution has been classified as medical, botanical and physical. Attempts have been made to express the damage in terms of dollars per year, but so far the medical profession has not agreed that this air pollution is responsible for ill health or a shorter life. The trees on city streets and the flowers and shrubbery in public parks grow vigorously, and buildings are torn down because of obsolescence long before the building materials show any serious signs of destruction by the foreign matter in the air. However, the smoke does discolor buildings and removal of the stains is a costly process. The dust and cinders make it difficult to keep offices clean and undoubtedly damage much merchandise.

In the large cities where the nuisance from smoke, dust and cinders is the most serious, limited areas obtain some relief by the use of district heating. The boilers in these plants are of large size designed and operated to burn the fuel without smoke and some of them are equipped with dust catching devices. The gases of combustion are usually discharged at a much higher level than is possible in the case of buildings that operate their own boiler plants.

SMOKE

Smoke is the finely divided solid matter formed by the incomplete or arrested combustion of the volatile hydro-carbons in fuel. (See definition of smoke on page 477, Chapter 33, Air Cleaning Devices). The smoke particles are extremely small and so light that they will not settle by gravity in still air.

By far the greater part of the smoke in the air comes from the exhausts of automobiles, and from the chimneys of dwellings, office buildings and industrial plants. The causes of smoke production are so numerous and varied that no general rule can be given to correct the trouble.

Smoke density is usually measured by comparison with the Ringelmann Chart (Fig. 1). In making observations of the smoke issuing from a chimney, four cards ruled like those in Fig. 1, together with a card printed in solid black and another left entirely white, are placed in a horizontal row and hung at a point about 50 ft from the observer and as nearly as convenient in line with the chimney. At this distance, the lines become invisible, and the cards appear to be of different shades of gray, ranging from very light gray to almost black. The observer glances from the smoke coming from the chimney to the cards, which are numbered from 0 to 5, determines which card most nearly corresponds with the color of the smoke, and makes a record accordingly, noting the time. Observations are made continuously during say one minute, and the estimated average density during that minute recorded, and so on, records being made once very minute. The average of all the records made during a boiler test is taken as the average figure for the smoke

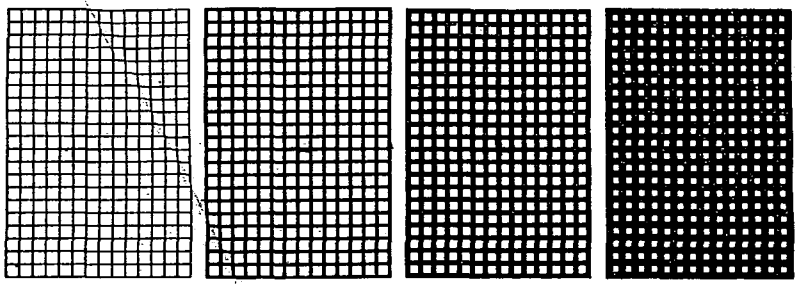


Fig. 1. Ringelmann Smoke Chart

density during the test, and the entire record is plotted on cross-section paper in order to show how the smoke varied in density from time to time.

Methods of Reducing Smoke Discharge

In general, time, temperature and turbulence are the essential requirements for smokeless combustion. Anything that can be done to increase any one of these factors will reduce the quantity of smoke discharged.

Checker or Alternate Firing, in which the fuel is fired alternately on separate parts of the grate, maintains a higher furnace temperature and thereby decreases the amount of smoke.

Coking and Firing, in which the fuel is first fired close to the firing door and the coke pushed back into the furnace just before firing again, produces the same effect. The volatiles as they are distilled thus have to pass over the hot fuel bed and will be burned if they are mixed with sufficient air and are not cooled too quickly by the heat-absorbing surfaces of the boiler.

Steam or Compressed Air Jets, admitted over the fire, create turbulence in the furnace and bring the volatiles of the fuel more quickly into contact with the air required for combustion. These jets are especially helpful

for the first few minutes after each firing. *Frequent firings* of small charges shorten the smoking period and reduce the density. *Thinner fuel beds* on the grate increase the effective combustion space in the furnace, supply more air for combustion, and are sometimes effective in reducing the smoke emitted. A *lower volatile coal* or a higher gravity oil always produce less smoke than a high volatile coal or low gravity oil used in the same furnace and fired in the same manner.

The installation of more modern or better designed fuel burning equipment, or a change in the construction of the furnace will often reduce smoke. The installation of a Dutch Oven will increase the furnace volume and will raise the furnace temperature, and often produces satisfactory results.

New Installations

In the case of new installations, the problem of smoke abatement can be solved by the selection of the proper fuel burning equipment and furnace design for the particular fuel to be burned and by the proper operation of that equipment. Constant vigilance is necessary to make certain that the equipment is properly operated.

DUST AND CINDERS

Dust and *cinders* in the air are those particles of solid matter larger than the largest smoke particle. (See definition of dusts on page 477, Chapter 33, Air Cleaning Devices). The term *dust* is usually applied to the particles of completely burned ash of small size, and the term *cinder* is usually applied to the particles of coke and ash of appreciable size discharged with the gases of combustion from burning coal.

The sources of these particles are numerous, such as roads and streets, plowed ground, insects, etc., but the particles of greatest concern are those discharged into the atmosphere along with the gases of combustion from solid fuel. Both dust and cinders are discharged from the smoke outlets of plants where coal is the fuel used. When the coal is fired on grates the cinders may cause annoyance, and when the coal is pulverized and burned in suspension, the dust problem can be serious.

The cinder particles are usually larger in size than the dust particles, they are gray or black in color, and are abrasive. Being of a larger size the range within which they may annoy is limited.

The dust particles are usually extremely fine, they are light gray or yellow in color, and are not as abrasive as cinder particles. Being extremely fine, they are readily distributed over a large area by air currents.

The nuisance created by the solid particles in the air is a function of the size and physical characteristics of the individual particles. The difficulty of catching the dust and cinder particles is principally a function of the size and specific gravity of the particles.

Nature's Dust Catcher

Nature has provided means for catching solid particles in the air and depositing them upon the earth. A dust particle forms the nucleus for each rain drop and the rain picks up dust as it falls from the clouds to the earth. In fact, without dust in the air to form the nuclei for rain drops it

would never rain and the earth would be continually enveloped in a cloud of vapor.

DUST AND CINDER ABATEMENT

The logical solution of the problem of dust and cinder abatement is to prevent the discharge of the dust and cinders into the atmosphere. Efforts in this direction, however, have not been entirely satisfactory.

Lower rates of combustion per square foot of grate area will reduce the quantity of solid matter discharged from the chimney with the gases of combustion. The burning of coke, coking coal, and sized coal from which the extremely fine coal has been removed will not as a general rule produce as much dust and cinders as will result from the burning of non-coking coals and slack coal when they are burned on a grate.

Modern boiler installations are usually designed for high capacity per square foot of ground area because such designs give the lowest cost of construction per unit of capacity. Designs of this type, discharge a large quantity of dust and cinders with the gases of combustion, and if pollution of the atmosphere is to be prevented, some type of catcher must be installed.

Dust and Cinder Catchers[1]

Many types of dust and cinder catchers of merit are on the market today. However, most of them are in the process of development and it will probably be some time before the best types for various classes of service are definitely determined.

The various types of dust and cinder catchers available today can be divided into six general classes:

1. Settling chambers.
2. Dust and cinder traps.
3. Centrifugal separators.
4. Electrostatic precipitators.
5. Gas scrubbers.
6. Filters.

The selection of the proper type of catcher calls for a careful study of the material to be caught and the draft and space available. After installation constant vigilance is necessary to keep the catchers in proper working condition if satisfactory operation is to be obtained.

If possible, the dust or cinder catcher should be installed on the inlet side of the induced draft fans because the dust and cinders in the gases seriously erode the wheels of the fans, the inlet connections and the scrolls. Where the induced draft fans operate at high tip speeds and no catchers are installed, it is not uncommon for the fans to require major repairs within one year and complete replacement within five years.

Disposal of Dust and Cinders

Even after the dust and cinders have been caught the disposal of the material caught presents a serious problem. The cinders discharged with

[1]See Smoke and Dust Abatement, by M. D. Engle. (*Heating, Piping and Air Conditioning*, February, 1931).

the gases from stoker-fired boilers are usually very high in carbon and contain from 50 to 80 per cent as much heat per pound as the coal which is being burned. It is possible, and usually economical, to burn these cinders. They cannot be satisfactorily mixed with the coal in the stoker hopper but they can be blown into the furnace over the stoker fuel bed and burned satisfactorily. If a sufficient quantity of cinders is caught, a small unit pulverizer can be installed to prepare them for burning over the stoker fuel bed. The same pulverizer can be used for coal at times of peak load and will materially increase the capacity of the fuel burning equipment for the boiler to which it is connected.

No satisfactory market has been developed for the dust caught from pulverized coal installations, but the possibilities are being investigated and it seems likely that in the future this material will have a market value that will go a long way toward paying the fixed charges on the cost of catching it.

Testing of Dust and Cinder Catchers

The problem of testing to determine the efficiency of a dust or cinder catcher after installation is extremely difficult. No test code is available at present but one is under development.

The distribution of dust in the gas entering and leaving the dust and cinder catchers is not uniform and is different in practically every installation, and varies widely with changes in furnace conditions. In order to obtain a representative sample it is necessary to traverse the inlet and outlet of the catcher with a sampling tube which faces into the gas flow. The velocity of the gas into the sampling tube must be the same as the velocity of the gas in the duct at the instant the sample is taken. The swirls and eddy currents in the ducts make it difficult to obtain consistent readings, but if the test is conducted by some one of experience, an indication of the approximate efficiency can be obtained.

Settling Chambers

Probably the oldest form of dust catcher is the settling chamber, which generally consists of a large-sized, gas-tight space into which the dust-laden gases are discharged before being delivered to the chimney. The velocity of the gas should be reduced to a point where the larger and heavier particles will be precipitated by gravity. For good operation, the velocity of the gas should be reduced to a maximum of 2 fps. The bottoms of the chambers should be provided with dump plates through which the collected dust can be removed. Because these chambers are not effective in removing the finer dust particles they have been practically superseded by smaller and less costly devices.

Dust and Cinder Traps

Various types of traps have been devised. In general they all depend upon breaking the gas up into thin strata and subjecting those thin strata to several abrupt changes in direction. The dust is thrown out of the gas stream into specially shaped pockets or impinged against a roughened surface. The trapping pockets are drained into a hopper below with a small quantity of gas and the dust settles out by gravity due to the low velocity in the hopper. In the roughened surface type, various

sections of the trap are closed off at intervals by means of dampers and the dust is shaken off the roughened surface into a hopper below.

These devices work very well in catching large size dust and cinders and trap much of the fine dust. They have been used most extensively on stoker-fired installations. They have the advantage of low pressure drop, relatively small space requirements, and low first cost.

Centrifugal Catchers

Centrifugal catchers obtain separation by projecting the particles tangentially out of the gas stream. The effectiveness of this type of catcher varies directly as the specific weight of the dust and as the square of the tangential velocity, and inversely as the radius of rotation.

Electrostatic Precipitators

Electrostatic precipitators are used for catching fine dust. These precipitators consist of dust-tight chambers in which are suspended reinforced concrete slabs on about 10-in. centers. Between the slabs are suspended bare metal rods. High-voltage unidirectional current is applied to the reinforcing rods in the concrete slabs acting as positive electrodes, the bare rods acting as negative electrodes. The dust-laden gas flows horizontally through the precipitator and the dust particles migrate toward the concrete slabs to which they adhere and then fall or are scraped off into the dust hoppers below.

Gas Scrubbers

Wet scrubbers have been used for many years for removing dust from gases. A number of different types of scrubbers are now being built for removing dust from boiler flue gases. One type depends upon saturating the gas and washing the dust out of suspension by a spray of water. For best results with this type, the water should be atomized into as fine a spray as possible.

Another type depends upon splitting the gas into thin strata and subjecting these strata to a number of abrupt changes in direction, throwing the dust against the wet surfaces. The main problem in developing a satisfactory wet dust catcher is to find suitable materials of construction that will resist the corrosive action of the wash water for a reasonable length of time.

Filters

Filters of many kinds have been used with variable success. The filter bags are made of cotton, wool or asbestos fabric.

One of the serious objections to all of these dust catchers is their relatively high cost of installation and maintenance, and space requirements.

Chapter 39

PHYSICAL DATA

Physical Units; Conversion Equations; Instruments for and Methods of Measurement; Water; Steam; Air.

MODERN engineering practice depends upon the correct application of basic principles already developed and established in such branches of physical science as mechanics, thermodynamics, hydraulics, physics and chemistry. In the United States the system of units in general use by engineers is known as the *foot-pound-second system*. The definitions of many common terms used in heating and ventilating work are given in Chapter 1.

PHYSICAL UNITS

Acceleration: $(a) = \frac{V}{t}$. Rate of change of velocity. Unit, one foot per second per second.

Acceleration Due to Gravity: (g). Rate of gain in velocity of a freely falling body; 32.174 fps per second, but usually taken as 32.2 fps per second. Unit, one foot per second per second.

Area: (A) = length × width. Unit, square foot or square inch. (See Table 1 for areas of circles).

Density: $(\rho$, rho$) = \frac{W}{V}$. Weight of a unit volume. Unit, one pound per cubic foot.

Force: $(F) = \frac{WV}{gt}$. The action on a body which tends to change its relative condition as to rest or motion. Unit, pound.

Length: $(L) = \frac{1}{2} at^2$. Unit, foot, which is 1/3 of the value of the standard U. S. yard, or 0.3048 meter. The symbol h is used for *height*.

Mass: $(m) = \frac{W}{g}$. The quantity of matter, in pounds, to which the unit of force (one pound) will give an acceleration of one foot per second per second. Unit, slug.

Mechanical Equivalent of Heat: (J) = 1 Btu = 777.5 ft-lb.

Power: $(P) = \frac{W}{t}$. The rate of performing work. Unit, horsepower. One horsepower is 550 ft-lb of work per second, or 33,000 ft-lb per minute.

Specific Gravity: Ratio of the weight of a body to the weight of an equal volume of water at some standard temperature, usually 39.2 F. (See Table 2).

Specific Volume: $(v) = \frac{1}{\rho} = \frac{W}{V}$. Volume per unit weight. Unit, one cubic foot per pound.

Time: (t). Unit, second, which is 1/86,400 part of a mean solar day. Time is also expressed in minutes and hours.

Velocity: $(V) = at = \frac{L}{t}$. Rate of motion of a body. Unit, one foot per second.

TABLE 1. CIRCUMFERENCES AND AREAS OF CIRCLES

DIAMETER IN INCHES	AREA		CIRCUMFERENCE		DIAMETER IN INCHES	AREA		CIRCUMFERENCE	
	Sq. In.	Sq. Ft.	Inches	Feet		Sq. In.	Sq. Ft.	Inches	Feet
1/4	0.049	0.0003	0.785	0.0652	28	615.8	4.276	87.97	7.330
1/3	0.196	0.0014	1.571	0.1309	28 1/2	637.9	4.430	89.54	7.462
3/4	0.442	0.0031	2.356	0.1964	29	660.52	4.587	91.11	7.592
1	0.785	0.0054	3.142	0.2618	29 1/2	683.5	4.747	92.63	7.725
1 1/4	1.227	0.0085	3.927	0.3273	30	706.8	4.909	94.25	7.854
1 1/2	1.767	0.0123	4.712	0.3927	31	754.8	5.241	97.39	8.116
1 3/4	2.405	0.0167	5.498	0.4582	32	804.3	5.585	100.5	8.378
2	3.142	0.0218	6.283	0.5236	33	855.3	5.940	103.7	8.639
2 1/4	3.976	0.0276	7.069	0.5891	34	907.9	6.305	106.8	8.901
2 1/2	4.909	0.0341	7.854	0.6546	35	962.1	6.681	109.9	9.163
2 3/4	5.939	0.0412	8.639	0.7200	36	1018.0	7.069	113.1	9.425
3	7.069	0.0491	9.425	0.7854	37	1075.0	7.467	116.2	9.686
3 1/4	8.296	0.0576	10.21	0.8510	38	1134.0	7.876	119.4	9.948
3 1/2	9.621	0.0668	10.99	0.9160	39	1195.0	8.296	122.5	10.21
3 3/4	11.04	0.0767	11.78	0.9818	40	1256.0	8.727	125.6	10.47
4	12.57	0.0873	12.57	1.047	41	1320.0	9.168	128.8	10.73
4 1/4	14.19	0.0986	13.35	1.113	42	1385.0	9.621	131.9	10.99
4 1/2	15.90	0.1104	14.14	1.178	43	1452.0	10.08	135.1	11.26
4 3/4	17.72	0.1231	14.92	1.243	44	1521.0	10.56	138.2	11.52
5	19.64	0.1364	15.71	1.309	45	1590.0	11.04	141.4	11.78
5 1/4	21.65	0.1504	16.49	1.374	46	1662.0	11.54	144.5	12.04
5 1/2	23.76	0.1650	17.28	1.440	47	1735.0	12.05	147.7	12.30
5 3/4	25.97	0.1840	18.06	1.505	48	1810.0	12.51	150.8	12.57
6	28.27	0.1964	18.85	1.571	49	1886.0	13.09	153.9	12.83
6 1/4	30.68	0.2131	19.64	1.637	50	1963.0	13.64	157.1	13.09
6 1/2	33.18	0.2304	20.42	1.702	51	2043.0	14.19	160.2	13.35
6 3/4	35.79	0.2486	21.21	1.768	52	2124.0	14.75	163.4	13.61
7	38.49	0.2673	21.99	1.833	53	2206.0	15.32	166.5	13.88
7 1/4	41.28	0.2867	22.78	1.899	54	2290.0	15.90	169.6	14.14
7 1/2	44.18	0.3068	23.56	1.964	55	2376.0	16.50	172.8	14.40
7 3/4	47.17	0.3276	24.35	2.029	56	2463.0	17.10	175.9	14.66
8	50.27	0.3491	25.13	2.094	57	2552.0	17.72	179.1	14.92
8 1/4	53.46	0.3713	25.92	2.160	58	2642.0	18.35	182.2	15.18
8 1/2	56.75	0.3942	26.70	2.225	59	2734.0	18.99	185.4	15.45
8 3/4	60.13	0.4175	27.49	2.291	60	2827.0	19.63	188.5	15.71
9	63.62	0.4418	28.27	2.356	61	2922.0	20.29	191.6	15.97
9 1/4	67.20	0.4668	29.06	2.422	62	3019.0	20.97	194.8	16.23
9 1/2	70.88	0.4923	29.85	2.488	63	3117.0	21.65	197.9	16.49
9 3/4	74.66	0.5185	30.63	2.553	64	3217.0	22.34	201.1	16.76
10	78.54	0.5454	31.42	2.618	65	3318.0	23.04	204.2	17.02
10 1/2	86.59	0.6010	32.99	2.750	66	3421.0	23.76	207.3	17.28
11	95.03	0.6600	34.56	2.880	67	3526.0	24.48	210.5	17.54
11 1/2	103.9	0.7215	36.13	3.011	68	3632.0	25.22	213.6	17.80
12	113.1	0.7854	37.70	3.142	69	3739.0	25.97	216.8	18.06
12 1/2	122.7	0.8520	39.27	3.273	70	3848.0	26.73	219.9	18.33
13	132.7	0.9218	40.84	3.403	71	3959.0	27.49	223.1	18.59
13 1/2	143.1	0.9937	42.41	3.535	72	4072.0	28.27	226.2	18.85
14	153.9	1.069	43.98	3.665	73	4185.0	29.07	229.3	19.11
14 1/2	165.1	1.146	45.55	3.796	74	4301.0	29.87	232.5	19.37
15	176.7	1.227	47.12	3.927	75	4418.0	30.68	235.6	19.63
15 1/2	188.7	1.310	48.69	4.058	76	4536.0	31.50	238.8	19.90
16	201.1	1.396	50.27	4.189	77	4657.0	32.34	241.9	20.16
16 1/2	213.8	1.485	51.84	4.321	78	4778.0	33.18	245.0	20.42
17	226.9	1.576	53.41	4.451	79	4902.0	34.04	248.2	20.68
17 1/2	240.5	1.670	54.98	4.582	80	5027.0	34.91	251.3	20.94
18	254.5	1.767	56.55	4.712	81	5153.0	35.78	254.5	21.21
18 1/2	268.8	1.867	58.12	4.845	82	5281.0	36.67	257.6	21.47
19	283.5	1.969	59.69	4.974	83	5411.0	37.57	260.8	21.73
19 1/2	298.6	2.074	61.26	5.105	84	5542.0	38.48	263.9	21.99
20	314.2	2.182	62.83	5.236	85	5675.0	39.41	267.0	22.25
20 1/2	330.1	2.293	64.40	5.367	86	5809.0	40.34	270.2	22.51
21	346.4	2.405	65.97	5.498	87	5945.0	41.28	273.3	22.78
21 1/2	361.1	2.508	67.54	5.629	88	6082.0	42.24	276.5	23.04
22	380.1	2.640	69.12	5.760	89	6221.0	43.20	279.6	23.30
22 1/2	397.6	2.761	70.69	5.891	90	6362.0	44.18	282.7	23.56
23	415.5	2.885	72.26	6.021	91	6504.0	45.17	285.9	23.82
23 1/2	433.7	3.012	73.83	6.153	92	6648.0	46.16	289.0	24.09
24	452.4	3.142	75.40	6.283	93	6793.0	47.17	292.2	24.35
24 1/2	471.4	3.274	76.97	6.415	94	6940.0	48.19	295.3	24.61
25	490.9	3.409	78.54	6.545	95	7088.0	49.22	298.4	24.87
25 1/2	510.7	3.547	80.11	6.676	96	7238.0	50.27	301.6	25.13
26	530.9	3.687	81.68	6.807	97	7390.0	51.32	304.7	25.39
26 1/2	551.6	3.832	83.25	6.938	98	7543.0	52.38	307.9	25.66
27	572.6	3.976	84.82	7.069	99	7698.0	53.46	311.0	25.92
27 1/2	593.9	4.125	86.39	7.199	100	7854.0	54.54	314.2	26.18

Volume: $(V) = A \times L$. Unit, cubic foot.
Weight: (W) Unit, pound, which is 7000 grains avoirdupois, or 453.6 grams.

CONVERSION EQUATIONS

Temperature

Fahrenheit degrees = 9/5 centigrade degrees + 32.

Centigrade degrees = 5/9 (Fahrenheit degrees − 32).

Absolute temperature, expressed in Fahrenheit degrees = Fahrenheit degrees + 459.6. In heating and ventilating work, 460 is usually used.

Absolute temperature, expressed in centigrade degrees = centigrade degrees + 273.1.

Power, Work, Etc.

1 ton refrigeration	= 199.038 Btu per minute
1 Btu	= 777.6 ft-lb = 0.293 watt-hours = 252.02 mean calories
1 watt hour	= 2,655.2 ft-lb = 3.415 Btu = 3600 joules = 860.648 mean calories
1 mean calorie	= 0.003968 Btu = 3.085 ft-lb = 0.0011619 watt-hours
1 kilowatt (1000 watts)	= 1.3405 horsepower = 56.92 Btu per minute = 44,252.7 ft-lb per minute
1 horsepower	= 0.746 kilowatt = 42.44 Btu per minute = 33,000 ft-lb per minute = 550 ft-lb per second
1 boiler horsepower	= 33,523.7 Btu per hour

Weight and Volume

1 gal (U. S.)	= 231 cu in. = 0.13368 cu ft
1 British or Imperial gallon	= 277.274 cu in.
1 cu ft	= 7.4805 gal = 1728 cu in.
1 cu ft water at 60 F	= 62.37 lb
1 cu ft water at 212 F	= 59.76 lb
1 gal water at 60 F	= 8.34 lb
1 gal water at 212 F	= 7.99 lb
1 lb (avdp)	= 16 oz = 7000 grains
1 bushel	= 1.244 cu ft
1 short ton	= 2000 lb
1 long ton	= 2240 lb

TABLE 2. SPECIFIC GRAVITY OF LIQUIDS (WATER = 1)

Alcohol	0.789	Oils (mineral lubricants)	0.90 –0.93
Draft gage oil (ellison)	0.834	Turpentine	0.861–0.867
Gasoline	0.66–0.67	Water, 39.1 deg. fahr.	1.000
Hydrochloric acid	1.20	Water 212 deg. fahr.	0.958
Kerosene	0.75–0.86	Water (ice)	0.88 –0.92
Nitric acid	1.50	Water (fresh fallen snow)	0.125
Sulphuric acid	1.80	Water (sea)	1.02 –1.03

Pressure

1 lb per square inch	=	144 lb per square foot 2.0416 in. mercury at 64 F 2.309 ft water at 62 F 27.71 in. water at 62 F
1 oz per square inch	=	0.1276 in. mercury at 62 F 1.732 in. water at 62 F
1 atmosphere	=	14.7 lb per square inch 2116.3 lb per square foot 33.974 ft water at 62 F 30 in. mercury at 62 F 29.921 in. mercury at 32 F
1 in. water at 62 F	=	0.03609 lb per square inch 0.5774 oz per square inch 5.196 lb per square foot
1 ft water at 62 F	=	0.433 lb per square inch 62.355 lb per square foot
1 in. mercury at 62 F	=	0.491 lb per square inch 7.86 oz per square inch 1.131 ft water at 62 F 13.57 in. water at 62 F

Metric Units

1 cm	= 0.3937 in.
1 in.	= 2.54 cm
1 m	= 3.281 ft
1 ft	= 0.3048 m
1 sq cm	= 0.155 sq in.
1 sq in.	= 6.45 sq cm
1 sq m	= 10.765 sq ft
1 sq ft	= 0.0929 sq m
1 cu cm	= 0.061 cu in.
1 cu in.	= 16.39 cu cm
1 cu m	= 35.32 cu ft
1 cu ft	= 0.0283 cu m
1 liter	= 1000 cu cm = 0.264 gal
1 kg	= 2.2046 lb
1 lb	= 0.4536 kg
1 metric ton	= 2205 lb (avdp)
1 gram	= 980.59 dynes = 0.002205 lb
1 kilometer per hour	= 0.6214 mph
1 gram per square centimeter	= 0.2896 in. mercury, at 0 deg C 0.394 in. water, at 15 C
1 kg per square centimeter (metric atmosphere)	= 14.22 lb per square inch
1 gram per cubic centimeter	= 0.03614 lb per cubic inch 62.43 lb per cubic foot
1 dyne	= 0.00007233 poundals
1 joule	= 10,000,000 ergs 0.73767 ft-lb
1 metric horsepower (force de cheval)	= 75 kg-m per second 0.986 hp (U. S.)
1 kilogram-calorie (large calorie)	= 1000 gram-calories (small calorie) 3.97 Btu
1 kilogram-calorie per kilogram	= 1.8 Btu per pound

1 gram-calorie per square centimeter	= 3.687 Btu per square foot
1 gram-calorie per square centimeter per centimeter	= 1.451 Btu per square foot per inch
1 gram-calorie per second per square centimeter for a temperature graduation of 1 deg C per centimeter	= 2903 Btu per hour per square foot for a temperature graduation of 1 deg F per inch of thickness.

INSTRUMENTS FOR AND METHODS OF MEASUREMENT

Pressure

The pressure of the atmosphere is usually measured by a *mecurial barometer* which, in its simplest form, consists of a glass tube about three feet long, closed at the upper end, filled with mercury and inverted in a shallow bath of mercury. The atmosphere, pressing on the exposed top of the mercury in the cistern, supports a column of mercury in the tube to a height of about 30 in. Readings are taken of the height of the column between the levels of mercury in the tube and in the cistern. The pressure of the atmosphere is the same as the pressure exerted by this supported column of mercury, and in pounds per square inch, is equal to its height times 0.491 which is the weight in pounds of one cubic inch of mercury. At latitude 45 deg and sea level, and at a temperature of 32 F, the atmosphere will support a column of mercury 29.921 in. in height. This pressure of 14.7 lb per square inch, derived by multiplying 29.921 by 0.491, is called *standard* or *normal barometric pressure.*

Pressure is usually measured by means of gages which indicate the difference between the pressure being measured and the pressure of the atmosphere at the same time and place. A gage which indicates higher pressures than that exerted by the atmosphere is known as a *pressure gage*, and a gage which indicates pressures lower than atmospheric pressure is known as a *vacuum gage.* The most common type of these gages contains a flexible hollow brass tube of oval cross section, known as a Bourdon tube. When subjected to pressure, this tube tends to straighten out, and the amount of pressure is measured by a pointer motivated by this straightening and reading against a suitably graduated scale.

A gage which indicates pressures slightly above or below that of the atmosphere is known as a *draft gage.* It is essentially a U-tube containing either water, kerosene, alcohol or mercury, with one leg exposed to the air and the other connected to the point where a pressure is to be determined. When the pressure being read is equal to that of the atmosphere, the level of the liquid in the legs will be the same, indicating a zero gage pressure. When a pressure is applied to a leg, one side will fall an amount and the other will rise an equal amount. The difference in height between the two liquid levels indicates the pressure expressed in inches of the liquid used in the gage.

Temperature

In engineering work, *mercurial thermometers* are largely employed to measure the intensity of heat. These depend on the uniform expansion of mercury to indicate changes in temperature. An amount of mercury held in a sealed tube with a bulb at one end, will rise to one definite level when immersed in melting ice, and to another definite level when immersed in boiling water. These two points are marked, and the space between them

is divided into a number of equal portions, each of which is called a degree. In the Fahrenheit scale, there are 180 degrees thus obtained, while the centigrade scale has 100 and the Reaumur has 80. Like divisions are marked off on the column above and below these two determined points in order that a greater range of temperature may be read.

For temperatures above 500 F various types of *pyrometers* are employed. The *mercurial pyrometer* is a thermometer with an inert gas, such as

TABLE 3. THERMAL PROPERTIES OF WATER[a]

Temp., °F	Sat. Pressure, Lb. per Sq. In.	Volume, Cu. Ft. per Lb.	Weight, Lb. per Cu. Ft.	Specific Heat	Temp., °F	Sat. Pressure, Lb. per Sq. In.	Volume, Cu. Ft. per Lb.	Weight, Lb. per Cu. Ft.	Specific Heat
20	0.050	0.01603	62.37	1.0210	370	173.2	0.01829	54.66	1.053
30	0.081	0.01602	62.42	1.0104	380	195.6	0.01843	54.25	1.057
40	0.122	0.01602	62.43	1.0048	390	220.1	0.01857	53.84	1.062
50	0.178	0.01602	62.42	1.0015	400	247	0.0187	53.42	1.067
60	0.256	0.01603	62.37	0.9995	410	276	0.0189	52.99	1.072
70	0.363	0.01605	62.30	0.9982	420	308	0.0190	52.55	1.078
80	0.507	0.01607	62.22	0.9975	430	343	0.0192	52.11	1.083
90	0.698	0.01610	62.11	0.9971	440	381	0.0194	51.66	1.089
100	0.949	0.01613	62.00	0.9970	450	422	0.0195	51.2	1.095
110	1.274	0.01616	61.86	0.9971	460	466	0.0197	50.7	1.101
120	1.692	0.01620	61.71	0.9974	470	514	0.0199	50.2	1.107
130	2.221	0.01625	61.55	0.9978	480	565	0.0201	49.7	1.114
140	2.887	0.01629	61.38	0.9984	490	620	0.0203	49.2	1.121
150	3.716	0.01634	61.20	0.9990	500	679	0.0205	48.7	1.130
160	4.739	0.01639	61.00	0.9998	510	743	0.0208	48.2	1.140
170	5.99	0.01645	60.80	1.0007	520	810	0.0210	47.6	1.151
180	7.51	0.01651	60.58	1.0017	530	883	0.0212	47.1	1.164
190	9.34	0.01657	60.36	1.0028	540	960	0.0215	46.5	1.181
200	11.53	0.01663	60.12	1.0039	550	1043	0.0218	45.9	1.200
210	14.12	0.01670	59.88	1.0052	560	1131	0.0221	45.2	1.222
220	17.19	0.01677	59.63	1.0068	570	1224	0.0224	44.6	1.249
230	20.78	0.01684	59.37	1.0085	580	1323	0.0227	44.0	1.281
240	24.97	0.01692	59.11	1.0104	590	1429	0.0231	43.3	1.318
250	29.83	0.01700	58.83	1.0125	600	1540	0.0235	42.6	1.362
260	35.44	0.01708	58.55	1.0148	610	1659	0.024	41.8	1.415
270	41.87	0.01716	58.26	1.0173	620	1784	0.024	41.0	1.479
280	49.22	0.01725	57.96	1.020	630	1917	0.025	40.2	1.559
290	57.57	0.01735	57.65	1.023	640	2057	0.025	39.2	1.661
300	67.02	0.01745	57.32	1.026	650	2205	0.026	38.2	1.793
310	77.68	0.01755	56.98	1.029	660	2361	0.027	37.2	———
320	89.65	0.01766	56.62	1.033	670	2526	0.028	36.0	———
330	103.0	0.01778	56.24	1.036	680	2699	0.029	34.5	———
340	118.0	0.01790	55.85	1.040	690	2882	0.031	32.6	———
350	134.6	0.01803	55.46	1.044	700	3075	0.034	29.7	———
360	153.0	0.01816	55.06	1.048	706.3	3200	0.048	20.9	———

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nitrogen or carbon dioxide, above the mercury column to prevent the mercury from boiling. The *expansion pyrometer* is based on the difference in expansion of two substances under the same heat conditions. It can be used for temperatures up to 1500 F. It is commonly made of a brass rod enclosed in an iron pipe, with one end of the rod attached to a cap at the end of the pipe and the other connected by a multiplying gear to a pointer moving around a graduated dial.

Thermo-electric pyrometers may be used to measure temperatures up to 2900 F and are based on the principle that when wires of two different metals are joined with two junctions which are held at different tempera-

TABLE 4. PROPERTIES OF SATURATED STEAM[a]

Absolute Pressure, Lb. per Sq. In.	Temperature, Deg. Fahr.	Volume, Cu. Ft. per Lb.	Weight, Lb. per Cu. Ft.	Heat Content in B.t.u.		Latent Heat in B.t.u.		Entropy		
				of Liquid	of Vapor	of Vaporisation	Internal	of Liquid	of Vaporisation	of Vapor
p	t	v_{fg}	$\frac{1}{v_{fg}}$	h_f	h_g	h_{fg}	u	s_f	s_{fg}	s_g
1	101.76	333.3	0.00300	69.76	1105.4	1035.6	973.9	0.1327	1.8448	1.9775
2	126.10	173.6	0.00576	94.02	1116.2	1022.2	957.9	0.1750	1.7452	1.9203
3	141.49	118.7	0.00843	109.38	1122.9	1013.5	947.6	0.2009	1.6862	1.8871
4	152.99	90.6	0.01104	120.9	1127.9	1007.0	939.9	0.2199	1.6438	1.8637
5	162.25	73.5	0.01360	130.1	1131.7	1001.6	933.6	0.2348	1.6107	1.8456
6	170.07	62.0	0.01614	137.9	1135.0	997.1	928.2	0.2473	1.5835	1.8308
7	176.85	53.7	0.01864	144.7	1137.8	993.1	923.6	0.2581	1.5603	1.8184
8	182.87	47.35	0.02112	150.8	1140.3	989.5	919.4	0.2675	1.5402	1.8077
9	188.28	42.41	0.02358	156.2	1142.5	986.3	915.6	0.2759	1.5223	1.7982
10	193.21	38.43	0.02602	161.1	1144.4	983.3	912.2	0.2835	1.5062	1.7897
11	197.75	35.16	0.02844	165.7	1146.2	980.5	909.0	0.2905	1.4916	1.7821
12	201.96	32.41	0.03086	169.9	1147.9	978.0	906.0	0.2969	1.4783	1.7752
13	205.88	30.07	0.03326	173.8	1149.4	975.6	903.2	0.3028	1.4659	1.7687
14	209.56	28.06	0.03564	177.5	1150.8	973.3	900.6	0.3083	1.4545	1.7628
14.7	212.0	26.81	0.03730	180.0	1151.7	971.7	898.8	0.3120	1.4469	1.7589
16	216.3	24.76	0.04038	184.3	1153.4	969.1	895.8	0.3184	1.4337	1.7521
18	222.4	22.18	0.04508	190.5	1155.7	965.2	891.4	0.3274	1.4153	1.7427
20	228.0	20.10	0.04976	196.0	1157.7	961.7	887.3	0.3356	1.3987	1.7343
22	233.1	18.38	0.0544	201.2	1159.6	958.4	883.6	0.3430	1.3837	1.7267
24	237.8	16.95	0.0590	206.0	1161.3	955.3	880.1	0.3499	1.3698	1.7197
26	242.2	15.73	0.0636	210.4	1162.8	952.4	876.8	0.3563	1.3570	1.7133
28	246.4	14.67	0.0681	214.6	1164.3	949.7	873.7	0.3622	1.3452	1.7074
30	250.3	13.76	0.0727	218.6	1165.7	947.1	870.7	0.3679	1.3340	1.7019
32	254.0	12.95	0.0772	222.4	1166.9	944.6	867.9	0.3731	1.3236	1.6967
34	257.6	12.24	0.0818	225.9	1168.1	942.2	865.2	0.3781	1.3137	1.6918
36	260.9	11.60	0.0862	229.4	1169.2	939.9	862.7	0.3829	1.3044	1.6873
38	264.2	11.03	0.0907	232.6	1170.3	937.7	860.2	0.3874	1.2956	1.6830
40	267.2	10.51	0.0951	235.8	1171.3	935.5	857.8	0.3917	1.2871	1.6788
42	270.2	10.04	0.0996	238.8	1172.2	933.5	855.5	0.3958	1.2791	1.6749
44	273.0	9.61	0.1040	241.7	1173.2	931.5	853.3	0.3998	1.2714	1.6712
46	275.8	9.22	0.1085	244.5	1174.0	929.6	851.2	0.4036	1.2640	1.6676
48	278.4	8.86	0.1129	247.2	1174.8	927.7	849.1	0.4072	1.2570	1.6642
50	281.0	8.53	0.1173	249.8	1175.6	925.9	847.1	0.4108	1.2501	1.6609
52	283.5	8.22	0.1217	252.3	1176.4	924.1	845.1	0.4142	1.2436	1.6577
54	285.9	7.93	0.1261	254.7	1177.1	922.4	843.2	0.4174	1.2373	1.6547
56	288.2	7.67	0.1304	257.1	1177.8	920.7	841.4	0.4206	1.2311	1.6517
58	290.5	7.42	0.1348	259.5	1178.5	919.0	839.5	0.4237	1.2252	1.6489
60	292.7	7.18	0.1392	261.7	1179.1	917.4	837.8	0.4267	1.2195	1.6462
62	294.9	6.97	0.1435	263.9	1179.7	915.8	836.0	0.4296	1.2139	1.6435
64	296.9	6.76	0.1479	266.1	1180.3	914.3	834.3	0.4324	1.2085	1.6409
66	299.0	6.57	0.1522	268.2	1180.9	912.7	832.7	0.4352	1.2032	1.6384
68	301.0	6.39	0.1566	270.2	1181.5	911.2	831.1	0.4379	1.1981	1.6360
70	302.9	6.22	0.1609	272.2	1182.0	909.8	829.5	0.4405	1.1931	1.6336
72	304.8	6.05	0.1652	274.2	1182.5	908.3	827.9	0.4431	1.1883	1.6313
74	306.7	5.90	0.1695	276.1	1183.0	906.9	826.4	0.4456	1.1835	1.6291
76	308.5	5.75	0.1738	278.0	1183.5	905.5	824.9	0.4480	1.1789	1.6269
78	310.3	5.61	0.1781	279.8	1184.0	904.2	823.4	0.4504	1.1744	1.6248
80	312.0	5.48	0.1824	281.6	1184.4	902.8	821.9	0.4527	1.1700	1.6227
82	313.7	5.35	0.1868	283.4	1184.9	901.5	820.5	0.4550	1.1657	1.6207
84	315.4	5.23	0.1910	285.1	1185.3	900.2	819.1	0.4572	1.1615	1.6187
86	317.1	5.12	0.1953	286.8	1185.7	898.9	817.7	0.4594	1.1574	1.6168
88	318.7	5.01	0.1996	288.5	1186.1	897.7	816.3	0.4615	1.1534	1.6149
90	320.3	4.905	0.2039	290.1	1186.5	896.4	815.0	0.4636	1.1495	1.6131
92	321.8	4.805	0.2081	291.7	1186.9	895.2	813.7	0.4657	1.1456	1.6113
94	323.3	4.709	0.2124	293.3	1187.3	894.0	812.4	0.4677	1.1419	1.6096
96	324.8	4.617	0.2166	294.8	1187.7	892.8	811.1	0.4697	1.1381	1.6079
98	326.3	4.528	0.2209	296.4	1188.0	891.6	809.8	0.4717	1.1345	1.6062
100	327.8	4.442	0.2251	297.9	1188.4	890.5	808.6	0.4736	1.1309	1.6045
102	329.2	4.359	0.2294	299.4	1188.7	889.3	807.4	0.4755	1.1274	1.6028
104	330.7	4.279	0.2337	300.9	1189.0	888.2	806.1	0.4773	1.1239	1.6012
106	332.0	4.202	0.2380	302.3	1189.4	887.1	804.9	0.4791	1.1205	1.5996
108	333.4	4.128	0.2422	303.7	1189.7	885.9	803.8	0.4809	1.1172	1.5981
110	334.8	4.057	0.2465	305.1	1190.0	884.8	802.6	0.4827	1.1138	1.5965
112	336.1	3.988	0.2508	306.5	1190.3	883.7	801.4	0.4844	1.1106	1.5950
114	337.4	3.921	0.2550	307.9	1190.6	882.7	800.3	0.4861	1.1074	1.5935
116	338.7	3.857	0.2593	309.2	1190.8	881.6	799.2	0.4878	1.1043	1.5921
118	340.0	3.795	0.2635	310.6	1191.1	880.6	798.0	0.4895	1.1012	1.5907

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tures, an electromotive force will be set up between these junctions. Its amount will depend on the composition of the wires and the difference in temperature. When one junction is held at a constant temperature, the electromotive force will be dependent on the temperature of the other junction, and if a delicate galvanometer of high resistance be connected to the *thermocouple*, as it is called, the deflection of the needle will indicate the temperature of this other junction. Instruments for the measurement of high temperatures are calibrated with the aid of the known melting points of pure metals.

TABLE. 4 PROPERTIES OF SATURATED STEAM[a] (Continued)

Absolute Pressure, Lb. per Sq. In.	Temperature, Deg. Fahr.	Volume, Cu. Ft. per Lb.	Weight, Lb. per Cu. Ft.	Heat Content in B.t.u.		Latent Heat in B.t.u.		Entropy		
				of Liquid	of Vapor	of Vaporization	Internal	of Liquid	of Vaporization	of Vapor
p	t	v_{fg}	$\frac{1}{v_{fg}}$	h_f	h_g	h_{fg}	u	s_f	s_{fg}	s_g
120	341.3	3.735	0.2678	311.9	1191.4	879.5	796.9	0.4911	1.0982	1.5893
122	342.5	3.676	0.2720	313.2	1191.6	878.5	795.8	0.4927	1.0952	1.5879
124	343.7	3.620	0.2762	314.4	1191.9	877.5	794.8	0.4943	1.0922	1.5865
126	345.0	3.566	0.2805	315.7	1192.1	876.4	793.7	0.4958	1.0894	1.5852
128	346.2	3.513	0.2847	316.9	1192.4	875.4	792.6	0.4974	1.0865	1.5838
130	347.4	3.461	0.2889	318.2	1192.6	874.4	791.6	0.4989	1.0836	1.5825
132	348.5	3.412	0.2931	319.4	1192.9	873.5	790.5	0.5004	1.0808	1.5812
134	349.7	3.363	0.2973	320.6	1193.1	872.5	789.5	0.5019	1.0781	1.5800
136	350.8	3.316	0.3016	321.8	1193.3	871.5	788.5	0.5033	1.0754	1.5787
138	352.0	3.270	0.3058	323.0	1193.5	870.5	787.4	0.5048	1.0727	1.5775
140	353.1	3.226	0.3100	324.2	1193.7	869.6	786.4	0.5062	1.0700	1.5762
142	354.2	3.182	0.3142	325.3	1193.9	868.6	785.4	0.5076	1.0674	1.5750
144	355.3	3.140	0.3184	326.5	1194.1	867.7	784.5	0.5090	1.0648	1.5738
146	356.3	3.099	0.3227	327.6	1194.3	866.8	783.5	0.5104	1.0623	1.5727
148	357.4	3.059	0.3269	328.7	1194.5	865.8	782.5	0.5117	1.0598	1.5715
150	358.5	3.020	0.3311	329.8	1194.7	864.9	781.6	0.5131	1.0573	1.5704
152	359.5	2.982	0.3353	330.9	1194.9	864.0	780.6	0.5144	1.0548	1.5692
154	360.5	2.945	0.3396	332.0	1195.1	863.1	779.7	0.5157	1.0524	1.5681
156	361.6	2.909	0.3438	333.1	1195.3	862.3	778.7	0.5170	1.0500	1.5670
158	362.6	2.874	0.3480	334.1	1195.5	861.4	777.8	0.5183	1.0476	1.5659
160	363.6	2.839	0.3522	335.2	1195.7	860.5	776.9	0.5196	1.0453	1.5649
162	364.6	2.806	0.3564	336.2	1195.8	859.6	776.0	0.5209	1.0429	1.5638
164	365.6	2.773	0.3606	337.3	1196.0	858.7	775.1	0.5221	1.0406	1.5627
166	366.5	2.741	0.3648	338.3	1196.2	857.9	774.2	0.5233	1.0384	1.5617
168	367.5	2.710	0.3691	339.3	1196.3	857.0	773.3	0.5245	1.0361	1.5607
170	368.5	2.679	0.3733	340.3	1196.5	856.2	772.4	0.5258	1.0339	1.5597
172	369.4	2.649	0.3775	341.3	1196.6	855.3	771.5	0.5270	1.0317	1.5587
174	370.4	2.620	0.3817	342.3	1196.8	854.5	770.6	0.5281	1.0295	1.5577
176	371.3	2.591	0.3859	343.3	1196.9	853.6	769.8	0.5293	1.0274	1.5567
178	372.2	2.563	0.3901	344.3	1197.1	852.8	768.9	0.5305	1.0252	1.5557
180	373.1	2.536	0.3943	345.2	1197.2	852.0	768.0	0.5316	1.0231	1.5547
182	374.0	2.509	0.3985	346.2	1197.4	851.2	767.2	0.5328	1.0210	1.5538
184	374.9	2.483	0.4027	347.1	1197.5	850.4	766.4	0.5339	1.0189	1.5528
186	375.8	2.457	0.4069	348.1	1197.6	849.5	765.5	0.5350	1.0169	1.5519
188	376.7	2.432	0.4111	349.0	1197.8	848.7	764.7	0.5361	1.0148	1.5509
190	377.6	2.408	0.4154	350.0	1197.9	847.9	763.9	0.5372	1.0128	1.5500
192	378.5	2.383	0.4196	350.9	1198.0	847.1	763.0	0.5383	1.0108	1.5491
194	379.3	2.360	0.4238	351.8	1198.1	846.3	762.2	0.5394	1.0089	1.5482
196	380.2	2.337	0.4280	352.7	1198.2	845.6	761.4	0.5404	1.0069	1.5473
198	381.0	2.314	0.4322	353.6	1198.4	844.8	760.6	0.5415	1.0049	1.5464
200	381.9	2.292	0.4364	354.5	1198.5	844.0	759.8	0.5426	1.0030	1.5456
202	382.7	2.270	0.4406	355.4	1198.6	843.2	759.0	0.5436	1.0011	1.5447
204	383.5	2.248	0.4448	356.2	1198.7	842.5	758.2	0.5446	0.9992	1.5438
206	384.4	2.227	0.4490	357.1	1198.8	841.7	757.4	0.5457	0.9973	1.5430
208	385.2	2.206	0.4532	358.0	1198.9	840.9	756.7	0.5467	0.9954	1.5421
210	386.0	2.186	0.457	358.8	1199.0	840.2	755.9	0.5477	0.9936	1.5413
212	386.8	2.166	0.462	359.7	1199.1	839.4	755.1	0.5487	0.9918	1.5405
214	387.6	2.147	0.466	360.5	1199.2	838.7	754.3	0.5497	0.9900	1.5396
216	388.4	2.128	0.470	361.4	1199.3	837.9	753.6	0.5507	0.9881	1.5388
218	389.2	2.109	0.474	362.2	1199.4	837.2	752.8	0.5516	0.9864	1.5380
220	390.0	2.090	0.478	363.0	1199.5	836.5	752.1	0.5526	0.9846	1.5372

[a]This table is abstracted by permission from *Properties of Steam and Ammonia*, by the late Prof. G. A. Goodenough.

In the measuring of room temperatures care must be exercised to prevent the results from being affected by the body heat of the observer, by drafts from doors, windows and other openings or by radiant heat from some local source such as a radiator, wall, etc. All thermometers should be mercury thermometers with engraved stems. The total graduations of the thermometers should be from 20 to 120 F, in one degree graduations. No ten degrees should occupy a space of less than one-half inch. The accuracy throughout the whole scale must be within one-half degree. The operator should take hold of the top and no part of the body, including the hand, should be nearer than 10 in. to the bulb. The thermometer should not be closer than 5 ft to any door, window, or other opening; should not be closer than 12 in. to any wall; and should be between 3 and 5 ft from the floor. A sling instrument should be used for extreme accuracy.

For measuring duct temperatures an angle-duct thermometer should be used, having a flange to bolt on the side of the duct, with the bulb extending into the duct at least 6 in.

Recording thermometers generally have considerable lag and should not be used for the taking of temperatures for testing, but rather for giving continuous records of the operation of the plant, as the charts will indicate any lack of attention on the part of those responsible for the operation of the plant.

Humidity

The sling psychrometer is the recognized standard instrument for determining humidities. In order to obtain accurate readings considerable skill is required on the part of the operator. The wicking must be clean, distilled water should be used, and the temperature of the water should be slightly above the wet-bulb temperature of the surrounding air.

The psychrometer should be swung rapidly and two or three observations should be made to see that the wet-bulb temperature has become stationary before the final reading is noted. Standard psychrometric tables should be used.

In taking humidity readings in ducts it is usually impracticable to use a sling psychrometer. For this work the stationary hygrodeik arranged for bolting on to the side of the duct, with two bulbs extending into the duct, will be found very convenient. Due to the velocity of the air passing over the bulbs within the duct an accurate reading will be secured, corresponding to that given by the sling psychrometer.

CO_2 Determinations

At ordinary concentrations carbon dioxide is not harmful. The amount of carbon dioxide in the air is a convenient index of the rate of air supply, and of the distribution of the air within large rooms. A high carbon dioxide concentration in parts of an occupied room may indicate air stagnation which can result in objectionable odors or in failure to remove local surplus heat.

The Petterson-Palmquist apparatus has been generally accepted as the standard device for the determination of carbon dioxide in air investigations. The principle involved is the measurement of a given volume of

air, the absorption of the contained carbon dioxide in a caustic potash solution, and the remeasurement of the volume of air at the original pressure in a finely graduated capillary tube, the difference in volume representing the absorbed carbon dioxide. (See Report of Committee on Standard Methods for Examination of Air, *American Public Health Association*, Vol. 7, No. 1; *American Journal of Public Health*, Jan., 1917).

Where field conditions are such that this apparatus may not be conveniently used, as in street cars, air samples may be collected in prepared bottles having rubber stoppers, and these may be subjected to laboratory analysis.

Dust

The Hill Dust Counter is a simple device with which to measure the number of very large particles of dust in the air, while more exact studies of dust may be made with the Konimeter, or with the Impinger. (See *Public Health Bulletin*, No. 144, 1925, U. S. Public Health Service).

Bacteria

The number of bacteria which are attached to heavy particles of dust or drops of moisture may be determined by the number of colonies that develop on a culture plate which has been exposed for two minutes. A standard 4-in. Petrie dish, with agar-agar for a media, is used for this purpose. The plates are incubated from 24 to 48 hours at a temperature of 98 F. At the end of this time the separate colonies have developed to a size which are easily counted. If an incubator is not available cultures may be grown at room temperatures (70 F) for a period of five days.

Volumetric Air Measurements

Volumetric air measurements must be made with skill and precision and great care must be exercised in securing the right conditions under which such measurements are made. There are two general methods in use for measuring air volumes, the first, by means of an anemometer, and the second, by means of a Pitot tube.

Anemometers and Pitot Tubes

When it is necessary to employ an anemometer for measuring air volume, the instrument must have been recently calibrated, and the greatest care must be exercised in methods of manipulation. The influence of obstructions at the register face, the distance from the register at which the anemometer is held and the great variation in velocities which exists over the area of most air discharge openings all combine to make an exact quantitative measurement of air by an anemometer a difficult matter.

For a further discussion of the measurement of air flow by means of the anemometer and Pitot tube, see Chapter 32.

Air Movement Determinations

Air movement is a vital factor in the prevention of stagnant areas and bodily discomfort. Where a determination of air movement is desirable the Kata-thermometer, as developed by Dr. Leonard Hill, of England, may be used. (See Chapter 32).

Air movement may be determined approximately by observation of the movement of a smoke cloud and the use of a stop watch; the smoke cloud being formed by means of an ammonium chloride cloud device, or by a smoke bomb. Carefully balanced gas balloons may also be used.

WATER

Composition of Water. Water is a chemical compound (H_2O) formed by the union of two volumes of hydrogen and one volume of oxygen, or two parts by weight of hydrogen and sixteen parts by weight of oxygen.

Density of Water. Water is at its greatest density at 39.2 F, and it expands when heated or cooled from this temperature. At 62 F a U. S. gallon of 231 cu in. of water weighs approximately 8⅓ lb, and a cubic foot of water is equal to 7.48 gal. The specific volume of water depends on the temperature and it is always the reciprocal of its specific density. (See Table 3).

Water Pressures. Pressures are often stated in feet or inches of water column. At 62 F, with h equal to the head in feet, the pressure of a column of water is $62.355h$ lb per square foot, or $0.433h$ lb per square inch. A column of water 2.309 ft (27.71 in.) high exerts a pressure of one pound per square inch at 62 F.

Boiling Point of Water. The boiling point of water varies with the pressure; it is lower at higher altitudes. A change in pressure will always be accompanied by a change in the boiling point, and there will be a corresponding change in the latent heat of evaporation.

Specific Heat. The specific heat of water, or the amount of heat (Btu) required to raise the temperature of one pound of water one degree Fahrenheit, varies with the temperature, but it is commonly assumed to be unity at all temperatures. Steam tables are based on exact values, however. The specific heat of ice at 32 F is 0.463 Btu per pound. The amount of heat required to raise one pound of water at 32 F through a known temperature interval depends on the average specific heat for the temperature range.

Sensible and Latent Heat. The heat necessary to raise the temperature of one pound of water from 32 F to the boiling point is known as the *heat of the liquid or sensible heat.* When more heat is added, the water begins to evaporate and expand at constant temperature until the water is entirely changed into steam. The heat thus added is known as the *latent heat of evaporation.*

STEAM

Steam is water vapor which exists in the vaporous condition because sufficient heat has been added to the water to supply the latent heat of evaporation and change the liquid into vapor. This change in state takes place at a definite and constant temperature which is determined solely by the pressure of the steam. The volume of a pound of steam is known as the specific volume and it decreases as the pressure increases. The reciprocal of this, or the weight of steam per cubic foot, is known as the density. (See Table 4).

Steam which is in contact with the water from which it was generated is

known as *saturated steam*. If it contains no actual water in the form of mist or priming, it is called *dry saturated steam*. If this be heated and the pressure maintained the same as when it was vaporized, its temperature will increase and it will become *superheated*, that is, its temperature will be higher than that of saturated steam at the same pressure. The relation between pressure and specific volume for dry saturated steam is given by the experimental equation (Goodenough) as:

$$pv^{1.6631} = 484.2 \qquad (1)$$

where

p = the pressure in pounds per square inch.
v = the specific volume.

The *total heat* of a dry saturated vapor for any pressure and temperature is the sum of the heat required to raise the temperature of one pound of the liquid from the freezing point to the given temperature and corresponding pressure plus the heat required entirely to vaporize it at this pressure.

Steam which is in contact with the water from which it was generated is called *wet saturated steam* if it contains more or less actual water in the form of mist or priming. The percentage of dry steam in a mixture of steam and water is known as the *quality* (x) of the steam. The total heat of wet vapor at any pressure and temperature is the sum of the heat required to raise the temperature of one pound of the liquid from the

TABLE 5. VELOCITIES OF DRY AIR IN FEET PER MINUTE (AT VARIOUS TEMPERATURES) CORRESPONDING TO VARIOUS VELOCITY PRESSURES IN OUNCES PER SQUARE INCH[a]

Barometric Pressure 29.921 In.

PRESSURE		TEMPERATURE, DEG. FAHR.									
Ounces	Inches	50°	60°	70°	80°	100°	150°	200°	300°	500°	550°
0.1	0.1734	1635	1653	1667	1683	1714	1788	1860	1996	2244	2410
0.2	0.3468	2313	2338	2358	2380	2424	2530	2632	2824	3174	3405
0.3	0.5202	2833	2864	2888	2915	2969	3098	3223	3458	3887	4175
0.4	0.6936	3272	3307	3335	3367	3428	3578	3722	3994	4489	4850
0.5	0.8670	3658	3698	3729	3765	3833	4000	4162	4466	5019	5395
0.6	1.0400	4007	4051	4085	4124	4199	4382	4559	4892	5498	5900
0.7	1.2140	4329	4375	4412	4454	4535	4733	4924	5283	5938	6380
0.8	1.3870	4626	4677	4716	4761	4848	5059	5263	5647	6347	6820
0.9	1.5605	4907	4960	5002	5050	5142	5366	5582	5990	6733	7250
1.0	1.7340	5172	5229	5273	5323	5420	5656	5884	6314	7098	7625
1.1	1.9073	5426	5485	5531	5584	5685	5933	6172	6623	7444	8000
1.2	2.0808	5664	5725	5774	5828	5935	6194	6443	6914	7772	8350
1.3	2.2540	5896	5960	6011	6068	6179	6448	6708	7198	8090	8700
1.4	2.4275	6120	6186	6238	6297	6412	6692	6962	7470	8396	9020
1.5	2.6010	6335	6404	6457	6520	6638	6928	7207	7733	8692	9345
1.6	2.7742	6543	6614	6670	6734	6856	7155	7444	7987	8977	9650
1.8	3.1210	6942	7017	7076	7143	7274	7591	7897	8473	9524	10220
2.0	3.4680	7315	7395	7457	7528	7665	8000	8322	8930	10037	10780
2.2	3.8145	7672	7755	7820	7894	8038	8462	8727	9364	10525	11300
2.4	4.1615	8012	8099	8168	8245	8396	8762	9115	9781	10995	11800
2.6	4.5080	8338	8429	8500	8581	8737	9118	9486	10179	11440	12280
2.8	4.8550	8654	8748	8822	8906	9068	9464	9845	10564	11873	12750
3.0	5.2020	8960	9057	9134	9220	9388	9798	10193	10938	12293	13200

[a]From *Fan Engineering*.

freezing point to the given temperature and corresponding pressure plus the heat required to vaporize the part x at this pressure.

AIR

Composition. Air is a mechanical mixture made up, by volume, of 20.91 per cent of oxygen and 79.09 per cent of nitrogen, or by weight, of 23.15 per cent of oxygen and 76.85 per cent of nitrogen. Air as found in nature always contains other constituents in varying amounts, such as carbon dioxide, ozone, water vapor, dust, bacteria, etc.

The *specific density* or weight per cubic foot of dry air decreases with an increase in temperature; and the specific volume, or volume per pound, increases with such increase. The *specific heat* of air at constant pressure, or the Btu required to raise the temperature of one pound one degree Fahrenheit, varies from 0.2375 to 0.2430 as determined by various investigators. The value 0.24 is recommended for engineering calculations. It has been found that a given volume of air expands when heated under constant pressure, and again that if the temperature of a given volume of air be kept constant and the pressure increased, contraction takes place. These changes follow definite laws, which apply to other gases as well as air, known as the *laws of perfect gases*. These laws do not generally apply to steam, since it is not a perfect gas, but superheated steam at high temperatures follows the laws approximately. (See Tables 5, 6, 7 and 8).

Boyle's Law refers to the relation between the pressure and volume of a

TABLE 6. VELOCITIES OF DRY AIR IN FEET PER MINUTE (AT VARIOUS TEMPERATURES) CORRESPONDING TO VARIOUS VELOCITY PRESSURES IN INCHES OF WATER[a]

Barometric Pressure 29.921 In.

PRESSURE		TEMPERATURE, DEG. FAHR.									
Inches	Ounces	50°	60°	70°	80°	100°	150°	200°	300°	500°	550°
0.1	0.0577	1242	1255	1266	1278	1300	1358	1413	1516	1704	1830
0.2	0.1154	1757	1776	1791	1808	1841	1921	2000	2145	2411	2590
0.25	0.1443	1965	1986	2003	2022	2059	2149	2235	2399	2696	2895
0.3	0.1730	2151	2175	2193	2214	2254	2352	2447	2626	2952	3175
0.4	0.2308	2485	2512	2533	2557	2603	2717	2827	3033	3409	3660
0.5	0.2884	2778	2808	2832	2859	2911	3038	3160	3391	3812	4095
0.6	0.3460	3043	3076	3102	3131	3188	3327	3462	3715	4175	4490
0.7	0.4037	3287	3323	3351	3383	3445	3595	3740	4013	4510	4850
0.75	0.4326	3402	3439	3468	3501	3565	3720	3870	4153	4668	5020
0.8	0.4614	3524	3552	3582	3616	3682	3843	3997	4290	4821	5185
0.9	0.5190	3728	3768	3800	3836	3906	4076	4241	4550	5114	5500
1.0	0.5768	3929	3971	4005	4043	4117	4296	4470	4796	5390	5795
1.25	0.7209	4393	4440	4478	4520	4602	4804	4997	5362	6027	6470
1.50	0.8650	4812	4864	4905	4952	5042	5262	5474	5874	6602	7100
1.75	1.0092	5197	5254	5298	5348	5446	5683	5912	6344	7131	7655
2.00	1.1535	5556	5616	5664	5718	5822	6076	6320	6783	7624	8195
2.25	1.2975	5892	5956	6007	6064	6174	6443	6704	7193	8085	8690
2.50	1.4418	6211	6278	6332	6392	6508	6792	7066	7582	8523	9150
2.75	1.5860	6514	6585	6641	6704	6827	7124	7412	7952	8938	9600
3.00	1.7300	6807	6879	6937	7003	7130	7440	7742	8307	9336	10000
4.00	2.3070	7857	7942	8010	8086	8233	8592	8940	9581	10780	11580
5.00	2.8840	8772	8867	8943	9027	9192	9593	9980	10710	12037	12900
6.00	3.4600	9623	9728	9810	9903	10083	10523	10950	11750	13203	14180

[a]From *Fan Engineering*.

gas, and may be stated as follows: *With temperature constant, the volume of a given weight of gas varies inversely as its absolute pressure.* Hence, if P_1 and P_2 represent the initial and final absolute pressures, and V_1 and V_2 represent corresponding volumes of the same mass, say one pound of

TABLE 7. PROPERTIES OF DRY AIR[a]

Barometric Pressure 29.921 In.

TEMPERATURE, DEG. FAHR.	WEIGHT PER CUBIC FOOT, POUND	RATIO OF VOLUME TO VOLUME AT 70 DEG. FAHR.	B.T.U. ABSORBED BY 1 CU. FT. DRY AIR PER DEG. FAHR.	CUBIC FEET DRY AIR WARMED 1 DEG. PER B.T.U.
−50	0.09690	0.7735	0.02335	42.82
−45	0.09573	0.7829	0.02307	43.34
−40	0.09459	0.7924	0.02280	43.87
−35	0.09348	0.8018	0.02253	44.39
−30	0.09239	0.8112	0.02226	44.91
−25	0.09133	0.8206	0.02201	45.43
−20	0.09029	0.8301	0.02176	45.96
−15	0.08927	0.8396	0.02151	46.48
−10	0.08828	0.8490	0.02127	47.00
− 5	0.08731	0.8585	0.02104	47.52
0	0.08636	0.8680	0.02080	48.08
5	0.08544	0.8772	0.02060	48.55
10	0.08453	0.8867	0.02039	49.05
15	0.08363	0.8962	0.02018	49.56
20	0.08276	0.9057	0.01998	50.05
25	0.08190	0.9152	0.01977	50.58
30	0.08107	0.9246	0.01957	51.10
35	0.08025	0.9340	0.01938	51.60
40	0.07945	0.9434	0.01919	52.11
45	0.07866	0.9530	0.01900	52.64
50	0.07788	0.9624	0.01881	53.17
55	0.07713	0.9718	0.01863	53.68
60	0.07640	0.9811	0.01846	54.18
65	0.07567	0.9905	0.01829	54.68
70	0.07495	1.0000	0.01812	55.19
75	0.07424	1.0095	0.01795	55.72
80	0.07356	1.0190	0.01779	56.21
85	0.07289	1.0283	0.01763	56.72
90	0.07222	1.0380	0.01747	57.25
95	0.07157	1.0472	0.01732	57.74
100	0.07093	1.0570	0.01716	58.28
105	0.07030	1.0660	0.01702	58.76
110	0.06968	1.0756	0.01687	59.28
115	0.06908	1.0850	0.01673	59.78
120	0.06848	1.0945	0.01659	60.28
125	0.06790	1.1040	0.01645	60.79
130	0.06732	1.1133	0.01631	61.32
135	0.06675	1.1230	0.01618	61.81
140	0.06620	1.1320	0.01605	62.31
145	0.06565	1.1417	0.01592	62.82
150	0.06510	1.1512	0.01578	63.37
160	0.06406	1.1700	0.01554	64.35
170	0.06304	1.1890	0.01530	65.36
180	0.06205	1.2080	0.01506	66.40
190	0.06110	1.2270	0.01484	67.40
200	0.06018	1.2455	0.01462	68.41
220	0.05840	1.2833	0.01419	70.48
240	0.05673	1.3212	0.01380	72.46
260	0.05516	1.3590	0.01343	74.46
280	0.05367	1.3967	0.01308	76.46
300	0.05225	1.4345	0.01274	78.50
350	0.04903	1.5288	0.01197	83.55
400	0.04618	1.6230	0.01130	88.50
450	0.04364	1.7177	0.01070	93.46
500	0.04138	1.8113	0.01018	98.24
550	0.03932	1.9060	0.00967	103.42
600	0.03746	2.0010	0.00923	108.35
700	0.03423	2.1900	0.00847	118.07
800	0.03151	2.3785	0.00782	127.88
900	0.02920	2.5670	0.00728	137.37
1000	0.02720	2.7560	0.00680	147.07
1200	0.02392	3.1655	0.00603	165.83

[a]From *Mechanical Equipment of Buildings*, Vol. 1, by Harding and Willard, second edition, 1929.

TABLE 8. PROPERTIES OF SATURATED AIR[a]

(*Standard Atmospheric Pressure of 29.921 in. of Mercury*)

TEMPERATURE, DEG. FAHR.	VAPOR PRESSURE, INCHES OF MERCURY	WEIGHT PER CUBIC FOOT OF MIXTURE			BTU ABSORBED BY 1 CU. FT. SATURATED AIR PER DEG. FAHR.	CUBIC FEET SATURATED AIR WARMED 1 DEG. PER BTU
		Weight of Dry Air, Pound	Weight of Vapor, Pound	Total Weight of Mixture, Pound		
0	0.0383	0.08625	0.000069	0.08632	0.02082	48.04
10	0.0631	0.08433	0.000111	0.08444	0.02039	49.05
20	0.1030	0.08247	0.000177	0.08265	0.01998	50.05
30	0.1640	0.08063	0.000276	0.08091	0.01955	51.15
40	0.2477	0.07880	0.000409	0.07921	0.01921	52.06
50	0.3625	0.07694	0.000587	0.07753	0.01883	53.11
60	0.5220	0.07506	0.000829	0.07589	0.01852	54.00
70	0.7390	0.07310	0.001152	0.07425	0.01811	55.22
80	1.0290	0.07095	0.001576	0.07253	0.01788	55.93
90	1.4170	0.06881	0.002132	0.07094	0.01763	56.72
100	1.9260	0.06637	0.002848	0.06922	0.01737	57.57
110	2.5890	0.06367	0.003763	0.06743	0.01716	58.27
120	3.4380	0.06062	0.004914	0.06553	0.01696	58.96
130	4.5200	0.05716	0.006357	0.06352	0.01681	59.50
140	5.8800	0.05319	0.008140	0.06133	0.01669	59.92
150	7.5700	0.04864	0.010310	0.05894	0.01663	60.14
160	9.6500	0.04341	0.012956	0.05637	0.01664	60.10
170	12.2000	0.03735	0.016140	0.05349	0.01671	59.85
180	15.2900	0.03035	0.019940	0.05029	0.01682	59.45
190	19.0200	0.02227	0.024465	0.04674	0.01706	58.80
200	23.4700	0.01297	0.029780	0.04275	0.01750	57.15

[a]From *Fan Engineering*.

TABLE 9. SPECIFIC HEAT OF VARIOUS SOLIDS AND LIQUIDS BETWEEN 32 AND 212 DEG. FAHR.[a]

SOLIDS	
Alloys:	
Bismuth-tin	0.040–0.045
Bell metal	0.086
Brass, yellow	0.0883
Brass, red	0.090
Bronze	0.104
Constantan	0.098
D'Arcet's metal	0.050
German silver	0.095
Lipowitz's metal	0.040
Nickel steel	0.109
Rose's metal	0.050
Solders (Pb and Sn)	0.040–0.045
Type metal	0.0388
Wood's metal	0.040
40 Pb + 60 Bi	0.0317
25 Pb + 75 Bi	0.030
Asbestos	0.20
Ashes	0.20
Basalt (lava)	0.20
Borax	0.229
Brick	0.22
Carbon-coke	0.203
Chalk	0.215
Charcoal	0.20
Cinders	0.18
Coal	0.314
Concrete	0.156
Cork	0.485
Corundum	0.198
Dolomite	0.222
Ebonite	0.33

SOLIDS	
Glass:	
Normal	0.199
Crown	0.16
Flint	0.12
Gneiss	0.18
Granite	0.195
Graphite	0.201
Gypsum	0.259
Hornblende	0.195
Humus (soil)	0.44
Ice	0.504
India rubber (Para)	0.27–0.48
Kaolin	0.224
Limestone	0.217
Marble	0.210
Oxides:	
Alumina (Al_2O_3)	0.183
Cu_2O	0.111
Lead oxide (PbO)	0.055
Lodestone	0.156
Magnesia	0.222
Magnetite (Fe_3O_4)	0.168
Silica	0.191
Soda	0.231
Zinc oxide (ZnO)	0.125
Paraffin wax	0.69
Porcelain	0.22
Quarts	0.17–0.28
Quicklime	0.217
Salt, rock	0.21
Sand	0.195
Sandstone	0.22
Serpentine	0.25
Sulphur	0.180
Talc	0.209

SOLIDS	
Tufa	0.33
Vulcanite	0.331
Wood:	
Fir	0.65
Oak	0.57
Pine	0.67
LIQUIDS	
Acetic acid	0.51
Alcohol (absolute)	0.58
Aniline	0.49
Benzol	0.40
Chloroform	0.23
Ether	0.54
Fusel oil	0.56
Gasoline	0.50
Glycerine	0.576
Hydrochloric acid	0.60
Kerosene	0.50
Naphthalene	0.31
Machine oil	0.40
Mercury	0.033
Olive oil	0.40
Paraffin oil	0.52
Petroleum	0.498
Sulphuric acid	0.336
Sea water	0.94
Toluene	0.40
Turpentine	0.42
Molten metals:	
Bismuth (535–725 F)	0.036
Lead (590–680 F)	0.041
Sulphur (246–297 F)	0.235
Tin (460–660 F)	0.058

[a]From Marks' *Mechanical Engineers' Handbook*.

TABLE 10. LINEAR EXPANSION OF SOLIDS AT ORDINARY TEMPERATURES[a]

(Tabular values represent increase per foot per 100 deg increase in temperature, Fahrenheit)

SUBSTANCE	TEMP. CONDITIONS[b] DEG. FAHR.	COEFFICIENT PER 100 DEG. FAHR.	SUBSTANCE	TEMP. CONDITIONS[b] DEG. FAHR.	COEFFICIENT PER 100 DEG. FAHR.
Brass (cast)	32 to 212	0.001042	Lead	32 to 212	0.001505
Brass (wire)	32 to 212	0.001072	Mercury[c]	32 to 212	0.009984
Copper	32 to 212	0.000926	Limestone	32 to 212	0.000139
Glass (English flint)	32 to 212	0.000451	Steel (Bessemer rolled, hard)	0 to 212	0.00056
Granite (average)	32 to 212	0.000482	Steel (Bessemer rolled, soft)	0 to 212	0.00063
Iron (cast)	104	0.000589	Steel (cast, French)	104	0.000734
Iron (soft forged)	0 to 212	0.000634	Steel (cast annealed, English)	104	0.000608
Iron (wire)	32 to 212	0.000800			

[a]From *Mechanical Equipment of Buildings*, Vol. 1, by Harding and Willard, revised edition, 1929.
[b]Where range of temperature is given, coefficient is mean over range.
[c]Coefficient of cubical expansion.

gas, then $\frac{V_1}{V_2} = \frac{P_2}{P_1}$, or $P_1 V_1 = P_2 V_2$, but since $P_1 V_1$ for any given case is a definite constant quantity, it follows that the product of the absolute pressure and volume of a gas is a constant, or $PV = C$, when T is kept constant. Any change in the pressure and volume of a gas at constant temperature is called an *isothermal change.*

Charles' Law refers to the relation between pressure, volume and temperature of a gas and may be stated as follows: *The volume of a given weight of gas varies directly as the absolute temperature at constant pressure, and the pressure varies directly as the absolute temperature at constant volume.* Hence, when heat is added at constant volume, V_c, the resulting equation is $\frac{P_2}{P_1} = \frac{T_2}{T_1}$, or, for the same temperature range at constant pressure, P_c, the relation is $\frac{V_2}{V_1} = \frac{T_2}{T_1}$.

In general, for any weight of gas, W, since volume is proportional to weight, the relation between P, V and T is

$$PV = WRT \qquad (2)$$

where

P = the absolute pressure of the gas in pounds per square foot.
V = the volume of the weight W in cubic feet.
W = the weight of the gas in pounds.
R = a constant depending on the nature of the gas.
T = the absolute temperature in degrees Fahrenheit.

This is the characteristic equation for a perfect gas, and while no gases are perfect in this sense, they conform so nearly that Equation 5 will apply to most engineering computations.

Chapter 40

GENERAL INFORMATION

Codes and Standards; Greenhouse Heating; Specifications; Humidification for Residences; Panel Heating System; Sound Level; Trouble Shooting.

CODES AND STANDARDS

THE following codes and standards relating to the design, installation, testing, rating and maintenance of materials and equipment used for the heating and ventilation of buildings, have been adopted by the AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS:

SUBJECT	TITLE	WHEN ADOPTED	REFERENCE
Air purity	Synthetic Air Chart	June, 1917	A.S.H.V.E. TRANSACTIONS, Vol. 23, p. 607, and THE GUIDE, 1931
Boilers (testing)	Standard and Short-Form Heat Balance Codes for Testing Low Pressure Steam Heating Solid Fuel Boilers (Codes 1 and 2)	June, 1929	A.S.H.V.E. TRANSACTIONS, Vol. 35, 1929. Reprints available
Boilers (testing)	Performance Test Code for Steam Heating Solid Fuel Boilers (Code 3)[a]	June, 1929	A.S.H.V.E. TRANSACTIONS, Vol. 35, 1929. Reprints available
Boilers—Oil Fuel (testing)	Code for Testing Steam Heating Boilers Burning Oil Fuel	January, 1931	*Heating, Piping and Air Conditioning*, March, 1931
Boilers (rating)	Code for Rating Steam Heating Solid Fuel Hand Fired Boilers	April, 1930	A.S.H.V.E. TRANSACTIONS, Vol. 36, 1930
Ethics	Code of Ethics for Engineers	January, 1922	A.S.H.V.E. TRANSACTIONS, Vol. 28, 1922, p. 6 (See also p. xiv GUIDE, 1932)
Fans	Standard Test Code for Disc and Propeller Fans, Centrifugal Fans and Blowers.	May, 1923. Revised June, 1931	A.S.H.V.E. TRANSACTIONS, Vol. 29, 1923, p. 407[b]

[a]Originally adopted by the *National Boiler and Radiator Manufacturers Association.*
[b]Also, see *Heating, Piping and Air Conditioning*, August, 1931, p. 743.

SUBJECT	TITLE	WHEN ADOPTED	REFERENCE
Garages	Code for Heating and Ventilating Garages	June, 1929	A.S.H.V.E. JOURNAL, May, 1929, p. 63
Heat transmission through walls	Standard Test Code for Heat Transmission through Walls	January, 1928	A.S.H.V.E. TRANSACTIONS, Vol. 34, 1928
Minimum requirements	Code of Minimum Requirements for Heating and Ventilation of Buildings, Edition–1929	June, 1925	A.S.H.V.E. Codes
Pitot tube	Code for Use of Pitot Tube	January, 1914	A.S.H.V.E. TRANSACTIONS, Vol. 20, 1914, p. 211
Radiators	Code for Testing Radiators	January, 1928	A.S.H.V.E. TRANSACTIONS, Vol. 33, 1927. Reprints available
Radiators (concealed)	Code for Testing and Rating Concealed Gravity Type Radiation (Steam Code)	January, 1931	*Heating, Piping and Air Conditioning*, August, 1931
Unit heaters	Standard Code for Testing and Rating Steam Unit Heaters[c]	January, 1930	A.S.H.V.E. TRANSACTIONS, Vol. 36, 1930. Reprints available

[c]Adopted jointly by the *Industrial Unit Heater Association*, and the A.S.H.V.E.

The following Codes and Standards have been endorsed or approved by the AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS:

SUBJECT	TITLE	SPONSORED BY	REFERENCE
Chimneys	Standard Ordinance for Chimney Construction	*National Board of Fire Underwriters*	Chapter 14, GUIDE, 1931
Piping systems	Identification of Piping Systems[d]	*American Society of Mechanical Engineers*	*Heating, Piping and Air Conditioning*, July, 1929
Warm air furnaces	Standard Code Regulating the Installation of Gravity Warm Air Furnaces in Residences	*National Warm Air Heating Association*	*National Warm Air Heating Association*, Columbus, Ohio

[d]Adopted November, 1928. Sponsored by (1) *American Society of Mechanical Engineers*, (2) *National Safety Council*.

GREENHOUSE HEATING

It is important that the heat shall be diffused evenly, that there shall be no high-velocity air currents, especially for flowers, and that no rapid temperature fluctuation shall be permitted.

Steam and hot water systems both are used in greenhouse heating. Electrically propelled unit heaters have been used with good results. Unfortunate results occasionally are encountered with all of these different kinds of apparatuses.

Table 1 gives the usual temperatures required in greenhouses. The heat losses from greenhouses are computed the same as are the heat losses from other types of buildings. The service is for 24 hours per day, and the peak demand occurs when the weather is cold and there is no sunshine, as at night. Leakage of air through cracks in the glass frames is not serious since in cold weather these freeze due to condensation, and seal tightly with ice. The boiler in a greenhouse must always be selected on the basis of the heat demand and will seem large in proportion to the square feet of radiation, since greenhouse radiators or convectors usually

TABLE 1. USUAL TEMPERATURES REQUIRED IN GREENHOUSES

KIND OF VEGETATION	TEMPERATURE REQUIRED, DEG. FAHR.
Violets, Camelias, Azaleas, Lettuce	40 to 45
Cool Palm Houses, Carnations	50 to 55
General Purposes, Roses, Mushrooms	55 to 60
Forcing Houses, Conservatories, Orchid Houses, Fern Houses	60 to 65
Peach House, Vinery, Early Tomatoes and Cucumbers, Tropical Palm House	65 to 70

are highly efficient. The piping, where direct heaters are used, is designed usually with a view to the kind of plants to be grown, though there is some tendency to use side wall and free hanging overhead heating surface in preference to piping under the plant benches.

It is probable that there are more low-pressure steam heating systems in greenhouses than any other kind of system. It is highly desirable that with such plants there shall be vacuum pump returns, with thermostatic heater traps. It is important, whatever the type of system, that the heating surface or out-put be well subdivided, so that no matter how much or how little heat shall be needed, just enough and no more than enough can be delivered. The heat must be distributed just as evenly over the whole area of the greenhouse as though all of the output were being delivered. One recommendation is that the heating surface be subdivided and provided with valves in increments of not exceeding 10 per cent.

The openings in the roof of a greenhouse which serve for ventilation are arranged in a row along the ridge and are spaced uniformly. If pipe coils are arranged lengthwise of the house they must be heated evenly and proportionately to the cooling effect of the ventilation. However, in practice excess radiation must always be placed at the ends of the house to compensate for the extra heat losses at the gable ends. The result is that when the roof ventilation is open, the ends of the building tend to over-heat. Any small leakage of supply valves or return traps also tends to cause over-heating of the ends of the long coils. A curious observation is that the air in a greenhouse tends to move in a direction opposite to that of the wind outside. This causes over-heating of the windward end and under-heating of the leeward end. This reverse interior current also causes a lowered relative humidity at the leeward end and excess moisture at the windward end; since such leakage as there is tends to enter from the leeward end.

In one case when unit heaters with electric fans were installed in a rose greenhouse, observations with thermometers and humidity instruments indicated excellent results, but the roses would not grow until the air velocity from the unit heaters was reduced to a very gentle current. The most recent testimony seems to indicate that in general, when steam is used the electric unit heater is satisfactory, using low velocities of air and rather close spacing of the heaters.

All successful greenhouse operators testify that great manual effort and exceedingly detailed attention must be applied to the air conditioning. There is a demand for very reliable automatic temperature control. One State University reports most favorable results with unit heaters and electric automatic control.

There is no question but that forced circulation hot water heating finds an especial field in greenhouse work, since the heaters may be almost as small as those used with steam, and since the temperature of the heating surface may be controlled within such a wide range either by thermostats or by hand, without the constant adjusting of supply valves necessary when steam is used.

HEATING AND VENTILATING SPECIFICATIONS

The specifications for the installation of heating and ventilating equipment form a contract document and as such they should be as carefully drawn as are the drawings to which they refer. In general, the purpose of the specifications is to describe the character and quality of the work, while the purpose of the drawings is to indicate the location and quantity of the work to be done.

It is well to have the specifications include other standard clauses which are important in a legal sense and which may be needed to clarify some of the conditions under which the work is to be carried on. If difficulties develop and the courts have to be resorted to, the importance of these standard legal clauses will be realized. It is therefore important that they be written carefully and also that they be included in every specification regardless of the character of the work. When the work is extensive or if the bidders are not selective, as in public works, a section on *Instructions to Bidders* should preface the specifications proper.

Chapter 34 of THE GUIDE, 1931, contains a list of major subjects which should usually be covered in a specification for heating and ventilating work. This chapter also contains some important general notes.

TROUBLE SHOOTING

The engineer who is called in to diagnose troubles with heating systems must be an experienced diagnostician. He needs, in many cases, to have intuition, because the basic reasons for trouble are not always easily located. Probably more heating-plant complaints are terminated by achieving cleanness than by means of any other prescription.

It is well known that the perfunctory washing out of core sand which sometimes occurs at the point of manufacture of ferrous castings does not by any means clean the castings. While any system of screwed piping is being fabricated there is a steady application of lubricating oil, and there are continual opportunities for cuttings, sand, plaster, mud, shavings, and other construction debris to enter the piping.

In case of trouble, experienced engineers almost invariably advise cleaning the piping and the heating units before looking elsewhere. Assistance may be given by the introduction into the boiler or system of chemicals which will neutralize some of the foreign elements, but eventually if the surfaces and pockets are clean, and the water is clean, the system will be free of unpleasant noises, and the fuel cost will be reduced.

Where excessive quantities of chemicals have been introduced it is not uncommon to find an acid condition in the condensate, and this may attack copper interiors, return traps and air vents, with the result that floats and expansion elements may develop leaks. Such leakage into any vacuum heating system of course prevents the maintenance of a proper vacuum and results in the necessity of the introduction of a jet of water at the pump. Where such a jet of water is introduced, raw water with its impurities usually must be supplied, calling for more chemicals which aggravate the situation. An examination of the interior parts of traps and air vents often reveals the seat of this sort of trouble.

The best test for water-cleanness usually is to put a sample of the water suspected of being polluted, in a dish on a stove alongside a similar dish containing fresh water. The fresh water usually will be boiling for some time before the higher surface tension of the polluted water can be broken.

When a boiler is blown off at its bottom the water line of course goes down, and much of the foreign matter, especially the oil, lighter in weight than water, which was floating above the water, clings to the boiler interior and contaminates the fresh water supply. The easiest way to get rid of this form of pollution is by the use of a blow-off opening at the water line which can operate as a skimmer. Many cases of supply valves to radiators, of return traps, and of pipes, all of which were suspected of being too small for the work which they were supposed to do, have been solved by a simple cleaning, without making any physical changes.

The removal of air and condensate from steam heated units, especially those in connection with a fan, is of major importance and manufacturers of such equipment offer suggestions in their literature as to the physical structure which should not be ignored. In many cases the real difficulty is by no means evident, and it is very easy to overlook a serious structural

fault. In a large school where complaint was made that the ventilation, formerly excellent, recently had become defective, it was found that the cold air intake and the exhaust openings were functioning and that the thermostats were operating. They were operating the housed supply fan in the wrong direction! When such a fan is operated backward the amount of air delivered may be about half of that normally delivered, and as the power demand is proportional to the work done, the electric motor functions satisfactorily. In this case, a careless workman in reconnecting the motor had transposed two of the leads and no one had noticed, in the dark fan chamber, the fact that the rapidly-turning wheels were going in the wrong direction.

In another case of deficient air delivery, the motor pulley was ordered correctly as 8 in. in diameter and the shipping list of the manufacturer and all of the records showed an 8-in. pulley, but unfortunately when the manufacturer sent out the motor he placed a 6-in. diameter pulley on it. Naturally the fan which this motor was propelling failed to deliver as much air as was expected and several days' delay and a long railroad trip were expended before the difficulty could be diagnosed.

Occasionally a thermostat in a school classroom is connected by mistake so as to control the air supply damper of some other classroom. Such a cross connection is often a long time in being discovered and corrected and may lead to very interesting temperature-complications. Thus the trouble shooter learns to doubt everything he reads or hears and to be suspicious even of what he sees and of what he feels.

HUMIDIFICATION FOR RESIDENCES

With most methods of heating, the problem of humidity control in residences is a difficult one, particularly in cold weather. Not infrequently the relative humidity is lowered to 20 per cent or less as a direct result of artificial heating. As much as 24 gal of water per day may be evaporated in an average home to maintain a relative humidity of 40 or 50 per cent. Pans of water on the radiators may help to supply moisture but the amount thus evaporated usually is not sufficient. Mechanical humidifiers of the cabinet or console type are effective. The unit conditioners described in Chapter 37 may also be used for residence humidification.

Humidifying devices which may be installed inside the duct work of existing warm-air heating systems are available. Fans may be incorporated to increase the air movement and evaporation. A modified type of central station equipment which in general consists of a fan furnace system with attached air washer and blower, and a system of distributing ducts, is available. (See discussion of fan furnace systems in Chapter 31).

The principles underlying humidity requirements and limitations for residences are summarized in University of Illinois Bulletin No. 48[1], as follows:

1. Optimum comfort is the most tangible criterion for determining the air conditions within a residence.

[1]See Humidification for Residences, by A. P. Kratz (University of Illinois, Bulletin No. 48).

2. An effective temperature of 65 deg[2] represents the optimum comfort for the majority of people. Under the conditions in the average residence a dry-bulb temperature of 69.5 F with relative humidity of 40 per cent is the most practical for the attainment of 65-deg effective temperature.

3. Evaporation requirements to maintain a relative humidity of 40 per cent in zero weather depend on the amount of air inleakage to the average residence, and vary from practically nothing to 24 gal of water per 24 hours.

4. Relative humidity of 40 per cent indoors cannot be maintained in rigorous climates without excessive condensation on the windows unless tight fitting storm sash or the equivalent are installed.

5. The problems of humidity requirements and limitations cannot be separated from considerations of good building construction, and the latter should receive serious attention in the installation of humidifying apparatus.

The following conclusions were drawn from the experimental results reported in the aforementioned bulletin:

1. None of the types of warm air furnace water pans tested proved adequate to evaporate sufficient water to maintain 40 per cent relative humidity in the Research Residence except only in moderately cold weather.

2. The water pans used in radiator shields tested did not prove adequate to maintain 40 per cent relative humidity in a residence similar to the Research Residence when the outdoor temperature approximates zero degrees Fahrenheit.

PANEL HEATING SYSTEM[3]

If a room is warmed by applying heat directly to the walls and/or ceiling, it is possible to render the room comfortable with an expenditure of less heat than if heat is supplied by warming the air. It is also found that the room is rendered equally comfortable if warmed by this method, when the room temperature is 5 deg or more below what is required when the room is warmed by convection.

The panel system, which has been in use in England for many years, is based on this principle. This system consists of coils of pipe through which water flows imbedded usually in the ceiling, although in some cases the pipes are embedded in the walls. The pipes which are ordinarily of ½ in. or ¾ in. diameter, are run parallel to each other on 4 to 6 in. centers and are embedded in the concrete in the underside of the ceiling of the room to be heated. The surface of the concrete is then plastered.

Heat is conducted from the pipes to the plaster face and is then emitted in radiant form. The surface temperature of the plaster is considerably lower than that of the water flowing through the pipes and is affected by their diameter and spacing. At 4 in. to 6 in. pipe centers, the temperature varies little over the whole of the panel.

SOUND LEVEL[4]

By the use of noise measuring instruments, sounds may be analyzed into various frequency bands within the range of audibility, and frequently the period of vibration enables noises to be analyzed and traced

[2]66 deg is recommended by the A.S.H.V.E. Committee on Research.

[3]See Panel Warming, by L. J. Fowler (A.S.H.V.E. TRANSACTIONS, Vol. 36, 1930).

[4]For additional information on this subject see Noise Reduction in Ventilating Units, by Warren Ewald, (*Heating, Piping and Air Conditioning*, November, 1930); Noise and Ventilation, by G. T. Stanton, (*Heating, Piping and Air Conditioning*, December, 1930); Some Studies on the Absorption of Noise in Ventilating Ducts, by G. L. Larson and R. F. Norris, (*Heating, Piping and Air Conditioning*, January, 1931).

to their source or sources. It is not improbable that in the near future the maximum sound level produced in a room by ventilating equipment will be specified, just as the quantity of air is now specified. The proper standard for office buildings is about 25 decibels[5], while in a space where quiet is of the greatest importance, as in residences, sound studios, etc., the level should be as low as 5 decibels. If these conditions are specified it will then be possible to make the contractor responsible for the quietness of operation, either through the use of low air velocities and low fan speeds, or by the use of special duct construction, or by sound deadeners, depending on what is shown by an evaluation of all factors, including construction cost, space assigned to ventilating equipment and ducts, horsepower consumed, etc. Further information on this subject will be found in Chapter 32.

AIR CONDITIONING OF LIBRARIES[6]

Temperature, per se, can be disregarded generally as having little effect upon the keeping qualities of books. There is an optimum temperature for the growth of each variety of mildew, but this growth can best be inhibited by depriving the mildew of water or by the use of chemical treatments. Too high a temperature (over 100 F), combined with low relative humidity, may cause the book materials to become brittle. A temperature much below freezing may cause permanent deterioration of the glue.

The relative humidity should be maintained between 40 per cent and 70 per cent, although these limits may be exceeded in either direction for short periods of time. If the relative humidity gets much below 40 per cent, first the glue and then the paper will tend to become brittle. This will not cause any permanent damage unless the book is used, or rather abused, while in this condition. Subsequent increase in humidity will bring the materials back to their normal condition. If the relative humidity gets much above 80 per cent, the growth of mildew may be expected.

[5]The decibel is the unit of sound level.
[6]Based on a paper by the Bureau of Standards.

CATALOG DATA SECTION

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with an

INDEX TO MODERN EQUIPMENT

(Pages 859–871)

and

INDEX TO ADVERTISERS

(Pages 873–876)

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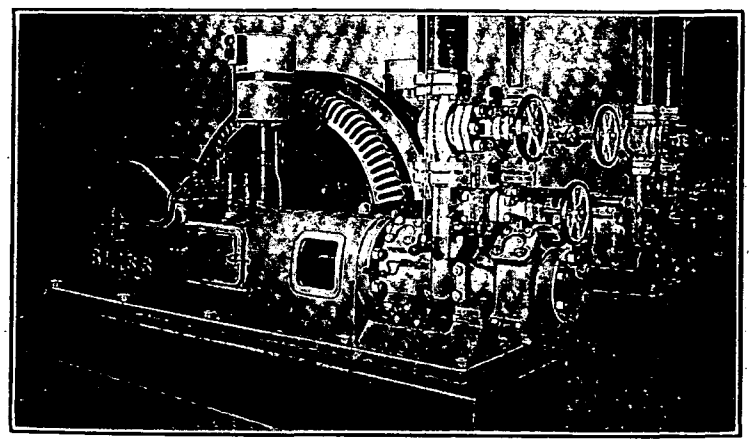
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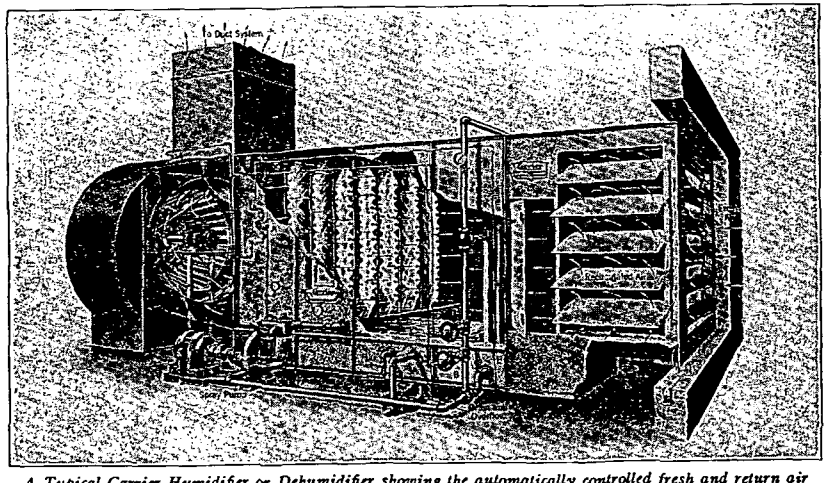
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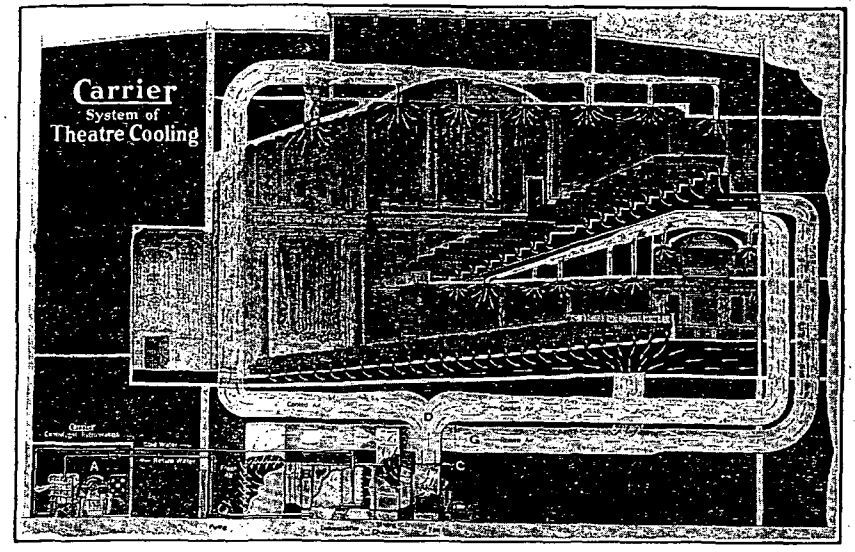
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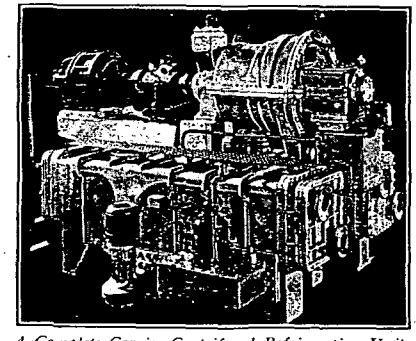


A Typical Carrier Humidifier or Dehumidifier showing the automatically controlled fresh and return air dampers, the spray chamber with pumping and water heating equipment and, on the left, the fan which delivers the air to the duct system



Cross Section of a Typical Theater equipped with a Carrier System for Cooling, Dehumidifying and Purifying the Air in Summer, and Warming, Humidifying and Purifying the Air in Winter. Note the use of Carrier Centrifugal Refrigeration in connection with this equipment
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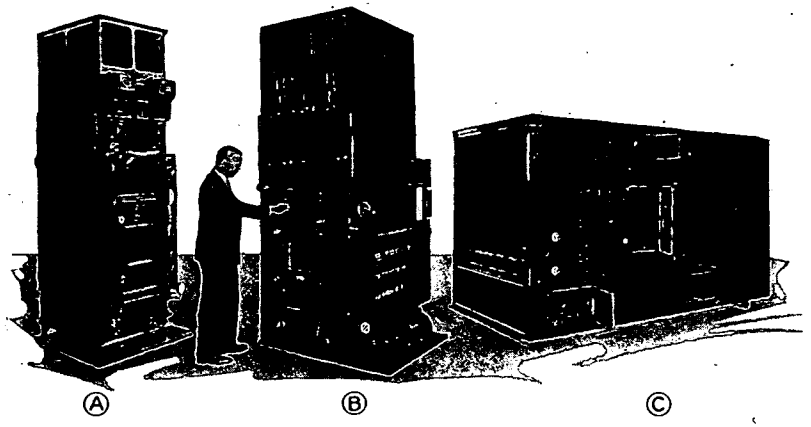


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Details covering any specific industry, or general literature, will be sent on request.



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When used to *condition for comfort*, that is, to cool and dehumidify the air during the hot summer months, or to warm and healthfully humidify the atmosphere in winter, these Units are particularly adaptable to barber shops, small retail clothing and millinery stores, restaurants and lunch rooms, candy shops and dozens of other places in which the health and comfort of patrons is an important consideration.

Five sizes and types are available to meet the demands of various industries and sizes of rooms or buildings. Capacities range from 1,000 to 10,000 cubic feet of conditioned air per minute, in vertical and horizontal types, also in one ceiling suspension type, especially suited to crowded manufacturing departments, such as in textile mills, where floor space is at a premium. One or more of these Units will meet the requirements of nearly any room.

Illustrated above are three standard models, with the following capacities and applications:

(A)—Vertical type, capacity 2,500 cu. ft. of conditioned air per minute. This is a complete unit including pump, fan, heaters and automatic control. Especially adaptable for air conditioning industrial plants, such as printing and lithographic plants, textile mills, candy factories, bakeries and certain types of testing laboratories.

(B)—Vertical type, capacity 5,000 cu. ft. of conditioned air per minute. Also complete as to pump, fan, heaters and automatic control, with applications the same as A. Floor space occupied by both these models has been reduced to a minimum. All parts are simple and readily accessible.

(C)—Horizontal type, capacity 10,000 cu. ft. of conditioned air per minute. When supplied with cold water, steam and electrical connections, this Unit constitutes a complete air conditioning plant. Contained within its casing are all moving parts, as well as the latest developments in sound silencers and automatic control.

This model is particularly adaptable for conditioning stores, restaurants and offices, as well as for general industrial air conditioning, heating, cooling, humidifying and dehumidifying.

Ask for Bulletins.

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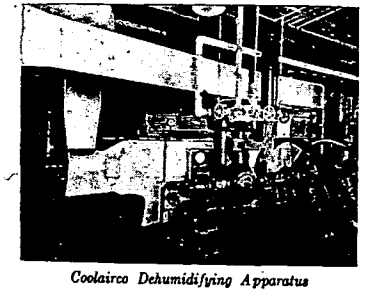
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PRODUCTS—Automatically Controlled Air Conditioning Systems—Cooling, Humidifying, Dehumidifying, Drying, Refrigeration. Automatic Temperature and Humidity Control Instruments.

Air Conditioning Systems for Theatres, Schools, Public Buildings, Auditoriums

To the field of "comfort" conditioning which is now an essential element of public building construction, the Coolairco organization brings the advantage of long specialized experience. Coolairco Systems maintain, without variation, both the uniform temperature and uniform percentage of relative humidity desired, regardless of season, outdoor weather conditions, extent of areas treated or accoustical requirements. An impressive number of the most prominent public buildings in America are Coolairco equipped.



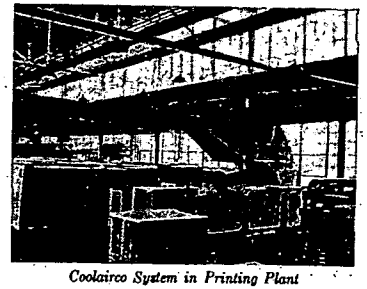
Coolairco Dehumidifying Apparatus

Air Conditioning for all Types of Industrial Buildings

The value of Coolairco Systems for manufacturing plants lies in the increased quantity and improved quality of production that they make possible. The health and efficiency of workers is also protected and assured by the uniform atmospheric conditions constantly prevailing. Any pre-determined condition of temperature and humidity deemed necessary for ideal operating and processing requirements can be maintained and automatically controlled against variation. Baking, Candy, Chemicals, Cold Storage, Flour, Paper, Printing, Rayon, Rubber, Tobacco and Textiles are some of the industries now profiting by Coolairco Automatic Air Conditioning.

Dependable Engineering Service

Our engineering staff is ready to cooperate with Plant Executives, Engineers and Architects in preparing a preliminary analysis of particular requirements. Literature on request.



Coolairco System in Printing Plant

Branches
Boston
New York
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Baltimore
Charlotte
Atlanta
Birmingham
Orlando

Frick Company

Waynesboro, Penna.

Refrigerating and Ice-Making Equipment

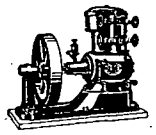
Since 1882

Branches
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FRICK

Ammonia Refrigerating Systems for Air Cooling

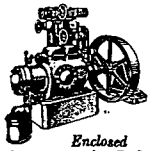
Furnished in refrigerating capacities from ½ ton up: combined units, enclosed compressors, horizontal machines; for steam, flat or V-belt, or direct motor drive. Automatic control where desired. Safe: used in over 100 hospitals. Ask for Bulletins 102, 104, 108, 112 and 138.



Enclosed Ammonia Compressor

Carbon Dioxide Refrigerating Systems for Air Cooling

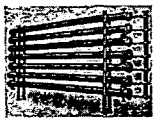
Of the enclosed type, with extra long pistons extending into crankcase, where wrist pins are engaged on both sides of piston by forked connecting rods. Force-feed oiling throughout. Six sizes, for any drive. Bulletins Nos. 118, 122, 124 and 208.



Enclosed Compressor for Carbon Dioxide

Condensers of All Types

Of either vertical or horizontal shell-and-tube type, double-pipe or atmospheric style, for both ammonia and carbon dioxide. Also separators and receivers to suit requirements. Bulletins 228, 230 and 232.

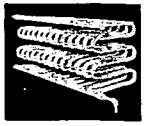


Type HS Shell and Tube Condenser

Coils and Coolers for Air Cooling Plants

Continuous welded coils, custom built to suit the exact needs of each job: also standard coils for carbon dioxide, ammonia and brine.

Coolers for brine, water, air, etc., in shell-and-tube and coil types. Vertiflow unit evaporators.



Type VW Cooling Coil

Ice Making Systems for Public Buildings

Hotels, hospitals, restaurants, clubs, etc., often require some ice-making capacity as part of their refrigerating system. Frick ice-making equipment is furnished in any size or type desired, for either clear or opaque ice. Ask for Bulletin 127.



Small Ice Tank with Refrigerating Unit

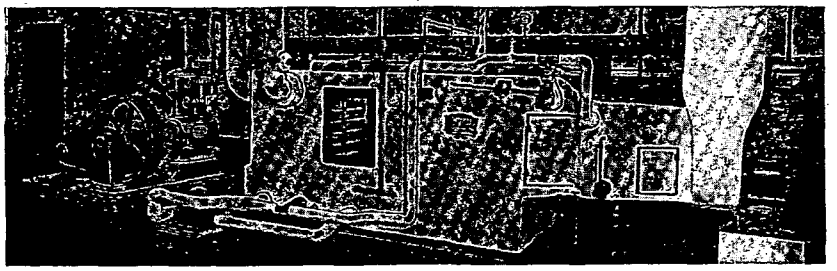
Valves and Fittings for Piping

Both ammonia and carbon dioxide valves and fittings are supplied in pipe sizes from ¼" up. Flanged and screwed types. Safety, check, sight glass and other valves. Ask for Catalog G.



Ammonia Valves

Frick Refrigerating Plant and "Drying Systems" Air Conditioner installed for Servel, Inc., Evansville, Ind.



Maryland Air Conditioning Corporation

Main Office and Works

Clarkson, McComas, Donaldson and Race Streets,

Baltimore, Md.

Representatives in Principal Cities

DESIGNERS AND MANUFACTURERS OF AIR CONDITIONING EQUIPMENT

Products

Air and Gas Washers—single and multi-stage.
Complete industrial and commercial air conditioning installations.
Cooling equipment.
Evaporative coolers—single and multi-stage.
Humidifiers and Dehumidifiers—horizontal and vertical.
Proof Boxes for bakeries—with or without humidifying equipment.
Dough and Fermentation Room air conditioning systems.
Bread Cooling Cabinets and Coolers.

Applications

In industries such as baking, confectionery, textile, paper, printing, leather, film, pharmaceutical, artificial silk, etc., product uniformity and production flow are often seriously affected by temperature and humidity variations. Maryland Air Conditioning Equipment provides a uniformity of temperature and humidity within predetermined limits. Controlled atmospheric conditions stabilize production, improve the quality of the product manufactured and raise the efficiency of workers by general improvement in working conditions.

Design

Maryland Air Conditioning Systems are designed for operation with mechanical refrigeration, with well water, for evaporative cooling or, where load conditions permit, to operate on the thermal storage system.



Maryland Air Conditioner (vertical type)—easily taken apart for cleaning and maintenance

Air Conditioners

These are built either single or multi-stage—vertical or horizontal—shed or spray type. Our engineers are prepared to make recommendations of the type best suited to any specific requirement.

The multi-stage machines are built on the counter flow principle and are adapted to dehumidification or cooling where a supply of low temperature well water is available, thus eliminating the cost of mechanical refrigeration.

If refrigeration is required, its control may be either manual or automatic. If space conditions prohibit the installation of a complete air conditioning unit, a dehumidifier with separate cooling unit is available.

Service

Maryland Air Conditioning Equipment is adjusted and tested before it is offered to a customer for final acceptance. The purchaser's operators are instructed in its operation and maintenance. At frequent intervals, our engineers visit installations which this company has made in order to insure continued satisfactory performance and to give advice on the operation of the equipment.

Every Maryland Air Conditioning unit is guaranteed to produce the conditions specified in the proposal. Competent engineers are available for consultation and are prepared to make a study and to submit recommendations covering any air conditioning installation.

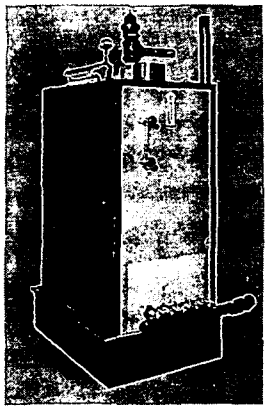
"SYNTHETIC ATMOSPHERE"

J. H. McCormick & Co.

Williamsport, Pa.

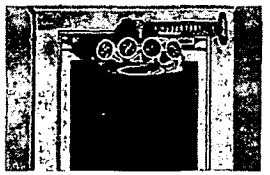
Makers of Airtrol air conditioning equipment which provides comfort without refrigeration.

AIRTROL



Airtrol Flash Boiler

All normal capacities, a quick-steaming "flash" boiler for any heating installation using gas or oil, especially adaptable for air conditioning because of short lag between the point of needed heat and heat supply.



Wall and Window Airtrols

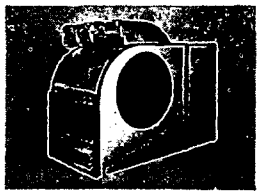
Capacity—300 c.f.m. at nozzle velocity of 1,000 f.p.m. Provides metered supply of fresh air, filters all air circulated, with automatic control of humidity and air tempering device for chilly days. Increased air circulation gives more heat from radiators and better distribution of heated air. Suitable for any room up to 6,000 cu. ft. Universal bracket installation fits anywhere for easy installation.

Products

Complete air conditioning equipment for the individual room or the largest building. Fans and blowers, air washers, humidity control devices, air filters and filter units; heating boilers for gas and oil; all-aluminum fin type heat exchangers.

Exclusive features are high velocity air flow from a "mixed-flow" impeller instead of conventional type fan, and quiet directional control by rifled nozzles, for controlled distribution over greater distances without stratification or drafts.

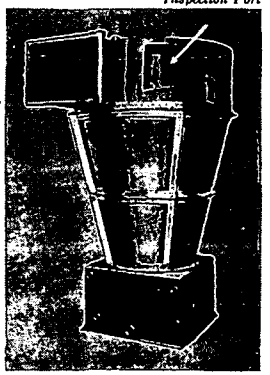
High velocities move large volumes of air, eliminating ducts inside the room, adding economy of installation to economy of operation. Controlled high velocities make it possible to secure effective cooling without refrigeration. Humidity and temperature automatically controlled. All units easily installed by any competent heating contractor.



Cabinet Airtrols

Capacities—2,000 to 10,000 c.f.m. at nozzle velocities of 2,500 to 5,000 f.p.m. Provides metered supply of fresh air, filters all air circulated, with automatic control of humidity and temperature. Winter heat by steam, summer cooling without refrigeration by means of Airtrol all-aluminum, fin type heat exchanger. Complete ventilating, humidifying, heating and cooling Airtrol, with air washer optional. For any room, store, restaurant, auditorium, school, factory, office, etc. Easily and quickly installed by any competent heating contractor.

Inspection Port



Airtrol Vortex Washer

Capacity 5,000 to 50,000 c.f.m. Removes all dirt, soot, pollen and odors. Small size, high capacity air washer and dehumidifier, equipped with both rain and atomizer sprays, with all heads removable. Built-in inspection ports, indicated by arrow. Hand cleanout in base. Automatic by-pass for admitting fresh water to pan when starting, eliminating stagnant water odors.

Niagara Blower Company

AIR ENGINEERING EQUIPMENT AND SYSTEMS

General Sales Office: 6 East 45th Street, **New York City**

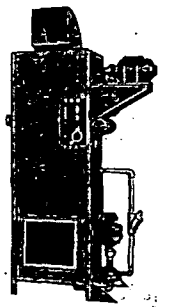
Branches: Boston, Cleveland, Philadelphia, Montgomery, Ala., Rochester, N. Y., Seattle, Buffalo, Pittsburgh, San Francisco

Complete Design of Systems for Air Conditioning, Humidifying, Dehumidifying, Drying, Cooling. Niagara Air Conditioners, Fan Coolers, Fan Heaters, Aluminum Heating Coils, Cooling Coils.

NIAGARA

NIAGARA AIR CONDITIONING SYSTEMS

For human comfort and for all industrial applications requiring controlled climatic conditions of temperature, relative humidity, air purity and air movement. Niagara Systems in satisfactory operation include central fan systems, air conditioning unit systems and combination of the two methods designed and installed complete by this Company.



Niagara Air Conditioner Type A

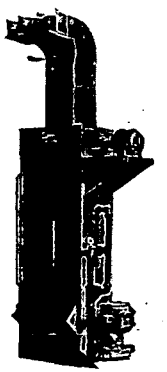
Illustration of single fan unit. Also manufactured in 2, 3 and 4 fan units.

NIAGARA AIR CONDITIONER—Type A

Maintains constant temperature and relative humidity, makes any change required in temperature and relative humidity, dries or moistens within tolerance of 1 deg. F. and 2 per cent R.H. in processing hygroscopic materials, cleans air more effectively than conventional air washers, secures saturation for dehumidifying, warms or cools air for comfort.

Constructed for life-time service and resistance to corrosion. Controls are reliable and accurate. Manufactured in seven sizes, see table below for capacity air per minute.

Write for Bulletin No. 26 for engineering data.



Niagara Spray Cooler

Illustration of single fan unit. Also manufactured in 2, 3 and 4 fan units.

NIAGARA AIR WASHERS

Designed especially for use in Niagara Air Conditioning systems. Manufactured in one, two and three spray bank types.

NIAGARA SPRAY COOLER

Recommended for all cold storage application, especially meat chilling and storage, freezing, pre-cooling and storage of fruits and vegetables. Cooling coils are in a constant brine spray for sub-freezing temperatures, water spray for refrigerant temperatures above 30 deg. F., no defrosting. Especially recommended where high humidities are required to avoid the drying out or wilting of meats or vegetables. Manufactured in seven sizes. See table for capacities.

Write for Bulletin No. 23 for engineering data and humidity control.

NIAGARA AIR CONDITIONER—TYPE 'A' CFM AIR—Rated Output Capacities

Unit No.	Fan Motor R. P. M.	Fan Motor H. P.	Pump Motor R. P. M.	Pump Motor H. P.	Cu. Ft. Air Per Min.	Lbs. Air Per Min.	Unit No.	Fan Motor R. P. M.	Fan Motor H. P.	Pump Motor R. P. M.	Pump Motor H. P.	Cu. Ft. Air Per Min.	Lbs. Air Per Min.
125 WB	720	½	1440	2	2600	195	125 N	1440	½	1440	2	1330	100
125 WF	720	¾	1440	2	2940	220	160 N	1160	¼	1730	2	1070	80
160 WB	1160	2	1730	2	4120	309	160 N	1730	½	1730	2	1600	120
160 WS	860	½	1730	2	2630	197	225 N	1440	¾	1440	2	2510	188
160 WS	1160	1	1730	2	3550	266	260 N	1160	½	1730	2	2020	151
225 WB	720	1	1440	3	4800	360	260 N	1730	1	1730	2	3010	226
225 WF	720	1½	1440	3	5300	398	325 N	1440	1	1440	2	3820	286
260 WB	1160	5	1730	3	7750	581	360 N	1160	½	1730	2	3080	231
260 WS	860	1	1730	3	4920	370	360 N	1730	1½	1730	2	4590	344
260 WS	1160	2	1730	3	6640	498	425 N	1440	1½	1440	3	5100	383
325 WB	720	1½	1440	3	6900	518	460 N	1160	¾	1730	3	4110	308
325 WF	720	2	1440	3	7500	563	460 N	1730	2	1730	3	6120	459
360 WB	1160	7½	1730	3	11,000	825							
360 WS	860	1½	1730	3	7040	527							
360 WS	1160	3	1730	3	9500	712							

NOTE—Units Nos. 125, 225, 325 and 425 are for 25-cycle current. Units Nos. 160, 260, 360 and 460 are for 60-cycle current.

NIAGARA FAN COOLER



Niagara Fan Cooler
Illustration of 3-fan unit. Manufactured also in 1, 2 and 4 fan units.

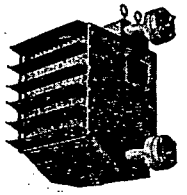
Recommended for comfort cooling, process cooling for photographic films, laboratories, dairies, chemical and pharmaceutical plants, confectionery manufacturing, low temperature storage for fruits, meats, food products, fur storage vaults, etc. Gives complete circulation of air at desired temperature with even temperature at all points. Saves space and weight. Refrigerant expands into *aluminum coils which save space and weight* over steel pipe coil. Manufactured in seven sizes. See table for capacities.

Write for Bulletin 17 for engineering data.

NIAGARA DISK FAN COOLER

A dependable efficient aluminum cooler for overhead suspension, saving floor space and providing the efficiency of moving air cooling for small storage areas, market coolers, etc. Manufactured in seven sizes. See table for capacities.

Write for Bulletin 25 for engineering data.

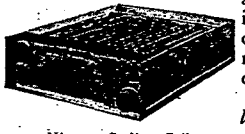


Niagara Disk Fan Cooler
Manufactured in 7 sizes including 2-fan unit.

NIAGARA COOLING COILS

Tested Cooling Coils as used in Niagara Fan Coolers and Air Conditioners are available encased in standard sizes for blast cooling installations. Seven sizes—20 in. and 30 in. widths. Steel coils in steel cases or aluminum coils in aluminum cases are furnished as required.

Write for Bulletin 16.



Niagara Cooling Coils

Basic Rating* of Niagara Fan Coolers

Model No.	R.P.M.	C.F.M.	H.P.	Basic Rating
1 N	1730	2040	¾	23,400
2 N	1730	3860	1	45,850
3 N	1730	5220	1½	68,600
4 N	1730	7500	2	92,700
1 W	1160	4060	1	43,000
2 W	1160	7900	2	86,200
3 W	1160	11,630	3	129,200

Basic Ratings—Niagara Spray Coolers

Model No.	Fan Motor		Pump Motor		Cu. Ft. Air Per Min.	Basic Rating
	R.P.M.	H.P.	R.P.M.	H.P.		
1 N	1730	1	1730	2	1850	49,500
2 N	1730	1½	1730	2	3400	89,100
3 N	1730	2	1730	2	5000	128,000
4 N	1730	3	1730	2	6700	172,000
1 W	1160	1½	1730	2	3650	97,700
2 W	1160	3	1730	2	7350	189,000
3 W	1160	5	1730	2	10,600	262,000

Note—Ratings are based on coils full flooded with ammonia. These ratings make no allowance for heat generated by motors

Basic Rating* of Niagara Disk Fan Coolers

Model No.	Motor H.P.	R.P.M.	C.F.M.	Basic Rating
129	⅛	1730	1100	6,100
1218	⅛	1730	1060	10,800
1913	1/6	1160	2850	12,200
2215	¼	1160	2900	15,400
1926	1/6	1160	2770	20,300
2230	¼	1160	2810	28,100
2636	2½	1160	6000	52,000

Model No. 2636 is a dual fan with horizontal tubes.
*These ratings for ammonia only.

FACTORS FOR OBTAINING B.T.U. CAPACITY

Room Temp. °F.	Temperature of Refrigerant (Brine or Ammonia)												
	+50	+45	+40	+35	+30	+25	+20	+15	+10	+5	0	−5	−10
70	.500	.625	.750	.875	1.000	1.125	1.250	1.375	1.500	1.625	1.750	1.875	2.000
65	.375	.500	.625	.750	.875	1.000	1.125	1.250	1.375	1.500	1.625	1.750	1.875
60	.250	.375	.500	.625	.750	.875	1.000	1.125	1.250	1.375	1.500	1.625	1.750
55	.125	.250	.375	.500	.625	.750	.875	1.000	1.125	1.250	1.375	1.500	1.625
50		.125	.250	.375	.500	.625	.750	.875	1.000	1.125	1.250	1.375	1.500
45			.125	.250	.375	.500	.625	.750	.875	1.000	1.125	1.250	1.375
40				.125	.250	.375	.500	.625	.750	.875	1.000	1.125	1.250
35					.125	.250	.375	.500	.625	.750	.875	1.000	1.125
30						.125	.250	.375	.500	.625	.750	.875	1.000
25							.125	.250	.375	.500	.625	.750	.875
20								.125	.250	.375	.500	.625	.750
15									.125	.250	.375	.500	.625
10										.125	.250	.375	.500
5											.125	.250	.375
0												.125	.250

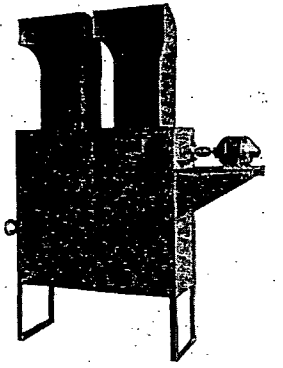
To obtain B.t.u. per hour capacity of a Niagara Cooler, select the factor at desired room temperature and refrigerant temperature and *multiply* by the *basic rating from the table above.*

To select the Niagara Coolers with capacity to maintain a given room temperature, take from factor table the factor at desired room temperature and refrigerant temperature. Then divide the required B.T.U. absorption by this factor which will give a required rating. The corresponding rating may be selected from the basic rating table.

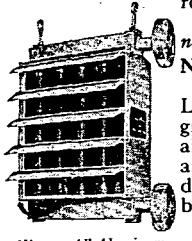
NIAGARA FAN HEATERS

For the heating and ventilating of large areas, industrial plants, storage buildings, etc. Especially recommended for packing plants, dye houses and wherever ventilation is required. Niagara Fan Heaters put the heat immediately where needed in the working zone, give quicker heating up to working temperatures, prevent cold floors, cold corners. Definitely built to the highest possible standards and to out-live other heating equipment. Niagara Fan Heaters have welded aluminum heating coils, welded frames, ball-bearing fan shafts and other improvements making for continuous, efficient service. Quiet in operation, they may be used to heat both office and industrial spaces. Ducts may be used for distribution to partitioned rooms. See tables for capacities.

Write for Bulletin No. 14 for engineering data.



Niagara Fan Heater
Illustration of 2-fan unit. Also manufactured in 1, 3 and 4 fan units.



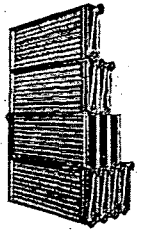
Niagara All Aluminum Disk Fan Heater

NIAGARA DISK FAN HEATERS

A most effective suspended heater. Lower resistance to air passage gives greater distance of discharge of warm air, effectively heating larger areas and keeping the heat down in the working zone. Operates with lower discharge temperature, cuts down roof and wall losses, diffuses heat better at lower cost, with fewer heaters.

Write for Bulletin No. 30 for capacities and engineering data.

NIAGARA ALUMINUM HEATING COILS



Niagara Aluminum Heating Coils

Designed for use with fan heating systems giving the advantage of aluminum, light weight and resistance to corrosion to this service. Manufactured in two widths 20 in. and 30 in. and in two types of three lengths, each in each width giving a complete range of sizes. Good for 150 lbs. working steam pressure. Completely encased ready for piping connections. Headers are cast aluminum welded by special process to U-bend aluminum tubes.

Write for Bulletins Nos. 20 and 14.

Niagara Booster Heaters, similar in construction to Niagara Aluminum Heating Coils are used for reheaters to control room temperature independently of the fan system.

RATED OUTPUT CAPACITIES—Niagara Fan Heaters

Model No.	R.P.M.	Motor H. P.	Cu. Ft. Air Per Min.	Entering Air 60° F. 5 lb. Steam			Entering Air 0° F. 5 lb. Steam			Equivalent Direct Rad. at 5 lb. Steam and 60° F. Entering Air
				Outlet Temp. °F	BTU Per Hour	Lbs. Cond. Per Hour	Outlet Temp. °F	BTU Per Hour	Lbs. Cond. Per Hour	
60 Cycle Motors										
160N	860	⅛	1315	134	95,700	99	100	128,000	133	416
	1160	¼	1775	129	121,000	125	94	165,000	171	526
	1730	½	2175	124	128,300	133	87	188,000	194	556
260N	860	¼	2500	134	182,000	188	100	244,000	252	790
	1160	¾	3330	129	226,000	234	94	309,000	407	965
	1730	1	4000	124	261,000	270	87	354,000	361	1135
360N	860	½	3620	134	263,000	272	100	353,000	360	1145
	1160	½	3970	132	269,000	277	98	364,000	371	1170
	1730	1½	5920	124	377,000	391	87	513,000	525	1640
460N	860	¼	4000	134	287,000	292	100	386,000	393	1250
	1160	¾	5360	126	348,500	360	89	468,000	480	1515
	1730	2	8000	120	480,000	492	82	653,000	666	2085
160W	860	1	4340	124	274,000	277	All steam pressures to 200 lbs. and entering air temperatures −20° to 160° F. are given in N. B. Co. Bulletin No. 3.			1190
	1160	1	4340	124	274,000	277				1190
260W	860	2	8680	124	542,000	554				2380
	1160	2	8680	124	542,000	554				2380
360W	860	3	12,600	124.5	800,000	808				3475
	1160	3	12,600	124.5	800,000	808				3475

Parks-Cramer Company

AIR CONDITIONING ENGINEERING AND EQUIPMENT

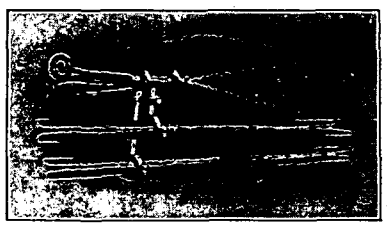
Fitchburg, Mass. Boston, Mass. Charlotte, N. C.

PARKSPRAY CERTIFIED CLIMATE

Six operations are involved in air conditioning: Heating, cooling, humidifying, dehumidifying, air cleansing, air change. Individual requirements may call for any combination of these. ParkSpray Certified Climate provides the atmospheric conditions which you specify. In the ParkSpray line of devices is apparatus to meet every requirement in the most economical manner.

TYPES OF APPARATUS

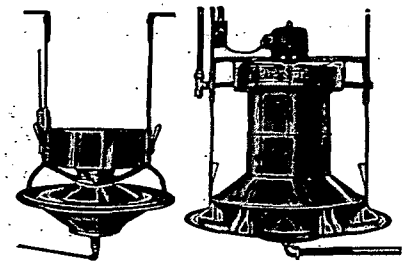
Turbo Humidifier—An "atomizer" type using compressed air to break up the water and produce a fine spray. The use also of centrifugal force improves the fine quality of the spray and reduces the amount of air used. Best suited to low posted rooms or where, for purposes of distribution, many units are desirable.



Turbo Humidifier

This type of humidifier contains no moving parts, is very easy to keep clean, and if it stops it cannot cause water damage. The exclusive "free blow" principle prevents "drooling" as humidifiers shut off. Air can be drawn from humidifying lines for air cleaning of machinery. Circular 227G describes this system in detail.

High Duty Humidifier—A miniature air washer. A fan blows air in at the top, through a sheet of fine spray, and discharges it in a flat blanket in all directions through the annular opening around the bottom.



Centrifugal Humidifier *High Duty Humidifier*

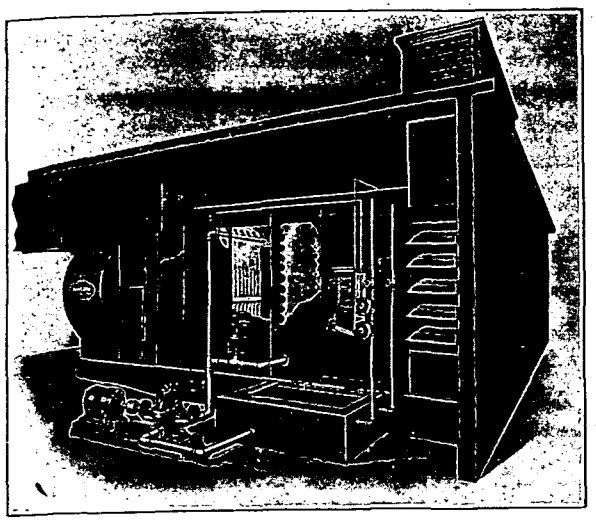
The capacity per unit is very high, and the evaporative efficiency is likewise high. This system is used in comparatively large rooms and where a high-heat factor is present. This type device is frequently used in ParkSpray Automatic Airchanger installations. (See below). High Duty Humidifiers are described in Circular 225G.

Centrifugal Humidifier—Uses water at ordinary pressure and eliminates air compressors and pumps. Best suited to small rooms that are free from lint and dust.

Water is atomized by means of a rapidly revolving disc, and is discharged in horizontal plane in all directions.

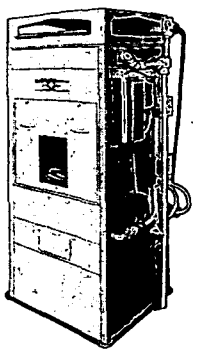
Central Station System—This consists of a centrally located apparatus for supplying the maximum of moisture required and changing the air with ample frequency; it usually includes indirect radiation for heating; suitable ducts and flues convey and distribute the conditioned air. Provision may be made for removal of all impurities in the air. Any specified conditions can be produced by this type of apparatus.

ADVANTAGES ARE: Immediate supply of heat and moisture in extremely cold weather, reduction of temperature and humidity in summer (by refrigerating water), responsibility for operation placed on plant engineering force, all apparatus can be placed outside room served. However, initial and operating costs are high.



Central Station

Unit Air Conditioner—Small, semi-portable, self-contained miniature central station. Built in a variety of forms to suit individual needs. Suitable for laboratories, conditioning machines and conditioning rooms, small manufacturing spaces, etc.



Unit Air Conditioner

ParkSpray Automatic Airchanger—A system of automatic regulation of ventilation by humidity regulator to utilize greatest possible cooling effect due to evaporation from free moisture type or humidifiers. Ask for Bulletin 131G.

Regulation—An air conditioning system can be no better than its regulation. Humidification to be economical must constantly balance evaporation with air change. Moisture demands vary greatly throughout the year; the month, the week—or even the day. Regulators automatically turn on and off the humidifiers as this demand changes.

Psychrostat—One of the most sensitive, accurate, and rugged regulators made. It operates on the principle of the sling



Psychrostat

psychrometer, universally recognized as the standard means of measuring humidity. It is made entirely of metal; there are no hygroscopic elements used. Continual circulation of air through the device is induced. It is easily and permanently adjusted.

Different types of this regulator are built to control humidity, temperature or ventilation, positively, gradually or in several stages. One instrument will perform any combination of the above functions. Send for Bulletin 226G.

ParkSpray Hygrostat—For use where less exacting requirements permit the economy of its lower cost, or where unusual conditions prevent use of Psychrostat. Its hygroscopic element is the most sensitive and dependable hygroscopic material known. It is as good a hygroscopic regulator as can be built.



Hygrostat

Engineering Service

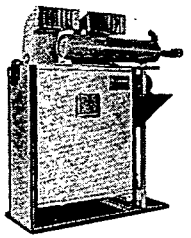
Our engineers are qualified to study any problem. They are familiar with the characteristics of practically every hygroscopic substance. Being manufacturers of all types of systems, our advice is impartial. This engineering service is available at your request.

York Ice Machinery Corporation

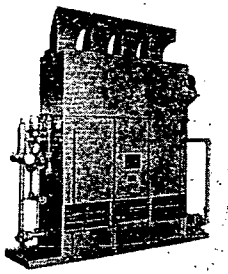
General Office: **York, Pennsylvania**

Direct Factory Branches in 71 U. S. Cities

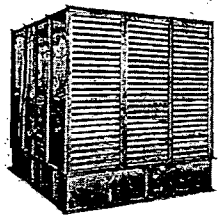
Complete Refrigerating and Air Conditioning Installations for all Types and Sizes of Industrial and Commercial Applications



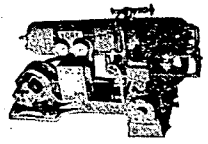
Coil Type Air Conditioner



Spray Type Air Conditioner



Air Washer



Complete Self-Contained Refrigerating Unit

Coil Type Air Conditioner:

A self-contained unit for cooling air by means of water, brine, carbon dioxide, methyl chloride or ammonia. Coil design insures maximum efficiency. Low speed fans designed for quiet operation. Exterior casing lacquered finish. Adapted to thermostatic control with defrosting feature.

Spray Type Air Conditioner:

Complete self-contained air conditioning unit requiring minimum space and including air washer with refrigerating coil, air heating coils, water heating coils, fan and motor, pump and motor, temperature and humidity controls, all assembled as a single unit.

Air Washer:

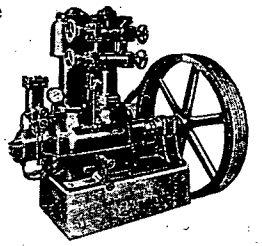
Galvanized iron and copper air washers of extra heavy construction, especially designed for refrigerating duty for water or brine. Washers furnished with or without cooling coils. Adjustable self-cleaning mist nozzles insure maximum humidifying efficiency.

Refrigerating Equipment:

Complete ammonia and carbon dioxide refrigerating plants of capacities suitable to any commercial installation. The design of York Compressors provides minimum clearances in the compressor working cylinders, low lift, large area valves, automatic lubrication of all bearing surfaces, quiet operation and a minimum amount of expert attention.

York Engineering Service

York experience in refrigeration and air conditioning includes not only a knowledge of equipment design and construction, but also a thorough and practical knowledge of installation and operation of York equipment in industry. This experience is available to Architects, Engineers and Contractors to facilitate their work.

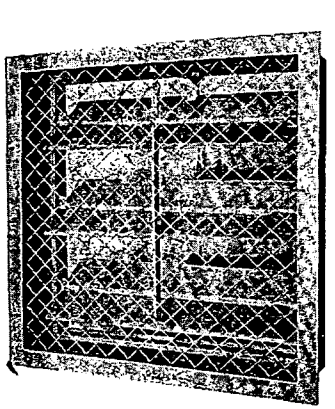


Vertical Single Acting Enclosed Ammonia Compressor

American Foundry & Furnace Co.

DEPARTMENT G

Bloomington, Illinois



A grille and border with louvres at rear, for use in fresh air or vent openings. Ball-bearing equipped. Operated by chain working through two pulleys and a claw. Pull chain has fusible link on both front and rear of louvres. These links melt at 160 degrees. In case of fire on either side of the louvres they close automatically by their own weight. Furnished with Metalace, flat or round wire, or expanded metal grille. Made in any size. Weight, nine pounds per sq. ft. Especially designed for schools, churches, hospitals, etc. Also furnished without fusible links, plain or ball-bearing, for manual or automatic control.

Plate KDG—Fire Damper and Grille

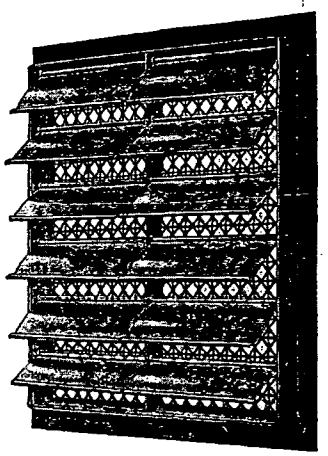


Plate M-2-GBPD

Back Pressure Damper—With metalace grille, round wire as per plate KDG, or expanded metal screen, for use at base of flues, etc., to prevent back draft. Dampers made from light, hard, strong aluminum. Smooth operation and freedom from binding secured by fibre spacers. Silent operation obtained by lining all dampers with felt. Dampers do not rattle.

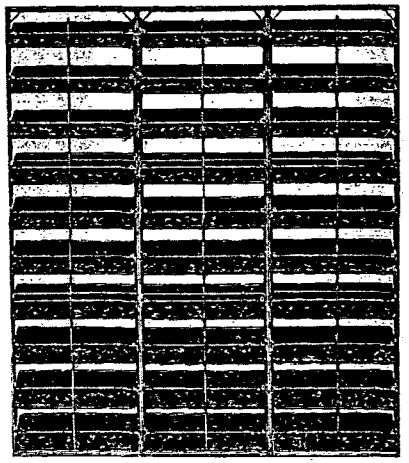


Plate F-17G

Fresh Air Louvre Damper—Made to fit any opening. Hand or Automatic control, plain or ball bearings. For schools, churches, hotels, theatres, power-houses, etc. Standard finish, black enamel. Made for vertical or horizontal installation.

PATENTED

Write for our catalog of Ventilating Equipment

Knowles Mushroom Ventilator Co.

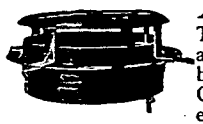
41 North Moore Street, **New York**

Knowles Air Diffusers for Auditoriums of Theatres, Churches, Schools

ORIGINAL——RELIABLE——STANDARD

Giving Satisfactory Service in Over 4,000 Installations

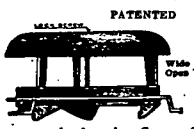
PRODUCTS:—Cast-Iron and All-Steel Adjustable Mushroom Ventilators; Aisle Hood, Tu-Way and Camelback Air Deflectors; Round and Oblong Gallery Riser Vents and Steel Grilles with adjustable volume damper attached



***Aero Valve*—The Improved Mushroom Air Diffuser**

The newest Knowles product. An up-to-date mechanically correct air unit of fixed height made of HEAVY steel, with strong supports bearing across 1-in. flange. Also furnished with CAST-IRON Dome Cap. Easy to regulate and install and low in price. Combines high efficiency with convenient adjustment affording finest control of air by simply turning screw on TOP of CAP. Can be positively locked at desired adjustment—is noiseless and made so that it cannot be taken apart before or after installation—an exclusive feature. Quick Anchorage to Wood or Concrete floors in one piece—Made in 6-in. and 8-in. diam. sizes—Same capacities as **Nu-Notch** type (see table below).

Knowles *Nu-Notch* Mushroom Ventilator or Air Diffuser



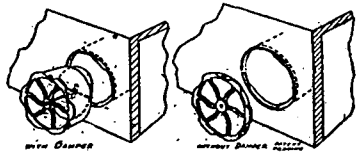


The ideal cast-iron mushroom. Head has three outer bearings and is absolutely rigid. Ten recessed notches give close regulation of air. Locked into positive adjustment by tightening head screw. Supplied with dome or flat tops. Three screw holes in floor flange for fastening to wood, or three angle L lugs for setting in concrete, or three tapped holes in floor collar for fastening with set-screws to sleeve.

Size	Cu. Ft. per Min. at 300 ft. Vel.	Area, Sq. Ft.	Weight Lbs.
5" diam.	42	0.1364	3.50
6" "	60	0.1964	4.25
7" "	81	0.2673	5.75
8" "	105	0.3491	8.00
10" "	165	0.5454	11.75

Specifications—Furnish and install where indicated on drawings or as hereinafter specified (5-in.), (6-in.), (7-in.), (8-in.), (10-in.), (Dome Top), (Flat Top). **Nu-Notch** Cast-Iron Mushroom Air Diffusers with recessed notches for the permanent adjustment of mushroom caps at any desired opening together with center locking screw feature as manufactured by Knowles Mushroom Ventilator Co., New York, N. Y.

Knowles *Disc-Loc* Gallery Riser



Ventilators are designed to insure better control of air. Round holes in the gallery risers do not weaken the construction but, on the contrary, with the cast-iron rings it is actually strengthened. The cast-iron grille is quickly inserted and locked by a simple twist motion—no bolts, screws or springs. Furnished with or without damper to fit same rings. MADE IN FOUR SIZES (See Booklet).

Dampagrille—A Steel Grille, with adjustable volume damper attached. Ideal for many purposes—(made in various sizes.)



***Tu-Way* Air Deflectors** are designed to deliver maximum area with minimum fixed height. The air is discharged at both sides along the row of seats. Heavy Cast-Iron—Ornamental design—Adjustable double-wing curved damper deflects air downward. Fine, positive adjustment—Rattleproof, noiseless. A DEVICE THAT DELIVERS THE FULL AREA OF FLOOR OPENING. Floor opening 6½ by 8½ inches—Area ⅓ Sq. Ft.—100 CFM at 300 Vel.

Standard Aisle Hood Air Deflectors are used to throw the fresh air out into the aisles in one direction. A curved damper reduces friction loss.

Large size: 8 in. long, 6 in. wide, 6 in. high; Small size: 8 in. long, 4½ in. wide, 4½ in. high.

Send for New Booklet of Complete Engineering Data or Samples

Burt Air Filter Corporation

45 E. South Street, **Akron, Ohio**

Representatives in Principal Cities

AUTOMATIC AIR FILTERS

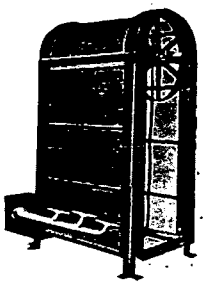
Polystage Viscous Type—Constructed to give six stages of air filtration through a media of viscous coated screens which remove the dirt from the air and precipitate it in a tank of Ozonol at the base of the filter.



Automatic Viscous Type Air Filter

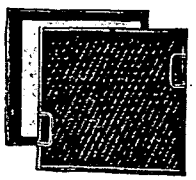
Dirt is automatically separated from the Ozonol by a special filter cup. The cleaned Ozonol is then automatically pumped back into the charging chamber of the filter just before the next cleaning operation. It is unnecessary to rotate the filter screens, except when the filter is being cleaned.

Absolutely the only attention necessary is an occasional cleaning of filter cup and removal of sediment. A drain is provided at filter cup for attaching directly to sewer or, if desired, sediment can be drained into a sludge pan. Burt Automatic Viscous Type Air Filters are made in capacities from 2,500 c.f.m. upward.



Automatic Fibre Type Air Filter

Dry Fibre Automatic—The filter media employed in this filter is made from layers of specially-developed, wire-woven jute fibre and selected cheese cloth which are built into an endless chain. The media is especially durable and is automatically cleaned by rotating filter pads over a series of vacuum nozzles which withdraw dirt and other particles which have been embedded in the filter media during the air cleaning operation. Velocity of air through filter media on the standard type is 286 f.p.m. at a resistance of .25 in. w.g. Can be furnished in sizes from 5,000 c.f.m. upward.



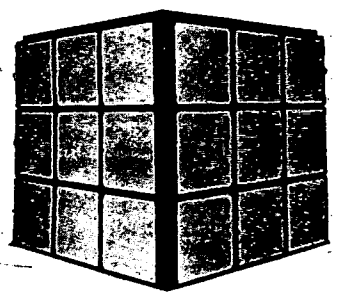
Metallic Type Cell with Frame

UNIT AIR FILTERS

Metallic Type—An all-metal filter which uses Ozonol, a specially treated oil, as its adhesive agent. Cleaning of air is accomplished by impingement of dust on the viscous coated surfaces of a series of screens having graduated openings. Cells are standard size and are interchangeable, each having a capacity of 1,000 c.f.m. at a resistance of .2 in. w.g. Many new features, such as improved handle design, specially constructed crimped wire filter pads, etc., are described in the bulletin on this filter.

Dry Fibre Type—The media employed in this filter is practically the same as that in the Dry Fibre Automatic. The cells are 20" square and are built for unit installations. They are cleaned manually by use of a small industrial vacuum cleaner. Large perforations permit close contact between nozzle and filter pad and assure positive cleaning without need of removing pad from the frame.

Other Burt Filters—Burt also manufactures a complete line of Metallic Compressor Filters, Metallic and Dry Unit Heater Filters, Furnace Filters and Special Filters designed to meet specific conditions.



Right Angle Installation of Fibre Type Units

AMERICAN AIR FILTER COMPANY INC.

1st Street and Central Avenue, **Louisville, Ky.**

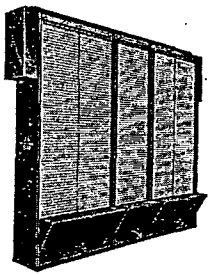
Representatives in Principal Cities

MIDWEST TRADE MARK — Reed Air TRADE MARK *filters* ALL METAL — NATIONAL AIR FILTERS TRADE MARK

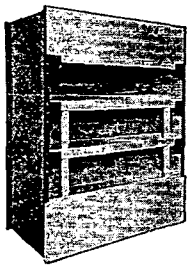
VISCOUS AIR FILTERS

Cleaning Principle—Cleaning is accomplished on the adhesive-impingement principle. Dust laden air is drawn by means of a fan or blower through a viscous coated filter media which breaks up the air into innumerable fine streams, causing many impingements of the dust against the surfaces of the media. Progressive increase in density of the filter media makes for high cleaning efficiency and large dust holding capacity at minimum resistance to air flow.

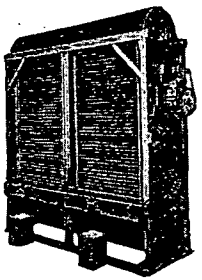
Automatic Air Filters—The automatic types of air filters pictured here are based on the most advanced principles of air filter engineering. Dependable self-cleaning systems on each assure maximum cleaning effectiveness and reduce maintenance to a minimum. These filters can be operated for months at a time without attention of any kind. The three models are furnished for either continuous or intermittent service and are available in sizes and set-ups suitable to any desired capacity or space conditions. Guaranteed cleaning efficiency on automatic air filters, 97-98 per cent, at a resistance of .25-.40 in. water gauge.



Automatic Multi-Panel



Automatic Horizontal



Automatic Phoenix

Multi-Panel Air Filter—Filter media consists of a multiplicity of closely overlapping Bakelite-coated screen panels which form a continuous movable curtain, giving unusually high cleaning efficiency at low resistance. Filter curtain automatically cleaned and recharged by moving thru a charging liquid bath located at the base of the filter.

Horizontal Air Filter—Filter media consists of horizontally placed cells of expanded metal, arranged in tiers one above another. Self cleaning accomplished by a flushing device which periodically moves over each tier of cells, cleaning and recoating them with a fresh supply of charging liquid.

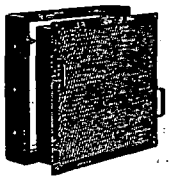
Phoenix Air Filter—Filter media made up of innumerable small metal plates incorporated in a rotating filter screen. The latter is automatically cleaned by intermittently moving thru a bath of charging liquid located at the base of the filter.

Standard Unit Filters

Incorporating the time-tested unit principle of construction. Each unit consists of a standard steel frame and interchangeable cell, equipped with automatic latches to facilitate removal for cleaning and recharging. Filter media either of expanded metal or crimped wire, scientifically graded to give maximum cleaning efficiency. Units arranged in wall type set-ups to meet space conditions and to deliver the required capacity.

Unit Filter Characteristics

Rated capacity—800 C.F.M.
Overall Dimensions— 20 in. x 20 in. x 4 in.
Air velocity thru Filter—355 F.P.M.
Effective opening—18 in. x 18 in. (2¼ sq. ft.)
Weight of cell, 20 lbs.—Frame 10 lbs.
Dust holding capacity—2 lbs.
Cleaning efficiency—97 to 99 per cent at a resistance of .18 in. to .25 in. water gauge.



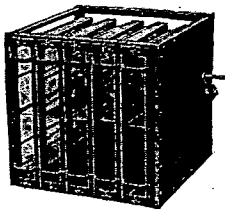
AMERICAN AIR FILTER COMPANY INC.

1st Street and Central Avenue, **Louisville, Ky.**

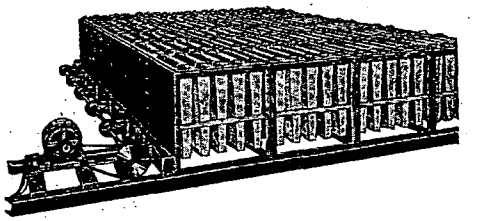
Representatives in Principal Cities

MIDWEST TRADE MARK — Reed Air TRADE MARK *filters* ALL METAL — NATIONAL AIR FILTERS TRADE MARK

AIRMAT DRY PROCESS FILTERS



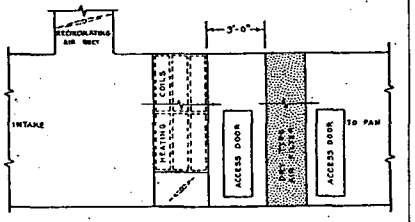
Airmat 6-Pocket Unit



Typical Airmat Dust Arrester

The basic element in this type is Airmat, a dry filter media consisting of extremely thin sheets of gauzy, celluloise tissue. Airmat sheets are supported in screen pockets mounted in a unit frame of box-like construction. These unit frames can be set up to meet any capacity requirements and space conditions. The Airmat sheets are renewable—their life depending on dust conditions and the hours of daily service. The unit frames are equipped with vibrating devices which serve to dislodge the bulk of the dust, thus extending considerably the life of the sheets.

Airmat dry process filters are available either in the "Pocket Type," Cabinet models, or in Dust Arrester "Systems" designed for individual needs. Airmat filters are used for both general ventilation and industrial air cleaning. In the latter field they are particularly well adapted for the recovery of valuable dust and for abating the dust nuisance which confronts so many industrial plants.

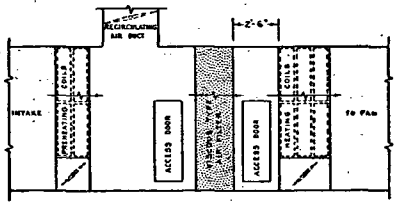


Typical Installation—Dry Type Filter

Recommendations for Installing Air Filters

Filters should be installed between air inlet and fan; in the case of the *Viscous* type filters, following the pre-heating coils and in front of the heating coils. *Dry* type filters should be placed behind the heating coils.

Filters should be installed so that face area is at right angles to air flow to avoid eddy currents and dead air corners . . . a clearance of at least 2 ft. should be provided on either side of the filter to allow room for inspection and servicing . . . sheet metal connections leading to and from filter should have access doors of suitable size . . . all sheet metal ducts and doors on the clean air side should be air-tight to prevent entrance of unclean air. Where filters are installed near air inlet they should be protected by weather louvers.



Typical Installation—Viscous Air Filter

For complete recommendations for installing air filters, see page 482.

Staynew Filter Corporation

6 Leighton Avenue, Rochester, N. Y.

Products—Protectomotor Air Filters for Buildings, Air-Using Machines, Compressed Air and Vacuum Lines, Automobiles, Etc.

The Dust Evil—The U. S. Weather Bureau estimates that ordinary city air contains about 100,000 dust particles per cubic inch. The National Conference Board on Sanitation estimates that it costs New York City alone $16,000,000 annually to clean and redecorate the interiors of buildings damaged by soot and smoke.

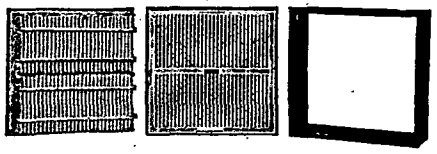
By keeping dirty air out of buildings, cleaning bills can be materially reduced—so can the cost of redecorating, repainting and refurnishing. Thousands of dollars worth of merchandise can be saved from ruin. And the health of occupants of buildings can be improved, for tests show the average person inhales more than a tablespoonful of dust every 24 hours, much of which contains dangerous disease germs.

Efficiency—Impartial tests made by the University of California, as well as by many other reliable authorities, gives Protectomotor Air Filters a filtration efficiency of 99.9 per cent when using a standard dust, 98.6 per cent of which will pass through a 200 mesh screen.

These Filters have a large filtering surface within a relatively small space. The intake air currents move parallel to the filtering surface at very low velocity. Consequently, dust and dirt are not packed on to the felt, but remain in a loose and porous condition, which permits air to pass through the accumulated dust as readily as through the felt itself. Dust and dirt do not enter the pores of the felt, which is of extremely fine texture. Efficiency is not affected by continuous service nor by any change in volume of air passed.

Resistance to the flow of air is less than ⅜ in. water gauge when operated at rated capacity. Less pressure drop may be obtained when required by using an oversized filter.

Protectomotor Panel Air Filters—This type of filter is for filtering large volumes of air for ventilating systems, turbo generators, dust recovery and standard flow type air machines. The panels are supported on pressed steel frames and may be arranged in any convenient formation to suit the space available for installation. This panel unit consists of a frame in either aluminum or steel, as desired, which supports a series of hollow fins, or loops of wire cloth, made from either galvanoid steel or bronze wire, as required. The wire cloth is covered with a single piece of specially prepared filter cloth of extremely fine texture.



The Panel Unit assembled in its frame occupies a space of 20 in. square by 6⅝ in. deep over-all and is conditionally rated at 600 to 800 CFM. This represents linear velocities from 12 to 18 feet per minute, respectively. It may be economically rated at 800 CFM for ordinary atmospheric air filtration conditions. This may vary according to severity and amount of dust per given volume of air.

The Protectomotor is a dry type filter. There is no viscous coating. No elaborate apparatus required for cleaning. It can be cleaned with either compressed air or vacuum cleaner in a few minutes per panel, without removal from supporting frames. Filter medium is easily replaceable. Does not need to be cleaned for two months or more.

More than 450,000 Protectomotor Air Filters are in use in buildings, on air-using machines, etc.

Specifications

Size of Filter and Frame	20x20x6⅝ in.	Efficiency under any and all conditions	99 9/10%
Capacity of filter unit (normal air)	800 c. f. m.	Size of Air Panel	19½x19½x6 in.
Linear velocity of air through filter medium	18 ft. per min.	Surface of filtering medium	45 sq. ft.
Resistance of clean filter to flow of air	¾ in. water gauge	Weight of filter panel	18 lbs.
Weight of filter panel and frame	28 lbs.		

Catalog—Our catalog, embracing a wealth of pertinent data for every Architect and Engineer, will be sent on request.

The Vinco Company, Inc.

75 Vesey Street, New York, N. Y.

CABLE ADDRESS—Vincomp, New York

Vinco for Internal Cleansing of New, Remodeled and Old Heating Systems

Vinco Superfine Boiler Leak Seal





In 1½, 3, 5 and 10 lb. cans

By this thorough cleansing Vinco stops foaming, priming, surging, incomplete circulation and poor radiation.

What Vinco Is

A positively harmless insoluble powder cleanser for new, remodeled and old heating systems.

What Vinco Does

VINCO permanently removes all the oil, grease, scale and dirt from the internal surfaces and from the boiler water *without the labor of blowing boilers over the top.*

How Vinco Works

Each minute grain of VINCO powder absorbs several times its own weight of oil, rust and dirt. These larger grains of absorbed impurities then settle and are blown through the bottom, according to directions on each can.

Vinco Specifications for New and Remodeled Steam and Vapor Systems

Cleaning the System—Upon completion of the installation, the contractor shall clean the system by the VINCO method to remove oil, grease, rust and dirt from the boiler using,*.....lb. of VINCO, in exact accordance with manufacturer's directions.

When VINCO is first introduced, have a low fire—just enough for the water to simmer—for three or four hours. After this, pressure can be raised.

This compound must remain in the boiler for 36 actual steaming hours, which corresponds to six or seven days average operation. At the end of this period, boiler must be thoroughly drained and flushed before refilling with clean water.

*In writing specification, insert in this space number of pounds of VINCO to be used in accordance with the following schedule. For systems having:

Up to	350	sq. ft. of	*radiation		3 lb.
351 "	600	"	"	"	5 "
601 "	1100	"	"	"	8 "
1101 "	1400	"	"	"	10 "
1401 "	1800	"	"	"	13 "
1801 "	2100	"	"	"	15 "
2101 "	2700	"	"	"	18 "
2701 "	3100	"	"	"	20 "
3101 "	3700	"	"	"	23 "
3701 "	4200	"	"	"	26 "
4201 "	4600	"	"	"	28 "
4601 "	5000	"	"	"	30 "

Above 5000 sq. ft. use an additional pound of VINCO for each additional 300 sq. ft. of radiation.

*In determining amount of VINCO to be used all radiation may be taken at actual rating.

Vinco Specifications for Hot Water Systems

Cleaning the System—Upon completion of the installation, the contractor shall clean the system by the VINCO method using **.....lb. of VINCO in exact accordance with manufacturer's special directions for hot water systems, given on their cans.

**Only one half above quantities required for hot water systems.

Vinco for Old Systems

Annual cleaning of the old heating system adds years of life to the boiler, prevents rust deterioration and saves much fuel and fire attendance.

For old systems use only one half quantities given in specification table.

Our Free Laboratory Service

Saves thousands of dollars by analyzing the boiler water *before* making needless mechanical changes. If desired, the boiler water is again examined *after* the VINCO treatment is completed, and "certified chemically correct" for boiler operation. Then if the boiler still primes, foams, or surges, look for mechanical flaws. (Write for details.)

Our Three-fold Guarantee

1. VINCO contains no potash, lye, soda of any kind, oil, acid, or other harmful ingredients.
2. VINCO meets every performance claim. Purchase price is refunded if results are not entirely satisfactory when VINCO has been used according to directions.
3. Your time, money and comfort are further safeguarded by our free laboratory service.

Vinco Distributors

VINCO is sold through leading boiler manufacturers and jobbers. *It is never sold under any other name or in bulk.* VINCO is put up only in 1½, 3, 5 and 10 lb. lithographed cans like illustration. Patents pending.

Vinco Superfine Liquid Boiler Seal

A new and better leak seal. It makes speedy, permanent repairs of all boiler and heating system leaks.

Fine to tighten up new jobs. Directions simple.



Quantities

Steam and Vapor Systems

Use 1 quart VINCO Liquid Boiler Seal to each 6 sq. ft. *grate* area.

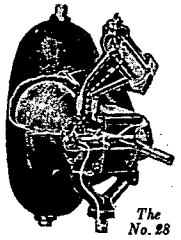
Hot Water Systems

Use 2 quarts VINCO Liquid Boiler Seal to each 6 sq. ft. *grate* area.

McDONNELL & MILLER
Boiler Feeders

"Doing one thing well"

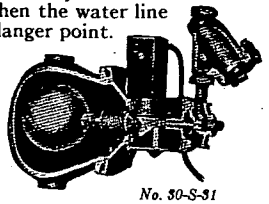
General Offices: Wrigley Bldg., Chicago



The No. 28

Dependable Feed Water Regulation—McDonnell Boiler Feeders offer a simple and positive means of maintaining the boiler water line in low pressure boilers. They protect the boiler from the costly repairs and shutdowns that result when someone forgets the boiler water line.

The McDonnell No. 30 Series Safety Feeders—These feeders are used as "safety" feeders; that is, they are located below the normal boiler water line in such a position that they will feed water only when the water line drops to the danger point. The source of sticking and binding is removed by isolating the feed valve from the heat of the float chamber so that the temperature of the water surrounding it never reaches the degree of heat where lime and scale is formed.



No. 30-S-31

The source of leakage and excess friction is also eliminated by using two Sylphon Bellows: One to take the place of a stuffing box between float chamber and toggle compartment; the other between the toggle compartment and feed valve.

The No. 30 Series is made in two sizes: 30-S (small) for boilers under 3000 feet capacity. 30-L (large) for boilers above this size. (See service recommendations).

McDonnell No. 31 Emergency Switch—Particularly on oil-fired or stoker-fired jobs where the boiler is subject to priming or foaming, the McDonnell No. 31 Emergency Switch when added to the No. 30-S or 30-L offers the double protection of a feeder and low water cut-off at the lowest possible cost. The feeder takes care of all normal operation—opens when the boiler water level falls to a point one and one-half inches above the bottom of the gauge glass. If, however, a priming or foaming condition draws out water faster than the feeder can supply it, the switch stops the burner until the feeder catches up and then turns the control of the boiler back to the feeder.

Typical Specifications No. 30 Series—

(If hand-fired or gas-fired).

Furnish and install on each (low-pressure) heating boiler one McDonnell No. 30 (-S or -L) Safety Feeder.

(If oil-fired or stoker-fired).

Furnish and install on each (low-pressure) heating boiler one McDonnell No. 30 (-S or -L) Safety Feeder with No. 31 Emergency Switch.

Installation to be in accordance with diagrams and detailed instruction sheet furnished by the manufacturer.

Other McDonnell Feeders are covered by the Service Recommendations and data below.

Service Recommendations

Boiler Size	Maximum Boiler Pressure	Service Conditions	Correct Feeder
		Hand or Gas Firing	
3000 Sq. Ft. or less	Vacuum to 15 Lbs.	Normal Heating or Process Work	No. 30-S Safety Feeder
	Vacuum to 25 Lbs.	Normal Heating or Process Work	No. 30-L Safety Feeder
Over 3000 Sq. Ft.	Vacuum to 25 Lbs.	Normal Heating or Process Work	No. 30-L Safety Feeder
	15 Lbs. or Less But no Vacuum	Where Condensation is apt to be held up in system	No. 28 Duplex
Any	25 Lbs. to 50 Lbs.	Normal Heating or Process Work	No. 29 Rotary Single Valve
		Oil or Stoker Firing	
3000 Sq. Ft. or less	Vacuum to 15 Lbs.	Normal Heating or Process Work	No. 30-S-31 Combination
	Vacuum to 25 Lbs.	Normal Heating or Process Work	No. 30-L-31 Combination
Over 3000 Sq. Ft.	Vacuum to 25 Lbs.	Normal Heating or Process Work	No. 30-L-31 Combination
	15 Lbs. or Less But no vacuum	Where condensation is apt to be held up in system	No. 28 Duplex and No. 32 individual cut off—either in parallel or at entirely separate locations
Any	25 Lbs. to 50 Lbs.	Normal Heating or Process Work	No. 29 Rotary Single Valve

Minimum Available Water Pressure Must be at Least 10 Lbs. Greater than Maximum Boiler Pressure.

Burnham Boiler Corporation

Irvington-on-Hudson, New York

New York Office: GRAYBAR BUILDING

Offices: BOSTON; PHILADELPHIA; CHICAGO; QUEENS VILLAGE, L. I.; SAN FRANCISCO; BALTIMORE; SPRINGFIELD; LANCASTER

Plants at IRVINGTON, N. Y.; ELIZABETH, N. J.; LANCASTER, PA.; ZANESVILLE, OHIO

There's a Burnham for every Heating purpose

1—Water Tube Boilers for Steam and Hot Water Heating.

17, 21, 27 and 36 in. Double shaking grates and long fire travel. Rating to 8,400 sq. ft. for steam and 13,985 sq. ft. for water.

2—Water Tube Boilers Jacketed in Color.

17 and 27 in. Steel Jacket and 4-ply air cell asbestos insulation. Enameled rich red. Jacket goes on after all other set up work. Rating to 3,850 sq. ft. for steam and 6,200 sq. ft. for water.

3—Big Twin Sectional Boilers.

50 in. Grate, divided for easy shaking. Twin sections, divided down the middle. Ratings to 16,550 sq. ft. for steam, 27,000 sq. ft. for water.

4—Tube Type Smokeless Boilers.

For burning soft coal efficiently and without smoke. Meet smoke ordinances everywhere. Similar to (1) above, with addition of smokeless feature.

5—Welded Steel Boilers—Also Three-Purpose Welded Steel Boilers.

For heating, hot water supply and incineration. Coal or oil. Completely welded for 15 lbs. working pressure. Multiple shaking grates. Sizes for commercial or domestic uses. Special folder sent on request.

6—Round Sectional Boilers.

This boiler made the long fire travel famous. Handled easily. Very large steam dome. Ratings up to 1,550 sq. ft. for steam, 2,560 for water.

7—High Pressure Hot Water Supply Boilers.

Sectional construction Guaranteed to 80 lbs. working pressure. Supplies up to 3,800 gallons.

8—Junior Hot Water Supply Boilers.

Will keep 175 to 700 gallon tank always full of hot water. Guaranteed to 80 lbs. working pressure.

9—Burnham Cast-Iron Radiators.

Occupy about ⅓ less space than ordinary cast-iron radiators of same rating. Shorter. Lower. Narrower. 3-tube type, 3¼ in. wide. 4-tube type 4 1/16 in. wide.

10—Fero Tube Radiators.

All heights—3, 4, 5, 6 and 7 tubes.

11—Burnham Air and Vacuum Valves.

Full line for radiators, risers and mains.

12—Complete Line of Heating Accessories.

Including steel tanks of all kinds.

Catalogs Sent on Request

AMERICAN RADIATOR COMPANY

40 West 40th Street, New York, N. Y.

Division of AMERICAN RADIATOR & STANDARD SANITARY CORPORATION

AMERICAN RADIATOR PRODUCTS

● BOILERS

IDEAL REDFLASH



The Ideal Redflash Boiler is a completely equipped, sectional, red-jacketed boiler made in a large range of sizes for homes and any other type of building, large or small. Its design embodies the latest principles of scientific heating resulting from more than 40 years of manufacturing and research experience.

THE NEW IDEAL ARCO BOILER



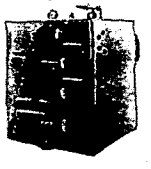
The new Arco Boiler is a jacketed round boiler, embodying in its design the new Arco circulator. It is made in sizes for small to medium sized houses. The red crystallized enamel finished jacket is lined with multi-ply insulation. Steam and water boilers are completely equipped with automatic regulation and all accessories.

IDEAL WATER TUBE BOILER



An extensive series of water-backed, vertical tubes divide the body of water in the Ideal Water Tube Boiler into many thin streams, and expose an unusually large amount of heat-absorbing surface. The sectional construction of Ideal Water Tube Boilers permits them to be placed in new or old buildings without difficulty, because they will go through any ordinary door or similar opening.

IDEAL MAGAZINE BOILER "25"



A modern, perfected boiler for burning coke, anthracite, or a mixture of these fuels with buckwheat or pea coal. Self-feeding and automatically regulated. Runs 12 to 24 hours on one fuel charge, depending on the outside temperature.

IDEAL SMOKELESS BOILER



Ideal Smokeless Boilers burn all grades of soft coal smokelessly and economically. They comply with the most rigid city smoke ordinances. This boiler accomplishes its high record of smokeless performance through its special, patented device, the Ideal Smoke Oxidizer.

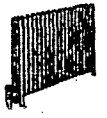
● RADIATORS

CORTO RADIATORS



Corto Radiators with their threaded nipple construction unite the advantages of both the faced and the threaded joint, making tight and safe construction. Every radiator is tested under severe hydraulic pressure before leaving the factory. American Corto Radiators are made in a complete range of sizes for every need.

ARCO RADIATORS



Occupying approximately one-third less space than older models, yet providing the same amount of heating surface, the new Arco Radiator is especially adapted for recessed or concealed installation. Its slender, graceful lines, compact and sturdy construction contribute another step in the progress of heating design.

NEW MURRAY RADIATORS



Murray Radiators were developed to supply the growing demand for a non-ferrous heating unit with high efficiency, light-weight, compactness and better sanitation, which could be recessed in the wall, and concealed with enclosures. The new Murray Radiator consists of steam chambers in the form of oval shaped seamless copper tubes, which are attached to the flues or extended surface by the special Murray patented process, through the use of electrically welded clips.

SEE IDEAL FITTER for Complete Data on American Radiator Products

AMERICAN RADIATOR COMPANY

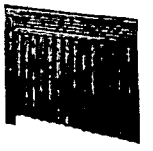
40 West 40th Street, New York, N. Y.

Division of AMERICAN RADIATOR & STANDARD SANITARY CORPORATION

AMERICAN RADIATOR PRODUCTS

RADIATORS—Continued

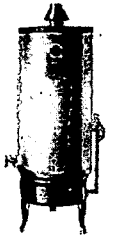
FANTOM RADIATORS



The American Fantom Radiator is recessed beneath a window without the usual loss of heating effectiveness. It occupies about one-third the room space required by a radiator standing in the open. Its simple, straight lines give it the pleasing effect of being an integral part of the room.

●WATER HEATERS

IDEAL HOTCOIL



An automatic gas water heater with an attractive enamelled jacket, made in 20, 30 and 40 gallon sizes. Provides constant hot water with no attention. Thoroughly insulated. Economical and convenient.

IDEAL KOLFLASH



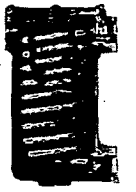
The Ideal Kolflash Water Heater is a completely automatic water heater of the self-contained storage type. Burns coal and provides constant hot water for only a few cents a day. Its convenience, economy and attractive appearance have won widespread public approval.

IDEAL HOT WATER SUPPLY BOILERS

The Ideal Hot Water Supply Boiler is for use where large quantities of hot water must be constantly available. Made of cast-iron and virtually immune to rust and corrosion. Designed to burn all kinds of fuel.

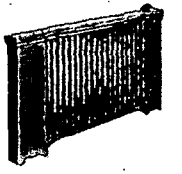
WATER HEATERS—Continued

EXCELSO

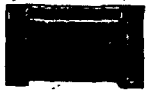


Excelso Indirect Water Heaters furnish domestic hot water supply at lowest possible cost. They eliminate troublesome pipe coils from the firepot of steam boilers.

● RADIATOR ENCLOSURES



Arco Radiator Enclosures answer all of the fundamental requirements of recessed and concealed radiation. They are artistically designed to harmonize with various interior treatments, can be installed easily, permit easy access for radiator regulation and cleaning, and assist in securing the best expression in heating efficiency from the radiator. They are available in a variety of models to answer individual needs and tastes.



IDEAL CASCADE HUMIDIFIER



The Ideal Cascade Humidifier with automatic control by means of the Arco Humidistat is designed to meet the demand for a practical home humidifier. The Ideal Cascade is a most efficient way to provide proper humidity.

SEE IDEAL FITTER for Complete Data on American Radiator Products

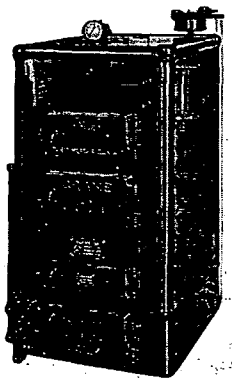
CRANE CO.

Manufacturers of Valves, Fittings, Fabricated Piping, Steam Specialties, Plumbing and Heating Materials

836 S. Michigan Avenue **Chicago, Ill.**

Branches in All Principal Cities

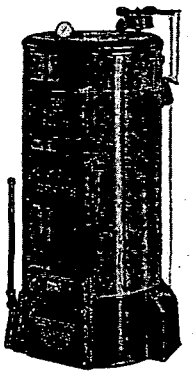
Write for catalogues and full information about any materials in which you are interested



Crane Boilers

Before Crane Co. developed its new line of boilers for hot water, steam, vacuum, and vapor heat; to burn all coals, coke, or oil; it devoted four years to intensive investigation and study. As a result of these, Crane Co. discovered 27 places where sectional boilers could be improved, and 24 places where round boilers could be bettered. Out of these improvements came the two Crane boilers illustrated here. Both are easier to install, easier to tend. Both are constructed to the A.S.M.E. and the A.S.H.V.E. standards. And finally, both have been built for lasting service: Heat resisting paint coats their exteriors, shaker handles are of unbreakable steel, insulation is of improved, sag-proof asbestos.

Crane Sectional Boiler



This boiler can be more economically installed. The jacket is put on after the boiler is completely assembled. By tightening four screws at the top corners it can be pulled to a perfect fit. The boiler can also be more economically fired. Its elongated two-pass gas flues are arranged for controlled water travel and give 50 per cent more heating surface. Back walls are corrugated to stand up under strain. Baffles direct water across the top of the combustion chamber. The water line is so devised that boiling water reaches it at only two points remote from the outlet, insuring drier steam.

Crane Round Boiler

Ease in tending as well as fuel economy distinguishes the Crane round boiler. The ash-pit is of generous size; the combustion chamber has a larger fuel capacity. The flue passages are planned to make the water rising up the sides of the combustion chamber cross the top and travel back and forth between each gas flue. This sets up positive circulation, sweeps away insulating film, and insures maximum contact with heating surface. The burning gasses are also directed for the longest fire travel. The top gas flue has a depression which maintains the velocity of the gas as it enters the smoke hood and also gives ample depth for water or steam storage space at the dome.

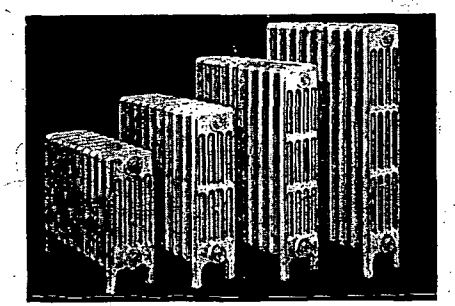


No. 226 Brass Radiator Valve

This valve has been designed for installation where high quality, lasting service, and good appearance are essential. It is of the non-rising stem type with rough body, nickel plated and is equipped with a quick thread to open fully in a three-quarter turn. A brass washer and nut hold the disc firmly in place; the self-adjusting stuffing box is packed with Cranite and asbestos which is held tight with a phosphor bronze spring. It can be repacked when wide open and under pressure. All wrenching surfaces and points where strains occur have been made extra heavy.

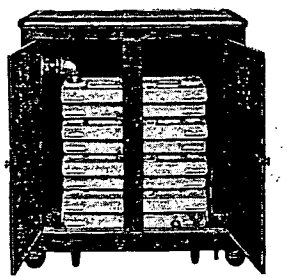
Crane Radiators

Since their announcement a year ago, Crane radiators have established a new standard of beauty and a new level of comfort in heating. Their simple, slender grace has no rival in according happily with the modern trends of interior decoration, nor, at the same time, are they surpassed in heating efficiency. These radiators are made in styles and sizes to meet every requirement in all types of buildings. They can be had in three, four, five, six, and seven tube types; and also legless, bathroom, wall, and hospital types.



Doherty-Brehm Humidifier

Doherty-Brehm Humidifying units provide the only fully automatic, low cost, and absolutely dependable method of banishing dry air from winter heated homes. In overcoming dry air, they eliminate all the ills it breeds . . . . sinus, skin, and throat infections; cracked and warped woodwork; brittle hangings, and disproportionately large fuel bills. The principle of their operation is amazingly simple, all moving parts that could get out of order, anything that could create noise or odor is dispensed with. One of these Humidifiers is enough to keep all the air in an average sized home, apartment, or office building at the proper degree of humidity. One can be installed as part of the regular heating system or as a separate unit, for a Doherty-Brehm Humidifier heats while it humidifies.



Molby Boiler Company *Incorporated*

Subsidiary of The Universal Pipe and Radiator Company

Molby Magazine-Feed, Downdraft-Crossdraft Boilers

for burning No. 1 Buckwheat Anthracite . . . Bituminous . . . or Coke

GRAYBAR BUILDING, LEXINGTON AVENUE AT 43rd STREET, NEW YORK

PHILADELPHIA BRANCH
2401 Chestnut Street

LANSDALE, PA. BRANCH
50 Central Avenue

CHICAGO BRANCH
332 S. Michigan Avenue



28 Sizes—for Homes, Apartment Houses and other Buildings.

The Molby heating boiler pays for itself. It is self-feeding and gives a steady, even heat over long periods, burning No. 1 Buckwheat at half the cost of large sizes of anthracite. Also burns free-burning bituminous. Also coke. Magazines need coaling only once a day. Built throughout in accordance with codes of A. S. M. E. and A. S. H. & V. E.

Tested and Certified by Outside and Unbiased Engineers of National Reputation.

Tests have been made, not alone by our own engineers, but in the nationally-known Frost Research Laboratory, at Norristown, Pa.—and these laboratory tests are certified to by Mr. Robinson V. Frost, C. E., Member A. S. M. E. and A. S. H. & V. E.

For the benefit of engineers, architect and contractor we will gladly furnish charts in fullest detail, as submitted by the Frost Research Laboratory, showing grate areas, ratings, boiler performances and efficiencies. Ask nearest office for these charts.

SIZES, RATINGS, DIMENSIONS, WEIGHTS, ETC.

STEAM			STEAM AND WATER							WATER	
No.	Water Line	Net Rating Steam	Size—Inches Height	Width	*Length	Smoke Pipe	Flow Return	Chimney Flue	Approximate Shipping Weight	No.	Net Rating Water
S-1-4	44	275	54	41	35½	10	2-3	8x12	2100	W-1-4	450
S-1-5	44	375	54	41	42	10	2-3	8x12	2530	W-1-5	615
S-1-6	44	475	54	41	48½	10	2-3	8x12	2980	W-1-6	780
S-1-7	44	575	54	41	55	10	2-3	12x12	3430	W-1-7	945
S-1-8	44	675	54	41	61½	10	2-3	12x12	3890	W-1-8	1110
S-2-5	50	839	62½	61	44	12	2-3	12x12	4210	W-2-5	1343
S-2-6	50	1087	62½	61	50⅜	12	2-3	12x12	4910	W-2-6	1739
S-2-7	50	1334	62½	61	56¾	14	3-3	12x16	5670	W-2-7	2135
S-2-8	50	1585	62½	61	63⅛	14	3-3	12x16	6430	W-2-8	2537
S-2-9	50	1852	62½	61	69½	14	3-3	16x16	7095	W-2-9	2964
S-2-10	50	2138	62½	61	75⅝	14	3-3	16x16	7800	W-2-10	3422
S-2-11	50	2405	62½	61	82	14	4-3	16x16	8460	W-2-11	3969
S-2-12	50	2600	62½	61	88¾	14	4-3	16x20	9120	W-2-12	4500
S-3-6	63	1900	80	75½	59	14	2-4	16x16	8620	W-3-6	3135
S-3-7	63	2275	80	75½	67½	16	3-4	16x16	9870	W-3-7	3750
S-3-8	63	2650	80	75½	76	16	3-4	16x20	11220	W-3-8	4370
S-3-9	63	3025	80	75½	84½	18	3-4	16x20	12430	W-3-9	4990
S-3-10	63	3400	80	75½	93	18	4-4	20x20	13730	W-3-10	5610
S-3-11	63	3775	80	75½	101½	18	4-4	20x20	14960	W-3-11	6225
S-3-12	63	4150	80	75½	110	18	4-4	20x24	16270	W-3-12	6845
S-3-13	63	4525	80	75½	118½	18	4-4	20x24	17480	W-3-13	7465
S-3-14	63	4900	80	75½	127	18	4-4	20x24	18860	W-3-14	8085

Note.—In ordering 26-in. boilers state whether you wish same fitted up with right hand or left hand end to the chimney, length includes Smoke Box.

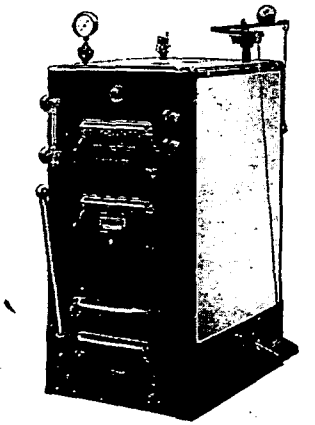
Equipment.—Each steam boiler is equipped with a full set steam trimmings, a pressure regulator and a complete set of firing and cleaning tools. Instruction books for erecting and operating accompany each boiler. Each water boiler is equipped with a thermometer, a water temperature regulator and a complete set of firing and cleaning tools. Instruction books for erecting and operating accompany each boiler.

*See assembling directions for exact length of boiler when it was assembled before leaving foundry.

Pierce, Butler & Pierce Manufacturing Corp.

41 East 42nd Street — **New York City**

Manufacturers of Cast-Iron and Steel Heating Boilers, Cast-Iron Screw Nipple Radiation, Hot Water Supply Boilers, Valves, Gauges and Thermometers.

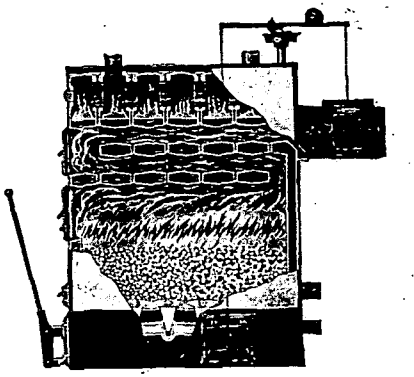


Pierce-Eastwood Jacketed Sectional Boiler

The Pierce-Eastwood Square Sectional Boiler with a Jacket in color.

Manufactured in three grate widths, 17 in., 19 in., 24 in., conservatively rated in steam from 245 to 2225 sq. ft. EDR, and in water from 390 to 3650 sq. ft. EDR.

Note the long fire travel, nearly three times the length of Boiler.

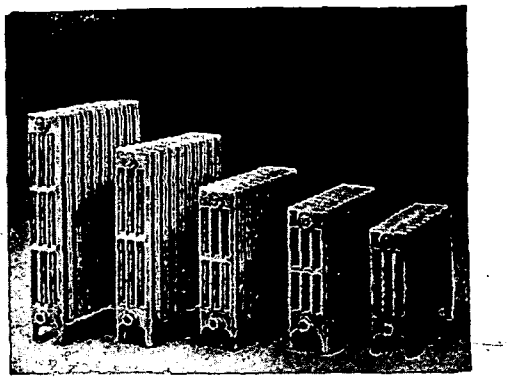


Cross Section View of Pierce-Eastwood Boiler

A group of Pierce Eastwood Screw Nipple Radiation. Due to generous proportions Eastwood Screw Nipple Radiation is unusually efficient.

Manufactured in all heights, in 3, 4, 5, 6 and 7 tube widths.

The slender, graceful Columns of Pierce-Eastwood Screw Nipple Radiation harmonize with any style interior.



Square Sectional Header Type Boilers, in 32, 40 and 46″ Grates. Hot Water Supply Boilers from 30 to 1000 Gallons capacity. Round jacketed Boilers in 18, 20 and 22″ Grates. Round Unjacketed Boilers in 17 to 31″ Grates. Low and High pressure steel Boilers and Engines (Ames Iron Works Div.) Valves, Gauges and Thermometers (Valve and Gauge Division).

RICHMOND RADIATOR COMPANY

INCORPORATED

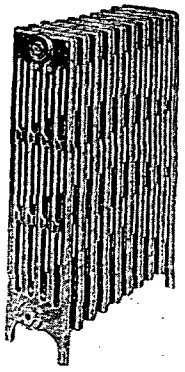
Executive Office: 1480 Broadway, New York

Sales Offices

CHICAGO, 1531 S. Peoria St.
BOSTON, Somerville, Mass.
PHILADELPHIA, 2241 N. American St.
CLEVELAND, 1424½ Keith Bldg.

Gas Boiler Division: 2241 North American St., Philadelphia, Pa.

Boiler, Radiator, Enameledware, and Heatomat Plant, Uniontown, Pa.

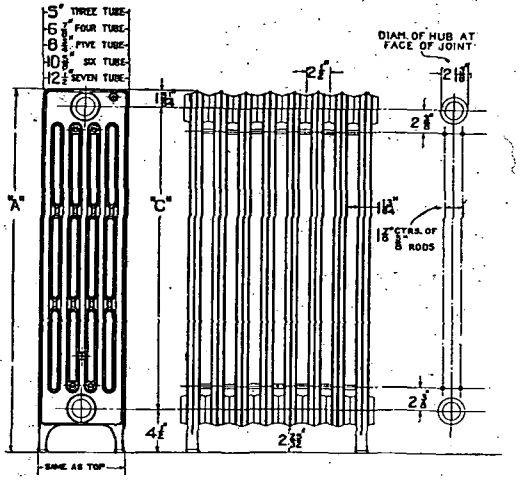


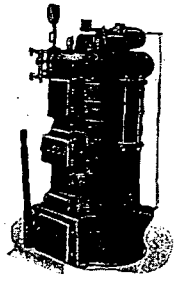
The "RICHMOND"

A masterpiece of design. Greater heating surface and space between sections. No protruding surfaces. Tested at Frost Laboratories in accordance with code of A. S. H. & V. E. Three, four, five, six and seven tubes in several heights.

"RICHMOND" TUBE RADIATION

PUSH NIPPLE CONSTRUCTION





New Richmond Round Boiler

For Steam and Hot Water

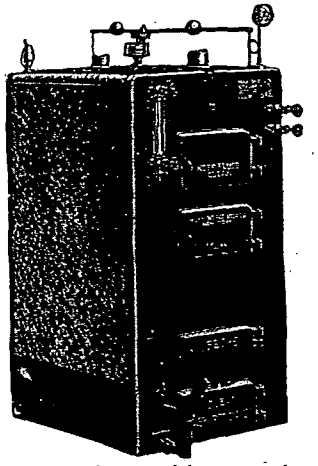
Type A—With flat shaking grate.
Type B—With triangular revolving grate.

Made in four, five, and six sections, each in 17, 19, 20, 23, 26, and 29 in. grate widths.

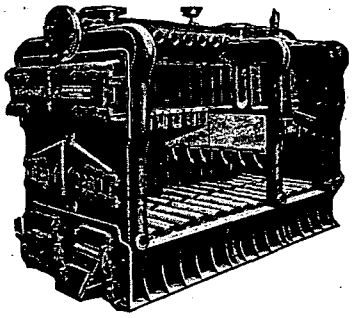
"RICHMOND-MODEL"

INSULATED AND JACKETED SECTIONAL BOILER

STEAM AND WATER

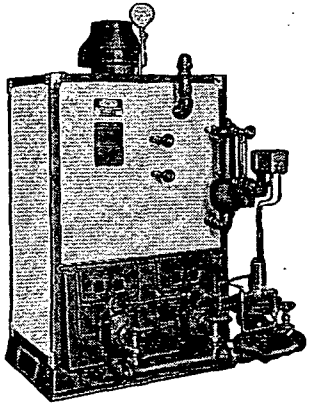


Available with or without smoke preventing device, made in widths of grates, 15 in. and 22 in.



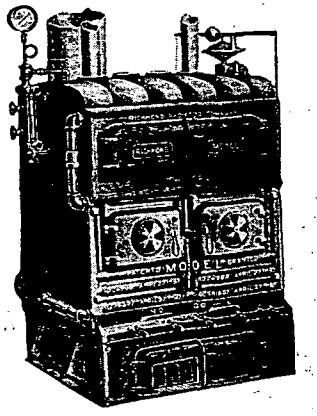
"Richmond" Heavy Duty Smokeless Boilers

Designed for Fuel Economy. Burns all grades of Hard or Soft Coal, Coke, Lignite, Natural Gas and Fuel Oils. Meets the requirements of the most rigid Smoke Ordinances. A 51 in. Boiler, 7 to 16 Sections, Steam and Hot Water.



Outstanding features of the Richmond Heatomat Gas Boiler

Vertical Tubular Construction.
Preheating return water flow with flue gas heat.
Water cooled walls absorb burner heat.
Secondary air intake regulated with gas flow.
Heat transmission scientifically baffled.
Only one burner, one primary air setting for battery.



Model Sectional Boilers

For Steam and Hot Water. Three to twelve sections, 18, 22, 30 and 40 in. grates. Compact, accessible, efficient heating surface and circulation system.

Spencer Heater Company

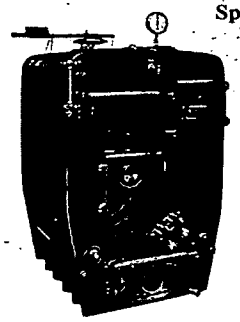
Division of Lycoming Manufacturing Company

Makers of Spencer Boilers

Williamsport, Pa.

New York, N. Y.	Rochester, N. Y.	Bethlehem, Pa.	Cincinnati, Ohio
Buffalo, N. Y.	Jamestown, N. Y.	Scranton, Pa.	Chicago, Ill.
Albany, N. Y.	Boston, Mass.	Harrisburg, Pa.	St. Louis, Mo.
Syracuse, N. Y.	Philadelphia, Pa.	Pittsburgh, Pa.	Birmingham, Ala.

PRODUCT: Spencer Magazine Feed Boilers



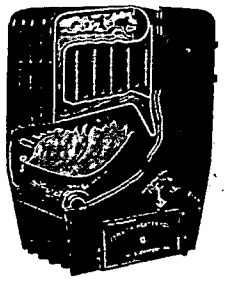
L-2 Series Spencer Cast-Iron Sectional Boiler

Spencer Boilers—The Spencer Boiler is the original magazine feed boiler with sloping grates, a gravity stoker boiler. The water jacketed magazine holds enough fuel for 12 to 24 hours. Fuel feeds automatically by gravity, as fast or as slow as the fire requires—no motors or mechanical or moving parts. Uniform depth of fire bed keeps fire always at most efficient combustion point, giving maximum efficiency at minimum fuel cost.

Spencer Boilers are made in sizes to suit every home or building, large or small. The direct cast-iron column radiation load which each size Spencer will carry is guaranteed. You are assured that the Spencer you specify will deliver sufficient heat for the radiation listed for it.

The Lowest Cost Heat You Can Buy—Spencer Boilers are designed especially to burn small-size, low-cost fuels, such as No. 1 Buckwheat anthracite or small size by-product coke. No. 1 Buckwheat anthracite, for example costs as much as $5 less a ton than the larger sizes. Where anthracite or coke is not available, smaller sizes of non-coking graded semi-bituminous, such as Pocahontas, may be successfully used. For any home or building, Spencer Automatic heat gives "The Lowest Cost Heat You Can Buy."

The new, improved Spencer Rotary Ash Receiver, furnished in six or eight can capacities, affords an ideal method of ash disposal. Ashes are raked directly from the ash pit into cans, contained in a water-tight steel tank sunk in the basement floor. Eliminates dust and ashes about the cellar.

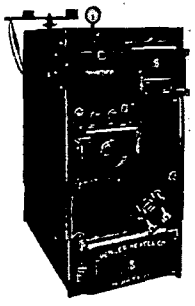


Spencer Combination Boiler for Coal, Coke or Gas

The Spencer Combination Boiler is designed to burn coal, coke or gas with equal efficiency and satisfaction, meeting the demands of those who desire to use gas now, or to burn gas as soon as it is available in their localities, or to burn gas during part of the heating season. Offers automatic heating with coal, coke or gas, and makes it possible to change instantly from coal or coke to gas; the specially designed gas burner is always there, ready for instant use, nothing to attach or connect. Furnished complete with burner, Minneapolis Jewell 8 day room temperature thermostat, pressure regulating valve, throttling valve and automatic pilot control.

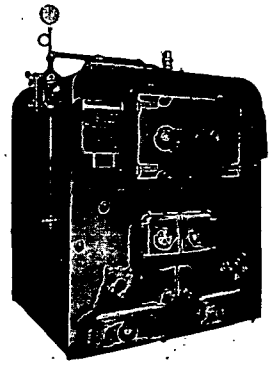
Spencer Automatic Heat for Different Types of Buildings—Spencer Boilers give the constant, uniform and healthful heat essential in schools, churches, apartments and theatres, without the attention of a night fireman; they are especially efficient in industrial buildings, greenhouses and garages where uniform heat is desirable.

For the home, Spencer Boilers are particularly convenient, insuring warm, comfortable rooms day and night, and requiring attention only once or twice in twenty-four hours.



Spencer Heavy Duty Steel Tank Heater

Spencer Heavy Duty Steel Tank Heaters are built of heavy copper bearing steel plates and Toncan Iron tubes to meet the hot water supply demands of large homes, apartments, hotels, restaurants, hospitals, office buildings and schools. The constant, uniform heat of the gravity feed Spencer affords a steady, continuous and dependable supply of hot water at lowest cost. Fully equipped with thermometer, safety relief valve and automatic damper regulator to carry any desired temperature. Built for working pressure up to 125 lbs.



M-7 Series Spencer Steel Tubular Boiler

Spencer Steel Tubular Boilers are combination water and fire tube construction, built of heavy steel plates and copper bearing tubes.

The Spencer Boiler is often referred to as the original "stoker." Improved and perfected through more than thirty-five years successful operation, it is still the ideal type of "stoker," operating entirely through the force of gravitation. It is positive in action, trouble free, always dependable; no machinery, no motors, blowers or moving parts. Everything needed for an automatic fire is in the Spencer Boiler itself.

The Spencer magazine feed and sloping grate construction automatically keep the fire-bed at the proper depth for efficient combustion. The depth of the fire bed never changes, the area of the combustion chamber remains constant. Consequently, Spencer Heat is always steady and uniform.

This Spencer combination of correct draft, correct depth of fire-bed, and correct size of combustion chamber supplies automatic heating at lowest cost.

Write for complete catalogue describing all Spencer Boilers.

GUARANTEED CAPACITIES AND DIMENSIONS

	Boiler No.	Direct Cast-Iron Column Radiation Loads, Sq. Ft.*		Grate Area	Outlets	Returns	Chimney Flue	Diameter Smoke Pipe	Over-all Dimensions		
		Steam	Water						Length	Width	Height
J Type	J-3	175	290	1.30	1-3″	2-3″	8″x 8″x35′	8″	26½″	24″	45″
	J-4	265	440	1.90	1-3″	2-3″	8″x 8″x35′	8″	33½″	24″	45″
	J-5	355	590	2.50	1-3″	2-3″	8″x 8″x35′	8″	40½″	24″	45″
L-1 Type	L-105	390	645	2.60	1-4″	2-4″	8″x 8″x35′	10″	39″	32″	57″
	L-106	510	845	3.33	2-4″	2-4″	8″x 8″x35′	10″	46″	32″	57″
	L-107	630	1,045	4.07	2-4″	2-4″	8″x12″x35′	10″	53″	32″	57″
	L-108	750	1,245	4.80	2-4″	2-4″	8″x12″x35′	10″	60″	32″	57″
L-2 Type	L-205	550	910	3.63	1-4″	2-4″	8″x12″x35′	10″	39″	40″	60″
	L-206	725	1,200	4.66	2-4″	2-4″	8″x12″x35′	10″	46″	40″	60″
	L-207	900	1,490	5.68	2-4″	2-4″	8″x12″x40′	10″	53″	40″	60″
	L-208	1,075	1,780	6.70	2-4″	2-4″	12″x12″x40′	10″	60″	40″	60″
	L-209	1,250	2,070	7.73	2-4″	2-4″	12″x12″x40′	10″	67″	40″	60″
L-3 Type	L-305	1,150	1,900	7.29	2-4″	2-4″	12″x12″x40′	14″	42″	56″	65″
	L-306	1,500	2,475	9.33	2-4″	2-4″	12″x12″x40′	14″	49″	56″	65″
	L-307	1,850	3,050	11.37	2-4″	2-4″	12″x12″x40′	14″	56″	56″	65″
	L-308	2,200	3,625	13.41	2-4″	2-4″	12″x16″x45′	14″	63″	56″	65″
	L-309	2,550	4,200	15.45	2-4″	2-4″	12″x16″x45′	14″	70″	56″	65″
	L-310	2,900	4,775	17.49	2-4″	2-4″	16″x16″x50′	14″	77″	56″	65″
	L-311	3,250	5,350	19.53	2-4″	2-4″	16″x16″x50′	14″	84″	56″	65″

*This includes ample provision for heat loss in covered mains, risers and returns, and for peak loads, as covered by guarantee.

GUARANTEED CAPACITIES AND DIMENSIONS

	Boiler No.	Direct Cast-Iron Column Radiation Loads. Sq. Ft.*	Grate Area	Outlets	Returns	Chimney Flue	Diameter Smoke Pipe	Over-all Dimensions		
		Steam						Length	Width	Height
(M6 Series)	M6-5	2,000	12.2	1-6″	2-2½″	12″x12″x40′	14″	58½″	58″	66″
	M6-6	2,300	14.0	1-6″	2-2½″	12″x12″x40′	14″	65½″	58″	66″
	M6-7	2,600	15.8	1-6″	2-2½″	12″x16″x45′	14″	72½″	58″	66″
	M6-8	2,900	17.6	1-6″	2-2½″	12″x16″x45′	14″	79½″	58″	66″
	M6-9	3,200	19.4	1-6″	2-2½″	16″x16″x50′	14″	86½″	58″	66″
	M6-10	3,500	21.2	1-6″	2-2½″	16″x16″x50′	14″	93½″	58″	66″
(M7 Series)	M7-6	4,000	19.0	1-8″	2-3″	20″x20″x60′	18″	75¼″	68″	80″
	M7-7	4,700	22.0	1-8″	2-3″	20″x20″x60′	18″	82½″	68″	80″
	M7-8	5,400	25.0	1-8″	2-3″	20″x20″x65′	18″	89¼″	68″	80″
	M7-9	6,100	28.0	1-8″	2-3″	22″x22″x70′	18″	96½″	68″	80″
	M7-10	6,800	31.0	1-8″	2-3″	22″x22″x70′	18″	103½″	68″	80″
(M8 Series)	M8-6	8,000	32.36	1-8″	2-4″	24″x24″x65′	24″	79¼″	108″	85″
	M8-7	9,750	37.02	1-8″	2-4″	24″x24″x65′	24″	86¼″	108″	85″
	M8-8	11,500	41.68	1-8″	2-4″	30″x30″x70′	24″	93¼″	108″	85″
	M8-9	13,250	46.34	1-8″	2-4″	36″x36″x70′	24″	100¼″	108″	85″
	M8-10	15,000	51.00	1-8″	2-4″	36″x36″x70′	24″	107¼″	108″	85″

*This includes ample provision for heat loss in covered mains, risers and returns, and for peak loads, as covered by guarantee.

Weil-McLain Company

Manufacturing Division: **Michigan City, Ind., Erie, Pa.**
General Offices: **641 W. Lake Street, Chicago**

NEW YORK OFFICES: **501 Fifth Avenue**

Prompt Weil-McLain Boiler and Radiator service is made conveniently available through local stocks carried by Weil-McLain Distributors with distributing centers and branches in the following cities:

New York
Albany
Brooklyn
Buffalo
Lynbrook, L. I.
Mineola, L. I.
New York City
Plattsburg
Port Chester
Poughkeepsie
Rochester
Stapleton
Staten Island
Syracuse
Utica

New Jersey
Atlantic City
Belmar
Camden
Elizabeth
Englewood
Irvington
Long Branch
Red Bank
Ridgewood

Connecticut
Bridgeport
Hartford
Meriden
New Haven

Vermont
Burlington

New Hampshire
Rochester

Massachusetts
Boston
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Rhode Island
Providence

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Allentown
Bryn Mawr
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Erie
Harrisburg
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Lansdale
Lansdowne
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Kentucky
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Indiana
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Terra Haute

Iowa
Cedar Rapids
Des Moines
Dubuque
Fort Dodge
Sioux City

Wisconsin
Milwaukee

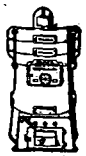
Michigan
Grand Rapids

Minnesota
Duluth
St. Paul

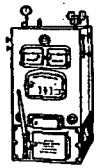
Missouri
Kansas City
St. Louis

Canada
Montreal
Toronto
Winnepeg
St. John

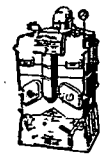
Weil-McLain
SCIENTIFIC COMBUSTION
BOILERS



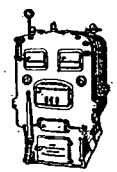
Round Type Boilers—With vital heating surface corrugated like this ~~~ to crowd in more heating surface and balanced long back and forth fire travel. Output capacities steam 400 to 1860 sq. ft. Output capacities water 660 to 3070 sq. ft.



Jacketed Type Boilers—With rounded live fire corners—all grates shaking grates—balanced fire travel and narrowest inside point of boiler at grate level. Output capacities steam 530 to 3350 sq. ft. Output capacities water 890 to 5570 sq. ft.



Self-Feed Boilers—For small, inexpensive sizes of anthracite and coke. Minimum attention. Vital heating surfaces corrugated like this ~~~ balanced back and forth fire travel; ashpit spray. Output capacities steam 440 to 1425 sq. ft. Output capacities water 720 to 2350 sq. ft.

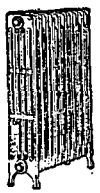


Square Type Boilers—Firebox narrowest at grate level. A wider combustion chamber and extra width in horizontal flue surface. Extended surface over fire; balanced fire travel. Output capacities steam 1220 to 15,230 sq. ft. Output capacities water 2010 to 25,125 sq. ft.

Smokeless Boilers—Patented smokeless design eliminates grate "vairea," the cause of short firing periods in ordinary smokeless boilers. Output capacities steam 1810 to 17,125 sq. ft. Output capacities water 2990 to 28,250 sq. ft.

CAMEO
WEIL-McLAIN RADIATORS

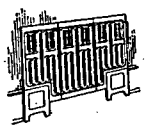
Tubes Are Oval — **For Added Strength**



Cameo Senior—2½ in. centers. Modern tube design radiator. Pleasing appearance. Complete range of heights and widths.



Cameo Junior—1½ in. centers. A compact radiator suitable for exposed, for cabinet and concealed installation.



Cameo Radiant Convectant Recess—Made entirely of cast iron. Is its own live metal front and grille. For Hot Water, Steam or Vapor Systems.



Cameo Wall—A two-tube wall radiator of pleasing appearance and harmonizing with conventional tube radiators. Made in two heights. Assembled in multiples of 1½ sq. ft. and 2 sq. ft. per section.

The Babcock & Wilcox Company

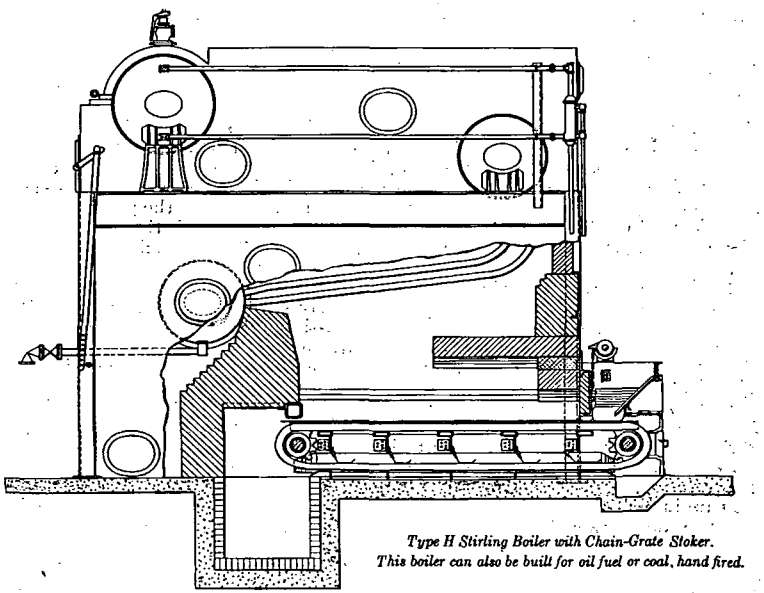
85 Liberty Street, New York, N. Y.

Manufacturers of

Water-Tube Boilers — **Chain-Grate Stokers**
Oil Burners — **Seamless Steel Tubing**

Branch Offices

Atlanta.....Candler Bldg.
Boston.....49 Federal St.
Chicago.....20 N. Wacker Drive
Cincinnati.....Carew Tower
Cleveland.....Guardian Bldg.
Dallas, Texas.....Magnolia Bldg.
Denver.....444-17th St.
Detroit.....411 Ford Bldg.
Galveston, Texas.....Security Bldg.
Houston, Texas.....Electric Bldg.
Los Angeles.....Central Bldg.
New Orleans.....344 Camp St.
Philadelphia.....Packard Bldg.
Phoenix, Arizona.....Luhr's Tower
Pittsburgh.....Koppers Bldg.
Portland, Ore.....805 Failing Bldg.
Salt Lake City.....Kearns Bldg.
San Francisco.....Sheldon Bldg.
Seattle.....Smith Tower
San Juan, Porto Rico.....Recinto Sur 45
Havana, Cuba.....Calle de Aguiar 104
Honolulu.....Castle & Cooke Bldg.



Type H Stirling Boiler with Chain-Grate Stoker. This boiler can also be built for oil fuel or coal, hand fired.

The Type H Stirling Boiler admirably meets the demand for a water tube boiler having unusual steaming capacity for the amount of floor space occupied and suitable for installations where the head room is limited.

The design is such that boilers can be set singly or in battery and settings can be increased in height to suit various conditions of firing by lengthening the supporting columns. The sizes range from 700 to 5000 sq. ft. of heating surface.

The smaller sizes can be shipped already assembled so that all that is necessary for installation is the small amount of brickwork for the setting.

Ample cleaning doors, conveniently located, allow for the thorough inspection and cleaning of all heating surfaces with the least effort and loss of time. Standard manhole openings in the drumheads give access for cleaning and turbining tubes. Tube replacements can be made with ease.

The excellent qualities of the boiler are attested by the fact that to date over 82,000 horse-power of these boilers, firing almost every conceivable kind of fuel in all types of furnaces have been installed and are giving satisfactory service.

A booklet, giving tables of setting heights, sizes, notable installations and other interesting and valuable data is available on request.

The Bigelow Company

ESTABLISHED 1860

Main Office and Works

New Haven, Connecticut

NEW YORK OFFICE—Graybar Building

BOSTON OFFICE—101 Milk Street

Manufacturers of

Bigelow Hornsby Water Tube Boilers
Bigelow Low Head Water Tube Boilers
Bigelow Three Drum Vertical Water Tube Boilers
Bigelow Horizontal Return Tubular Boilers
Bigelow Electric Steam Generators
Bigelow Two Pass Boilers
Bigelow Manning Boilers
Bigelow Upright Boilers

The Bigelow Two Pass Boiler for Heating and Power

The requirements in considering a boiler especially for steam heating—are first cost, efficiency and maintenance, and the steel heating boiler particularly the Bigelow Two Pass type we believe meets the above desired requirements most favorably.

First Cost—The F. O. B. price of a steel boiler is often higher than for other types, but, of course, the installed cost is the correct way to figure. For the proper erection of a sectional boiler experienced and high priced men are required while the Bigelow Two-Pass Boiler is shipped practically all assembled and requires but a small amount of mason work.

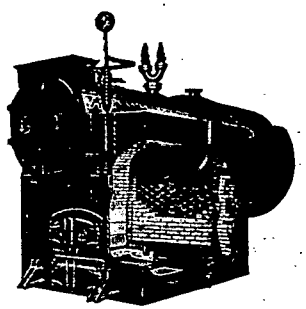
Efficiency—Correctly designed as a heat absorbing piece of apparatus, the area of the gas passage in the first pass is approximately one third greater than that of the return pass. This results in better heat transmission, due to the more uniform velocity of the gases over the heating surface as they are cooled.

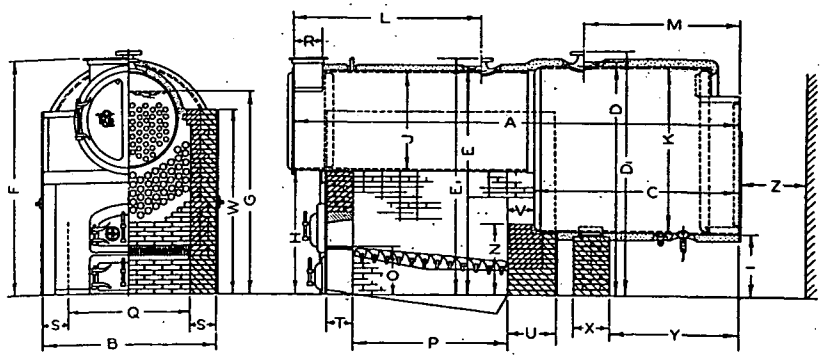
The furnace is constructed of standard fire and red brick and is encased in a heavy sectional plate steel casing which adds to the neat appearance of the installation and prevents infiltration of air through cracks that may develop in the brick work.

Maintenance—The Bigelow Two-Pass Boiler is constructed without crown sheet or water legs, so there are no staybolts to break and cause leakage or danger of rupture. Being constructed of steel, there is no likelihood of cracking sections due to sudden changes of temperature, variation in thickness of material under pressure, and no unequal strains are set up in assembling. The many installations of the Bigelow Two-Pass Boiler both for heating and power, have proven it to be economical in operation and low in maintenance cost.

Features of the Bigelow Two-Pass Boiler

No Staybolts
Easy to Install
Quick Steamer
Low Draft Loss
Easy to Handle
Long Gas Travel
Efficient to Operate
Low Maintenance Cost
Ample Water Capacity
Occupies Small Floor Space
Low Exit Gas Temperature
Ample Steam Storage Capacity
Inside of Boiler Readily Accessible
Furnace Suitable for Oil Burning
No Cast Iron in Contact with Pressure
Large Furnace Volume for Combustion
Area of Gas Passes Properly Proportioned
No Special Brick Shapes Required for Furnace
No Clearance Required at Rear for Tube Removal
Constructed to A.S.M.E., or Mass. State Requirements
Fire Brick Furnace Walls, which Aids Combustion
Built in Units of 25, 50, 75, 100, 125 and 150 hp.
All Sizes Built as a Standard for 15 and 125 lb. W. P.
Special Boilers can be Constructed for Higher Pressures
Brick Work Easily and Cheaply Repaired when Necessary
Furnace readily adapted to Mechanical or Semi-Mechanical Stokers
Boiler Rating Based on 10 sq. ft. of Water Heating Surface per hp.





GENERAL INFORMATION OF BIGELOW TWO-PASS BOILER

No. of Boiler for Heating, 15 lb. W. P. / Power, 125 lb. W. P.		240H / 240	241H / 241	242H / 242	243H / 243	244H / 244	245H / 245
Horse Power Based on 10 sq. ft. W. H. S.		27	50	75	100	127	150
Total Heating Surface, sq. ft.		270	505	751	1003	1273	1501
Capacity Steam Hand Fired Coal, sq. ft.		3750	7000	10500	14000	17500	21000
Capacity Steam Oil Fired, sq. ft.		4550	8550	12700	17000	21500	25500
Capacity Water Hand Fired Coal, sq. ft.		6000	11200	16800	22400	28000	33600
Capacity Water Oil Fired, sq. ft.		7250	13600	20300	27200	34400	40800
Grate Area, sq. ft.		12.3	18.7	23.3	28.0	31.0	36.1
Diameter stack, one boiler, in.		16	20	24	27	30	30
Diameter stack, two boilers, in.		20	27	30	34	38	42
Height stack, feet		60	60	60	60	60	60
Area breeching, one boiler, sq. ft.		1.3	2.2	3.0	3.8	4.5	5.2
Area breeching, two boilers, sq. ft.		2.2	3.8	5.2	6.3	8.0	9.4
Size of steam outlet, 15 lb. W. P., in.		6	6	8	8	8	8
Size of steam nozzle, 125 lb. W. P., in.		3	4	4	4	6	6
Size of safety valve outlet, 15 lb. W. P., in.		2	2½	3	4	4	4
Size of safety valve nozzle, 125 lb. W. P., in.		3	4	4	4	4	2–3"
No. and size pop valves, 15 lb. W. P., in.		1–2"	1–2½"	1–3"	1–4"	1–4"	1–4"
No. and size pop valves, 125 lb. W. P., in.		1–2"	2–2"	2–2"	2–2½"	2–2½"	2–3"
Blow down and return conn., 15 lb. W. P., in.		3	3	3	4	4	4
Blow-off connection, 125 lb. W. P., in.		2	2	2	2	2	2½
No. red brick required		1400	1650	1750	2100	2300	3000
No. fire brick required		550	675	775	800	900	1050
Area of shell to be insulated, sq. ft.		100	120	145	170	195	220
Weight bare boiler, lbs.		4675	8482	10732	14000	16717	18823
Weight boiler complete cstgs., trmgs. and steel casing, lbs.		7993	12492	15607	19841	23133	25859
Length over all, ft. in.	A	11' 9"	13' 0"	14' 1"	16' 2"	16' 4"	18' 10"
Width over all, ft. in.	B	5' 4"	6' 5"	6' 11"	6' 11"	7' 5"	7' 5"
Length large shell, ft. in.	C	5' 8"	6' 2"	6' 8"	7' 8"	7' 8"	8' 8"
Steam outlet to floor, 15 lb. W. P., ft. in.	D	7' 7 1/16"	8' 1 3/8"	8' 10 7/8"	9' 2 15/16"	9' 11 1/16"	9' 11 1/16"
Steam nozzle to floor, 125 lb. W. P., ft. in.	D1	7' 9 3/16"	8' 4 1/16"	9' 1 1/2"	9' 5 11/16"	10' 1 3/4"	10' 1 3/4"
Safety valve outlet to floor, 15 lb. W.P., ft. in.	E	7' 4 3/16"	7' 10 5/16"	8' 7 1/4"	8' 11 5/8"	9' 7 5/16"	9' 7 1/2"
Safety valve noz. to floor, 125 lb. W.P., ft. in.	E1	7' 6 3/16"	8' 1 5/16"	8' 10 1/8"	9' 2 1/8"	9' 10 1/8"	9' 10"
Flue neck to floor, ft. in.	F	7' 9½"	8' 3½"	9' 0½"	9' 4½"	10' 0½"	10' 0½"
Water line to floor, ft. in.	G	6' 5¼"	6' 11¾"	7' 8 3/16"	7' 11¼"	8' 6 3/16"	8' 6 3/16"
Floor to shell at front of boiler, ft. in.	H	4' 7"	4' 7"	5' 0"	5' 0"	5' 4"	5' 4"
Floor to shell at rear of boiler, ft. in.	I	2' 10"	2' 4"	2' 7"	2' 5"	2' 7"	2' 7"
Diameter of small shell, in.	J	32"	38"	42"	46"	50"	50"
Diameter of large shell, in.	K	54"	66"	72"	78"	84"	84"
Front of boiler to C safety valve nozzle, ft. in.	L	3' 4"	4' 7"	5' 3"	6' 3"	6' 5"	6' 0"–8' 0"
Rear of boiler to C steam nozzle, ft. in.	M	4' 2"	4' 2"	4' 7"	5' 8"	5' 8"	6' 7"
Height of bridge wall, ft. in.	N	3' 3"	3' 0"	3' 1"	2' 11"	2' 11"	2' 11"
Grate to floor, ft. in.	O	2' 1"	2' 1"	2' 1"	2' 1"	2' 1"	2' 1"
Length of furnace, ft. in.	P	4' 0"	4' 6"	5' 0"	6' 0"	6' 0"	7' 0"
Width of furnace, ft. in.	Q	3' 1"	4' 2"	4' 8"	4' 8"	5' 2"	5' 2"
Size of flue neck, in.	R	8"x22"	11"x24"	12½"x32"	13½"x36"	15½"x40"	15½"x42"
Thickness of side wall, in.	S	13½"	13½"	13½"	13½"	13½"	13½"
Thickness of front wall, in.	T	9"	9"	9"	9"	9"	13½"
Thickness of bridge wall at bottom, ft. in.	U	1' 4"	1' 4"	1' 4"	1' 4"	1' 4"	1' 6"
Thickness of bridge wall at top, in.	V	6½"	6½"	6½"	6½"	6½"	8"
Floor to top of setting, ft. in.	W	6' 5"	6' 8"	7' 3"	7' 3"	7' 11"	7' 11"
Depth and width of rear pier, ft. in.	X	1' 0"x3' 0"	1' 0"x3' 0"	1' 0"x3' 6"	1' 4"x4' 0"	1' 6"x4' 6"	1' 6"x4' 6"
Back of pier to rear of boiler, ft. in.	Y	3' 1½"	3' 7½"	4' 1½"	4' 9½"	4' 7½"	5' 7"
Distance required to open rear cleanout doors, ft. in.	Z	1' 10"	2' 1"	2' 4"	2' 6"	2' 10"	2' 10"

Fitzgibbons Boiler Co., Inc.

Established 1886

General Offices: 570 Seventh Avenue, New York, N.Y.

Works: OSWEGO, N.Y.

Branches and Representatives in Principal Cities

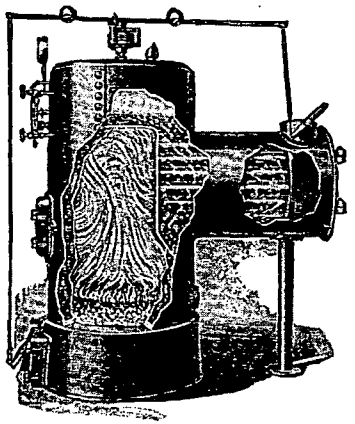
The Sign of the BEST in STEEL BOILER HEAT

PRODUCTS: Fitzgibbons Steel Heating and Power Boilers, as listed on this and the following three pages, meet the heating requirements of all buildings from the small home to the gigantic modern skyscraper. The line includes types for burning anthracite, bituminous (soft) coals or coke, or for oil, gas or stoker firing, in steam, vapor, vacuum or hot water systems, as specified. In other words, there is a Fitzgibbons Steel Boiler for every fuel and every heating system, in installations of every size from the smallest to the largest.

Distinctive Characteristics: Highest quality construction down to the last detail; quick "pick-up" of the heating load; high efficiency resulting in large fuel savings, even with below average attendance; easy installation; compact space requirements; durability that outlasts the enclosing buildings; complete heating satisfaction from every point of view.

Descriptive Literature: Illustrated Catalogs and Bulletins, giving full details of design and construction will be mailed on request.

Ratings: The ratings given in the following tables can be depended upon. They are the **total radiation loads** (taken at the boiler outlet), which the respective boilers will heat, with 2 lbs. pressure at the boiler for Steam and 180° F for Hot Water. Ratings are expressed in sq. ft. of equivalent cast-iron radiation, emitting 240 B.t.u. per sq. ft. per hour for Steam, and 150 B.t.u. per sq. ft. per hour for Hot Water.



FITZGIBBONS
Copper-Steel Residence Heating Boilers
Electric-Welded.

for Small and Medium Size Heating Plants. All Fuels and All Heating Systems.

TABLE 1 — for Anthracite, Bituminous Coals or Coke.

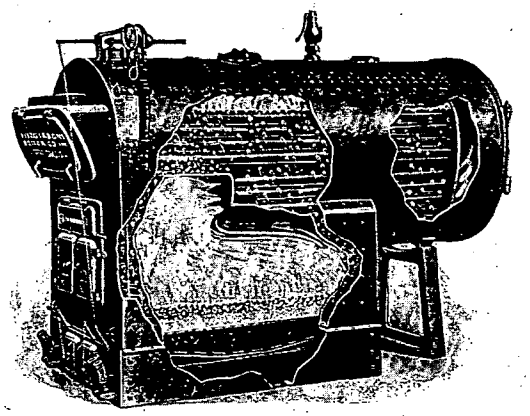
TABLE 1 - B — for burning Soft Coal Smokelessly.

TABLE 1-OH—for Oil, Gas, or Domestic Stoker firing. Bulletins giving ratings of Table 1-OH boilers sent on request.

Ratings and Dimensions TABLES 1 and 1-B Combined—Sizes: 400 to 3200 sq. ft. Steam Radiation Built for 15 lbs. w.s.p.—A.S.M.E. Code

Number of Boiler		J-8	H-8	J-12	H-16	H-20	H-24	H-28	H-32	H-36	H-44	H-50	H-58	H-64
Number of Smokeless Boiler		None	B-8	B-12	B-16	B-20	B-24	B-28	B-32	B-36	B-44	B-50	B-58	B-64
Steam Rating	sq. ft.	400	400	600	800	1000	1200	1400	1600	1800	2200	2500	2900	3200
Hot Water Rating	sq. ft.	700	700	1000	1300	1600	1900	2200	2600	2900	3500	4000	4600	5100
Heating Surface	sq. ft.	33	35	51	67	78	95	108	123	150	192	233	249	295
*Comp. Grate Area	sq. ft.	2.5	3.36	3.36	4.35	4.35	5.84	5.84	7.10	7.10	8.50	8.50	10.00	10.00
Diam. Vertical Shell	inches	24	27	27	30	30	34	34	38	38	41	41	44	44
Length Boiler	ft. in.	3–3	3–9	4–5	4–9	5–3	5–8	6–2	6–9	7–9	7–7	8–7	8–4	9–4
Diam. Horizontal Shell	inches	18	18	18	21	21	23	23	27	27	31	31	33	33
Height Overall	ft. in.	4–2	4–3	4–3	4–8	4–8	5–0	5–0	5–5	5–5	5–9	5–9	6–1	6–1
Water Line	ft. in.	3–5	3–7	3–7	4–0	4–0	4–4	4–4	4–7	4–7	4–11	4–11	5–2	5–2
Diameter Grate	inches	19	22	22	25	25	29	29	32	32	35	35	38	38
Diameter Base	inches	26½	30	30	33½	33½	37½	37½	40½	40½	42¾	42¾	45¾	45¾
Space to Draw Tubes	inches	18	18	22	24	30	27	32	31	43	35	47	40	52
Smoke Uptake	inches	5½x12½	5½x12½	5½x12½	6½x15½	6½x15½	7½x17½	7½x17½	8½x20½	8½x20½	9½x22	9½x22	10x25	10x25
Stack Diameter	inches	8	8	8	10	10	12	12	14	14	16	16	18	18
Stack Height	feet	40	40	45	40	45	45	45	50	50	50	60	60	60
Approx. Covering Surface	sq. ft.	29	33	37	52	58	60	66	72	80	86	94	102	110
Approx. Shipping Weight	lbs.	920	1150	1225	1525	1625	2000	2100	2400	2460	3000	3200	3550	3800

*It has been established that the Circular Grate in the Fitzgibbons Cylindrical Furnace is more effective than a rectangular grate the size of the circumscribed square. Hence, for comparative purposes, the **Comparative Grate Area** shown in the Tables is the area of the square circumscribed upon a circle the size of the Fitzgibbons Grate.



Up-Draft Type

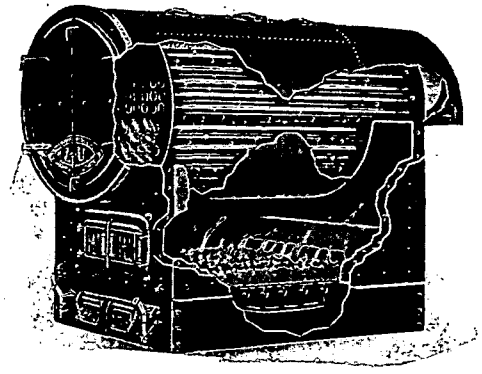
FITZGIBBONS
Z-U Steel Firebox Boilers
for All Fuels and All Heating Systems

Smokeless; Up-Draft; Oil, Gas, Stoker Types.

Sizes: 2300 to 38000 sq. ft. Steam Ratings—Built for 15 lbs. w.s.p.—A.S.M.E. Code.

Boiler No. Up-Draft Type	Boiler No. Smokeless Type	Rating Steam, Sq. Ft. D&V Types	Boiler No. Oil, Gas, Stoker Type	Rating Steam, Sq. Ft. M-Type	Heating Surface, Sq. Ft.	Grate Area, Sq. Ft.	Diam. Boiler, Inches	Length Boiler, Ft-In.	Height Overall, Inches	Water Line, Inches	Smoke Uptake, Inches by Inches	Diam. Stack, Inches D&V Types	Height Stack, Feet D&V Types	Size Outlet, Inches	Size Return, Inches	Apprx. Covering Surface, Sq. Ft.	Apprx. Shipping Wght., Lbs. V&D Types
*D23	*V23	2324	*M28	2822	166	9.1	36	5–8	68	60	8x23	20	50	5	3	60	3600
*D29	*V29	2912	*M35	3536	208	10.4	36	6–5	68	60	8x23	20	50	6	4	70	3900
*D35	*V35	3500	*M42	4250	250	11.7	36	7–5	68	60	8x23	20	55	6	4	75	4200
*D40	*V40	4004	*M48	4862	286	12.9	36	8–5	68	60	8x23	22	55	6	4	80	4500
*D45	*V45	4508	*M54	5474	322	14.0	42	7–9	72½	63	10x24	22	55	6	4	105	5400
*D50	*V50	5012	*M60	6086	358	15.5	42	8–9	72½	63	10x24	22	60	6	4	113	6100
D55	V55	5502	M66	6681	393	15.5	42	9–6	72½	63	10x24	24	60	6	4	119	6400
*D59	*V59	5960	*M72	7242	426	16.3	48	7–9	80½	69	10x32	24	60	6	4	126	6800
D69	V69	6944	M84	8432	496	18.1	48	9–1	80½	69	10x32	24	65	6	4	142	8000
D80	V80	8022	M97	9741	573	19.8	48	10–1	80½	69	10x32	24	65	6	4	155	8800
*D90	*V90	9002	*M109	10931	643	22.7	54	9–4	86½	74	11x34	26	60	8	6	166	9800
D100	*V100*	*10010*	M121	12155	715	22.7	54	10–1	86½	74	11x34	26	65	8	6	177	10600
D110	V110	11088	M134	13464	792	24.7	54	11–1	86½	74	11x34	28	65	8	6	192	11900
D123	V123	12386	M149	14948	879	25.5	60	10–2	95½	82	14x40	30	65	8	6	198	12700
D136	V136	13608	M165	16524	972	27.8	60	11–2	95½	82	14x40	30	70	8	6	212	13400
D151	V151	15106	M183	18343	1079	30.0	60	12–2	95½	82	14x40	30	75	8	6	228	14800
D170	V170	17010	M206	20655	1215	30.8	66	11–9	103½	89	15x40	32	80	8	6	250	16800
D189	V189	18900	M229	22950	1350	33.3	66	13–0	103½	89	15x40	32	85	8	6	272	18500
D210	V210	21000	M255	25500	1500	36.7	72	12–2	111½	96	16x46	32	85	8	6	280	20000
D230	V230	23002	M279	27931	1643	36.7	72	13–2	111½	96	16x46	32	90	8	6	300	21000
D250	V250	25004	M303	30362	1786	40.0	78	12–4	117½	100	16x52	34	90	10	6	318	22000
D270	V270	27006	M327	32793	1929	40.0	78	13–2	117½	100	16x52	34	95	10	6	335	23000
D302	V302	30212	M366	36686	2158	43.3	84	12–6	123½	105	18x58	36	95	10	6	336	25000
D347	V347	34720	M421	42160	2480	46.6	84	13–10	123½	105	18x58	40	100	10	6	368	27000
D378	V378	37828	M459	45934	2702	46.6	84	15–0	123½	105—	18x58	40	110	10	6	398	29000

*No rear stand required or furnished on these sizes of boiler.



Up-Draft Type

FITZGIBBONS

R-Z-U Steel Firebox Boilers Rear Smoke Outlet

for All Fuels and All Heating Systems

The Z-U Boiler arranged to meet the requirements of installations where conditions make it desirable to place smoke outlet at the rear.

Sizes: 2600 to 34000 sq. ft. Steam Ratings.
Built for 15 lbs. w.s.p.—A.S.M.E. Code.

Boiler No. Up-Draft Type	Boiler No. Smokeless Type	Rating Steam, Sq. Ft.	Boiler No. Oil, Gas, Stoker Type	Rating Steam, Sq. Ft.	Heating Surface Sq. Ft.	Grate Area, Sq. Ft.	Width Boiler, Inches	Length Boiler, Inches	Height Overall, Inches	Water Line, Inches	Diam. Stack, Inches V&D Types	Height Stack, Feet V&D Types	Size Outlet, Inches	Size Return, Inches	Apprx. Covering Surface, Sq. Ft.	Apprx. Shipping Wght., Lbs. V&D Types
RD26	RV26	2660	RM32	3230	190	10.4	36	79	72	64	18	55	5	3	80	4700
RD36	RV36	3680	RM44	4470	263	11.7	36	100	72	64	18	55	6	4	100	5300
RD43	RV43	4300	RM52	5220	307	12.9	36	112	72	64	18	55	6	4	112	6100
RD48	RV48	4800	RM58	5831	343	14.0	42	105	81	72	20	60	6	4	108	6400
RD55	RV55	5530	RM67	6715	395	15.5	42	116	81	72	22	60	6	4	112	7000
RD59	RV59	5960	RM72	7225	425	16.3	48	102	87	76	24	60	6	4	123	7800
RD70	RV70	7000	RM85	8500	500	18.1	48	115	87	76	24	65	6	4	138	8800
RD80	RV80	8080	RM98	9809	577	20.6	54	108	93	81	26	65	8	6	150	9700
RD91	RV91	9140	RM111	11101	653	22.6	54	119	93	81	26	65	8	6	164	10900
RD102	RV102	10200	RM123	12376	728	24.6	54	128	93	81	28	65	8	6	176	12300
RD120	RV120	12020	RM146	14603	859	27.7	60	124	102	89	28	75	8	6	188	13800
RD140	RV140	14080	RM171	17102	1006	30.0	60	140	102	89	30	75	8	6	204	15200
RD163	RV163	16380	RM198	19890	1170	30.8	66	138	111	97	30	80	8	6	224	17600
RD180	RV180	18010	RM218	21862	1286	33.3	66	152	111	97	32	80	8	6	240	18800
RD201	RV201	20150	RM244	24463	1439	36.7	72	149	117	102	32	85	8	6	260	21200
RD221	RV221	22160	RM269	26911	1583	36.7	72	160	117	102	34	90	8	6	280	22000
RD243	RV243	24340	RM295	29563	1739	36.9	78	153	123	106	34	100	10	6	298	24100
RD270	RV270	27000	RM327	32759	1927	40.6	78	164	123	106	38	100	10	6	313	28300
RD302	RV302	30270	RM367	36754	2162	43.3	84	157	129	111	38	100	10	6	318	29600
RD339	RV339	33980	RM412	41259	2427	46.5	84	172	129	111	40	110	10	6	348	31000

FITZGIBBONS

500-Series Portable Firebox Boilers

Welded—Return Tubular

for All Fuels and All Heating Systems

Sizes: 5960 to 36900 sq. ft. Steam Ratings.
Built for 15 lbs. w.s.p.—A.S.M.E. Code.

Number of Boiler		555	556	557	558	559	560	561	562	563	564	565	566	567	568
Steam Rating	sq. ft.	5960	6940	8020	8630	10080	11660	14390	16620	17430	20130	24120	27580	32410	36900
Hot Water Rating	sq. ft.	9530	11100	12830	13800	16130	18650	23020	26600	27890	32200	38600	44130	51850	59000
Heating Surface	sq. ft.	434	510	578	617	724	840	1038	1191	1245	1443	1723	1980	2319	2636
Grate Surface	sq. ft.	16.3	18.0	19.7	20.6	22.7	24.6	27.7	30.0	30.8	33.3	36.7	39.4	42.9	45.9
Diam. Boiler	inches	48	48	48	54	54	54	60	60	66	66	72	72	78	78
Length Boiler	ft. in.	9–2	10–6	11–9	10–8	12–3	13–11	13–6	15–2	13–11	15–9	15–8	17–8	17–9	19–9
Height Overall	inches	77	77	77	83	83	83	92	92	100	100	106	106	112	112
Water Line	inches	66	66	66	71	71	71	79	79	86	86	91	91	95	95
Width Firebox	inches	42	42	42	48	48	48	54	54	60	60	66	66	72	72
Length Firebox	inches	56	62	68	62	68	74	74	80	74	80	80	86	86	92
Height Firebox	inches	36½	36½	36½	41¼	41¼	41¼	42½	42½	49½	49½	51	51	55	55
Size Outlet	inches	6	6	6	8	8	8	8	8	8	8	10	10	10	10
Size Return	inches	4	4	4	6	6	6	6	6	6	6	6	6	6	6
Diam. Stack, 1 boiler	inches	20	20	22	22	24	25	25	28	28	30	32	34	34	36
Diam. Breeching, 1 blr.	inches	22	22	24	24	26	28	28	30	30	32	34	36	36	38
Height Stack, 1 boiler	feet	55	55	60	60	70	80	80	80	80	90	90	90	95	100
Allow to open rear door	inches	27	27	27	30	30	30	33	33	36	36	39	39	42	42
Approx. Cov. Surface	sq. ft.	138	157	174	180	202	225	240	264	274	306	330	366	400	440
Approx. Ship. Weight	lbs.	7800	8800	9600	10300	11800	12800	14700	17100	18000	20300	23000	26000	28500	31500

FITZGIBBONS

P-Series Portable Firebox Boilers

Riveted—Return Tubular

for All Fuels

Sizes: 50 to 225 Horse Power.
Built for 100 lbs. w.s.p.—A.S.M.E. Code.

Number of Boiler		P-50	P-75	P-100	P-125	P-150	P-175	P-200	P-225
Horse Power based on 10 sq. ft. W. H. S.		50	75	100	125	150	175	200	225
Steam Rating	sq. ft.	7000	10160	14060	17500	20170	24130	28000	31500
Heating Surface	sq. ft.	500	750	1004	1250	1505	1750	2000	2250
Grate Surface	sq. ft.	18.6	22.7	27.7	30.8	33.3	36.7	39.9	42.9
Diameter of Boiler	inches	54	54	60	66	66	72	78	78
Length of Boiler	ft. in.	10–5	13–1	15–2	14–6	17–0	16–1	16–2	17–11
Height Overall	inches	86	86	95	103	103	109	115	115
Water Line	inches	76	76	83	91	91	97	101	101
Width Firebox	inches	48	48	54	60	60	66	72	72
Length Firebox	inches	56	68	74	74	80	80	80	86
Height Firebox	inches	42	42	45½	50½	50½	52¾	57	57
Size Feed	inches	1¼	1¼	1½	1½	1½	1½	2	2
Size Blowoff	inches	2	2	2	2	2	2	2½	2½
Diam. Stack, 1 boiler	inches	22	26	28	30	32	34	36	36
Diam. Breeching, 1 boiler	inches	24	28	30	32	34	36	38	38
Height Stack, 1 boiler	feet	55	70	80	80	90	90	90	95
Allowance to open rear door	inches	30	30	33	36	36	39	42	42
Approx. Cov. Surface	sq. ft.	175	212	268	288	332	345	376	410
Approx. Ship. Weight	lbs.	11700	15500	18300	22000	24500	27000	30500	33000

Data on Smokeless Down-Draft Portable Firebox Boilers furnished on request.

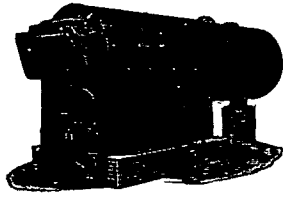
Farrar & Trefts

Incorporated

Buffalo, N. Y.

POWER AND HEATING BOILERS—Horizontal Return Tubular Boilers, Firebox Return Tubular Heating Boilers (up-draft and down-draft types), F & T Bison Boilers, Scotch Boilers for marine and stationary use, Vertical Firetube Boilers, and Portable Oil Drilling Boilers.

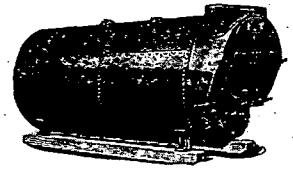
STEEL PLATE CONSTRUCTION — Welded and Riveted Steel Pipe, Storage and Pressure Tanks, Welded and Riveted Buoys, Condensers and Kettles, Receivers, Stills, Smokestacks, and Special Work in Stainless Steel and Alloy Metals.



Firebox Return Tubular Heating Boilers—Both up-draft and down-draft types are designed to operate at from 15 to 150 lbs. working pressure. They are used for steam or hot water heating in public buildings, such as schools, hospitals, office buildings, etc. Efficiency combined with low cost of installation is the feature of this type of boiler.

Stainless Steel and Alloy Metal Plate Work—Our special work in Stainless Steel and Alloy Metals is recognized by outstanding industries as work of quality. Fabricated products of alloy metals have proved highly satisfactory.

Steel Tanks—Storage and Pressure Tanks are built in standard capacities or designed and fabricated to meet special requirements.

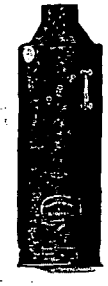


Scotch Boilers for Marine and Stationary Use—One of the most compact boilers made. They are constructed in sizes from 15 to 200 hp. for any working pressure, are quickly fired, steam rapidly and require small space for operation. Little attention is needed to obtain plenty of power and heat.



Horizontal Return Tubular Boilers—These boilers are made for 30 to 250 hp. and for working pressures of 100, 125 and 150 lbs. They are economical in operation and with ordinary care will give long years of continous service with a minimum amount of repair work.

Steel Plate Work—In addition to our large production capacity for standardized products, we are equipped to handle plate work designed for special purposes. Our Engineering Department is available for consultation on all heavy and special work, such as, Welded or Riveted Steel Pipe, Digesters, Stills, Condensers, Receivers, etc.



Vertical Firetube Boilers—These upright boilers are made in sizes from 10 to 125 hp. for working pressures of 100 to 150 lbs. Low initial cost and simplicity of operation make these boilers popular.

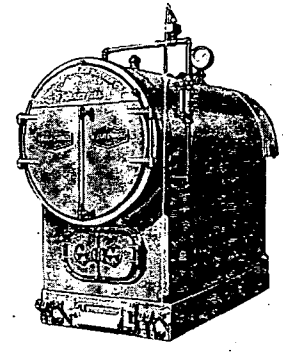
Smokestacks—We build and erect smokestacks of any desired size or height. Self-supporting stacks are made complete with breechings. Guyed stacks are shipped in sections.

Heggie-Simplex Boiler Co.

Joliet, Illinois

Heating Boiler Division of James G. Heggie & Sons, Manufacturers of Steel Boilers for Over 40 Years

Representatives in Principal Cities



Heggie-Simplex Boilers combine the recognized advantages of all other types of boilers into one portable steel unit, with four distinctive features of fundamental importance:

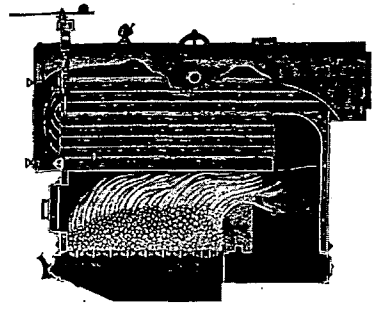
An extra large combustion chamber and a maximum of direct heating surface.

A secondary combustion chamber that provides ample room for complete combustion before flues are reached.

A flue passage that permits only heat stripped gases to enter the chimney.

A single body of water that is not impeded by any restricted passages.

For Any Fuel



For Burning Any Solid Fuel

The construction of Heggie-Simplex Boilers lends itself to the firing of any type fuel—hand-fired coal or coke, oil, gas or stoker firing.

To burn cheap soft coal without smoke or waste, more air is necessary than can be drawn thru the fuel bed. This needed air is supplied thru the carbureting chamber of Heggie-Simplex Smokeless Boilers.

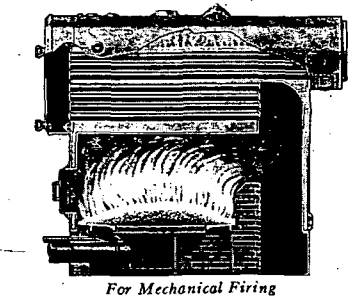
For oil or gas firing, Heggie-Simplex Mechanically Fired Boilers are unsurpassed. For stoker firing, where building conditions do not permit of a higher water line, these boilers are also highly satisfactory.

Heggie-Simplex High Firebox Boilers are meeting a need long felt by the stoker manufacturers for a boiler which provides sufficient combustion space to burn all of the fuel where its heat is most effectively utilized.

Uniform Ratings

All Heggie-Simplex Boilers are rated in conformity with the "Steel Heating Boiler Institute's Code for Rating Low Pressure Heating Boilers."

To determine the Heggie-Simplex Boiler required to heat a building, it is only necessary to compute the total radiation load (consisting of connected radiation, piping, water heater or other apparatus), to be placed on the boiler at its outlet and then select a size rated as near this load as possible.



For Mechanical Firing

HEGGIE-SIMPLEX STEEL HEATING BOILERS

Direct Draft		Oil Fired								One Boiler			Two Boilers					
Catalog Number	Rating, Steam	Catalog Number	Rating, Steam	Heating Surface,* Square Feet	Grate Area, Square Feet	Height Water Line, Inches	Height of Boiler, Inches	Width of Boiler, Inches	Length of Boiler, Inches	Diameter Breeching, Inches	Diameter Stack, Inches	Minimum Height Stack, Feet	Diameter Breeching, Inches	Diameter Stack, Inches	Minimum Height Stack, Feet	Size Steam Outlet, Inches	Size Return, Inches	Boiler Covering Required, Sq. Ft.
334-A	1690	734-A	2060	121	8.2	62¼	72	34	67¼	20	18	45	28	26	55	6	3	66
334-C	2110	734-C	2570	151	10.5	62¼	72	34	79¼	20	18	50	28	26	60	6	3	78
334-E	2530	734-E	3080	181	10.4	62¼	72	34	91¼	20	18	55	28	26	65	6	3	89
340-A	3110	740-A	3770	222	12.4	69¼	79	40	80¼	22	20	60	30	28	70	6	3	92
240-B	3500	740-B	4250	250	13.7	69¼	79	40	86¼	22	20	60	30	28	70	6	3	98
340-D	4120	740-D	5000	294	13.7	69¼	79	40	98¼	22	20	60	30	28	70	6	3	110
340-E	4510	740-E	5470	322	13.7	69¼	79	40	104¼	22	20	60	30	28	70	6	3	116
347-A	5010	747-A	6090	358	14.7	72½	86	47	101¼	24	22	65	34	32	75	8	4	125
347-B	5490	747-B	6660	392	16.5	72½	86	47	107¼	24	22	65	34	32	75	8	4	133
347-C	5960	747-C	7240	426	16.5	72½	86	47	113¼	24	22	65	34	32	75	8	4	141
352-A	6500	752-A	7890	464	18.6	78½	91	52	103¼	26	24	70	38	34	80	8	4	136
352-B	7000	752-B	8500	500	18.6	78½	91	52	109¼	26	24	70	38	34	80	8	4	144
352-C	7520	752-C	9130	537	20.7	78½	91	52	115¼	26	24	70	38	34	80	8	4	152
352-D	8040	752-D	9760	574	20.7	78½	91	52	121¼	26	24	70	38	34	80	8	4	160
357-A	9100	757-A	11050	650	22.9	81¼	97	57	115¼	28	27	70	40	36	80	8	4	167
357-C	10420	757-C	12650	744	25.2	81¼	97	57	127¼	28	27	70	40	36	80	8	4	184
357-D	11070	757-D	13450	791	25.2	81¼	97	57	133¼	28	27	80	40	36	90	8	4	193
363-A	12520	763-A	15200	894	28.1	93	108	63	123¼	30	30	75	44	40	85	10	5	197
363-B	13360	763-B	16220	954	28.1	93	108	63	129¼	30	30	75	44	40	85	10	5	206
363-C	14200	763-C	17240	1014	28.1	93	108	63	135¼	30	30	75	44	40	85	10	5	215
363-D	15040	763-D	18260	1074	30.6	93	108	63	141¼	34	33	80	44	40	90	10	5	224
370-A	16020	770-A	19450	1144	31.0	96¼	116	70	129¼	34	33	80	50	46	90	10	5	230
370-B	17020	770-B	20670	1216	31.0	96¼	116	70	135¼	34	33	80	50	46	90	10	5	240
370-C	18030	770-C	21900	1288	33.9	96¼	116	70	141¼	38	36	90	50	46	100	10	5	250
378-A	20010	778-A	24290	1429	35.0	106¼	126	78	135¼	38	36	90	54	50	100	10	5	258
378-C	22390	778-C	27180	1599	38.2	106¼	126	78	147¼	38	36	90	54	50	100	10	5	281
384-A	25000	784-A	30360	1786	38.0	113	132	84	141¼	42	40	100	56	54	110	10	5	291
384-C	28010	784-C	34020	2001	41.3	113	132	84	153¼	42	40	100	56	54	110	10	5	314
384-E	31010	784-E	37660	2215	44.8	113	132	84	165¼	42	40	100	56	54	110	10	5	337
384-G	34010	784-G	41290	2429	44.8	113	132	84	177¼	42	42	115	56	54	125	10	5	361

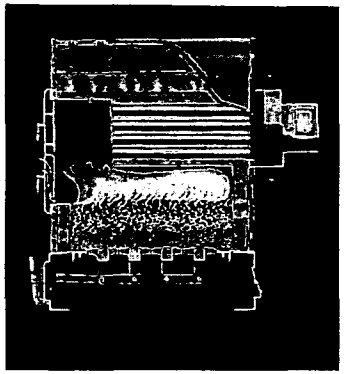
For Heggie-Simplex Smokeless Boilers use data given for direct draft boilers.

HEGGIE-SIMPLEX HIGH FIREBOX BOILERS

Catalog Number	Rating, Steam	Heating Surface* Square Feet	Furnace Volume Cubic Feet	Height Water Line, Inches	Height of Boiler, Inches	Width of Boiler, Inches	Length of Boiler, Inches	One Boiler			Two Boilers			Size Steam Outlet, Inches	Size Return, Inches	Boiler Covering Required, Sq. Ft.
								Diameter Breeching, Inches	Diameter Stack, Inches	Minimum Height Stack, Feet	Diameter Breeching, Inches	Diameter Stack, Inches	Minimum Height Stack, Feet			
S-34A	2060	121	22.3	62¼	72	34	67¼	20	18	45	28	26	55	6	3	66
S-34C	2570	151	27.9	62¼	72	34	79¼	20	18	50	28	26	60	6	3	78
S-34E	3080	181	33.5	62¼	72	34	91¼	20	18	55	28	26	65	6	3	89
S-40A	3890	229	40.7	75¼	85	40	80¼	22	20	60	30	28	70	6	3	100
S-40B	4390	258	44.6	75¼	85	40	86¼	22	20	60	30	28	70	6	3	107
S-40D	5150	303	52.3	75¼	85	40	98¼	22	20	60	30	28	70	6	3	120
S-40E	5630	331	56.3	75¼	85	40	104¼	22	20	60	30	28	70	6	3	127
S-47A	6360	374	74.9	82½	96	47	101¼	24	22	65	34	32	75	8	4	143
S-47B	6940	408	80.6	82½	96	47	107¼	24	22	65	34	32	75	8	4	152
S-47C	7530	443	86.3	82½	96	47	113¼	24	22	65	34	32	75	8	4	161
S-52A	8160	480	86.1	88½	101	52	103¼	26	24	70	38	34	80	8	4	155
S-52B	8790	517	92.5	88½	101	52	109¼	26	24	70	38	34	80	8	4	164
S-52C	9440	555	98.9	88½	101	52	115¼	26	24	70	38	34	80	8	4	172
S-52D	10080	593	105.3	88½	101	52	121¼	26	24	70	38	34	80	8	4	179
S-57A	11370	669	114.1	91¼	107	57	115¼	28	27	70	40	36	80	8	4	188
S-57C	12990	764	129.0	91¼	107	57	127¼	28	27	70	40	36	80	8	4	207
S-57D	13800	812	136.5	91¼	107	57	133¼	28	27	80	40	36	90	8	4	217
S-63A	15710	924	157.0	108	123	63	123¼	30	30	75	44	40	85	10	5	230
S-63B	16760	986	166.6	108	123	63	129¼	30	30	75	44	40	85	10	5	240
S-63C	17800	1047	176.3	108	123	63	135¼	30	30	75	44	40	85	10	5	251
S-63D	18840	1108	185.9	108	123	63	141¼	34	33	80	44	40	90	10	5	261
S-70A	20080	1181	196.9	113¼	133	70	129¼	34	33	80	50	46	90	10	5	271
S-70B	21320	1254	208.5	113¼	133	70	135¼	34	33	80	50	46	90	10	5	282
S-70C	22580	1328	220.1	113¼	133	70	141¼	38	36	90	50	46	100	10	5	293
S-78A	25080	1475	246.8	126¼	146	78	135¼	38	36	90	54	50	100	10	5	308
S-78C	28020	1648	274.8	126¼	146	78	147¼	38	36	90	54	50	100	10	5	334
S-84A	31480	1852	317.8	140	159	84	141¼	42	40	100	56	54	110	10	5	353
S-84C	35210	2071	353.1	140	159	84	153¼	42	40	100	56	54	110	10	5	391
S-84E	38930	2290	388.4	140	159	84	165¼	42	40	100	56	54	110	10	5	418
S-84G	42640	2508	423.7	140	159	84	177¼	42	42	115	56	54	125	10	5	446

To determine ratings of hot water heating boilers add 60 per cent to corresponding steam boiler ratings.
*Figured according to Steel Heating Boiler Institute's Rating Code.

Heggie-Simplex Jacketed Steel Boilers Establish New Standard in Residence Heating



The same practical advantages that have made *steel* boilers the accepted standard in large buildings, now are available for houses and small buildings in the Heggie-Simplex Jacketed Boiler —at prices well within everyone's means.

It is built of steel, electrically welded. Thus, the danger of cracking, inherent in more brittle material, is avoided; and continuous, leak-proof service is assured.

Its large fuel capacity insures long firing periods. Its spacious firebox, large amount of direct heating surface, tubular flues, free circulation, and deep steam space afford unparalleled efficiency. It is economical and equally as well adapted to hard coal, soft coal, coke, gas or oil; and to hand or mechanical firing.

This modern boiler is simple and inexpensive to install. Ranging from 24 to 30 in. wide, even the largest size goes through any door. There are no sections to join, no headers to connect, no packing or other costly assembling operations.

Heggie-Simplex Jacketed Boilers are rated in conformity with the "Steel Heating Boiler Institute's Code for Rating Low Pressure Heating Boilers." They will not only develop these ratings but are warranted capable of handling substantial overloads with ease.

HEGGIE-SIMPLEX JACKETED BOILERS
For Hard Coal or Coke, and for Oil, Gas or Stoker Firing†

Boiler No. With Jacket	Steam Rating Hard Coal or Coke	Boiler No. With Jacket	Steam Rating Oil, Gas or Stoker Firing	Boiler No. With Jacket	Water Rating Hard Coal or Coke	Boiler No. With Jacket	Water Rating Oil, Gas or Stoker Firing	Heating Surface Sq. Ft.	Grate Area Sq. Ft.	Diam. Stack Req'd In.	Height Stack Req'd Ft.	Size* Outlet In.	Size* Return In.
2SJ1	370	2SCJ1	540	2WJ1	590	2WCJ1	860	32	2.6	10	30	3	3
2SJ2	510	2SCJ2	680	2WJ2	820	2WCJ2	1090	40	3.5	10	30	3	3
2SJ3	670	2SCJ3	820	2WJ3	1070	2WCJ3	1310	48	4.3	10	30	3	3
2SJ4	800	2SCJ4	970	2WJ4	1280	2WCJ4	1550	57	5.1	10	30	3	3
2SJ5	950	2SCJ5	1160	2WJ5	1490	2WCJ5	1860	68	5.4	12	40	4	4
2SJ6	1110	2SCJ6	1340	2WJ6	1780	2WCJ6	2140	79	6.0	12	40	4	4
2SJ7	1300	2SCJ7	1580	2WJ7	2080	2WCJ7	2530	93	7.0	12	40	4	4
2SJ8	1480	2SCJ8	1800	2WJ8	2370	2WCJ8	2880	106	7.8	12	40	4	4
2SJ9	1620	2SCJ9	1970	2WJ9	2590	2WCJ9	3150	116	7.9	14	50	5	5
2SJ10	1830	2SCJ10	2230	2WJ10	2930	2WCJ10	3570	131	9.0	14	50	5	5

*Water Boilers are furnished with Two Outlet and Two Return Openings of the sizes listed unless otherwise requested on order.
†Equipped with 2 in. flues.

For Soft Coal‡

Boiler No. With Jacket	Steam Rating Soft Coal	Boiler No. With Jacket	Water Rating Soft Coal	Heating Surface Sq. Ft.	Grate Area Sq. Ft.	Diameter Stack Required In.	Height Stack Required Ft.	Size* Outlet In.	Size* Return In.
3SJ1	370	3WJ1	590	30	2.6	10	30	3	3
3SJ2	510	3WJ2	820	38	3.5	10	30	3	3
3SJ3	630	3WJ3	1010	45	4.3	10	30	3	3
3SJ4	740	3WJ4	1180	53	5.1	10	30	3	3
3SJ5	840	3WJ5	1340	60	5.4	12	40	4	4
3SJ6	980	3WJ6	1570	70	6.0	12	40	4	4
3SJ7	1160	3WJ7	1860	83	7.0	12	40	4	4
3SJ8	1300	3WJ8	2080	93	7.8	12	40	4	4
3SJ9	1370	3WJ9	2180	98	7.9	14	50	5	5
3SJ10	1570	3WJ10	2510	112	9.0	14	50	5	5

*Water Boilers are furnished with Two Outlet and Two Return Openings of the sizes listed unless otherwise requested on order.
‡Equipped with 3 in. flues.

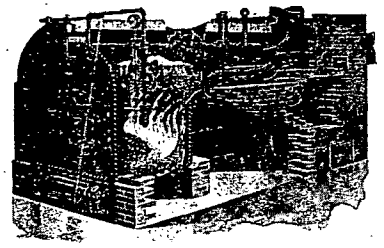
Kewanee Boiler Corporation

Kewanee, Illinois

BRANCHES IN 33 PRINCIPAL CITIES

Steel Heating and Power Boilers, Water Heating Garbage Burners, Tabasco Heaters and Tanks

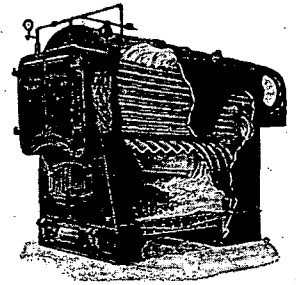
KEWANEE STEEL HEATING BOILERS



KEWANEE FIREBOX BOILERS
Brick-set Type

Kewanee offers the most complete line of Steel Heating Boilers in the country. **11** Types, **159** Sizes, to carry the Radiation load of any kind of building.

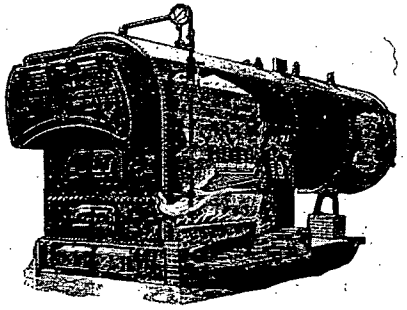
Kewanee Boilers are all built of steel using as a minimum basis the rules of construction adopted by the *American Society of Mechanical Engineers*, known as the *A. S. M. E.* Boiler Code.



KEWANEE WELDED
TYPE C BOILERS

The rated capacity is the amount of direct radiation that the boiler will carry with a firing interval of three to four hours depending upon the grade of fuel used. No discount in rating is advised as reserve capacity has been allowed to care for the most severe weather conditions.

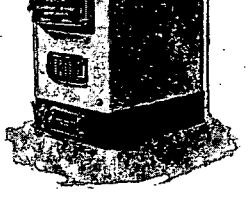
Kewanee Boilers represent 60 years of intensive study and effort to make the highest grade equipment for heating buildings. They are adapted to the burning of any grade of fuel and will maintain high efficiency when operating to supply the variable demands of a heating load.



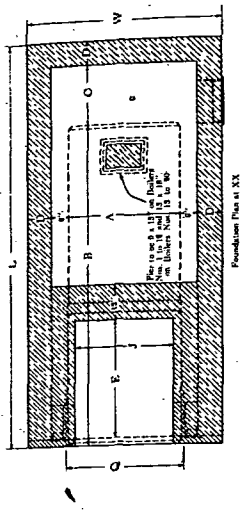
KEWANEE SMOKELESS BOILERS
Portable Type

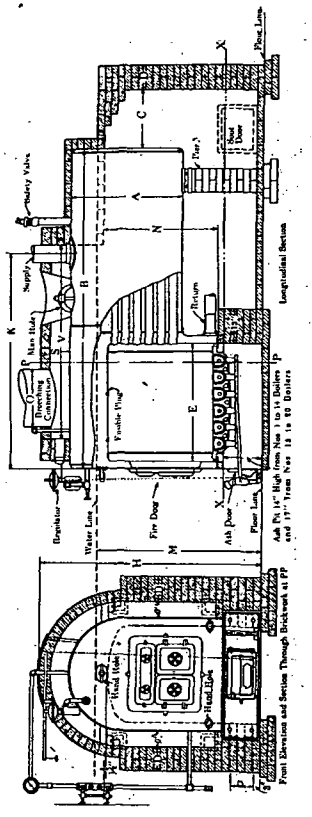
Uniform Ratings

The ratings published in this GUIDE are in conformity with the Steel Heating Boiler Institute's Code for Rating Low Pressure Heating Boilers.



KEWANEE RESIDENCE
TYPE R BOILERS

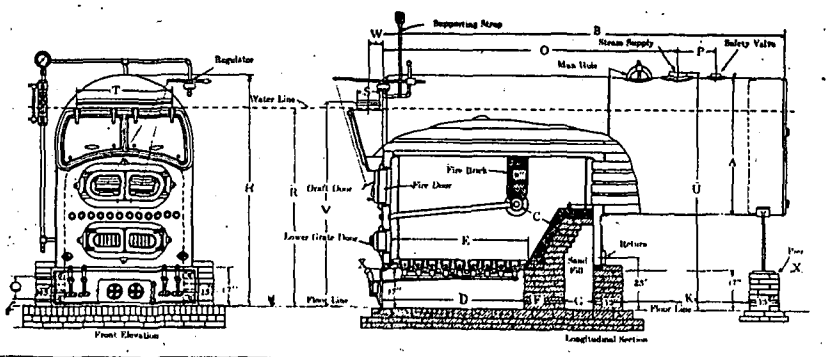


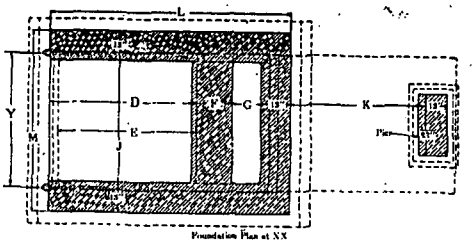


KEWANEE FIREBOX BOILERS—BRICK-SET TYPE

Number of Boiler	0	1	2	3	4	5	6	8	9	10	11	12	13	14	15	16	17	18	19	20
Capacity, Steam.....sq. ft.	510	690	940	1240	1380	1830	2410	3340	4170	4300	5130	6070	7440	8770	10310	12080	12420	14670	16340	18610
A—Diameter of Boiler.....in.	24	30	30	30	36	36	42	42	42	48	48	48	48	54	54	60	60	66	72	72
B—Length of Boiler.....ft.	7	6½	7½	8½	9	10½	10	11½	11½	10½	12	13½	14	16½	15½	18	16	18	16	18
Heating Surface.....sq. ft.	84	113	131	147	180	215	250	305	350	368	420	472	560	673	743	873	954	1080	1167	1329
Area of Grate.....sq. ft.	3.5	4.4	5.4	6.4	6.8	8.0	9.3	11.1	12.6	12.9	14.7	16.5	18.8	20.8	22.9	25.1	25.5	28.0	30.8	33.5
Diameter of Breeching.....in.	10	12	12	14	14	16	16	18	20	20	22	24	26	26	30	30	32	30	34	36
Diameter of Stack.....in.	10	12	12	14	16	16	16	18	20	20	22	24	26	26	30	30	32	30	34	36
Minimum Height of Stack.....ft.	35	40	40	40	40	40	45	45	45	45	50	50	50	50	55	55	60	60	60	60
Diameter of Breeching, Two Boilers.....in.	16	18	20	22	22	24	24	28	32	32	32	34	36	36	40	40	40	42	44	46
Diameter of Stack, Two Boilers.....in.	16	18	20	22	22	24	26	28	28	30	30	32	34	34	36	36	36	38	40	42
Minimum Height of Stack, Two Boilers.....ft.	40	45	45	45	45	45	45	50	50	50	50	50	55	60	60	70	70	70	70	70
Size of Steam Opening.....in.	3	4	4	5	5	6	6	6	6	6	6	8	8	8	8	8	8	8	8	8
Size of Return.....in.	2	2½	2½	3	3	3	3	4	4	4	4	5	5	5	5	5	6	6	6	6
Size of Safety Valve.....in.	1	1¼	1¼	1¼	1¼	1¼	2	2	2	2	2	2½	2½	3	3	3½	3½	3½	4	4
C—Rear Space.....in.	14	17	17	17	17	17	17	22	22	22	22	22	24	24	24	24	24	24	28	28
D—Thickness Wall.....in.	9	9	9	9	9	9	9	9	9	9	9	9	13	13	13	13	13	13	13	13
E—Length Grate.....in.	26	26	32	38	32	38	44	44	50	44	50	50	56	56	62	62	68	68	68	74
J—Width Ash-pit.....in.	19	25	25	25	31	31	31	37	37	43	43	43	49	49	54	54	60	60	66	66
H—Total Height.....in.	64	70	70	70	77	77	77	83	83	90	90	90	96	96	108	108	114	114	120	120
K—Location of Supply.....ft. in.	4-0	4-0	4-8	5-6	4-11	5-11	6-11	6-8	7-2	7-0	7-10	8-6	9-2	9-8	9-6	10-8	9-8	10-8	9-9	10-9
M—Height of Waterline.....ft. in.	47	52	52	52	55	55	55	58½	58½	61	61	61	66	66	75	80	75	80	85½	85½
N—Height of Side Flue.....ft. in.	2-6	2-8	2-8	3-0	3-0	3-0	3-0	3-3	3-3	3-6	3-6	3-6	4-0	4-0	4-3	4-3	4-10	4-10	5-3	5-3
O—Diameter Breeching Connection.....in.	10	12	14	16	16	18	18	20	22	22	24	24	28	28	32	32	32	32	36	36
S—Top Flue Space.....in.	6	6	6	6	6	7	7	7	7	8	8	8	8	8	10	10	10	10	10	10
V—Length of Arch.....ft. in.	3-2	3-2	3-10	4-9	4-1	5-1	6-1	6-3	6-9	6-3	7-3	7-9	8-1	8-7	8-5	9-7	8-7	9-8	8-9	9-9
P—Anchor Bolt Centers for Ash-pit Front.....in.	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	11	11	11	11
Q—Anchor Bolt Centers for Ash-pit Front.....in.	24	30	30	30	36	36	36	42	42	48	48	48	54	54	60	60	66	66	72	72
L—Total Length Over-all.....ft. in.	8-8	8-7	9-8	10-8	9-8	11-2	12-8	12-7	14-1	13-1	14-7	16-1	17-0	19-6	18-7	21-1	19-1	21-1	19-5	21-5
W—Total Width Over-all.....ft. in.	4-6	5-0	5-0	5-0	5-6	5-6	6-0	6-0	6-0	6-6	6-6	6-6	7-8	7-8	8-2	8-2	8-8	8-8	9-2	9-2
*Number of Common Brick.....1325	1450	1600	1750	1900	2150	2400	2650	3000	3300	3600	5300	5900	6450	10350	11350	12550	12400	13450	13250	13850
*Common Brick for Two Boilers.....2250	2450	2700	2950	3300	3750	4100	4750	5350	5400	5900	6450	8350	10350	11350	12550	12400	13450	13250	13850	14450

*Foundations not included. NOTE—A Firing Space of about 8'-0" should be maintained at front of Boilers. This provides sufficient space to draw tubes through firedoor. Capacity for Oil, 1440 to 26,600 sq. ft. Rated Capacity for Water Boiler is 60 per cent Greater than Capacity of Steam Boiler.



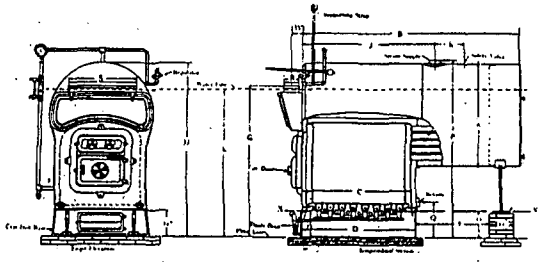


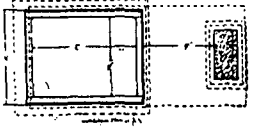
Boilers 307 to 309 have Cast Iron Base.
Boilers 310 to 314 have Brick Base 9 in. thick.
Boilers 315 to 324 have Brick Base 13 in. thick.

KEWANEE SMOKELESS BOILERS—PORTABLE TYPE

Number of Boiler	307	308	309	310	311	312	313	314	315	316	317	318	319	320	321	322	323	324
Capacity, Steam....sq. ft.	3390	4260	5020	6100	6950	7650	8290	9000	10100	10820	12770	14740	16860	18420	20410	21690	29040	36810
Heating Surface....sq. ft.	297	352	391	446	496	546	592	643	721	773	912	1053	1204	1316	1458	1549	2074	2629
Area of Upper Grate....sq. ft.	8.8	10.1	11.4	12.9	14.7	16.5	17.1	18.5	20.0	21.4	23.5	25.9	28.5	29.9	32.6	34.6	41.7	44.8
A—Diameter of Boiler....in.	48	48	48	54	54	54	60	60	60	60	66	66	72	72	78	78	84	84
B—Length of Boiler Over-all....ft. in.	9-1	10-5	11-5	10-11	11-11	12-11	12-11	13-11	15-3	16-3	15-9	17-9	16-7	17-11	17-10	18-10	20-1	24-1
Diameter of Stack....in.	20	20	20	22	22	22	24	24	26	26	28	30	32	32	34	34	38	40
Minimum Height of Stack....ft.	50	55	55	55	55	60	60	60	65	65	65	70	70	70	80	90	90	100
Diameter of Stack, Two Boilers....in.	28	28	28	31	31	31	34	34	36	36	40	42	46	46	48	48	54	54
Minimum Height of Stack, Two Boilers....ft.	60	65	65	65	65	70	70	70	75	75	75	80	80	80	90	100	100	110
Size of Steam Opening....in.	6	6	6	6	6	6	8	8	8	8	8	8	8	8	8	8	10	10
Size of Return....in.	4	4	4	4	4	4	5	5	5	5	6	6	6	6	6	6	6	6
Size of Safety Valve....in.	2	2	2	2½	2½	2½	3	3	3	3½	3½	4	4	4	2-2½	2-3	2-3	2-3½
Distance Required to Open Rear Flue Doors....in.	26	26	26	28	28	28	32	32	32	32	35	35	37	37	40	40	43	43
E—Length Grate....in.	37	43	49	49	55	61	55	61	61	67	61	67	67	73	73	73	79	85
C—Header to Bridge Wall....in.	9	10	11½	11	12½	14	12½	14	14	15	15	16	16	17	17	18	18	19
D—Length Ash-pit....in.	38	44	50	50	56	62	56	62	63	69	63	69	69	75	75	75	81	87
K—Rear Wall to Pier....in.	29	39	45	27	33	39	45	51	57	63	62	80	63	74	72	79	84	126
J—Width Ash-pit....in.	37	37	37	43	43	43	49	49	53	53	59	59	65	65	71	71	77	77
M—Width Foundation....in.	46	46	46	61	61	61	67	67	79	79	85	85	91	91	97	97	103	103
L—Length Foundation....in.	61	67	73	84	90	96	90	96	107	113	107	113	113	119	119	125	131	137
H—Height Boiler....in.	84	84	84	89	89	89	98	98	101	101	107	107	113	113	115	115	121	121
U—Height Supply....in.	85	85	85	90	90	90	99	99	103	103	109	109	115	115	117	117	123	123
R—Height Water-line....in.	71	71	71	76	76	76	83	83	87	87	90	90	96	96	97	97	105	105
V—Height of Breeching Connection....in.	76	76	76	80	80	80	88	88	90	90	93	93	100	100	101	101	109	109
O—Location Supply....ft. in.	5-11	6-8	7-3	7-6	8-2	8-9	8-9	9-3	10-11	11-6	11-3	11-9	11-7	12-2	12-2	12-9	13-8	15-0
P—Location Safety Valve....in.	12	14	14	13	13	15	15	18	16	18	16	18	15	18	18	16	18	20
W—Center Breeching Connection to Front of Boiler....in.	8	8	8	8	8	8	9¼	9¼	9¼	9¼	10½	10½	11½	11½	11½	11½	13	13
S—Width Breeching Connection....in.	10	10	10	10	10	10	12½	12½	12½	12½	15	15	17	17	17	17	20	20
T—Length Breeching Connection....in.	36	36	36	42	42	42	46	46	46	46	50	50	54	54	60	60	64	64
†Req'd at Front to Draw Tubes....ft. in.	7-7	8-11	9-11	9-5	10-5	11-5	11-5	12-5	13-8	14-8	14-0	16-0	14-8	16-0	16-0	17-0	18-0	22-0
†Req'd at Rear to Draw Tubes....ft in.	6-0	7-4	8-4	7-10	8-10	9-10	9-10	10-10	12-2	13-2	12-4	14-4	12-10	14-2	14-1	15-1	16-0	20-0
*Number Common Brick.......	200	200	200	800	825	850	1025	1050	1300	1350	1300	1350	1375	1450	1400	1475	1575	1600
Number Fire Brick.......	115	115	115	155	155	155	195	195	210	215	240	240	255	255	290	315	425	425
Outside Surface to be Covered....sq. ft.	148	157	173	184	212	221	255	265	266	280	290	330	335	360	370	400	455	545

*Foundations not included. †If space is available at front, it is not necessary at rear, and vice-versa.
Capacity for Oil, 5050 to 44,700 sq. ft. Rated Capacity for Water Boiler is 60 per cent Greater than Capacity of Steam Boiler.



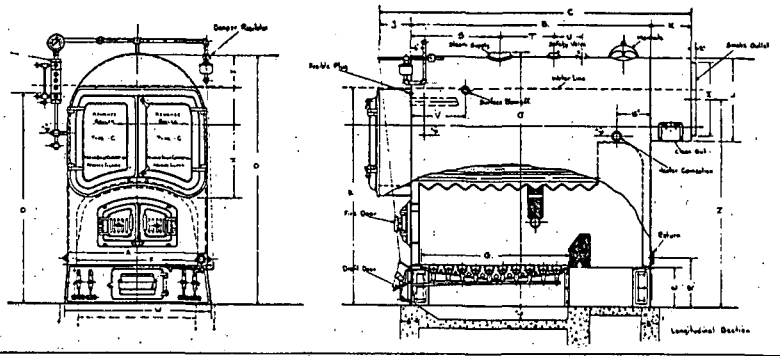


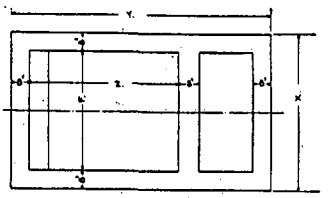
KEWANEE FIREBOX BOILERS—PORTABLE TYPE

Boilers 407 to 409 have Cast Iron base as shown.
Boilers 410 to 414 have Brick base 9 in. thick.
Boilers 415 to 424 have Brick base 13 in. thick.

Number of Boiler	407	408	409	410	411	412	413	414	415	416	417	418	419	420	421	422	423	424
Capacity, Steam....sq. ft.	2550	3340	4170	4300	5130	6070	7440	8760	8700	10310	12420	14560	16350	18240	21200	23950	30930	33980
Heating Surface....sq. ft.	278	310	373	416	465	515	565	626	676	778	929	1040	1168	1303	1514	1711	2209	2427
Area of Grate....sq. ft.	9.6	11.1	12.6	12.9	14.7	16.5	18.8	20.8	20.7	22.9	25.5	28.0	30.8	33.5	36.6	39.6	42.9	46.1
A—Diameter of Boiler....in.	48	48	48	54	54	54	60	60	60	60	66	66	72	72	78	78	84	84
B—Length of Boiler....ft. in.	8-7	9-6	11-1	10-0	11-1	12-1	12-5	13-7	14-4	16-2	15-9	17-4	15-11	17-6	17-11	19-11	20-1	22-1
Diameter of Stack....in.	20	20	20	22	22	22	24	24	26	26	28	30	32	32	34	34	38	40
Minimum Height of Stack....ft.	50	50	55	55	55	60	60	60	65	65	65	70	70	70	80	90	90	100
Diameter of Stack, Two Boilers....in.	28	28	28	31	31	31	34	34	36	36	40	42	46	46	48	48	54	54
Minimum Height of Stack, Two Boilers....ft.	60	60	65	65	65	70	70	70	75	75	75	80	80	80	90	100	100	110
Size of Steam Opening....in.	6	6	6	6	6	6	8	8	8	8	8	8	8	8	8	8	10	10
Size of Return....in.	4	4	4	4	4	4	5	5	5	5	6	6	6	6	6	6	6	6
Size of Safety Valve....in.	2	2	2	2	2½	2½	2½	3	3	3	3½	3½	4	4	2-2½	2-3	2-3	2-3
Distance Required to Open Rear Flue Doors....in.	26	26	26	28	28	28	32	32	32	32	35	35	37	37	40	40	43	43
C—Length of Fire-box....in.	38	44	50	44	50	56	56	62	56	62	62	68	68	74	74	80	80	86
D—Length of Ash-pit....in.	45	51	57	47	53	59	59	65	60	66	66	72	72	78	78	84	84	90
E—Width of Ash-pit....in.	36	36	36	43	43	43	49	49	53	53	59	59	65	65	71	71	77	77
F—Ash-pit Base to Pier....ft. in.	3-3	3-8	4-9	3-9	4-4	4-10	5-2	5-10	6-7	7-11	7-5	8-5	6-11	7-11	8-4	9-10	9-10	11-4
G—Height Breeching Connection....in.	76	76	76	80	80	80	88	88	90	90	93	93	100	100	101	101	109	109
H—Height of Boiler....in.	84	84	84	89	89	89	98	98	101	101	107	107	113	113	115	115	121	121
P—Height of Steam Supply....in.	85	85	85	90	90	90	99	99	103	103	109	109	115	115	117	117	123	123
L—Height of Water-line....in.	71	71	71	76	76	76	83	83	87	87	90	90	96	96	97	97	105	105
J—Location of Steam Supply....ft. in.	4-8	5-3	6-3	5-6	6-4	8-0	8-3	8-8	8-5	9-5	9-4	10-2	9-8	11-1	11-3	12-0	12-6	12-6
K—Location of Safety Valve....in.	13	14	18	16	18	13	16	18	21	29	18	32	18	26	24	30	24	21
W—Center of Breeching Connection to Front of Boiler....in.	8	8	8	8	8	8	9¼	9¼	9¼	9¼	10½	10½	11½	11½	11½	11½	13	13
R—Width Breeching Connection....in.	10	10	10	10	10	10	12½	12½	12½	12½	15	15	17	17	17	17	20	20
S—Length Breeching Connection....in.	36	36	36	42	42	42	46	46	46	46	50	50	54	54	60	60	64	64
†Req'd at Front to Draw Tubes....ft. in.	7-1	8-0	9-7	8-7	9-7	10-7	11-0	12-2	12-10	14-8	14-1	15-8	14-1	15-8	16-1	18-1	18-1	20-1
†Req'd at Rear to Draw Tubes....ft. in.	5-6	6-5	8-0	6-11	7-11	8-11	9-4	10-6	11-3	13-1	12-4	13-11	12-2	13-9	14-2	16-2	16-2	18-2
*Number Common Brick.......	70	70	70	450	480	510	530	560	680	710	740	760	790	820	840	885	900	935
Outside Surface to be Covered....sq. ft.	115	130	150	155	175	185	190	220	250	280	290	310	315	345	385	425	455	505

*Foundations not included. †If space is available at front, it is not necessary at rear, and vice-versa.
Capacity for Oil, 4730 to 40,480 sq. ft. Rated Capacity for Water Boiler is 60 per cent Greater than Capacity of Steam Boiler.

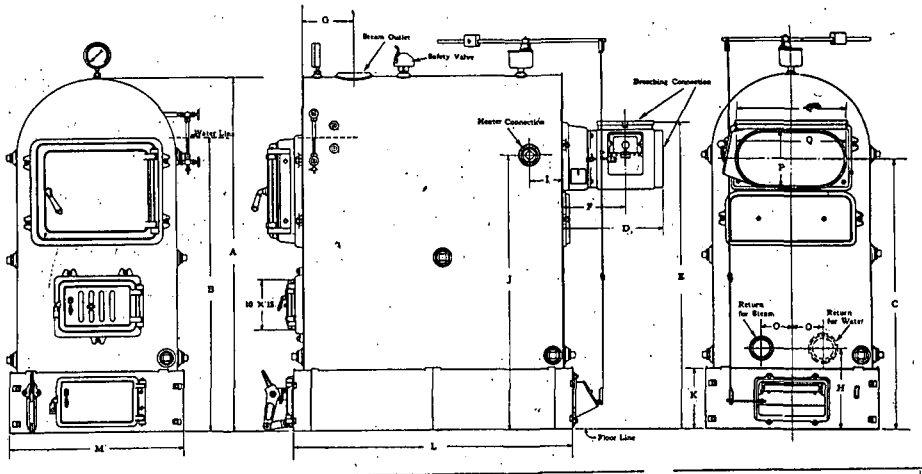




KEWANEE STEEL BOILERS
TYPE C—ELECTRIC WELD
For Burning Coal

Number of Boiler	749	750	751	752	753	754	755	756	757	758	759	760	761	762	763	764	765	766	767	768	769	770
Capacity, Steam....sq. ft.	2300	2690	3250	3630	4060	4550	5250	5950	6470	7000	8280	9610	10850	12110	14300	16380	18660	20750	22520	25530	28780	33070
Heating Surface....sq. ft.	164	192	232	262	290	325	375	425	462	498	591	686	775	865	1025	1170	1333	1482	1608	1824	2056	2362
Area of Grate....sq. ft.	9.1	10.3	11.0	11.6	12.4	13.9	15.5	18.0	19.7	21.5	22.4	24.3	24.7	26.9	27.6	30.1	32.9	35.6	36.0	38.9	42.1	45.2
Diameter of Stack....in.	18	20	20	20	22	22	22	24	24	26	26	28	30	30	32	32	34	34	38	38	40	40
Minimum Height of Stack....ft.	45	50	50	55	55	55	60	60	60	65	65	65	70	70	70	80	90	90	90	100	100	100
Diameter of Stack, Two Boilers....in.	26	28	28	28	31	31	31	34	34	36	36	40	42	42	46	46	48	48	52	54	54	54
Minimum Height of Stack, Two Boilers....ft.	55	60	60	65	65	65	70	70	70	75	75	75	80	80	80	80	90	100	100	100	110	110
Size of Steam Opening....in.	6	6	6	6	6	6	6	8	8	8	8	8	8	8	8	8	8	8	8	10	10	10
Size of Return Opening....in.	4	4	4	4	4	4	4	5	5	5	5	5	6	6	6	6	6	6	6	6	6	6
Size of Safety Valve Opening....in.	2	2	2	2	2	2	2½	2½	3	3	3	3½	3½	3½	3½	4	4	2-2½	2-2½	2-3	2-3	2-3
A—Width of Boiler....in.	36	36	36	36	42	42	42	48	48	48	54	54	60	60	66	66	72	72	78	78	84	84
B—Length of Boiler....ft. in.	4-2	4-8	5-8	6-4	5-10½	6-6½	7-6	6-1	6-7	7-1	7-5½	8-7	8-0½	8-11	9-7	10-10	9-10½	10-11	10-10	12-2½	10-11	12-5
C—Overall Length of Boiler....ft. in.	5-10	6-4	7-4	8-0	7-10½	8-6½	9-6	8-3	8-9	9-3	9-8½	10-10	10-4½	11-3	11-11	13-2	12-8½	13-9	13-8	15-0½	13-9	15-3
D—Overall Height of Boiler....in.	77½	77½	77½	77½	83½	83½	83½	97	97	97	99	99	108½	108½	111½	111½	117½	117½	121½	121½	135	135
E—Height of Ash-pit Base....in.	14	14	14	14	14	14	14	14	14	14	14	14	17	17	17	17	17	17	17	17	21	21
F—Width of Grates and Ash-pit....in.	30	30	30	30	36	36	36	42	42	42	47½	47½	52½	52½	58½	58½	64	64	70	70	76	76
G—Length of Grates....in.	43	49	56	56	50	56	62	62	68	74	68	74	68	74	68	74	74	80	74	80	80	86
H—Height of Front Smokebox....in.	34	34	34	34	34	34	34	42	42	42	42	42	48	48	48	48	51	51	52	52	61	61
I—Top Front Smokebox to Top of Boiler....in.	10	10	10	10	13	13	13	16	16	16	16	16	16	16	18	18	17	17	19	19	21	21
J—Depth of Front Smokebox....in.	9	9	9	9	10	10	10	11	11	11	12	12	12	12	12	12	14	14	14	14	14	14
K—Depth of Rear Smokebox....in.	11	11	11	11	14	14	14	15	15	15	15	15	16	16	16	16	20	20	20	20	20	20
L—Height of Rear Smokebox....in.	26	26	26	26	29	29	29	35½	35½	35½	35	35	36	36	39	39	43	43	45½	45½	49½	49½
M—Diameter of Smoke Outlet....in.	22	22	22	22	24	24	24	26	26	26	28	28	32	32	34	34	36	36	40	40	42	42
N—Height Smoke Outlet above Floor....in.	64½	64½	64½	64½	69	69	69	79	79	79	81½	81½	90½	90½	93	93	96	96	99	99	110	110
O—Height of Water Column....in.	67	67	67	67	70	70	70	80	80	80	82	82	91	91	92½	92½	98	98	100	100	111½	111½
P—Height of Water Line....in.	69	69	69	69	72	72	72	82	82	82	85	85	94	94	95	95	101	101	103	103	114	114
Q—Height of Steam Supply....in.	79½	79½	79½	79½	85½	85½	85½	99	99	99	101	101	110½	110½	113½	113½	119½	119½	123½	123½	137	137
R—Height of Return....in.	18	18	18	18	18	18	18	19	19	19	19	19	22	22	22	22	22	22	22	22	26	26
S—Location of Steam Supply....in.	10½	14	14	16	14	16	18	16	18	21	18	21	18	21	18	21	21	21	21	21	21	24
T—Location of 1st Safety Valve....in.	8½	10	10	10	10	10	11	12	13	14	13	14	13	14	13	14	14	14	14	14	14	15
U—Location of 2nd Safety Valve....in.																		10	10	11	11	12
V—Location of Surface Blow-Off....in.	12	12	12	12	12	12	12	12	12	12	18	24	24	24	24	24	24	24	24	24	24	24
W—Width of Base....in.	38½	38½	38½	38½	44½	44½	44½	50½	50½	50½	56½	56½	63	63	69	69	75	75	81	81	87½	87½
X—Width of Foundation....in.	46	46	46	46	52	52	52	58	58	58	63½	63½	68½	68½	74½	74½	80	80	86	86	92	92
Y—Length of Foundation....in.	59	65	77	85	80	88	99	82	88	94	99	112	106	115	123	138	127	140	138	154	139	157
Z—Length of Ash-pit....in.	43	49	56	56	50	56	62	62	68	74	68	74	68	74	68	74	74	80	74	80	80	86
Outside Surface to Cover....sq. ft.	62	68	80	89	93	102	115	116	124	132	145	165	172	187	210	234	231	252	265	294	294	328

Boiler Nos. 1749-1770 for Oil, Gas or Stoker. Nos. 2749 to 2770 for Anthracite, furnished without Drum and Arch. Rated Capacity for Water Boiler is 60% Greater than Capacity of Steam Boiler.



KEWANEE
RESIDENCE
TYPE R
BOILERS

Nos. 740-748
For Burning Coal

Number of Boiler	740	741	742	743	745	746	747	748
Rated Capacity, Steam....sq. ft.	370	510	690	920	1210	1560	1780	1960
Rated Capacity, Water....sq. ft.	590	820	1100	1470	1940	2500	2850	3140
Heating Surface....sq. ft.	44	54	63	73	101	114	127	140
Grate Area....sq. ft.	2.6	3.5	4.4	5.3	6.3	7.3	8.4	9.4
Width of Boiler....in.	31	31	31	31	31	31	31	31
Length of Boiler....in.	27½	33½	39½	45½	45½	51½	57½	63½
Size of Steam or Water Outlet....in.	3	3	4	4	5	6	6	6
Size of Steam Return Inlet....in.	2½	2½	2½	2½	3	3	3	3
Size of Inlet added for Water....in.	2½	2½	2½	2½	4	4	4	4
Size of Safety Valve Opening....in.	1	1	1¼	1¼	1½	1½	1½	2
A—Overall Height, Floor to Top of Shell....in.	59½	59½	59½	59½	70¼	70¼	70¼	70¼
B—Height of Water-line....in.	48	48	48	48	58½	58½	58½	58½
Diameter of Chimney....in.	12	12	12	12	16	16	16	16
Height of Chimney....ft.	35	35	35	35	40	40	40	40
Diameter of Breeching....in.	14	14	14	14	18	18	18	18
Size of Breeching Connection, P x Q....in.	8½x17	8½x17	8½x17	8½x17	11x22	11x22	11x22	11x22
C—Height of End Breeching Connection Center....in.	49½	49½	49½	49½	54	54	54	54
D—Back of Boiler to End Breeching Connection....in.	17½	17½	17½	17½	20	20	20	20

Number of Boiler	740	741	742	743	745	746	747	748
E—Height of Breeching Connection....in.	55¾	55¾	55¾	55¾	61½	61½	61½	61½
F—Back of Boiler to Top Breeching Connection Center....in.	11¼	11¼	11¼	11¼	12½	12½	12½	12½
G—Steam Outlet Center to Boiler Front....in.	11	11	11	11	12	12	12	12
H—Height of Return Inlet Ctrs..in.	15¼	15¼	15¼	15¼	16	16	16	16
O—Return Inlet Offset from Boiler Center....in.	5	5	5	5	6	6	6	6
Heater Connection Size....in.	2	2	2	2	2	2	2	2
I—Heater Connection Center from Back of Boiler....in.	6½	6½	6½	6½	6½	6½	6½	6½
J—Heater Connection, Height from Floor....in.	43¾	43¾	43¾	43¾	54¼	54¼	54¼	54¼
K—Height of Base....in.	12	12	12	12	12	12	12	12
L—Length of Base....in.	31½	37½	43½	49½	49½	55½	61½	67½
M—Width of Base....in.	30	30	30	30	34	34	34	34
Outside Surface to Cover, Unjacketed....sq. ft.	33	38	43	48	60	66	71	77
Approximate Weight....lbs.	1700	1900	2150	2360	2800	3050	3300	3550

Oil Burning Boiler Nos. 1740-1748—Capacity, Steam, 450 to 2380 sq. ft.; Water, 720 to 3810 sq. ft. For Anthracite, Nos. 2740-2770—Capacity, Steam, 430 to 1960 sq. ft.; Water, 690 to 3140 sq. ft.

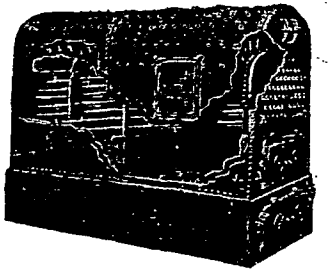
A. D. Granger Co.

ESTABLISHED 1893

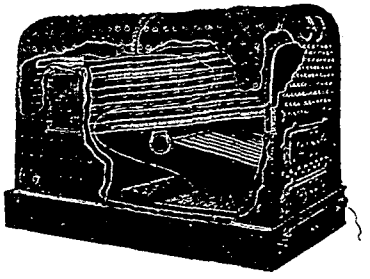
19 Park Row — New York City

Boilers, Engines, Turbines, Feed Water Heaters, Pumps, Stacks, Grates, Steel Plate Construction, Cranes, Hoists, Complete Plants.

"Oswego" Water Tube Boilers



Type "A," Up-Draft



Type "B," Down-Draft

A self-contained, internally fired, Water Tube Boiler, with straight inclined water tubes connecting front and rear water spaces. Inner and outer shells form a complete water jacket surrounding the fire. Steel construction, no cast-iron used in boiler proper. Built in both up-draft and down-draft types. All under *A.S.M.E.* Code for working pressures up to 150 lbs.

Type "A," for anthracite coal, up-draft is made in 22 sizes, both low and high pressures, ranging from 20 H. P. to 300 H. P. or an equivalent in radiating surfaces of from 2000 sq. ft. to 30,000 sq. ft.

Type "B" is a development from Type "A," to include the down-draft water grate for the smokeless combustion of bituminous coal. Also made in 22 sizes with radiating surfaces from 2000 sq. ft. to 30,000 sq. ft.

Type "W." A welded unit, built for 15 lbs. working pressure, under the *A.S.M.E.* Code, made in 20 sizes to carry from 2000 sq. ft. of radiation to 30,000 sq. ft. This is built with either vertical or horizontal baffles.

Space—Oswego Boilers are compact and occupy very small space per horsepower.

Designed for Maximum Fuel Economy and to obtain highest efficiency. The furnace is entirely surrounded by water surface and the water tubes take the direct heat from the fire as well. The gases of combustion must pass across the bank of tubes three times to the smoke outlet.

Designs for Oil Burners and Natural Gas. We have units operating with all the best known oil burners and several installations with gas burners.

Low Pressure Type "A" Oswego Internally Fired Water Tube Boilers

Number of Boiler...	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54
Width.....ft. in.	4-2	4-2	4-2	4-2	4-2	4-2	4-10	4-10	4-10	4-10	5-0	5-0	5-0	5-9	5-9	6-11	6-11
Length.....ft. in.	9-2	9-10	10-6	11-0	11-4	11-4	11-6	11-6	13-0	13-0	13-0	13-0	14-0	14-0	15-0	15-0	18-0
Total Height.....ft. in.	6-11	7-1	7-2	7-2	7-2	7-5	7-8	8-0	8-0	8-0	8-11	9-5	9-5	9-11	10-6	10-6	10-6
Height of Base.....ft. in.	1-5	1-5	1-6	1-6	1-6	1-6	1-8	1-8	1-8	1-8	1-8	1-8	1-8	2-0	2-0	2-0	2-0
Height Water Line..ft. in.	6-1	6-3	6-4	6-4	6-4	6-7	6-10	7-1	7-1	7-2	7-11	8-3	8-3	8-7	8-11	8-11	8-11
Diameter Smoke Flue..in.	21	22	23	23	23	25	26	28	30	30	34	34	34	37	39	40	42
Grate Surface.....sq. ft.	16.8	17.6	18.8	19	19	20.7	25	25.5	28.5	28.5	31	31	31	37	40	48	57
Radiating Surface..sq. ft.	5000	6000	6500	7000	7600	8500	9000	10500	11000	12500	13500	15500	18000	20000	22500	25000	30000
Corresponding H. P.....	50	60	65	70	75	85	90	100	110	125	135	150	175	200	225	250	300

TRADE MARK REGISTERED

The Titusville Iron Works Company

Titusville, Pennsylvania

Manufacturers of Riveted and Welded Steel Fire-Tube Boilers for Power and Heating; Fronts, Grates, Castings, Smoke Stacks, Tanks and Oil Field Boilers; Steam, Gas, Oil and Gasoline Engines; Pumping Powers and Oil Well Machinery

Atlanta, Ga......511 Grand Theatre Bldg.
Barre, Vt......46 Pearl St.
Birmingham, Ala....239 Brown-Marx Bldg.
Buffalo, N. Y......1502 Marine Trust Bldg.
Charlotte, N. C......705 Realty Bldg.
Chicago, Ill......20 N. Wacker Drive
Cleveland, Ohio.....National Bldg.
Dallas, Texas.....803 Burt Bldg.
Detroit, Mich......729 Seward Ave.
Erie, Pa......507 Cherry St.
Kansas City, Mo......712 E. 31st St.
Los Angeles, Calif......940 Maple Ave.
Nashville, Tenn......1605 Church St.
New Orleans, La......1666 Abundance St.
New York, N. Y......285 Madison Ave.
Philadelphia, Pa......1015 Chestnut St.
Pittsburgh, Pa......2224 Farmers Bank Bldg.
Richmond, Va......1708 Lewis St.
St. Louis, Mo......1010 Telephone Bldg.
Washington, D. C......1013 Woodward Bldg.

Facilities—At the Titusville Iron Works Company every practicable mechanical provision is made for the bending, flanging, riveting, and electric welding so essential to high grade products.

Construction—In addition to being thorough in engineering design, Titusville Boilers are built by men experienced in every detail of their particular operations.

All riveting is done by competent steel workers and all welding is done exclusively by experts who do nothing but welding. Wherever possible Titusville Welded Boilers are welded *inside* as well as outside.

A. S. M. E. Code—Our boilers are built in strict accordance with the latest *A. S. M. E.* Boiler Code Standards and to local requirements when specified.

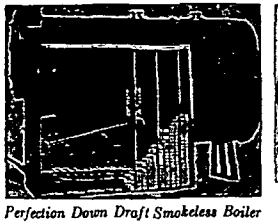
Inspection and Test—Titusville Boilers are continually inspected during construction by a resident representative of the Hartford Steam Boiler Inspection and Insurance Company, Hydrostatic tests are made upon completion. Insurance company certificate furnished free on request.

Working Pressures—Boilers are built in two-pressure ranges: 100-350 lb. working pressure, *A. S. M. E.* Code, for power and high-pressure service, and 15 lb. w.p. —*A. S. M. E.* Code, for heating service.

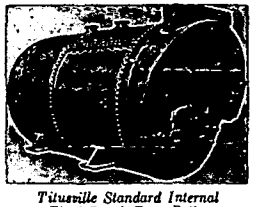
Grates, Stacks, Etc.—All boilers are provided with complete sets of doors, fronts, castings, etc., as illustrated and of the types which are standard for our boilers. Special grates furnished on request.

This company also offers its facilities for the construction of stacks, breechings and steel plate work.

Catalogs—Descriptive catalogs of our boilers and equipment will be sent upon request.



Perfection Down Draft Smokeless Boiler



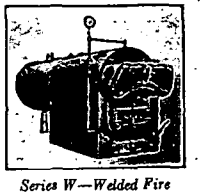
Titusville Standard Internal Fired Scotch Type Boiler



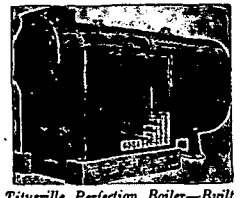
Titusville Vertical Tubular Boiler



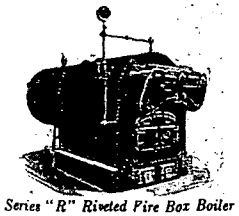
Series SR—Compact Type Welded Boiler



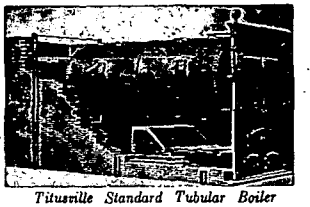
Series W—Welded Fire Box Boiler



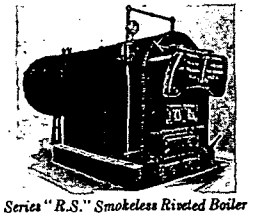
Titusville Perfection Boiler—Built in Sizes 25 H. P. to 200 H. P. from 15 lbs. to 150 lbs. Working Pressure



Series "R" Riveted Fire Box Boiler



Titusville Standard Tubular Boiler



Series "R.S." Smokeless Riveted Boiler

Monitor Boiler Company

Affiliated with UNITED DRY DOCKS, INC., NEW YORK

1505 Race Street **Philadelphia, Pa.**

MONCO FIRE TUBE STEEL HEATING BOILERS, COIL STEEL HEATING BOILERS AND WATER HEATERS FOR COAL AND OIL BURNING

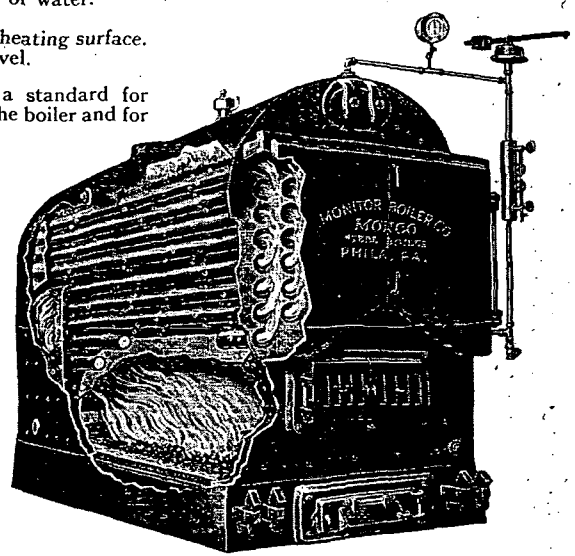
Monco Fire Tube Steel Heating Boilers are electrically welded and are designed according to the Code of the A. S. M. E. covering welded boilers and are constructed for a maximum working pressure of 15 lb. steam and 30 lb. water. All Boilers are constructed under the direct supervision of a Certified Insurance Inspector and are tested and stamped by this inspector before shipment.

The following are some of the outstanding features:

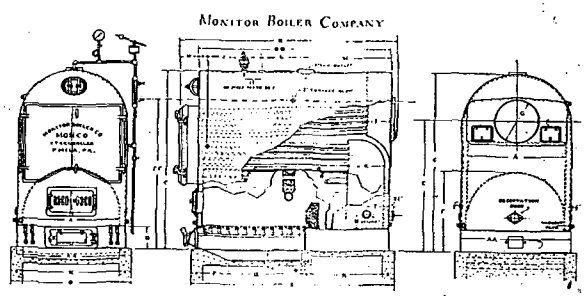
Arched self-cleaning crown sheet.
Large combustion chamber.
Unrestricted circulation of water.
Low water line.
Large amount of direct heating surface.
Long three-pass fire travel.

Ratings are based on a standard for steam of 2 lb. pressure at the boiler and for water on a mean temperature of 180 deg. as the water leaves the boiler. Any **Monco** Fire Tube Steel Heating Boiler will carry its full-rated load in direct radiation or equivalent, if sufficient radiation is installed to heat the building to 70 deg. fahr.

The standard equipment for coal burning boilers includes all castings as shown on boiler, heavy steel base and shaking grates. Standard steam trimmings include damper regulator, steam gauge with syphon, water column with gauge cocks and water glass, safety valve, tube, brush and firing tools. No trimmings furnished with hot water boilers.



Monco *Fire Tube Steel Heating Boiler for Coal and Oil Burning*



For Dimensions and Specifications see following page

Coal and Oil Burning Boilers

Monco Fire Tube — **Steam Specifications**

Catalog Number Coal	Catalog Number Oil	S. H. B. I. Steam Ratings Coal	S. H. B. I. Steam Ratings Oil	Shipping Weight Approx. Coal	Shipping Weight Approx. Oil	Grate Area, Sq. Ft.	Heating Surface	One Boiler Coal or Oil: Diam. Smoke Breech	One Boiler Coal or Oil: Diam. Stack Inches	One Boiler Coal or Oil: Min. Ht. Stack Feet	Two Boilers Coal or Oil: Diam. Smoke Breech	Two Boilers Coal or Oil: Diam. Stack Inches	Two Boilers Coal or Oil: Min. Ht. Stack Feet	Coal or Oil: Size Steam Outlet	Coal or Oil: Size Return	Coal or Oil: Safety Valve No. Size	Coal or Oil: Covering Required Sq. Ft.
301-5	301-6	1360	1650	3250	2700	6.9	97	16	16	45	24	22	50	5	2-2½	1-1½	46
302-5	302-6	1720	2090	3650	3000	8.0	123	16	16	50	24	22	55	5	2-2½	1-1½	56
303-5	303-6	2070	2520	4050	3300	9.0	148	16	16	55	24	22	60	5	2-2½	1-1½	66
401-5	401-6	2240	2720	4400	3550	10.7	160	18	18	50	26	24	55	6	2-3	1-1½	67
402-5	402-6	2700	3280	4950	4000	12.1	193	18	18	55	26	24	60	6	2-3	1-2	78
403-5	403-6	3150	3830	5500	4550	12.1	225	18	18	60	26	24	65	6	2-3	1-2	90
404-5	404-6	3700	4490	6000	4900	13.5	264	20	20	55	28	26	60	6	2-3	1-2	94
405-5	405-6	4340	5270	6800	5700	13.5	310	20	20	60	28	26	65	6	2-3	1-2	107
406-5	406-6	4980	6050	7600	6400	14.9	356	20	20	65	28	26	70	6	2-3	1-2½	120
471-5	471-6	5360	6510	8300	7000	16.3	383	22	22	60	34	32	65	8	2-4	1-2½	116
472-5	472-6	6150	7460	8900	7450	18.0	439	22	22	65	34	32	70	8	2-4	1-2½	130
473-5	473-6	6940	8430	9500	7900	19.7	496	22	22	70	34	32	75	8	2-4	1-3	135
551-5	551-6	8460	10270	11000	9200	21.5	604	24	24	65	36	34	70	8	2-4	1-3	159
552-5	552-6	9420	11440	12200	10300	23.0	673	24	24	70	36	34	75	8	2-4	1-3½	174
553-5	553-6	10390	12610	13400	11500	23.0	742	24	24	75	36	34	80	8	2-4	1-3½	190
651-5	651-6	11610	14090	15000	12950	25.2	829	28	26	75	38	36	80	10	2-5	1-3½	192
652-5	652-6	12950	15730	16500	14250	27.6	925	28	26	80	38	36	85	10	2-5	2-3	210
653-5	653-6	14280	17340	18000	15550	29.9	1020	28	26	85	38	36	90	10	2-5	2-3	228
740-5	740-6	16700	20280	20200	17550	31.9	1193	30	28	80	42	40	85	10	2-5	2-3	239
741-5	741-6	18650	22640	21800	19150	31.9	1332	30	28	85	42	40	90	10	2-5	2-3	251
742-5	742-6	20590	25010	23400	20550	34.7	1471	30	28	90	42	40	95	10	2-5	2-3½	273
743-5	743-6	22540	27370	25000	21900	37.4	1610	30	28	95	42	40	100	10	2-5	2-3½	295
860-5	860-6	24680	29970	27200	23850	40.9	1763	36	34	90	52	50	95	12	2-6	2-3½	305
861-5	861-6	27380	33250	29000	25650	40.9	1956	36	34	95	52	50	100	12	2-6	2-3½	335
862-5	862-6	30080	36530	30800	26450	40.9	2149	36	34	100	52	50	110	12	2-6	2-4	370
863-5	863-6	32790	39810	32600	29000	44.1	2342	36	34	110	52	50	120	12	2-6	2-4	400

Height Water Line—see FF in table below. Height Boiler—see C in table below. Length Boiler—see BB in table below. Width Boiler—see A in table below. To figure ratings of hot water boilers add 60 per cent to steam rating.

Measurements of **Monco** Fire Tube Boilers

Number of Boiler	Width of Firebox A	Width of Base AA	Length of Boiler Overall B	Length of Boiler BB	Height of Boiler C	Height of Base D	Floor to Center of Smoke Connection E	Height Floor to Top of Combustion Chamber F	Height of Water Line FF	Diameter of Smoke Connection G	Depth of Front Smoke Box H	Depth of Rear Smoke Flood I	Location Safety Valve J	Rear Combustion Chamber Dimension K	Distance from Safety Valve to Steam Outlet L	Location Steam Outlet M	Width of Ashpit N	Width of Foundation O	Foundation Dimension P	Foundation Dimension Q	Foundation Dimension R	Length of Foundation S	Location of Returns T	Location of Returns U
301*	25¼	30	61	51½	62½	12	49¼	34	54½	16	6	9⅞	7½	19⅛	12	26¼	22	38	8	27⅛	23⅜	59½	12¼	9
302*	25¼	30	73	63½	62½	12	49¼	34	54½	16	6	9⅞	13½	19⅛	12	32¼	22	38	8	33⅛	83⅛	71½	12¼	9
303*	25¼	30	85	75½	62½	12	49¼	34	54½	16	6	9⅞	13½	19⅛	18	38¼	22	38	8	39⅛	143⅛	83½	12¼	9
401*	33¼	40	74½	64	69	12	53½	38	59	18	7	10⅜	12	19⅛	12	34¼	32	48	15	26⅝	83⅛	72	12¼	9
402*	33¼	40	86½	76	69	12	53½	38	59	18	7	10⅜	14	19⅛	16	40¼	32	48	15	32⅛	143⅛	84	12¼	9
403*	33¼	40	98½	88	69	12	53½	38	59	18	7	10⅜	16	19⅛	20	46¼	32	48	15	32⅛	263⅛	96	12¼	9
404*	33¼	40	91½	78	80	12	62	40	69	20	9	12⅝	12	21⅛	18	42¼	32	48	15	38⅛	103⅛	86	13½	9
405*	33¼	40	103½	90	80	12	62	40	69	20	9	12⅜	16	21⅛	20	48¼	32	48	15	38⅛	223⅛	98	13½	9
406*	33¼	40	115½	102	80	12	62	40	69	20	9	12⅜	24	21⅛	20	52¼	32	48	15	44⅝	283⅛	110	13½	9
471*	40¾	47	103½	90	84	12	63⅜	41	71	22	9	12⅜	16	21⅛	20	48¼	39	55	18	35⅝	223⅛	98	12¾	9¼
472*	40¾	47	115½	102	84	12	63⅜	41	71	22	9	12⅜	24	21⅛	20	52¼	39	55	18	41⅛	283⅛	110	12¾	9¼
473*	40¾	47	127½	114	84	12	63⅜	41	71	22	9	12⅜	28	21⅛	20	60¼	39	55	18	47⅜	343⅛	122	12¾	9¼
551*	48¾	55	127½	114	89	12	68	44	74	24	9	12⅜	30	21⅛	18	60⅜	47	63	18	41⅝	403⅛	122	12¾	8¾
552*	48¾	55	139½	126	89	12	68	44	74	24	9	12⅜	32	21⅛	22	66⅜	47	63	18	47⅜	463⅛	134	12¾	8¾
553*	48¾	55	151½	138	89	12	68	44	74	24	9	12⅜	38	21⅛	22	72⅜	47	63	18	47⅞	583⅛	146	12¾	8¾
651*	57	64½	132	117½	104	15	81½	52	89	28	10	15⅞	33½	24	15	63⅜	56½	72½	18	41¼	44¼	125½	14¾	11⅛
652*	57	64½	144	129½	104	15	81½	52	89	28	10	15⅞	36½	24	18	57⅜	56½	72½	18	47¼	50¼	137½	14¾	11⅛
653*	57	64½	156	141½	104	15	81½	52	89	28	10	15⅞	39½	24	27	57⅜	56½	72½	18	53¼	56¼	149½	14¾	11⅛
740*	66	73½	132	117½	122	15	89⅝	55	102	30	10	15⅞	36½	24	18	45⅜	65½	81½	18	47¼	38¼	125½	14¾	10¾
741*	66	73½	144	129½	122	15	89⅝	55	102	30	10	15⅞	36½	24	18	57⅜	65½	81½	18	47¼	50¼	137½	14¾	10¾
742*	66	73½	156	141½	122	15	89⅝	55	102	30	10	15⅞	39½	24	27	57⅜	65½	81½	18	53¼	56¼	149½	14¾	10¾
743*	66	73½	168	153½	122	15	89⅝	55	102	30	10	15⅞	42½	24	30	60⅜	65½	81½	18	59¼	62¼	161½	14¾	10¾
860*	77¾	85½	139½	123½	134	15	99¾	56⅛	112	36	11½	16	36½	24	18	51⅞	77½	93½	18	54⅜	37⅛	131½	15¾	12⅝
861*	77¾	85½	151½	135½	134	15	99¾	56⅛	112	36	11½	16	36½	24	18	63⅜	77½	93½	18	54⅜	49⅛	143½	15¾	12⅝
862*	77¾	85½	163½	147½	134	15	99¾	56⅛	112	36	11½	16	39½	24	27	63⅜	77½	93½	18	54⅜	61⅛	155½	15¾	12⅝
863*	77¾	85½	175½	159½	134	15	99¾	56⅛	112	36	11½	16	42½	24	30	66⅜	77½	93½	18	60⅜	67⅛	167½	15¾	12⅝

*Numbers of all Monco Fire Tube Boilers, Coal and Oil Burning, begin with these three numerals.

Orr & Sembower, Inc.

Reading, Pa.

Representatives in Principal Cities

MANUFACTURERS OF STEEL BOILERS SINCE 1885

The Knowlton Watertoob Steel Heating Boiler

Designed especially for Oil and convertible to Gas. Can be equipped with McDermott submerged heaters for domestic hot water, and also with a few grate bars for emergency heating or for burning rubbish and garbage if desired.

The first line of oil burner boilers to be rated by the National Rating Committee for the Heating and Piping Contractors National Association as a result of performance tests conducted in a disinterested laboratory, under the rules prescribed by the American Society of Heating and Ventilating Engineers Standard and Short-Form Heat Balance Codes for Testing Low Pressure Steam Heating Solid Fuel Boilers (Codes 1 and 2).

Boiler is made of 5/16 in. copper bearing steel. All electrically welded in one unit.

Tubes in oil and gas burning boilers are made of copper, given longer life and greater heat absorbing qualities. Tubes are placed close together on an angle, increasing water circulation and heating efficiency. Tubes are expanded into tube sheets at right angles to the inclination necessary for proper circulation.

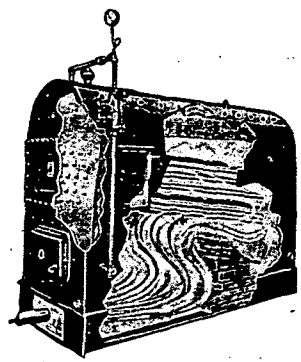
Construction is such that gas cannot take short cut to chimney. Gas travel is equivalent to about three times the length of fire box. Baffling is sectional horizontal type, removable through cleanout doors and supported on non-buckling removable bars.

Equipped with

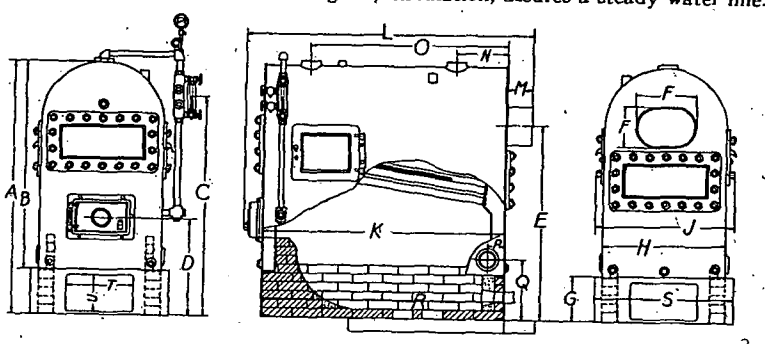
Copper Tubes for

Efficiency and Quick Action

Tried—Proven—Accepted



The Knowlton, with its large water content, large disengagement area and correct circulation, assures a steady water line.



NOTE.—Dimensions and Specifications—Next page.

All Performance Tests conducted by THE FROST RESEARCH LABORATORY, Norristown, Pa., U. S. A.

WORKING PRESSURES 15 lbs. Steam 30 lbs. Water

B. T. U. per lb. of Oil 19400
Wht. of Oil, 7.2 lbs. per gal. at 70°

RATINGS—KNOWLTON WATERTOOB BOILERS

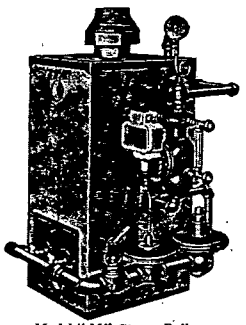
Boiler Number	20	21	22	23	24	25	26½	27	27½	28	29	30	31	32	33	34
Output at Boiler Outlet.....Thousands B.t.u. per hour	204	288	360	528	638	765	947	1130	1290	1450	1651	1993	2337	2737	2977	3160
Output at Boiler Outlet, Guaranteed Designed Loads (Steam), sq. ft.	850	1200	1500	2200	2660	3185	3945	4710	5370	6040	6880	8300	9720	11400	12400	13160
Output at Boiler Outlet, Guaranteed Designed Loads (Water), sq. ft.	1360	1920	2400	3520	4257	5100	6310	7530	8600	9680	11000	13280	15550	18240	19850	21070
Recommended Max. Net Loads, Steam, sq. ft. In 70°F	630	890	1110	1695	2050	2450	3035	3625	4135	4650	5500	6640	7775	9120	9920	10530
Recommended Max. Net Loads, Water, sq. ft. In 70°F	1010	1425	1775	2710	3280	3920	4855	5800	6615	7440	8800	10625	12440	14590	15870	16850
Output at Boiler Outlet.....Lbs. Steam per hour	210	297	371	544	658	788	976	1162	1328	1492	1702	2050	2410	2815	3068	3257
Gallons Oil burned.....per hour	1.8	2.55	3.22	4.68	5.72	6.77	8.45	10.0	11.5	13.0	14.9	18.0	21.0	25.0	27.1	28.7
Water Evaporation per lb. of Oil.....lbs.	16.2	16.2	16.0	16.1	16.0	16.2	16.0	16.2	16.0	16.0	15.9	15.8	15.95	15.6	15.7	15.7
Boiler Efficiency.....per cent	80.9	80.9	80.4	80.7	80.0	81.1	80.0	80.9	80.3	80.0	79.6	79.3	79.9	78.4	78.8	78.8
Flue Gas Temperature.....degrees	441	480	523	572	597	535	570	565	595	615	620	627	613	625	640	634
Draft at Smoke Outlet.....Inches Water	0.02	0.02	0.02	0.03	0.04	0.04	0.04	0.04	0.04	0.04	0.05	0.06	0.08	0.16	0.22	0.20
Size of Chimney—One Boiler	8x12 x30	8x12 x30	12x12 x30	12x12 x30	12x16 x30	12x16 x30	12x16 x30	12x16 x30	12x16 x30	16x16 x30	16x20 x30	20x20 x35	20x20 x35	20x20 x40	24x24 x60	24x24 x60
Size of Chimney—Two Boilers	12x12 x30	12x16 x30	12x16 x30	12x16 x30	16x16 x30	16x16 x30	16x20 x30	16x20 x30	20x20 x30	20x20 x30	20x24 x30	24x24 x35	24x24 x35	24x24 x40	24x30 x60	24x30 x60
Combustion Area.....sq. ft.	2.50	3.83	4.80	6.50	7.58	8.45	9.67	11.27	12.09	12.88	14.11	16.90	19.98	22.51	25.0	25.0

DIMENSIONS OF KNOWLTON WATERTOOB STEEL HEATING BOILERS

A—Height of Boiler.....inches	55¼	56	58	59½	62½	62½	71	72	73	72	74	81	81	82½	82½	85
B—Height of Boiler Shell.....inches	43¼	44	46	47½	50½	50½	59	59	61	60	62	69	69	70½	70½	73
C—Height of Boiler Water Line.....inches	47	48	50	51½	54	54	60½	63	63	64	65	69	69	70	70	73
E—Height CL. Smoke Outlet.....inches	39	39¼	42	42½	44½	44½	50	53	50¼	53½	55	58½	58½	58½	58½	60¼
H—Width of Boiler.....inches	26	29	29	32	32	35	35	35	35	35	39½	39½	43½	43½	43½	43½
J—Width over-all of Boiler.....inches	29	32	32	35	35	38	38	38	38	38	38	42½	42½	46½	46½	46½
L—Length over-all of Boiler.....inches	36	42	48	54	60	60	67	75	79	83	89	96½	110½	110½	120½	120½

B-Line Boiler Company

Cleveland, Ohio



Model "M" Steam Boiler

Manufacturers of Gas Boilers for Hot Water, Steam and Vapor Heating; Hot Water Generators; Automatic Controls for Gas Heating Appliances.

B-Line Gas-Fired Boilers are built for use in connection with Steam, Vapor or Hot Water systems of heating; Industrial Steam Supply Units, and Volume Water Heating Units.

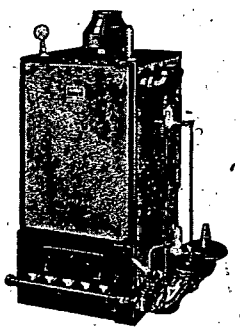
B-Line Boilers are constructed of cast-iron sections assembled with cast-iron push nipples. The heat absorbing surface is unusually large and arranged so as to transmit practically all available heat into the water.

B-LINE BOILER RATINGS

Boiler No.	Btu Output per Hour	Boiler Hp.	A. G. A. Rating		Radiation Load	
			Steam	Water	Steam	Water
Model "M" Boilers						
22	38,400	1.1	160	260	105	165
23	76,800	2.3	320	510	210	325
24	115,200	3.4	480	770	310	495
25	153,600	4.6	640	1020	415	655
26	192,000	5.7	800	1280	520	820
27	230,400	6.9	960	1540	630	1010
Models "K" and "DK" Boilers						
43	158,400	4.7	660	1060	425	680
54	211,200	6.3	880	1410	575	920
65	264,000	7.9	1100	1760	730	1170
76	316,800	9.5	1320	2110	885	1420
87	369,600	11.0	1540	2460	1040	1665
98	422,400	12.6	1760	2820	1195	1915
109	475,200	14.2	1980	3170	1350	2160
1110	528,000	15.8	2200	3520	1505	2410
1211	580,800	17.3	2420	3870	1660	2660
1312	633,600	18.9	2640	4220	1815	2905
1413	686,400	20.5	2860	4580	1970	3155
1514	739,200	22.1	3080	4930	2130	3410
1615	792,000	23.6	3300	5280	2295	3675
1716	844,800	25.2	3520	5630	2455	3930
1918	950,400	28.4	3960	6340	2780	4450
2019	1,003,200	30.0	4180	6690	2950	4720
2120	1,056,000	31.5	4400	7040	3110	4980
2322	1,161,600	34.7	4840	7740	3440	5505
2524	1,267,200	37.8	5280	8450	3770	6035
2726	1,372,800	41.0	5720	9150	4090	6545
2928	1,478,400	44.1	6160	9860	4400	7040
3130	1,584,000	47.3	6600	10560	4710	7540
3332	1,689,600	50.4	7040	11260	5030	8050
3534	1,795,200	53.6	7480	11970	5340	8545
3736	1,900,800	56.7	7920	12670	5660	9060
3938	2,006,400	59.9	8360	13380	5970	9555
4140	2,112,000	63.0	8800	14080	6290	10065

B-Line Boiler control system is entirely automatic in operation, or semi-automatic, if desired. The controls are mechanical, gas operated type, consisting of a hand control valve; gas pressure regulator; snap action fuel control valve to cut on or off, the fuel supply at a predetermined steam pressure or water temperature. Automatic low water fuel cut-off is furnished for steam boilers. Thermostatic pilots are optional. Automatic secondary air control which cuts off the air supply to the combustion chamber when the fire is extinguished, thus eliminating rapid cooling of the boiler sections is furnished on Model "K" Boilers only.

B-Line Boilers tested and approved for all sizes by A. G. A.

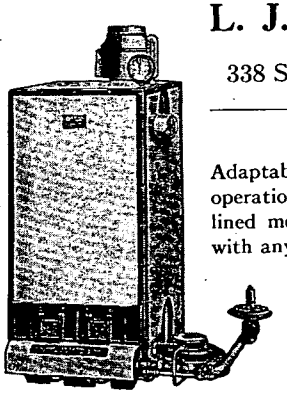


Model "K" Water Boiler

L. J. Mueller Furnace Co.

ESTABLISHED 1857

338 So. Second St., **Milwaukee, Wis.**



Gas-Era Gas-Fired Boilers

Adaptable for steam or hot water heating. Completely automatic operation. Cast iron construction for durability, with asbestos-lined metallic jacket. Vertical burner adjustment permits use with any manufactured or natural gas. Have steady water line and will not prime. Interior surfaces may be thoroughly cleaned without disturbing jacket. Multiple unit construction permits increase in size when desired. Boiler is highly efficient, securing maximum heat utilization with minimum gas consumption.

HOT WATER		STEAM		Floor Space Inches	VENTS		Size Gas Connection Required
Boiler No.	*A.G.A.* Rating	Boiler No.	*A.G.A.* Rating		Number	Diameter Inches	
13-W	670	13-S	420	31¼ x 46½	1	4	1
24-W	1,005	24-S	630	35¼ x 46½	1	6	1
25-W	1,340	25-S	840	39 x 47⅞	1	7	1¼
37-W	2,010	37-S	1,260	46¾ x 51⅞	1	9	1½
49-W	2,680	49-S	1,680	54½ x 53⅝	1	10	2
511-W	3,350	511-S	2,100	62¼ x 54¾	1	11	2
613-W	4,020	613-S	2,520	70 x 51⅝	2	9	2½
715-W	4,690	715-S	2,940	79¾ x 53⅝	2	10	2½
817-W	5,360	817-S	3,360	87½ x 53⅝	2	10	2½
919-W	6,030	919-S	3,780	95¼ x 54¾	2	11	2½
1021-W	6,700	1021-S	4,200	103 x 54¾	2	11	2½
1123-W	7,370	1123-S	4,620	110¾ x 56⅛	2	12	2½
1225-W	8,040	1225-S	5,040	120½ x 53⅝	3	10	2½
1327-W	8,710	1327-S	5,460	128¼ x 54¾	3	11	3
1429-W	9,380	1429-S	5,880	136 x 54¾	3	11	3
1531-W	10,050	1531-S	6,300	143¾ x 54¾	3	11	3
1634-W	10,720	1634-S	6,720	87½ x 107¼	2	14	3
1838-W	12,060	1838-S	7,560	95¼ x 109½	2	16	3
2042-W	13,400	2042-S	8,400	103 x 109½	2	16	4
2246-W	14,740	2246-S	9,240	110¾ x 112¼	2	17	4
2450-W	16,080	2450-S	10,080	120½ x 107¼	3	14	4
2654-W	17,420	2654-S	10,920	128¼ x 109½	3	16	4
2858-W	18,760	2858-S	11,760	136 x 109½	3	16	5
3062-W	20,100	3062-S	12,600	143¾ x 109½	3	16	5

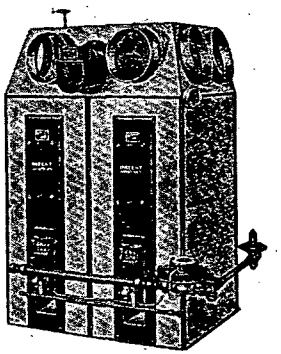
Gas-Era Gas-Fired Warm Air Furnace

Cast iron construction, with green lacquered casing. Completely automatic. Accessible for cleaning. Automatic moisture supply. Adaptable for forced air heating.

Furnace No.	*A.G.A.* Input Rating B.t.u. per Hour	Total Load B.t.u. per Hour	Capacity Warm Air Pipes Sq. In.
1 (10)*	65,000	47,500	430
2 (20)	130,000	95,000	860
3 (30)	195,000	142,500	1290
4 (40)	260,000	190,000	1720
5 (50)	325,000	237,500	2150
6 (60)	390,000	285,000	2580
7 (70)	455,000	332,500	3010
8 (80)	520,000	380,000	3440
9 (90)	585,000	427,500	3870
X-10 (100)	650,000	475,000	4300

*Same furnace, less electrical equipment and automatic hum difier.

Write for catalogs on above units, also on Gas Era Steel Furnaces and Climator Air Conditioning Systems, complete with blowers, humidifiers, filters, washers and cooling equipment.



Gas Era Furnace

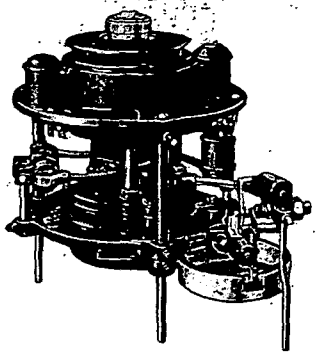
Gas-Era Furnaces and Boilers tested and approved for all sizes by American Gas Association

Automatic Burner Corporation

1823 Carroll Avenue, **Chicago, U. S. A.**

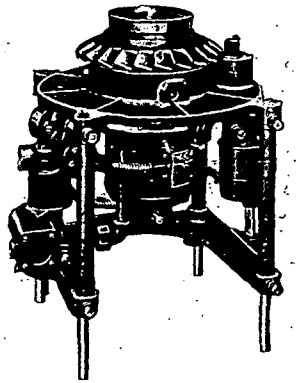
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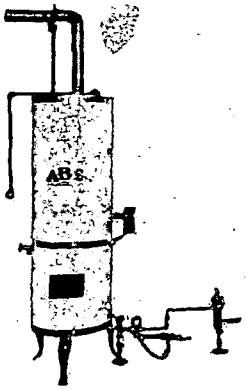
CHICAGO · DETROIT · NEW ROCHELLE · WASHINGTON, D. C. · BALTIMORE · PHILADELPHIA



Type E Automatic Oil Burner—ABC Oil Burners are of the rotary atomizing type. Oil is raised to the atomizing cup through a hollow tapered armature shaft by centrifugal force. Special 1/10 h.p. motor runs at 10,000 r.p.m. No fans or blowers. Orange flame is applied over the entire grate area at grate level. Gas or electric ignition. Burns cheaper grades of oil. Easily installed in practically all types of gas fired warm air furnaces; steam, vapor and unit, heater systems and hot water plants. Three sizes of Type E handle 1200, 3000 and 6000 feet of steam radiation respectively.

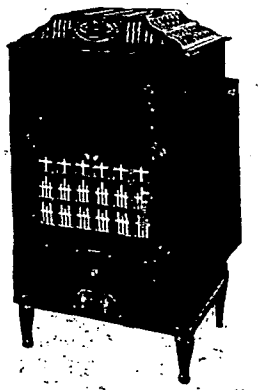
Type H Burner is also of the vertical spindle rotary type with 1/20 h.p., 110 volt, motor operates at a constant speed of 3400 r.p.m. Power consumption of this burner is only 70 watts at full load. This burner has an oil rating of from one to two gallons per hour and will handle 600 feet of steam radiation or the equivalent in hot water, warm air or vapor. This burner can be installed in practically any heating plant within its capacity. Type H Burner may be installed in connection with either inside or outside storage tanks of any capacity.





ABC Automatic Hot Water System—This unit consists of a water storage tank, valve, constant level device and fuel reservoir. Several elements in the construction have been left flexible to make it adaptable to varied installation conditions. The ABC system is furnished with either *manual or automatic high-low flame control.* This system can also be installed as a conversion unit to replace coal or automatic gas heaters. It is exceptionally economical.

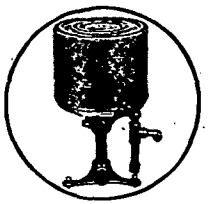


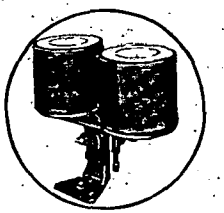


ABC Space Heater—This unit is ideal for heating garages, out buildings or single rooms in the house. It is ruggedly built and shows, in actual tests, an over-all efficiency of 80 per cent. It is designed to heat approximately 2000 cu. ft. of space. Rated B.t.u. input is 17,500 B.t.u. per hour. Heats approximately 2000 cu. ft. of space. Walnut or blue steel finish; top, door, bottom and legs are cast-iron. Shell is blue steel. Full mica door. Height 38 in., width 13 in. Depth with oil container, 24 in. Capacity one pint per hour.

ABC Circulating Heater—Provides, clean, even, economical heat for one to three rooms. Attractive walnut finish or blue steel as desired. Scientifically designed for low stack temperature and high over-all efficiency. (80 per cent by actual test). Strongly built, steel shell. Cast-iron top, door, bottom and legs, finished to match. Heats approximately 4000 cu. ft. of space. Rated B.t.u. input, 35,000 B.t.u. per hour. Height 41 in., width 22½ in., depth with oil container, 26 in. Fuel capacity two and one-quarter pints per hour.

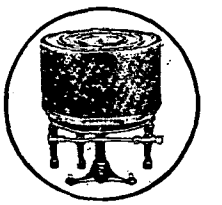
ABC 6½ in. Stove Burner Unit—This unit can be installed in water heaters, small parlor stoves, Quebec heaters, hot blast stoves, base burners, garage heaters, etc. Shells are made of high quality chromium steel. Heats quickly as there are no heavy castings to heat. Capacity approximately 1⅛ pint per hour.

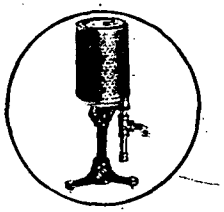




ABC Double 6½ in. Stove Burner Unit—For use in cook stoves and parlor stoves with oval fire boxes, laundry stoves and similar types of installation. The same construction is used in all stove burner units. All parts are interchangeable, simplifying service problems. Capacity approximately 2¼ pints per hour.

ABC 9 in. Stove Burner Unit—This unit may be used as shown (standard) or with a 4 in. shell in the center. Can be used for circulating heaters with round fire boxes, salamanders, large water heaters, base burners, Quebec heaters, hot blast stoves, etc. Capacity of 9 in. standard, approximately 2¼ pints per hour. Capacity of 9 in. with 4 in. approximately 2¾ pints per hour.





ABC 4 in. Stove Burner Unit—For use in brooders, small water heaters, glue pots and similar installations. Like all ABC units it is easy to install, easy to clean, economical and sturdy. Heats quickly, full capacity fire in five minutes. Fuel capacity approximately ½ pint per hour.

The Anthony Company

LIQUID FUEL ENGINEERS

47-33 Fifth Street, **Long Island City, N. Y.**

PRODUCTS—Anthony Nebulyte Oil Burning and Gas Burning Systems for steam boilers, hot water heaters, hot air furnaces, cooking ranges, etc. Anthony Nebulyte System for Heavy Gravity Oil. Anthony Single and Duplex Strainers. Anthony Steam and Electric Fuel Oil Heaters. Tank Suction Units.

Engineering Service—Anthony engineers are prepared to discuss all heating problems and design special oil, tar or gas fired apparatus for specific needs.

Having designed a great variety of successful industrial heat treating systems, they have wide experience in this field to place at a client's disposal.

More than 25 years of success.

Anthony Nebulyte System for Boilers—The Anthony is a mechanical nebulizing system for liquid fuel, and normally produces 80% to 86% evaporating efficiency.

In this highly developed system of gas firing with oil fuel, an instantaneous conversion of liquid to gas is effected by correct combination of essential elements.

Performance—Every item of Anthony equipment has been selected and developed to meet exacting requirements, and is fully guaranteed to be free from defects in materials and workmanship. In spite of the severest operating conditions, the annual maintenance costs have averaged no more than 2% over a period of 10 years. A completely installed Anthony Nebulyte system is assurance of successful operation.

Equipment—This includes storage tanks and fittings, suction and discharge strainers, heaters, pumps, blowers, burner sets, valves, piping, gauges and thermometers, together with firing chambers and attachments.

Anthony oil heaters, for use with heavy gravity oils, are supplied to give the required temperature to the particular grade of oil specified. Complete with safety relief valve, thermometer and, where desired, with automatic temperature control. Either steam or electric.

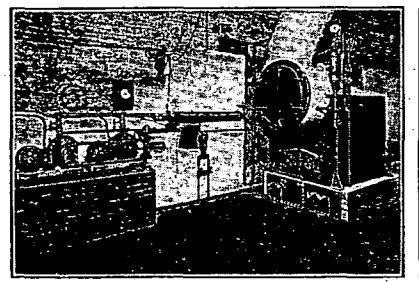
Anthony strainers are made in both single and duplex patterns. In the duplex strainers, either side can be cut out of service by a single lever movement. They need never be taken apart for cleaning. They are easily applied to any pipe line. The cleaning operation is made so simple that there is no excuse for strainers ever becoming foul.

Control—Usually by hand, but automatic controls of proven reliability can be furnished, where specified, to maintain definite boiler pressure, water temperature or both.

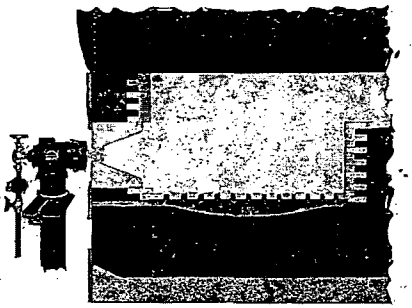
Application—The Anthony Nebulyte system is adapted for burning oil or gas under heating and power boilers in apartment houses, hotels, clubs, public buildings, etc. The combination oil and gas system offers special advantages in many instances.

Anthony Nebulyte System for Heavy Gravity Oil—Heavy gravity asphaltum base oils cause many troubles and often condemn an oil burning system that is not installed to provide for all the necessary conditions. Yet the use of such oils at their lower prices is necessary in order to show satisfactory operation figures in comparison with coal. The Anthony system can be so installed as to handle such oils equally as well as those of the lighter gravity.

Changing Present Systems for Heavier Oils—The overcoming of existing troubles and improvement in the present operating conditions of other systems already installed, comprises a major portion of the work of THE ANTHONY COMPANY. Send us full details.



Typical Installation of an Anthony Mechanical System
(Units in duplicate)



Gas Firing with Oil Fuel

Crystal Oil Burner Corporation

General Office and Factory: 211 Coit Street, **Irvington, N. J.**

Dealers in all Principal Cities

Crystal Blue Flame Oil Burner

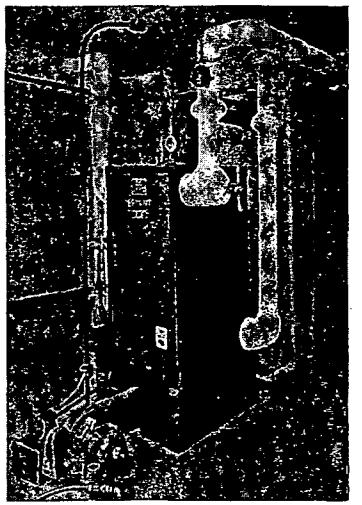
For Installation and Automatic Operation in Any Type Heating Plant of Residence, School, Church or Small Public Building.

The Crystal Blue Flame Oil Burner has been manufactured, and in successful operation for the past ten years.

It is fully automatic; thoroughly efficient; clean and perfect combustion; and is made in four sizes covering a range of from 350 ft. to 5000 ft. of steam radiation.

Approvals—Listed and labeled by the Underwriters' Laboratories, Inc. Approved by the Board of Standards and Appeals of New York City, and fire prevention bureaus of principal cities. Member of Oil Heat Institute and The American Oil Burner Association.

Fuel Burning Feature—The outstanding feature of the Crystal Blue Flame Oil Burner is the method of burning the oil. The blue flame which is produced by the Crystal is accountable for Crystal efficiency. This blue flame is the result of converting the oil into a gas and then burning the gas. This is accomplished by carrying the air and oil through the carburetor with a fan and passing the mixture of air and oil through the cracking chamber to the burner. Passing through the chamber the mixture turns to a thin vapor. Upon reaching burner it has become a gas.



Crystal Blue Flame Oil Burner Installed in Gas-fired Boiler
Note that no changes have been made in boiler setting or piping system.

Contact and Safety Switch—The flame of the Crystal Blue Flame Oil Burner gives immediate and direct heat contact with the entire surface to be heated.

The gas is ignited by a still gas pilot direct from city gas lines. The pilot uses .6 cu. ft. gas per hour.

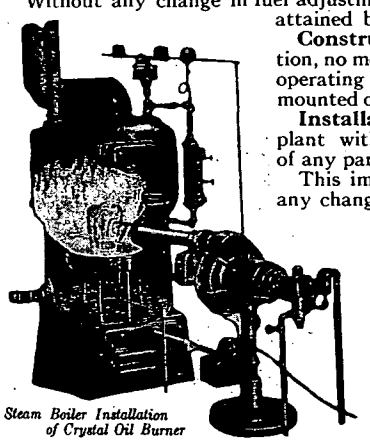
Safety switch controls the burner, automatically shutting off current and burner in case of overflow or failure of pilot.

Throttle Control—The Crystal automatic control gives positive control of the flame, thus assuring that burner will carry the predetermined load without needless use of fuel. Without any change in fuel adjustments a range of 50 per cent in capacity can be attained by automatic control alone.

Construction—Rugged construction, simple in operation, no moving parts inside furnace. The only mechanical operating part in the entire burner is the motor and fan mounted on one shaft which is located outside the furnace.

Installation—Quickly installed in any type heating plant without removal of grates, alteration or change of any part of furnace or flues.

This important feature includes gas-fired plant without any changes to boiler setting or piping system.



Steam Boiler Installation of Crystal Oil Burner

CAPACITIES, H.P. AND OIL CONSUMPTION OF CRYSTAL BLUE FLAME OIL BURNERS

Model	Steam Radiation Capacity, Ft.	Motor Hp	*Oil Consumption per Hr., Gal.	
			Minimum	Maximum
A	350	1/6	3/4	1 1/2
A-1	600	1/6	1 1/2	2 1/2
B	1000	1/4	2	3 1/2
C	3000	1/4	3 1/2	7
D	5000	1/4	7	11

*Controlled by Crystal Automatic Throttle Control.

Petroleum Heat & Power Company

Manufacturers of Petro-Nokol Oil Burner Equipment, Petro Automatic Boilers for Oil or Gas, Oil Burner Accessories, and Distributors of Fuel Oil.

FACTORY: **Stamford, Conn.**

Offices in

NEW YORK CITY
BOSTON, MASS.
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Subsidiary Companies

BOSTON HARBOR OIL CO.
EAST COAST FUEL OIL CO.
POWER PLANT ENGINEERING CO.
PETROLEUM HEAT AND POWER CO. OF CALIF.

PETRO-NOKOL

A Special Model for Every Type of Domestic, Commercial, and Industrial Heating Plant:

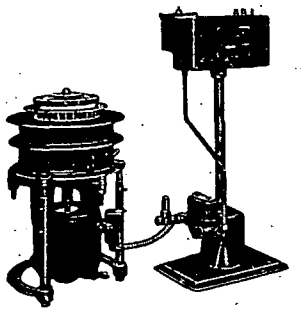
Heating engineers and even mechanically inclined laymen have for some time recognized that though a certain type of oil burner functions perfectly in one type of heating plant under certain conditions, operating results are often quite the contrary when this same burner is employed under other conditions or installed in another type of heating plant. To provide for the widely varying conditions encountered in the field, the PETROLEUM HEAT AND POWER COMPANY manufactures a complete line of oil burner equipment, specifically designed for every operating condition. The recommendation of a PETROLEUM HEAT AND POWER COMPANY representative therefore can be relied on . . . . for it will be the result of an impartial, unbiased analysis of the specific peculiarities of each heating or power problem.

A Public Service Enterprise—Undivided Responsibility:

The PETROLEUM HEAT AND POWER COMPANY is also one of the largest distributors of fuel oil in the country. Serving as a public service enterprise, the company's responsibility is undivided where the installation of its equipment is combined with its fuel oil service.

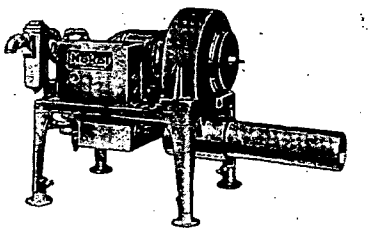
Model "R" Rotary Type Burner (Domestic):

The Model "R" is a fully automatic, forced draft, centrifugal atomizing burner for the small round boiler or furnace. Its design provides for complete control of the air for combustion over the oil consumption range. This assures maximum operating efficiency. The air and oil are delivered through a rotary head assembly revolving at a speed of 1750 r.p.m. Air and oil are thoroughly mixed in their passage across the deck installed to cover the grate area. Ignition, either gas or electric, takes place slightly above the base of the sections of a refractory ring provided to aid combustion. Model "R" produces the brilliant luminous flame, characteristic of all Petro-NoKol Burners. It provides the radiant heat which most boilers are designed to take advantage of. This flame is concentrated at the grate level . . . where the coolest water absorbs the maximum heat. Model "R" burners are built for operation with No. 2 oil or lighter, and have a capacity up to 3¾ gal. per hour.



Model	Grade oil	Ignition	Motor h.p.	Gal. per hr.	Round boiler or hot air furnace, in.	Average radiation* Sq. in. hot air	Sq. ft. Steam	Sq. ft. Hot water	Max. gal. hot water per hr.**
R-1	No. 1	Gas or	1/20	½	17 to 23	452	408	653	117
R-2	or	elec-	1/20	to	17 to 26	656	543	865	157
R-3	No. 2	tric	1/20	3¾	22 to 30	807	725	1,160	210
R-4			1/20		22 to 30	1,414	1,300	2,100	375

*Total equivalent cast-iron radiation measured at the boiler outlet.
**60 per cent efficiency, 90° temperature rise.



Model "G"

Model "G" Pressure Type Burner (Domestic):

The Model "G" burner is of the pressure atomizing mechanical draft type, equipped with full automatic controls for operation on alternating current of commercial voltages and frequencies. The oil discharged from the pump passes through a Duplex Regulating Valve and is delivered to the atomizing nozzle at a constant pressure. As the finely atomized oil leaves the nozzle it mixes with the air from the fan to form the combustible.

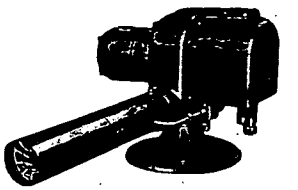
The ignition system is designed to provide entirely dependable operation. The full electric, constant spark, maintained at the proper location with respect to the atomized oil assures the elimination of all trouble due to failure of the oil to ignite. Model "G" is designed for use with No. 3 oil or any lighter oil.

Model	Grade oil	Ignition	Motor, h.p.	Gal. per hr.	Radiation,* sq. ft. Steam	Radiation,* sq. ft. Hot water	Maximum gal. hot water per hour**
G-1	No. 3	Electric	1/6	1 to 3	1,050	1,680	200
G-2	No. 3	Electric	1/4	2 to 7½	2,400	3,850	700
G-3	No. 3	Electric	1/2	7½ to 15	5,000	8,000	1,450

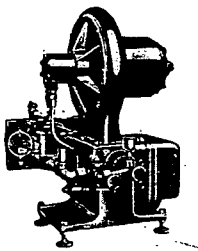
*Total equivalent cast-iron radiation measured at the boiler outlet. **60 per cent efficiency, 90° temperature rise.

Model "P-2" Advanced Pressure Type Burner (Domestic):

A fully automatic, forced draft, pressure atomizing burner. Design provides complete control of the air required for efficient combustion over the oil consumption range assuring maximum operating efficiencies. The air is delivered to the combustion chamber through vanes arranged tangentially to the flow of air in the tube which impart to the air a centrifugal motion. This swirling stream of air mixes thoroughly with the oil atomized from the nozzle to form a lightly combustible compound. The quantity of air is regulated by means of the fan intake shutter.



Model "P-2"



Model "D"

The Model "P-2" burner is designed for electric ignition operation and for use with No. 3 fuel oil or any lighter oil—2 to 8 gals. per hour. Total equivalent cast-iron radiation measured at the boiler outlet: 2700 sq. ft. steam; 4320 sq. ft. water.

Model	Grade Oil	Ignition	Motor h.p.	Gal. per hr.	Radiation,* sq. ft. Steam	Radiation,* sq. ft. Hot water
P-2	No. 3	Electric	¼	2 to 8	2,700	4,320

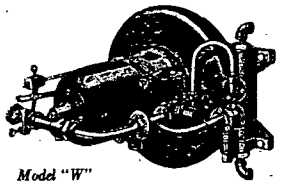
*Total equivalent cast-iron radiation measured at the boiler outlet.

Model "D" Air-Turbine Driven Cup Type Burner (Domestic and Commercial):

Model "D" burners are the distinctive "air driven" rotary cup type burners, fully automatic, and intermittent firing. Model "D" burners are designed to burn commercial fuel oils No. 4 and No. 5. Ignition is accomplished by means of a gas-electric type of ignition. Model "D" is available in six sizes with capacities ranging from 2½ to 52 gal. per hour.

Model	Grade oil	Ignition	Motor, h.p.	Gal. per hr.	Radiation,* sq. ft.	
					Steam	Hot water
D-10	No. 3	Gas-electric	1/8	2.5	750	1,200
D-11	No. 3	Gas-electric	1/6	5.0	1,750	2,800
D-12	No. 5	Gas-electric	1/4	10.0	3,500	5,600
D-13	No. 5	Gas-electric	1/2	20.0	7,000	11,200
D-14	No. 5	Gas-electric	1	42.0	14,500	23,200
D-15	No. 5	Gas-electric	1 1/2	52.0	18,000	28,800

*Total equivalent cast-iron radiation measured at the boiler outlet.



Model "W"

Model "W" Direct Driven Rotary Cup Type Burner (Commercial-Industrial):

The Model "W" is equipped with full-automatic controls for use with No. 5 oil or lighter. It may be used as a semi-automatic unit with No. 6 oil.

The weight of the burner is not carried on oil piping. Service and mechanical attention has been minimized by design of burner. The Model "W" is an advanced development of this well known type of oil burner and is adaptable to every industrial or commercial oil burning requirement.

Burners "W-3" and "W-4"—single phase and polyphase.

Burners "W-5," and "W-6" and "W-7" —polyphase only.

Model	Grade oil	Ignition	Motor, h.p.	Gal. per hr.	Maximum boiler h.p.	Radiation,* sq. ft., steam
W-2	See note below	Gas-electric	1/4	1 to 6	15	2,100
W-3		Gas-electric	1/2	5 to 20	50	7,000
W-4		Gas-electric	1/2	15 to 25	63	8,750
W-5		Gas-electric	1	20 to 30	75	10,500
W-6		Gas-electric	1 1/2	25 to 45	113	15,750
W-7		Gas-electric	2	25 to 60	151	21,000

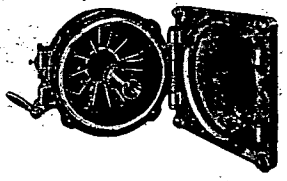
(All Model "W" burners use No. 5 oil or lighter when operated manually, automatically and semi-automatically. No. 6 oil when desired is used with pre-heaters for manual and semi-automatic operation).
*Total equivalent cast-iron radiation measured at the boiler outlet.

Model "A" Air Turbine Driven Cup Type (Commercial-Industrial):

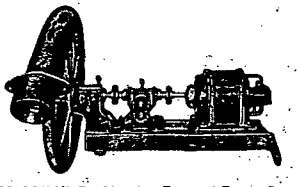
The Model "A" is designed to burn oils as heavy as No. 6 or Bunker "C". Model "A" burners are of the air driven rotary cup type and have registers through which secondary air for combustion is admitted and controlled as to volume and direction. No boiler plant equipped with Model "A" oil burning system need be shut down through failure of burner equipment, for every system can be provided with stand-by combination fan and pump sets and spare burner assembly. Due to the simplicity of its operation, a complete change over of fan and pump sets and burners can be effected without any loss of boiler steam pressure.

Any Model "A" burner gun requiring inspection can be removed from its register and replaced in thirty seconds with a clean, spare gun furnished for just such purposes. All guns of the same size are interchangeable.

Capacities of from 50 to 175 b. hp. may be obtained from one burner under natural draft conditions. By the use of forced draft this capacity may be increased to 330 b. hp. Model "A" burners can fire any boiler of any size with multiple burner installations.



Model "A" Burner and Register Assembly



Model "A" Combination Fan and Pump Set

Model	Capacity, b. hp.	
	Minimum	Maximum
1-A	15	36
2-A	36	140
3-A	100	180
4-A	120	330

Mechanical Type (Commercial-Industrial):

Atomizes the oil by pumping it at a relatively high pressure through an atomizing nozzle. The oil is forced through the grooves in the atomizer disc toward the center where it enters tangentially by means of which a rotary motion is imparted to it as it expands through the orifice.

Pumping and heating equipment may be located at some distance from the boiler or in a separate room. Boilers of any rating may be fired. Capacities of from 50 to 175 b. hp. may be obtained from one burner under sufficient natural draft conditions. By the use of forced draft this capacity may be increased to 300 b. hp. per burner assembly.

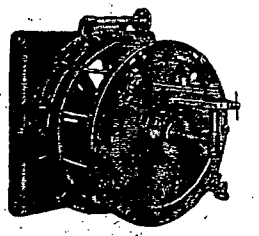
Petro Automatic Boilers—for Oil or Gas:

The Petro Automatic Boiler is the first combination of oil burner and boiler in one handsome, automatic, self-contained unit. A highly efficient Petro-NoKol Rotary Burner is completely concealed within. Because of the fact that the burner is constructed especially for use with the boiler, efficiencies of from 20 per cent to 30 per cent higher are obtained than are usually found with regular conversion jobs.

Where gas is more economical than oil, the oil burner unit may be removed and a gas burner unit quickly substituted.

The Petro Automatic Boiler is regularly finished in tangerine or cardinal and blue or in two shades of green or blue.

Equipment Includes: Burner with all fully automatic boiler and burner controls. Temperature and pressure Gauges. Boiler relief valve. Water level indicator.



Mechanical Type

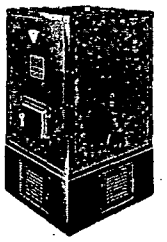
(Steam) Connections for Taco or similar domestic hot water supply heaters. Loop connections for standard heater.

Ignition: Gas ignition for No. 3 oil. Electric ignition for No. 2 oil.

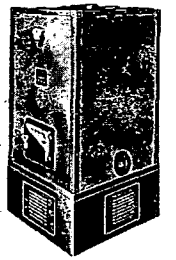
Descriptive literature on any of these products and on the complete line of Petro-NoKol oil pumps and other oil burner accessories will gladly be sent on request to the factory or to any of the branches or dealers of the Petroleum Heat and Power Company.

Model (S—steam) (W—water)	Radiation sq. ft.*		Gal. of water per hr., (100° F. rise)
	Steam	Water	
T-S-11	285		
T-W-11		456	82
T-S-12	390		
T-W-12		624	112
T-S-13	495		
T-W-13		792	142
T-S-14	600		
T-W-14		960	173
T-S-2	800		
T-W-2		1280	230
T-S-3	1200		
T-W-3		1920	345

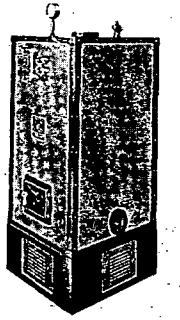
*Total equivalent cast-iron radiation measured at the boiler outlet.



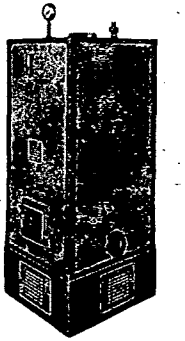
Model "T-W-11"



Model "T-W-12"



Model "T-S-13"



Model "T-S-14"

National Airoil Burner Company

ESTABLISHED 1912 INCORPORATED 1917

Salesroom and Offices: 1327 Girard Avenue

Factory

Ninth and Thompson Streets, **Philadelphia, Pa.**

Oil Burners, Gas Burners and Furnace Equipment

PRODUCTS—Oil Burners and Gas Burners for every industrial purpose: Motor-driven Rotary Burners, Air-driven Rotary Burners, Low Pressure Air Burners, Steam Atomizing Burners, Gas Burners, Combustion Units for Gas and Oil, Fuel Oil Pump Sets, Fuel Oil Strainers. Engineering advice, design, supervision or installation of complete oil or gas burning systems for every commercial and industrial purpose.

Type I-R Rotary Burner (Air Driven)

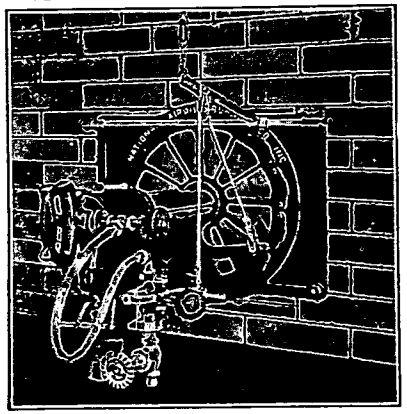


Fig. P-115—National Airoil, type I-R Rotary Burner, semi-automatic (high-low), type, in firing position

This Burner is of the mechanical-centrifugal atomizing type, air-driven, and is ideal for firing heating boilers, high pressure steam boilers and all types of industrial furnaces, especially where a battery of Burners is required. It will burn *without preheating* any commercial fuel oil down to 20° Baume (No. 5 Oil), and Bunker C fuel oil (No. 6 Oil), when preheated to 150° F. Oil pressure required only sufficient to deliver oil to atomizing cup. Air pressure required is from 8 ounces to 16 ounces. Write for Bulletin No. 60, giving details of **Type I-R Rotary Oil Burners** and also details on Combination Pump and Blower Units for operating these Burners.

Controls—This Burner can be arranged either for semi-automatic (high-low) operation (as shown), or manual operation.

Capacity—This Burner is made in two nozzle sizes, giving a capacity range of from 5 gallons to 40 gallons of oil per Burner, per hour.

Capacities vary depending on furnace dimensions. Write for Bulletin No. 61, giving complete chart of capacities and furnace dimensions.

Type D-R Rotary Burner (Motor Driven)

This Burner may briefly be described as a self-contained, motor-driven oil burner, of the mechanical-centrifugal atomizing type, with but three moving parts, consisting of totally enclosed motor, hollow shaft through which the oil is fed to the atomizing cup and on which is mounted a blower, a worm-driven, slow speed rotary fuel pump which draws oil from the storage tank and delivers it through proper regulating valves to the atomizing cup, and other necessary parts, such as Pressure Regulating Valve, Pressure Gauge, Indicating Oil Regulating Valve, Air Register, Refractory Burner Block, etc.

This Burner is ideal for firing heating boilers, high pressure steam boilers and various industrial furnaces, where fully automatic, semi-automatic or manual operation is desired.

Fuel Used—No. 5 oil without preheating, or No. 6 oil preheated to 150° F. Write for Bulletin No. 70 for complete details.

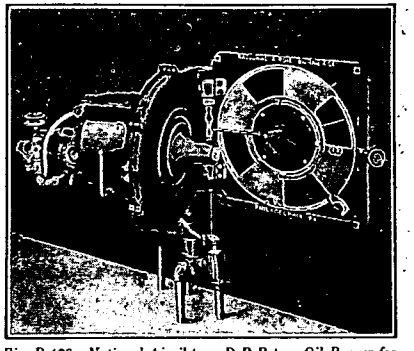


Fig. P-150—National Airoil type D-R Rotary Oil Burner for full automatic operation—swung out of firing position, showing atomizing cup, Air Register, and Furnace Plate with fire cone and pilot housing

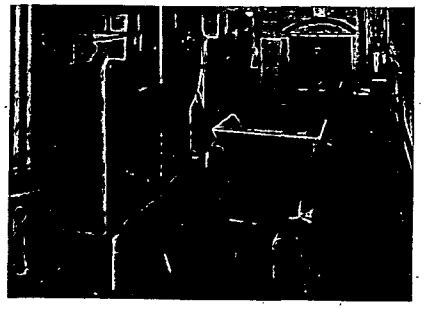


Combustioneer, Inc.

Automatic Anthracite or Bituminous Coal Burners

Goshen, Indiana

Factory Branches: CHICAGO—DETROIT



There is a Combustioneer for every size of boiler from the small house-heating type to a power plant where the hourly coal consumption does not exceed 1,200 pounds. Both Bituminous and Anthracite automatic coal burners for residences are built with automatic ash-removers.

Firing—The Combustioneer forced-draft, underfeed firing is the correct combustion method. The green coal is slowly warmed and fed into the fire from below—thus all gases are burnt—smoke and soot eliminated.

Controls—Combustioneer electric controls automatically regulate coal feeding to maintain the exact degree of temperature or pressure required.

Gear Case—Dial control for multiple speeds. Twenty speeds. All parts accessible from front.

Shearing Plate—Provides easy and quick removal of any foreign substance that may form an obstruction.

Retort—Is built up of sections to take care of expansion and contraction.

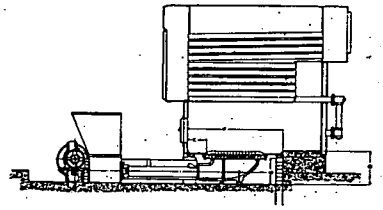
Installation—Combustioneer may be installed in any boiler from 6¾ to 240 H.P., and in a period of a few hours without interruption to business.

COMBUSTIONEER RATINGS

Based on 11,500 B. t. u. Coal—Motor Speed 1750 R. P. M.

The Model	Maximum Coal Burning Capacity Lbs. per Hour	Motor H. P.	Boiler H. P.	Capacity Steam Radiation Sq. Ft.	Capacity Hot Water Radiation Sq. Ft.	Average Maximum Projection Outside Boiler, Inches
**No. A-3 (Anthracite)	30	¼	6¾	750	1,200	62
**No. B-3 (Bituminous)	30	¼	6¾	750	1,200	62
No. A-4 (Anthracite)	40	⅓	9	1,000	1,600	59
No. 6 (Bituminous)	60	⅓	12	1,320	2,100	59
Furnastoker	50	¼	10	1,100	1,760	58
No. 9	90	½	18	2,000	3,200	65
No. 13	130	¾	26	2,900	4,640	65
No. 20	200	1	40	4,400	7,040	63½
No. 35	350	1½	70	7,700	12,320	68
No. 50	500	2	100	11,000	17,600	83½
No. 80	800	3 or 5	160	17,600	28,160	83½
No. 120	1200	5 or 7½	240	26,400	42,240	83½

**Based on 12,500 B. t. u. coal.



Combustioneer pit installation in a Steel Heating Boiler. Stoker should be located under the boiler so that a 12 inch end plate can be installed between the front edge of the retort and the front of the fire box. Pit should have two or three feet clearance back of gear case.

Combustioneer serves equally well in home, office building, power plant or factory—for heat, hot water and high or low pressure steam. It burns fewer tons of the lower priced sizes of coal, and eliminates smoke and soot. Combustioneer is recommended for reliable, economical, automatic heat. **FREE Engineering Service:** Our combustion and heating engineers will study your problems and make recommendations to you without cost or obligation. Descriptive folders, and special installation data sent on request.

Combustioneer Anthracite Burners are approved by the Anthracite Institute Laboratory.

Iron Fireman Manufacturing Company

Automatic Coal Burners

Portland, Oregon

Factories: PORTLAND, ORE.; CLEVELAND, OHIO; TORONTO, CANADA

Retail Branches or Subsidiaries

CHICAGO, ILL. MILWAUKEE, WIS. ST. LOUIS, MO. NEW YORK, N. Y.

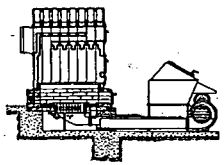
Dealers in Principal Cities and Towns in the United States and Canada

IRON FIREMAN Automatic Coal Burners



"Forced Underfiring" Principle—Iron Fireman "Forced Underfiring" is based on the scientific principle of feeding fuel to the fire from below, under forced draft. From the conveyor screw, coal enters the firebox under the fire and is gradually forced upward into the flame. As the coal approaches the fire, it is gradually heated. The volatile gases are distilled off in the presence of an excess of oxygen and are thoroughly ignited while passing through the incandescent fuel bed. This insures complete combustion. The ash is fused into clinkers which are easily removed.

Advantages—Iron Fireman saves money and increases heating plant efficiency in four major ways: (1) Cuts fuel costs; (2) reduces labor costs; (3) provides steady, even heat or power; (4) eliminates the smoke nuisance.

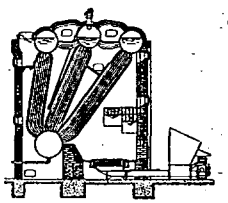


Typical Iron Fireman Installation under Cast Iron Boiler

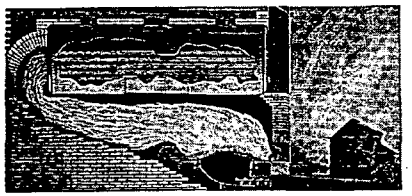
Installation and Sizes—Iron Fireman is made in a range of sizes for commercial heating and power plants up to 250 h.p. boilers, and also for homes. It can be installed quickly in practically any solid fuel boiler or furnace, old or new. If necessary, the installation can be made with practically no interruption of the service from the boiler.

Machines are shipped complete from the factory. All parts are standard and interchangeable.

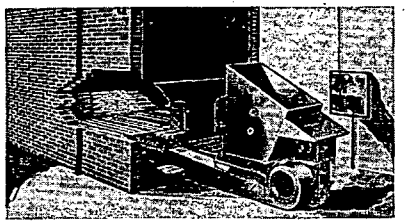
Features of Design and Construction—Construction and operation of the Iron Fireman are characterized by simplicity throughout. Outstanding features of design and construction are: (1) Pressed steel construction. (2) Gear shift for transmission—three speeds and neutral. (3) Continuous feed transmission. Gears run in bath of oil. (4) Electric motor—standard make. (5) V-belt drive. (6) Safety shear pin protects mechanism from damage. (7) Quiet ball bearing fan supplying forced draft to fire. (8) Automatic fire banking damper—conserves fuel and holds fire in proper condition when stoker is idle. (9) Positive pneumatic fume eliminator—an auxiliary air supply that insures positive movement of all gases through the fire. (10) Sectional retort especially designed to allow for heat expansion. (11) Dead plates of heavy iron and ribbed. (12) Sectional, self-cleaning tuyere blocks. (13) Conveyor screw cast of special Iron Fireman alloy steel from one-piece pattern. (14) Automatic electric controls, designed for and used exclusively on Iron Fireman.



Typical Iron Fireman Installation under Four Drum Water Tube Boiler

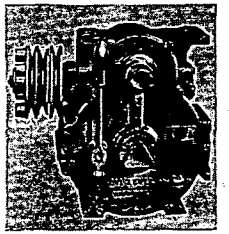


Iron Fireman in Operation. Installed under Horizontal Return Tubular Boiler. Low Bridge Wall. Hot "Blast Furnace" Fire



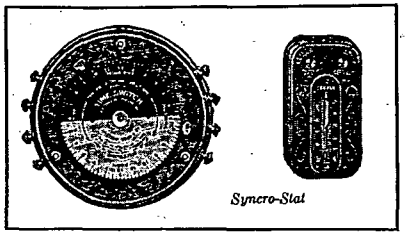
Cutaway View, showing details of Typical Iron Fireman Installation

Transmission and Continuous Feed Principle—The Iron Fireman speed reduction unit and its patented speed-change gears are an exclusive Iron Fireman development. This transmission drives the conveyor screw at a constant speed which in turn feeds the coal to the fire in a slow, steady stream at the required rate for proper burning. As a result a steady, non-agitated fire is obtained. The Iron Fireman transmission has three speeds and three neutrals. The gears can be shifted while the stoker is in operation; in fact more easily than when the stoker is idle, and it is impossible to strip gears while shifting. All the gears operate in a bath of lubricating oil and the unit is most quiet. In design, materials and precision of construction, the Iron Fireman transmission is like that of a fine automobile.



Iron Fireman Transmission

Automatic Controls—Iron Fireman starts and stops at the command of sensitive, accurate automatic controls. Directing controls govern stoker operation according to demands of time, temperature, or pressure. An example of the superiority of Iron Fireman directing controls is the "Syncro-Stat" which provides automatic control of day and night temperature. It is powered by a Telechron motor, thus eliminating winding or setting, and making it an accurate all-electric temperature regulator. Other directing controls include pressure regulators, hot water and furnace regulators and the "Timetactor" a device which runs the Iron Fireman during predetermined intervals in order to keep the fire alive during mild weather.



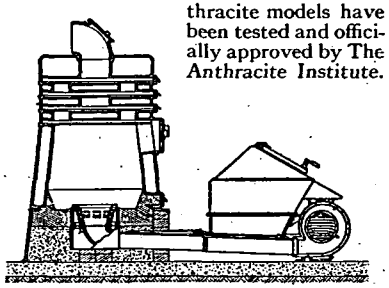
Syncro-Stat

The most important unit of the operating control system is the motor-driven relay switch. This device starts and stops the stoker motor at the command of the Syncro-Stat or other directing controls. In the case of the larger stokers a magnetic operating switch works in conjunction with the relay switch.

Important Factor in Plant Economy—Iron Fireman users report savings of from 15 per cent to 50 per cent on fuel costs alone. In a recent investigation of 342 users, fuel savings alone averaged an earning of 39.44 per cent a year on the total cost of their installations.

Iron Fireman for Homes—The Iron Fireman "De Luxe" model employs "Forced Underfiring" principle the same as larger machines, with simplified operation. The enclosed hopper accommodates sufficient small size coal for an ordinary day's consumption.

Can be recommended for any steam, hot water, vacuum or warm air furnace. Quickly installed. Models for both bituminous and anthracite coal. All anthracite models have been tested and officially approved by The Anthracite Institute.



Iron Fireman Installed in a Domestic Boiler

ENGINEERING SERVICE

The Iron Fireman organization is nation-wide. Trained men—backed by one of the largest manufacturing organizations in the field—are at your service to help you with the experience and practical heating information gained through servicing thousands of boiler rooms and heating plants in all parts of the country.

Any Iron Fireman engineer will gladly call and submit any additional information requested.

CATALOGUE AND INFORMATION

Catalogue No. 31 gives full information about the Iron Fireman. Descriptive folders give special data about installation in particular types of industries and in homes.

Secure them by addressing the factory or any Iron Fireman representative.

250 Park Avenue

MOTOR STOKOR CORPORATION

New York City

MOTORSTOKOR AUTOMATIC COAL BURNER

MODELS Both **Anthracite** and **Bituminous** types. Anthracite models handle up to 3000 feet of steam radiation load. Bituminous models handle up to 1000 ft.

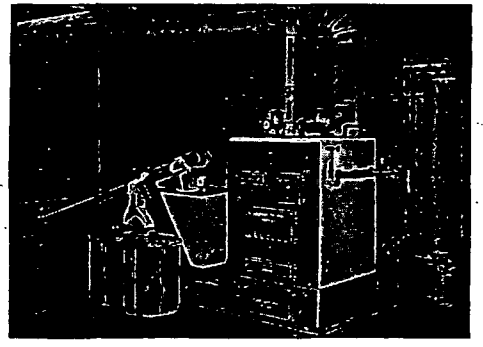
FUEL BURNED Buckwheat and Rice Anthracite. Bituminous slack, including coking and caking, high and low volatile coals.

OPERATION Feeds the coal to base of fire, screw conveyor. Agitation in bituminous burner head breaks up fire bed and admits air freely. Ash (with both types) removed by screw inside tube and by bucket-and-chain elevator to full size cans with dust-proof covers.

Intermittent operation.

AUTOMATIC CONTROLS All models equipped with full automatic controls of leading make, as standard.

AUXILIARY EQUIPMENT Motorstokor Coal Conveyor, which takes coal from bin to stoker without shoveling. Extra long elevator for large batteries of ash cans up to seven—elevator for two cans standard.



RANGE OF SERVICE The Motorstokor, within the range of capacity outlined above, serves all types of buildings—residences, banks, theatres, hotels, stores, churches, schools, municipal buildings, garages, hospitals, clubs, apartment buildings, telephone exchanges, railroad stations, etc. It is used for both heating and the hot water supply, including hot water alone for the summer months.

INSTALLATION Stoker is set up nearly complete, grates removed, and stoker then inserted either through ash door or through side of base casting. Electrical controls are installed in advance.

ADVANTAGES Simplicity and consequent reliability. Adaptability to any existing heating plant, steam, hot water, vapor, or warm air.

Economy—burns low-cost coal.

Ease and Speed of Installation. No interruption to heating service.

Cleanliness and quietness. Air intake through coal in hopper, which serves as a muffler.

Complete safety.

CONTROL OF TEMPERATURE Owner sets thermostat for desired degree of heat. Stoker starts and stops as necessary to maintain same. Fire remains the same for several days without attention, due to automatic handling of coal and quantity disposal of ash.

Literature or specific engineering data promptly supplied upon request.

Field force maintained for direct consultation wherever desired.

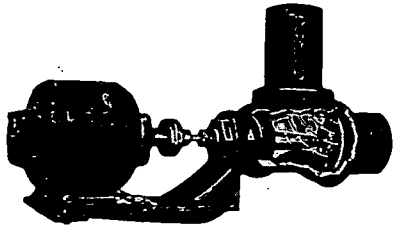
The Rochester Circulator Company

34 Lake View Park, **Rochester, N. Y.**

The Rochester Circulator, for Hot Water Heating Plants, Domestic Hot Water Systems, Ice Water Circulation, or for circulating any liquid in a pipe system under a balanced head.

Rochester Electrically Circulated Hot Water Heating means Low First Cost, High Operating Economy, and Ideal Heating Comfort.

Low First Cost—Steam sized radiation, the elimination of automatic air relief valves and steam traps, extremely simple piping, small pipe sizes, and perfect freedom in locating boiler, piping and radiation, insure a low first cost. *Neither cellar nor boiler pit is essential.*



High Operating Economy—Fuel consumption is always lower, for a bigger percentage of the total heat from the burning fuel is taken up by the *cooler, rapidly flowing* water, as it leaves the boiler. Less sensible heat remains in the flue gas going out the chimney—less fuel is needed to put the required heat into the building. The saving in fuel always greatly exceeds all costs chargeable to the *Rochester Circulator*. *Rochester Electrically Circulated* Hot Water Heating Systems show higher over-all efficiencies in even the most extreme weather, and that advantage increases, as the weather moderates.

Ideal Heating Comfort—Every radiator in the building—any hour—is held at the exact mean surface temperature needed to replace the heat loss from the room. There can be no "slacker" radiators on a *Rochester* system. The water temperature is varied at the boiler by the thermostat control to suit the weather demand, and the *Rochester Circulator* puts that temperature—almost instantly—into every radiator regardless of its position. Radiator surfaces may be held well above the atmospheric boiling point in extreme weather—at medium temperatures in average weather—and just above room temperatures in the mildest weather. Always enough heat—*never too much!*

Rochester Circulators are rigidly guaranteed, both as to material and workmanship, and also as to the performance of the heating plant, when installed to our instructions. Use Standard *Rochester Circulators* on old systems; use either Standard or High Pressure units on new installations. For Domestic Hot Water or Ice Water Circulation use either type, according to the requirement. There is a correct size of unit for any job, from 12 in. pipe size down to 1½ in.

The piping itself usually supports the unit, which screws right into a standard pipe tee or cross just like a pipe plug. Installation may be at a normal elbow in the pipe, or in any straight run of pipe, either vertical, horizontal or at any angle.

Rochester Circulators, installed according to our instruction transmit no hum or other vibration to the radiation, and cannot be heard outside of the boiler room. The hydraulic efficiency of the *Rochester Circulator* is very high. A small power consumption moves an enormous volume of water.

Sizes and Nominal Capacities

Standard Models

Size	Size of Pipe Tee Inches	Plug Size Inches	Motor H. P.	Nominal Capacity Gals. per Hour	Shipping Weight Lbs.	List Price
1½	1½x1½x1½	1½	1/20	500	35	$60.00
2	2x1½x2	1½	1/20	800	36	66.00
2½	2½x1½x2½	1½	1/20	1,450	37	70.00
3	3x2x3	2	1/20	2,700	38	80.00
3½	3½x2x3½	2	1/10	5,120	39	84.00
4	4x3x4	3	1/6	8,250	50	100.00
4½	4½x3x4½	3	1/6	10,000	52	104.00
5	5x3x5	3	1/6	13,500	55	110.00
6	6x6x6	3	1/4	16,500	70	127.00
7	7x7x7	3	1/2	20,000	110	136.00
8	8x8x8	3	1/2	27,500	135	146.00
10	10x10x10		3/4	48,500	225	240.00
12	12x12x12		1	76,000	275	300.00

High Pressure Models

2	2x2x2	2	1/10	1,200	40	81.00
3	3x3x3	3	1/4	9,000	52	105.00
4	4x4x4	3	1/2	16,000	120	146.00

NOTE—6, 7 and 8-inch Circulators are shipped mounted in the corresponding Standard Bushings; 10 and 12-inch are shipped mounted in Companion Flanges; High Pressure Models are shipped mounted in the Galvanized Tee specified

Write for complete technical data and prices

Armstrong Cork & Insulation Company

Lancaster, Pa.

Offices

Albany	Cleveland	Jacksonville, Fla.	Pittsburgh
Atlanta	Dallas	Kansas City	Rochester
Boston	Denver	Milwaukee	St. Louis
Buffalo	Detroit	Minneapolis	Syracuse
Charlotte, N.C.	Grand Rapids	New York	Montreal, Que., Can.
Chicago	Houston, Tex.	Omaha	Toronto 2, Ont., Can.
Cincinnati			Winnipeg, Man., Can.

Armstrong Cork Company, Ltd.,
London, England

Representatives

Baltimore	John R. Livezey	Philadelphia	John R. Livezey
Los Angeles	Gay Engineering Corp.	Portland, Ore.	Gillen-Cole Co.
New Orleans	H. T. Steffee	San Francisco	Van Fleet-Freear Co.
Washington	John R. Livezey		

Detailed information, samples, and descriptive literature may be obtained on application to any of these offices or representatives.

Armstrong's Vibracork is a special cork material for absorbing noise and vibration under moving machines such as fans, motors, etc.

The natural resilience of cork and the fact that it does not "set" under pressure nor harden with age make it especially suitable for this use.

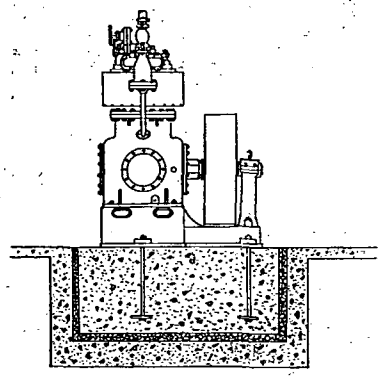
Another advantage of Armstrong's Vibracork is that, being a manufactured product, its density can be varied to suit different conditions. Armstrong's is made in varying grades or densities. By adapting the grade to weight and type of machine, much better results are obtained than by using a single grade for all installations.

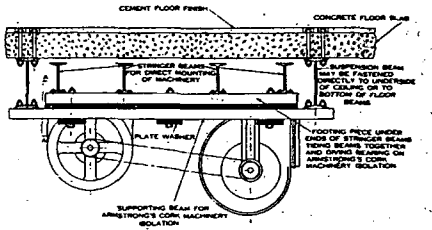
Armstrong's Vibracork is made in boards 12 in. by 36 in. by 1, 1½, 2, 3, 4, 5, and 6 in. thick. The standard boards may be sawed or cut into the desired shape or size as readily as lumber, and where large pads are required, they can be made in sections and cemented together.

The density and thickness to be used cannot be determined accurately until such factors as the weight, speed, and character of the machine to be isolated are known. Generally speaking, the grades which should be used under different classes of machines are as follows:

Small fans, motors, generators, etc.	Light
Large fans, medium size motors and generators, light machines, and machine tools, etc.	Medium
Heavy motors and generators, large machines and machine tools, engines, etc.	Heavy

Two methods of installing Armstrong's Vibracork are usually followed. In the first, the foundation pits are lined with Armstrong's Vibracork on the bottom and sides. The foundation proper is then poured in on top of the cork. In the second, the cork is placed between the base of the machine and the foundation, floor or ceiling, to which it is fastened. See figures below.





Mundet Cork Corp.

450 Seventh Avenue — **New York, N. Y.**

Manufacturers of Corkboard, Cork Pipe Covering, Compressed Machinery Isolation Cork, Natural Cork Isolation Mats, Cork Tile, Cork Bulletin Board, and all kinds and varieties of Cork Specialties.

Branches

Atlanta, Ga.	Chicago, Ill.	Houston, Texas	Memphis, Tenn.	St. Louis, Mo.
Boston, Mass.	Cincinnati, Ohio	Kansas City, Mo.	New Orleans, La.	San Francisco, Calif.
Buffalo, N. Y.	Detroit, Mich.	Los Angeles, Calif.	Philadelphia, Pa.	Tulsa, Okla.

Agents

Cleveland, Ohio	C. S. Ross	Portland, Ore.	Pacific Asbestos & Supply Co.
Des Moines, Iowa	John Kennedy	Salt Lake City, Utah	L. A. Roser
Minneapolis, Minn.	Insulation Sales Co.	Seattle, Wash.	Pacific Asbestos & Supply Co.
Portland, Ore.	F. J. Leonard	Utica, N. Y.	George Weisenberger

Engineering and Specification Service

Our engineering department is at the service of Architects and Engineers at all times to assist and advise in the preparation of specifications pertaining to cork. This service is also available to any one who has a cold insulation or a vibration isolation problem, and is rendered without obligation. Send for our catalogue now. It is replete with valuable information and should always be within reach of every specification writer whose field touches our products.

Contract Service

We contract for the erection of our products in order that we may be certain that our material is installed in accordance with best established practice, and in order to eliminate divided responsibility for a given installation. No contract involving cork is too large or too small. All materials and workmanship are unqualifiedly guaranteed.

Mundet "Jointite" Corkboard

Mundet "Jointite" Corkboard is 100 per cent pure cork, fabricated in accordance with the U. S. Government Master Specification, and is unsurpassed in its field. It is used for all cold insulation services and for acoustical correction. We manufacture only one grade of corkboard. Mundet "Jointite" Corkboard is sold in the standard 12 in. x 36 in. sheet. Standard thicknesses are ½ in., 1 in., 1½ in., 2 in., 3 in., 4 in. and 6 in.

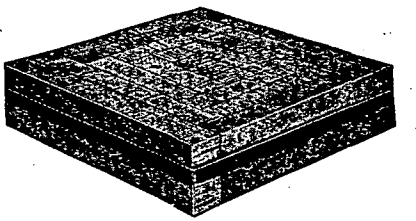
Mundet "Jointite" Cork Pipe Covering

Mundet "Jointite" Cork Pipe Covering is the complement of Mundet "Jointite" Corkboard and is used for all types of cold lines. The three thicknesses in which it is manufactured make it suitable for pipes carrying sub-zero to 50° temperature. The pipe covering comes in sections 36 in., long. A complete line of standard fitting covers is available in the three thicknesses.

Mundet Cork Vibration Isolation

Machinery isolation is today a most important part of the design of all structures. The transmission of machine vibration can be easily and permanently prevented by the use of proper cork isolation. Mundet Natural Cork Isolation Mats are best adapted to most of the isolation field and Mundet Machinery Isolation Cork to the balance.

Mundet Natural Cork Isolation Mats are blocks of pure cork. These blocks are held together within a rigid steel frame. Mats are constructed to fit under any type of machine foundation.



Above is shown a typical Mundet Natural Cork Isolation Mat. Note the natural cork strips within the steel frame.

Mundet Machinery Isolation Cork is manufactured board and comes in the three standard densities. It is composed of granules of pure cork, fabricated and baked under pressure. The standard size board is 12 in x 36 in. but these can readily be cut into any size or shape.

Both types of isolation are furnished in 1 in., 1½ in., 2 in., 3 in., 4 in. and 6 in., thicknesses, depending on the class of service.

E. B. Badger & Sons Co.

63-75 Pitts Street, **Boston, Mass.**

Engineers and Manufacturers

NEW YORK OFFICE, 271 Madison Avenue — OFFICES IN PRINCIPAL CITIES

PRODUCTS: Corrugated Expansion Joints, Pipe Bends, Chemical Apparatus, Copper and Sheet Metal Work, Copper Boilers and Hot Water Tanks.

BADGER SELF-EQUALIZING EXPANSION JOINTS

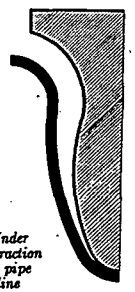
These have been on the market for more than forty years and as sold today represent the results of a series of distinct improvements. Badger engineers are responsible for such developments in the corrugated type of joint as special analysis copper of which the seamless tubes have been made, the equalizing rings, the monel metal sleeve to protect against superheated steam, the welding end joint.

Now, Badger Joints carry another big improvement in a new design corrugation, made of Everdur, which functions on the principle of Directed Flexing.

Before passing to this subject, a word about the importance of using the corrugated type of joint. Not only is it compact and easily installed, but it requires no maintenance. It uses no packing.

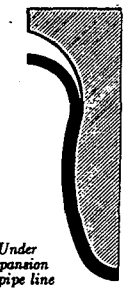
Directed Flexing

The shape of the new Badger Corrugation is entirely curved. There are no straight sides where flexing stresses can localize and thus cause crystallization of the metal. In action the corrugation undulates, using the equalizing ring as a guide. This is the so-called "Directed Flexing". Instead of being left to chance, the flexing of the metal is guided so as to undulate along an all-curved surface.



Under contraction of pipe line

Longer joint life is the direct result of this improvement. The use of Everdur, a stronger, more durable metal, means that higher pressures can be withstood and more expansion and contraction taken care of. A new bulletin, describing this new corrugation, will be sent on request.

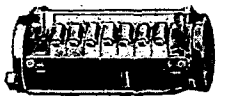


Under expansion of pipe line

Different Types Available

Both flanged end and welding end joints are available from 3 in. (welding) and 4 in. (flanged) up. Single or double joints with or without service outlets. All joints can be equipped with telescoping monel metal sleeves to protect against superheated steam.

Flanged Types



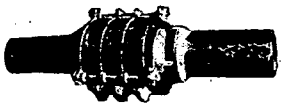
Fitted with alignment bars on the 4 and 5 in. sizes. Choice of standard or extra heavy flanges.



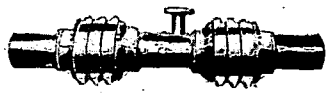


On 6 in. pipe and larger, no alignment bar is used. Standard 125 lb. or extra heavy 250 lb. flanges as required.

Welding Types



For use with both saturated and superheated steam. Single type from 3 in. up, to take care of 1 in. expansion or more. Pipe nipples welded directly into pipe line.



Double units for 2 in. expansion or more. Equipped with service outlets, if desired. Complete units furnished, mounted on base plate, with anchor and guides.

Single and Multiple Corrugated Expansion Joints for Low Pressure

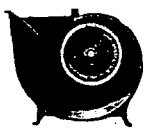
For use between turbine or engine exhausts and condenser or on low pressure lines. Excellent for absorbing shock and vibration. Flanges in round, oval or rectangular shapes. Guaranteed up to 30 lb. pressure.

Bayley Blower Company

1938 S. 4th Street — *Branches in Principal Cities* — Milwaukee, Wis.

Builders of Heating, Ventilating, Cooling, Purifying, Humidifying and Air Washing Equipment; Exhaust and Drying Apparatus, Mechanical Draft and Blast, Fans and Blowers of all Types

Bayley Plexiform Fan:



Is a multi-blade fan for for supplying air for heating and ventilating systems, manufacturing processes, drying systems, forced and induced draft systems. It is suitable for handling high or low temperature gases at medium or low pressure. Will deliver maximum quantities requiring minimum space with great economy.

This is a distinct Bayley product, high class material and workmanship, properly designed to avoid excessive vibration and overstressing of parts. Inlets and outlets are properly sized for maximum delivery and maximum efficiency. Fans are furnished in single or double width of any required arrangement and with sleeve or anti-friction bearings.

Aeroplex Fan:

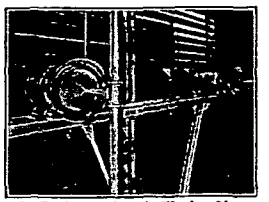
Is of high speed design with self limiting power characteristics. Application parallel to the Plexiform Fan. Highly efficient and quiet in operation.

Bayley Exhausters and Pressure Blowers:



Type "B" exhaust fan is for heavy duty, handling refuse from industrial and textile plants. Type "SE" is used in handling smoke, fumes and dust-laden gases. Type "H" for high-pressure work. These units are highly efficient and of high class design and workmanship.

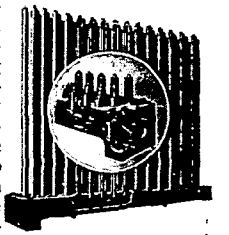
Bayley Turbo Air Washers, Humidifiers and De-Humidifiers:



The Bayley Turbo Air Washer Showing Turbo Atomizer and Eliminator

The Turbo Atomizer used in the Bayley Washer produces a steady, fine spray. Water at low pressure is delivered to the center of a rapidly revolving cone-shaped rotor provided with atomizing pins set in its periphery. This atomizer requires very little attention, and will operate successfully under low water pressure. The orifices are large and this atomizer, unlike high pressure nozzles, cannot clog.

Bayley Chinook Heating Sections:



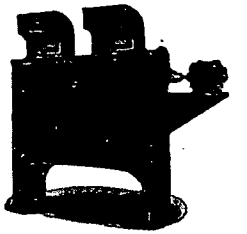
The Chinook section is used with blast heating, venttilating and drying systems, and is suitable for high or low pressure steam circulation. The base is divided into two chambers. Steam enters (see cut) the lower chamber, rising through ⅜-in. pipes located within the 1¼-in. pipes leading from the upper chamber. Condensation takes place in the larger pipes, the water falling into the upper chamber and draining away through the return outlet. The Chinook can be repaired in the middle of the bank without breaking steam connections or taking down a section.

Shipped assembled in smaller sizes, and knocked down in the larger units. May be installed in horizontal or vertical position.

Bayley Chinookfin Heating Sections:

Are the same design as the Chinook Heaters, using heavy gauge copper fin tubes. As compared with Chinook it is much lighter and occupies less space.

Bayley Plexfin Unit Heaters:



This unit incorporates Chinookfin radiation and Plexiform or Aeroplex fans. The fan assembly including top plate and motor is removable as a unit for maintenance and inspection. The heating element is a removable unit. Casing all welded extra heavy gauge. This is an exceptionally high grade unit at a moderate price.

The Buckeye Blower Company

Main Office and Factory

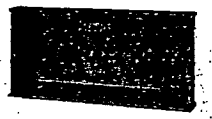
425 West Town Street, **Columbus, Ohio**

Branch Sales and Service Offices

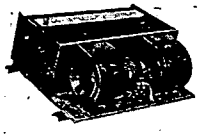
Atlanta, Ga.			Salt Lake City, Utah
Boston, Mass.	Denver, Colo.	Louisville, Ky.	San Francisco, Calif.
Buffalo, N. Y.	Detroit, Mich.	Minneapolis, Minn.	Seattle, Wash.
Chicago, Ill.	Indianapolis, Ind.	New York City	South Bend, Ind.
Cleveland, Ohio	Kansas City, Mo.	Pittsburgh, Pa.	Spokane, Wash.
Dallas, Texas	Los Angeles, Calif.	Richmond, Va.	St. Louis, Mo.

IN CANADA: TORONTO, ONTARIO

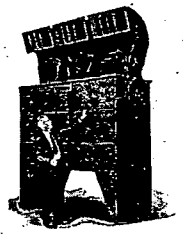
Manufacturers of BUCKEYE Heating and Ventilating and Air Conditioning Apparatus



The Double Duty DeLuxe 900 Series BUCKEYE HEAT-OVENT has been developed for use in School Rooms and other places where quiet running, temperature control, quick heating and positive ventilation are requisites. This machine is equipped with the **Buckeye** all-copper radiators which freezing does not harm. Air Deliveries from 450 to 1560 c.f.m. Ask for Double Duty 900 Series Data Book. "The Unit that carries the **Full Heating Load.**"

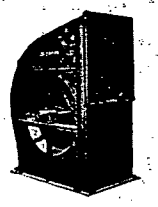


The Type "E" Buckeye Thermovent a Unit Ventilator and Heater for Auditoriums, Churches, etc., where quiet operation is essential. Made in Fresh Air and Recirculating Styles, in both Horizontal and Vertical Models. 2000 to 4000 c.f.m. Ask for Data Book No. 129.



The Type "F" Buckeye Thermovent for installations requiring larger heating and air capacities, such as Public Garages, Factories, Terminal and Storage Warehouses. Horizontal Models for ceiling suspension, Vertical Models for floor installation. Made in both Fresh Air and Recirculating Styles. 2000 to 6500 c.f.m. Ask for Data Book No. 127.

The Buckeye Giant Unit Heater was especially designed and developed for Airplane Hangar and high roof Industrial Building Heating. Capacities up to 20,000 c.f.m. and 2,760,000 B.T.U. Ask for Buckeye Giant Data Broadside.



Multiblade Fans for heating, ventilating, drying, dust removal and allied uses in all sizes up to 100,000 c.f.m. and up to 6 in. static pressure. Ask for Bulletin 833.

Engineering service available in all branch offices

Buffalo Forge Company

"Air Engineers For Over Fifty Years"

450 Broadway, **Buffalo, N. Y.**

Sales Engineering Offices

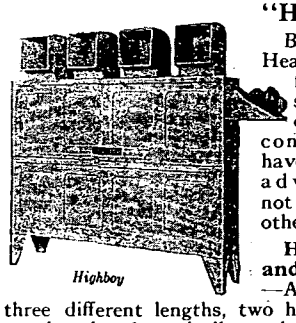
Albany	414 Standard Bldg.	Los Angeles, Calif.	610 Pershing Sq. Bldg.
Boston, Mass.	10 Milk Street	Minneapolis, Minn.	459 N. Western National Life Bldg.
Chicago, Ill.	15 N. Jefferson Street	New York, N. Y.	39-41 Cortlandt Street
Cincinnati, Ohio	605 Mercantile Library Bldg.	Omaha, Neb.	923 W. O. W. Building
Cleveland, Ohio	368 Rockefeller Bldg.	Philadelphia, Pa.	810 Land Title Bldg.
Dallas, Texas	2710 Live Oak Street	Pittsburgh, Pa.	927 Union Trust Bldg.
Denver, Colo.	1621-17th Street	San Francisco, Calif.	140 First Street
Detroit, Mich.	2051 W. Lafayette Blvd.	St. Louis, Mo.	906 Chemical Bldg.
Greenville, S. C.	P. O. Box 563	Seattle, Wash.	303 Alaska Bldg.
Hartford, Conn.	750 Main Street	Toledo, Ohio	1817 North 13th Street
Indianapolis, Ind.	1125-1127 Circle Tower	Washington, D. C.	403 Com. Natl. Bank Bldg.

Complete line manufactured in Canada by: CANADIAN BLOWER & FORGE CO., LTD., Kitchener, Ontario

PRODUCTS—Heating and Ventilating Equipment, including: Unit Heaters, Gas, Steam or Electric, Multiblade Fans, Buffalo Air Washers, Exhaust Fans, Blowers, Dust Collectors, Disc Fans, Spray Nozzles, Mechanical Draft Fans, Drying Equipment, Multistage Blowers and Exhausters.

Complete Illustrated Literature on Request

"Heat With Unit Heaters"



Highboy

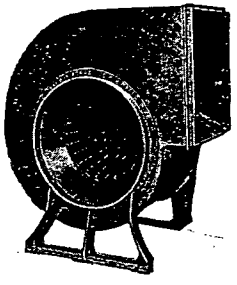
Buffalo Unit Heaters, made for either steam, gas or electric connections, have distinct advantages not found in other types.

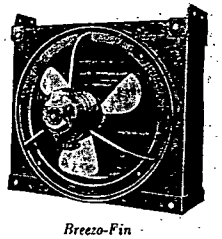
Highboy and Lowboy—Available in three different lengths, two heights and can be placed vertically or horizontally. All parts are accessible for inspection.

Wetboy—The Wetboy will wash and moisten the air in addition to heating it.

Gas Fired Unit—This unit has many features, including automatic safety devices. It will admirably act as a booster unit to assist your present heating system, take care of new additions—cold corners.

Silex Conoidal Fan—These ventilating fans designed from our experiments and experience reduce audible noise to a minimum. The cone is carried out beyond casing in order to get best conversion efficiency, and to provide an extremely quiet stream line fan cut off. Also made in "Limit Load" type.





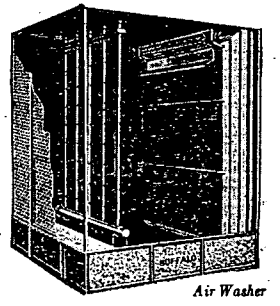
Breezo-Fin

Breezo-Fin—The improved Model "B" has an improved fan design that delivers a large volume of heated air with less power consumption. Excellent for suspension from ceiling or wall bracket.

Electric Unit—Recommended for heating small areas where steam or gas is not available. The alloy-plate electric heating element used in these heaters operates at a black temperature below the kindling point of explosive gases.

Unit Air Washers—Meet the needs of those requiring reasonably priced units for supplying washed, tempered air throughout the year.

Air Washers—Buffalo Air Washers outstanding features: eliminators in one piece and demountable; spray nozzles non-clogging; flooding nozzles guarantee wet scrubbing surfaces; suction screen extends entire width of tank; maximum contact between air and water spray.



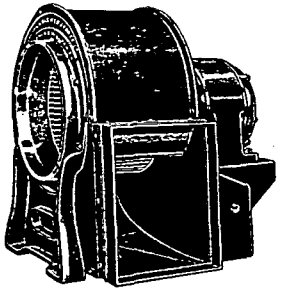
Air Washer

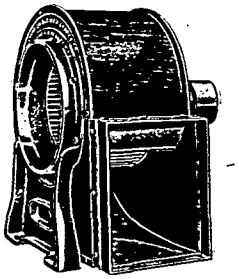
Champion Blower & Forge Co.

Manufacturers and Engineers

Plant and General Offices: Lancaster, Pa.

Manufacturers of Blowers, Ventilating Fans, and Exhaust Fans for Air and Material; Unit Heaters and Blast Gates.

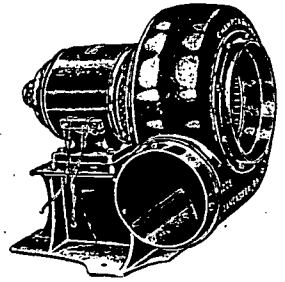




Type "SE" Electric Driven Fans **Type "S" Manivane Belt Driven Fans**

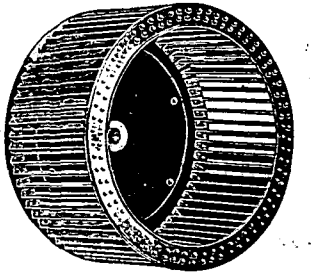
Sizes—6″ to 36″ Wheels

For Heating, Ventilating, Cooling, Drying or Forced Draft



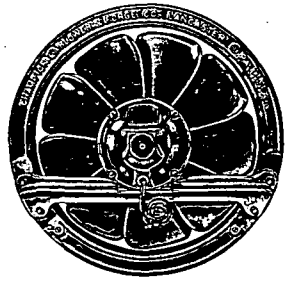
Type "CE" Manivane Fans

For Duct Work and Quiet Operation.



Type "C" Manivane Blast Wheel

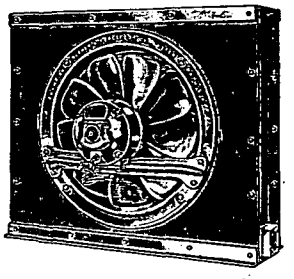
Built Strong and Substantial. Free from Vibration and Noise. Very desirable for Oil Burners and General Heating and Ventilating Purposes, especially where noise is an objection.



Super Fans for Free Air

To Ventilate and Remove Odors or Foul Air from Rooms, Shops, Mills, Factories, Foundries and Steam in Laundries and Steam Rooms.

Sizes—12″ to 36″.



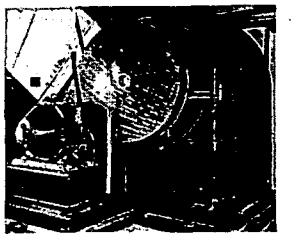
Manifin Unit Heaters

Made in Four Sizes.

Clarage Fan Company

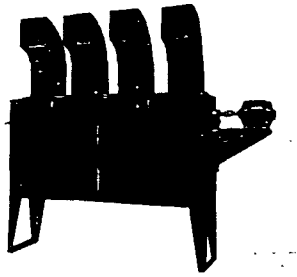
Kalamazoo, Michigan

Sales Engineering Offices in Principal Cities



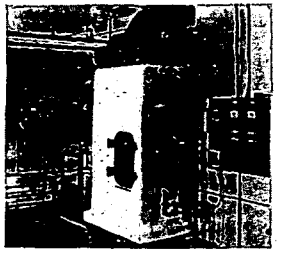
Multiblade Fans—

Designed for heating, ventilating, cooling and air conditioning in schools, theatres, churches, office buildings, tunnels, industrial plants, etc. Silent in operation. Built in Types HV and HSV. Type HV Fans particularly adapted to flat belt drive. Type HSV Fans ideal for direct motor or short center, V-belt drive. HSV Fans have full self-limiting horsepower characteristic. Built single and double width with capacities from 50 to 500,000 c.f.m.



Unitherm Unit Heaters—

Suitable for all types of industrial heating, for garage and airplane hangar installation, etc. Equipped with positive centrifugal fans having a self-limiting horsepower characteristic and with heating coils capable of pressures up to 200 lbs. All parts accessible, both fan assembly and coil easily removed. Built in sizes with capacities from 217,000 to 866,000 B.t.u., either for ceiling or floor mounting. Quiet in operation.



Unit Air Conditioners—

Designed to cool, humidify or dehumidify as desired. Successfully used in the process industries, in paper mills, textile plants, tobacco factories, printing plants, etc. As compared with older types of equipment, these units offer greater flexibility, closer and easier control, eliminate a costly duct system, and produce equal or better results at a decided saving. Built to meet individual requirements. No conditioning job is too large for a battery of these units.



Air Washers—

For central station air purifying and cooling in public buildings and industrial plants. Sizes to cover every possible requirement.

Clarage also builds mechanical draft equipment, exhaust fans, volume blowers, pressure blowers and blast gates in all accepted types and in a large range of sizes. Write for Catalogs or engineering assistance.

De Bothezat Impeller Co., Inc.

Manufacturers of

De Bothezat Disc Pressure Fans, Blowers and Air Conditioning Equipment

1922 Park Avenue, New York, N. Y.

Branch Offices and Representatives in All Principal Cities

Foreign Office

WEBB DUST REMOVING & DRYING CO., LTD., STOCKPORT, ENGLAND
ASANO BUSSAN CO., LTD., TOKIO, OSAKA, JAPAN; SHANGHAI, CHINA
ALFREDO DELANO, SANTIAGO, CHILI, SOUTH AMERICA
KRUGER, LTD., UNION SOUTH AFRICA

De Bothezat Fans are guaranteed to have a **non-overloading power characteristic,** that is, to absorb at constant revolutions practically the same power whatever the static pressure under which they are operating for the **whole range between free delivery and no delivery.** This important property insures the complete safety of their operation under any conditions to be met in practice.

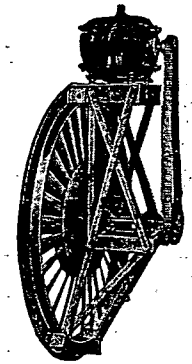
De Bothezat Pressure Fans made in all sizes from 8 in. to 10 ft. Motors for these fans are furnished from 1/50 hp. to 100 hp. The capacities of the fans run from 350 c.f.m. to 254,000 c.f.m. Static pressure from 1/8 in. to 3 in.

High efficiency and large air volume, together with high pressure characteristics are a few of several qualities which distinguish De Bothezat Disc Pressure Fans.



GIANT FAN—Sizes from 5 ft. to 10 ft.

Powers from 2 hp. to 100 hp. Volume from 16,000 c.f.m. to 254,000 c.f.m. Static Pressure from 1/8 to 3 in. Speed from 175 r.p.m. to 700 r.p.m. Fan and motor mounted on same base securing perfect alignment. Requires minimum floor space. Chain driven, texrope drive, or directly connected



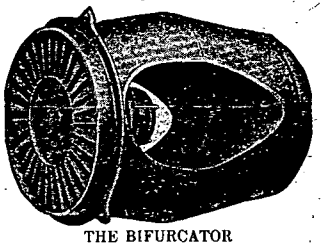
48 in. DISC PRESSURE FAN

5 hp. 650 r.p.m. 15,000 c.f.m. against 1-in. s.p. and 28,000 c.f.m. against 1/8-in. s.p.

The Bifurcator

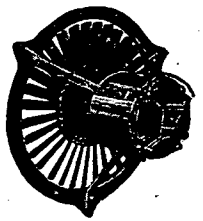
For special Ventilating jobs where fumes of excessive temperature or corrosive character are to be removed.

The bifurcator is a device that permits the use of a straight-way duct. It eliminates right angle bends and long shaft connections, at the same time protecting and automatically cooling the motor. The fan chamber is stream lined in section, and the bifurcated duct is not reduced in area at this point.



THE BIFURCATOR

Full details on request.



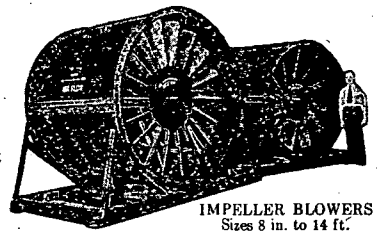
30 in. DISC PRESSURE FAN

2 hp.. 1140 r.p.m., 8,000 c.f.m. against 1-in. s.p. and 12,000 c.f.m against 1/8-in. s.p.

Impeller Blower

The Impeller Blower is a new type of multiple stage disc fan. This type of fan constitutes a long sought solution of the multiple stage disc fan arrangement. The Impeller Blower has a very high efficiency and is capable of developing high pressure and attaining high air deliveries at low R.P.M.

The Impeller-Blower has been designed to exceed the performance range of the average blower. Beginning with capacities of a few hundred c. f. m. at 1/8 in. s. p. Impeller-Blowers can exceed deliveries of 1,000,000 c. f. m. at pressures in excess of 20 in. of water column, thus keeping within very reasonable size limits.



IMPELLER BLOWERS
Sizes 8 in. to 14 ft.

Diehl Manufacturing Company

Electrical Division of

THE SINGER MANUFACTURING CO.

Elizabethport, New Jersey

DIEHL

QUALITY FAN AND MOTOR MANUFACTURERS SINCE 1888

District Offices

ATLANTA, GA.	172 Trinity Ave., S.W.	DALLAS, TEXAS	324 Santa Fe Bldg.
BOSTON, MASS.	75 Kneeland St.	NEW YORK, N. Y.	95 Liberty St.
CHICAGO, ILL.	1017 W. Jackson Blvd.	PHILADELPHIA, PA.	112 North 12th St.
COLUMBUS, OHIO	506 Clinton Bldg.	ST. LOUIS, MO.	1409 Syndicate Trust Bldg.

Sales Representatives in all Principal Cities



High Speed Exhaust Fan



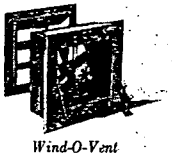
Low Speed Exhaust Fan



Flat Blade Ventilating Fan



Bucket Blade Ventilating Fan



Wind-O-Vent

Diehl offers a complete line of ventilating and exhaust fans for use in restaurants, hotels, hospitals, kitchens, garages, auditoriums, industrial plants, dye houses and other locations where efficient, economical movement of air is required. The design and construction embody modern engineering practices which result in exceptionally sturdy units that will give many years of service under severe operating conditions.

Several types of fans are regularly furnished, in sizes ranging from 9-in. to 48-in. in diameter, with capacities from 600 to 19,000 cu. ft. of air per minute. They are powered by especially developed, cool operating, totally enclosed, highly efficient motors which require only infrequent lubrication.

HIGH SPEED EXHAUST FANS—18 to 48-In.

The high speed type fans are recommended for all general applications such as restaurants, garages, dye houses, industrial plants and all other installations where the maximum volume of air is desired for a given size of fan. Since extreme quietness of operation is not essential for these applications, a considerably greater air movement is obtained by the use of a high speed type fan. This fan is furnished with broad, deep pitch blades, expressly designed for extremely large air movement. The use of this fan with a duct 15 to 20 ft. long is permissible provided the duct is not smaller in diameter than the fan wheel. In such cases the air delivery will be reduced.

LOW SPEED EXHAUST FANS—18 to 60-In.

When the quietness of operation is of primary importance, the low speed design exhaust fan is recommended. It is equipped with bucket shaped, pressed steel fan blades which effectively move a large volume of air without objectionable noise, due to the relatively low speed. This fan is especially suitable for offices, schools, churches and similar applications. Low speed fans should never be installed in connection with duct systems.

FLAT BLADE VENTILATING FANS—9-12-16-In.

Diehl Flat Blade Ventilating Fans are suitable for removing smoke, impure air, and objectionable odors from offices, kitchens, lavatories, etc. May be readily installed in transoms, window frames or partitions, providing excellent ventilation at small expense.

BUCKET BLADE VENTILATING FANS—9-12-15-In.

Diehl Bucket Blade Ventilating Fans are intended for use where the maximum volume of air is to be moved and space for a fan is limited. In proportion to their size these fans handle a comparatively large volume of air, possessing the same general characteristics as large type exhaust fans.

WIND-O-VENT VENTILATORS

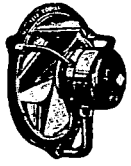
The Wind-O-Vent wall cabinet is an efficient ventilating unit which quietly removes cooking odors, smoke, steam, etc., from kitchens or other rooms. They may be furnished either as illustrated or with window panels for mounting directly in windows.

ILG Electric Ventilating Company

Propeller Fans, Blowers, Unit Heaters, Unit Coolers

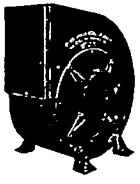
2880 North Crawford Avenue, **Chicago, Ill.**

Sales Representatives in all Principal Cities



Ilg Self-Cooled Motor Propeller Fans

Furnished with direct-connected fully enclosed and self-cooled motor. Wheels rotational static balanced. Sizes 12 to 72 inches. Capacities 750 to 40,500 cubic feet per minute. Self-Cooled motor makes fan especially effective in handling gases and extreme heat. Used everywhere for general exhaust ventilating.

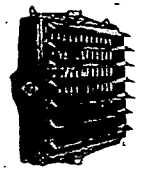


Ilg Universal Multiblade Blowers

Ilg Type B Universal Blowers are designed so as to combine compactness, high efficiency, quietness and low power consumption. The motor is recessed in the side of the blower requiring no separate base and insuring quietness of operation, economy of installation. Ilg Blowers are furnished either direct connected to Ilg ballbearing motors or for belt drive. Sizes 25 to 90 single or double width.

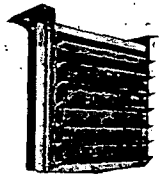
Ilg Unit Heaters—Steam and Electric

Ilg built throughout with copper tube and fin coil and patented fully enclosed, self-cooled motor. For operation on steam or hot water. Tested with 500 pounds hydrostatic pressure. Available in 14 capacity sizes. Ilg electric unit heaters for all electric operation, available in 5 sizes for wall or ceiling suspension and for floor mounting.



Ilg Kold Cooling Systems

A new and simpler system of unit cooling for stores, offices, factories, restaurants, homes, etc. Floor cabinet or ceiling suspension units. Combines air cooling and air dehumidifying to obtain better hot weather air conditions. Installation can be made with a minimum of expense and time. Quiet and extremely effective.



OTHER ILG PRODUCTS

Kitchen Ventilators, Power Roof Ventilators, Humidifiers, Automatic Shutters, Ilg Columnar Heat Systems.

For Offices, Stores, Factories, Restaurants, Theatres, Public Buildings, Homes, Etc.

VENTILATION

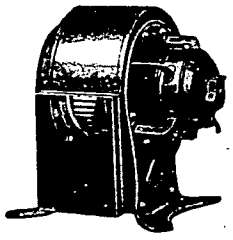
PHONE CALUMET 6650

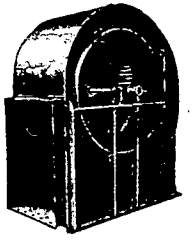
FANS AND BLOWERS
AIR FILTERS AND WASHERS
FAN FURNACES
UNIT-HEATERS

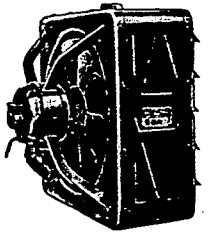
The NEW YORK BLOWER COMPANY

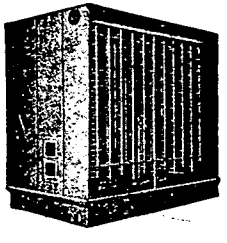
GENERAL OFFICES
3169 SHIELDS AVE.
ARMOUR P.O. STA.
CHICAGO, ILL.

FACTORIES AT LA PORTE, IND. AND CHICAGO, ILL.









Type ME Fan

Type ME Fans cover a wide range of capacities from 100 c.f.m. to 300,000 c.f.m. ME Junior Fans are of all steel construction, wheel diameters being 6½ in., 10 in. and 13½ in. Sizes up to and including No. 38 made with cast-iron inlet stands and are reversible, the larger sizes made non-reversible. Fans deliver large quantities of air at high efficiency. ME Cone Back Multi-Blade Wheels are used exclusively. Fans are regularly made either with overhung pulley or overhung wheel of all hands and discharges.

We also manufacture Fans for mechanical draft, conveying systems, foundries, gas plants and stokers.

Write for Catalog No. 100 containing complete data.

Comet Unit-Heaters

For use with steam. Made in eight sizes, as shown in table. A Heavy Duty Disc Fan direct connected to motor drives air over heating coils.

Write for Catalog 105 which gives complete data including B.t.u. capacities under various conditions.

Size Heater	Cu. Ft. per Min.	Cu. Ft. per Hr.	Motor		Dimensions			E.D.R.	Wght. Complete
			R.P.M.	H.P.	Height	Width	Depth		
4	400	24,000	1250	1/40	12	12	5¼	120	48
6	600	36,000	1580	1/30	12	12	5¼	154	48
8	800	48,000	1140	1/20	15	15	8½	240	80
12	1200	72,000	1750	1/10	15	15	8½	308	80
18	1800	108,000	860	1/10	23	22½	10	582	200
24	2400	144,000	1150	1/6	23	22½	10	720	200
60	6000	360,000	680	1/2	35½	35½	13	1800	550
75	7500	450,000	850	1	35½	35½	13	2050	550

All sizes with either constant or variable speed motors.

Air-Washers and Humidifiers

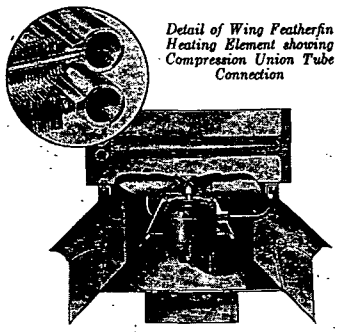
Peerless Air-Washers and Humidifiers, Types "D" and "E," with capacities ranging from 3600 c.f.m. to 112,000 c.f.m. of value for washing, drying, humidifying and cooling. Also for special processes as paper, textiles, tobacco, glue, leather and wood.

Write for more detailed descriptive literature.

L. J. Wing Mfg. Co.

Branch Offices in Principal Cities — 59 Seventh Avenue, **New York** — PHONE: CHELSEA-3 0027-0030 — **Factory: NEWARK, N. J.**

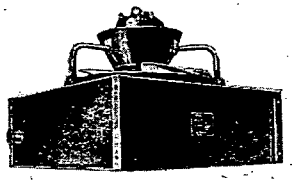
Wing Featherweight Unit Heaters and Process Heating Units; Utility Unit Heaters; Wing Scruplex Safety Ventilating Fans, Fog Eliminators and Exhausters; Wing Forced Draft Blowers, Turbine or Motor-Driven; Steam Turbines; Man-Coolers.



Detail of Wing Featherfin Heating Element showing Compression Union Tube Connection

TYPE LC UNIT

Cross-Section showing location of motor and fan. Used in buildings having low roofs or ceilings



TYPE HC UNIT

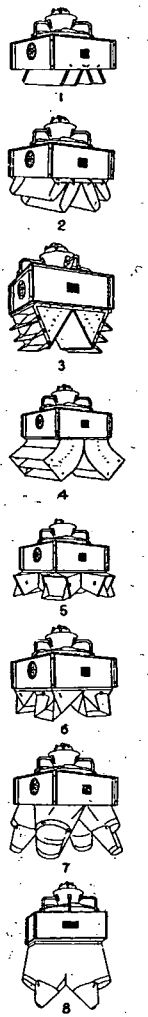
Complete coverage accomplished with any of discharge outlets illustrated at right

THE original and exclusive features of Wing Featherweight Unit Heater design—their light weight, the vertical downward discharge of the heated air, and multiple discharge outlets which step up the velocity of the air leaving the heater—are directly responsible for definite economies in the actual cost of industrial plant heating and in the cost of the equipment itself.

New Wing Featherfin Heating Element—(Tested to 1000 lbs. Pressure). Extremely light in weight. By simple variations of the heating surface any desired final air temperature may be obtained with any given steam pressure. Standardized for steam pressures of 5, 40, 70, 100 and 130 lbs. all producing the same low final air temperatures.

Fin and tube extended surface type. Hairpin or return bend design. Headers of steel, tubular design. Tubes secured to headers by steam-tight compression union. Easily removed and replaced in case of damage.

Standard Discharge Outlets for Type HC

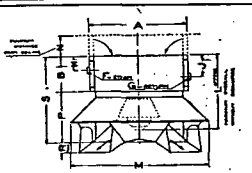


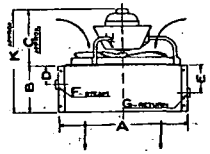
Condensed Table of Engineering Data

Type H. C.

Size	C.f.m. at Inlet	R.p.m.	Fan Hp.	Rated Motor Hp.	Air Temp. ° F. In.	Air Temp. ° F. Out.	B.t.u. per Hour	Equiv. Direct Rad.	Approx. Net Wt. Lb.†
13-HC	800	1750	0.06	1/15	60	123	55,500	231	95
17-HC	1400	1150	0.10	1/10	60	125	100,500	418	130
19-HC	2000	1150	0.21	¼	60	123	139,500	581	160
22-HC	2750	1150	0.25	¼	60	128	206,000	859	200
25-HC	4300	1150	0.40	½	60	126	315,000	1312	285
30-HC	6600	850	1.03	1	60	123	461,000	1920	430
36-HC	9800	850	2.01	2	60	120	656,000	2730	560
Type L C									
13-LC	750	1750	0.06	1/15	60	122	47,500	198	95
17-LC	1310	1150	0.10	1/10	60	124	85,500	356	130
19-LC	1860	1150	0.19	¼	60	122	118,500	494	160
22-LC	2530	1150	0.23	¼	60	127	175,000	729	200
25-LC	4000	1150	0.36	½	60	125	268,000	1117	285
30-LC	6150	850	1.01	1	60	122	392,000	1633	430
36-LC	9130	850	1.90	2	60	119	557,500	2320	560

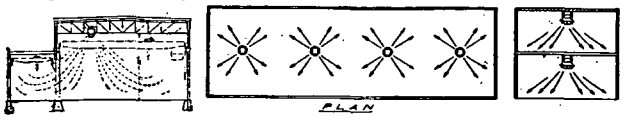
Inlet and Outlet temperatures, also B.t.u. same for 5, 40, 70, 100 and 130 lb. steam pressure.
†This weight does not include weight of discharge outlet.
Space does not permit complete table but this data will gladly be furnished on application.





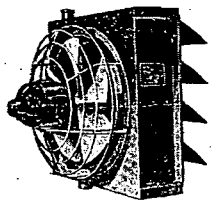
Size	A	B	C	D	E	F Steam 0 to 40 Lb.	F Steam 40 Lb. Up	G Return 0 to 40 Lb.	G Return 40 Lb. Up	H	J	K	L	M	N	P	R	S
13	16	8	12½	3¼	5⅜	1¼	1¼	1¼	1¼	2⅝	4¾	20½	18¼	25	6	12	2¾	20
17	19¾	8	14	4⅜	6½	1¼	1¼	1¼	1¼	1½	5⅜	22	21¼	29	6	12	2¾	20
19	22¾	9	15½	5⅛	7⅜	1½	1¼	1¼	1¼	1⅝	5⅜	24½	22	30	6	12	3	21
22	27¾	9	14¾	5⅛	7⅜	2	1½	1½	1½	1⅝	5⅜	23¾	23	38	6	13⅜	3½	22⅜
25	32¾	9	15	5	7½	2	1½	1½	1½	1½	4	24	24	46	7	16½	4	25½
30	39⅛	12	18	7	9⅝	2½	2	2	2	2⅝	5	30	29	54	8	20	4½	32
36	45⅛	12	18½	6⅝	10	*2	2	*2	2	2	5⅜	30½	30	64¾	8	23⅝	5¼	35⅝

*All units have single connections except those marked * which have two.



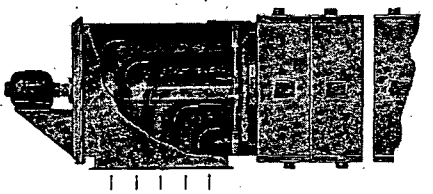
Method of Heater Installation—First diagram shows a Type HC Unit installed above a traveling crane, the heater arranged so that the lower left portion of the building is also heated. Second diagram shows a plan view illustrating the general distribution and diffusion of heated air from Wing Heaters. The third pictures a typical multistory building heated with type LC Wing Units. The best and most economical installation of Wing Featherweight Unit Heaters is when they are placed close to roof or ceiling.

Wing Utility Unit Heater



A general purpose heater. Delivers heated air in one general direction. With vane diffusers and safety guard for fan. Capacity data same as Type HC on preceeding page.

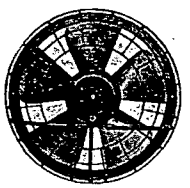
Wing Featherfin Process Heating Units



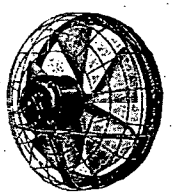
For manufacturing processes such as drying, ageing, etc., requiring the recirculation of the heated air. Motor or turbine located outside air current.

Wing-Scruplex Fog Eliminators supply tempered fresh air to completely de-fog any building or room where steam, fog or fumes are liberated in manufacturing processes.

Wing-Scruplex Safety Ventilating Fans

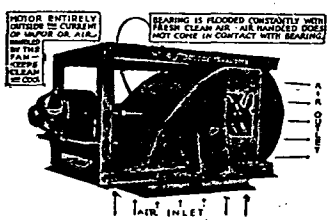


An integral guard of strong steel rings welded to the frame features every model of the Wing-Scruplex Safety Ventilating Fan. This guard removes the ever-present danger which exists whenever fans are in an exposed location, and does not reduce fan efficiency.



The high volumetric efficiency of Wing-Scruplex Safety Fans is due to their true screw propeller design which moves the air forward in straight lines without eddy. Motor is fully enclosed, easily accessible and generously proportioned. Can also be supplied with pulley or turbine drive.

Wing-Scruplex Safety Fans are built in the following sizes: 10, 13, 17, 22, 25, 30, 36, 42, 48, 54 and 60 in.—capacities from 950 c.f.m. to 33,000 c.f.m. Up to 25 in. dia. propellers are made of cast-aluminum—larger sizes of pressed steel.

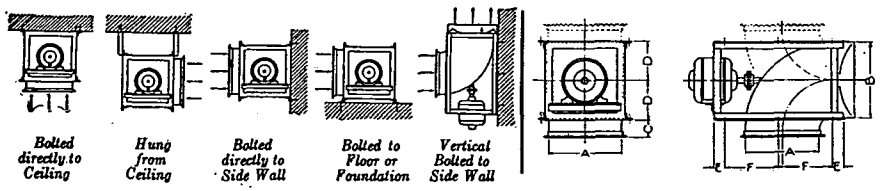


Wing-Scruplex Exhauster with bottom inlet

Wing-Scruplex Exhausters

In the Wing-Scruplex Exhauster the motor is entirely outside the exhaust housing, therefore always easy of access, clean and cool. As an elbow in any duct system where resistance is moderate this exhauster provides efficient, low cost, convenient ventilation. For acid laden air, fan and exposed parts can be supplied in Monel metal.

Wing-Scruplex Exhausters are made for either horizontal or vertical operation—top, bottom or side intakes.



Bolted directly to Ceiling — *Hung from Ceiling* — *Bolted directly to Side Wall* — *Bolted to Floor or Foundation* — *Vertical Bolted to Side Wall*

Sizes, Capacities and Dimensions of Wing-Scruplex Exhausters

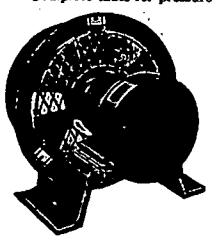
Size	Speed, R.p.m.	Motor, Hp.	Capacity: Free Air, C.f.m.	Capacity: Hp.	Capacity: ¼ in. static	Capacity: Hp.	Capacity: ½ in. static	Capacity: Hp.	Dimensions, in.: A	B	C	D	E	F	Net wgt., Lb.
1-A	1750	1/10	850	.052	330	.060	.....	.....	10	10½	2⅝	5½	3	7½	105
2-A	1150	⅛	1440	.060	395	.090	.....	.....	13½	14	2⅝	7⅛	3	9½	130
2-B	1750	¼	2050	.195	1695	.216	750	.285	13½	14	2⅝	7⅛	3	11	140
3-S	850	⅛	2130	.090	460	.100	.....	.....	16¾	17½	2¾	8⅛	3	12¼	220
3-A	1150	⅓	2700	.180	1550	.221	.....	.....	16¾	17½	2¾	8⅛	3	12¼	190
3-C	1750	1	4000	.600	3510	.655	2810	.720	16¾	17½	2¾	8⅛	3	12¼	220
4-S	850	⅛	2850	.100	1610	.120	.....	.....	21	21¾	2¾	11⅛	3	15	270
4-A	1150	⅓	3570	.170	2775	.220	1550	.280	21	21¾	2¾	11⅛	3	15	235
4-C	1750	1	5400	.540	4990	.650	4440	.750	21	21¾	2¾	11⅛	3	15	270
5-A	1150	½	5200	.330	4250	.440	2610	.600	25	25	2¾	14⅛	3	17¾	300
5-B	1750	2	8000	1.330	7540	1.400	6900	1.540	25	25	2¾	14⅛	3	17¾	390
6-A	600	½	5500	.210	2375	.330	.....	.....	30	30	3½	17¼	3½	21½	450
6-B	850	1	7400	.550	5450	.740	3400	.960	30	30	3½	17¼	3½	21½	400
6-C	1150	2	10250	1.500	8950	1.570	7340	1.760	30	30	3½	17¼	3½	21½	420

Note: Also available in sizes 7, 8 and 9. Data on request.

Net weights shown are approx. For shipping weights add 35 per cent.

Where particularly quiet operation is desired, as in offices, residences, hospital wards, churches, laboratories, etc., we use lowest speeds in all sizes. For toilet rooms, laboratories, motion picture booths, stockrooms, etc., use any speed in sizes 1 and 2; low and medium speeds in all other sizes. In industrial plants, hotel and restaurant kitchens, engine rooms, workshops, etc., use any speed.

Complete table for pressure up to 1-in. static sent on request.



Wing EM Blower

Wing Blowers for Forced Draft

The installation of Wing Motor-driven Type EM Blowers on heating boilers of all sizes makes possible the use of Buckwheat coal and other inexpensive fuels with great savings in fuel costs, which usually pay for the blower in the first year of operation.

These blowers are of the propeller type fan construction. They afford large air passages and low air velocities, resulting in quiet operation and even fires.

Wing Blowers are controlled by speed regulation, conveniently operated from the front of the boiler. Totally enclosed motors keep out the dust and dirt of the boiler room, insuring many years of service without repair. Automatically controlled, they make the fireman's work easier.

Ask for Bulletin No. 46 describing Wing EM Units. For High-Pressure Boilers ask for Bulletin No. 87 describing Turbine Blowers.



The Wing Blower in foreground supplies forced draft to hot water supply heater; while blower in background serves two return tubular heating boilers.

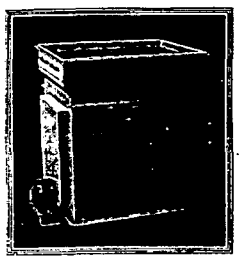
Lakeside Company

Hermansville, Mich.

Makers of Furblo Warm Air Furnace Blower and Air Conditioning System.

FURBLO WARM AIR Furnace Blower

Scientifically designed to insure proper circulation of warmed air throughout, even in most remote corners of the home. Perfect balance of parts and canvas duct connections insure quiet vibrationless operation. Absence of louvers simplifies operation, yet blower may be used for combination gravity and mechanical circulation if desired. Use of furnacestat makes action automatic; blower starting only when proper heat exists in furnace.



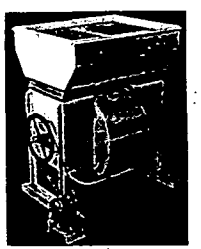
Type "A" Furblo

Type "A" (blower only) is supplied for those preferring to build their own blower casing, thus making blower an integral part of the furnace. Made in sizes from 500 CFM to 15,000 CFM.



Type "B" Furblo

Most economical type because of ease of connection to cold air pipes and furnace. Illustration shows type "B" equipped with cabinet holding V-M air filters. Drawer slides out, for access to filters when renewing filter medium.



Furblo is available in complete range of styles and sizes for all installations.

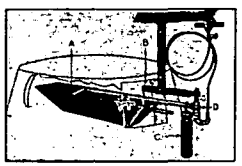
Complete Data Supplied on Request

V-M Air Filter

Sheet steel casing encloses cotton substance for efficiently removing soot, dirt, smoke from air. Crimping of filler medium increases efficiency and capacity. Filler Medium quickly and inexpensively replaced by clean one when necessary without washing or use of fluids. Sizes available: 16 x 25 in., 20 x 20 in., or 20 x 30 in. 2½ inches high.



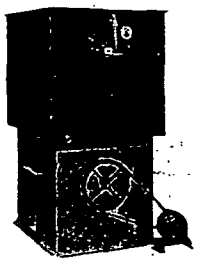
IXL Humidifier



Maintains automatically constant water level, pan (A) being balanced by weight (C). Moving weight (C) adjusts water level for correct humidity. Rustproof. Clogproof.

IXL Air Washer

Designed for installation on top of type "C" Furblo. Cold air return enters at top. Air is cleaned and humidified by passing through fine spray. Water strikes eliminator plates which permits no water to enter blower. Complete range of sizes.



Complete Air Conditioning

Furblo, IXL Humidifier, Furnacestat, V-M Air Filter and IXL Air Washer comprise a complete efficient air conditioning system for the home, office, church, store, garage, etc.

We also furnish Furnacestat, Thermostat, Humitrol and other electrically operated automatic controlling devices for heating and air conditioning.

Carling Turbine Blower Co.

Worcester, Mass.

Branch Offices

Atlanta, Ga.	Denver, Colo.	Philadelphia, Pa.	Scranton, Pa.
Boston, Mass.	Memphis, Tenn.	Pittsburgh, Pa.	London, Eng.
Chicago, Ill.	New Orleans, La.	St. Louis, Mo.	Montreal, Que.
Cleveland, Ohio	New York, N. Y.	San Francisco, Cal.	Paris, France

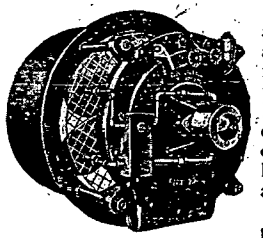
PRODUCTS—Carling Turbo Blowers; Motor Driven Under-grate Blowers; Carling Stoker Fans; Turbine Pressure Fans; Gas Producer Blowers; Turbine Volume Fans; Motor Driven Volume Fans; Carling Steam Turbines, and patented Steam Turbine Specialties; Generator Sets.

Also Carling Turbines with Reduction Gears.

Carling Turbo Blowers—Carling Steam Trubine Blowers are made in 10 sizes with capacities ranging up to 30,000 cu. ft. per minute at pressures up to 8-in. static. The Carling Turbo Blower is equipped with a patented safety flange which prevents explosion of the turbine through runaway should the fan wheel become detached from the main shaft.

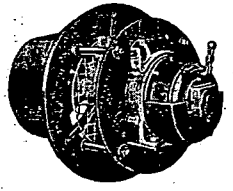
This feature is covered by Patent No. 1,037,111.

This is an ideal forced draft unit for mechanically stoked and hand fired boilers up to 1000 hp. It is quiet in operation and can be installed quickly and cheaply. Automatic gravity feed lubrication.



Turbo Blower

Motor Driven Under-grate Blower—The fan is similar in construction to that in the turbo blower and, like the latter, is made in 10 sizes. It can be furnished equipped with either constant or variable speed motors to suit any size boiler up to 600 hp. Motor speeds are 1750, 2400 or 3450 r.p.m. Capacities of the fan will be mailed on request.

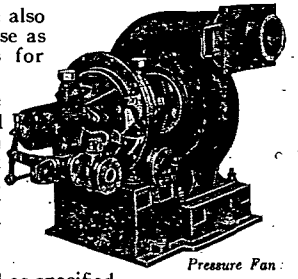


Motor Blower

Turbine Pressure Fans—Carling Turbine Pressure Fans are made in 12 sizes with a wide capacity range at high static pressures. They are designed for gas producers and oil furnaces, for conveyors for sawdust and other light materials, and for industrial drying purposes.

They are also made for use as exhausters for gases, etc.

They are furnished either with or without a blast gate, with any angle of discharge and either right or left hand as specified.

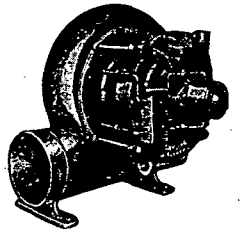


Pressure Fan

Turbine Volume Fan—Designed for delivering a large volume of air at low pressures up to 10-in. static. It is supplied as a blower with two air inlets or as an exhauster with one inlet for pipe connections. The fan may be placed in any position. No special foundation is required as there is no vibration because of special care in balancing. It is built as a unit, the fan wheel being mounted direct on the end of the turbine shaft, thus eliminating the necessity of a coupling. The turbine shaft is mounted on ball bearings, reducing friction to a minimum.

Built for continuous service it requires no attention other than lubrication. All parts are of heavy and substantial design with a wide margin of safety. Ideal unit for hollow blast grates and for many other purposes.

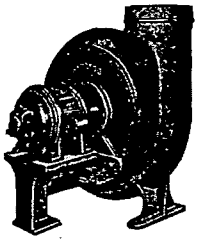
Furnished in 15 sizes with any angle of discharge.



Turbine Volume Fan

Motor Driven Volume Fans—Carling Motor Driven Volume Fans of the centrifugal type are made in 20 sizes from 50 to 20,000 cu. ft. per minute capacity. They are furnished with any type motor and with any angle of discharge either right or left hand.

They are designed especially to furnish forced draft for boilers, but can also be built for exhausters, for use with conveyor systems, and for handling fumes, etc.



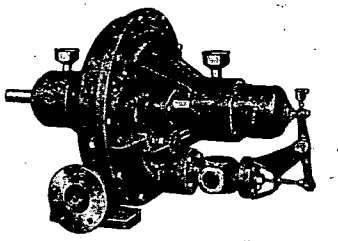
Motor Driven Volume Fan

Carling Steam Turbines Type "A"—Carling Steam Turbines are covered by seven distinct patents which embody the latest engineering developments and design.

Turbine Casing and Cover—Made of solid semi-steel castings of heavy construction to withstand high back pressure and superheated steam. The steam inlet and passages are especially designed for easy flow and tested at 300-lb. hydraulic pressure per square inch. The turbine cover fits into the turbine casing with a ground metal joint, making it absolutely steam-tight.

Rotor—Is of the two-velocity stage, impulse type, cast of solid phosphor bronze, with ten buckets per inch of diameter.

Rotor Blading—Made of monel metal, is cast into the bronze casting by our patented process which makes it impossible



Steam Turbine Type "A"

for the blading to work loose or come out. The blading is further protected by a shroud ring riveted around the entire periphery, top and bottom.

Main Governor—Is of the centrifugal type, mounted on the shaft which operates a balanced steam admission valve. It controls the speed of the turbine within close limits of variation.

Emergency Governor—Is provided to automatically shut off the steam if the main governor should fail to operate. This governor is adjusted to function at 15 per cent above the set speed of the main governor.

Safety Flange—Is a patented feature of all Carling Turbines. It prevents bursting of the rotor through runaway in case of accident to the governor mechanism.

Nozzles—Made from tobin bronze or monel metal and are so inserted that they cannot work loose.

Packing—Is of the patented Q.P. type, consisting of a series of conical fibrous rings. It automatically seals itself, is self-lubricating, requires no adjustment after it is once put in and will withstand 30 lb. back pressure without leaking.

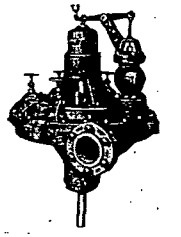
Ball Bearings—Are of the heavy-duty, double-row, precision type, held in removable wearing sleeves. Both bearings can be replaced in less than one hour.

Lubrication—Can be by either light grease or oil, depending on the customer's preference which should be specified when ordering.

Direction of Rotation—Can be either clockwise or counter-clockwise as specified.

Vertical Steam Turbines—Made in five frame sizes and are furnished complete with bosses and supporting studs.

Refer to Type "A" Carling Steam Turbine for general specifications. With or without governor.

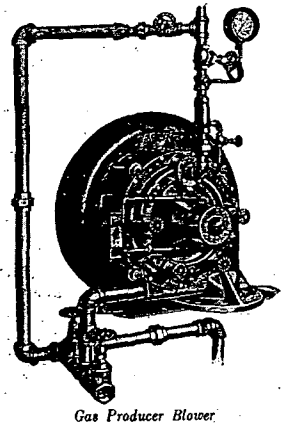


Vertical Turbine Type "V"

Gas Producer Blower—Will greatly increase the capacity of any type of gas producer and substantially improve the quality of gas output.

Furnished complete with piping, blast gate and valves, ready to mount to any type of gas producer.

250 gas producers now equipped.



Gas Producer Blower

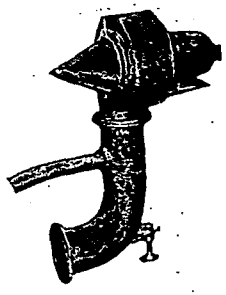
W. L. Clayton, Inc.

901 Bergen Avenue — Jersey City, N. J.

Manufacturers of DIOXOR Buckwheat Coal Burner

Description:

DIOXOR equipment consists of an aluminum blower housing secured to a casting which is fastened to the ash-pit of the boiler and braced securely to the floor. A special device is bolted to the intake of the blower housing which is adjustable to insure the proper amount of air supplied to fan. This fan is mounted directly on shaft of motor.

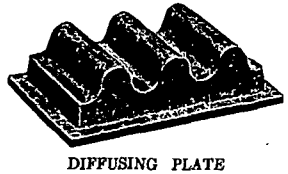


Size of motor is selected on each particular job to deliver sufficient air under the grates to insure the efficient burning of No. 1 Buckwheat anthracite, white ash coal, and the correct amount of air over the fuel bed to a vacuum flexible tubing into a diffusing plate attached to the inside of the fire door.

The automatic control is of the Contactor Type, consisting of a single pole switch of the Mercoid Type, which operates direct to the motor adjusted to the boiler pressure, water temperature, or room temperature.

Operation:

The new and improved balanced draft correctly applies the principle outlined by the United States Bureau of Mines for complete combustion in coal burning furnaces. Balanced air admission such as results from DIOXOR permits the use of smaller sizes of Anthracite coal. Designed by Combustion Engineers, DIOXOR is scientifically built for each individually different furnace, assuring high efficiency with low operating cost.

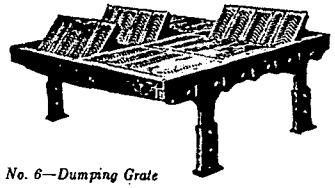


DIFFUSING PLATE
For spraying heated oxygen over Fuel Bed

DIOXOR automatically controls heat at an even temperature throughout the building.

Installation:

All equipment is installed in a workmanlike manner, all electrical work in accordance with the standard of underwriter's laboratories. A hand control switch is placed on each installation so that the power can be cut out by hand.



No. 6—Dumping Grate

The grates used in DIOXOR Buckwheat Equipment are of heavy duty gray iron. Especially patented to give increased air space and help to increase the efficiency of the boiler.

They are made in a variety of shapes and sizes, adaptable to the different types of furnaces, including round boilers. They are constructed as per specifications, to burn coal dust, bituminous coal, rice, buckwheat, and other special sizes.

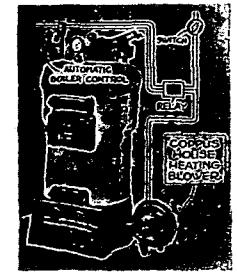


Coppus Engineering Corporation

339 Park Avenue, **Worcester, Mass.**

MANUFACTURERS OF BLOWERS, STEAM TURBINES, AIR FILTERS

Coppus Combustion Control



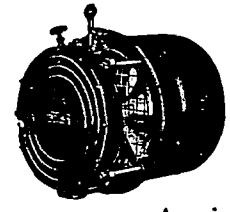
For heating plants burning from 7 to 250 tons of fuel per heating season. Consists of electric motor driven blower unit connected to ash pit to deliver air under grate (no grate changes necessary), controlled by room thermostat and pressure or temperature limiting device on boiler.

Gives luxury of automatic temperature regulation and economy of low priced fuels. Burns buckwheat, screenings, culm, coke, breeze, or soft coal mixtures.

Permits banking fire for extended periods with assurance of quickly livening up independent of chimney draft. Overcomes poor draft conditions.

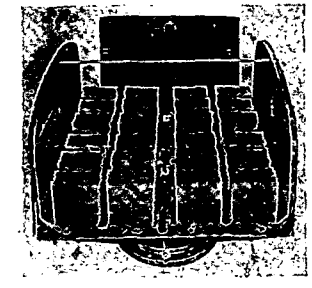
Send for Bulletin 205.

Forced Draft Blowers



Types "C" and "CM," respectively steam turbine and electric motor driven, in capacities up to 20,000 c. f. m. for stoker or hand fired boilers. Fan wheels designed for specific static pressures up to 5 in. Turbines are of one or two row velocity stage impulse type designed and constructed according to advanced turbine practice with resultant high efficiency. Provide increased boiler capacity, maintain even steam pressure independent of natural draft and permit burning low priced fuels and mill wastes. *Send for Bulletins 145 and 148.*

Annis Air Filters



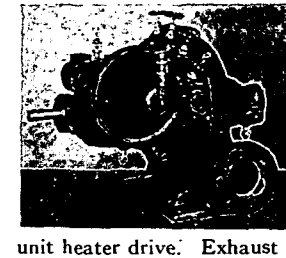
Used in general ventilation, air conditioning, drying operations, and in ventilating electrical machinery; also on air intake of compressors or internal combustion engines.

Filters are dry type of simple, strong unit construction, 100 per cent efficient by test. Wool felt filter element "slips on like a glove" over welded wire spacer frame, forming unit, clamped to base by spacer grid.

Elements impose minimum constant restriction to air passage and may be cleaned without removal, by vacuum cleaner or air lance. Weatherproof housing for outdoor erection can be supplied as part of assembly. Made for any capacity in multiples of 100 c. f. m.

Send for Bulletin F-310.

Steam Turbines



Economical prime movers for pumps, blowers, mixers and many other process machines requiring dependable and compact drive. Ideal application where exhaust steam is used for heating. Can be equipped with reliable low speed fully enclosed governor, designed especially for these turbines. Unique safety trips also available. Combine good steam economy with outstanding reliability of operation. Built in horizontal and vertical types and sizes from 1 to 60 H. P. *Bulletin 135.*

Fractional H.P. steam turbines especially built for unit heater drive. Exhaust steam piped directly into the heating unit. Small in size, low in price, reliable in operation.

Other Coppus Products

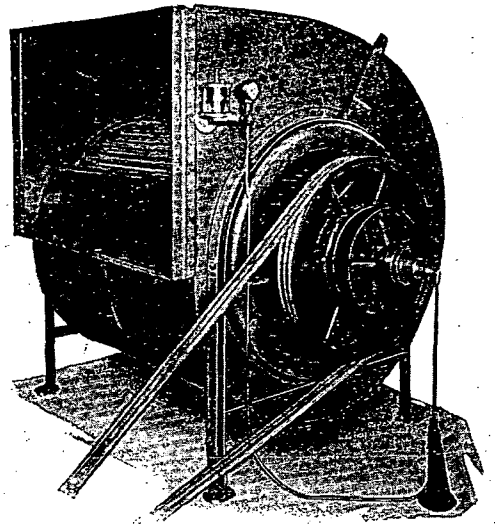
Centrifugal Turbo Blowers.
Heat Killers (Man Cooling Blowers).
Boiler Manhole Blowers.
Vano Blowers for industrial ventilation.
Cable Manhole Ventilators.
Steam Separators.

Horton Manufacturing Company

3016 University Avenue, Southeast

Minneapolis, Minn.

VARIABLE AND CONSTANT SPEED DRIVES FRACTIONAL HORSE POWER AND UP



Can't Leak Hydraulic or mechanically controlled variable speed fan drives. Widely used in public buildings and sound equipped theatres where fan speed change and quiet operation is demanded. Will not overheat when operated constantly at intermediate sets. Speed changes anything between a crawl and belted speed.

Reduction in monthly power bills quickly liquidates cost of equipment—no delicate parts to wear or give trouble—extreme long life—will install on four inch shaft projection. Hydraulic and mechanical control are interchangeable.

We agree to replace no charge F. O. B. factory any part which in normal use fails to function during the first year in service.

Information Required with Orders

1. Fan name and speed.
2. Fan shaft diameter.
3. Horse Power and speed of driving motor.
4. When possible, specify Brake Horse Power.
5. Diameter of motor shaft and dimensions of keyway.

AEROFIN CORPORATION

850 Frelinghuysen Avenue
Newark, N.J.

Manufacturers of AEROFIN

THE STANDARDIZED LIGHT-WEIGHT FAN SYSTEM HEAT-SURFACE

11 West 42nd Street, NEW YORK

Land Title Building	United Artists Building	Burnham Building
PHILADELPHIA	DETROIT	CHICAGO

AEROFIN is the modern Standardized Light-Weight *Fan System* Heat-Surface originated by *Fan Engineers* to meet the present-day requirements of this highly specialized field, and to afford an adaptability which permits and fosters the new and advanced applications of tomorrow.

A new, improved AEROFIN available February 1st, 1932

The AEROFIN Corporation announces a new, improved, advanced AEROFIN, available after February 1, 1932. This new Surface is called Flexitube AEROFIN (Fig. 1) and is designed for steam pressures from 1 to 200 lbs., temperatures to 388° F, one- and 2-row Units (some 2-row Units equivalent to 3-row Units of former Low Pressure AEROFIN) and for both Tempering and Re-Heater service.

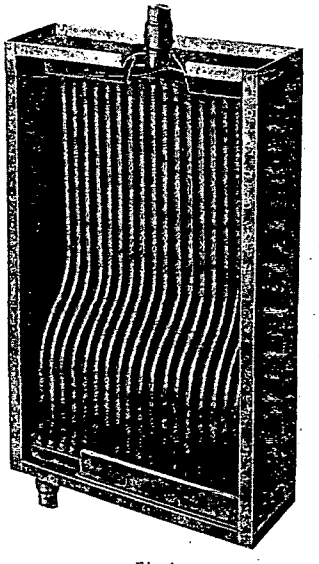


Fig. 1

Flexitube AEROFIN thus supplants the former Low Pressure AEROFIN (the original light-weight, non-corrodible, encased Heat-Surface) and will, we believe, eventually supplant Universal AEROFIN, as Architects and Engineers become familiar with its unusually adaptable characteristics.

Flexitube AEROFIN is distinguished from all other developments by its off-set tubes, as shown. This ingenious idea imparts to the tube a flexibility which enables it to expand or contract, under temperature changes, without strain upon itself, the header joints, the header or the casing. Hence the name Flexitube AEROFIN.

The flexibility of the off-set tube permits a single-pass, header-to-header design which allows the use of rigid headers and so perfectly relieves or absorbs expansion and contraction strains that header and header-joint construction adequate for high pressure service may be employed, and the permanency of the construction assured thruout the practically unlimited life of the surface.

Single-pass tube construction is essential for low pressure service and is desirable for intermediate pressure service (up to 200 lbs.) since it insures uniform steam or cold water distribution and proper, quiet drainage of condensate, while permitting installation of the Unit *in any position*. The off-set tube of Flexitube AEROFIN is the first definite achievement of the ideal single-pass, header-to-header design. Tests equivalent to a life-time of service show that Flexitube AEROFIN will stand up indefinitely against the strains of expansion and contraction because the Unit, due to its design, does not *resist* these strains, but absorbs them in its flexible tubes without rack or injury.

The headers are one-piece brass castings, machined for tube joints and pipe tappings.

The joints between the tubes and the headers are of a patented type made by using a brazing material applied at high temperature and have proved stronger than the tube itself under all operating conditions for which AEROFIN is sold. We believe this joint to be the most practical and dependable yet developed.

Steam tappings are located on the center line of the casing with respect to its width, off-set from center line with respect to its depth. Return tappings are eccentric, at opposite end of casing.

This arrangement of Supply and Return connections readily lends itself to every installation requirement and permits installation in any position, tubes vertical or horizontal, or Units "laid flat" for vertical air flow.

Uniform steam or cold water distribution thru every tube is assured by proper orifice restriction at supply ends of tubes, this being accomplished without use of separate orifice rings, by machine-shaping the tube ends.

Complete descriptive and Engineering Data are presented in our new *Bulletin G32*, which Architects, Engineers and Contractors are urged to secure at once by request to Newark.

Design and Construction: The heat-transfer surface in AEROFIN is a plurality of seamless copper tubes about which is wound a helix of copper ribbon, crimped on its inner edge to permit winding and to afford maximum contact between tube and fin. The extended fin surface is applied and tinned while held in position, by highly developed automatic machines, being accurately crimped and spaced. The tinning of the tube and the extended surface makes them metallicly integral, affording maximum heat transmission and permanent effectiveness. The thickness and width (height) of the extended surface, the crimping and the pitch of the helix were determined by careful experiment, to afford maximum heat transfer, uniform air flow and minimum resistance thereto. The copper tubes and fins of AEROFIN transmit heat eight times as effectively as iron. So scientifically is AEROFIN designed that air is heated more in passage through a single row of its tubes, a travel of 1⅛ in., than in passage through an entire section of cast-iron surface, a travel of 9 in.

Flexitube AEROFIN is constructed as briefly described above. In Universal AEROFIN and High Pressure AEROFIN the seamless tubes, with their extended fin surface, are continuous. (See Figs. 2 and 3.)

Flexitube AEROFIN, Universal AEROFIN and High Pressure AEROFIN are furnished as completely encased Units, ready for pipe and duct connections. The casings are built of pressed steel and are exceptionally strong and rigid, protecting the Unit from all the strains of pipe connections and expansion or contraction in service. The casings are flanged on both faces, top and bottom, and template punched for bolting together adjacent Units, or for duct connection.

Standard Casings: The casings of all AEROFIN Units (including the new Flexitube, which is interchangeable with former

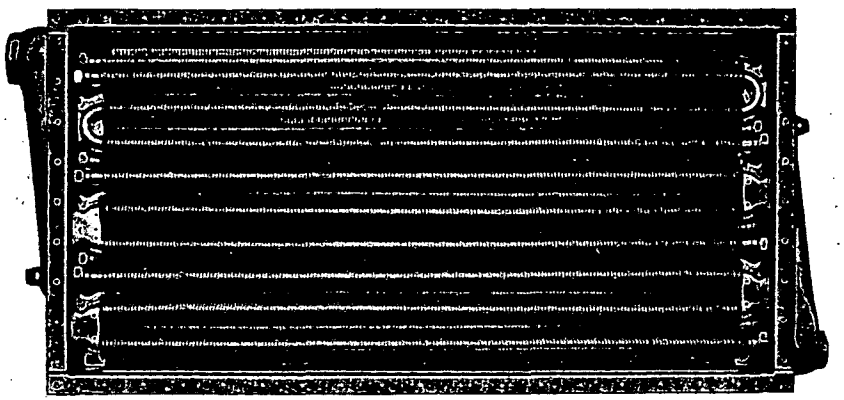


Fig. 2

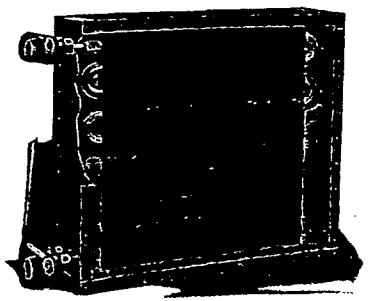


Fig. 3

Low Pressure), whether comprising one, two or three rows of tubes, are 29 in. wide (except 6-tube Universal AEROFIN which is 21 5/16 in.) across tubes, from outer edge one flange to outer edge opposite flange, and 10 in. deep in direction of air flow. Length of casing is nominal tube length plus 8½ in.

AEROFIN Sizes: Flexitube AEROFIN: Made in thirteen standard tube lengths, either one or two staggered rows of tubes per Unit, in 5 series (as explained in Bulletin). There are thus sixty-five standard Units available, a range which adequately meets all requirements.

Tubes are furnished of any length between 2 ft. and 6 ft., in increments of 6 in., and between 6 ft. and 10 ft. in increments of 1 ft.

Complete tables of sizes and capacities are shown in *Bulletin G32*, mailed gratis upon request. This bulletin also contains 19 proved Piping Diagrams in four colors.

UNIVERSAL AEROFIN: Available in one-row or two-row Units, 6-tubes or 9-tubes across face, in seventeen standard tube lengths (distance between end baffle plates, or between 180° bends) between 2 and 10 ft., inclusive, in increments of 6 in. Batteries of double width are easily assembled by setting Units end-to-end, leaving space for pipe connections.

Complete information is contained in our *Bulletin G32*, mailed gratis upon request.

HIGH PRESSURE AEROFIN: Made in five standard tube lengths (*i.e.*, length of straight section of tube, between 180° bends) 2 ft.; 2 ft. 6 in.; 3 ft.; 3 ft. 6 in.; 4 ft., either one, two or three staggered rows of tubes per Unit. There are thus fifteen standard units now available, meeting practically all requirements. Since the supply and drip connections of High Pressure AEROFIN are located on the same end (Figure 3) Units may be placed end-to-end, thus affording battery widths of twice the standard tube-lengths. Complete tables of sizes and capacities are shown in our *Bulletin G32*, mailed gratis upon request.

Aerofin Booster Units: (Fig. 4) for horizontal or vertical air flow. Six sizes 150 to 1624 c.f.m., 200 lbs. working steam pressure. Complete information upon request to Newark. Ask for *Bulletin G32*.

Steel Supporting Legs: Standard steel supporting legs, 18 or 24 in. high, template punched to same bolt hole centers as standard casing, are furnished when ordered. These legs may be attached quickly and obviate necessity of any other foundation.

Advantages: AEROFIN weighs but 9 to 16 per cent as much as equivalent cast-iron and occupies but 35 per cent of the space required by equivalent cast-iron (2-row units). Two men can easily carry any AEROFIN Unit. Expensive foundations are unnecessary, building re-enforcement is not required and the Units may readily be suspended from beams or roof trusses, or installed snugly in any out-of-the-way corner.

Ask Newark for *Bulletin G32* at once.

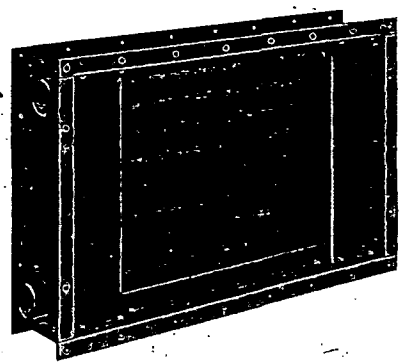


Fig. 4

Sales: AEROFIN is sold only by manufacturers of nationally advertised Fan System Apparatus. List upon request.

The Bush Manufacturing Co.

100 Wellington St., **Hartford, Conn.**

Manufacturers of
Seamless Finned Tubing, Electric Refrigerator Condensers, Evaporator Coils

Bush Finned Tubing *is the result of twenty-two years experience in the building of* automotive radiators, and is now widely used for refrigeration and heating.

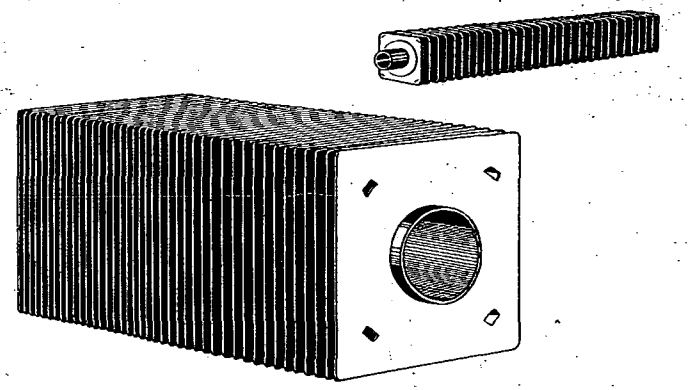
Bush Finned Tubing is made of seamless copper or steel tubing and aluminum, brass, copper or steel fins, with and without solder.

The soldered type of fin to tube is used mainly for electric refrigerator condensers and are made up in continuous tubing and also with elbows or "U" bends.

For ammonia cooling units, seamless steel tubing with steel fins are used. A special process of fastening the fins to the tubing insures perfect metal to metal contact to secure the highest efficiency. Cadmium plated steel tubes and aluminum fins can also be used.

For heating purposes, seamless copper tubing with copper or brass fins employing same process of construction is used.

For evaporator coils seamless copper tubing with aluminum fins are used where methyl chloride or sulphur dioxide is the refrigerant. The coils are adaptable for use with any style of condensing machine.



Bush Finned Tubing is available in a wide variety of sizes from 7/8 in. to 4 15/16 in. square. Tube sizes 1/4 in. to 2 1/8 in. O. D. Special sizes to order.

Condensers for large or small refrigeration compressor in standard sizes or to your specifications.

The use of Bush Finned Tubing has made possible economies in many industria applications.

For Room Coolers, in Baudelot Coolers, and other Air Conditioning work proper sizes are available.

The Heating Industry will find other types adapted to Concealed Radiators, Garage Heating and other industrial installations.

Companies who are developing equipment for national distribution will find Bush in a position to cooperate 100 per cent on special requirements.

The G & O Manufacturing Company

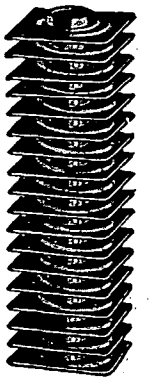
138 Winchester Avenue **New Haven, Connecticut**

G&O

INDIVIDUAL FIN TUBING

for

UNIT HEATERS (HIGH AND LOW PRESSURE), CONCEALED RADIATION, REFRIGERATION CONDENSERS AND COOLERS



G & O Individual Fin Tube Data

O.D. of Tube	Fin Size	Fin Spacing per Inch	Surface per Linear Foot
3/8"	3/4" sq.	6	0.59 sq. ft.
3/8"	7/8" sq.	6	0.81 sq. ft.
3/8"	7/8" r'd.	6	0.64 sq. ft.
3/4"	1 1/2" r'd.	6	1.61 sq. ft.
3/4"	1 3/8" sq.	6	2.50 sq. ft
1"	2 1/8" sq.	6	4.00 sq. ft.
1 1/4"	2 1/2" r'd	5	3.55 sq. ft.



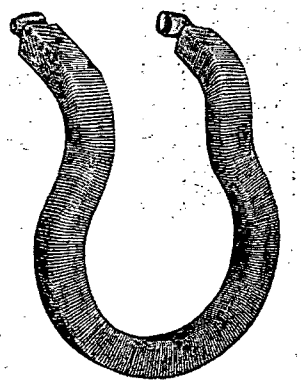
Individual G & O Fins—The use of individual fins results in high efficiency in heat transfer from primary tube surface to secondary fin surface, because all G & O fins have ample collars around the tube opening insuring liberal contact with tubing.

Any Size or Shape—Fins of any size or shape may be obtained giving any desired proportion of primary and secondary radiating surface.

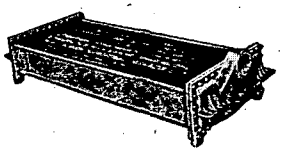
Square Fins—A square fin has 20 per cent greater surface than a round fin of a diameter equal to a side of the square.

Individual Fins—Individual fins permit of any fin spacing: also, of using fins in groups at intervals along tubes. Fins placed at practically any angle on tubes.

Various Shapes—G & O individual fin tubing is furnished in straight lengths: in U bends with short radii, or other shapes. Ends of tubes may be left free of solder for mechanical joints.



SPECIAL BENDS



HEATING ELEMENTS

The Rome-Turney Radiator Co.

Rome, N. Y.

Exclusive Manufacturers of ROME-TURNEY Finned Tubing for use in Unit and Fan System Heaters, Concealed Radiation, Oil Coolers, Refrigeration Condensers and Evaporators and Intercoolers on Air Compressors.

ROME-TURNEY Finned Tubing—Seamless Copper, Brass or Steel Tube with a continuous *flat* radiating fin. Perfect contact between fin and tube insures highest efficiency. No corrugations to hold dust and dirt.

ROME-TURNEY Unit Heaters—sturdily constructed of Seamless Copper Tube. Reliable, efficient and moderate in cost.

ROME-TURNEY Blast Heaters in all sizes suitable for public building and school heating. Complete engineering data on request.

ROME-TURNEY Concealed Copper Radiation—For high pressure steam heating on shipboard. Other types for homes and offices. Send for bulletin.

ROME-TURNEY Finned Tubing Data
Standard Sizes

O. D. of Plain Tube	Width of Fins	O. D. of Finned Tube	No. Fins per Inch	Surface per Linear Foot
5/16"	5/16"	11/16"	6	54.38 Sq. In.
5/16"	5/16"	11/16"	7	61.48 " "
5/16"	5/16"	11/16"	8	68.58 " "
3/8"	1/4"	7/8"	6	85.13 " "
3/8"	1/4"	7/8"	7	96.83 " "
3/8"	1/4"	7/8"	8	108.63 " "
1/2"	1/4"	1"	5	89.80 " "
1/2"	1/4"	1"	6	103.85 " "
1/2"	1/4"	1"	7	117.95 " "
5/8"	1/4"	1 1/8"	5	106.17 " "
5/8"	1/4"	1 1/8"	6	122.77 " "
3/4"	3/8"	1 1/4"	5	187.47 " "
3/4"	3/8"	1 1/4"	6	219.27 " "
1"	3/8"	1 3/4"	5	232.70 " "
1"	1/2"	2"	5	320.70 " "
1 1/4"	1/2"	2 1/4"	5	377.20 " "
1 1/4"	5/8"	2 1/2"	5	489.20 " "
1 5/8"	5/8"	2 9/16"	5	506.50 " "
1 5/8"	7/8"	3 1/16"	5	774.50 " "

Data covering special sizes on request.

Standard construction—seamless copper tube with copper fins. Steel and brass is supplied when specified for either tube or fins. Tubes bent and formed over short radii to specifications.



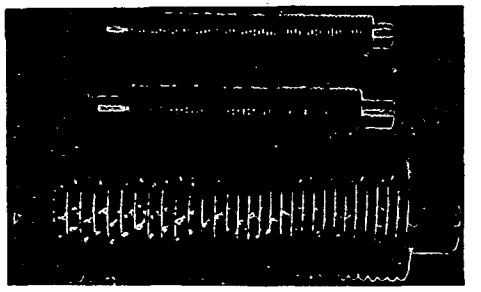
ROME-TURNEY Refrigeration Condensers—Evaporators and Cooling Coils for domestic and commercial refrigeration installations.

27 Years' Experience Built into ROME-TURNEY Products

SCHUTTE KŒRTING

1154 Thompson Street, **Philadelphia, Pa.**

Jets, Condensers, Valves, Oil Burners, Heat Transfer Equipment and Gear Pumps.



S&K RADIAFIN TUBES

for air-heating and air-cooling units

S&K Radiafin Tubes have from 7 to 16 times as much surface as plain tubes of the same size and length. This feature insures maximum heating or cooling capacity with minimum quantity of tubing and low initial and operating costs.

RADIAFIN TUBING AND PIPING DATA

Type of Tube or Pipe	Size of Tube or Pipe	Width of Fins	O. D. of Finned Tube or Pipe	Pitch of Fins	Ratio of Air Contact Surface to Water or Steam Contact Surface	Total Surface per Lineal Foot	Weight per Lineal Foot	Price per Lineal Foot	Price Flanges per Pair
Seamless Drawn Brass and Copper Tubing with Copper Fins. Pressures up to 250 lbs.	1/2"	1/4"	1"	1/7"	9.93 to 1	1.05 sq. ft.	0.357 lbs.	Prices on Application	
	5/8"	1/4"	1 1/8"	1/7"	8.70 to 1	1.2 "	0.6 "		
	3/4"	5/16"	1 3/8"	1/6"	9.34 to 1	1.55 "	0.83 "		
	1"	3/8"	1 7/8"	1/5"	10.6 to 1	2.41 "	1.09 "		
	1 1/2"	3/8"	2 3/4"	1/4"	11.6 to 1	3.99 "	2.04 "		
Seamless Drawn Steel Tubing with Steel Fins. Pressures up to 250 lbs.	3/4"	1/2"	1 3/4"	5/16"	16.3 to 1	2.64 "	1.2 "		
	1"	5/8"	2 1/4"	1/4"	14.75 to 1	3.22 "	1.93 "		
	1 1/2"	3/4"	2 3/4"	5/16"	13.72 to 1	3.80 "	2.80 "		
	1 1/2"	7/8"	3 1/4"	3/8"	13.0 to 1	4.35 "	4.4 "		
	2"	1 1/8"	4 1/4"	1/2"	12.0 to 1	5.52 "	6.1 "		
	3"	1 1/4"	5 1/2"	5/8"	9.17 to 1	6.55 "	10.5 "		
Standard Steel Pipe with Steel Fins. Pressures up to 125 lbs.	3/8"	5/16"	1.3"	1/6"	11.6 to 1	1.5 "	1.03 "		
	1/2"	3/8"	1.59"	1/5"	10.9 to 1	1.78 "	1.41 "		
	3/4"	1/2"	2.05"	1/4"	11.1 to 1	2.41 "	1.95 "		
	1"	5/8"	2.56"	1/4"	13.5 to 1	3.7 "	2.9 "		
	1 1/4"	3/4"	3.16"	5/16"	12.2 to 1	4.4 "	4.02 "		
	1 1/2"	7/8"	3.65"	3/8"	12.1 to 1	5.1 "	5.75 "		
	2"	1 1/8"	4.62"	1/2"	11.2 to 1	6.07 "	8.2 "		
	2 1/2"	1 1/8"	5.12"	5/8"	9.47 to 1	6.12 "	9.54 "		
	3"	1 1/4"	6.0"	3/8"	8.97 to 1	7.2 "	13.77 "		
	4"	1 1/2"	7.5"	3/4"	8.6 to 1	9.05 "	20.89 "		
	6"	1 3/4"	10.12"	1"	6.7 to 1	10.64 "	31.07 "		

S&K Radiafin Tubes and Pipes can be furnished with plain or flanged ends and in any lengths up to 15 ft. Sold as separate pieces or assembled with headers. Also made up in spiral coils, flat coils and other special shapes.

WOLVERINE TUBE CO.

SEAMLESS COPPER BRASS & ALUMINUM

1453 Central Avenue, **Detroit, Michigan**

Sales Offices—Cleveland; Chicago; Atlanta; Los Angeles; Denver; Dayton, Ohio; New York City; Dallas, Texas

Seamless Copper, Brass and Aluminum Tubing For:

Unit Heaters; Water Heaters; Oil Burners; Air Compressors; Refrigeration Compressors; Lubrication Systems; Thermostatic Devices; Gas, Oil and Air Lines; Water Coolers; Pressure Gauges; Humidifiers; Cooling Systems.

Seamless Copper Tubing—Deoxodized 99.98 per cent Pure Copper. Bright, uniform annealing, clean inside and out. Non-scaling, perfect flaring, bending, swedging. Up to 2″ diameter in various gauges.

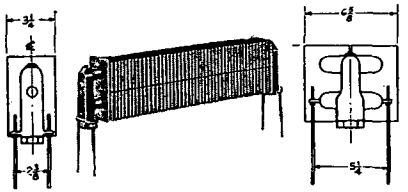
Seamless Brass Tubing—70-30 Mixture. Perfect threading, bending, flaring, swedging. Up to 2″ diameter in various gauges.

Seamless Aluminum Tubing—Accurate, uniform, bright—flawless virgin metal. Up to 2″ diameter in various gauges.

Coils and Bends of Seamless Copper, Brass and Aluminum—All shapes and sizes which use tube from 1/16″ to 2″ outside diameter. Coils and bends of copper and brass are made without flattening, tested up to 250 lb. and delivered free from discoloration—inside and outside.

Concealed Copper Radiation:

Built with Cast-Bronze Headers in types for any kind of pipe hook-up. Oval section tubes of seamless copper.



Vertical flue fins of copper, metalically bonded to oval tubes.

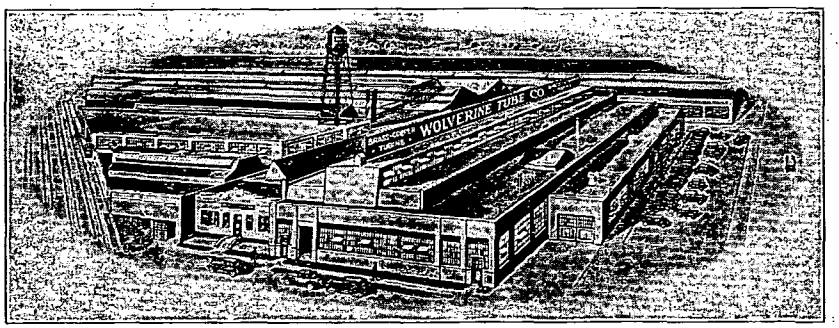
This unique construction gives maximum heat transfer—large volume at low temperature—and insures full uniform distribution in room. These units in all standard sizes to fit every reasonable requirement.

Available in single or double types as shown above. No joints or seams, uniform temperature, one-tenth the weight of cast-iron.

All units tested at 100 lbs. pressure, Suitable for steam, hot water or vapor. Conservative ratings.

Wolverine Radiation Cabinets—Made in four styles; Removable Front Panel Cabinet (SRP); Wall Hung Removable Front Cabinet (SWH); Plaster in Wall Cabinet (SIW); In Wall Plastered Metal Face (SMF). Designed to take standard sizes of Wolverine Radiation Units. Finished in prime over filler. Built of 18 gauge auto body steel.

Guaranteed to be free of defects in workmanship and material for five years.



The Modern 5-acre Mill of the Wolverine Tube Co., Detroit, Michigan

American Blower Corporation

General Offices: **Detroit**

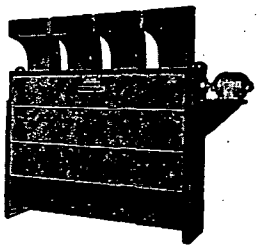
Works: Detroit, Michigan—Bond Hill, Cincinnati, Ohio

Branch Offices in Principal Cities of United States and Canada

HEATING AND VENTILATING EQUIPMENT

"SIROCCO" UNIT HEATER

Built with all the requirements of the ideal industrial heating system in mind—high efficiency, light weight heating element, compactness, dependability, even distribution of heat, economy of installation and operation, accessibility of parts, ease of control. For a given size and tip speed the "Sirocco" Unit Heater delivers more heated air than any unit of which we know. Fourteen standard sizes. Capacities: 290 to 3200 sq. ft. E. D. R.

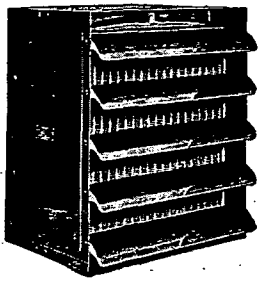


"Sirocco" Unit Heater

VENTURAFIN UNIT HEATERS

For use in modern industrial buildings, stores, garages, etc., and designed to keep the heat in working areas where it is needed.

Venturafin Units are adaptable to High, Medium or Low Pressure Steam Applications—for floor, wall or ceiling installation. Venturafin Units are easy to install—economical to operate and maintain. Eight standard sizes. Capacities: 130 to 1200 sq. ft. E. D. R.



Venturafin Unit Heater

Complete Catalogs and Data Supplied on Request

(1072)

Carrier-York Corporation

A Division of

CARRIER CORPORATION

1541 Sansom Street **Philadelphia**

Branch Offices and Representatives in all Principal Cities

CARRIER ATMOSPHERIC CABINETS for Stores, Offices, Etc.

The Carrier Atmospheric Cabinet

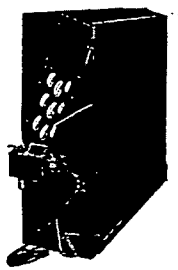
This is a complete, self-contained air conditioning unit, combining an attractive piece of furniture with year-round utility. In winter it provides evenly heated, adequately humidified, gently circulated filtered air; in summer, when used in conjunction with a refrigeration machine or when connected with a building's regular source of refrigeration, it distributes cool, clean, properly dehumidified air throughout the room in which it is installed. Heating only, cooling only, or both heating and cooling may be combined, depending on the type cabinet selected.

Range of Applications—The Carrier Atmospheric Cabinet has an extremely wide range of applications, and proves a profitable investment from the standpoint of health, comfort, productiveness, patronage and profits. Ideal for business, doctors' and dentists' offices, small retail stores, barber shops, cafeterias, tea rooms, bakeries, candy shops, etc.

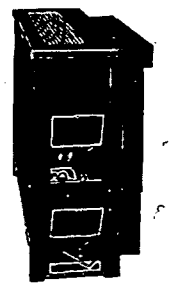


Carrier Atmospheric Cabinet installed in a business office

Installation—A radiator is simply replaced with one of these compact units, using the same supply and return lines already available for the steam or hot water heating system, and adding small supply and drain lines for humidification. To provide for cooling, the only additional piping required is the installation of supply and return lines to and from the source of refrigeration.



(LEFT) *Complete internal cabinet assembly, showing heating coils, humidifier, air filter and control damper*



(RIGHT) *External and internal cabinets assembled ready for installation, showing at the right the outdoor intake, which may be easily adjusted to varying sill heights*

External Cabinet Cover—An Art Metal removable enclosure, walnut grain finish, baked enamel undercoat, with heavy steel grille top. This cabinet conceals all fittings and connections and is provided with access doors.

Finish—Grained walnut is standard, but other finishes, to harmonize with interior decorations and appointments, may be had on special order.

Internal Cabinet—Constructed of galvanized steel completely painted. Contains the heating and cooling coils, fans and motor, air filter and humidifying equipment. A connection for outdoor air is provided. All pipe connections are made externally at each end of the inner cabinet, and are totally enclosed by the external cabinet.

Fans and Motor—Each Cabinet is provided with two fans, of silent multi-blade type. A small motor operates the two fans, and may be connected to the lighting circuit.

Carrier-York Corporation

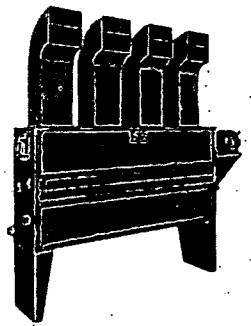
A Division of

CARRIER CORPORATION

1541 Sansom Street **Philadelphia**

Branch Offices and Representatives in all Principal Cities

SUPER-CONTROL HEAT-DIFFUSING UNITS FOR INDUSTRIAL HEATING



No. 334 Super-Control Heat-Diffusing Unit

Super-Control Heat-Diffusing Units

These units are convertible. Thus, should it become necessary or advisable through re-arrangement of plant layout to change the units from floor mounted to suspended, or vice versa, the same units may be re-used, since by removing the legs a floor mounted unit becomes a vertical suspended unit. To make the vertical suspended unit a into horizontal suspended or an inverted type, all that is necessary is to revolve the bearing plates and reverse the coil.

Temperature Regulation—Super-Control regulation gives a constant balance between heat requirements of the room or building and the heat output from the units, which insures minimum overheating of the upper areas and maximum fuel economy. In addition, the constant air circulation produces an extremely even temperature distribution over the entire area served. Temperature regulation may be either pneumatic, electric or manual.

Construction—The fans are of the non-overloading, housed type. Each fan wheel is balanced statically and each fan and shaft assembly then balanced dynamically, insuring smooth operation. Patented feature permits complete fan assembly being inserted in unit without disturbing this rotating balance.

Kroy Unit Heaters—Disc Fan Type

Kroy suspended Unit Heaters are available in a wide range of capacities, and may be had with floor recircutating boxes where desired.

CONDENSED* CAPACITY TABLES

300, 400 and 600 Series SUPER-CONTROL HEAT-DIFFUSING UNITS

Size Unit	R. P. M.	C. F. M. in the Fans	H. P. Motor	Recirculating Air at 60° F. Entering Unit, and Steam at 2 Lb. Gauge Pressure on the Heating Surface†				No. of Air Outlets
				B.t.u. per Hour	Final Temp.	Lbs. Cond. per Hour	Equiv. Direct Rad.	
322	1750	3,350	¾	215,500	125.4	223	898	2
422	1160	2,220	½	156,000	132.4	162	650	
622								
333	1750	5,050	1½	335,000	127.7	347	1395	3
433	1160	3,340	½	241,000	134.5	250	1003	
633								
334	1750	6,700	1½	455,000	129.5	471	1895	4
434	1160	4,440	½	328,000	136.6	340	1368	
634								
344	1750	8,400	2	574,500	130.0	595	2390	4
444	1160	5,560	¾	414,000	137.1	428	1725	
644								
353	1160	13,000	3	765,000	119.2	792	3185	3
453	870	9,750	1½	612,000	123.6	634	2550	
653								

NOTE:—It is understood that the specified steam pressure is to be maintained on the heating surface. A suitable pipe line drop must be added in determining the pressure to be carried at the boiler. When air is to enter the unit at a temperature below freezing, the steam pressure on the heating surface should be maintained at not less than 5 lb. gauge.

*Catalog gives capacities at other 60 cycle current speeds as well as 25 cycle current speeds; a total of 660 ratings.

†See Chapter 35 of this issue of THE GUIDE for B.t.u. constants for other steam pressures and entering air temperatures.

McCord Radiator & Mfg. Co.

2587 E. Grand Boulevard

Detroit, Mich.

Factories

DETROIT, MICH. WYANDOTTE, MICH. PLYMOUTH, IND. WALKERVILLE, ONT.

Manufacturers of Unit Heaters, Metallic Asbestos Gaskets, Refrigeration Evaporators and Condensers, Spiral fin Tubing.

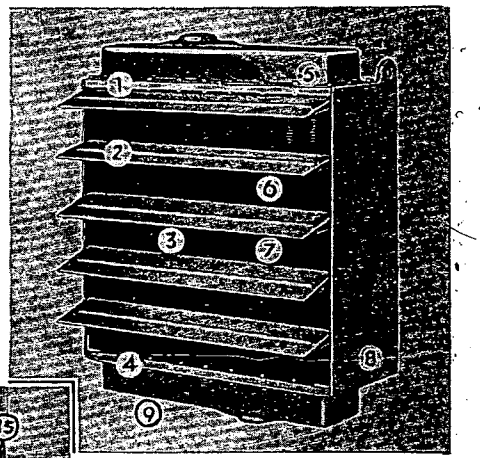
McCord pioneered the development and manufacture of spiral fin tubing for unit heaters and has supplied leading unit heater manufacturers for many years. The first light weight unit heaters introduced commercially used McCord spiral fin tubing.

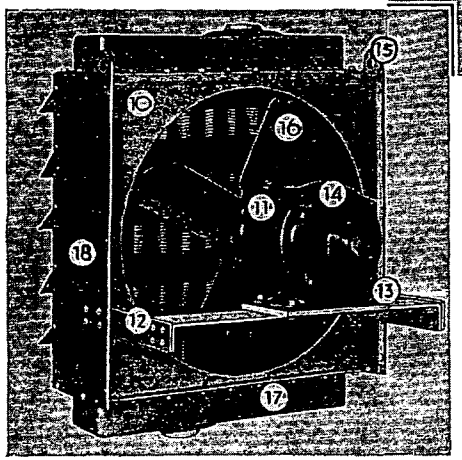
Now, after two years of engineering research, McCord announces its own unit heater, which sets a new standard in accessibility and convenience. It features a newly developed copper fin that is twice the width commonly used. This increase in fin surface balances the ratio between it and the tube surface, permitting a tube spacing that reduces air resistance and allows a better air flow.

1. Extra heavy header plates.
2. Adjustable louvers.
3. Individual spiral fin tubes—removable for inspection or replacement.

4-5. Tanks are bolted to header plates, removable for cleaning.

6. Tubes are scientifically spaced, result: air resistance low.
7. Extra wide fins tightly joined to tubes by special tinning process—better heat conductivity.
8. Attractive green lacquer finish.
9. Entire unit heavily tinned inside and out. Tested for 125 lb. working steam pressure.





10. Scientific design of fan shroud makes for efficiency.
11. Fan removable without disturbing motor.

12-13. Two point motor support—no strain on radiator tanks.

14. Standard makes of unit heater motors supplied.
15. Balanced suspension—no strain on steam pipes.
16. Extremely quiet balanced fan.
17. Clean cut appearance.
18. Heavy side plates support motor and fan independent of radiator.

McCord Unit Heaters are built to last as long as the boiler and piping systems. An advanced design, McCord has incorporated sound and practical engineering features that make for long life and freedom from interruptions in service. These features include extra heavy seamless copper tubes with an extra wide spiral copper fin, as developed by McCord for unit heater use. New standards in accessibility make it possible to completely dismantle the heater for cleaning or to replace any single part without the necessity of purchasing a complete unit. Individual tubes may be removed by loosening specially designed brass compression nuts. Tanks are bolted to the header plates and are removable. These are important features in maintenance which the buyer has a right to expect in the purchase of a unit heater.

Research and numerous experiments have shown that the individual copper tube with spiral fin has definite advantages for unit heater use. The results of these experiments led to the development by McCord of a new type of spiral fin tube. The flat spiral fin is twice as wide as that previously used in unit heaters. The size of the tube was another factor carefully considered, the result being a balanced design. A McCord Unit Heater has four times more lineal heat dissipating surface than the conventional automotive type.

In winding the fin on the heavy seamless copper tubing the inner edge is compressed or crimped, making the area in contact with the tube equal to the outer circumference of the fin. A perfect metal contact in more readily obtained with the round tube, as used by McCord, than with an oval or flat tube.

The spiral finned tubes are rigidly fastened in the header plates by brass compression nuts and asbestos gaskets. This type of construction has many advantages. It permits the removal of an individual tube for replacement, the result of damage. The long bearing surface makes a tight joint at this point where the greatest strain occurs.

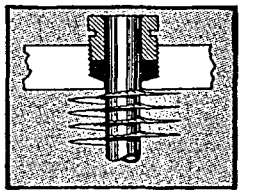
Sound engineering and careful design of radiator and fan make McCord a quieter heater without annoying vibrations. A balanced suspension takes the strain off the steam pipes and helps to make for still quieter operation.

Any standard make of motor built for unit heater use, such as G. E., Westinghouse, Emerson and Baldor, for any any type of current, can be supplied. Variable speed and explosion proof motors can be supplied at slight extra cost.

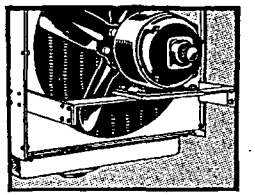
McCord Unit Heaters are carefully inspected and tested for 125 lb. working steam pressure before shipment.

McCord Unit Heaters

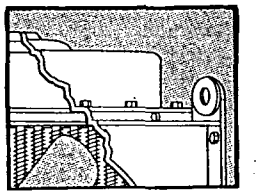
	MODELS				
	12	14	16	18	21
Height	18	20	22	23	26
Width	14¼	16¼	18¼	20¼	23¼
Weight	#80	#110	#140	#175	#200



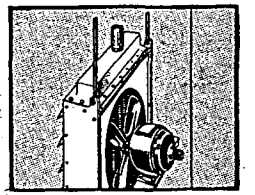
Compression Nut Makes Tight Joint



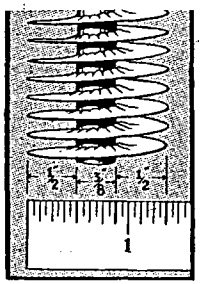
Two Point Motor Suspension



Heavy Tanks



Balanced Suspension

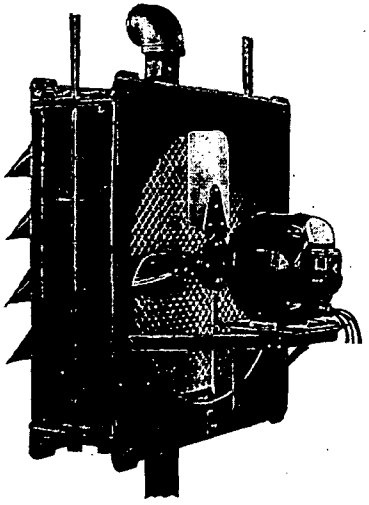


Spiral Fin Tubing

Multicell Radiator Corporation

Lockport, N. Y.

Manufacturers of Multicell Unit Heaters and Multicell One-piece Pure Copper Heating Surface for Special Heating and Refrigerating Purposes



Multicell Heating Surface is made of one piece seamless copper by an exclusive and patented process of electrical deposition. The surface is cellular in design and has an accordion-like pattern which allows it to absorb expansion and contraction within itself.

Every Multicell section is tested with 100 pounds air pressure under water. Multicell Surface is heavily tinned inside and outside to make it proof against corrosion.

The accordion-like action of the Multicell section is made possible by the diagonal pattern of its one-piece sections. This feature takes care of any expansion or contraction.

Multicell Frames are of all cast-iron construction with flow and return headers cast integral with upper and lower frame members respectively. This rigid all cast frame absorbs all piping strains and will not deteriorate from corrosion.

In case of accidental damage individual sections on Multicell Heaters can easily be removed simply by uncoupling one union at each end of section.

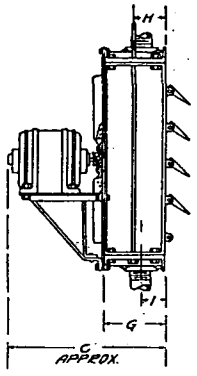
Multicell Sections have ample waterways. They present so little resistance to steam flow that pressures are practically the same at inlet and outlet.

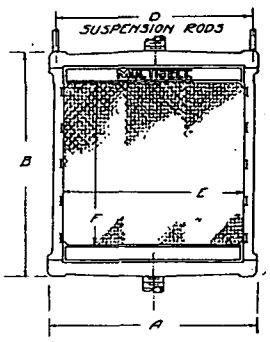
Multicell Elements will not gather dust and lint. Their surfaces are smooth and self-cleaning, thus maintaining their original high efficiency without attention

Multicell Motors do not require special wiring.

In addition to heating factories, Multicell Unit Heaters have many other uses. When equipped with variable speed motors, they are especially adaptable to churches, auditoriums, etc.

Multicell Unit Heaters are tested and rated in accordance with the standard code for testing and rating steam unit heaters, adopted January 1930, by Industrial Unit Heater Association and the American Society of Heating and Ventilating Engineers.

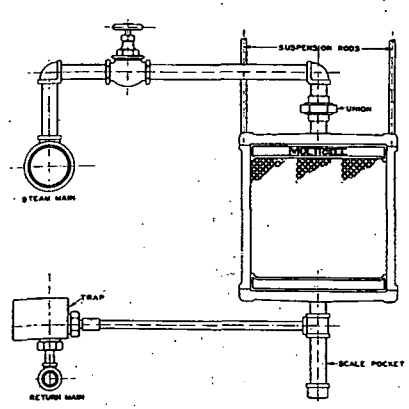




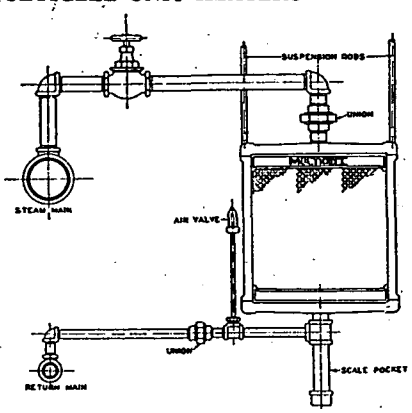
DIMENSIONS OF MULTICELL UNIT HEATERS

No. of Heater	Characteristic Speed	Net Weight	Tapping		Dia. of Fan	Dimensions								
			Flow	Return		A	B	C	D	E	F	G	H	I
13-B	Const.	86	1¼	1¼	12	15	19	15	14	13⅛	12⅜	6	3	2⅜
	Var.		1¼	1¼	12	15	19	15	14	13⅛	12⅜	6	3	2⅜
18	Const.	137	2	2	18	21¾	24⅝	16	20¾	19¼	17¼	6½	3¼	2½
	Var.		2	2	18	21¾	24⅝	16	20¾	19¼	17¼	6½	3¼	2½
180	Const.	179	2½	2½	18	28⅛	24⅝	16	27¼	25⅝	17¼	6½	3¼	2¼
	Var.		2½	2½	18	28⅛	24⅝	16	27¼	25⅝	17¼	6½	3¼	2¼
24	Const.	256	2½	2½	24	28⅛	31¾	19½	27¼	25⅝	24	6½	5½	2¼
	Var.		2½	2½	24	28⅛	31¾	21	27¼	25⅝	24	6½	5½	2¼

PIPING DIAGRAMS FOR MULTICELL UNIT HEATERS



VACUUM RETURN SYSTEM



GRAVITY RETURN SYSTEM

TABLES OF RATINGS

Tested and rated in accordance with the standard code for testing and rating steam unit heaters, adopted January, 1930 by the Industrial Unit Heater Association and the American Society of Heating and Ventilating Engineers.

NO. 13-B MULTICELL UNIT HEATER

R.P.M.	Motor H.P.	C.F.M. at Ent. Temp.	2 Lbs. Steam				5 Lbs. Steam			
			B.T.U. per Hour	E.D.R.	Final Temp. Deg. F.	Cond. Lb./Hr.	B.T.U. per Hour	E.D.R.	Final Temp. Deg. F.	Cond. Lb./Hr.
Air Entering Heater 70° F.										
860	1/30	445	29,000	120.9	130.3	30.0	30,600	127.5	133.4	31.9
1140	1/20	595	36,300	151.1	126.5	37.6	38,300	159.4	129.3	39.9
1440*	1/20	755	43,400	181.0	122.9	44.9	45,700	190.5	125.7	47.6
1725	1/10	900	48,900	203.5	120.0	50.6	51,600	214.9	122.6	53.4
Air Entering Heater 60° F.										
860	1/30	445	31,600	131.5	124.2	32.7	33,200	138.2	127.4	34.6
1140	1/20	595	39,500	164.5	120.1	40.9	41,500	173.0	123.1	43.2
1440*	1/20	755	47,200	196.8	116.4	48.9	49,600	206.2	119.2	51.6
1725	1/10	900	53,300	220.0	113.3	55.2	56,000	233.0	116.0	58.0

NO. 18 MULTICELL UNIT HEATER

Air Entering Heater 70° F.										
860	1/15	1074	72,500	302.0	131.5	75.0	75,900	316.0	134.9	79.0
1140	1/6	1425	90,100	375.5	128.2	93.2	95,000	396.0	131.3	98.8
1440*	1/6	1425	90,100	375.5	128.2	93.2	95,000	396.0	131.3	98.8
Air Entering Heater 60° F.										
860	1/15	1074	78,200	326.0	125.7	81.0	82,100	342.0	129.0	85.4
1140	1/6	1425	98,100	408.0	122.1	101.4	103,000	429.0	125.2	107.1
1440*	1/6	1425	98,100	408.0	122.1	101.4	103,000	429.0	125.2	107.1

NO. 180 MULTICELL UNIT HEATER

Air Entering Heater 70° F.										
860	1/15	1288	87,600	365.0	132.8	90.6	92,500	386.0	136.1	96.2
1140	1/6	1705	109,200	456.0	129.1	113.1	115,100	480.0	132.1	120.0
1440*	1/6	1705	109,200	456.0	129.1	113.1	115,100	480.0	132.1	120.0
Air Entering Heater 60° F.										
860	1/15	1288	95,500	389.0	126.9	98.8	100,300	417.5	130.3	104.4
1140	1/6	1705	118,900	495.0	122.9	123.0	124,800	520.0	126.1	129.9
1440*	1/6	1705	118,900	495.0	122.9	123.0	124,800	520.0	126.1	129.9

NO. 24 MULTICELL UNIT HEATER

Air Entering Heater 70° F.										
860	1/4	2560	152,100	634.0	124.6	157.5	161,500	674.0	128.0	168.0
1140	1/2	3380	190,000	791.0	121.7	196.8	200,800	835.0	124.6	209.0
1440*	1/2	3380	190,000	791.0	121.7	196.8	200,800	835.0	124.6	209.0
Air Entering Heater 60° F.										
860	1/4	2560	165,800	691.0	118.3	171.8	174,000	725.0	121.4	181.0
1140	1/2	3380	207,000	862.0	115.4	214.1	217,200	905.0	118.0	226.2
1440*	1/2	3380	207,000	862.0	115.4	214.1	217,200	905.0	118.0	226.2

*25 cycle motors only.

The Original

SKINNER BROTHERS MANUFACTURING COMPANY INC.

1474 South Vandeventer Avenue, **St. Louis, Mo.**

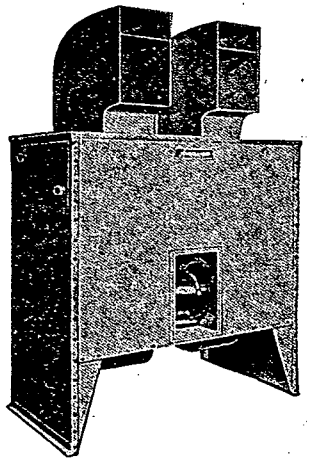
MANUFACTURERS OF ALL TYPES AND SIZES OF SUSPENDED AND FLOOR MOUNTED UNIT HEATERS

Representatives in the following cities:

Baltimore, Md.	Chicago, Ill.	Detroit, Mich.	Memphis, Tenn.	Richmond, Va.
Bethlehem, Pa.	Cincinnati, Ohio	Greenville, S. C.	Nashville, Tenn.	San Francisco, Calif
Birmingham, Ala.	Cleveland, Ohio	Houston, Texas	New Orleans, La.	Seattle, Wash.
Boston, Mass.	Columbus, Ohio	Indianapolis, Ind.	New York, N. Y.	Spokane, Wash.
Buffalo, N. Y.	Dallas, Texas	Kansas City, Mo.	Philadelphia, Pa.	Syracuse, N. Y.
Charleston, W. Va.	Denver, Colo.	Louisville, Ky.	Pittsburgh, Pa.	St. Paul, Minn.
Charlotte, N. C.				Washington, D. C.

Skinner Brothers Unit Heaters are made in many styles and types and are highly recommended for efficiently heating and ventilating industrial buildings—regardless of size—whether they be of permanent or temporary construction—sawtooth, or monitor—single or multi-story. They are ideally adapted for use in industries where the dampening effect of condensation and dripping must be eliminated—such as in paper and pulp mills, dye houses, packing plants, laundries, dairies, etc.

Skinner Brothers Unit Heaters are made in floor type or suspended type, steam or direct fired with either prime or extended surface coils, and can be made to operate on live or exhaust steam at low or high pressures. The coils of all Skinner Brothers Heaters are tested to 150 lb. hydraulic pressure to assure ample margin of safety. The fans are given a static and dynamic balance so they will give the highest efficiency and smoothness in operation, and may be operated by electric motor, steam turbine, or gas engine. If you are planning new heating or ventilating equipment, our engineers can be of service. They will be glad to study your requirements and make recommendations as to the type of heater best suited to your building and most economical.



Skinner Bros. AIRBLANKET *Type Unit Heater*

AIRBLANKET TRADE MARK

HEATING

The Skinner Brothers "Airblanket" method of heating actually creates an artificial "ceiling" or blanket of fast-moving air superimposed on the warm air issuing from the Heater. The following advantages result: *Greater Economy* because heat losses in the upper portion of the building are minimized . . . . *Greater Efficiency* because heat is more homogeneously distributed throughout the breathing zone . . . . *Greater Comfort* because the warm air stratum is maintained at the floor . . . . *Shortened Warm-up Period* because warmth is kept in the breathing zone.

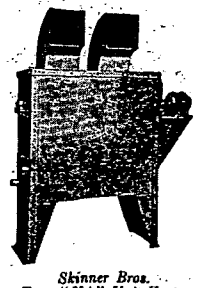
Be sure to investigate these and additional merits of the Skinner Brothers "Airblanket" Method of Unit Heating. Complete information and engineering advisory service are available, without obligation.

SKINNER BROS. TYPE "UA" UNIT HEATER

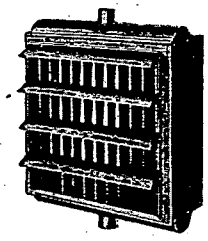
Capacities

Recirculating Air at 60 deg. Steam Pressure 5 lb.

Size	Cu. Ft. per Minute	Horsepower	Revolutions per Minute	B.t.u. per Hour	Final Temperature	Lbs. Condensation
22–1	1,750	½	1160	113,000	126	118
22–2	3,500	¾	1160	226,000	126	235
22–3	5,250	1½	1160	339,000	126	353
33–2	7,000	1½	1160	445,000	125	463
33–3	10,500	2	1160	668,000	125	696
44–2	9,000	2	870	574,000	125	597
44–3	13,500	3	870	861,000	125	896



Skinner Bros. Type "UA" Unit Heater



Skinner Bros. Type "LW" Unit Heater

SKINNER BROS. TYPE "LW" UNIT HEATER

Capacities

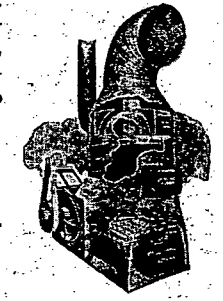
Recirculating Air at 60 deg. Steam Pressure 5 lb.

Size	Cu. Ft. per Minute	B.t.u. per Hour	Final Temperature	Lbs. Condensation
52-A	1,055	54,900	112	57
53-A	1,030	67,500	127	70
72-A	2,685	125,100	106	130
73-A	2,660	162,400	122	169
92-A	4,140	196,600	107	205
93-A	4,040	254,000	124	264

SKINNER BROS. "Patented" Direct Fired Heater

This is the outgrowth of a demand for equipment having the versatilities and efficiencies of the Unit Heater and not requiring a boiler. Buildings that are heated intermittently; isolated buildings to which it is impractical to pipe steam for heating purposes, but which require warmth in winter; and buildings under construction in cold weather are found to be excellently suited to the Direct Fired Heater.

For Fuel, coal, coke, wood, gas or oil may be used.



Skinner Bros. Patented "Direct Fired" Air Heater

Capacities

Size	Cu. Ft. per Minute	Horsepower	Sq. Ft. Heating Surface	B.t.u. per Hour
A	2,900	1	48	160,000 to 300,000
B	5,400	1½	65	300,000 to 600,000
C	8,400	3	88	600,000 to 1,000,000

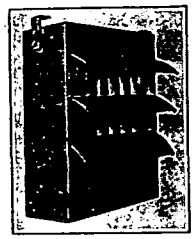
Complete information and catalogs on all types of Skinner Brothers Unit Heaters including Prime Surface Unit Heaters will be sent upon request.

The Trane Company

La Crosse, Wis.

See Heating and Ventilating Units, page 678; Concealed Radiation, pages 760-761; Heating Specialties, page 824

BRANCHES IN ALL PRINCIPAL CITIES

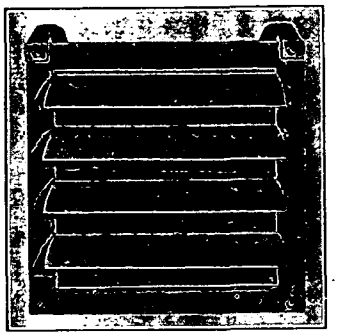


No. 10 Unit Heater for Small Offices

TRANE UNIT HEATERS

Trane Unit Heaters are furnished in approximately 30 different sizes. These sizes are divided into two types—the propellor fan type and the blower type. It is impossible to give complete information on all sizes in this publication, but complete data and engineering information will be sent on request.

Trane Units are guaranteed for any pressure ranging from 2 to 150 lbs., and can be connected to any two-pipe steam heating system. The heating element used in all styles of Trane Unit Heaters is the standard Trane Extended Surface of non-ferrous metal fins attached by a patented process to the steam-carrying tubes. There are no soldered or welded joints. The steam-carrying tubes are rolled into heavy inlet and outlet headers in typical boiler tube style. Curved type louvers are furnished on all units. Two inlet and two outlet piping connections. Either may be used. Propellor type fans have heavy stamped aluminum blades and brass hubs. Propellor type fans are of special design, which eliminate outside ring and are perfectly balanced. Motors are "silent mounted" on heavy steel base.



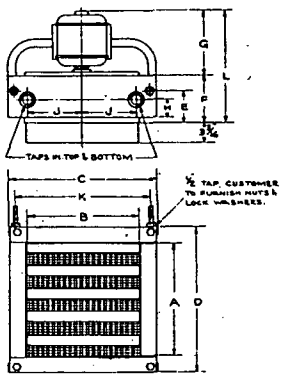
Front View of Unit Heater

Both types of Trane Unit Heaters can be furnished with ceiling mounting or with recirculating boxes. Ventilation air ducts may be attached to casing for combination heating and ventilating installations.

Complete catalogs and data will be sent on request.

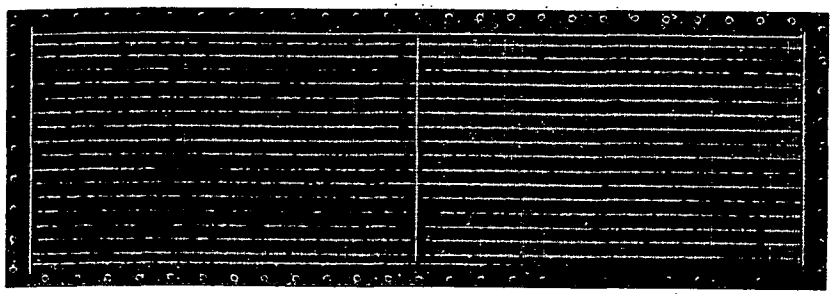
Roughing-in Dimensions for Single Fan Unit Heaters

Heater Size	A	B	C	D	E	F	G	H	J	K	L	Size Tap
12	12"	12"	16½"	17"	4"	7⅝"	7⅝"	2⅝"	5⅛"	14¾"	15⅛"	1¼"
15	15"	15"	20"	20"	4"	7⅝"	7¾"	2⅝"	7"	18¼"	15⅛"	1½"
18	18"	18"	23"	23"	4"	7⅝"	10⅜"	2⅝"	8½"	21¼"	17¾"	1½"
21	21"	21"	26"	26"	5⅛"	10⅜"	10⅜"	2⅝"	10"	24½"	20¼"	1½"
24	24"	24"	29½"	29"	5⅛"	10⅜"	10⅜"	2⅝"	11⅞"	28"	20¼"	2"
24-A	24"	24"	29½"	29"	5⅛"	10⅜"	10⅜"	2⅝"	11⅞"	28"	23¼"	2"



Unit Heaters with one heating element and two fan and motor assemblies are also available—complete dimensions and data on request.

TRANE EXTENDED SURFACE ELEMENTS



A typical Trane Extended Surface Heating Element

Flexibility

Trane Extended Surface is not only highly efficient in heat transfer, but its extreme flexibility in arrangement for securing capacities to meet definite requirements, has met with a great deal of approval from the engineering profession.

This is due to the fact that the construction of the element permits the banking of units in extremely small spaces to increase the capacity. Trane construction also permits the consolidation of two rows of prime surface tubes in one header, which reduces manufacturing and installation costs. On such consolidations, the extended fin surface is one uninterrupted piece, which provides very efficient heat transfer.

Low Friction

It is a well-known fact that the power requirements of a fan are affected by the friction loss set up by the ducts and the heating element. Consequently, the heat transfer surface which has the lowest friction is the least expensive to operate. Here again Trane Surface triumphs, as the small diameter of the prime surface tubes and their strategic location on the smooth secondary surface fin-sheets, give this heating surface a lower friction than the ordinary helical or spiral wound fin surface, cast-iron surface or pipe coils.

Comparative Friction and Comparative Final Temperatures of Trane and Other Equipment

Rows Deep	Friction		
	Trane	Helical or Spiral	Cast-Iron
1	.06	.148	.109
2	.12	.222	.160
3	.18	.370	.262
4	.24	.444	.313
6	.36	.666	.415

For approximately the same temperature rise competitive equipment will give higher air frictions than Trane as noted in the above table.

Rows Deep	Final Temperature		
	Trane	Helical or Spiral	Cast-Iron
1	53°	32°	35°
2	88°	60°	62°
3	118°	83°	86°
4	137°	103°	106°
6	162°	133°	135°

Trane based on 600 F. V. Cast-iron based on 1000 F. V. Spiral based on 600 F. V.

The same features of Trane Extended Surface which have made it so popular for use in the heating and ventilating field have also developed a strong following for it in the process and industrial industries. Here are a few of the applications for which Trane Surface is already in use:

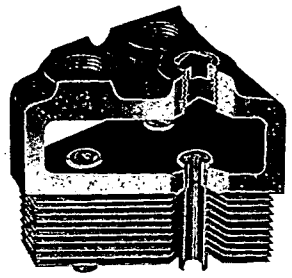
Air or Gas Heating:
Using steam, water, or other fluid for air heating required for:
Ventilation; Hot Blast Heating; Drying.

Air or Gas Cooling:
Using water, brine or direct expansion refrigerants for:
Air Conditioning; Dehumidifying; Generator Coolers; Rectifier Cooler; Other Electrical Apparatus.

Water or Liquid Cooling:
Diesel Engines; Radio Transmitters; Gasoline Engines; Gas Electric Locomotives; Refrigeration.

Condensors:
Air Cooled for Refrigeration; Air and Water for Refrigeration; Chlorine and other Chemicals; Solvent Recovery Systems; Steam.

Complete data and catalogs will be furnished on request.



Sectional view through header of Trane Extended Surface Unit. Note the cut open tube showing construction—integral fit of Extended fins to tube and orifice distribution bushing.

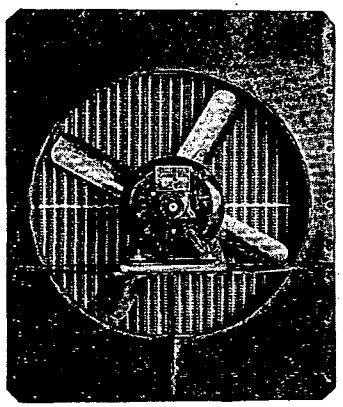
THERMIDAIRE

CORPORATION

2441-45 CHARLOTTE STREET

KANSAS CITY, MO.

An E. K. Campbell Company



Type PF

The Thermidaire Heating Element is manufactured with a special process of fusing copper, enabling the entire unit to be built with it, thus eliminating internal expansion and contraction strains, and giving freedom from trouble.

The joints have great strength. Numerous tests to 1200 lbs. hydrostatic pressure have shown no weaknesses. Production since early 1929 for higher steam pressures has developed no troubles or leaks.

Type PF units are manufactured with all rolled-copper heating elements guaranteed for 100 lbs. steam working pressure. For the Type CF units and higher steam pressures in the Type PF units a special all copper construction is used, which is guaranteed for 200 lbs. steam working pressure.

The following ratings are at 60° entering temperature and 5 lbs. steam pressure at the heater:

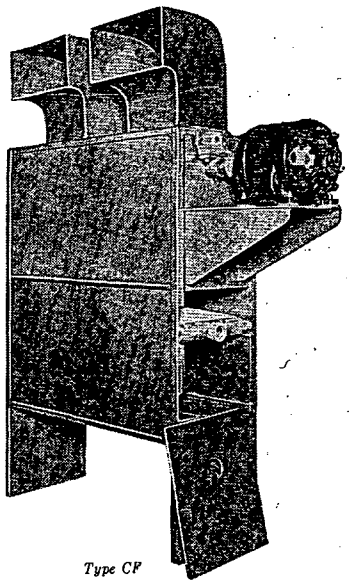
TYPE PF

Unit No.	R. P. M.	C. F. M.	B. T. U.
4	1750	400	33,100
5	1150	500	43,500
8	850	800	72,000
10	1150	1000	84,000
14	1150	1450	117,800
15	850	1500	134,800
20	1150	2000	168,000
24	1150	2450	181,800
25	850	2500	210,000
30	1150	3000	224,000
40	850	4000	336,000
50	1150	5000	372,000

TYPE CF

Unit No.	R. P. M.	C. F. M.	B. T. U.
182	1750	3,000	225,600
183	1750	4,500	350,400
184	1750	6,000	475,200
302	1150	8,000	533,760
303	1150	12,000	801,600

Complete data furnished on request.



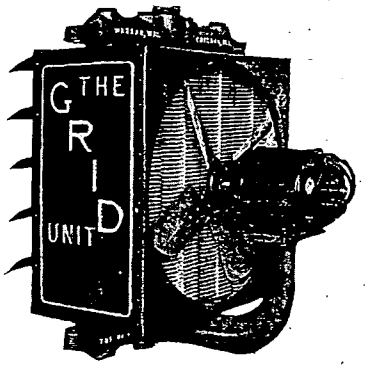
Type CF

The Unit Heater and Cooler Co.

Wausau, Wisconsin

Offices in Principal Cities

MANUFACTURERS OF THE GRID UNIT



Sturdy—Permanent
THE GRID UNIT
(A product of the D. J. Murray Mfg. Co.)

The Grid Unit is attractive, compact, light in weight, strong, safe and efficient. Heating element affords unrestricted flow of air and permits a large volume at a moderate temperature.

The Grid Unit is constructed for constant use with minimum attention. Able to handle a large volume of air and give it a relatively small temperature rise. Extremely high temperature in air leaving the heater is avoided. Circulates large volume of air and distributes it evenly to all parts of the building.

Performance and construction guaranteed.

The Grid Unit may be suspended from a pipe line, or from rods to truss or rafters. Both methods may be used at the same time.

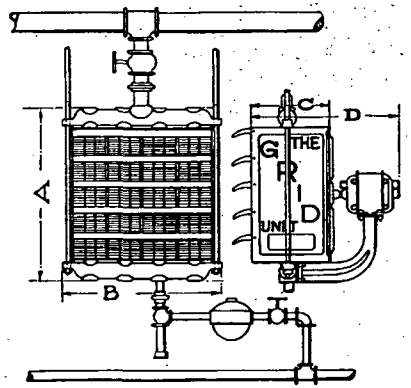
Heating Element is composite casting of close grained grey iron and aluminum alloy. Steam chamber is gray iron capable of withstanding highest pressures ordinarily used on heating systems, while the alloy fins are of light weight and cast integral with the iron center.

Few joints, none brazed, welded or soldered.

The Manifold is a grey iron casting with lugs for attaching supporting rods, thus taking all strains off connections between manifolds and heating elements.

The Casing or Cabinet is made of pressed sheet steel, securely attached to manifold. Will not rattle.

Cooling and Refrigerating. The Grid Unit is adapted for the circulation of cold water, sodium or calcium brine, by direct connections to refrigerant pipe lines. Direct Expansion ammonia may be used with safety.



Typical Installation of Grid Unit Heater

GRID DATA

"Delivers More Warm Air to Floor and Working Zone"

Model No.	Dimensions A	B	C	D	Face Area Sq. Ft.	Motor Hp.	R.p.m.	Volume C.f.m.	Velocity C.f.m.	Capacities 5 lb. Pres. 60 deg. B.t.u.	Sq. Ft. Rad.	Max. Trap Capacity per Hour	Net Weights	Shipping Weights	Pipe Sizes Sup.	Outlet
15	22	18	11¼	20	1.56	1/10	1750	1700	1100	76080	317	115	200	250	1¼	¾
						1/20	1150	1200	770	53280	222					
20	27	23¼	11½	21½	2.78	1/6	1150	3000	1100	136000	566	200	250	350	2	1
						1/10	850	2400	880	108800	450					
25	32	28½	11½	28	4.34	½	1150	4700	1100	217300	906	300	500	500	2	1
						¼	850	3700	880	173950	725					
30	38	33¼	13¾	29	6.25	1½	1150	8200	1300	382500	1600	450	700	800	2½	1¼
						½	850	6600	1050	306000	1280					

Young Radiator Company

HEATING DIVISION

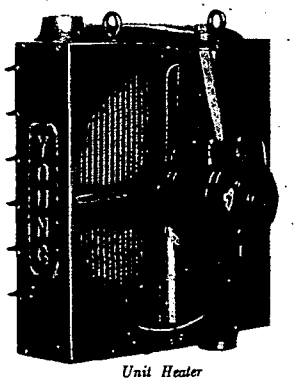
700 Mead Street

Racine, Wisconsin

Young Quality

TRADE MARK
Reg. U. S. Patent Office

Young Unit Heaters produce a large volume of heated air at high velocity with a resulting low final air temperature. This means increased circulation; that hot blasts are avoided, and that air changes are made at minimum cost.



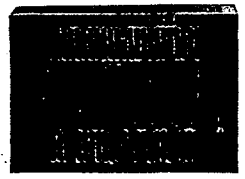
Unit Heater Catalogue 1250

Specifications

All copper core, seamless elliptical copper tubes, ⅛" copper header plate, cast-nickel iron headers, copper fins, straight line tubes and fins to facilitate free air flow and self cleaning.

Manufactured in fifteen sizes with constant and multi-speed motors.

Furnished with chromium plated housings if desired, at extra cost.



Recessed Cabinet Catalogue 651-251

Young Convectors Concealed Radiation

Young copper convectors are manufactured in several hundred different sizes. Due to the great variance in capacities, complete data should be taken from the Young Catalogue.

Young Copper Radiation is manufactured in three types.

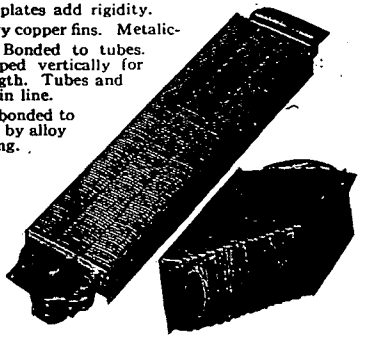
1. Cabinets which stand out in the room.
2. Recessed cabinets which fit into the wall.
3. Completely concealed or plastered-in.

Of these there are numerous patterns of each, and a size to meet every specification.

The Young core with straight fins and elliptical tubes offers minimum resistance for air passage, thus increases air velocity, throwing more heat into the room at proper height and equalizes room temperatures by lowering ceiling temperatures and increasing floor temperatures.

The all copper construction of the core offers immediate response to controls to maintain an even heat.

1. All copper core. 2. Malleable Iron Header.
3. Header and Tubes brazed together. Young Patented Process.
4. Seamless elliptical tubes.
5. Side plates add rigidity.
6. Heavy copper fins. Metalically Bonded to tubes. Crimped vertically for strength. Tubes and Fins in line.
7. Fins bonded to tubes by alloy coating.



All Copper Convector Core Section

Sales Offices in all important cities. Write for catalogue.

There is a Young Unit to suit your heating requirements.

Peerless Unit Ventilation Company, Inc.

"PEERVENT" Heating and Ventilating Units

Bridgeport, Connecticut

Sales Representatives from Coast to Coast

Products

PEERVENT

"PEERVENT" Heating and Ventilating Units, for schools, hospitals, libraries, churches, dormitories, club-rooms, theatres, hotels, banks, offices, auditoriums and all places of public or semi-public assembly; in short wherever people congregate, where ventilation without objectionable drafts is desired.

The "PEERVENT" consists of two multi-blade fans operated by a quiet, low-speed electric motor. These fans draw in outdoor air thru an opening in the back of the unit usually located near the floor. This air is filtered, then driven upward thru a highly efficient copper radiator where it is heated from the outside temperature to the degree required for the particular room being served. This warmed air is discharged in a vertical direction thru a grille at the top of the unit at a relatively high velocity to provide a pleasing air motion and thorough diffusion without objectionable drafts. These parts are housed in a furniture steel cabinet, small in size and attractive in appearance.

All "PEERVENTS" can be equipped with thermostatic and electric or pneumatic attachments for thermostatic control of the room temperature and electric or pneumatic control of the inlet damper. This equipment is optional.

The PEERVENT" is designed with such flexibility that it can be made to function as desired by the operator, or as intended by the architect, engineer or owner. The room temperature may be controlled in either one of two ways. The Series 32 "PEERVENT" has a by-pass damper in front of and parallel to the radiator for controlling the air temperature. In the Dual Radiator "PEERVENT" the air temperature is controlled by regulation of the steam supply.

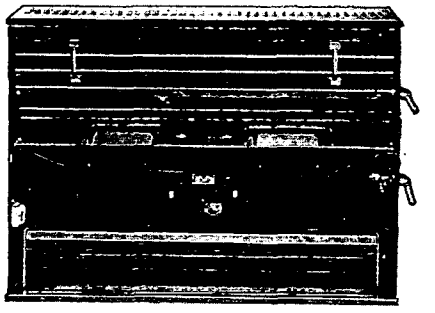
Either the Series 32 or Dual Radiator "PEERVENT" will deliver all outside air, all recirculated air or any percentage of recirculated air.

Several types of "PEERVENTS" have been standardized. One or another of these standard types will meet practically any architectural requirement including installations in existing buildings. In keeping with our policy of continual improvement, new developments are immediately incorporated in "PEERVENTS." It is not, therefore, possible to give complete information in these pages. A request to our nearest representative or to the factory at Bridgeport, Connecticut, will insure your receiving the latest catalogs, dimension sheets and rating tables.

"PEERVENTS" give perfect results in connection with any two pipe high pressure, vapor, vacuum, gravity or modulation steam heating system. "PEERVENTS" for capacities up to 1800 c.f.m. are only 32" high by 14" deep. Larger sizes are also available up to 5000 c.f.m. in various arrangements for floor or ceiling mounting.

Each "PEERVENT" is entirely independent. The cost of running it depends upon actual service rendered in the one room which it serves, regardless of any other room in the building. All expense of ventilating unoccupied rooms is eliminated. An open window cannot disrupt the entire heating and ventilating system thruout the building, but affects only the room in which it is located.

One of the merits of a "PEERVENT" is that it overcomes the greatest objection to the central fan duct system, that is, the unsanitary features of the uncleanable surfaces over which the air supplied for ventilation must pass. The elimination of this tremendous sanitary problem is of major importance.



Series 32 "PeerVent" with front removed

The Herman Nelson Corporation

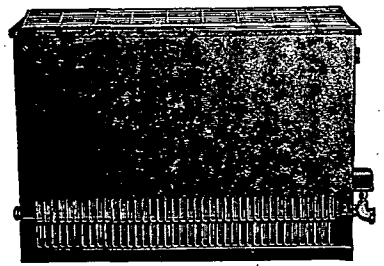
Moline, Illinois

Manufacturers of the

Her-Nel-Co System of Ventilation; the Herman Nelson Invisible Radiator; the Herman Nelson hiJet Heater; the Herman Nelson Univent System of Ventilation; Herman Nelson Wedge Core Radiator Sections

The Her-Nel-Co System of Ventilation

The Her-Nel-Co System of Ventilation reduces to practice the newer science of ventilation as applied to school class rooms and similar spaces. The essential difference between the older and newer idea in ventilation is this: Under the older science a fixed amount of outdoor air was supplied at all times, whereas, with the Her-Nel-Co System of Ventilation outdoor air is admitted only when and as required to maintain proper temperatures.



Her-Nel-Co Ventilator

The system will not only provide a more positive ventilating result, but will effect large economies in fuel consumption, building construction and operating costs.

The principal equipment used in the Her-Nel-Co System of Ventilation is the Her-Nel-Co Ventilator, illustrated. One or more of these machines, together with a sufficient amount of auxiliary direct radiation is placed in each room to be heated and ventilated.

No vent flues or exhaust air outlets are ordinarily employed.

The Her-Nel-Co Ventilator is beautifully finished in genuine Morocco enamel with bronzed fittings. It is arranged to be fastened against the wall with a gasket which prevents any air leakage around the cabinet. The entire front is removable, giving free access to all parts. The cabinet contains a radiator for heating the recirculated air (only), a fan and motor unit for forcing circulation, a filter for removing dust and dirt, a steam jet humidifier and the dampers and mechanism which regulates the admission and intermixture of indoor and outdoor air.

The radiator is the well known Herman Nelson Wedge Core Section, which has been used exclusively in Herman Nelson ventilating equipment since 1925. It is constructed entirely of aluminum, and is light, compact, sturdy and non-leakable. The front open view of the Her-Nel-Co Ventilator shows the position of the radiator, fan and motor unit, filter, damper control, etc.

The Her-Nel-Co System may be manually or automatically controlled.

In principle, the Her-Nel-Co System provides for the reheating and recirculating of indoor air after a delayed firing period, such as in the beginning of a school class day. After the recommended room temperature has been reached, over-heating is prevented by restricting the heat supply of the direct radiator.

The next step in the cycle, is the complete closing off of both the direct radiation and the radiator in the Her-Nel-Co Ventilator.

There will naturally be a further rise in room temperature due to the heat given off by the occupants of the class room, together with the sun's rays, and this brings us into the next step of the cycle.

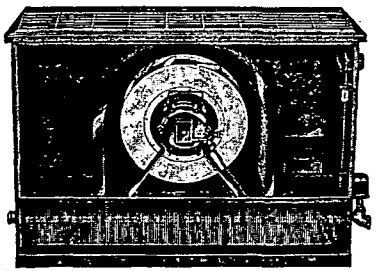
All radiation is closed off and the indoor air is recirculated and intermixed with the right proportion of outdoor air in order to maintain a constant room temperature.

The next step is the admission of outdoor air entirely, without recirculation, and with all radiation closed off.

This system fulfills the requirements that science has prescribed viz., Air Motion; Humidity Regulation and Maintainance of a proper Temperature.

The fan motor unit is quiet, efficient, sturdy, powerful, sanitary, simple and reliable. It is located in the forward upper compartment of the Her-Nel-Co. Ventilator along with the filter, and draws air from either indoors or outdoors or both,

according to the position of the dampers, and delivers it through the filter and discharge nozzle into the room. It is portable and easily inspected, cleaned, oiled or taken out when the cabinet front is removed. The cone type fan is constructed entirely of aluminum.



Her-Nel-Co Ventilator Front Open View

The air filter is of a special horseshoe design, arranged to give extra large filtration area. No air can be delivered into the room without passing through the filter. Filter can be easily inspected or removed for cleaning when the front of the cabinet is removed. Filter is located on the discharge side of the fan where it is not subject to low temperatures or weather effects and therefore the oil remains viscous and highly effective. At the same time, since it is not exposed to radiant heat effects, the oil is not evaporated and wasted.

The dampers used in the Her-Nel-Co Ventilator are of the balanced type, carefully designed and mounted on weather-proof bearings. A single blade damper, located near the bottom of the rear compartment of the Ventilator on the discharge side of the radiator, is used for controlling the admission of recirculated indoor air. The damper which controls the admission of outdoor air is of the multiblade louver type and is located directly in the outdoor inlet opening. These dampers are mechanically interconnected so that the outdoor air supply is reduced as the indoor air supply is increased and vice versa.

When required, a steam jet humidifier is furnished and located in the lower radiator compartment and connected to the radiator in such a manner that it operates whenever the radiator operates, thereby providing humidity whenever the air is heated and expanded but not at other times.

The Her-Nel-Co Ventilator is made in but one size designated as the 4500 series. It can be had in two models, however.

The Model "J" is arranged to take outdoor air through an opening in the wall behind the machine and is the type generally preferred. When the intake opening is through an outer wall, as is usually the case, it should be protected with an air intake.

The Model "K" is designed with the idea of taking outdoor air through the lower portion of a window opening and is provided with a long narrow intake located at the top of the cabinet and arranged to be built into the window construction. The intake sleeve is so constructed that it may be cut to fit on the job and a heavy wire screen in a steel frame is provided for use in the intake opening.

The Her-Nel-Co Ventilator may be arranged for either hand or automatic temperature control and is adaptable to either vapor, vacuum, gravity steam, or hot water systems. Filters and humidifiers are always recommended but may be omitted at the option of the purchaser.

All motors are of the adjustable speed type to obtain varying air deliveries and may be furnished for all of the more usual current characteristics.

As shown in the capacity table, both models are rated at three air deliveries and can be equipped with two different radiators, giving two heating capacities for each air delivery. All air deliveries are determined by the A.S.H.V.E. standard anemometer method with the anemometer held 2 in. above the face of the grille. The air delivery in c.f.m. is determined by multiplying this velocity in feet per minute by the gross area of the discharge grille in sq. ft. (1.58 sq. ft.).

All heating capacities are given in equivalent sq. ft. of standard direct radiation (240 Btu) based on 218 F steam temperature and 70 F. room temperature. For all practical purposes the heating capacity of the Her-Nel-Co Ventilator, when the motor is not running and the outdoor dampers are closed, is equal to about 20 sq. ft. of direct radiation.

HER-NEL-CO VENTILATOR

Capacity Table—Models "J" and "K"

Serial No.	4514	4515	4524	4525	4534	4535
Cu. Ft. of Air per Minute	700	700	800	800	900	900
Heating Capacity Sq. Ft.	70	105	75	115	80	120

The Architects' and Engineers' catalog of any Herman Nelson product containing complete Engineering information will be gladly sent Architects and Engineers upon request.

John J. Nesbitt, Inc.

Executive Offices and Factory
State Road and Rhawn Street, **Holmesburg, Philadelphia**

Branch Office, 11 Park Place, NEW YORK

Sales and Service Through Offices of the American Blower Corp.
In all the Principal Cities of the United States

PRODUCTS

1: Universal Heating and Ventilating Unit for SCHOOL ROOMS.

2: Universal Unit Heaters for LARGE ROOMS like Banking Rooms, Show Rooms, Stores, Sales Rooms, Offices, Assemblies, Churches, etc.

3: Nesbitt Concealed and Cabinet Radiators for HOMES, Offices, Etc.

.1.

Universal Heating and Ventilating Unit for SCHOOL ROOMS

"Universal" has always been at the forefront in the use and development of the features that have made the Unit system universally accepted as ideal for schoolroom heating and ventilating. Among many other major improvements, the Universal Unit introduced the light weight heater, the present-day form of unit with motor and fan assembly in base of cabinet, alternating current motors with rigid metal to metal mounting and the successful use of the blast system whereby direct radiation is eliminated from the class room.

"Universal" Multifin Copper Tube Radiator

Standard Universal Units are supplied with horizontal seamless copper tube radiators, the ends of the tubes of which are connected to cast iron headers by means of ground joints, thus being free of soldered, braised, welded or packed joints. Over these tubes are hydraulically pressed thin copper plates or fins, thus insuring real thermal contact between tubes and plates, making a highly efficient heating unit. Tested at 125 pound working pressure, and will stand freezing without breaking.

Motor

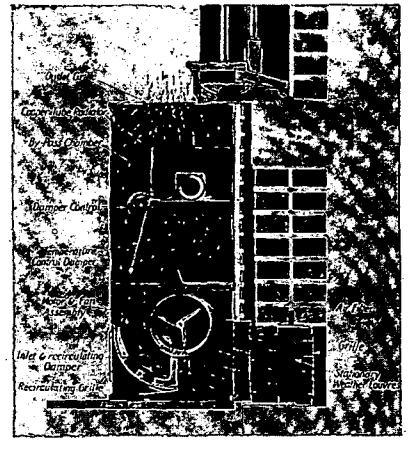
The motors used in the Universal quiet operating units can be mounted for any character of current and are of the condenser, transformer, induction type with three-way switch speed control. These motors have oversize bronze bearings with wool packed oiling system requiring oil only once per heating season.

Three Point Mounting

The Motor and Fan assembly of the Universal Unit is mounted in the cabinet on three steel ball points in contact with lead liners, making a very quiet operating unit, with no electrical noises. It has also made practical the use of alternating current motors with a permanent and rigid supporting device.

Fans

Universal fans are of the Sirocco type, multiblade, low speed, double inlet, designed to operate at 720 r.p.m. plus or minus 5 per cent. No greater efficiency known. The by-pass chamber is parallel



to heating chamber and so located as to guide the column of cool air across the currents of warm air when mixing—thus creating an absolutely vertical discharge—and guide the cool air away from room occupants when completely by-passing. The large space between the fan and the radiator results in the uniform distribution and heating of entire air volume.

Thermostatic Control Optional

All Universal Units can be equipped with thermostatic and pneumatic attachments for pneumatic control of the inlet damper and thermostatic control of the by-pass damper. This equipment is optional.

Sizes and Capacities

Universal Unit Heating and Ventilating Cabinets for schools are obtainable in eighteen sizes of cabinets, with nine different air capacities. Two different radiator sizes are available for each cabinet size.

Refer to table of Capacities and Dimensions on pages 26 to 30 of the "Universal Heating & Ventilating Unit," publication No. 214—(A. I. A. File No. 30-d-11) for complete information. Send for this publication—as well as our Catalogue and Engineers Data Book.

.2.

Universal Unit Heaters for LARGE ROOMS

and beautiful interiors like Banking Rooms, Show Rooms, Stores, Offices, Assemblies, Churches, etc.

The Universal Unit Heater maintains a uniform temperature in the room—ceiling and floor alike—and it does this to the satisfaction of the heating engineer. It is also sufficiently attractive to meet the exacting requirements of the architect, and so quiet in operation as not to annoy those in the room.

Universal Unit Heaters are made on the same principles that have made the Universal Heating and Ventilating Unit for Schools so popular during the past 16 years. In them you will find the same high velocity vertical discharge, the same highly efficient Universal Multifin Copper Tube Radiator with its ground joint connections and its extra strength for more than working pressures and ability to stand up under freezing without breaking.

You will find the same low speed, long life, trouble free motor—either alternating or direct current—with the three point suspension of motor and fan on lead liners, making an assembly almost entirely free from operating noises.

You will find the same Sirocco type aluminum multiblade low speed double inlet fan. You will find the same volume regulators on the outlet of the fan housing so the air delivery of the Unit can be regulated to the requirements of the room.

ADVANTAGES *of Universal Unit Heaters*

Attractive in Appearance: Encased in a beautiful Cabinet of heavy high grade furniture stock steel.

Larger Heating Capacity in Smaller Space: Universal Unit Heaters with five times the heating capacity require but one-fifth the space taken up by direct radiators and can often be entirely concealed. This is especially important in centers of high rent where the best use must be made of all space.

Tremendous Saving in Fuel: High velocity heat diffusion from the vertical discharge results in uniform temperature over entire area, with only slight difference between floor and ceiling, effecting a tremendous saving in fuel by eliminating overheating of upper areas.

Quick Heating of Large Areas: Rapid circulation of air by low speed motor driven fans over a high efficiency copper tube radiator results in quick heating of



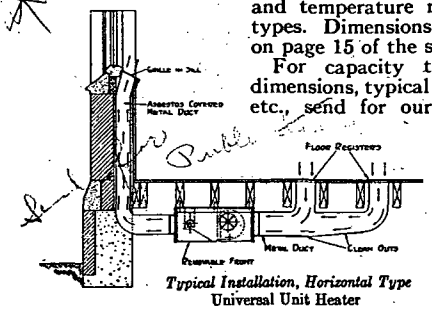
Typical installation in a Sales Room, where every inch of space is valuable, the Universal Unit *takes less space and is more efficient.*

large areas—a vital matter in the heating of churches and assembly rooms.

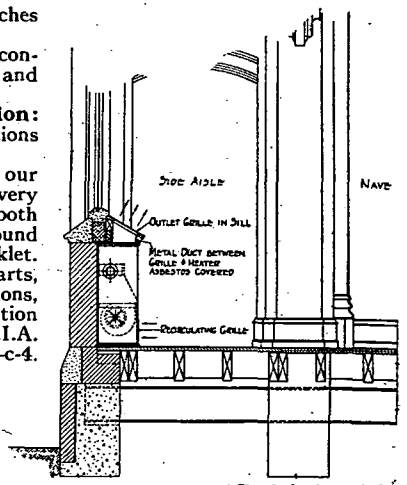
Temperature Control: Simple and effective control of room temperature by means of making and breaking electric contact in line to motor.

Less Expensive to Install than Direct Radiation: Piping system simplified and number of connections reduced, effecting a saving in labor and material.

Sizes of Heaters: The charts on page 14 of our Publication No. 209 give the heating capacity, air delivery and temperature rise for both types. Dimensions will be found on page 15 of the same booklet. For capacity these charts, dimensions, typical installations, etc., send for our Publication # 209, A.I.A. File # 30-c-4.



Typical Installation, Horizontal Type Universal Unit Heater



Detail from transverse section of Church showing typical Universal Unit *Installation.*

.3.

Nesbitt Concealed Radiators

These modern radiators of light-weight, copper-fin construction are now available in a great variety of sizes, types and styles suitable for installations in residential, commercial, public or community buildings.

The heating element is the strong, all-copper, Multifin Radiator, described in preceding pages. The cabinets or enclosures are durable, good looking and easy to install. The combination makes complete apparatus ready to install without extra materials or troublesome details.

Nesbitt Concealed Radiators are available in any of the following types:

Walled-in Radiators, completely hidden in the wall construction.

Flush-panel Radiators, fully recessed, and having removable metal fronts.

Partly-recessed Radiators, for use where building walls will not permit depths of recess sufficient for complete concealment.

Floor and Wall Cabinets, exposed in rooms and installed in a similar manner to ordinary cast-iron radiators.

Any type of Nesbitt Concealed Radiator may be arranged for Face Discharge or Top Discharge of warmed air to the room. Where draperies or other decorations are in the path of rising heated air, Face Discharge types are preferred. For radiators installed with discharge through window sills in commercial, school, church and other buildings where draperies are not a factor for consideration, the Top Discharge types are desirable.

Available sizes of Nesbitt Concealed Radiators are printed on the following page.

How to Select Nesbitt Radiators:

Assuming that the required square feet of equivalent of direct radiation for each proposed location has been determined according to usual practice and reliable data and formula, it is then necessary to select sizes of Nesbitt Concealed Radiators from the tables.

The selection in each case will be a Nesbitt radiator not less in square feet rating than the figured requirements and one which will best fit the width, length and height of the recess or other space at the proposed location. It should be borne in mind during this selection that the nominal or casing dimensions W, L and H

are not extreme dimensions of outside grilles or panels. Small additional dimensions of an inch or two must be allowed for actual installations.

The choice of type,—Walled-in, Panel, Partly Recessed or Cabinet—depends upon the thickness of walls or partitions and what part of the wall, if any, can be taken for recesses. Of the two completely recessed types, Walled-in and Panel, the former is usually chosen unless there is special necessity, as in hospitals, medical offices, etc., for complete accessibility of interiors or where the decoration schemes bring about a desire for panel fronts.

Cabinets may be floor or wall type, the choice being made according to the preference between cabinets set on legs and attached to floor or hung by suitable bolts or brackets fixed in the wall construction.

RATINGS FOR NESBITT CONCEALED RADIATORS

These ratings are from condensation tests and are based upon standard ratings of 240 B. T. U. per square foot, PLUS TEN PERCENT for convection heating. The tabular values below are equivalent square feet of direct radiation. They may be converted to standard ratings of 240 B. T. U. per square foot by dividing by the factor 1.10.

Dimensions in this table are measured inside of casings.

Face Discharge		WIDTH = 4¼" (Radiator Width—4") Length—Inches								
Overall Height	Draft Head									
Inches	Inches	16	20	24	30	36	42	48	54	70
20	8	6.0	11.0	14.5	18.0	22.5	27.5	31.5	35.0	45.0
22	10	6.7	11.9	15.8	19.7	24.7	29.8	34.2	38.0	48.4
24	12	7.5	12.9	17.1	21.4	26.9	32.1	36.9	41.0	51.8
26	14	8.2	13.9	18.4	23.1	29.1	34.4	39.6	44.0	55.2
28	16	8.9	14.9	19.7	24.8	31.3	36.7	42.3	47.0	58.6
30	18	9.6	15.9	21.0	26.5	33.5	39.0	45.0	50.0	62 0
36	24	10.7	17.2	22.8	28.8	36.2	43.0	49.8	55.0	70.0
42	30	11.7	18.3	24.4	30.7	38.1	46.5	54.0	59.5	76.5
*48	36	12.7	19.3	25.8	32.5	40.7	49.5	57.8	63.8	82.5
*60	48	13.6	21.4	28.0	34.6	42.5	51.3	64.0	66.7	88.5
*72	60	14.3	23.1	29.7	36.3	44.0	52.8	62.7	69.3	93.5
		WIDTH = 6¼" (Radiator Width—6") Length—Inches								
		16	20	24	30	36	42	48	54	70
20	8	8.5	16.5	21.5	27.0	33.0	41.0	46.5	52.0	66.0
22	10	9.5	18.0	23.1	29.2	35.5	43.8	50.4	56.6	71.0
24	12	10.5	19.6	24.8	31.5	38.0	46.6	54.3	61.2	76.0
26	14	11.5	21.2	26.5	33.8	40.6	49.4	58.2	65.8	81.0
28	16	12.5	22.7	28.1	36.1	43.1	52.2	62.1	70.3	86.0
30	18	13.5	24.2	29.7	38.4	45.6	55.0	66.0	74.8	90.0
36	24	14.9	25.5	31.4	40.3	49.1	60.7	73.4	82.2	97.0
42	30	16.2	26.8	33.1	42.2	52.6	66.4	80.7	89.6	105.0
*48	36	17.5	28.0	34.7	44.0	56.0	72.0	88.0	97.0	110.0
*60	48	18.2	29.0	35.4	45.0	58.0	76.0	91.5	102.0	120.0
*72	60	18.7	30.0	36.0	46.0	60.0	80.0	95.0	105.0	130.0
		WIDTH = 8¼" (Radiator Width—8") Length—Inches								
		16	20	24	30	36	42	48	54	70
20	8	11.6	20.4	26.4	33.6	40.7	47.3	55.0	59.0	76.6
22	10	12.8	21.5	27.5	35.5	43.2	50.7	59.0	64.0	82.6
24	12	14.1	22.6	28.6	37.3	45.8	54.0	63.0	69.0	88.3
26	14	15.4	23.8	29.8	39.2	48.4	57.4	67.0	74.0	94.1
28	16	16.7	24.9	30.9	41.1	51.0	60.7	71.0	79.0	100.0
30	18	18.0	26.0	32.0	43.0	53.5	64.0	75.0	84.0	106.0
36	22	19.4	29.0	36.7	47.7	64.2	71.3	85.0	96.0	119.0
42	30	20.7	32.0	41.5	52.5	69.0	78.6	95.0	106.0	131.0
*48	36	22.0	35.0	46.0	57.2	69.3	85.8	104.0	118.8	143.0
*60	48	23.0	36.2	47.8	60.5	73.2	91 3	110.9	125.4	151.5
*72	60	24.0	37.4	50.6	63.8	77.0	96.8	117.7	132.0	160.0

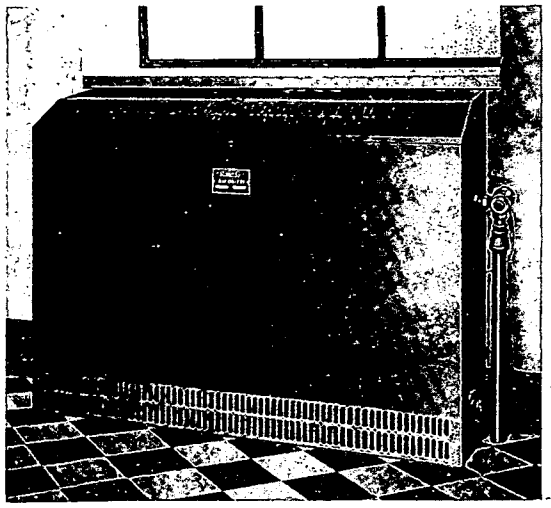
*Radiators higher than 42" are available only for Walled-In types.

The Trane Company

La Crosse, Wis.

See Unit Heaters, pages 666-667; Concealed Radiation, pages 760-761; Heating Specialties, page 824.

BRANCHES IN ALL PRINCIPAL CITIES



The Trane Air-o-lizer brings a new method of controlling the temperature of the ventilated air to school and office buildings, which entirely eliminates drafts and overheating. A varying orifice temperature control valve with the control bulb in the path of the ventilated air supplies just the proper amount of heat to the ventilated air to prevent overheating or drafts. It is perfectly obvious to the engineer that air supplied for ventilation at 50° requires a much smaller amount of heat than air at 0°. While by-pass dampers have to some extent kept the temperature of the room within the desired limits, they have not been able to do it without inducing unheated outside air, even at low outside temperatures, to offset momentary overheating. The Trane Air-o-lizer can never overheat the air or produce drafts as the amount of heat supplied to the ventilated air is controlled by the temperature of the ventilated air and not by room temperatures. The Air-o-lizer is furnished with the control as standard equipment and it is recommended that Trane Temperature Control Valves be installed on any auxiliary convection heaters or radiators in the room. The Air-o-lizer with complete automatic control for the room is in the price range of ordinary unit ventilators without control. If automatic control is contemplated for competitive equipment the Trane installation will generally run at least $100.00 per room less.

The Standard Trane Extended Surface Heating Element is used in the Air-o-lizer—Fans are of the centrifugal type with low tip speed and are noiseless in operation. Motors are standard manufacture. Dry type filters furnished as standard equipment. *Complete catalogs and data will be sent on request.*

Trane Cooling Systems

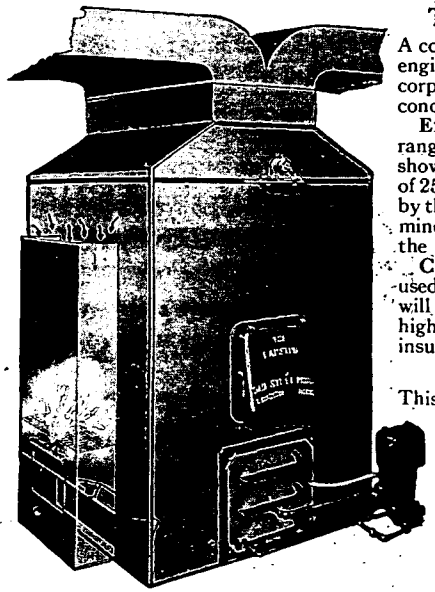
Trane Unit Coolers are available in a variety of sizes and types for every type of cooling problem from residential room cooling to process cooling. It is almost impossible to give complete data on this equipment in this publication but our engineering department will be glad to cooperate with the engineer in working out any cooling problem with which he may be confronted. These unit coolers are available either for water and brine or direct expansion refrigerants.

Catalogs and complete data will be furnished on request.

Dail Steel Products Company

1150 Main Street, **Lansing, Michigan**

Manufacturers of The Lansing Dailaire System of Heating and Air Conditioning for Oil or Gas Burners and Coal Stokers, a variety of sizes up to 750,000 B.t.u. output for homes, churches, factories, stores, garages and etc.



Lansing Dailaire System with casing showing washer on side

The Lansing Dailaire System

A compact heating and air conditioning unit, engineered to modern standards of living, incorporating the latest and best ideas of air conditioning and warm air heating.

Efficiency—The efficiency of these units ranges from 80 to 85 per cent which is best shown by the extremely low stack temperature of 250 degrees as recorded, and is accomplished by the large radiating surface of each unit, the mineral wool blankets and the manner in which the circulated air contacts all rubbing surface.

Chrome Steel—U. S. S. 17 Chrome steel is used in combustion dome, construction, which will withstand temperatures 700 degrees higher than that which affects ordinary steel, insuring a long lived unit.

Conditioned Air

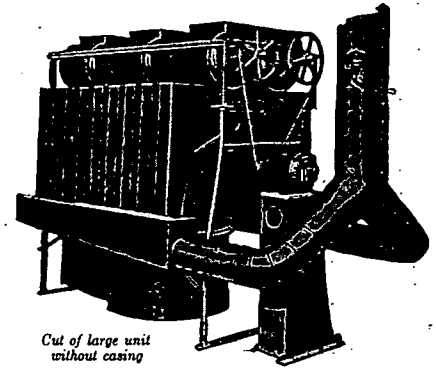
This unit is more than just a heating plant. All circulated air is forced by blower to all parts of home, rendering an even room temperature. Return air is drawn through the air washers on each side of casing and thoroughly cleaned and washed and humidified. In summer the blower and washer unit may be operated as a summer circulating and cooling system. Cooling depending on water and basement temperatures.

Lansing Dailaire Ratings on Oil

Furnace No.	B. T. U. Output on Gravity	Maximum Sq. In. Pipe Area Gravity	B. T. U. Output with Blower	C. F. M. Delivery	Static Pressure	Sq. In. of Radiating Surface
6	85,000	625	115,000	900	1/8	9,735
8	115,000	890	175,000	1800	1/8	11,670
12	160,000	1200	225,000	1800 to 3600	1/8	17,000
18	300,000	2200	375,000 to 560,000	4800 to 7200	1/8	24,400
24	For Blower Use Only		784,000	See Special Fan Information		35,725

Large Dailaire Systems

The fact that these units having been engineered in larger units and the extreme large radiating surface and excellent efficiency makes it possible to heat larger buildings that heretofore were considered steam jobs only. Many Lansing Dailaire jobs are now heating factories, large churches, dance halls, spacious homes costing many thousands of dollars, and are chosen because they deliver more than most heating plants.



Cut of large unit without casing

Engineering Service

On matters pertaining to installations, etc., we will appreciate your consulting our Engineering Department.

Catalogs—Complete literature, information and prices are available at your request.

Carrier-Lyle Corporation

Division of CARRIER CORPORATION

850 Frelinghuysen Avenue, Newark, N. J.

District Sales Offices

East Orange, N. J.	626 Central Ave.	Chicago, Ill.	Burnham Bldg.
New York, N. Y.	50 East 42nd St.	Albany, N. Y.	51 State St.
Pittsburgh, Pa.	1504 Clark Bldg.	Detroit, Mich.	6535 Third Ave.
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Cleveland, Ohio	1824 Union Trust Bldg.		

CONSULT LOCAL TELEPHONE DIRECTORY

AIR CONDITIONING SYSTEM FOR HOMES IN WINTER

THE CARRIER WEATHERMAKER

The Carrier Weathermaker is a compact, self-contained gas fired unit; clean, efficient, quiet, and economical to operate. It *warms* the air, *controls the temperature, maintains automatically the proper humidity* for health and comfort, *cleans the air* of floating dust particles, ridding it of germs. It distributes this cleaned, warmed, humidified air under pressure throughout the home.

This System is not an attachment for the present heating plant or an individual type unit, but a complete system of Winter air conditioning in homes and for small commercial buildings.

Regulates Both Temperature and Humidity Automatically

The Weathermaker System for homes is the result of five years' research by Willis H. Carrier, of the Carrier Engineering Corporation, and engineers associated with him to adapt to residential use in winter the principles of Manufactured Weather which were first developed and applied to industry and later to stores, theatres, offices and public buildings.

For more than three years these systems have been in use in homes throughout the country. Today Manufactured Weather for the home in winter may be considered an actual proven fact.

The most important feature of the System is its ability to regulate automatically *both* temperature and humidity and at the same time provide for their manual control at the will of the home owner.

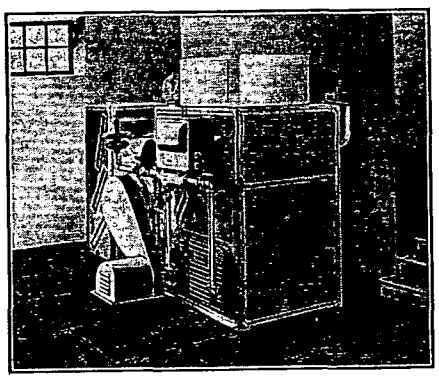
Two instruments on an attractively finished wall panel do this. A temperature control operates like a standard thermostat. Humidity control is obtained by moving an indicator which causes the Weathermaker to carry out the owner's desires for more or less moisture in the air.

The forced distribution of air in the Weathermaker System makes for a compact arrangement of ducts. This, in addition to the saving caused by the elimination of fuel storage facilities, allows the architect to convert the basement into a usable part of the house.

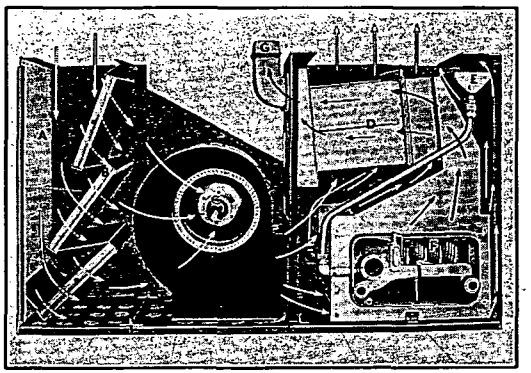
Of even more value is the space that can be saved upstairs. Inconspicuous grilled openings for the conditioned air are provided flush with walls and may be painted to harmonize with the decorative scheme of the room. With this System the full artistic effect of fine paneling and woodwork is obtained.

Every Weathermaker System is laid out and installed under direct supervision of company engineers cooperating with the consulting engineer and architect. Each installation is studied as an individual case and planned according to the particular operating problem involved.

In the near future the Weathermaker System will be adapted for Summer cooling by the addition of special equipment now under development.



Exterior View of Carrier Weathermaker



Sectional View Showing Details of Carrier Weathermaker Construction

A. Opening connected to duct through which air is drawn from house.

B. Filters through which air passes, removing dust, dirt and impurities.

C. Blower operated by electric motor, which draws air in and then passes it over and around the outside of heating sections (*D*).

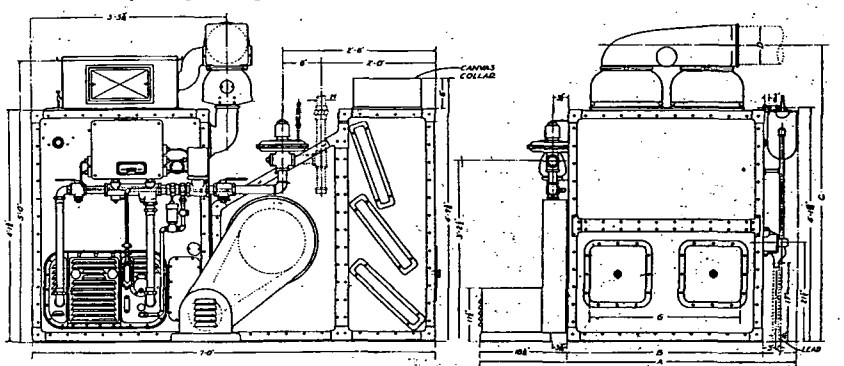
D. Heating sections warmed by gas, which transmit heat to the air.

E. Vaporizer containing water which supplies moisture at the point where the clean warmed air leaves the Weathermaker unit. The temperature of this water is maintained by a separate gas burner connected to a hygrostat upstairs by which the amount of humidity is regulated automatically.

F. Gas burners which supply heat to sections around which the air travels. The combustion chamber and gas passages through the heating sections are totally separate from the air travel.

G. Exhaust for waste gases which is connected to the chimney.

After the air is cleaned, warmed and humidified it enters a system of ducts taken off from the top of the unit above the heat interchanger and is distributed to the rooms.



DIMENSIONS

No. Weathermaker	Over-all Length, Ft.	Over-all Width A, Ft.-In.	Height to Center of Flue Connection C, Ft.-In.	Flue Diam. D, In.	Return Air Opening, In.	Air Discharge Opening, In.
301	7	4–1	5–3⅜	6	14x16	24x12
302	7	4–6½	5–3⅜	8	14x24	24x18
303	7	5–6⅛	5–4⅝	8	14x32	24x24
304	7	5–11⅝	5–4⅝	10	14x40	24x30
305	7	6–6⅜	5–4⅝	10	14x48	24x36

RATINGS

Output B.t.u. per Hr.	Motor Hp.	Gas Supply, In.	*Gas Consumption Cu. Ft. per Hr.	Shipping Weight, Lb.
100,000	⅛	1¼	220	2300
150,000	¼	1¼	330	2500
200,000	⅛	1½	440	3100
250,000	⅛	1½	550	3300
300,000	½	2	660	3700

*Based on 550 B.t.u. gas with 3½ inches water pressure at the regulator.

The General Iron Works Company

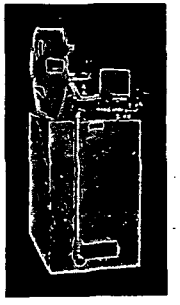
Cincinnati

SALES AND SERVICE information from any gas company.
DIRECT FACTORY REPRESENTATIVES in principal cities.

Hot-Kold was the forerunner of many of the forced air-direct fired air conditioning systems. The first units, built and installed eight years ago are still giving their owners the kind of service that causes them to write us that "Mr. Blank wants a heating system like mine."

Eight Years of intensive improvement and development work have improved the product, brought out the best methods of installation, and built a sales and service organization comprising basically the more important Public Utility Companies of the country. Most of these have a select list of approved local installers who are competent as regards both financial responsibility and physical equipment to undertake jobs of any size.

We Considered this ground work necessary before it should be offered to the Architect and Engineer. You may now specify it freely for residences, schools, detached buildings of the long rambling type of architecture, industrial plants, and structures of a similar character.



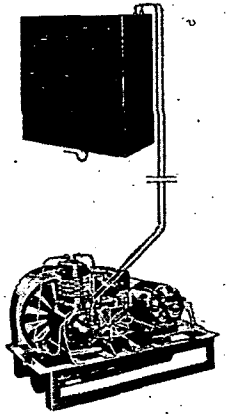
HOT

The Unit System

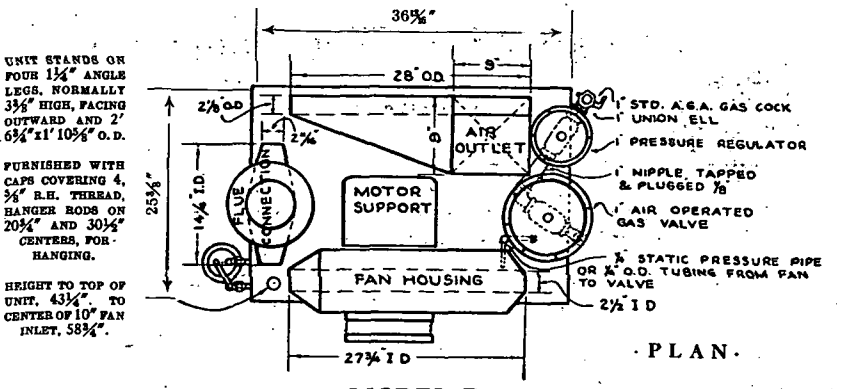
is invariably used excepting in very small residences, grouping the rooms according to their usage, each group having its own thermostat.

Hot-Kold is exactly what the name implies, the **Hot** side consisting of a gas burning heat exchanger through which air is driven by a fan, and automatically controlled.

The Kold side consists of a unit to fit, developed by engineers of The Frigidaire Corporation after years of tests. This is a simple section of heat exchanger surface and an automatically controlled refrigeration compressor. This unit is sold and installed by the Frigidaire Corporation which maintains 24 hour a day service in all principal cities.



KOLD



MODEL B

Gas input—90,000 B.t.u. hourly.
Heat output—84,500 B.t.u. hourly.
Weight, crated—1000 lbs.
Dimensions — actual working drawings herewith.
Fan capacity. C.F.M.*
Motor H.P.*

*Various fans and motors are furnished dependent on the duty of the unit. Generally, these are ⅛ H.P. constant speed with air deliveries up to 625 C.F.M. and ¼ H.P. variable speed, with air deliveries from 600 to 865 C.F.M. Fans are always spring floated, direct connected, backward curve, multiblade type.

Heater, filter, cooler and compressor are furnished as four independent units, to be located as desired, which permits best economy of space occupied.

The Present Known Requirements of Perfect Air Conditioning

AIR MOTION — Overhead high velocity introduction toward cold wall provides thorough mixing with room air. This settles into the breathing zone and returns without objectionable draught to recirculation grilles.

HUMIDITY — Water from fire, literally. Once set, the rate of moisture addition will never vary. Total amount added depends on time of operation.

CLEAN AIR — Filter medium is the most efficient dry type. A woman can change it in five minutes.

TEMPERATURE CONTROL — Automatic dual speed absolutely eliminates the usual time lag. A complete cure for "Cold 70."

NO ODORS — All welded construction. No leaks possible. Air is warmed by passing heating surfaces at such high velocity as to prevent scorching suspended matter.

The Equipment Must Have These Characteristics

LONG LIFE — Heat exchanger section made of 16 ga. Chromium (stainless) steel. Various estimates of corrosion rates set probable life at 50 to 100 years.

ECONOMY — Unquestionably the most efficient vented gas unit made today.

RELIABILITY — Two service calls from 100 units, winter 1929-30, Cincinnati.

SIMPLICITY — The complete absence of "trick gadgets" has been favorably commented upon by hundreds of engineers.

SAFETY — Approved by *A. G. A.* Testing Laboratory, and in many ways, far improves upon the Laboratories requirements.

Most of the above features are covered by HOT-KOLD patents and patents pending. Model 2-B, a larger unit, will be in production by January 1. Send for complete *A. I. A.* file which includes Specification and Data Sheets.

Leader Boiler and Heater Company

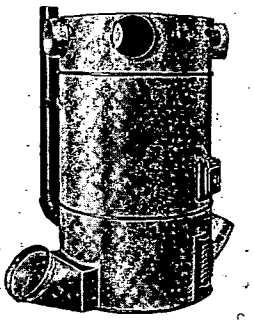
176 West Adams Street, **Chicago, Illinois**

"THE KOOLSTACK LINE"—Oil and Gas Fired Domestic Heating Boilers; Oil and Gas Fired Industrial Boilers; Oil and Gas Fired Warm Air Furnaces; Economizers for Oil Burners; Koolstack Air Conditioner.

SUMMERAIR FURNACES—For Oil or Gas

With the idea firmly in mind, that a successful heating unit is the one especially designed for the purpose for which it is to be used, this company has had extremely successful experience with the Koolstack line of Steam and Hot Water Boilers, fired with gas (either natural or manufactured) or fired with oil.

The Summerair Furnace, aside from the casing, is a complete steel unit, electrically welded at all joints and free from any possibility of gas leaks. The furnace itself has been raised from the floor to allow the utmost circulation of air. Because of their ease of installation they can be selected for replacement work as well as for new jobs.



Summerair Furnace equipped with gas burner

Other outstanding features of Summerair Furnaces follow:

The counter-flow principle of heating the cold air in the tubes and around the economizer section.

Equipped with our patented automatic chimney temperature control damper.

Scientifically designed and laboratory tested to present a minimum resistance to the natural flow of cold air through the unit.

Entire design is circular in type, providing unrestrained heating action and easy installation of furnace outlets.

Casing is provided with a radiant plate which greatly reduces casing loss.

Can be furnished with Blowers, Filters and Humidifiers.

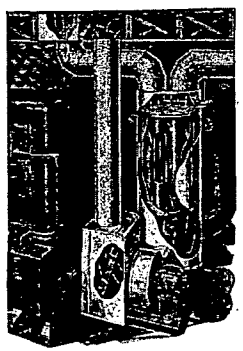
Summerair Furnaces are made in three models. Heating surfaces from 83 sq. ft. to 108 sq. ft.; casing diameter from 36 in. to 44 in.; number of tubes from 8 to 12; height of flue cap 59 in. to 61 in. Send for bulletin giving full data.

"KOOLSTACK"—Air Conditioner

Koolstack Air Conditioner has been designed to meet a demand for an economical, serviceable and efficient home air conditioning installation for steam, vapor or hot water boilers and warm air furnaces, when converted from coal to oil burning.

Koolstack Air Conditioner consists of four sub-units combined into one installation. Each unit has been already proved efficient and the combination has been tested thoroughly under actual working conditions.

The Koolstack Air Conditioner has been developed with a combination of appliances for utilizing the waste heat which would otherwise pass up the stack, filtering the air content and providing humidification with mechanical circulation.



Koolstack Air Conditioner

The unit can be installed on any existing oil burning plant without inconvenience or interruption in service. It occupies very little space, needing a floor space twenty inches by forty inches only. If more space is available the blower and filter cabinet can be installed as illustrated or it may be suspended above or near the heating plant.

Specifications

Economizer—Casing, Diameter, 20". Casing Height, 58". Economizer Section Diameter, 16". Economizer Section Height, 48". Tubes, Seven, each 4" in diameter. Flue Connection, 10". Fifty sq. ft. of heating surface. Will deliver 20,000 to 40,000 B.t.u. per hour depending upon the temperature and volume of flue gases. Upper head is Cast-Iron and acts as Vaporizing pan.

Blower—Type, 4" x 8" Multi-blade. Motor, Standard ⅙ horse power, 60 cycle, 1140 R.p.m., capacity about 700 cubic feet per minute. With 1750 R.p.m. capacity 1100 cubic feet per minute. Other than Standard motor at extra charge according to manufacturer's prices.

Filter—Oil Type, 16" x 25". Capacity, 800 cubic feet per minute.

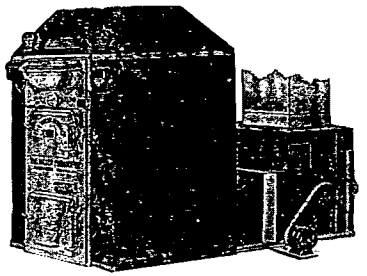
Humidifier—Furnished with an adjustable valve, four feet of ¼" copper tubing, connector for ½" or ¾" water pipe and main shut-off valve.

THE MEYER FURNACE COMPANY

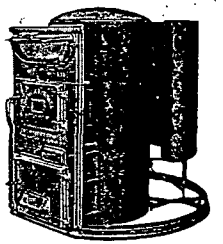
PEORIA, ILLINOIS

Manufacturers of Domestic Heating and Air Conditioning Units for Coal, Gas and Oil Burning

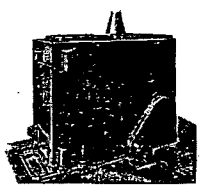
Branches and Distributors
KANSAS CITY, MO.
OMAHA, NEB.
GREEN BAY, WIS.
PITTSBURGH, PA.
NEW ORLEANS, LA.
DETROIT, MICH.
ST. LOUIS, MO.
SAN FRANCISCO, CALIF.



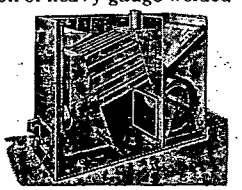
The Weir Conditioned-Air Unit for coal or oil burning, with the Weir Steel Furnace as its basis, is, as its name implies, a complete unit for conditioning the air in the home with respect to temperature, humidity, and air-cleansing. Casing is double-walled and finished in blue crinkle. Equipment includes thermostatic draft and damper regulator with limit control, automatic humidifier, air filters and centrifugal blower for mechanical circulation, with bonnet control. (Refer to table below for data on installations for gravity as well as mechanical circulation.)



No.	Grate Surface (Sq Ft.)	Ratio Htg. to Grate Surface	Smoke Outlet Diam. (In.)	Gravity Circulation				Fan Circulation		
				Casing Dimen.		Rated Output		Casing Dimen. (In.)	Air Delivery (C.F.M.)	Rated Output at register (Btu/Hr.)
				Round (In.)	Rect'lar (In.)	At Reg. (Btu/Hr.)	Pipe Area (Sq. In.)			
621	1.26	41.2	9	48	....	54,400	400	....	....	....
624	1.78	33.9	10	52	51x49	73,600	541	51x102	1200	92,000
628	2.32	29.2	10	54	55x51	94,100	692	52x103	1600	118,000
630	3.08	26.4	10	58	61x57	119,000	875	54x111	2000	148,000
633	3.82	22.7	10	65	61x63	138,000	1015	57x117	2300	172,000
636	4.74	19.4	10	67	61x66	160,000	1180	57x123	2700	200,000
540	6.25	19.3	12	..	....	.....	....	60x106	4000	264,000
544	7.60	18.5	12	..	....	.....	....	64x114	5000	316,000



The Meyer Gas Fired Air-Conditioner automatically provides complete "conditioned-air." It is as attractive in appearance as it is compact and efficient. Heating section of heavy gauge welded steel, gas- and fume-tight construction; casing thoroughly insulated and finished in blue crinkle. Equipment also includes specially designed automatic humidifier (which may be provided with room control if desired), renewable filters, centrifugal blower with bonnet control, motor gas valve, gas-electric safety pilot with hand valve, pressure regulator, hand shut-off valves, and draft hood.



No.	Output at Bonnet (Btu/Hr.)	Input at Burner (Btu/Hr.)	Gas Consumption		Air Delivery at ½" S.P. (C.F.M.)	Motor Size (HP).	Vent. Diam. (In.)	General Dimensions			Approx. Shipping Weight (Lb.)
			Natural 1000 Btu (C.F.H.)	Mfd. 550 Btu (C.F.H.)				Width (In.)	Length (In.)	Height (In.)	
1-B	72,500	88,000	88	160	1000	1/6	4	20½	52	42	600
2-B	145,000	176,000	176	320	2000	1/3	7	41	52	42	1100
3-B	217,500	264,000	264	480	3000	½	8	61½	52	42	1600
4-B	290,000	352,000	352	640	4000	¼	9	82	52	42	2100
5-B	362,500	440,000	440	800	5000	¾	10	102½	52	42	2600

Data on refrigerating equipment for summer cooling, to be used in conjunction with any of the above mechanically circulating systems supplied upon request.

Motor Wheel Corporation

HEATER DIVISION

701-735 E. Saginaw Street, **Lansing, Michigan**

UNIT HEATING, VENTILATING AND AIR CONDITIONING FOR HOMES

THE M-W WEATHER CONTROL UNIT

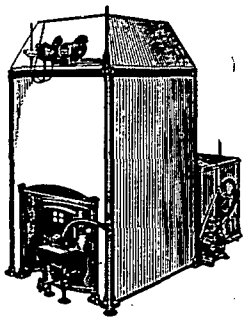
General Description and Use

The M-W Weather Control Unit is a *Unit* Oil Burning, Heating, Ventilating and Air Conditioning System for Homes in winter, and in summer an air circulating and ventilating system.

Automatic Control of Heat, Humidity and Air Circulation

The Weather Control Unit's oil flame is controlled from a convenient location in the living quarters by a Minneapolis-Honeywell thermostat which also controls the forced air blower. Humidity requirement increases with a rise in temperature and decreases with a fall in temperature. Therefore, a thermostatic valve in the humidifier water supply line is used to control evaporation.

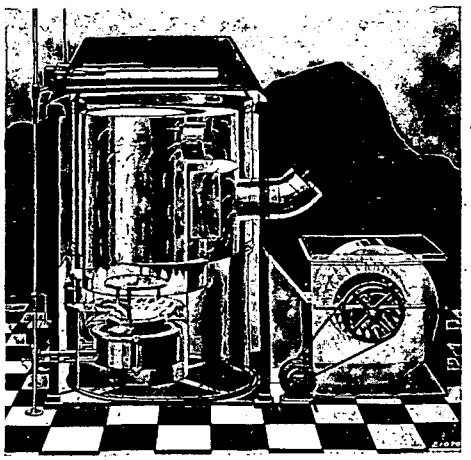
FEATURES



Efficiency and Construction

A maximum number of heat units from the oil burned are made available for heating the rooms because of five *highly important* factors in M-W design:

1. The Heat Chamber is designed to utilize a maximum number of heat units released by the M-W Burner.
2. The Burner is likewise designed for the M-W Heat Chamber alone.
3. The Burner *is installed in the Heat Chamber at the factory.*
4. A continuation of the economizer inner shell completely encircles the main drum and gives additional radiation surface from which heat units are picked up by the efficient Blower scrubbing action.
5. A Double Outer Casing minimizes basement loss.



Models

M-W Weather Control Units are available in Three Models representing a size and price range from small six room houses up to homes of about fourteen rooms. Batteries of two and more have successfully been installed in very large homes.

Underwriters' Approval

All units are Listed and Labeled by the Underwriters' Laboratories. *Ratings* are guaranteed.

Technical Description

A. Combination Blower and Burner Limit Control.
B. Automatic Humidifier.
C. Welded Steel Heat Chamber.
D. Flue Connection.
E. Burner Control.
F. M-W Patented Burner.
G. Air Circulating Blower.

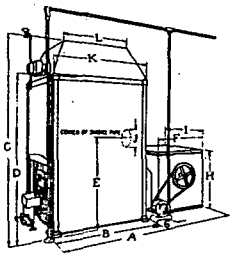
SPECIFICATIONS

General Dimensions

SQUARE

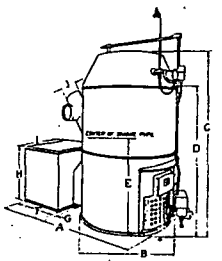
Dimensions in Inches

Model	A	B	C	D	E	F	G	H	I	J	K	L
307		Not Available in Square Casing										
308	77	41¼	73	58½	37	26	8	28¼	30	8	39	27¼
305		Larger Unit—Write Factory for Data										



ROUND

Dimensions in Inches



Model	A	B	C	D	E	F	G	H	I	J	K
307	70	37½	70¼	56	34½	23½	7½	24	26	8	
308	74	41½	70¼	56	37	27½	7½	28¼	30	8	
305		Larger Unit—Write Factory for Data									

RATINGS and DATA

Model	Maximum B. T. U. Output	Oil Consumption Gals. per Hour Maximum	Blower Motor H. P.	Flue Diameter	Oil Connection	Minimum Return Air Opening	Free Air Area	Warm Air Pipe Area*
307	96,000	1	1/6	8"	¼	300 sq. in.	373"	533
308	144,900	1½	1/6	8"	¼	350 sq. in.	435"	799
305			Larger Unit—Write Factory for Data					

*This is based on Standard Code Rating for Warm Air Furnaces and is used only as a basis for comparison. Warm air basement pipe areas in mechanical systems should never exceed 60 per cent of Standard Code areas.

Catalogues

Detailed catalogues, descriptive literature and operating instructions on request.

PAYNE FURNACE & SUPPLY CO. INC.

336 NORTH FOOTHILL ROAD, BEVERLY HILLS, CALIFORNIA

MANUFACTURERS OF GAS-FIRED WARM AIR HEATING SYSTEMS

Jobbers and Dealers in Nearly All Principal Cities

PRODUCTS—

Payne Unit Gas Furnaces, Payne Floor Furnaces, Payne Duplex Register Furnaces, Payne Suspended Furnaces, Payne Central Gas Furnaces, Payne Heavy Duty Gas Furnaces and Payne Console Room Heaters.

Payne Engineering Service

Our engineers are prepared to study any heating problem and submit layout specifying the type of equipment and method of installation that will give the desired results. Communicate direct with the Factory or through your nearest Gas Company, Payne Jobber or Dealer.

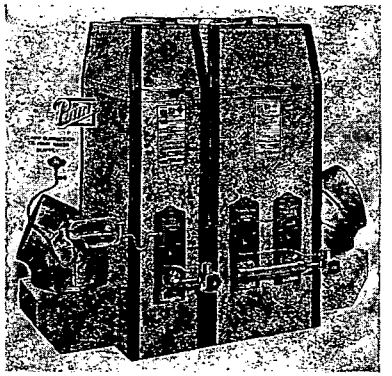
TYPES OF BUILDINGS

Residential, such as one, two and three story houses, duplexes, flats, apartments and small hotels; **Commercial,** such as stores, offices, banks, cafes, restaurants, clubs, ballrooms, flower shops, garages, airplane hangars, warehouses, lofts and packing plants; **Industrial,** such as shops, foundries, factories and all manufacturing establishments; **Public Buildings,** such as one- and two-story schools, colleges, hospitals, sanitariums, churches, auditoriums and government offices.

VENTS

All Payne Gas Furnaces are designed and built to provide separate air-sealed passages for the products of combustion which are carried out of doors through a properly installed gas vent or flue.

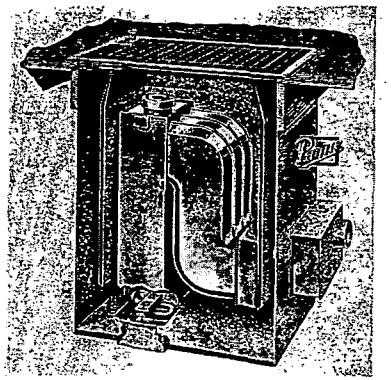
Payne Unit Furnaces



Basement-type multiple furnace system for heating medium and large size residences. Each room or natural group of rooms is connected by heat pipes to its own independently controlled furnace. Greater heating efficiency due to shorter pipe runs, since furnaces may be located singly or in batteries. Extreme saving in fuel, because furnaces are turned on one at a time in various rooms as needed. Cold air return is provided in accordance with local climatic conditions and building requirements. Furnished with electric push-button, room thermostat or manual control. Write for Bulletin No. 3.

Payne Floor Furnaces

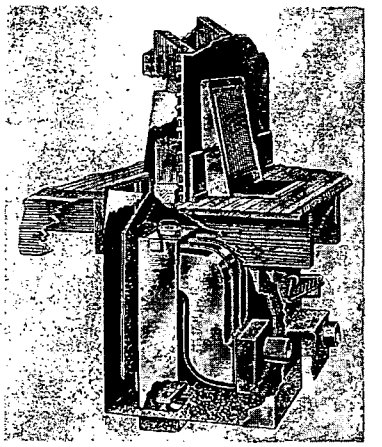
Easily installed circulating warm-air plant for heating single rooms and two or three room combinations connected by arch or corridor in one story buildings without basement. Floor register and furnace are combined in one compact unit. Furnace sets in floor opening and is hung from joists under the house, taking up no room space. Register is machine-finished cast-iron, made in two sections. The removable center section is directly over the heating element and admits warm-air to the rooms. The outer section admits cool air off the floors to the furnace. Constant gravity air circulation through the furnace is assured by a double wall inner casing between the heating element and outer casing, which prevents heat from radiating



into the outer cold air passages. Also useful during fall and spring as auxiliary to large central system. Write for Bulletin No. 4.

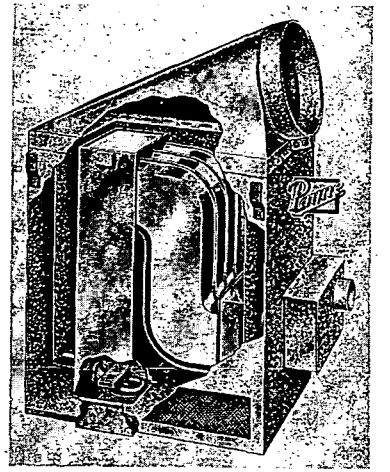
Payne Duplex-Register Furnaces

Same as Floor Furnace, but furnished with double register box for partition between two adjacent rooms. Double register is heavily insulated with air cell asbestos covering. Female collar and cleats in top of register box permit connecting riser for heating upstairs rooms. Furnace is hung from joists under the house, directly below the double register box. If register valves are used, at least one register must be valveless to avoid all registers being closed at one time. Duplex-Register Furnaces solve many difficult heating problems in one- and two-story single and duplex dwellings. Write for Bulletin No. 5.



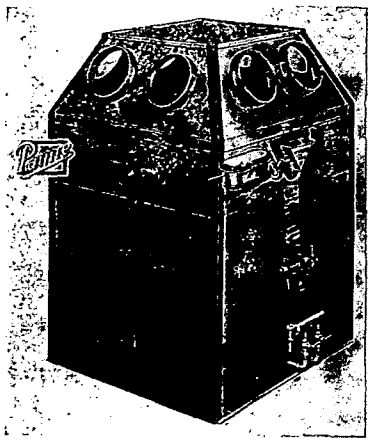
Payne Suspended Furnaces

Same as Floor and Duplex-Register Furnaces, but have transition top with draw-band collar and no registers. May be connected to first floor registers or second floor riser by means of boot. Brackets on outer casing permit suspending furnace from floor joists by means of wire or iron straps. Screened openings are



provided in the sides of the furnace for taking in cold air under the house. Cold air return ducts may be installed, however, if necessary. A single wall inner casing entirely around the heating element prevents radiation losses through the outer casing. Suspended Furnaces successfully meet practically any heating problem in multiple dwellings, such as one- and two-story single and double residences, flats, apartments and smaller hotels. They provide all the advantages of unit heating, without the expense of excavating and entirely eliminating long leader pipes from the furnace to individual suites of rooms. Write for Bulletin No. 11.

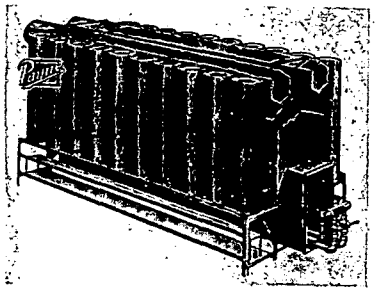
Payne Central Furnaces



Large heavy-duty basement type furnaces for heating medium and large size buildings where the problem of heat delivery to individual room registers is not complicated and unusually long warm air pipes are unnecessary. Central furnaces are furnished with casing and bonnet which may be cut for cold air return and heat pipes as required by individual jobs. Furnished with electric push-button, thermostat or manual control. Write for Bulletin No. 6.

Payne Heavy-Duty Furnaces

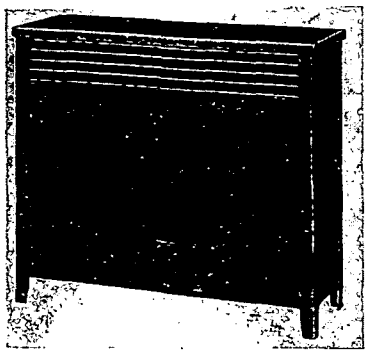
Large special furnaces, furnished with or without casing for built-in heating and ventilating installations in theatres, churches and large auditoriums. Furnished with or without controls. Write for Bulletin No. 8.



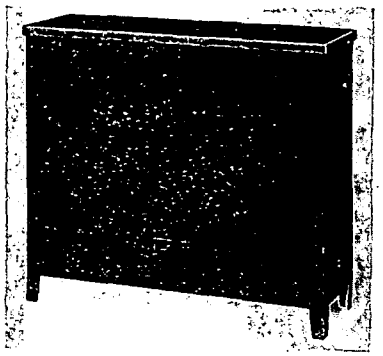
Payne Console Room Heaters

Cabinet-type warm-air circulators for residential, commercial, school and certain industrial installations. Provide complete warm-air circulation through air-sealed heating elements and elimination of disagreeable gas fumes and odors through a vent. Down-draft diverter is built into vent manifold, permitting heater to be placed closer to the wall. Air space around inner casing keeps outer casing cool. Baked and processed antique walnut crinkle finish. Furnished in two styles. Write for Bulletin No. 10.

New Standard Console—with louvers for discharging heat through opening in front of heater.



Open

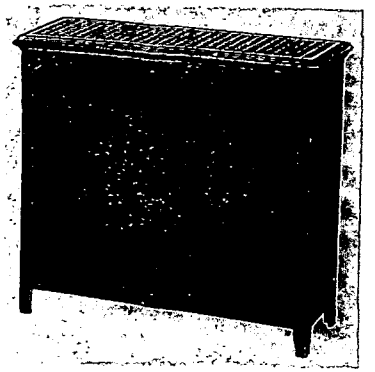


Closed

(Gas cannot be turned on when heater is closed)

Top Grille Console

With one-piece, square lattice grille in top of heater. Top grille is finished in statuary bronze.



Payne Construction Features

All Payne Furnaces and Heaters are the gas-fired warm-air circulating type. Heating elements and fire boxes are all-welded, gas-tight construction, made of pure, rust-resisting ingot iron, the best obtainable. Heating element radiators are provided with widest possible "wiping" areas to insure fullest utilization of heat units in the fuel being used and are curved, tapered and beveled in a manner to completely eliminate "buckling" noises during rapid expansion and contraction. Design also eliminates "air pockets" where moisture might collect and cause rust and corrosion —thereby lengthening the serviceable life of the furnace considerably. Burners are scientifically designed for each furnace to give the proper balance between heating efficiency and economy. The flame never impinges upon the walls of the firebox, avoiding burn-outs. Outer and inner casings are so constructed that radiant heat is reduced to a minimum and a constant and uniform circulation of air through the furnace is maintained at all times, whether the burner is operating on Low, Medium or High Heat.

Control Systems

Payne Gas Furnaces are furnished with various types of controls as ordered. Control valves and other equipment for electric push-button or thermostat assemblies are furnished at extra cost.

Manual Control

Provides standard gas manifold and means for turning on or shutting off the furnace by a valve, key or dial and chain.

Electric Push-Button Control

Provides standard gas manifold with connection for four position electro-magnetic Control-O-Gas valve (High, Medium, Low and Off) for remote control by means of single or multiple switch plates conveniently located. Standard **"Valve Package"** assembly provides Control-O-Gas Valve, a dull brass wall switch, transformer, necessary wiring and wiring diagram. Switch plate can be furnished in Bakelite or any other material on special order. Multiple or "gang" switches (with or without clock attachments) are available for selective control in multiple unit furnace installations.

Automatic Heat Regulation or Thermostatic Control

Provides standard gas manifold with connection for thermostat valve for turning the furnace on or off automatically, thus maintaining a predetermined temperature without any attention whatsoever. Standard **"Thermostat Package"** assembly includes a single position magnetic control valve, Minneapolis Tel-O-Stat, transformer, necessary wiring and wiring diagram. Any other standard make of thermostat will be furnished if desired. Thermostat controls are furnished with or without clock attachments.

Automatic Pilot Valve

Is recommended and furnished when ordered, for automatically shutting off the main gas supply in the event the pilot should become extinguished due to interrupted service.

Automatic Humidifying Water Pans Are available at additional cost

Payne Gas Furnaces may be equipped with booster fans and other accessories for combined heating and ventilating work as determined by individual job specifications.

ENGINEERING DATA

Please write us if you desire any special information, capacity data or specific recommendations regarding any particular warm air heating installation.

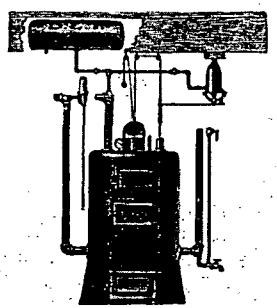
Payne Gas Furnaces are built to give perfect and lasting satisfaction under both Eastern and Western climatic conditions.

D. & T. Manufacturing Company

St. Louis, Mo.

AUTOMATIC HOT WATER HEATING SPECIALTIES

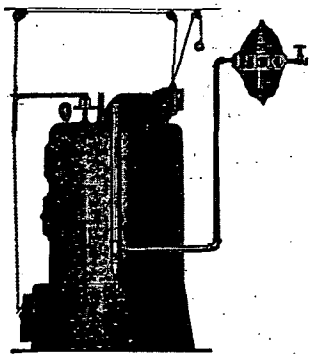
D. &. T. Original Tank-In-Basement System



The D. & T. original Tank-in-Basement Self-Regulated Hot Water Heating System.

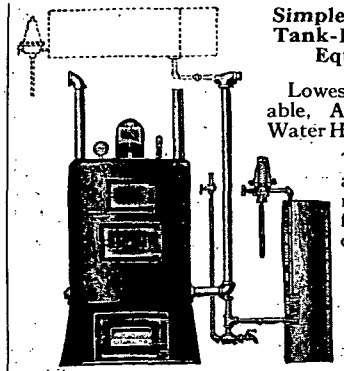
Economical, efficient and durable.

D. & T. All-In-One System



A reliable, self-contained Closed System.

Operates entirely automatic either without or with Expansion Tank.



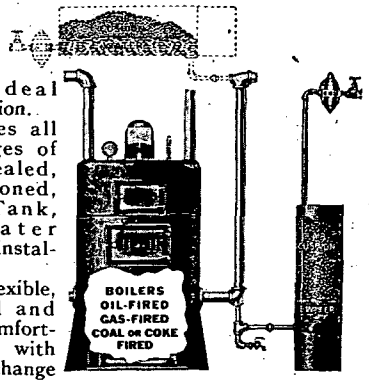
Simplex Air-Sealed Tank-In-Basement Equipment

Lowest cost, dependable, Air-Sealed Hot Water Heating System.

Tank is standardized and may be set on floor or hung on Ceiling.

Self-Filling Air Cushioned Tank Equipment

Especially Built for Oil-Fired and Gas-Fired Boiler



The Ideal Combination.

Includes all advantages of an air-sealed, air-cushioned, closed Tank, Hot Water Heating installation.

The flexible, healthful and always comfortable heat with varying change in weather.

An automatic control—keeping the System constantly under pressure.

No worry about keeping the plant filled with water.

The special "Self-Filling" feature—with no attention of the owner—automatically adds water—just as it is needed—to the System.

Especially built for Oil-Fired and Gas-Fired Hot Water Boilers. Keeps the water in the System.

Equally adaptable for the solid fuel Boiler.

Combined Catalog and Text Book

The D. & T. "Progress in Hot Water Heating" Catalog in addition to listing, and describing and illustrating our complete line of Automatic Systems and Specialties for Hot Water Heating also **includes 50 Pages of Useful Data** design and standard practice detail, as substantiated and enthusiastically endorsed also by A.S.H.&V.E.

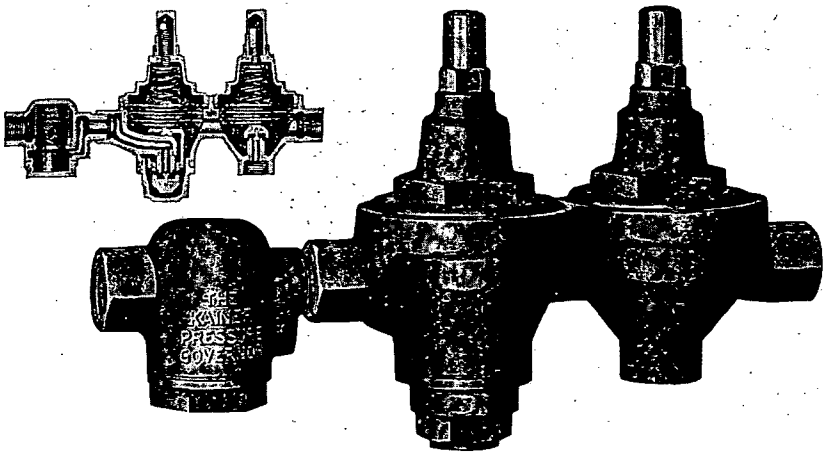
Write Today for Your Copy

Kainer & Company

761-771 Mather Street, **Chicago, Ill.**

KAINER SPECIALTIES

For Hot Water Heating Systems



THE KAINER PRESSURE GOVERNOR

Entirely Automatic Heat Control

Any ordinary gravity hot water job, old or new, equipped with the Kainer Pressure Governor, Kainer Sylphon Hot Water Damper Regulator, and Kainer Pressure Gauge, gives an entirely automatic and fully closed system that maintains uniform room temperatures by controlling the water temperature, effects marked fuel economy and lengthens the interval between firing periods.

The Kainer Pressure Governor is a simple, safe and accurate device for pressure reducing and relief service on any hot water heating system, old or new. It is comprised of two automatic valve units (cast integral) and a filter. One valve unit reduces and governs the water supply; the other valve unit relieves the heating system when excessive pressure due to expansion develops.

Full flow opening in the reducing unit permits very quick filling of the system when first installed.

The Kainer Bellows Diaphragm, of phosphor bronze, is used on both valve units. It contains no material requiring service or replacement.

The entire Governor is of cast or phosphor bronze — rust - proof, scale - proof, trouble-proof. It can be instantly disassembled for inspection.

The Governor is tested at 60 pounds pressure and set at the factory to maintain 10 pounds on the system and to relieve the system when pressure due to expansion reaches 30 pounds.

Diaphragm is sensitive to any set pressure and operates the valve on a differential of one pound pressure or less.

List price Kainer Pressure Governor, complete with instructions for mounting.....$24.00

WRITE FOR BULLETIN 32 SHOWING COMPLETE LIST OF KAINER HOT WATER HEATING SPECIALTIES.

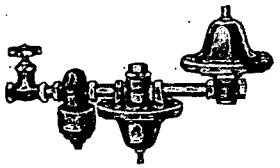
Mueller Co.

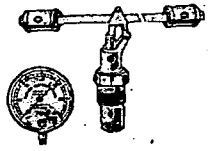
Decatur, Illinois

Branches

NEW YORK SAN FRANCISCO DALLAS CHICAGO

Heating System





H-9500

Service—The Mueller H-9500 Heating System is designed to automatically supply water to hot water heating boilers and to automatically discharge water should the pressure approach a danger point or boiler guarantee. The damper control affords automatic draft with reduced fuel consumption and more even room temperatures. The entire unit lends itself to clean, efficient and safe heating without fear of forgetfulness or carelessness, both of which, as human elements, are destructive and dangerous.

Size—The Mueller Heating System is made in ½" size only and is adapted for any job up to and including three stories in height or comprising less than 15,000 sq. ft. radiation.

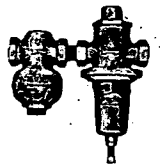
Construction—All valves have removable seats of bronze with special composition seat disc and with phosphor bronze diaphragm, which are extremely resistant to corrosion and high temperature. All valve working parts are of bronze with close fitting joints and without sediment collecting pockets. The large sediment collecting chamber with inverted wire screen basket prevents any particle of sand, pipe scale, or chips entering valves and interfering with their operation.

Engineers and contractors will recognize the dependability of the Mueller Heating System because careful designing as a result of many years experience have eliminated:

(1) Rubber or solder joint in diaphragm; (2) Soft and easily corroded seat disc; (3) Possibility of creating excess pressure; (4) Sediment or lime collecting pockets; (5) Complicated valve mechanism; (6) Corrosive metal working parts; (7) Close fitting guides or guide rings; (8) Working parts which cannot be easily replaced.

The big Mueller Heating System is designed correctly with proper diaphragm area for long and dependable service.

Regulator



H-9000

Service—The Mueller H-9000 Pressure Reducing and Regulating valve is suitable for hot or cold water and air. It is especially adapted for residence, building, apartment and industrial service.

Sizes—¼", ⅜" ½", ¾", 1", 1¼", 1½", 2" and 2½".

Construction—The H-9000 valve is made entirely of brass and bronze. The full seat opening insures a full volume of water even at the reduced pressure.

Valves are regularly stocked for initial pressures up to 250 lb. and delivery pressures from 20 to 75 lb. All valves are set at 45 lb. unless otherwise specified.

Relief Valve



H-9045

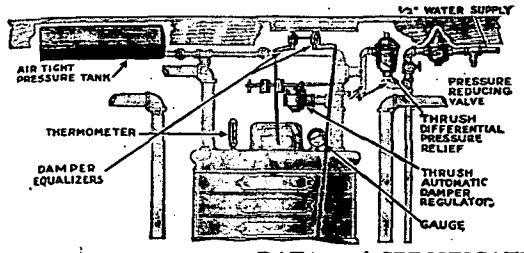
Service—The Mueller H-9045 is designed to relieve dangerous and excess pressures. It is particularly adapted to hot or cold water installations but will serve equally as well on air or oil.

Size—½" size only with ¾" outside thread inlet; ½" inside thread outlet.

Pressure Range—Valves are carried in stock set at maximum relief pressures of 50, 75, 100, 125 and 150 lb. Valves can be supplied set at any pressure between 50 and 150 lbs. upon request. To insure prompt delivery order stock valves.

H. A. Thrush & Company

Thrush Differential Pressure Relief | **Automatic Dual Control Unit** | **Makers of Thrush Systems** Factory and Offices **Peru, Ind.** | **Thrush Electric Water Circulator** | **Thrush Automatic Damper Regulator**



Thrush System comprises equipment to be added to any unregulated gravity Hot Water Heating plant to make it a "Closed System" operating under additional pressure and with automatic control of dampers. It increases heat transmission and reduces fuel consumption. It is made in four types as listed below.

DATA and SPECIFICATIONS

Class AA Equipment consists of Thrush Differential Pressure Relief Valve, Automatic Temperature Damper Regulator, Pressure Reducing Valve, Copper Bearing Steel Pressure Tank and special Gauge and Thermometer. It is automatic filling.

Class A Equipment

This is the same as Class AA Equipment except that it has no Pressure Reducing Valve for automatic filling.

Class BB Equipment

Consists of Thrush Differential Pressure Relief, Pressure Reducing Valve, Copper Bearing Steel Pressure Tank and Special Gauge and Thermometer.

Class B Equipment

Same as above except that it does not have Pressure Reducing Valve for automatic filling.

Sizes

Size No. 0 up to 350 sq. ft. of radiation
Size No. 1 up to 700 sq. ft. of radiation
Size No. 2 up to 1200 sq. ft. of radiation
Size No. 3 up to 2000 sq. ft. of radiation

Automatic Dual Control Unit

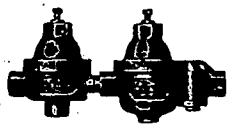


Fig. 2

An inexpensive heating system for competitive job. The Automatic Dual Control Unit may be used for small to medium sized hot water heating plants, easily and economically, by merely installing the Dual Control Unit in the water supply line. Furnished with strainer.

Thrush Differential Pressure Relief



Fig. 3

This valve is designed with large valve area and has a capacity for relieving excess pressure for both large and small installations. The valve seat is submerged in water, so designed that corrosion or sediment accumulation is prevented. It is always Safe. (Tapping ¾ in.).

Thrush Automatic Temperature Damper Regulator

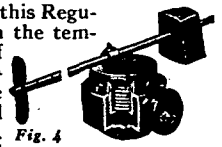


Fig. 4

The operation of this Regulator depends upon the temperature change of the water circulating through the heating system and not upon pressure. Easily installed and very efficient. (Tapping 1½ in.).

Thrush Electric Circulator

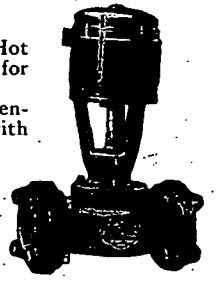


Fig. 5

Here is a method of assuring positive circulation on any Hot Water Heating job. The Thrush Electric Circulator will pay for itself in less than one season in fuel saving.

Highly recommended for oil and gas fired boilers, also for greenhouses, garages, apartments, store buildings, works perfectly with blower units. Cheaper to install than low pressure steam, vapor or vacuum vapor jobs. 110 or 220 A.C. 60 cycle motor for light or power line. Low operating cost. Any type motor shipped from stock.

Tapping	Gallons Capacity	Radiation Capacity	Price
No. 15—1½ inch	15 per minute	1000 sq. ft.	$ 90.00
No. 22—2 inch	30 per minute	2500 sq. ft.	131.25
No. 23—3 inch	70 per minute	6000 sq. ft.	150.00

Woodward Wanger Co.

225 W. Ohio Street
Chicago, Ill.

1106-16 Spring Garden Street
Philadelphia, Pa.

Distributors of

RED TOP RELIEF VALVE

Made by Neptune Meter Company, New York City

PROTECTION AGAINST BOILER EXPLOSIONS

PRODUCTS—Red Top Relief Valve, Model No. 2, the basis of your own closed hot water heating system, and for protecting hot water heating systems against boiler explosions, cracked boiler sections, and other ruptures.

Red Top Relief Valve, Model No. 1, for protecting range boilers, tank heaters, piping and fixtures in domestic hot water supply systems against dangerous pressures.

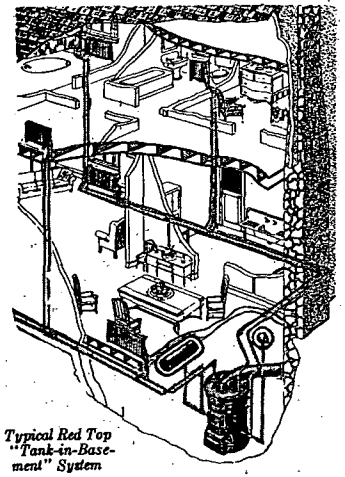
Red Top "Tank-in-Basement" or Pressure System of Hot Water Heating

A No. 2 Red Top Relief Valve, and *any air-tight tank of good make* are the *only two special parts* required for the most efficient, low-cost system of hot water heating.

The illustration shows a typical Red Top System in a two story residence. The air-tight tank—which gives a cushioning effect that promotes rapid circulation—is placed in the basement where it belongs. Since the hot water circulation is more rapid, smaller piping and less radiation surface may be used.

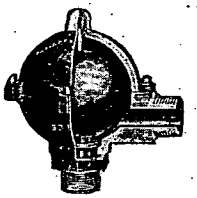
For a "closed" system the following sizes of air-tight expansion tank are suggested:

Up to 500 ft. rad., 15 gal. tank 12 in. diam. x 30 in. long
500 to 800 ft. rad., 21 gal. tank 12 in. diam. x 42 in. long
800 to 1200 ft. rad., 26 gal. tank 12 in. diam. x 54 in. long
1200 to 1600 ft. rad., 42 gal. tank .... diam. .... long



Typical Red Top "Tank-in-Basement" System

Red Top "Tank-in-Basement" Systems Offer These Advantages:



Sectional View, Model No. 2, Red Top Relief Valve

1. No more cracked boiler-sections or costly ruptures due to excessive pressures.
2. No more frozen overflow pipes, or corroded and clogged expansion tank outlets.
3. More efficient heating due to faster circulation of hot water—twice as fast as in old type overhead gravity systems.
4. Water, returning to the boiler at a higher temperature, requires less reheating.
5. Fuel is saved—frequently up to 20%.
6. Less firing—saving labor.
7. Expansion tank is in basement. It does not take up usable space in some other part of house.
8. No waste of water from system. No water can leave until pressure reaches danger point, when water is automatically released by the Red Top Relief Valve.
9. Very moderate in cost. Easily applied when the heating plant is installed.
10. Old systems can be changed over to the Red Top with little trouble and small cost.
11. First, last and *always* a *safe* system—protecting property and life from dangerous rising pressures.

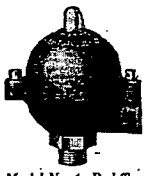
Approved by Underwriters

Red Top Relief Valves, both Model No. 1 and No. 2, are approved by the Underwriters' Laboratories, and by state and municipal bureaus of water and boiler inspection.

In Model No. 2, a special nickel weighted piston is lifted off its seat when pressure reaches 30 lb. No springs, levers, diaphragms or other complicated parts to get out of order. Made for either "open" or "closed" systems.

Model No. 1 for Domestic Hot Water Supply

Protects domestic hot water supply and prevents range boiler explosions. Inlet threaded for standard ½ in. pipe fitting and outlet drilled and tapped for ½ in. connection. Adjustable to relieve at 50, 75, 100 and 130 lb. pressure.



Model No. 1, Red Top Relief Valve

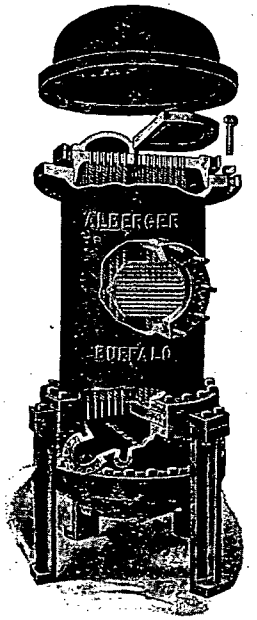
Alberger Heater Company

HOWARD IRON WORKS

281 Chicago St. :-: :-: :-: BUFFALO, N. Y.

REPRESENTATIVES IN PRINCIPAL CITIES

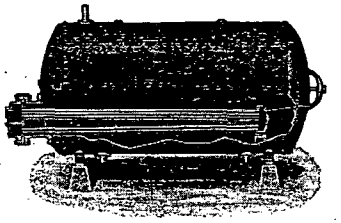
Heaters — Condensers — Coolers — Economizers — Expansion Joints



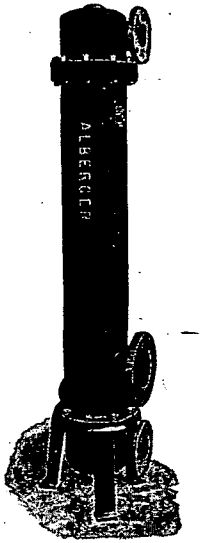
Instantaneous Water Heater Furnished in Vertical or Horizontal Type

Alberger-Buffalo Heaters are built in several types to meet a large range of standard and special water heating requirements. The standard instantaneous water tube type with floating heads is a highly efficient device embodying economy in space and maintenance cost. The storage water heater is used where the steam supply is intermittent or insufficient to take care of peak water demands. The swimming pool heater is especially designed for the purpose and is also extensively used with air washer equipment.

All of these heaters are built in either horizontal or vertical arrangement. **Alberger-Buffalo** equipment is widely used for many special requirements involving the heating or cooling of water and other liquids, and for the interchange of heat from one liquid to another.



Storage Type Heater



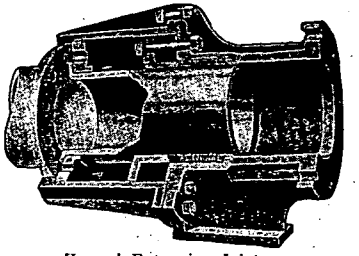
Swimming Pool Heater Single Pass Furnished in Vertical or Horizontal Type

ARCHITECTS ENGINEERS CONTRACTORS

If you have not already done so, send immediately for a copy of the ALBERGER HEATER DATA BOOK which gives complete information regarding capacities and dimensions of our various types, as well as service and installation data. Also remember that our experience in designing and building special heaters and coolers is available to prospective clients.

The Howard Guided Expansion Joint is a most satisfactory means for taking care of expansion in pipe lines because it is designed with only one object in view—100% service. The construction is mechanically correct—deep stuffing box—bronze sliding sleeve—totally enclosed construction to eliminate accumulation of dirt—exterior adjustment of packing gland—ready accessibility when packing is renewed. It is a most economical joint to use because it stays on the job and leaves a satisfied customer.

Send for—Bulletin XJ-5 for full details.



Howard Expansion Joint

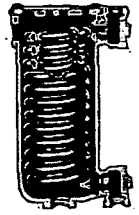
Bell & Gossett Company

3000 Wallace Street — Chicago, Ill.

AIR MAIL SERVICE ON SKETCHES

B & G Indirect Water Heaters

For Steam, Vapor or Vacuum Heating Boilers

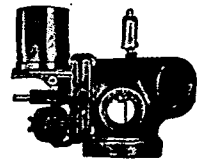


Note Exclusive Removable Coil Feature

Patent Number 1769735

B & G Double Duty Indirect Water Heaters

For Automatically Fired Hot Water Heating Boilers



B & G Double Duty Valve No. 5

And Other Patents Pending — Patent Number 1533630

B & G Indirect Water Heaters

For Steam, Vapor or Vacuum Heating Boilers

Description	Number	Capacity Heater below Water Line Gallons	Capacity Heating Water with Live Steam (5 lbs. press.) Gallons	Shipping Weight (crated) Pounds
SINGLE COIL For residences of all sizes, Duplex apartments and small buildings.	30 (Sp.)	30	...	13
	35	35	50	19
	45	45	75	22
	60	60	100	32
	90	90	150	40
	120	120	200	42
	145	145	220	48
DOUBLE COIL For larger apartments, garages, medium sized factories and office buildings.	160	160	250	60
	200	200	300	70
	300	300	450	85
	400	400	600	100
TRIPLE COIL For heavier requirements.	600	600	900	230
	800	800	1200	250
	1000	1000	1500	290
DOUBLE TRIPLE COILS	1200	1200	1800	568
	1600	1600	2400	642

B & G Horizontal Indirect Water Heaters

For Steam, Vapor or Vacuum Heating Boilers

Capacity of 2000 to 8000 gallons. Information upon request.

B & G Double Duty Indirect Water Heaters

For Automatically Fired Hot Water Heating Boilers

The B & G Double Duty Heater System is a combination of the motor operated Double Duty Valve and a regular B & G Indirect Water Heater.

Series Number	Description	Shipping Weight Pounds	Recommendations
51	B & G Heater #145 Double Duty Valve #5	98	Bungalows and Small Residences 1 Bath
52	B & G Heater #200 Double Duty Valve #5	120	Moderate Sized Residences 1 or 2 Baths
53	B & G Heater #300 Double Duty Valve #5	135	Large Residences Small Apartments 2 or 3 Baths
54	B & G Heater #400 Double Duty Valve #5	150	Residences and Apartments 3 or 4 Baths

B & G Double Duty Main Valves

For Automatically Fired Hot Water Heating Boilers

Number	Description	Shipping Weight
3	Single 3-in. Main	25 pounds
4	Single 4-in. Main	48 pounds
5	Two 3-in. Mains	50 pounds

One hundred degrees temperature rise in three hours. If storage tanks are small or partially below the water line increase the size of heater and tank connections.

No. of Heater...	30 (Sp.)	35	45	60	90	120	145	160	200	300	400	600	800	1000	1200	1600
Length... Inches	10	11¼	15	12	16	19¾	24	12½	15	20	24	22	26	30	24	29
Diameter... "	5	5	5	6	6	6	6	9	9	9	9	13¾	13¾	13¾	22x29	22x29
Shell Openings "	1	1	1	1½	1½	1½	1½	2	2	2	2	3	3	3	4	4
Coil Openings "	¾	¾	¾	1	1	1	1¼	1½	1½	1½	1½	2½	2½	2½	3½	3½

Send for complete catalog information. Information on Unitem Submerged Water Heaters, B & G Firepot Coil Water Heaters, B & G Oil Pre-Heaters, Etc.

Paracoil WATER HEATERS

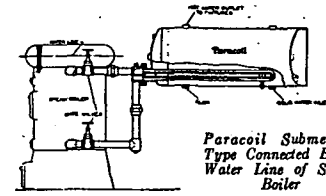
Davis Engineering Corp.

90 West Street, New York, N. Y.

For the smallest residence or the largest apartment house, office building or industrial plant, there is a Paracoil water heating unit to fulfill every hot water requirement.

Over twenty years of responsibility and keen engineering skill stand back of these Paracoil water heating units. Each Paracoil heater carries a rigid guarantee both as to workmanship and performance.

Paracoil Submerged Type Storage Water Heater



Paracoil Submerged Type Connected Below Water Line of Steam Boiler

For heating and storing water for residences and apt. houses up to 10 families.

The result of an insistent demand of plumbers and heating engineers for a storage tank and heater combined in one unit —to be applied economically to the small job, the same as the below water-line installation has been applied in the large Paracoil storage units for office buildings, etc.

This unit is installed below the water line of the heating plant boiler and is both efficient and economical in operation.

Advantages

Clogging of circulating lines lessened. Tank and heater in one unit. Installation costs less. Less piping required. Fuel saved. No water hammer. No separate summer heater needed. Hot water always instantly available (even when fires are banked.)

Paracoil Storage Water Heaters

(Submerged Type)

Sizes, Dimensions, Capacities, Weights, Connections, Etc.

Htr. No., Steam Heating System	Htr. No., Hot Water Htg. Sys.	No. of Families	Tank-Shell Diam. Inch	Tank-Shell Lgth. Inch	Gals. Cap.	Water Inlet and Outlet Diam. Inches	Size of Boiler Circulating Lines—Inches Steam Htg. System	Size of Boiler Circulating Lines—Inches Hot Htg. System	Approx. Weight
1S	1H	1	14	60	40	1	1	1¼	240
2S	2H	2	18	60	60	1	1¼	1½	300
3S	3H	3	20	60	82	1½	1½	2	410
4S	4H	4	24	60	120	1½	1½	2	470
5S	5H	5	24	72	141	1½	1½	2	550
6S	6H	6	30	60	180	1½	1½	2	670
8S	8H	8	30	84	250	1½	2	2½	720
10S	10H	10	30	96	300	1½	2	2½	750

(For heaters of greater capacity write for Catalog A-19.)

Paracoil Instantaneous Water Heater



For instantaneous heating of water for apartment houses, office buildings, etc. Capacities 400 to 12,500 gals. and up. Write for Catalog A-21.

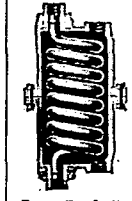
Paracoil Storage Water Heater

(Steam Tube and Submerged Type)

For heating and storing large quantities of water for office, industrial and large apt. buildings, laundries, hospitals, etc.



Specially designed for connection below water line of heating boiler by which method it will heat water supply even when fires are banked. Also designed to utilize exhaust steam. Pressures 100 lbs. standard and up. Sizes 200 to 20,000 gallons per hour heated to 180 degrees F. Write for Paracoil Catalog A-19.



Paracoil Indirect Residence Water Heater

Paracoil Domestic Water Heater

For residences and small apartment houses.

Connected below the water line of steam or vapor boilers, furnishes adequate hot water even when fires are banked.

Paracoil Fire Pot Type Hot Water Heater for Hot Air Furnaces

Used to procure hot water from hot air furnace installation. Used also in conjunction with Paracoil Indirect Type Water Heaters for hot air and hot water installations.



Paracoil Fire Pot Type Water Heater

Foster Wheeler Corporation

165 Broadway, New York, N. Y.

Works: Carteret, N. J., Cleveland, Ohio, Dansville, N. Y.

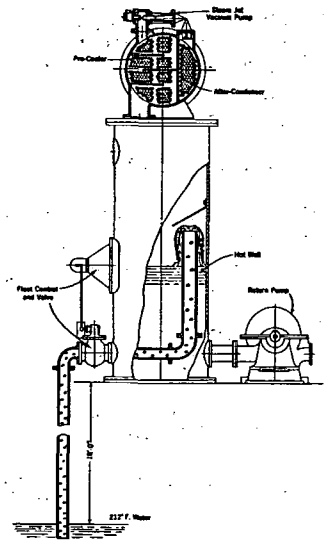
Branch Offices in Principal Cities

PRODUCTS—

Vacuum hot water return pumps, cooling towers, vacuum refrigeration systems, hot water heaters, expansion joints, complete steam generating equipment for power plants.

Vacuum Hot Water Return Pumps

Foster Wheeler vacuum return pumping equipment has been developed for use in large heating systems served from a central plant. It provides for the positive return of the condensate to the central station. The presence of water vapor flashed from the hot water, either in a pocket in a return line, or from a return tank located below the level of the pump, does not affect the operation of the pump.

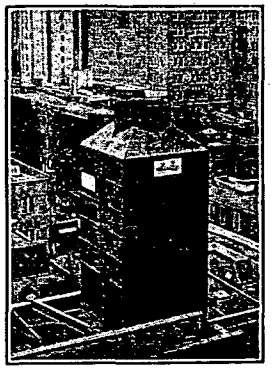


Hot Water Heating Systems

The Wainwright Hot Water Heater as offered by Foster Wheeler is served either with live or exhaust steam. It is adaptable for forced or gravity circulation hot water heating systems or for the supplying of domestic service water.

Cooling Towers

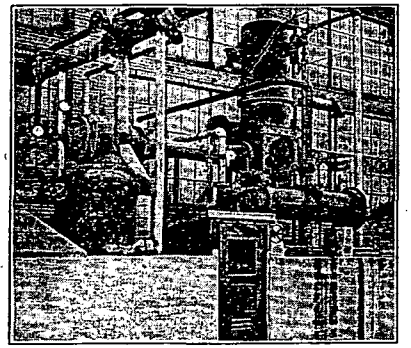
Cooling towers are furnished by Foster Wheeler in all sizes in forced draft, induced draft and atmospheric types.



Foster Wheeler Induced Draft Cooling Tower

Vacuum Refrigeration Systems

Foster Wheeler has developed a system of refrigeration for cooling water or brine to temperatures as low as 32° F using no chemical refrigerant and having no moving parts except the rotors of two centrifugal water pumps. The system can be used wherever steam is available.



75-ton Vacuum Refrigeration System

Wainwright Expansion Joints

These are made in all sizes and for high and low pressures. They are of the flexible accordion type requiring no packing.

O. E. Frank Heater and Engineering Co., Inc.

London Office: Underhill Street

New York Office: 33 West 42nd St.

Canadian Office
1104 Bay Street, Toronto, Ont.

OEF BUFFALO Henri E. Frank

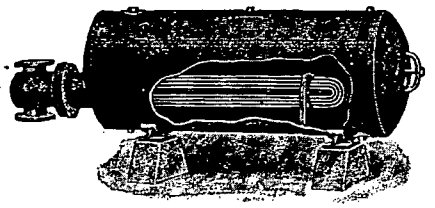
Main Offices and Factory
9 Grimes St.
Buffalo, N. Y.

Canadian Factory
Niagara Falls, Ont.

O. E. F. Products—U-Tube and Straight Tube Storage Heaters, Everdur Storage Heaters, U-Tube and Straight Tube Instantaneous Heaters, Heat Re-Claimers, U-Tube and Straight Tube Feedwater Heaters, U-Tube and Straight Tube Swimming Pool Heaters, Bleeder Turbine Heaters, Domestic Service Heaters, Power Plant Heaters, Oil Coolers, Special Heat Exchange Equipment for Industrial Plants.

O. E. F. Storage Heaters are furnished in either the U-Tube or Straight Tube types to meet your requirements.

Tanks are made of high quality flange boiler steel. Tube Sheets of rolled steel, Castings of heavy gray iron, and Tubes of heavy gauge copper.



O. E. F. U-Tube Storage Heater
Write for Bulletin No. 50

All Heaters, unless otherwise specified are constructed for a working pressure of 100 lb. Information for higher pressures furnished on request.

When it is necessary to use both high and low pressure steam, the steam chamber and tubes can be so arranged as to eliminate installation of a separate tube bundle.

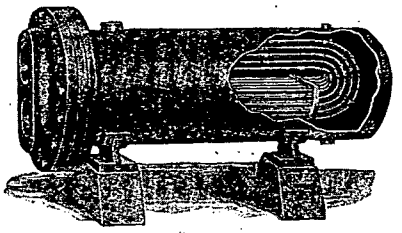
All tube bundles or heating elements are removable from the tank for ease in inspection, cleaning, or repairing.

O. E. F. Storage Heaters

For heating water from 50 to 180 deg. fahr. with steam at 212 deg. fahr

Storage Capacity Gal.	141	370	940	1445	2956	2538	2961
Tank Size Inches	24 x 72	36 x 84	48 x 120	54 x 144	60 x 168	72 x 144	72 x 168
Gallons per Hour							
100	C-5	K-5	W-5	CX-5	MX-5	PX-5	RX-5
200	C-11	K-11	W-11	CX-11	MX-11	PX-11	RX-11
500	C-27	K-27	W-27	CX-27	MX-27	PX-27	RX-27
800	C-43	K-43	W-43	CX-43	MX-43	PX-43	RX-43
1000	....	K-54	W-54	CX-54	MX-54	PX-54	RX-54
1500	....	K-81	W-81	CX-81	MX-81	PX-81	RX-81
2000	....	K-108	W-108	CX-108	MX-108	PX-108	RX-108
3000	....	.....	W-162	CX-162	MX-162	PX-162	RX-162
5000	....	.....	W-269	CX-269	MX-269	PX-269	RX-269

O. E. F. U-Tube Instantaneous Heaters and Economizers—An economical heater low in price but having high heating efficiency and made of best materials. Extensively used for heating water instantaneously or for connection to storage tanks. Also for use as economizers in cooling condensate in steam systems or generators in hot water heating systems.



O. E. F. Instantaneous U-Tube Heater and Economizer
Write for Bulletin No. 50

These heaters are adaptable for connecting below the water line of the boiler.

Capacities and General Dimensions O. E. F. U-Tube Instantaneous Heaters

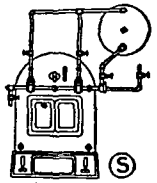
Heating Water from 50–180 deg. fahr., with Steam at 212 deg. fahr.

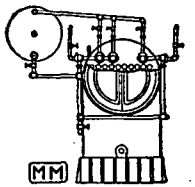
Gallons per Hour	Size	Width In.	Length Ft.-In.	Steam In.	Water In.	Drain In.
100	U-6	11	4-9⅞	3	1½	1
500	U-15	13½	6-3¼	3	2	1½
800	U-24	13½	6-3¼	3	2½	1½
1000	U-30	16	6-3¼	3	2½	1½
1500	U-45	16	7-4¾	4	3	1½
2000	U-60	19	7-5¾	4	3	1½
3000	U-90	19	7-5¾	6	4	2
5000	U-150	22¼	7-7¾	8	4	3

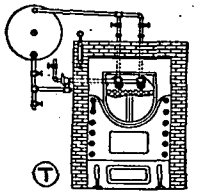
McDERMOTT WATER HEATERS, INC.

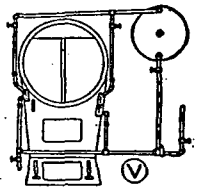
101 Park Avenue **New York City**

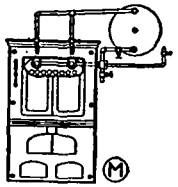
SOLD BY JOBBERS AND BOILER MANUFACTURERS

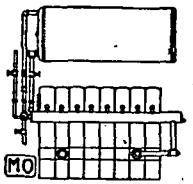












Installation—Minimum cost and time required for the installation of McDermott Water Heaters are outstanding features. The reason is as follows: A clearance hole (not threaded) is cut in a few minutes. Two holes are drilled alongside and tapped ⅜″ (pipe size). The ⅝″ stud bolts furnished are placed in the two holes and when the nuts are on the job is done. It's a flange connection. 1 gasket (also serves as a template), a thermometer, 1 pressure relief 125 lbs., complete instructions and blue print of connections between boiler and tank accompany each shipment.

Specify the number of longest units 2″ shorter than the longest boiler tubes, that will total the tank requirements.

For Tankless Heaters specify 4 V4106 or 3, if V4108, M4210 or M4212 units are used. They connect in series, 1¼″ pipe if V type, and raise 9,000 G.P.H. 140° F. If M type, no larger than 2″ pipe is used to series the units which will raise 19,000 G.P.H. 140° F. Both ratings at 50 lb. pressure and 200° F. boiler water. McDermott Tankless units enable you to specify any tubular boiler for instantaneous water heating.

Ratings When Used With Tanks

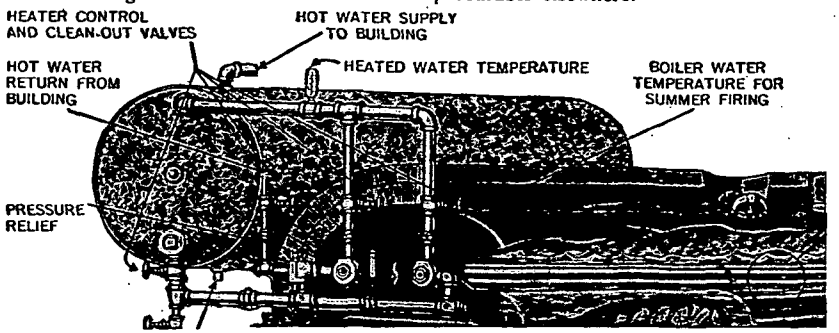
Size	Length	Capacity, Gallons	Tank Connections Inches
V4103	3′ 0″	150	1¼″
V4106	6′ 0″	245	1¼″
V4108	8′ 0″	350	1¼″
M4210	10′ 0″	550	2″
M4212	12′ 0″	800	2″

Ratings based on 100° temperature rise in three hours and delivery is assured as rated.

Tested at 450 lbs. and **Guaranteed** for one year.

Sixty-six Questions and Answers—A letter size book that helps solve water heating problems, should be in your files.

The First Submerged Unit in New York was installed by McDermott. McDermott patented features are not procurable elsewhere.



The National Pipe Bending Co.

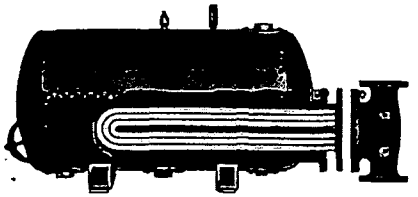
104 River Street, **New Haven, Conn.**

Offices in the Following Cities:

Atlanta, Ga.	Butte, Mont.	Cleveland, Ohio	Los Angeles, Calif.	New York, N. Y.
Baltimore, Md.	Chicago, Ill.	Denver, Colo.	Memphis, Tenn.	Philadelphia, Pa.
Boston, Mass.	Cincinnati, Ohio	Duluth, Minn.	Minneapolis, Minn.	Pittsburgh, Pa.

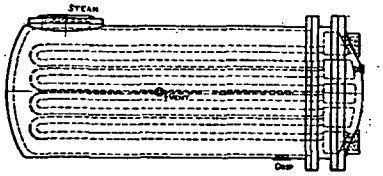
PRODUCTS—Water Storage Heaters, Instantaneous Water Heaters, Swimming Pool Heaters, Feed Water Heaters, Coal Burning Tank Heaters, Oil Burning Tank Heaters, Special Heaters, Coolers for all purposes, Coils and Bends of Pipe and Tubing.

National Red Head Storage Heaters



A line of well built heaters stocked in sizes and capacities most generally used. Equipped with U-Bend heating element of Anaconda Copper. Steel Tank. Improved flanged T cover gives unrestricted flow area for entering steam. Tested to 100 lbs. working pressure, 150 lbs. hydrostatic pressure. For installations requiring heaters other than listed below use regular National individually engineered heaters described in Bulletins No. 55, 57, 65. Our engineering service is at your command.

National Instantaneous Heaters



Furnished in Water or Steam Tube types for gravity or pressure circulation.

Heats water as it flows either continuously or intermittently. Built for steam pressures up to 75 lb. per sq. in. U-Bend copper tubes through which the water passes are fitted into a cast iron or steel shell through which the steam for heating is passed. Made in sizes from 210 to 12,000 gal. of hot water per hour at temperatures from 40° to 180° F.

DATA to be used with RED HEAD Heaters

SHELLS (Horizontal) Manhole 11″ x 15″ in all sizes above 18″.						HEATING ELEMENTS Temperature range based on heating water from 50 degrees to 180 degrees F. at steam pressure 0 to 5 lbs.			
No.	Gallons One Filling	Size of Shell	Thickness of Shell	Thickness of Head	Weight of Shell	No.	Gallons per Hour	Smallest Shell into which element goes Inches	Weight of Element Lbs.
A	80	18x 72	3/16	3/8	380	NS-1	80	18x 72	85
B	141	24x 72	3/16	3/8	530	NS-2	100	18x 72	88
C	220	30x 72	1/4	3/16	870	NS-3	150	18x 72	96
D	310	36x 72	1/4	3/16	1020	NS-4	200	18x 72	117
E	365	36x 84	1/4	3/16	1130	NS-5	250	18x 72	122
F	475	36x108	1/4	3/16	1350	NS-6	300	18x 72	185
G	575	42x 96	5/16	1/2	1750	NS-7	350	36x 84	189
H	645	42x108	5/16	1/2	1900	NS-8	400	36x 84	195
I	720	42x120	5/16	1/2	2050	NS-9	450	42x 96	205
J	860	42x144	5/16	1/2	2350	NS-10	500	42x 96	210
K	940	48x120	5/16	1/2	2410	NS-11	600	42x 96	260
L	1130	48x144	5/16	1/2	2770	NS-12	700	42x108	270
M	1300	48x168	5/16	1/2	3100	NS-13	800	42x108	285
N	1425	54x144	3/8	5/16	3750	NS-14	900	42x108	343
O	1665	54x168	3/8	5/16	4300	NS-15	1000	42x108	357
P	2000	60x168	3/8	5/16	5200	NS-16	1250	42x108	440
Q	2460	72x144	1/2	3/8	6500	NS-17	1500	42x108	468
R	2875	72x168	1/2	3/8	7600	NS-18	1750	42x108	575
						NS-19	2000	42x108	620
						NS-20	2500	42x108	755

How to Specify NATIONAL RED HEAD STORAGE HEATERS. Combine the number of the required storage and heating elements. To heat 1000 gallons per hour with a storage capacity of approximately 500 gallons, refer to tables above and specify one National Red Head Heater NS-15-F.

The Whitlock Coil Pipe Company

Manufacturers and Engineers

HARTFORD, CONN.

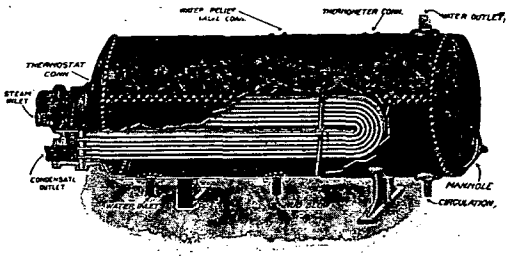
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WHITLOCK SERVICE WATER HEATERS

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Manufacturers of and Sales Agents for Whitlock Heaters in Canada—DARLING BROS., LTD., 120 Prince St., Montreal

See Telephone *Directory for Local Address*



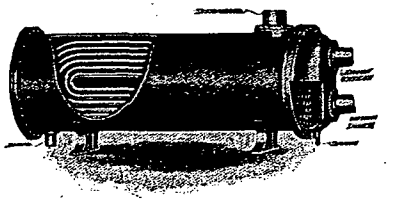
Whitlock type "K" storage heaters are manufactured in both horizontal and vertical types. The table shows sizes of the horizontal heaters only. We will gladly furnish dimensions of horizontal heaters and vertical heaters upon request. That this type of heater is of particularly sturdy construction is evidenced by the increasing number of prominent engineers and architects who are specifying their use in all types of buildings, including many of the largest and finest buildings constructed.

Whitlock Type K Storage Heaters, Horizontal

SHELLS — To be used with Type K Heating Section. Shell Prices include Cradle. Manhole 11"x15"							HEATING SECTIONS — Capacity based on Heating from 40° to 180° with Steam at 0 lbs. pressure. For other temperatures and Steam Pressures see Bulletin No. 27				
Number	Gallons One Filling	Diameter of Shell	Length of Shell	Thickness of Shell	Thickness of Head	Weight of Shell	Number	Gallons per Hour	Maximum Size Steam Pipe Inches	Smallest Shell into which Section will Fit Inches	Weight of Entire Heating Section Lbs.
1	65	18	60	1/4	3/8	400	H 0	100	2	18x 48	75
2	80	18	72	1/4	3/8	450	H 1	150	2	18x 60	80
3	118	24	60	1/4	3/8	600	H 2	200	2	18x 72	90
4	141	24	72	1/4	3/8	700	H 3	250	3 1/2	18x 48	175
5	164	24	84	1/4	3/8	800	H 4	300	3 1/2	18x 48	185
6	185	30	60	1/4	3/8	750	H 5	350	3 1/2	18x 60	190
7	220	30	72	1/4	3/8	850	H 6	400	3 1/2	18x 60	200
8	255	30	84	1/4	3/8	950	H 7	500	3 1/2	18x 72	210
9	290	30	96	1/4	3/8	1050	H 8	550	3 1/2	18x 72	215
10	365	36	84	5/16	1/2	1300	H 9	600	3 1/2	18x 84	220
11	420	36	96	5/16	1/2	1450	H10	700	5	24x 60	300
12	475	36	108	5/16	1/2	1600	H11	800	3 1/2	18x 96	260
13	525	36	120	5/16	1/2	1800	H12	900	3 1/2	18x108	270
14	575	42	96	5/16	1/2	1850	H13	1000	3 1/2	18x120	285
15	720	42	120	5/16	1/2	2150	H14	1250	5	24x 84	370
16	860	42	144	5/16	1/2	2500	H15	1500	5	24x108	425
17	1000	42	168	5/16	1/2	2900	H16	1750	5	24x120	450
18	950	48	120	3/8	1/2	2850	H17	2000	6	30x 96	570
19	1140	48	144	3/8	1/2	3250	H18	2400	6	30x120	620
20	1310	48	168	3/8	1/2	3700	H19	2800	6	30x132	670
21	1480	48	192	3/8	1/2	4100	H20	3200	8	36x 96	860
22	1190	54	120	3/8	1/2	3250	H21	3600	8	36x108	920
23	1430	54	144	3/8	1/2	3700	H22	4000	8	36x120	950
24	1670	54	168	3/8	1/2	4200	H23	4400	8	36x132	1020
25	1900	54	192	3/8	1/2	4700	H24	4800	10	36x 96	1200
26	1420	60	120	3/8	5/8	4300	H25	5400	10	36x108	1300
27	1710	60	144	3/8	5/8	4900	H26	6000	10	36x120	1380
28	2000	60	168	3/8	5/8	5600	H27	7000	12	42x 96	1950
29	2300	60	192	3/8	5/8	6200	H28	8000	12	42x 96	2000
30	2460	72	144	3/8	5/8	5700	H29	9000	12	42x108	2300
31	2880	72	168	3/8	5/8	6400	H30	10000	12	42x108	2460

DIRECTIONS FOR USE—Select the size storage you require and combine its designating number with the number which designates the desired hourly output. Assuming a required storage of 1000 gallons (No. 17 shell 42 x 168) and a required hourly output of 1750 gallons (No. H16 Heating unit) you would specify a Whitlock Type K No. 17H16.

WHITLOCK TYPE R INSTANTANEOUS HEATERS



This type of heater is used extensively as an instantaneous heater in connection with a separate storage tank, as a swimming pool heater, as a hot water convertor for use with a heating system, as well as for various special conditions.

Standard sizes of the multi-pass and 4 pass heaters are shown in the table. Dimensions on 2 pass heater will be furnished on request.

Standard Sizes, Capacities, Dimensions and Weights

	MULTI PASS, TEMP. RANGE 40° F. to 180° F.						4 PASS TEMP. RANGE 40° F. to 120° F.					
Size No.	Capacity Gallons per Hour	Over-all Length	Diameter of Shell	Size Water Connections	Size Steam Connections	Weight	Capacity Gallons per Hour	Over-all Length	Diameter of Shell	Size Water Connections	Size Steam Connections	Weight
0	25	15 3/8	7	3/4	1	90	80	11 3/8	7	3/4	1	80
1	60	26 3/8	7	3/4	1 1/4	125	150	16 3/8	7	3/4	1 1/4	100
2	150	37 3/8	7	3/4	1 1/2	160	300	21 3/8	7	1	2	115
3	200	39 1/2	9 1/2	1	1 1/2	280	480	26 3/8	7	1	2	135
4	250	48 1/2	9 1/2	1	2	325	650	31 3/8	7	1 1/4	2 1/2	150
5	300	31 3/4	9 1/2	1	2	250	800	38 3/8	7	1 1/4	2 1/2	170
6	400	40 3/4	9 1/2	1 1/4	2 1/2	300	960	24 3/4	9 1/2	1 1/2	3	220
7	500	43 3/4	9 1/2	1 1/4	3	325	1350	30 3/4	9 1/2	2	3	270
8	600	48 3/4	9 1/2	1 1/4	3	350	1600	35 3/4	9 1/2	2	3 1/2	300
9	800	52	12	1 1/2	3 1/2	575	2100	43 3/4	9 1/2	2	4	350
10	1000	61	12	1 1/2	3 1/2	645	2600	55 3/4	9 1/2	2 1/2	5	420
11	1250	74	12	1 1/2	4	760	3300	52	12	2 1/2	5	620
12	1500	59 7/8	15	2	5	870	4000	61	12	3	6	700
13	2000	72 7/8	15	2	5	1020	5300	79	12	3	6	860
14	2500	59	17	2 1/2	6	1035	6600	55 7/8	15	3 1/2	8	940
15	3000	71	17	2 1/2	6	1175	8000	65 7/8	15	4	8	1070
16	4000	89	17	2 1/2	8	1420	10500	71	17	5	10	1390
17	5000	74 7/8	20	3	8	1910	13300	83	17	5	10	1580
18	6000	88 7/8	20	3	10	2185	16000	72 7/8	20	5	10	2020
18 1/2	7000	101 7/8	20	3	10	2475	18500	82 7/8	20	5	12	2230
19	8000	64 5/8	26	4	10	2800	21000	92 7/8	20	6	12	2430
19 1/2	9000	71 5/8	26	4	10	3000	24000	62 5/8	26	6	12	2800
20	10000	78 5/8	26	4	12	3220	26700	67 5/8	26	6	12	3000
21	12500	94 5/8	26	4	12	3725	33300	82 5/8	26	6	14	3480
22	15000	89	30	5	14	4125	40000	73	30	8	14	4015
23	20000	113	30	6	16	4860	53300	92	30	8	16	4600
24	25000	96	36	6	18	6350	66700	83	36	10	20	6100
25	30000	112	36	6	20	7175	80000	95	36	10	22	6900
	Sizes 0 to 8 inclusive, have 3/4" O. D. No. 18 B. W. G. Copper Tubes. Remainder have 1" O. D. No. 17 B. W. G. Copper Tubes.						Sizes 0 to 10 inclusive, have 3/4" O. D. No. 18 B. W. G. Copper Tubes. Remainder have 1" O. D. No. 17 B. W. G. Copper Tubes.					

Whitlock Heat Transfer Equipment includes the following types of apparatus in addition to the Storage and Instantaneous Heaters shown above: Feed Water Heaters; Heat Exchangers; Fuel Oil Heaters; Superheaters; Condensers and Coolers for all kinds of liquids; also pipe coils of any kind of pipe or tubing, and Air and Ammonia Receivers.

Additional information and quotations covering any of this apparatus will be gladly furnished upon request.

BULLETINS Nos. 25 and 40, issued during 1931, and therefore up-to-date, covering Type R and Type K heaters respectively, will be sent on request.

They contain many useful tables, such as the "Hot Water Fixture Capacity Table", tables on the rating of "Hot Water Convertors", and so forth.

Several other bulletins, covering other types of Whitlock Heaters and Heat Exchangers, have been issued recently. A complete set will be a worth while addition to your file of engineering data.

The Patterson-Kelley Co.

99 Park Avenue - New York City

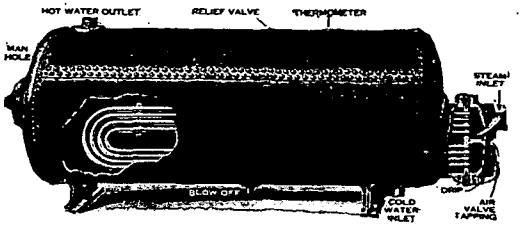
Hot Water Heaters for all purposes. Pool Heaters and Converters. Preheaters, Heat Exchangers, Heaters for Chemicals, Gases, Oils. Coolers for Brine, Chemicals, Gases, Oil and Water.

The Patterson Combined Hot Water Service and Storage Heater, Type B, is for any service where requirements for *hot* water are not constant, or where a large volume must be stored for sudden heavy demands.

We *guarantee* to furnish heaters that will deliver the quantity of hot water called for. Without obligation our Engineering Department will be glad to give engineers the benefit of our 52 years' experience.

General Specifications

Constructed like a high grade boiler—of heavy steel plate. Steam inlet and outlet chamber is a heavy, grey iron casting. Tube head is a heavy, steel forging into which both ends of each tube are expanded. Tubes are of pure, cold drawn seamless copper and "**U**" *shaped to provide* against contraction and expansion strains. Heater is for any service and in any required size per tables below. Write us for engineering advice.



HEATING CAPACITIES—

40° F. to 180° F.—Steam at Atmospheric Pressure

No.	Gallons per Hour	Approx. Wt. in Lb.	No.	Gallons per Hour	Approx. Wt. in Lb.
1H	100	200	15H	2000	700
2H	150	215	16H	2500	800
3H	200	235	17H	3000	900
4H	250	255	18H	3500	1050
5H	300	285	19H	4000	1200
6H	400	315	20H	4500	1350
7H	500	350	21H	5000	1500
8H	600	370	22H	6000	1750
9H	700	400	23H	7500	2000
10H	800	425	24H	10000	3200
11H	1000	450	25H	12500	3800
12H	1250	500	26H	15000	4500
13H	1500	550	27H	20000	5100
14H	1750	600	28H	25000	5800

Note.—To specify Type B. Heaters, combine the numbers of the required storage and heating capacities. For example, "One Patterson Type B. Heater with No. 22 S. and No. 17 H." has 1000 gallons storage with 3000 gallons hourly heating capacity.

STORAGE CAPACITIES

No.	Dimensions in Inches	Capacity in Gals.	Approx. Wt. in Lbs.	No.	Dimensions in Inches	Capacity in Gals.	Approx. Wt. in Lbs.
1 S	24 x 48	94	650	21 S	42 x 144	860	2450
2 S	24 x 60	118	750	22 S	42 x 168	1000	2800
3 S	24 x 72	141	850	23 S	42 x 192	1155	3100
4 S	24 x 84	164	950	24 S	48 x 96	750	2600
5 S	30 x 60	180	875	25 S	48 x 120	940	2925
6 S	30 x 72	215	1000	26 S	48 x 144	1125	3350
7 S	30 x 84	255	1150	27 S	48 x 168	1300	3840
8 S	30 x 96	285	1300	28 S	48 x 192	1500	4200
9 S	30 x 120	360	1500	29 S	54 x 120	1190	3500
10 S	36 x 72	310	1250	30 S	54 x 144	1425	3900
11 S	36 x 84	365	1400	31 S	54 x 168	1665	4300
12 S	36 x 96	415	1550	32 S	54 x 192	1900	4700
13 S	36 x 108	475	1700	33 S	60 x 120	1400	4300
14 S	36 x 120	500	1850	34 S	60 x 144	1700	4950
15 S	36 x 144	640	2100	35 S	60 x 168	2000	5600
16 S	42 x 72	430	1500	36 S	60 x 192	2240	6200
17 S	42 x 84	500	1650	37 S	72 x 174	3000	7000
18 S	42 x 96	575	1800	38 S	84 x 168	4000	8700
19 S	42 x 108	650	1950	39 S	96 x 168	5200	10000
20 S	42 x 120	720	2200	40 S	96 x 192	6000	11000

GRINNELL COMPANY INC.

Heating, Industrial and Power Plant Piping, Fittings, Hangers, Valves, Pipe Bending, Welding, Piping Supplies, Etc.

Executive Offices: **Providence, R. I.**

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PRODUCTS AND SERVICES—

Complete Service on materials to specification on Power Plant Piping, Industrial Piping, and Industrial Heating Systems; Fabricated piping including bends, welded headers, lap joints and the Grinnell Triple XXX line of products for Super Power; Grinnell Equiflo Valve; Grinnell Pipe Hangers and Fittings; Grinnell Thermolier (A Development in Unit Heaters); Thermoflex Heating Specialties.

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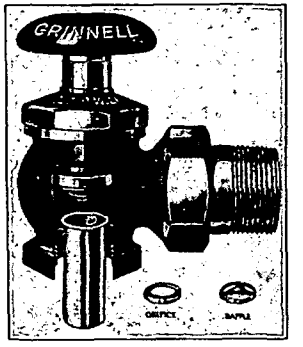
Brass, Bronze and other Castings; Valves: Air Relief, Globe, Angle, Cross, Check, Quick Opening and Closing, Non-return, Tank, Pressure Reducing and Regulating, Safety and Y.

Pipe Bends and Coils; Unions, Tees, Ells and Nipples; Cast Iron, Steel and Wrought Iron Pipe; Pipe Rolls; Steam Traps.

Automatic Sprinkler Systems.

For data on Thermoflex Heating Specialties, see page 790.

A Revolutionary Development in Forced Hot Water Heating—One of the chief difficulties in the way of a broader use of forced hot water heating systems with their many important advantages has been the determination of pipe sizes by the complex and arduous method of calculating frictional resistances. Failure to do this, plus easily possible installation mistakes



Equiflo Valve

has resulted in many unsatisfactory installations of this type of heating system.

This whole problem has now been simplified by the invention of the *Grinnell Equiflo Valve.*

The Grinnell Equiflo Valve for forced hot water heating *permits:*

1. The calculation of pipe sizes for this system by simple tables, similar to those commonly used in connection with the design of vacuum steam systems.

2. Change in locations of radiators or piping during installation to take care of local construction conditions without recalculation of pipe sizes.

The Grinnell Equiflo Valve for forced hot water heating *accomplishes:*

1. More nearly perfect equalization of flow to every radiator than has ever been

GRINNELL COMPANY INC.

Heating, Industrial and Power Plant Piping, Fittings, Hangers, Valves, Pipe Bending, Welding, Piping Supplies, Etc.

practical by even the most careful calculation of pipe sizes. Size or location makes no difference.

2. The introduction of sufficient frictional resistance to completely overcome that trouble so pronounced in most forced hot water heating systems which is due to the well-known war between pump head (a constant) and the gravity or temperature head (a variable). This insures absolutely equalized circulation at all temperatures.

3. Lower pumping costs.

The Grinnell Equiflo Valve:

1. Serves as the regular shut-off valve for each radiator. It is of the packless type.

2. Is so designed that after the installation is completed a multiple-orifice cartridge or tube, having a definite resistance pre-determined by Grinnell Company, is dropped into place in the valve.

In order to obtain all the advantages of this recent development, it is only necessary for the Consulting Engineer to specify that *each radiator shall be equipped with a Grinnell Equiflo Valve.* This device is marketed through the regular heating trade, and proper results are guaranteed by the standing of Grinnell Company in the hot water heating field.

Fabricated Piping Materials: Lap Joints, Pipe Bends, Welded Headers—

The making of pipe bends, welded headers, lap joints of every description, and a complete line of miscellaneous pipe fabricated materials, has for many years been a specialty of Grinnell Company. In work of this kind experienced workmen are essential to quality products. Due to its Engineering and Laboratory facilities, its training of welders, and other pipe fabrication developments, Grinnell Company has a corps of workmen who can be depended upon to translate a specification into a satisfactorily finished product.

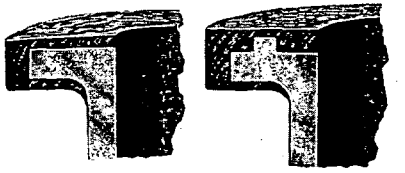
These experienced workmen have the best modern facilities to work with. Pipe fabrication plants are strategically located at Auburn, Rhode Island; Warren, Ohio; and Atlanta, Georgia. Grinnell pipe bends are true to radius and free from buckles and flat places. Bends are furnished according to dimensions from standard and extra heavy wrought iron and steel pipe, as well as from seamless steel tubing.

One item that works to standardize quality in Grinnell-made pipe bends is our mechanical filling and hammering machines which replace the old method of hand filling and eliminate the human element in this important feature of pipe bending work. In filling of pipe for bends, specially prepared sand is used which does not crystallize or adhere to the inside of the pipe.

Grinnell Pipe Bends can be furnished with Lap Joint Flanges, with Screwed-on and with Welded Flanges; also with Screwed Ends or with Scarfed Ends for field welding. Lap Joints may be plain faced having 100 per cent thickness in Laps, or with Male and Female, Tongue and Groove, or "Sarlun" facings with a thickness equal to 100 per cent of pipe walls at thinnest point, and suitable for all pressures up to 1350 lb. W. S. P. at a total temperature of 750 deg. Fahr.

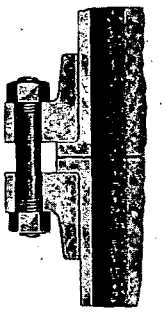
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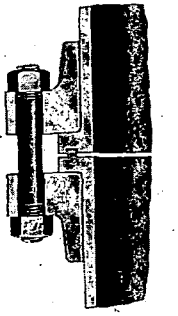


Square Lap in Rough Lap *Small Tongue in Rough Lap*

Above illustrations show clearly how the ample thickness of perfect metal in the rough-forged lap allows for machining front and back for any conceivable face with a finished lap of at least 100 per cent thickness and strength.



Finished Square Lap



Finished Tongue and Groove Lap

The Place of Triple XXX in Power Plant Piping

Triple XXX is a line of fabricated piping material developed by Grinnell Company to meet the demands of high pressures and temperatures in modern power plants. It is standard with us for all working steam pressures of Series 40 (400 lb. W. S. P.) and over, and recommended for Series 30 with high temperatures. The line is complete, comprising all types of pipe joint faces, welded headers and pipe bends. Each piece of material is stamped XXX showing that it has been produced for this special service.

Grinnell Fittings, Cast Iron and Malleable—Impartial purchasers agree that accuracy of threading and machining, freedom from sand holes, and smoothness of cores speed up installations, reduce replacements, and cut friction losses wherever Grinnell Fittings are specified and used.

Grinnell Cast Iron Fittings—In standard and extra heavy weights and made to conform to the American Standards for the following types are available to all users:—Flat Band Screwed Fittings; Long Turn Sprinkler Fittings; Flanged Fittings.

Grinnell Malleable Iron Screwed Fittings—Are now also available in standard weight with flat bands and made to the American Standard.

Grinnell Adjustable Pipe Hangers and Supports

One of the chief advantages of Grinnell Adjustable Hangers is that they permit adjustment of pipe lines after installation, thus obviating the necessity of turnbuckles or the removal of hangers. And their time and trouble-saving qualities during installation are equally exceptional. On the following pages are shown a few Grinnell Hangers and Supports of particular interest to heating engineers. Send for Grinnell Hanger Catalogue, a catalogue covering the complete line of Pipe Hangers and Supports, giving illustrations, list prices and dimensions.

GRINNELL COMPANY INC.

Heating, Industrial and Power Plant Piping, Fittings, Hangers, Valves, Pipe Bending, Welding, Piping Supplies, Etc.

Solid Ring—Adjustable Swivel Ring—Split Ring



Fig. No. 101 Solid Ring

THIS Malleable Iron Adjustable Swivel Ring can be used with Coach Screw Rod or Machine Threaded Rod in connection with practically any type of Ceiling Flange, Expansion Case, Insert, etc.

With the Swivel Shank, an adjustment of at least 1½ in. is secured by turning the nut on the shank.

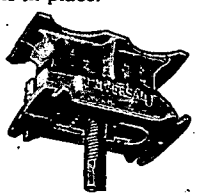
An unique locking device on the Swivel Shank automatically locks, preventing loosening due to vibration in the pipe line.



Fig. No. 104 Split Ring Patented—No. 1,772,062

The Split Ring Type has the same adjustment as in Fig. No. 101, either before or after the hinged section is fastened in place. The off-center hinging of the Ring provides sufficient seating to hold the pipe before closing the Ring. A wedge type Pin is loosely but inseparably cast into the hinged section for fastening this section after pipe is in place.

Universal Insert—Simplex Insert



Universal Insert Fig. No. 280

MADE of charcoal malleable iron, they have ample vertical and horizontal adjustment. Four widely separated nail slots, low height and large bottom surface all tend to minimize the chance of displacement during construction, whether nailed to wood or pasted to steel forms.



Simplex Insert Fig. No. 281

Universal Inserts are made in one body size, to take a special removable nut. Nuts are furnished tapped for ⅜ in., ½ in., ⅝ in. or ¾ in. rod as required, and are automatically locked laterally by means of serrated teeth on both insert and nut.

Simplex Inserts are made in five body sizes, with nuts assembled in place and not removable, for rod tappings ⅜ in. to ⅞ in. inclusive.

Universal Clamps

(Patented—Nos. 1,134,395 and 1,568,122)

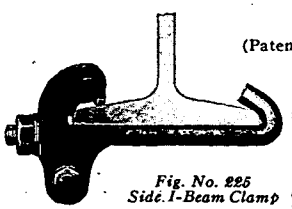


Fig. No. 225 Side I-Beam Clamp

THE Side I-Beam Clamp has ample strength for hanging ¾ to 12 in. pipe from I-Beams. Made in different sizes to fit all sizes of Standard and Bethlehem I-Beams, and most sizes of Bethlehem Girder Beams.

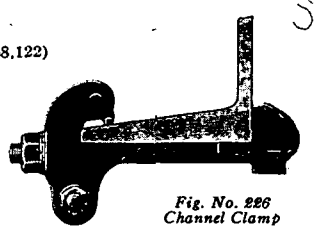


Fig. No. 226 Channel Clamp

The Grinnell Channel Clamp, made in three sizes with varying lengths of clamp rods, will meet most of the conditions encountered in practical installation work in connection with channels.

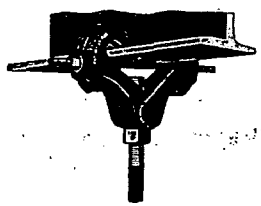


Fig. 228 U. F. S. I-Beam Clamp

UFS
(Universal Forged Steel)
I-BEAM CLAMP
(Patented—No. 1,604,590)

THE UFS (Universal Forged Steel) I-Beam Clamp is a recent addition to the Grinnell Hanger line and is an outstanding development in convenience, strength and adjustability. While made only in three sizes, it covers the whole range of beam sizes from the smallest to Bethlehem 24-in. Forged steel construction gives to each size the same strength as the maximum rod strength involved. Rods carried range from ⅜ to 1½ in., providing for all pipe sizes up to 24 in.

Grinnell Company, Inc. Industrial Heating and Piping Systems

GRINNELL COMPANY INC.

Heating, Industrial and Power Plant Piping, Fittings, Hangers, Valves, Pipe Bending, Welding, Piping Supplies, Etc.

Adjustable Wall and Wrought Radiator Brackets

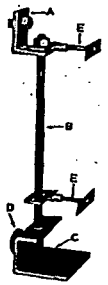


Fig. No. 192

THE Bracket, Fig. No. 190, is designed to support a single tier of wall radiation. A similar Bracket, No. 191, is designed to support a double tier, one in front of the other. The Wrought Bracket, Fig. No. 192, is designed to support legless radiation of the new Tube Type.

Only one bolt is necessary to securely fasten these brackets to the wall. This means low installation cost and it cuts drilling holes down to a minimum.

When hook bolt is used, it can be set without extremely accurate measurements, due to the liberal range of vertical and horizontal adjustment, and as only two or three points of the bracket touch the wall, the difficulty so often experienced with rough brickwork is practically eliminated.



Fig. No. 190

Adjustable Wall Coil Hangers

(Patented—No. 1,062,372)



Fig. No. 160

THE Adjustable Wall Coil Hanger can be furnished with four separate brackets—two for single coils and two for double coils. The brackets locate the center of the coils 2¼ or 6¼ in. from back of bracket. Where double coils are used the second hangs 3½ in. in front of the first.

Single Pipe Rolls



Fig. No. 171

GRINNELL Single Pipe Rolls are especially designed to take care of expansion and contraction. Rolls are made hollow which means small surface in contact with roll rod. The Adjustable Sockets permit vertical adjustment at the roll. The nut at the bottom of the hanger rod fits into a recess in the socket, thus preventing loosening or turning from vibration.

Adjustable Swivel Pipe Roll

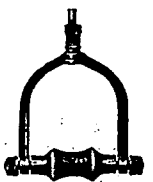


Fig. No. 174

THE Adjustable Swivel Pipe Roll supplies the need for an adjustable type of pipe roll hanger with single hanger rod. It is unique inasmuch as vertical adjustment can be made by use of the Swivel Shank at the top of the hanger.

Adjustable Pipe Stand—Anchor Chair—Pipe Seat—Welded Steel Bracket

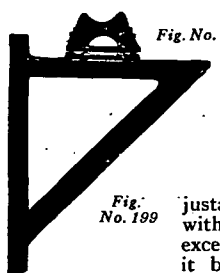


Fig. No. 196

Fig. No. 199

WELDED STEEL BRACKET, Fig. No. 199 is light in weight and was designed primarily for use with the Grinnell Adjustable Pipe Stand, Fig. No. 196, Anchor Chair, Fig. No. 197 and Pipe Seat, Fig. No. 198.

These combine the strongest type of brackets and pipe supports. The Adjustable Pipe Stand as used with the Steel Bracket has excellent adjustment features, it being possible to obtain both vertical and lateral adjustment.

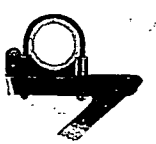


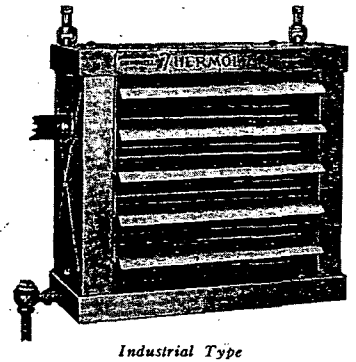
Fig. No. 197



Fig. No. 198

GRINNELL COMPANY INC.

Heating, Industrial and Power Plant Piping, Fittings, Hangers, Valves, Pipe Bending, Welding, Piping Supplies, Etc.



Industrial Type

Grinnell Thermolier

THE Grinnell Thermolier is a modern development of unit heaters. This principle of heating is rapidly becoming standard for use in many kinds of buildings. The reason for this may be briefly stated: (1) Low initial cost; (2) economy of operation; (3) adaptability; (4) maintenance; (5) depreciation.

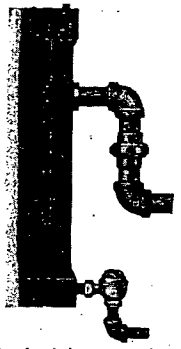
This unit is the result of more than three years' intensive investigation and test by the Grinnell organization which for over 70 years has been recognized as a leader in industrial heating work. No pains have been spared to make it a most dependable, efficient and long-lived unit. Heat is obtained from brass-finned, seamless, copper U-tubes rolled into a cast iron tube sheet. No solder is used for joints and there are no flat horizontal surfaces to catch dirt.

One model 800 Thermolier may be used to heat a floor area of 500 to 5000 sq. ft. Units may be controlled manually or automatically, singly or in groups.

Installation and piping are extremely simple and inexpensive, hence the unit may be moved from one location to another at small cost if found desirable on account of changes in building or occupancy. Furnished in two types (Industrial and Factory) and 16 models (or capacities) as listed on following page.

Thermoliers provide excellent distribution of heat free from objectionable drafts. May be used when desirable with steam pressures up to 125 lb.

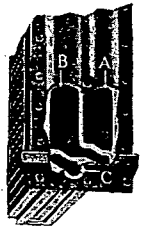
Specifications—Fan: Grinnell, special, of rugged construction. **Motor:** Heavy duty, oversize, enclosed, moisture-proof. **Housing:** Copper on Industrial Type with rubbed lacquer finish; steel on Factory Type finished in gray duco. **Frame:** Heavy pressed steel, providing rugged support for motor and fan. **Special features:** Adjustable swivel hanger rod couplings; louvers rigid, but easily adjustable; integral cooling leg insuring complete drainage through one ½-in. trap on Models 100 and 200, ¾-in. on Models 300 to 800, 1-in. on Model 1200, 1¼-in. on Model 1600, for pressures up to 25 lb. For pressures not exceeding 125 lb., a thermostatic trap of proper construction can be used and should be attached directly to unit; same sizes as above except a ½-in. trap on Models 300 and 400, 1-in. on Model 1600.



Simple piping connections, both on same side, with close return trap

Particular attention is called to the integral cooling leg, a unique feature of the Thermolier which is of vast importance to the heating man. Due to the construction of the header in Thermolier, steam circulation and removal of condensation in this unit are distinctly different than is usual in such heaters.

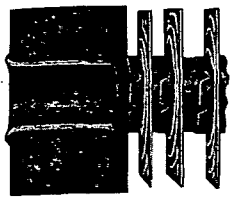
Steam is delivered into Chamber "A" of the header and circulates from there through the pitched U-tubes carrying its condensation with it into Chamber "B." By partitioning off the tubes at the bottom of the Steam Supply Chamber "A," these lower tubes carry all condensation from Chamber "B" into Drain Chamber "C." In passage of this condensation through these tubes, the air from the fan is rapidly carrying off heat just as it does in the rest of the unit. The result is that these lower tubes form an efficient internal cooling leg, integral with the unit. The actual cooling effect of this construction is equal to a run of more than 100 feet of the ordinary, exterior cooling leg piping.



Unique header construction forces all condensation through integral cooling leg

GRINNELL COMPANY INC.

Heating, Industrial and Power Plant Piping, Fittings, Hangers, Valves, Pipe Bending, Welding, Piping Supplies, Etc.



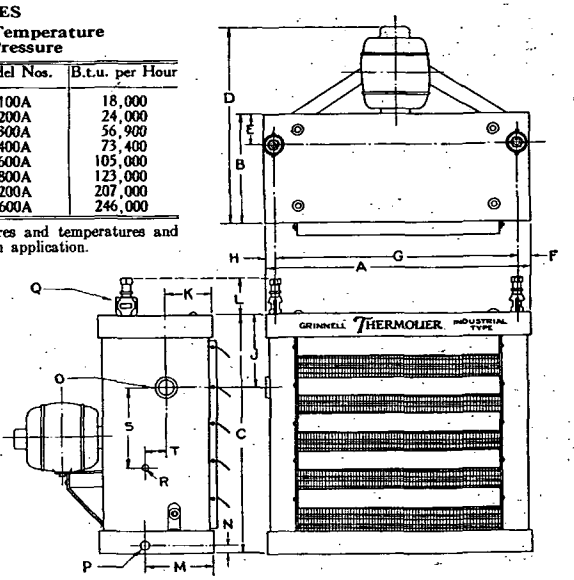
Tubes expanded into cast iron tube sheet

Due to the efficient functioning of the internal cooling leg, it is practical with the Grinnell Thermolier to make an exceedingly close connection of the return trap, as indicated on the drawing on previous page. The condensation coming from the unit is cool enough so that the trap will operate continuously even when the unit is working at maximum capacity for long periods. This feature, combined with the fact that the steam supply connection is at the same end of the unit, makes for compactness and neatness in the piping connections.

CAPACITIES
60°F. Entering Air Temperature
5 Lb. Steam Pressure

Model Nos.	B.t.u. per Hour	Model Nos.	B.t.u. per Hour
100	24,500	100A	18,000
200	32,900	200A	24,000
300	82,300	300A	56,900
400	110,800	400A	73,400
600	159,500	600A	105,000
800	199,100	800A	123,000
1200	311,000	1200A	207,000
1600	388,000	1600A	246,000

Data Book covering other pressures and temperatures and complete installation information on application.



DIMENSIONS—Industrial Type

Model Numbers	A	B	C	D	E	F	G	H	J	K	L	M	N	O	P	Q	S	T
100—200	14¼	8½	11¾	*15	2⅜	15/16	12⅝	1 1/16	2¾	3¼	2⅜	5 1/16	1 3/16	1¼	½	†⅜	4½	2⅛
300—400	21⅛	10 1/16	18 1/16	*17	2⅝	1	19⅛	1	3¾	4 1/16	3⅛	6⅝	1 3/16	1½	¾	†½	7⅜	2⅜
600—800	27¾	11⅞	25½	*21	3⅜	1 1/16	24⅞	1 3/16	7⅝	4⅞	4	6⅝	1 1/16	2	1	†⅞	10⅞	2
1200—1600	36½	12¾	32⅝	*25	4¼	1½	33 1/16	1¼	9 1/16	5 3/16	5⅛	6⅞	1¼	2½	1¼	†⅞	12⅝	1¾

All Dimensions given in Inches.
*This Dimension varies slightly with different motors.
O = Supply, P = Return, R = ⅜-in. Air Vent Outlet—can be bushed as required.
†Adjustable Swivel Coupling (furnished with Thermolier) Tapped Standard Bolt Thread.
‡Outlets bushed to pipe size next smaller than indicated in table.
NOTE—Models 600 and 800 have 5 louvers placed as shown on above sketch. Models 100, 200, 300 and 400 have 4 louvers; 1200 and 1600, 6 louvers.
All essential dimensions of the Industrial Type, as given in table above, will also apply to the Factory Type. "A" Units have same dimensions as Standard Units.

Branches
Boston
New York
Philadelphia
Pittsburgh
Akron
Birmingham

The Bristol Company

Waterbury, Conn.

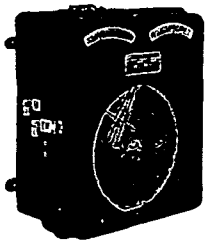
(Established, 1889)

Manufacturers of Indicating, Recording and Controlling Instruments.

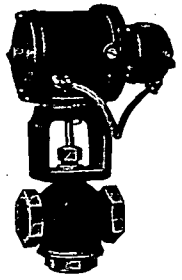
Branches
Chicago
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Detroit
Denver
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San Francisco

TRADE MARK
BRISTOL'S
REG. U.S. PAT. OFFICE

Humidity Recorder Controller



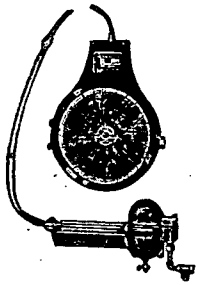
A new development for automatically controlling atmospheric temperature in relation to humidity. Extensively used in dry kilns, textile mills, etc. Suitable for both progressive and charge type kilns. Recorder and Controller operate from one sensitive bulb, but otherwise the systems are entirely independent. The equipment is reliable in its action and not dependent on auxiliary equipment. The Recorder chart is 10-in. size. Case construction is moisture-proof. Simple to install and operate.



Valves

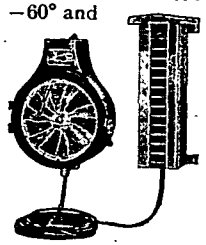
Bristol's Motor Operated BK Valve used in steam and spray line, operates under the guidance of controller. Compact in design and available in body sizes for ½ to 2½-in. pipe sizes. Standard motor voltage and frequencies available.

Recording Psychrometers



Where Automatic Temperature and Humidity Controllers are not used a Recording Psychrometer will guide operator in regulating spray and steam lines. Suitable for use wherever a knowledge of relative humidity is necessary to efficient operation.

Recording Thermometers—For all commercial ranges from −60° and +1000° F. Furnished with plain bulbs for use in open spaces; or bulbs with union and screw connections for recording temperatures of liquids in closed spaces under pressure. Illustration is an outdoor atmospheric recording thermometer. Sensitive-Bulb located in weather house exposed to elements; instrument located within building. Chart may be 12 or 8 in. and provide record for 24 hours or 7 days.



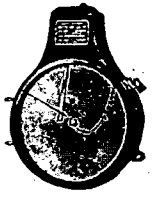
Handy Portable Recording Thermometer—Especially useful for recording temperatures in cold storage rooms, refrigerating units, dairies, greenhouses, dwellings, theatres, hospitals, schools, hotels, etc. Available for suitable temperatures from −30° to 150° F. Chart size 4 in., ranged for continuous record of 72 hours. Rugged, light in weight and easily portable. Case can be furnished in either white or black enamel.



Thermostat Temperature Controllers—For automatically controlling temperatures up to 1000° F. this type of instrument gives excellent results. Used for such applications as cooling chambers, room temperatures, ovens, pasteurizers, chromium plating, etc.



Recording Pressure and Vacuum Gauges—For securing continuous records of pressure or vacuum. For steam, air, gas and liquids. Charts furnished to read in pounds, ounces, inches, feet, metric or any desired unit. For ranges, from full vacuum to 12,000 lb. per sq. in.



Consolidated Ashcroft Hancock Co., Inc.

Bridgeport, Conn.

BRANCHES IN PRINCIPAL CITIES

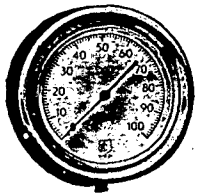
Makers of AMERICAN INDUSTRIAL INSTRUMENTS—Since 1851

Subsidiary of Manning, Maxwell and Moore, Inc.

Manufacturers of Indicating and Recording Gauges; Gauge Testers; "U" Gauges; Draft Gauges; Indicating and Recording Thermometers; Tachometers; Dial Thermometers; Pressure and Temperature Controllers; Electric Temperature Controllers; Pop Safety and Water Relief Valves; Steam Traps; Engine Indicators; Counters; Absolute Pressure Gauges.

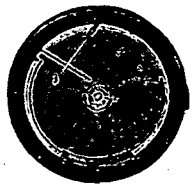
Also manufacturers of Bronze, Cast Steel and Forged Steel Valves, Locomotive and Engine Room Clocks; Barometers; Mercury Column Gauges; Steam Whistles; Hydraulagraphs; Gauge Boards.

Ashcroft American Gauges—Ashcroft American Gauges are made in all sizes from 2½ to 12 in., for pressures from 8 oz. to 25,000 lbs. and also for vacuum. Cases are cast-iron or cast brass. The movements are Heavy Duty and all bearings are Monel Metal. Write for Catalog No. A-59.



For Mercury Pressure and Vacuum Gauges, "U" Gauges, Draft Gauges and Mercurial Barometers, write for Catalog B-59.

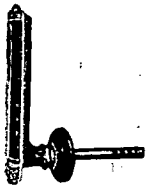
American Recording Gauges—American Recording Gauges are made for all pressures from 15 in. of water to 10,000 lbs. and for vacuum. They are made in one size only to accommodate a 10 in. chart, having an effective scale width of 3⅝ in. The case is Die Cast with a dull black hard-rubber finish and with either bottom or back connection. The pen-arm is made of non-corrosive Monel Metal and is of the inverted type. Operating instructions are lithographed on the chart plate so that they cannot be lost.



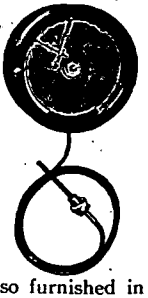
Especially designed Seth Thomas clocks are used, and all customary time periods can be furnished.

American Recording Gauges are equipped with the Time Punch which virtually makes each instrument a time clock, since a hole is punched in the chart whenever a reading is taken. Write for Catalog E-59.

American Air Duct Thermometer—Designed especially for both warm and cold air ducts. Fitted with polished brass "V" shaped case, glass front. Furnished with 9-in. or 12-in. scale graduated 0-160° F. Write for Catalog F-59.



American Recording Thermometers—Made for recording temperatures from minus 40 to plus 1000° F. or equivalent C. Very flexible connecting tubing up to 200 ft. One size only to accommodate 10 in. chart, with an effective scale width of 3⅝ in.



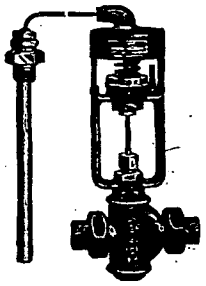
Same case as for the American Recording Gauge, so that all instruments are uniform in appearance when mounted on Gauge Boards. American Indicating Gauges and Dial Thermometers are also furnished in same case. Write for Catalog H-59.

American Dial Thermometers—American Dial (mercury-filled) Indicating Thermometer has the accuracy of the standard glass tube thermometer and the reading convenience of a dial face. Entire working mechanism is made of steel, meaning long life.



Standard size of dial 6 and 12 in. Furnished with rigid connection or flexible capillary steel tubing up to 200 ft. long. For temperature ranges from minus 40 to plus 1000° F. Write for Catalog G-59.

American Precision Temperature Controllers—Self-operated and simple in construction. For regulating temperatures from 25° to 385° F. Under favorable conditions temperature will be held within 1°. Sensitive, rugged and accurate. For hot water service tanks, water heaters, etc. Standard ranges carried in stock. Size of valve must be specified. Write for Catalog R-59.



Taylor Instrument Companies

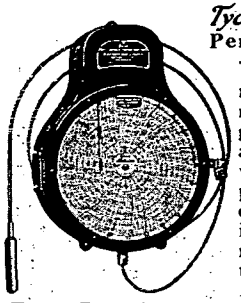
Rochester, N. Y., U. S. A.

IN CANADA—Taylor Instrument Companies of Canada, Ltd., Toronto

NEW YORK	PHILADELPHIA	LOS ANGELES	ST. LOUIS	DETROIT
CHICAGO	PITTSBURGH	INDIANAPOLIS	CINCINNATI	ATLANTA
BOSTON	CLEVELAND	SAN FRANCISCO	TULSA	MINNEAPOLIS

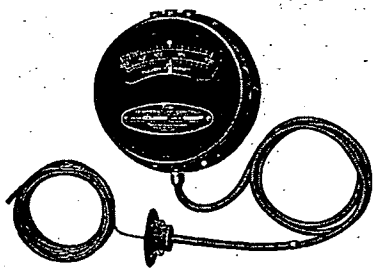
Manufacturing Distributors in Great Britain, Short & Mason, Ltd., London

Manufacturers of Tycos Instruments for Indicating, Recording and Controlling Temperature, Pressure and Humidity



***Tycos* Suspended-Pen Recorders**—Temperature ranges and time requirements vary greatly in heating and ventilating work. Tycos Suspended - Pen Recorders are made in many scale ranges and several time periods to meet these needs. Tycos Recorders are sturdy and reliable. The friction of moving parts has been reduced to a minimum. Charts are easily changed, and each instrument is locked and sealed against malicious or unintentional interference with the mechanism. Cases are handsomely finished and are dust and moisture proof. Instruments may be quickly tested and calibrated. Write for special information suitable to your needs.

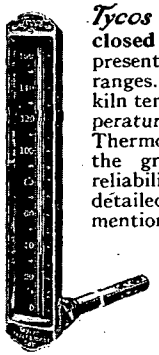
***Tycos* Electric Contact Temperature Control**—These instruments combine in the same case an electrically-operated



temperature regulator with an indicating thermometer. One tube system only is required to operate both units.

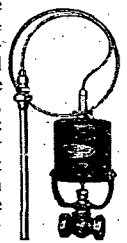
Direct-Set Control Feature—This feature has been developed in Tycos Electric-Contact Controls until we believe that no similar instrument on the market can compare with it for convenience and accuracy. The Tycos Direct-Setting Feature is a real time saver, because it eliminates making a series of adjustments in order to obtain the proper control. Only one adjustment is required.

The instrument will control at this point within the limits of its contact until re-set for another temperature.



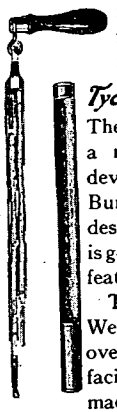
***Tycos* Thermometers for Enclosed Spaces**—The Tycos line presents many styles and scale ranges. Suitable for air ducts, kiln temperatures and oven temperatures. Tycos Industrial Thermometers are made with the greatest care, and their reliability is unquestioned. For detailed information, write direct, mentioning your requirements.

***Tycos* Self-Acting Temperature Regulator**—Is adapted to use on hot-water storage tanks, etc. It is "self-acting" in that it requires no auxiliary motive power, such as compressed air, to open and close the steam valve. As heat is applied to the bulb the volatile liquid inside sets up a vapor pressure proportional to the temperature. This pressure is transmitted to a "stack" of metal diaphragms attached to the upper end of the valve stem, thus moving the valve disc toward the valve seat. By means of the adjustment at the top of the diaphragm housing, the valve can be closed at any desired temperature, or a throttling action can be obtained within the temperature range of the instrument. Not practicable on pipe lines having steam pressure over 125 lbs.



Should be installed in a vertical position on top of the line; never hanging underneath the line. The line itself should be horizontal rather than vertical.

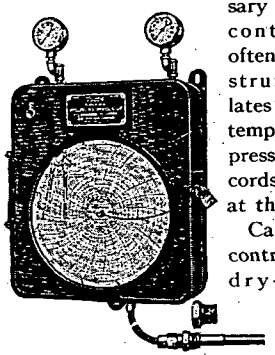
Operating range 100 deg. to 160 deg. fahr., 140 deg. to 212 deg. fahr., or 190 deg. to 270 deg. fahr., as specified.



***Tycos* Sling Psychrometer**—The Tycos Sling Psychrometer is a modification of the pattern developed by the U. S. Weather Bureau. The fact that our design has been generally copied is good evidence of its practicable features.

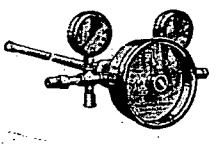
The advantage of this form of Wet-and-Dry-Bulb Hygrometer over the stationary form is the facility with which tests can be made and the accuracy of the readings obtainable, as in whirling the bulbs they are subjected to perfect circulation.

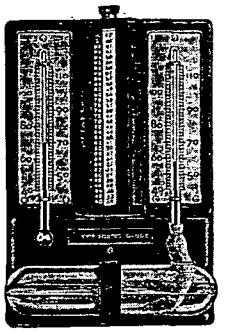
***Tycos* Recording Regulator**—Recommended for applications where it is necessary to change control points often. This instrument regulates one or two temperatures or pressures and records one or both at the same time.



Can be used to control wet and dry-bulb temperatures in closed spaces. Setting is made directly by moving a pointer to the desired temperature on the chart.

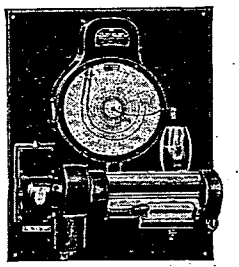
***Tycos* Type-P Regulator**—A compact and very sensitive regulator, ideal for air-ducts, air-washing machines, cooling rooms and similar applications. Uses compressed air as an actuating medium.



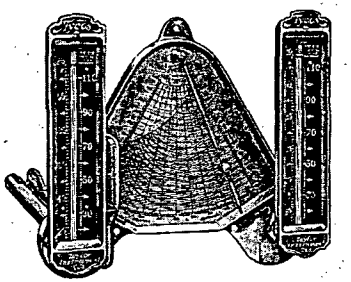


***Tycos* Humidiguide**—A handsome small hygrometer for the wall of the home, office, school or other building where a neat, easy-reading and inexpensive instrument is desired. It is self-contained, requiring no charts or separate tables. Frame is Mahogany Bakelite.

***Tycos* Recording Hygrometer**—This instrument records both wet and dry - bulb temperatures on the same chart in different colored inks, making comparison very easy.



Type shown above with motor-driven fan for conditioned rooms or passages in which circulation is poor. Can be supplied without fan for installations where circulation across bulb is good.



***Tycos* Hygrodeik**—This self-contained hygrometer is designed for air-ducts, kilns, driers and similar applications. Mounting is made through wall into enclosed space. Thermometers are highly accurate Tycos Industrial type and water reservoir is of generous capacity.

Write for additional information on any of the Tycos Instruments on this page.

The Palmer Company

MANUFACTURERS

426 Clay Street, **Cincinnati, (St. Bernard) Ohio**

Something New In Industrial Indicating Thermometers.
Red—Reading—Mercury.

With the new glass which we have originated, we are now able to furnish a pure mercury tube, which will show a bright **RED** color in the reading column instead of the silver, mercury. This is done by means of reflecting a piece of red glass in the tube onto the mercury column. We add nothing to the mercury to change its purity or sensitiveness. **Write us about this before ordering thermometers.**

Industrial Thermometers:

Made in three standard case sizes:
12″; 9″ and 7″.

Forms: Straight - - - - - - - - - - - - - - - Reclining or Inclining Case
90° Angle - - - - - - - - - - - - - - - Right or Left Side Angle



Illustrating Air Duct Thermometer with Flange-Union Connection

Fittings:
Plain shank;
Fixed flange;
Adjustable flange (movable on stem);
Adjustable clamp hook;
Fixed taper thread;
Flanged Union connection; (as illustrated)
Union connection;
Separable Socket
Parallel thread fitting with locknut (for rooms, ovens, etc.).
Insulation between case and stem (for frost, etc.).
Extension neck (stem to pass through pipe covering, etc.).
Standard stem length: 3½″; other lengths can be ordered. All ranges of temperature can be furnished.

Construction:
Lens, **RED—READING—MERCURY** tube; large diameter glass, very easily read;
Graduated brass scale; large numbers;
V-shaped case; Glass front protection over tube;
All tubes annealed to prevent change with age;
Accuracy Guaranteed on every thermometer;
For registering air temperatures, the bulb is bare and protected by a perforated metal steam around bulb (as illustrated);
For liquids, a mercury chamber is furnished around bulb;
Extra guards can be supplied with thermometer for protection to the bulb.

Air Duct Thermometers:

9″ and 12″ case with glass front protection.
Polished chromium-plated finish.
Flanged-Union connection; perforated stem around bulb; stem 6″, 12″, 18″, 24″, etc.
Standard range: +30 +160°F. with reservoir up to 300°F. nitrogen filled tube;
Illustration shows 50° Reclining case (measure stem in vertical position). Also supplied in regular 90° Angle, etc.
Of course, **All Palmer** Air Duct Thermometers would have the new

Red Reading Mercury

Send for free descriptive Bulletin on this.

Wet and Dry-Bulb Hygrometers—write us.

141 Milk Street **Samuel Cabot** Incorporated **Boston, Mass.**

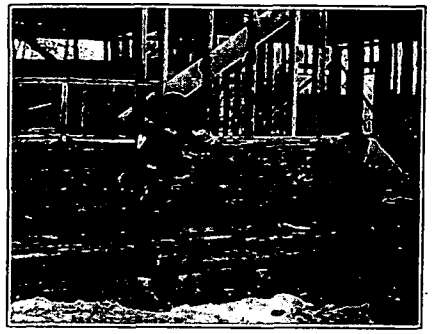
101 Park Avenue, NEW YORK
5000 Bloomingdale Avenue, CHICAGO
PHILADELPHIA, KANSAS CITY, MINNEAPOLIS, LOS ANGELES, SAN FRANCISCO, SEATTLE, PORTLAND

Agents in All Principal Cities

Cabot's Insulating Quilt

Uses—For insulating houses and other buildings to make them warm in winter and cool in summer; for insulating cold storage and ice houses, refrigerators, etc.

Description—Cabot's Quilt is a felted matting of zostera marina, a marine plant, stitched between two layers of very strong Kraft paper. Zostera marina, forms a matted structure full of tiny dead air cells. Dead air cells have the best insulation known. Cabot's Quilt has a heating insulating value, inch for inch, exceeding or equalled by only two other insulators, irrespective of cost. Quilt is exceedingly low in cost.



Cabot's Quilt being applied to under side of roof and walls, for heat insulation

Permanency—Cabot's Quilt will not rot, foul or harbor insects or vermin. It has been used for more than 35 years without deterioration.

Fire Resistance—Quilt is highly fire resistant. This has been proved in many buildings.

Flexibility—Being flexible, Quilt will fit any surfaces, corners, projections or jogs, without danger of cracking or injury to the insulating qualities.

Application—Quilt can be applied at the lowest labor cost like any common felt or paper, is cut easily with an ordinary knife or shears and requires no skill to apply.

18″ Width—Quilt is now made in 18″ as well as 36″ width, for quick application between studs and roof rafters.

U. S. Government Bureau of Standards Letter Circular No. 227, reporting tests of numerous Insulating Materials, gives **Cabot's Quilt** a Thermal Conductivity rating of 0.25 per inch, which was equalled by only two other insulators, regardless of cost.

Tests conducted by Prof. Gordon B. Wilkes, of the Massachusetts Institute of Technology, show the following savings in heat leakage in different methods of construction, by the use of **Cabot's Quilt.**

CONSTRUCTION WALL	Conductivity Uninsulated "H"	Conductivity Insulated with Cabot's Double Ply Quilt—"H1"	Percentage Heat Saving
Clapboard, studding	0.70	0.26	63
Clapboard, studding, lath, plaster	0.44	0.21	52
Clapboard, sheathing, studding, lath, plaster	0.28	0.16	43
8 in. brick	0.40	0.20	50
8 in. brick, furring, lath, plaster	0.27	0.16	41
4 in. tile, stucco, outside, plaster inside	0.40	0.20	50
12 in. concrete	0.46	0.21	54
Corrugated iron	1.50	0.32	79
12 in. stone	0.49	0.22	55
12 in. concrete, furring, lath, plaster	0.40	0.20	50
Stucco, studding, plaster	0.45	0.21	53
ROOF			
Tar, gravel on 4 in. concrete	0.60	0.24	60
Metal on tongue and groove sheathing	0.42	0.20	52
Corrugated iron on wood frame	1.80	0.32	82
Tile or slate on wood sheathing	0.82	0.27	67
Tar, gravel, tar paper, 2 in. wood plank	0.26	0.16	39
Shingles, sheathing, studding, lath, plaster	0.30	0.17	43
Wood shingles on shingle lath	0.64*	0.24	63

*Average value from JONES' tables, *The Heating and Ventilating Magazine.*

The cost of **Cabot's Quilt** is so low, for material and application, that reduction in Heating Equipment more than pays for entire insulation. Thereafter there is a yearly fuel saving.

Sound proof: Quilt has a very wide and successful use in Soundproofing buildings.

Armstrong Cork & Insulation Company

Lancaster, Pa.

Offices

Albany	Cleveland	Jacksonville, Fla.	Pittsburgh
Atlanta	Dallas	Kansas City	Rochester
Boston	Denver	Milwaukee	St. Louis
Buffalo	Detroit	Minneapolis	Syracuse
Charlotte, N.C.	Grand Rapids	New York	Montreal, Que., Can.
Chicago	Houston, Tex.	Omaha	Toronto 2, Ont., Can.
Cincinnati			Winnipeg, Man., Can.

Armstrong Cork Company, Ltd.,
London, England

Representatives

Baltimore	John R. Livezey	Philadelphia	John R. Livezey
Los Angeles	Gay Engineering Corp.	Portland, Ore.	Gillen-Cole Co.
New Orleans	H. T. Steffee	San Francisco	Van Fleet-Freear Co.
		Washington	John R. Livezey

Detailed information, samples, and descriptive literature may be obtained on application to any of these offices or representatives.

Over 50 per cent of the heat supplied to an uninsulated residential building is lost by conduction and radiation through the walls and roofs. But when the house is adequately insulated this loss is so materially reduced that it can be heated comfortably with less fuel. Heat requirements of the insulated building, as compared with an uninsulated building, are reduced by 25 to 40 per cent.

When heating with oil, gas, or electricity is contemplated, the saving which can be made through adequate insulation frequently justifies the use of a higher priced and more convenient fuel than could otherwise be used.

Insulated houses also are heated much more uniformly, have no cold side or rooms that are hard to heat, and are decidedly freer from drafts. The greater comfort and economy of the insulated house react directly to the benefit of the heating engineer or contractor, since it reflects credit on the efficiency of his plant and the value of his services.

Two efficient Armstrong insulations are available for the insulation of residences and commercial and industrial buildings. Where requirements are severe, use of Armstrong's Corkboard is recommended. For the less severe conditions encountered in residences and in general applications in the building industry, Armstrong's Temlok, the improved low-cost fibreboard insulation, will give efficient and economical service.

Armstrong's Corkboard

Armstrong's has been standard insulation in many industries for more than a quarter of a century. Many millions of feet of corkboard are in use in cold storage plants, refrigerators, refrigerator cars, and in industrial rooms where temperature control is essential. Its dependability and permanence have been proved under the most exacting conditions.

Armstrong's Corkboard is composed of clean granules of pure cork, compressed and solidified by a baking process into firm, semi-rigid boards of uniform quality. Armstrong's Corkboard is furnished in boards 12 in. wide by 36 in. long and in 1, 1½, 2, 3, 4, and 6 in. thicknesses. It is obvious that with this wide range of thicknesses, any required thickness can be applied in a single layer at a considerable saving in labor cost.

Armstrong's Corkboard is light in weight and can be erected easily in any type of construction, being applied in portland cement mortar, nailed to studs,

joists, and rafters and laid in asphalt or pitch on roof decks. Plaster can be applied directly over the corkboard, and standard roofings can be laid over the corkboard when used as roof insulation.

Armstrong's Temlok

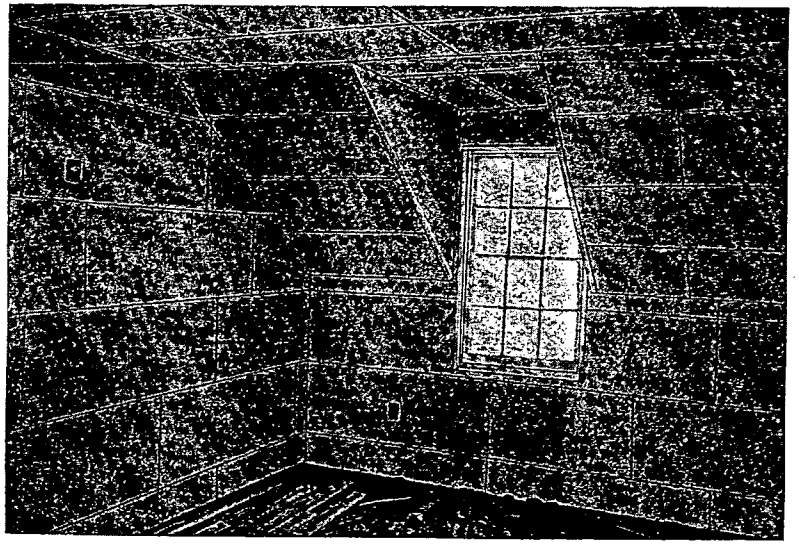
Temlok, the new low-cost fibreboard insulation, was developed by Armstrong to meet the need for a permanently efficient insulation which could be furnished at a moderate cost. Temlok has behind it the prestige and experience of the Armstrong Cork & Insulation Company in the insulation field, and it meets the high standard of excellence set for all Armstrong products.

Fabricated from the heartwood of southern pine, Temlok has exceptionally low moisture absorption. It also has low thermal conductivity, light weight, structural strength, and is sterile and odorless. Temlok is easy to saw and nail and is an excellent plaster base. Temlok is furnished as insulating lath and as insulating board to replace sheathing. Temlok Insulating Lath is 18 in. wide by 48 in. long, with long edges shiplapped. Temlok Insulating Board is 4 feet wide by 6, 7, 8, 8½, 9, 9½, 10, and 12 feet long. In both forms Temlok is available in full half-inch and full inch thicknesses.

Temlok Roof Insulation is furnished in boards 22 in. wide by 47 in. long in full half-inch and full inch thicknesses. Temlok Roof Insulation can be applied to any type of roof deck and it provides a firm, protective base for roofing.

Further Information

Complete specifications and detailed information will be found in the booklets, "The Insulation of Walls and Roofs with Armstrong's Corkboard," "Armstrong's Temlok Building Insulation" and "Armstrong's Temlok Roof Insulation," which will be mailed free upon request.



Illustrating Armstrong's Temlok being applied as insulating lath in a residence.

The Celotex Company

919 N. Michigan Ave., Chicago, Ill.

Mills: NEW ORLEANS, LA.

Branch Sales Offices
(See Telephone Books for Addresses)

BOSTON, MASS. DENVER, COLO. MINNEAPOLIS, MINN. ST. LOUIS, MO.
DALLAS, TEXAS LOS ANGELES, CALIF. NEW YORK, N. Y. SEATTLE, WASH.

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CANADIAN REPRESENTATIVES: ALEXANDER MURRAY & COMPANY, LTD.
MONTREAL, QUE. TORONTO, ONT. ST. JOHN, N. B. HALIFAX, N. S. WINNIPEG, MAN. VANCOUVER, B. C.

CELOTEX
BRAND
INSULATING CANE BOARD

PRODUCTS—

Building Board.
½″ and 1″ Lath.
¾″ Sheathing.
Ozite Building Blanket.
Compo-Board.
Acousti-Celotex.
Tile Board.
Cemesto-Board
Roof Insulation.
Lanite Insulating Blanket.
Wallboards.

Insulation Headquarters

With the addition of several important products, the Celotex Company now offers a complete line of insulating materials to the building industry. Under this policy, full information on any type of insulation is available from one source.

Celotex Cane Fibre Insulation

Celotex is a rigid insulation manufactured by felting strong tough cane fibres into a continuous board. Several products are then fabricated for various purposes. The resulting products combine high insulating efficiency with unusual structural strength.

The thermal conductivity of Celotex is 0.33 B.t.u. per hour, per square foot, per 1 degree Fahrenheit, per inch thickness (based on a density of 13.5 lb. per cubic foot and a mean temperature of 70° F.). Tests conducted at Armour Institute of Technology and at recognized laboratories confirm this figure.

The Celotex Company maintains an engineering and research staff which is available for investigations of all types of insulation installations. Engineers are invited to address their problems to The Company at Chicago.

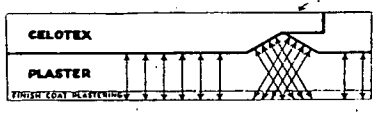
Celotex Building Board

Two surface utility. One side smooth for stenciling and other interior finish treatments. The other retains that unique Celotex texture. Sizes—4 feet wide and 7, 8, 8½, 9, 9½, 10 and 12 feet long. $\frac{1}{16}$″ thick.



Celotex Lath

A natural bond for plaster—a continuous plastering surface providing special resistance to lath cracks—eliminated lath marks—beveled and shiplapped joints (see diagram). Size: 18″ x 48″. ½″ and 1″ thick.



Celotex ¾″ Sheathing

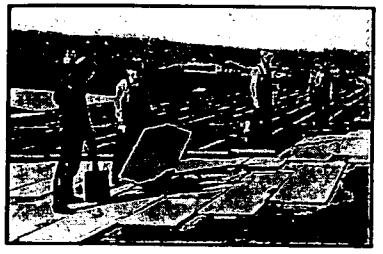
E X T R A insulation and structural strength. May be used with standard frames. ¾″ thick, 4 feet wide: 7, 8, 8½, 9, 9½, 10 and 12 feet long.

Celotex Tileboard

For tile effects on walls and ceilings, smooth surface like Building Board, to leave plain, stencil or paint. Beveled joint. Sizes: $\frac{7}{16}$″ and $\frac{13}{16}$″ thick. Range of sizes from 6″ to 12″ to 18″ x 32″.

Celotex Roof Insulation Board

Preferred as insulation over wood, concrete, steel, unit tile and poured gypsum



roof decks. Sizes 22″ x 47″ approximately ½″ thick. Also furnished laminated from 2 to 8 plies.

Celotex Cemesto-Board

Made by integrally surfacing one or more layers of Celotex with asbestos cement. Combines the fire protective and weather resisting qualities of asbestos cement with the insulation efficiency of Celotex (.33 B.t.u.). Provides light reflection, rigidity, water-proofing, fire resistance, permanence and economy with pleasing appearance. Suitable for low temperature dryers (200° maximum continuous temperature) and air ducts, industrial partitions and roof decks wherever fire protection and insulation are desired. Sizes: Standard 4′ x 8′ thickness of Celotex core from ½″ to 2″ in multiples of ½″ plies; surfaced one or both sides with ⅛″ asbestos cement.

OTHER INSULATING MATERIALS

Ozite Building Blanket

A modern flexible form of all hair felt. Permanent. Resistant to decay and deterioration from the elements, as well as to fire. Ozite Building Blanket consists of chemically treated hair stitched between layers of heavy crepe paper, duplex asphalted for water-proofness and repellence to rodents and vermin, durable and puncture resistant. Distinguished by reinforcing hair in the paper surface.



Lanite Insulating Blanket

Chemically treated mixture of animal hair and imported fibre between layers of crepe duplex asphalted paper for water-proofness and rodent and vermin repellence. A modern blanket form of insulation. Fire resistant.

Service

The Celotex Company makes its products available throughout the world. In Canada, Alexander Murray & Co., Ltd., handle them.

This world-wide service has a background of trained insulation engineers who are at your service whenever some unusual insulating problem is before you. Don't hesitate to inquire about this service or to use it without obligation of any kind.

Flax-li-num Insulating Company

Chicago Office
228 North La Salle

Home Office and Factory
St. Paul, Minnesota

New York Office
GRAYBAR BUILDING,
420 Lexington Avenue

Manufacturers of FLAX-LI-NUM and BI-FLAX

Flax-li-num is a thermal insulation and sound control material. It is made exclusively from the long tough fibers of flax, interwoven and felted into semi-rigid sheets of convenient size, and in thicknesses of ¼ in., ½ in., ¾ in. and 1 in. The very nature of the flax fiber guarantees the durability of Flax-li-num. When installed it remains in place with undiminished efficiency as long as the building stands.

Flax-li-num has a thermal conductivity of 0.31 B.t.u. per hour per square foot per degree Fahrenheit per inch thickness (U. S. Bureau of Standards). However, the actual thickness of commercial 1 in. Flax-li-num is 1⅛ in., and the conductance of this thickness is 0.28 B.t.u. per hour per square foot per degree Fahrenheit difference in temperature between the two surfaces, calculated from the U. S. Bureau of Standards test for the 1 in. thickness.

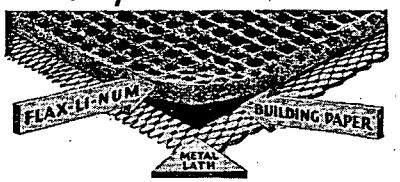
Flax-li-num is designed for application according to the two air-space method. When so installed an extra air space is created which in insulating value is equal to more than ¼ in. of the material.

Flax-li-num is extensively used for industrial roofs to insulate against heat and cold and to prevent condensation; in building construction to reduce heat loss and heat penetration; in party walls and floors to reduce the transmission of sound; in refrigerator cars and domestic refrigerators for the economical preservation of foods.



BI-FLAX

The *Only* Material of It's Kind



Bi-Flax is an entirely new insulating plaster base, the only material of its kind. It is a permanent combination of three time-proven building materials—Flax-li-num Insulation, waterproof paper, and flat expanded metal lath. It is manufactured in two weights, Standard and Extra Heavy; in thicknesses of 1 in. and ½ in. and in sheets 24 in. x 48 in. Extra Heavy Bi-Flax is recommended for ceilings and Standard Bi-Flax for sidewalls.

The metal lath of Bi-Flax extends 1 in. beyond the insulation on one side and one end—when applied the sheets of Flax-li-num butt tightly together and the metal lath overlaps at all joints.

Bi-Flax is the only insulating plaster base that provides a mechanical key for the plaster. When plaster is applied to Bi-Flax, it passes through the metal mesh and squashes out behind it, completely embedding the metal lath. Consequently the steel reinforces the plaster, minimizing plaster cracks and blemishes.

Maximum insulating value is secured by separating the insulation from the plaster with waterproof paper.

Bi-Flax reduces fuel bills; reduces the transmission of sound through party walls and floors and minimizes plaster cracks.

The Insulite Company

(A BACKUS-BROOKS INDUSTRY)

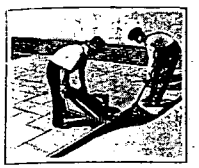
INSULITE *the Wood-Fiber Insulating Board* **Minneapolis Minn.** INSULITE *the Wood-Fiber Insulating Board*

Offices:

BOSTON
NEW YORK
PHILADELPHIA
WASHINGTON
CLEVELAND
DETROIT
CHICAGO
KANSAS CITY
LOS ANGELES

Offices in all Principal Cities

Detailed information, samples and literature may be had by application to any of the branch offices.

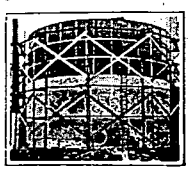


Insulite is made from the strong, tough fibres of northern woods, chemically treated to resist moisture and is not subject to rot or disintegration. This rigid board insulation is used extensively for general building, as plaster base, for sound deadening and acoustical correction, for roof insulation, and in refrigeration construction.

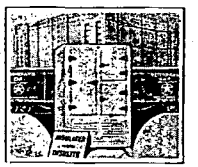


Insulite Roof Insulation is easy to handle, quickly and economically applied. Made in units 18 in. x 36 in. either ½ in. or 1 in. thick. The 1 in. unit is made of two ½ in. layers of Insulite offset on all four edges and firmly fastened together. This ship lap edge eliminates heat leaking joints.

Insulite Air Duct Lining gives both high insulating value and superior sound absorbing qualities. In the Insulite lined duct the air can be easily maintained at the desired temperature for long distances—fan noise is absorbed long before it reaches the outlet.



The Outstanding Features of Insulite are durability, toughness, resilience, low thermal conductivity, high tensile strength and low capillarity and vapor absorption. Insulite is stocked by lumber dealers everywhere.



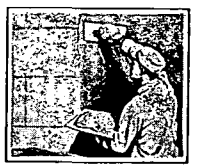
Insulite Tank Insulation possesses all the necessary requirements to efficiently insulate practically any type of storage tank. It has rigidity, toughness, durability, great tensile strength, water resisting properties, and its high insulating value means closer temperature control.

Insulite for Refrigeration has many advantages—its special low density insures high thermal insulating efficiency. Insulite will not rot, mold or disintegrate under the most adverse moisture conditions. It is odorless and will not absorb odors.



Engineering Service

The Insulite Co. maintains a staff of engineers who will gladly assist you with any special insulation problem you may have. Their services are available to Architects and Heating and Ventilating Engineers without cost.



Insulite Sheathing, in addition to its high insulating value, has several times the bracing strength of lumber horizontally applied. The use of Insulite sheathing is economical—it replaces non-insulating materials and the large, rigid panels are easily handled and quickly applied—it speeds up construction and reduces labor costs.

Insulite Lath grips plaster with twice the strength of wood lath. It is made in ½ in., ¾ in. and 1 in. thicknesses, 18 in. x 48 in. The 1 in. unit is made by offsetting two ½ in. layers one inch on all four edges, and firmly fastening them together. The beveled edges and shiplapped joints reinforce against plaster cracks—lath marks are eliminated.

International Fibre Board Limited

TEN/TEST Insulating Building Board

PYRO/TEST Non-Inflammable Insulating Building Board

Sales Offices
OTTAWA—MONTREAL—TORONTO—WINNIPEG
Administrative Offices and Mills: GATINEAU, QUE.
London Office
THE TENTEST FIBRE BOARD CO. (1929) LTD.
ASTOR HOUSE, ALDWYCH, LONDON, W. C. 2., ENGLAND

TEN/TEST is a manufactured lumber made from spruce fibres, solidly pressed under hydraulic pressure into a strong, homogeneous board. The fibres are chemically treated and water-proofed during process of manufacture, until the insulation is non-hygroscopic, free from capillary attraction and moisture-resisting in service commensurate with the maximum degree of insulation obtainable.

Official Tests

Conductivity. **TEN/TEST** has a conductivity of 0.33 B.T.U. per hour per square foot per degree fahr. per 1 in. thick. Authority: Professor E. A. Allcut, M. Sc. M. I. Mech. E. Mem. A.S.M.E. Professor of Applied Mechanics, University of Toronto. Tests performed by Hot-Plate method. Mean temperature 47.8 deg.

Tensile Strength 228 lb. per sq. in. Tests made on 7/16 in. board cut to strips 1 in. wide and tested in a Riehle Tensile Testing Machine, the grips being 2 in. apart. 228 lb. is the mean average of seven series of tests.

Transverse Strength (equal deflection) is 28.4 lb. Test made on 7/16 in. board, 6 in. wide, 18 in. long, on 12 in. centers, and load being applied to breaking point.

Plaster Bonding Strength 2163 lb. per sq. ft. Brown and scratch plaster coats were applied to standard 7/16 in. board, and the pull registered in an Oslen Testing Machine. Authority: Columbia University Testing Laboratories, New York.

Moisture Resisting. **TEN/TEST,** after complete immersion in water for 24 hours, registered 37.5% increase in weight.

NOTE.—Authority for tensile strength, transverse and moisture tests; J. T. Donald & Co., Ltd., Chemical Analysts and Engineers, Montreal, Que.

TEN/TEST Products

TEN/TEST Insulating Building Board. Standard insulation for use as exterior sheathing, interior finish; between walls and under floors for sound deadening. Standard Industrial Insulation for refrigeration and the prevention of condensation. Manufactured in convenient sizes: 4 ft. wide and up to 17 ft. long, ½ in. to 2 in. thick.

TEN/TEST Notch Board Plaster Base. Insulating plaster base having tongue and groove interlocking joints. Provides an effective bond with plaster without use of metal lath at joints. Sizes: 16 in. wide; 32 in. and 47¾ in. long. Thicknesses from ½ in. to 2 in.

TEN/TEST Roof Board. An effective roof insulation. Manufactured in two sizes: 1 x 4 ft. and 2 x 4 ft. Thicknesses from ½ in. to 2 in.

TEN/TEST Ashlar Block. (Acousti "A"). For interior decoration and acoustical correction. Absorbs 35 per cent of incident sound at a frequency of 512. Manufactured in small panels 6 in x 6 in. to 12 in. x 24 in. with bevelled edges.

ACOUSTI/TEST AA. Sound absorbent for acoustical correction. Can be supplied in an unlimited variety of designs and sizes to harmonize with any decorative treatment, allowing the architect much freedom in design and finish of churches, auditoriums, theatres, etc. Coefficients of absorption from 56 per cent at 512 determined by Bureau of Standards, Washington.

TEN/TEST Panel Strip. Provides pleasing trim and finish for joints, corners and openings. Manufactured in widths of from 2 in. to 6 in. and lengths up to 12 ft.

PYRO/TEST. Non-inflammable, fire-resistant, insulating building board with same physical characteristics as TEN/-TEST.

HYDRO/TEST. Water proof, insulating building board, designed particularly for low temperature requirements.

Stewart INSOBOARD Corporation

Manufacturers of Dependable Building Insulation
St. Joseph, Missouri

PRODUCTS

InsoBoard and InsoLath, structural insulating board made of wheat straw fiber, for home, factory, hotel, apartment, office buildings, farm buildings, refrigerators and refrigerator cars, cold storage plants, etc. InsoLath is ideal for plaster base.

Made from the long, tough, sterilized fibers of wheat straw, interlaced into flawless, sturdy panels 7/16 of an inch thick, 48 in. wide and 6 to 12 ft. long, INSOBOARD is



used as sheathing or wall board. It adds structural strength as well as insulation and does not increase building costs, because it replaces boxing, lath or other materials. The labor cost of installing INSOBOARD is less because it is easier and more quickly applied than other materials.

Its chief use is for the reduction of fuel bills in winter and for the minimizing of summer heat in the home. Fuel costs are reduced with INSOBOARD insulation. INSOBOARD also is effective as sound-proofing material and it retards fire as well.

It insures warm floors and keeps a house free from dampness and draughts. INSOBOARD is used, not only in new construction, but for the remodeling of old homes, to prevent heat losses through the roof. Time and the elements have no effect on it, submersion tests having shown the tendency to warp and buckle to be negligible.

InsoLath is made of the same material as INSOBOARD. It is free-expanding and non-warping and takes the place of ordinary wood lath as a plaster base. It is fabricated into convenient sizes, 18 in. by 48 in. In INSOLATH can be found (1) shiplapped, beveled edges and ends, which provide permanent expansion space all the way around, and so arranged that this space cannot be filled with plaster and (2) nailing slots which permit free expansion of lath without binding and resultant bulges and warping. The usual insulation features are present in INSOLATH as in INSOBOARD. It has great strength, increased plaster bond and is a perfected many-purpose material which successfully combines all the desirable features of a perfect insulating plaster base.

The "flat-plate" test was used in tests of INSOBOARD by G. F. Gebhardt, Mechanical Engineer of the Armour Institute of Technology at Chicago an internationally known and recognized authority on insulation values. The flat plate conductivity of INSOBOARD is 0.33 Btu per hour per square foot per degree Fahrenheit per one inch thickness, based on a density of 17 lb per cubic foot and a mean temperature of 68 F.

The result of these tests by this disinterested authority proves that INSOBOARD possesses a high degree of insulating efficiency and should be specified on jobs calling for maximum structural insulation.

The Upson Company

Lockport, New York

UPSON BLUE STRIPE INSULATION

Also Upson Board and Upson Fibre-Tile

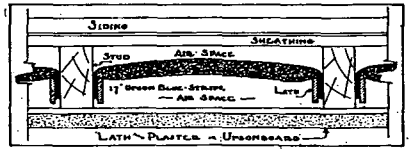
Product

Upson *Blue*-Stripe Insulation is a flexible, quilt-like blanket for insulating all exterior walls, upper floor ceilings and roofs, in order to conserve heat.

Folded fan-fold and packed in strong dust-proof cartons, Upson *Blue*-Stripe Insulation comes in three standard widths:

17 in., for use between studs on 16 in. centers; 166⅔ sq. ft. or 118 lineal feet to carton; 25½ in. for use between studs on 24 in. centers or less; 250 sq. ft. or 118 lineal feet to carton and 34 in. for looping on alternate studs on 16 in. centers; 166⅔ sq. ft. or 59 lineal feet to carton.

It is about ¾ in. thick.



Advantages

1. Upson *Blue*-Stripe Insulation is Flexible, Cellular and Fibrous. It can be fitted or folded into and around corners and odd shaped places. Convenient to install, and practically every crack and crevice in wall or roof can be effectively sealed up, thus securing real effective insulation. The liners, water-proofed on the outside, likewise, stop the passage of air.

2. It is light in weight. A density of 4.11 lb. per cubic foot. The filler of the Upson *Blue*-Stripe Insulation is made of light, woolly fibers especially chosen for their insulating efficiency.

3. While its commercial thickness is approximately three-fourths of an inch, it *fluffs* out or expands to almost double this thickness when installed in the wall, thereby decreasing density and adding to its insulating value.

4. Upson *Blue*-Stripe Insulation is not a structural material nor does it replace any structural material. It is *added* to the wall or roof, thereby adding its own insulating value to the insulating value of the wall or roof itself. Should be applied midway the depth of studs or joists. This gives the two-air-space construction recommended by leading scientific authorities.

Features

The high insulating value of Upson *Blue*-Stripe Insulation maintains the temperature of inside surfaces of exterior walls well above the dew point, prevents condensation, even under conditions of relatively high humidity. Protected on the outside by waterproofed liners, which prevent absorption of moisture from the air.

Upson *Blue*-Stripe Insulation is compressed at the edges, making it easily flanged and quickly applied. Each edge is sewed and reinforced with heavy Kraft tape. The stitching does not, however, penetrate the outside liners. The insulation is fire resistant and offers an additional safety factor for frame buildings.

The fibers in Upson *Blue*-Stripe Insulation are interlocked and felted, preventing easy shifting or settling. Moreover, the edges are reinforced and sewed.

Contains no undestroyed vegetable matter. Will not harbor rats, mice or vermin, since it is chemically treated.

Does not flame readily, nor does it smolder or burn easily.

Requires no special skill for installation. Full directions as to application are included in every carton.

Savings

Sizeable returns on the investment are shown through:

1. Fuel Savings.
2. Lower cost of heating plant.
3. Increase in comfort.
4. Maintenance of healthful living conditions.

The real cost of an insulating material is the cost per *square foot of insulating value.*

The insulating value of a material increases with an increase in its thickness. The cost of the material per square foot

of area increases with the thickness. But insulating value does not always increase in direct proportion to an increase in thickness and the increase in cost.

There is a point, therefore, in this matter of thickness beyond which it is not economical to go.

The *economical* thickness, therefore, lies between the extremes of the relatively thin layer and the relatively thick layer.

Over six years ago, Upson Engineers surveyed the entire field to determine the economical thickness to meet all conditions. Their objective was to find, not only the kind of materials, but the type or form best suited to meet the requirements.

Only after exhaustive research and experiment were the final specifications of Upson *Blue*-Stripe Insulation adopted. The results of this survey indicated that high efficiency, and economy, could be obtained in an insulation that was:

1. Flexible, cellular and fibrous.
2. Light in weight.
3. Of sufficient thickness to secure economy.
4. Added to the wall in such position as to form two air spaces.

Upson *Blue*-Stripe Insulation fulfills these requirements.

Tests

Tests made at Pennsylvania State College and other authoritative laboratories show Upson *Blue*-Stripe Insulation to have a RESISTANCE OR INSULATING VALUE OF 3.03.

Conductance of Commercial Thickness —0.33 B.t.u. per square foot per hour per one degree Fahrenheit Temperature Difference, based on a density of 4.11 lb. per cubic foot and a mean temperature of 93.5 F.

Conductivity per one inch of thickness —0.29 B.t.u. per square foot per hour per one degree Fahrenheit Temperature Difference.

Typical reductions in heat losses are indicated by the following coefficients of transmission computed according to formulæ and data given in the Text Section of THE GUIDE.

Frame wall—clapboards, sheathing wood lath and plaster	0.262
Frame wall—same with UPSON *BLUE*-STRIPE	0.129
Brick Veneer—wood lath and plaster on furring	0.247
Brick Veneer—same with UPSON *BLUE*-STRIPE	0.125
8 in. Brick Wall—plaster on wood lath furred	0.250
8 in. Brick Wall—same with UPSON *BLUE*-STRIPE	0.126
Stucco on metal lath—wood sheathing—wood lath and plaster	0.302
Stucco same with UPSON *BLUE*-STRIPE	0.138

Specifications

(*a*) All work of insulation shall be continuous. All joints and sides shall be airtight.

(*b*) Full widths of insulation shall be used and they shall run in the same direction as studs, joists or rafters.

(*c*) All insulation applied midway the depth of studs, joists, or rafters shall be fastened on all four sides with wood lath securely nailed.

(*d*) All open spaces, such as between joists and rafter ends, shall be thoroughly insulated.

(*e*) Where the attic is used, roof insulation will be substituted for insulation of the top floor.

(*f*) All odd spaces to be filled to avoid air leakage or infiltration.

Upson *Blue*-Stripe Insulation may be easily identified by the inch wide blue stripe running lengthwise of one side. The blue stripe is for identification and measuring purposes and may be removed after insulation is installed.

The *Blue*-Stripe is marked with orange colored dots at each foot making it unnecessary to measure the desired lengths with a rule.

Like famous Upson Board and Upson Fibre-Tile, Upson *Blue*-Stripe Insulation is sold by discriminating lumber dealers everywhere.

If you do not know the name of your nearest Upson dealer we shall be glad to supply it.

Upson Engineers are ready to assist in the solution of your insulating problems.

Wood Conversion Company

General Office and Factory at

Cloquet, Minnesota

Manufacturers of

Balsam-Wool Blanket

District Sales Offices

Chicago, Ill.	1908 London Guaranty Bldg.	New York, N. Y.	3107 Chanin Bldg.
Detroit, Mich.	515 Stephenson Bldg.	Minneapolis, Minn.	414 Baker Bldg.
Kansas City, Mo.	231 West 47th St.	San Francisco, Calif.	149 California St.
Seattle, Wash.	621 Ligget Bldg.		

Also Mfgrs. of NU-WOOD the All-Wood Insulating Wall Board and Lath

BALSAM-WOOL Standard Building Insulation is a flexible insulating blanket made from pure wood fibers in fleecy wool form, permanently matted together between two sheets of asphalt-coated, tough, flexible, creped Kraft paper. These patented crepe paper liners are capable of 25 per cent stretch which makes them virtually puncture proof, and the fact that these liners are not stitched renders BALSAM-WOOL windproof and waterproof. In the process of manufacture, BALSAM-WOOL is chemically treated to make it fire resistant, vermin and rot proof. It is clean, odorless and sanitary—a Weyerhaeuser product.

Sizes—BALSAM-WOOL for building insulation comes in three standard widths, 17, 25 and 33 in. and in two standard thicknesses, ½ and full inch. It comes rolled, wrapped and sealed. ½ in. BALSAM-WOOL weighs 240 lb. per 1,000 sq. ft., and full inch BALSAM-WOOL weighs 370 lb. per 1,000 sq. ft.

Application—In frame construction, BALSAM-WOOL 17 and 25 in. wide is



applied between the studding, joists or roof rafters, flanged in the air space between sheathing and plaster. BALSAM-WOOL 33 in. wide is applied to the inside face of the studding or joists with furred out lath and plaster. In solid masonry construction, 17 or 25 in. BALSAM-WOOL is applied by flanging between furring strips 16 or 24 in. on center. 33 in. BALSAM-WOOL is applied with either single or double furring strips.

Efficiency—BALSAM-WOOL has been tested for insulating efficiency in various laboratories throughout the country. In a building insulated with BALSAM-WOOL, 20 to 35 per cent less radiation and boiler capacity is required. The coefficients given on the next page are recommended for use in computing the heat loss through sections insulated with BALSAM-WOOL. A complete file showing coefficients and the method of computing radiation requirements and fuel saving (A.I.A. File No. 37-b) will be mailed on request.

Test Results

Hot Plate Method

Material	Mean Temp. Deg. Fahr.	Thermal Conductivity per Hour	Authority
Balsam-Wool	70	0.246	Peebles
Balsam-Wool	90	0.27	Bureau of Standards

Hot Box Method

Description	Mean Temp. Deg. Fahr.	Heat Transmission Factor *U*	Authority
*⅜" Wood Lath and ⅜" Plaster, ¾" fir sheathing, building paper, 4" lap siding, insulation "C," flanged midway in air space between studding.	40.2	0.115	Rowley

*Taken from Journal of A. S. H. & V. E., Vol. 34, No. 7 (July, 1928), Page 536.
Insulation "C"—½ in BALSAM-WOOL

Heat Transmission Coefficients for Building Construction Insulated With BALSAM-WOOL

Section No.	TYPE OF CONSTRUCTION	Plastered Direct	Furred Wood Lath and Plaster	½" B-W Single Furring*	½" B-W Double Furring†	1" B-W Single Furring*	1" B-W Double Furring†
	Walls, Masonry						
1	9" Brick	0.332	0.209	0.141	0.116	0.112	0.096
2	13" Brick	0.263	0.179	0.127	0.107	0.103	0.089
3	18" Brick	0.208	0.152	0.113	0.097	0.093	0.082
4	6" Hollow Tile, Stucco	0.299	0.196	0.135	0.112	0.108	0.093
5	8" Hollow Tile, Stucco	0.273	0.184	0.129	0.108	0.104	0.090
6	12" Hollow Tile, Stucco	0.193	0.144	0.108	0.093	0.090	0.079
7	4" Brick Veneer, 4" H.T.	0.277	0.186	0.130	0.109	0.105	0.091
8	4" Brick Veneer, 6" H.T.	0.246	0.171	0.122	0.104	0.100	0.087
9	4" Brick Veneer, 8" H.T.	0.228	0.162	0.118	0.100	0.097	0.084
10	4" Brick Veneer, 12" H.T.	0.169	0.130	0.100	0.087	0.084	0.075
11	12" Stone	0.415	0.239	0.154	0.125	0.120	0.102
12	16" Stone	0.356	0.218	0.145	0.119	0.114	0.098
13	20" Stone	0.311	0.200	0.136	0.113	0.109	0.094
14	8" Concrete, Stucco	0.437	0.246	0.157	0.127	0.121	0.103
15	10" Concrete, Stucco	0.395	0.232	0.151	0.123	0.118	0.100
16	12" Concrete, Stucco	0.361	0.220	0.146	0.120	0.115	0.098
17	16" Concrete, Stucco	0.308	0.199	0.136	0.113	0.109	0.094
18	8" Concrete Block	0.348	0.215	0.144	0.119	0.114	0.097
19	12" Concrete Block	0.271	0.183	0.128	0.108	0.104	0.090
20	6" Cinder Block, Stucco	0.328	0.207	0.140	0.116	0.111	0.095
21	8" Cinder Block, Stucco	0.276	0.185	0.129	0.108	0.104	0.090
22	12" Cinder Block, Stucco	0.210	0.153	0.113	0.097	0.093	0.082
23	4" Cut Stone Veneer, 9" Brick	0.300	0.196	0.134	0.112	0.108	0.093
24	4" Cut Stone Veneer, 13" Brick	0.234	0.165	0.119	0.101	0.098	0.085

Section No.	TYPE OF CONSTRUCTION	Not Insulated	½" B-W†	1" B-W†
	Walls, Frame			
25	Siding or Wood Shingles, Paper, Sheathing, Wood Lath and Plaster	0.227	0.122	0.099
26	Brick Veneer, Paper, Sheathing, Wood Lath and Plaster	0.216	0.118	0.097
27	Stucco, Paper, Sheathing, Wood Lath and Plaster	0.257	0.130	0.105
	Ceilings:			
28	Wood Lath and Plaster, No Floor Above	0.502	0.172	0.131
29	Wood Lath and Plaster, 1" Pine Flooring Above	0.234	0.124	0.101
30	Wood Lath and Plaster, 1" Pine, 13/16" Oak or Maple Flooring Above	0.202	0.114	0.094
	Partitions:			
31	Studding, Wood Lath and Plaster One Side	0.502	0.172	0.131
32	Studding, Wood Lath and Plaster Both Sides	0.251	0.128	0.104
33	4" Hollow Tile, Plaster One Side	0.31**	0.181*	0.135*
	Roofs:			
34	Built-up Roofing on 1" Roof Boards, Wood Lath and Plaster Inside	0.258	0.130	0.105
35	Same as 34, with 2" Roof Boards	0.213	0.117	0.097
36	Wood Shingles on Roof Boards, No Inside Finish	0.483	0.170	0.129
37	Same as 36, Wood Lath and Plaster Inside	0.246	0.127	0.103
38	Asphalt or Asbestos Shingles on Roof Boards, No Inside Finish	0.515	0.174	0.131
39	Same as 38, Wood Lath and Plaster Inside	0.259	0.130	0.105
40	Slate or Tile on Roof Boards, No Inside Finish	0.549	0.177	0.134
41	Same as 40, Wood Lath and Plaster Inside	0.262	0.131	0.105
	‡Roof and Ceiling Combined—Use Ceiling Area:			
42	Wood Shingles, Wood Lath and Plaster Ceiling, No Attic Floor	0.289	0.137	0.110
43	Same as 42, with Single Floor	0.174	0.105	0.088
44	Asphalt or Asbestos Shingles, Wood Lath and Plaster Ceiling, No Attic Floor	0.297	0.139	0.111
45	Same as 44, with Single Floor	0.177	0.106	0.089
46	Slate or Tile, Wood Lath and Plaster Ceiling, No Attic Floor	0.305	0.141	0.112
47	Same as 46, with Single Floor	0.180	0.107	0.089
	Floors:			
48	1" Yellow Pine on Joists	0.440	0.164	0.126
49	13/16" Maple or Oak Flooring on 1" Yellow Pine on Joists	0.339	0.148	0.116
50	Same as 49 with ¾" Matched Ceiling Boards Below	0.270	0.133	0.107

*Applied with one air space.
†Applied with two air-spaces, except where noted.
**Plastered Direct.
‡Figured on basis of ½ pitch roof; sufficiently accurate for roofs of ¼ to ½ pitch.

The Wood Fibre Board Corporation

Room 1109
Statler Building
Boston, Mass.

Sales and General Office
51 East 42nd Street, **New York, N. Y.**

Room 800
180 N. Michigan Ave.
Chicago, Ill.

Mill: Brunswick, Maine

ARBORITE Acoustical Tile.

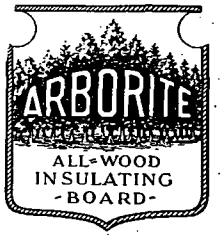
ARBORITE Building Tile.

ARBORITE Insulating Building Board.

ARBORITE Insulating Lath.

ARBORITE Special Low Density Roof Insulation.

ARBORITE Special Low Density Board for refrigerator and other industrial uses, and sound deadening.



Highest grade raw materials and improved methods of manufacture are responsible for the strength and exceptionally low density of Arborite. Manufactured from only the best peeled pulpwood, Spruce and kindred species, by a purely mechanical process Arborite in the finished homogeneous sheet retains essentially the nature and permanence of sound lumber.

Density and Thermal Conductivity—the density of Arborite averages only 14.4 lbs. per cu. ft., equivalent to a weight of only 600 lbs. per thousand square feet of full ½ in. thickness. That densities of materials are comparative indicators of their insulating values is a widely accepted principle, expressed briefly by the U. S. Bureau of Standards as follows:—"In general, the lighter the material per unit total volume the better its insulating value per inch of thickness."

Strength—Tests conducted at Columbia University, New York City, demonstrated that Arborite, applied as sheathing in buildings, offers greater resistance to distortion than horizontal wood sheathing. The same tests placed the tensile strength of Arborite at 216 lbs. per sq. in.

Moisture Resistance—Previous to being felted into a solid homogeneous sheet, the individual fibres of Arborite are thoroughly coated with a water-proofing film, insuring high moisture resistance throughout the finished sheet.

Durability—Due to care in selection of raw material, Arborite consists only of sound live wood fibres, offering great resistance to decay in any form, and no attraction to vermin or rodents.

Plaster Bond—Tests at Columbia University also showed an average bond value of 2140 lbs. per sq. ft. between Arborite and gypsum plaster.

Uniform Quality—Uniformity of raw material and continuous testing by a trained laboratory staff make possible the maintenance of high quality in Arborite within exceptionally close tolerances.

Appearance and Decoration—Arborite, with its naturally light cream color and delicately rippled finish affords a very pleasing effect for interiors without additional treatment, or lends itself readily to all forms of decoration.

Thickness and Size—Arborite Building Board is supplied in standard thicknesses of ½ in., ¾ in. and 1 in., standard width of 4 ft., and standard lengths of 6, 7, 8, 9, 10, 11 and 12 ft.

Arborite Insulating Lath is supplied in standard thicknesses of ½ in., ¾ in. and 1 in., standard width of 18 in., and standard length of 48 in., with the long edges ship-lapped to prevent heat losses due to open joints.

Special thicknesses, consisting of ½ in. stock firmly stapled or glued together, and special widths and lengths up to 8 x 20 ft. can be supplied on request.

Special Low Density Insulation

Arborite Special Low Density Insulation, a most recent development in the field of rigid insulating materials, is manufactured in the same manner and from the same high grade material as Arborite Standard Building Board. The density of Arborite Special Low Density Insulation runs as light as 10 lbs. per cu. ft. A very slight sacrifice in strength has made possible the production of this board of markedly lower density, and consequent increased efficiency as an insulator. Other physical characteristics of Arborite Special Low Density Insulation correspond exactly to those of Arborite Standard Building Board described on this page.

Arborite Special Low Density Roof Insulation is manufactured in solid sheets of full ½ in., ¾ in. and 1 in. thicknesses, and can also be supplied in stapled or laminated form. Standard widths and lengths of sheets are 24 in. x 47 in. and 24 in. x 60 in.

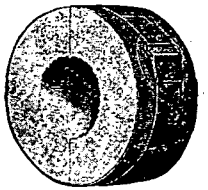
Johns-Manville

Executive Offices
292 Madison Avenue, **New York, N. Y.**

SAN FRANCISCO CLEVELAND CHICAGO NEW ORLEANS TORONTO

J-M 85% Magnesia

For High-Pressure and Intermediate-Pressure Steam Lines, high-pressure drip piping, including connections to all engines, turbines, pumps, auxiliaries, water columns, safety valves, superheaters



Johns-Manville 85% Magnesia

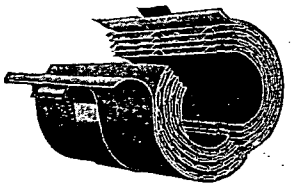
and soot blowers, use Johns-Manville 85% Magnesia Insulation.

J-M 85% Magnesia pipe insulation and blocks are suitable for insulating all surfaces where temperatures up to 600 deg. fahr. are encountered.

Improved Asbestocel

For Low-Pressure, Exhaust Steam and Feed Water Piping use Johns-Manville Improved Asbestocel Sectional Insulation, 4 ply. Sectional Improved Asbestocel is furnished in thicknesses of 2, 3 and 4 ply, each ply being approximately ¼ in. in thickness. It is made in three foot sections with canvas jacket and brass-lacquered bands, to fit standard sizes of pipe.

For Steam Heating Supply and Return Mains, Risers and Radiator Branches use Johns-Manville Improved Asbestocel 4 ply. Concealed radiator branches should be insulated with 3 ply Improved Asbestocel. All other low-pressure and hot water pipes at pressures below 25 lb. or 267 deg. fahr., except heating returns, runouts and concealed radiator branches, should be insulated with Johns-Manville 4 ply Improved Asbestocel Insulation.



Johns-Manville Improved Asbestocel Insulation

Underground Insulation

For Steam, Hot Water and Fuel Oil Piping to be Installed Underground.

Johns-Manville's many years' experience in insulating underground lines, coupled with the J-M organization of approved insulation contractors throughout the country, assures scientific insulating materials and expert application. For full details write Johns-Manville, 292 Madison Ave., New York City.

Other Johns-Manville Insulations

Johns-Manville Superex Combination Insulation is recommended for all superheated steam piping with temperatures of 600 deg. fahr. and higher.

Johns-Manville Asbesto-Sponge Felted is used on all high-pressure steam piping and high-pressure drip piping at temperatures up to 700 deg. F., where insulation may be subjected to rough usage or where maximum efficiency and durability are desired.

Johns-Manville Anti-Sweat Insulation is recommended for all cold water service piping, including risers and concealed fixture connections, also soil or waste lines.

Johns-Manville Asbestocel Sheet Insulation is specified for warm-air ducts, flues, heater casings and fan housings in the ventilating system.

Block and cement insulation, to the same thickness as the adjacent pipe insulation, should be used on all fittings, valves and flanges. Block insulation should be the same material as the adjacent pipe covering, and plastic material used should be hard finish Asbestos Cement.

Johns-Manville Insulating Board—a structural insulation made of wood fibre. J-M board has an attractive natural texture, is structurally strong, has high insulating efficiency, makes a superior plaster base and sheathing and is adaptable for many other uses in home building and other types of building construction.

Johns-Manville Home Insulation—A "fill" type insulation of rock wool—fireproof, vermin proof—blown under pneumatic pressure into the outer walls and attic floor, providing an unusually efficient and economical insulation for homes, apartment buildings, and certain types of industrial buildings.

Keasbey & Mattison Company

"Makers of the Best in Asbestos"

Ambler, Pa.

Branches

BALTIMORE, MD.	CINCINNATI, OHIO	MILWAUKEE, WIS.	PHILADELPHIA, PA.
BOSTON, MASS.	CLEVELAND, OHIO	MINNEAPOLIS, MINN.	PITTSBURGH, PA.
CHICAGO, ILL.	DETROIT, MICH.	NEW YORK, N. Y.	ST. LOUIS, MO.

WAREHOUSE DISTRIBUTORS

BIRMINGHAM, ALA., Dixie Asbestos Co. LOS ANGELES, Farrington Engineering Co.

BUFFALO, N. Y., E. J. Eddy, Inc.

PRODUCTS:—"Featherweight" 85 Per Cent Magnesia Pipe Covering and Blocks. Ambler High-Temperature Covering and Blocks. Ambler Asbestos Aircell Covering. Ambler Asbestos Cement. Asbestos Textiles of all kinds. Asbestos Building Products. Write for complete Catalog.

Company's Source of Asbestos

As Keasbey & Mattison Co. controls its source of crude asbestos, owning the Bell Asbestos Mines at Thetford Mines, P. Q., Canada, perhaps the world's most productive mines of high-grade Chrysotile Asbestos, this company is assured of a constant supply of long-fibred asbestos so necessary in making a thoroughly efficient insulation.

K & M 85 Per Cent Magnesia "Featherweight" Sectional Coverings and Blocks

Keasbey & Mattison Co. were the originators of 85 Per Cent Magnesia Covering, so called because it is composed of about 85 per cent basic carbonate of magnesia and 15 per cent of asbestos fibre. The magnesia is bound together with the long-fibred asbestos, giving it the necessary structural strength. K & M 85 Per Cent Magnesia "Featherweight" is very light in weight, fireproof and extremely durable. It will not injure piping and has a very high insulation value. Impartial expert engineering tests showing its superiority will gladly be sent upon request.

K & M 85 Per Cent Magnesia "Featherweight" Sectional Coverings are canvas-jacketed and 36 in. long per section. They are made in all standard and double standard thicknesses, 2-in. thickness, and 3-in. broken joint construction, and also in combination with Ambler High Temperature Insulation.

Ambler High Temperature Sectional Covering and Blocks

Recommended for temperatures in excess of 700 deg. fahr. These coverings are composed chiefly of asbestos fibre, bonded with inorganic binders found by experience to be best fitted for this class of insulation.

These coverings have a high insulating value and will withstand temperatures up to 1200 deg. fahr. Furnished in same moulded shapes and thicknesses as 85 Per Cent Magnesia Coverings and Blocks.

Ambler Asbestos Cement

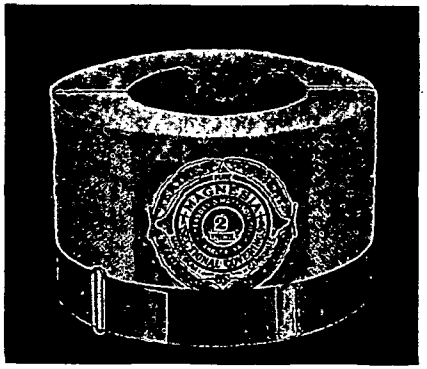
Composed of asbestos fibre and inert materials having high insulating value, being superior to ordinary asbestos cements and surpassed only by 85 Per Cent Magnesia Cement.

Ambler Asbestos "Velvet" Cement

A fire-resisting and waterproof cement which gives a hard, smooth and beautiful finish to cement and block work, fittings and large or irregular steam surfaces. Furnished in 100-lb. bags.

Ambler Asbestos Paper, Textiles, Gaskets and Boards

Ambler Asbestos Aircell Coverings—These are composed of various thicknesses of asbestos corrugated paper, each ply being about ¼ in. thick. These thicknesses united form a covering which is light, fireproof and very satisfactory for low domestic heating and piping insulation. Made in 2, 3 and 4 plies.



The RIC-WIL Company

REG. U. S. PAT. OFF.

RIC-WIL

CONDUIT SYSTEMS FOR UNDERGROUND STEAM PIPES

Union Trust Bldg. **Cleveland, Ohio**

Branches: NEW YORK, CHICAGO, ATLANTA

Agents in Principal Cities

ESTABLISHED 1910

PRODUCTS—Ric-wiL Tile and Cast Iron Conduit, Base Drain Foundation, Pipe Supports, Dry-paC and other Insulating Fillers, for underground steam, hot water, fuel oil and refrigeration pipes.

Ric-wiL Conduit—Vitrified tile, bell and spigot type, which splits on the job for easy installing. Special Loc-liP Side Joints seal top and bottom halves together after pipes and insulation are installed—a strong, water-tight joint. Sections 2 ft. long. Sizes I. D. 4 to 27 in.

Ric-wiL Base Drain—Vitrified tile. Designed to be a base drain foundation for supporting and lining up conduit and also providing ample drainage immediately under conduit. Slotted for conduit bells, thus interlocking with conduit.

Ric-wiL Pipe Supports—Made of rust-proof cast iron and designed to carry one or more pipes. Usually spaced 12 ft. apart. Rest entirely on Base Drain shoulder, imposing no load on conduit itself.

Ric-wiL Cast Iron Conduit—For extra heavy duty—under railroads, etc. Available in all Types shown for Ric-wiL Tile Conduit. Has Loc-liP Side Joints and is interchangeable with Tile Conduit.

Dry-paC Insulating Filler—A waterproof asbestos insulating filler, permanently impervious to moisture. Unusually high in efficiency—is non-corrosive and will not slump down away from pipes. Also Ric-wiL No. 11 and No. 22 Insulating Fillers.

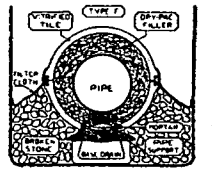
Engineering Service—Assistance with plans and layouts, also supervision. Catalogs and special information on request.

Ric-wiL Type F System—For steam heating and power pipes and superheated steam. A System that assures super-efficiency when insulated with Dry-paC or Ric-wiL No. 11 Filler packed around pipes in closed construction.

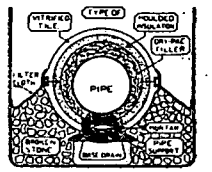
Ric-wiL Type SPC System—For steam heating and power pipes and superheated steam. Insulation is standard pipe covering.

Ric-wiL Type DA System—For hot water, fuel oil and condensation returns. Sil-O-Cel Insulation moulded to inside of conduit and keyed in. Pipes insulated from outside ground but not from each other.

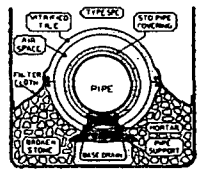
Ric-wiL Type DF System—For steam heating and power pipes and superheated steam. Same as Type DA with addition of Dry-paC or Ric-wiL Insulating Filler packed around pipes.



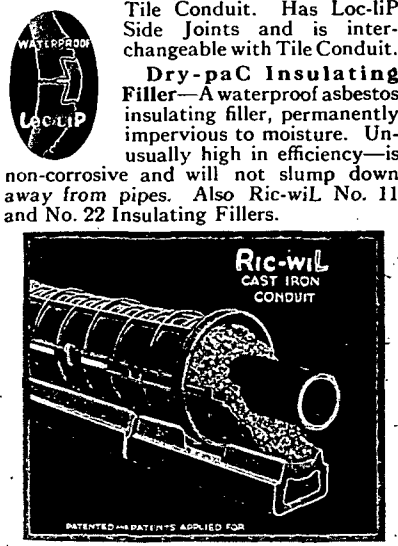
Ric-wiL Type F



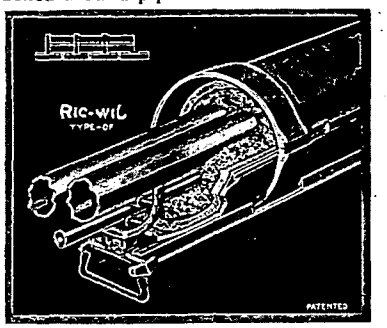
Ric-wiL Type DF



Ric-wiL Type SPC



Ric-wiL Type F Cast Iron Conduit System, single pipe installation, with extra heavy Base Drain Foundation and Dry-paC Insulating Filler



Ric-wiL Type DF Tile Conduit System, multiple pipe installation, with Base Drain Foundation, moulded insulation on inside of tile and Dry-paC Insulating Filler

The Higgin Manufacturing Co.

Newport, Ky.

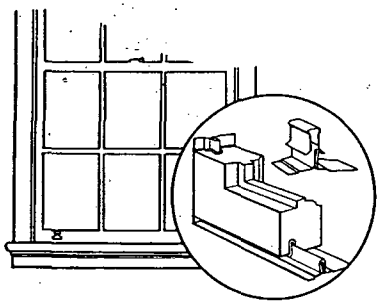
Manufacturers of Metal Weatherstripping for Windows and Doors and Metal Access Panels for Heating and Plumbing Systems.

Representatives in Principal Cities

HIGGIN ALL METAL Weatherstrips

Higgin all-metal weatherstrips are distinctly different from those of other manufacturers. HIGGIN not only has the usual metal strip which is fitted to the four sides of the window frame, but also a *special spring bronze insert strip* that fits into the groove of the window *sash!*

Thus a metal-to-metal contact is established! The spring bronze insert literally *hugs* the window, and provides absolute protection against drafts, dust, dirt, and irritating rattles. Even though the



window sash shrinks (as so often happens) the metal-to-metal contact remains totally uneffected—cold air positively cannot gain entrance. The efficiency of the heating system is increased 25 per cent and upwards!

THE HIGGIN ORGANIZATION, backed by 35 years of constant progress, is fully prepared to weatherstrip all types of openings —double hung windows, casements and doors. With branches and special representatives in all large cities, HIGGIN offers you maximum service and co-operation *plus* a brand of weatherstripping without equal.

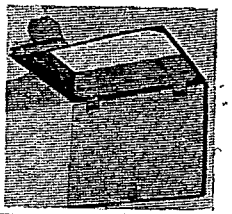
Space here does not allow the reproduction of test data on the Higgin Insert Equipment prepared at the University of Wisconsin. A folder however is available covering this test and copies will be sent on request.

HIGGIN ALL METAL Access Panel

The Higgin All Metal Access Panel was designed to meet a pressing need for an inconspicuous flush panel for access to critical places in Heating, Plumbing and Refrigerating systems. The panel is entirely of metal.

They are made as a unit. No assembling at the job.

Installation is simple and no special framing or grounds are necessary. The panel is composed of a frame and lid. The frame is in one piece with a continuous angle on the inside, forming a rabbet for the lid. Perforated angles are spotwelded to outside of frame for fastening and plaster key.



Hinged type panel in ceiling. Either hinged or removable lid may be furnished.

On the smaller panels, friction catches hold lid in place. For the larger sizes, retaining clips and special cam fasteners are used. Concealed hinges may be provided if desired in place of the retaining clips. Panels may be installed in walls faced with plaster, tile or marble. They can be painted, decorated or papered over.

Higgin All Metal Access Panels are ideal for use in Hospitals, Apartment Houses, Hotels, Residences, Offices and other Buildings.

Stock Sizes

7½ x 11½
12½ x 16½
14½ x 18½
18½ x 24½
18½ x 30½

Measurements are in rabbet.

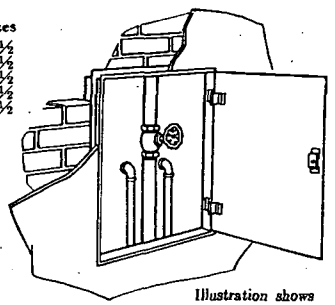


Illustration shows panel used for access to concealed valve.

WRITE FOR COMPLETE DESCRIPTIVE LITERATURE

Builders Iron Foundry

9 Codding Street — **Providence, R. I.**

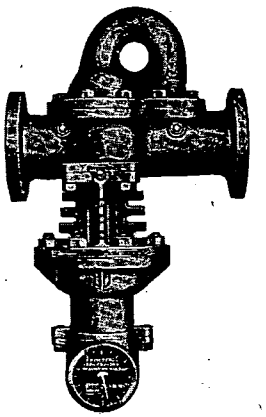
Branch Offices and Representatives

CHICAGO, ILL.	812 Peoples Gas Building
NEW YORK, N. Y.	25 Church Street
PHILADELPHIA, PA.	907 Elverson Building
PITTSBURGH, PA.	1403 Oliver Building
ATLANTA, GA.	Mr. William F. Wilcox, 4th Nat'l. Bank Building
BUFFALO, N. Y.	Empire Equipment Co., 310 McKinley Ave., Kenmore
CHARLOTTE, N. C.	Grinnell Co., P. O. Box 336
DALLAS, TEXAS	Morey & Morey, 417 Praetorian Building
DETROIT, MICH.	Poe Company, 2842 W. Grand Boulevard
LOS ANGELES, CALIF.	Mr. Percy Keatinge, Black Building
SALT LAKE CITY, UTAH	Ambler & Riter, Kearns Building
SAN FRANCISCO, CALIF.	Mr. Percy Keatinge, Monadnock Building
SEATTLE, WASH.	California Filter Co., 514 Fourth Ave.
ST. LOUIS, MO.	Power Equipment Co., 5473 Delmar Boulevard
TROY, N. Y.	Industrial Equipment Co., Mt. Pleasant Ave.

Builders of the Venturi Meter, Oriflo Meter, Shunt Steam Meter, Etc.

SHUNT STEAM METER

The Shunt Steam Meter fills the need for a low priced, practical steam meter which is easily installed and accurate over a wide range. It is used to advantage in measuring steam sold or in checking the distribution of steam (also air or gas) to various buildings, departments, machines or processes. Illustration shows the complete Meter. An orifice in the main line of flow deflects a portion of the steam through nozzles and against the turbine located in the shunt circuit out of the main line of flow. The turbine shaft extends through a housing into a condensation chamber below the main line. A damping fan attached to this shaft operates under water, keeping the speed low and eliminating bearing trouble. Magnetic drive between this chamber and the counter mechanism protects the latter from moisture. The meter is installed as a unit in 2, 3 and 4-in. lines. For larger size mains a small meter is installed in a by-pass line around an orifice in the main line.



Shunt Steam Meter, Type K S.

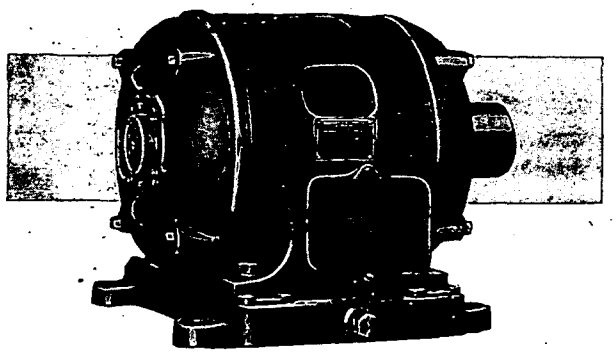
	Steam Pressure Lbs. per Sq. In. Gauge	Rated Capacity of Saturated Steam—Lbs. per Hour (Meters with largest orifice)						
		2" Meter	3" Meter	4" Meter	6" Meter	8" Meter	10" Meter	12" Meter
Low Pressure Meters	0	600	1,400	2,530	5,660	9,850	15,200	19,000
	5	800	1,900	3,350	6,500	11,300	17,500	21,800
	10	1000	2,350	4,170	7,220	12,600	19,400	24,200
	15	1200	2,750	4,750	7,860	13,700	21,100	26,300
	20	1400	2,950	5,150	8,480	14,700	22,800	28,300
	30	1650	3,400	5,850	9,550	16,600	25,600	31,900
	40	1800	3,750	6,450	10,500	18,200	28,200	35,000
	50	2000	4,050	7,000	11,400	19,800	30,500	38,000
Standard Meters	50	2650	6,000	10,600	22,200	39,000	60,500	75,500
	75	3650	8,250	14,600	25,800	45,400	70,500	88,100
	100	4150	9,500	16,600	29,000	51,000	79,200	99,000
	125	4600	10,500	18,300	31,800	56,000	86,800	109,000
	150	5000	11,400	20,000	34,400	60,500	94,000	117,000
	175	5350	12,300	21,400	36,800	64,800	100,000	126,000
	200	5700	13,000	22,700	39,000	68,600	107,000	133,000
	225	6000	13,700	24,000	41,200	72,400	112,000	140,000
	250	6300	14,400	25,200	43,200	76,000	118,000	148,000
Extra Heavy Meters	275	6600	15,200	26,500	45,000	79,400	123,000	154,000
	300	6900	15,700	27,500	46,800	82,500	128,000	160,000

Table shows rated capacities only. Minimum Capacities equal one-tenth tabulated quantities. Bulletin 255 gives complete information.

Century Electric Company

1806 Pine Street, **St. Louis, Mo.**

40 U. S. and Canadian Stocks and More Than 75 Outside Thereof



10 Horsepower Century 2-Speed Squirrel Cage Induction Polyphase Motor

BLOWER MOTORS

Designed with special reference to the noise problems frequently encountered in the operation of fans and blowers in modern constructed buildings, are available in the following types:

Squirrel Cage—Single and multiple speed, ¼ to 250 horsepower.

Slip Ring—Constant and varying speed, ¼ to 200 horsepower.

Single Phase—Repulsion Start Induction, ⅛ to 40 horsepower.

Direct Current—Constant and adjustable speed, 1/10 to 100 horsepower.

Also

Special Portable Motors.
Unit Heater Motors.
Refrigeration Motors.
Vertical Motors.
Totally Enclosed Fan-Cooled Motors.
Enclosed Motors.
Generators.
Rotary Converters.
Motor Generator Sets.
Emergency Lighting Equipment.

GENERAL ELECTRIC COMPANY

SCHENECTADY, N. Y.

SALES OFFICES, WAREHOUSES, SERVICE SHOPS AND DISTRIBUTORS IN PRINCIPAL CITIES

For Code Wire, Conduit Products, Wiring Devices, Insulating Materials, etc., address Merchandise Department, Bridgeport, Conn.

Quiet Operating Motors and Control

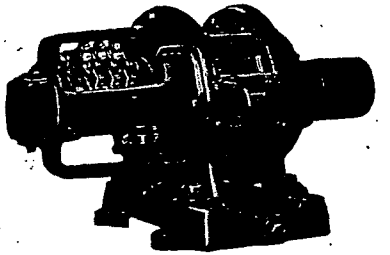
For Heating, Ventilating and Air Conditioning Systems

In this time and age the public are demanding that unnecessary noises be subdued. Modern public buildings use electric motor driven ventilating fans to supply fresh and conditioned air. Ordinary motors will drive such equipment satisfactorily, but the occupants are likely to be well aware of the fact that such motors are in operation.

General Electric has designed and have available for shipment a complete line of quiet operating induction motors for use in office buildings, hotels, theatres, hospitals and other places where unnecessary noise is objectionable.

The same high standards of quality, electrical and mechanical strength, and reliability are maintained in these quiet operating motors as in the well-known G-E General Purpose Motors. Each motor is tested for quietness before shipment.

The best method of mounting is to have both motor and fan on a common base, the whole base being mounted on proper insulating supports. Where the fan and motor are not on the same base, it is difficult to use any sound absorbing insulation under the motor without causing difficulty in keeping the equipment properly lined up.



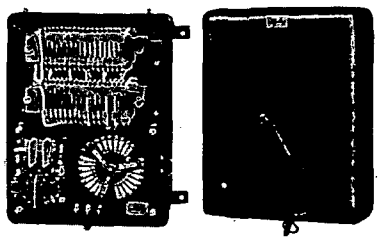
MTB Wound Rotor Quiet Operating Induction Motor

The location of the motor in the building with reference to the acoustics of the surrounding structure is a very important point, and while in one location a perfectly standard motor may be acceptable, the same motor may be entirely unsuitable in another location.

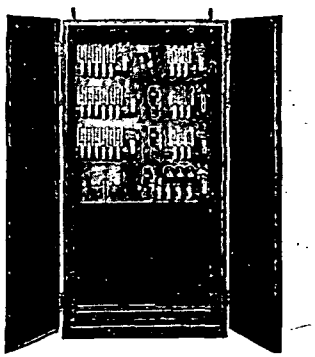
Alternating Current Control

The General Electric Co. manufactures a complete line of control devices for starting and controlling motors driving ventilating fans. All controllers are of the enclosed type externally operated. Speed regulators are designed to give 50 per cent speed reduction on fan load and arranged to maintain equalized current in all phases of the rotor which is necessary to maintain quiet operating motors.

Details may be obtained at the nearest sales office.



CR7765, 1-5 Hp. Controller



CR7761-F1, 20-50 Hp. Controller

FOR USE WITH WOUND ROTOR MOTORS

This Company will gladly assist in the solution of any electrical problem in relation to heating and ventilation

Westinghouse Electric & Manufacturing Co.

East Pittsburgh **Pennsylvania**

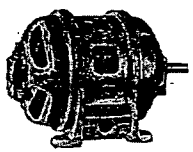
Research, Application and Design Engineers will cooperate and solve any electrical problem for heating and ventilating systems.

Sales Offices and Service Shops in all Principal Cities

Drives

For heating and ventilating systems, Westinghouse offers the most complete line of drive equipment developed by a single manufacturer. This includes motors, control, "De-ion" breakers for circuit protection, Cog-Belt drives and gears.

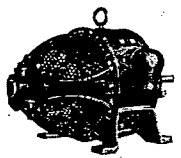
With more than 22,000 different types and ratings of standard motors, and control to match, Westinghouse can supply the *right drive* right away.



The new CS motor for A-c. drives

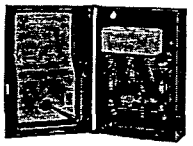
Motors

The new type CS and CW alternating-current motors are remarkably *quiet, clean* and *dependable*—rigid frame construction, die-cast rotors, Sealed Sleeve bearings, dual-protected windings and directed air circulation assure these qualities.



The SK motor for D-c. drives

For direct-current applications, Westinghouse SK motors—industry's most popular—offer quiet, trouble-free performance because of their mica insulation, sparkless commutation, directed air circulation, Sealed Sleeve bearings and a sturdy rolled steel frame.

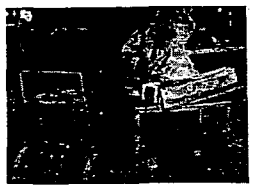


The Linestarter A-c. control

Motor Control

Reduced installation costs, lower maintenance and new operating conveniences are possible with Westinghouse compact Line-starters and circuit breakers, which can be mounted with all control in a flush-type panel.

The new Westinghouse "De-ion" circuit breaker is so effective that the 100-ampere rating will successfully rupture 10,000 amperes short circuit current. Fuse replacements are eliminated, as the breaker can be reset by a flip of the hand. It is fool-proof.



The FlexArc A-c. welder for simplified fabrication

Arc Welding

For the fabrication of thin-gauge materials such as ducts, Westinghouse offers a radically new arc welding machine—the FlexArc A-c. It may be connected to the ordinary single phase power circuit for operation. Because of its extreme arc flexibility, its operation is simple. Power cost averages less than 15 cents an hour.

Stockham Pipe & Fittings Co.

Birmingham, Alabama

Warehouses:
BOSTON NEW YORK CHICAGO
HOUSTON LOS ANGELES

PIPE FITTINGS

Cast Iron — *Screwed — Flanged; Drainage — Sprinkler*

Malleable — *Standard — Extra Heavy; Hydraulic — Oil Country; Fire Line — Railroad; Ground Joint Unions*

Electric Cast Steel — *Flanged; Screwed*

There are over 12,000 patterns in the complete Stockham line. Every pipe fitting requirement for gas, water, steam, oil or air, is met by Stockham. All Stockham Fittings are accurately threaded and flanged. They are always in perfect alignment. Made according to the American Standard, therefore interchangeable on any standard pipe lines. Free from sand holes, blow holes or sponginess; strong, far in excess of probable strain. Tough, uniformly grained metal, easily drilled or otherwise machined; smooth inside and out; attractively finished, and when galvanized, coated with a double lustrous coat of finest quality spelter.

CAST IRON FITTINGS

Screwed Drainage **Flanged Sprinkler**



Made according to the American Standard. Accuracy in pattern, accuracy in proportioning materials, accuracy in melting, accuracy in molding, accuracy in finishing, accuracy in inspecting and testing.

Stockham Sprinkler Fittings are made in accordance with the requirements of the National Fire Protection Association and are known as American Standard Sprinkler Fittings, being made to the specifications of the American Standards Association. They also have the approval of the Associated Factory Mutual Fire Insurance Co's. and the Underwriters Laboratories.

MALLEABLES

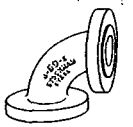
Standard, Extra Heavy, Hydraulic, Oil Country, Fire Line, and Railroad 300 lb.



All Stockham Malleables are made according to the quality standard which distinguishes all Stockham fittings. Annealing under definite temperature control which gives ductility, uniform structure and high strength with great resistance to shock and strain.

CAST STEEL

Flanged Fittings and Flanges

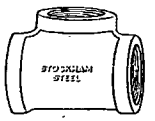


Conform to the American Standard. Walls are designed thicker than American Standard Requirements. Regular in outline; conformity to patterns; ample fillets well rounded. Meet specifications of the *American Society for Testing Materials.*

Every fitting hydrostatically tested before shipment. Exceptionally smooth inner and outer surfaces; accurate facings and fine appearance. Made for pressures of 150, 300, 400, 600, 900 and 1350 lb. and for temperatures according to the American Standard.

CAST STEEL

Screwed Fittings



Every needed design and size. Same quality standard as Flanged Fittings and Flanges. Accurate threads, accurate alignment, smooth inner surfaces. Strength far in excess of probable strain.

Descriptive Catalogs on request.

STOCKHAM FITTINGS

Are sold by leading wholesalers

Farley Sleeve & Hanger Company

3748 East 71st Street, **Cleveland, Ohio**

Telephone, Mi-2594

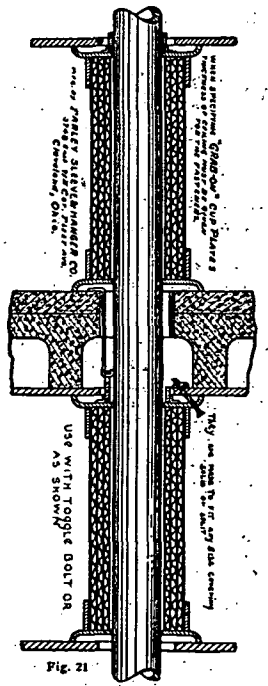
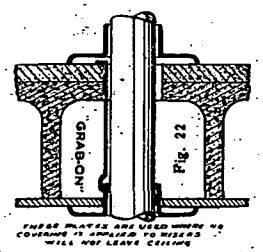


Fig. 21

Fig. 21—These Cup-plates are sold singly, to fit any condition. They are 2 in. high for ceilings or floors. They are split in order to be installed at any time. Thickness of covering must be specified. They can be fastened by a toggle bolt or strap or double wire.



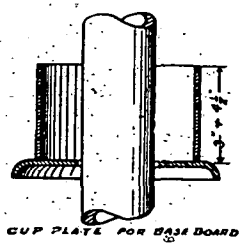

CUP PLATE FOR BASE BOARD

Fig. 22—Plates are used for old or new work, without covering, and can be fastened same as Fig. 21. Plates are made from ½" to 14" pipe sizes. They make a perfect finish for walls or ceilings and are also used in old buildings as well.

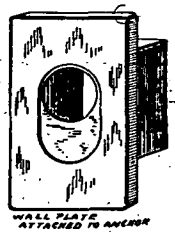


Fig. 9

Fig. 9—The Box Expansion Wall Plates are made solid only.

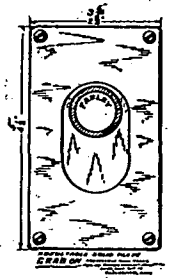

Fig. 3

Fig. 3—The Single Expansion Wall Plate. Made split or solid.

Double Expansion Wall Plates are made vertical or horizontal.

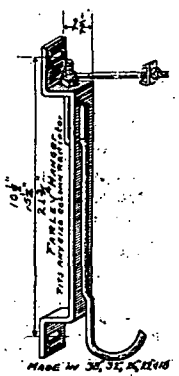
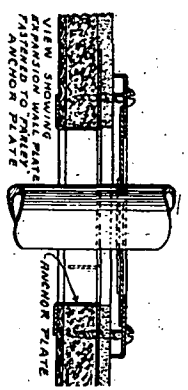

Fig. 16

Fig. 16—Radiator Hangers. Will fit any make of radiation.



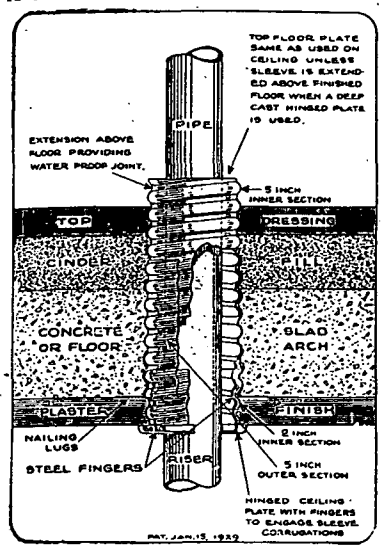
We also make Three-Way Expansion Ceiling Plates

CATALOG FURNISHED ON REQUEST

Knowles Pipe Sleeve Co.

41 North Moore Street, **New York, N. Y.**

A Standard Extensible Sleeve for All Kinds of Buildings and All Sizes of Pipe



SUPER SLEEVE

PAT. JAN. 15, 1929

Provides the original form for hole through concrete, fill and cement dressing and is adjustable for each stage of construction as it progresses. Provided with lugs for nailing to form before concrete is poured. Provides form for plaster finish around pipe on ceilings. Provides Hinged Plates which may be fitted around pipes after all construction work is completed. Plates will remain permanently in position, becoming an integral part of the sleeve. Protects piping from external erosion from contact with concrete, cinder fill and cement. Eliminates expensive "after-patching." Is strong enough to withstand construction abuse, yet light and easy to handle. Saves **Time—Labor—Expense** in providing and setting special sizes to order. Eliminates clipping sleeves to length on job. Improves construction and affords a satisfactory finished job.

Made in

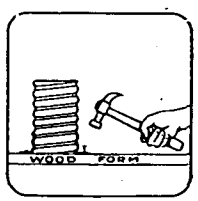
Sizes of Supersleeve Sections

Outer Sleeve Sections 3 in., 5 in. and 7 in. long (in four diameter sizes).
Inner Sleeve Sections 2 in., 5 in. and 7 in. long (in four diameter sizes).
(allow minimum of ½ in. for joining each section).

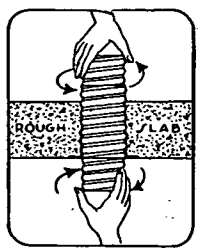
FOR PIPE SIZE ¾ in., 1 in., 1¼ in. diam.	Specify or Order Supersleeve No. 2
FOR PIPE SIZE 1½ in., 2 in. diam.	Specify or Order Supersleeve No. 3
FOR PIPE SIZE 2½ in., 3 in., 3½ in. diam.	Specify or Order Supersleeve No. 4½
FOR PIPE SIZE 4 in., 5 in. diam.	Specify or Order Supersleeve No. 6

Standard Outer Sections in all lengths are furnished with lugs to nail to forms—unless specified to be without lugs for use as additional Outer sections for providing longer sleeves. All Inner sections are furnished without nailing lugs unless required.

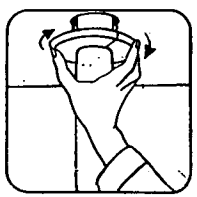
Specify or Order HINGED CEILING OR FLOOR PLATES according to diameter pipe sizes to be fitted.

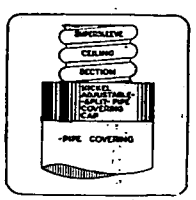


Outer section nailed to form holds SUPERSLEEVE *firmly in place until concrete slab is poured and set.*



When ready to lay fill and top cement dressing, extend top inner section to desired height by a simple twist of the hand. Will remain extended as set and can be quickly altered if necessary before cement hardens. When ready to plaster ceiling extend the short inner section below slab FLUSH TO LEVEL OF FINISHED CEILING.


After all construction is completed snap our patented plate around pipe and twist up flush against finished ceiling, floor or wall surfaces, thus locking plate permanently into place.



USE KNOWLES PIPE COVER CAP—Adjustable, *Split, Polished Nickel; inexpensive; tightly fitting around pipe covering*—FLUSH WITH CEILING AND INTEGRAL WITH SLEEVE.
SEE CIRCULAR.

Send for Booklet for Complete Data

Radi-Ion Corporation

PHYSICISTS - MANUFACTURERS - CHEMISTS

Pacific Coast
MONTGOMERY BROTHERS
61 Fremont Street
SAN FRANCISCO

General Office and Laboratories
54 West Illinois Street
Chicago, U. S. A.

Canada
DARLING BROTHERS, LTD.
140 Prince Street
MONTREAL

RADI-ION

Radi-Ion is recommended for air purification, in mechanical ventilation, where the air supply is drawn from the city streets or recirculated for reasons of economy in heating and air conditioning.

Radi-Ion is not a *chemical* and produces no odor. It is an electrical apparatus that subjects air to the combined effects of ultra-violet light and a special electric discharge that is radiant in character. These combined forces act on the oxygen of the air to produce therein a state of excitation, or activation, that enormously intensifies the chemical activity of oxygen. This excited or activated oxygen immediately reacts with odoriferous gases, present in the air supply, as well as those produced by the occupants of the building, immediately oxidizing them to stable, non-odoriferous substances. No new *chemical* form of oxygen is produced. Simply the physical structure and properties of the oxygen molecules are changed, and these changes specifically conduce to a state of high chemical activity. This physical activation of the oxygen differs materially from methods producing so-called chemical or allotropic modifications of oxygen. In the latter case a new chemical form of oxygen, that possesses an odor of itself, is produced. Radi-Ion activates the ordinary oxygen of the air so that it removes odors by immediately oxidizing them, and produces no odor inherent in the apparatus or process.

RADI-ION IS DESIGNED FOR VENTILATION ONLY

Radi-Ion is the only air purifying apparatus that is designed for just that purpose. It has no other application or function. Radi-Ion is the result of the experience and research of scientists and engineers who have devoted their lives to ventilation.

Radi-Ion is intended for general ventilation only. It is not intended for heavy duty deodorizing, such as is required for many industrial exhausts, kitchens, etc. For such purposes special controlled oxidizing equipment will be recommended.

Radi-Ion is as nearly an exact duplication of the forces resident in Nature that operate to keep the atmosphere pure and invigorating, as is now physically possible to obtain. Nature has been closely paralleled in Radi-Ion apparatus and it is the only apparatus used for air purification that accomplishes a perfectly natural result in a perfectly natural way.

RADI-ION SERVICE

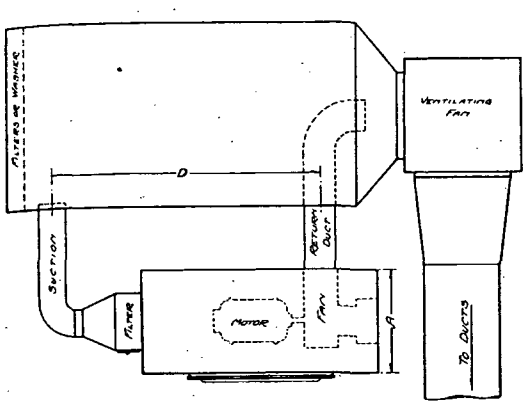
The services of our engineers are at all times available to assist in the detail necessary for the application of Radi-Ion apparatus to existing ventilating systems, or those in process of construction or contemplation. This expert service costs you nothing. Important technical publications and informative trade literature on Radi-Ion will be furnished for the asking.

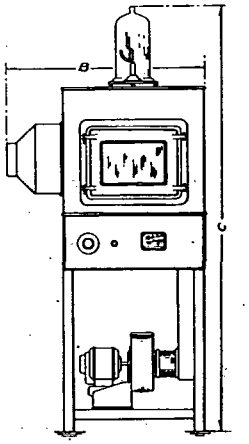
MONTGOMERY BROTHERS CONTROLLED OZONE EQUIPMENT

For specific problems in industrial and exhaust deodorization Montgomery Brothers, 500 N. Dearborn Street, Chicago, offer a comprehensive service backed by a full line of ozone producing apparatus. This company offer the services of specialists in the purification of air in cold storage, the prevention of odor absorption by foods and the prevention of fungi growths.

CONTROLLED OZONE WATER PURIFYING EQUIPMENT

Montgomery Brothers Water Purifying equipment is widely used for the purification of potable water, industrial purposes and swimming pools. Special problems in filtration and the removal of unstable mineral constituents are also undertaken.





ELEVATION OF RADI-ION APPARATUS.

The scheme of installation is illustrated at the left of the cut. Elevation of typical unit given at the right. Over-all dimensions are given by the following table:

Capacity of Vent System C.F.M.	Dimensions in Inches			Capacity of Elec. Service K.V.A.
	A	B	C	
2500 to 7500	16	28	82	0.175
10,000 to 20,000	17	36	82	0.475
25,000 to 30,000	26	56	82	0.575
35,000 to 50,000	26	56	84	0.820

Detail of larger sizes given in our Bulletin No. 10.

N. B. Dimension D may be anything down to zero, in which case the duct shown in broken lines must be provided. When D exceeds three feet this duct is not necessary.

SPECIFICATIONS

1. GENERAL: The contractor shall provide and install, as indicated on the ventilating plans, RADI-ION air purifying and ionizing equipment, as manufactured by the Radi-Ion Corporation, Chicago, Illinois.

2. CAPACITY: Each RADI-ION apparatus shall be of such capacity as to deodorize and purify the quantity of air handled by the ventilating fan which it serves.

> Here specify fans to be served by Radi-Ion equipment, either by number and capacity, or other means that will serve to identify the fans for the contractor.

3. CONSTRUCTION: The RADI-ION apparatus shall employ special, evacuated discharge tubes, of transmission glass, excited by high tension electric current. The discharge produced shall not occur between superimposed electrodes. All electric contacts must be housed so as to render accidental contact with same impossible. The tubes shall be inclosed in a sheet metal housing, hinged glass door being provided for access to tubes. Duct connections of sufficient size shall be provided for connecting the RADI-ION apparatus with the ducts of the ventilating system.

Special transformers shall be provided for exciting the tube and so housed that accidental contact with live parts is impossible.

A rheostat shall be provided for controlling the intensity of the electric field.

An indicating instrument shall be provided for indicating the intensity of the electric field.

A conoidal type fan, directly connected to suitable size motor, shall be provided for drawing air from the ventilating system, passing same over ionizing tubes and returning it to ventilating system.

4. ELECTRIC SERVICE: RADI-ION apparatus shall operate on (here specify characteristics of electric service). N. B. Only single phase can be utilized.

5. INSTALLATION: the contractor shall provide and install ducts connecting the RADI-ION apparatus with the ventilating system. Air must be taken from the ventilating system, downstream with respect to the filters or other air conditioning apparatus, and connect same with inlet of the RADI-ION apparatus. He will further provide connections between the discharge of the RADI-ION apparatus and the ventilating system, for the return of the activated air. The return connection is made preferably immediately upstream with respect to the inlet of the main ventilating fan. Where the tap-off for supplying the RADI-ION apparatus must necessarily be close to the point of return of the activated air, suitable baffles shall be provided to prevent diffusion taking place between the air to and from the RADI-ION apparatus.

6. GUARANTEE: the contractor shall guarantee, through the manufacturer, the equipment to be free from inherent defects of material and workmanship for a period of one year after date of installation. The apparatus is also guaranteed to maintain the ionic content of the atmosphere equivalent to that normally occuring in Nature. It is further guaranteed that the ionizing equipment will maintain the air pure and free from odor, both in the case of recirculated air, or drawing air from the outside in the congested districts of the city.

Buffalo Pumps, Inc.

450 Broadway, **Buffalo, N. Y.**

Complete Line manufactured in Canada by
Canadian Blower & Forge Co., Ltd., Kitchener, Ont.

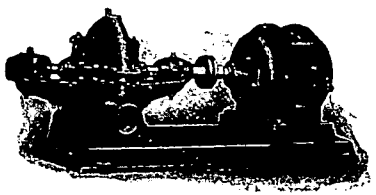
PRODUCTS

Centrifugal Pumps For All Purposes—Single and Double Suction, Single and Multistage, Horizontal and Vertical. Steam Pumps—Duplex

Complete descriptive catalogs furnished on request.

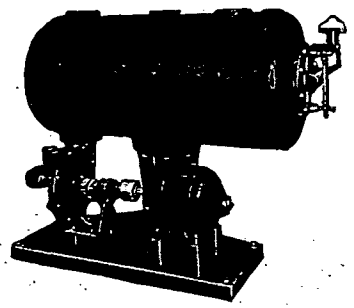
Sales Engineering Offices

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ATLANTA	Neville & Cleary, Inc., Candler Bldg.
BOSTON	10 Milk St.
CHARLOTTE	J. W. Fraser & Co., P. O. Box 376,
CHICAGO	15 N. Jefferson St.
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CLEVELAND	368 Rockefeller Bldg.
DENVER	Stearns, Roger Mfg. Co., 1635-17th St.
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PITTSBURGH	927 Union Trust Bldg.
SAN FRANCISCO	Herberts Moore Machinery Co., 140 First St.
SEATTLE	303 Alaska Bldg.
ST. LOUIS	906 Chemical Bldg.
TOLEDO	1817 North 13th St.
WASHINGTON	403 Comm. National Bank Bldg.



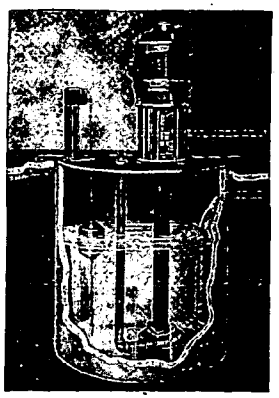
Class "S" Double Suction Centrifugal Pump

Horizontally divided casing. Extensively used with air washers, and for circulating systems and booster service. Full line of sizes.



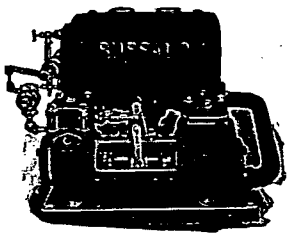
Centrifugal Condensation Return Pump and Receiver

Also built vertical with receiver pit. Especially adapted for low pressure boilers. Automatic in operation.



Automatic Sump Pump

Self contained. Ball bearing thrust.



Duplex Steam Pump and Receiver

Entirely automatic. Can be furnished for high or low boiler pressure.

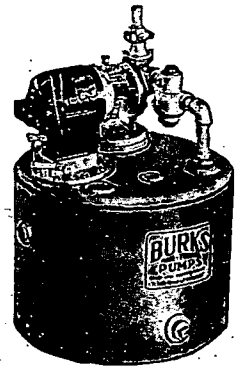
Decatur Pump Company

Decatur, Ill.

BURKS SUPER-TURBINE PUMPS

Only one moving part

A SATISFACTORY CONDENSATION RETURN UNIT TO INSTALL



Series 4700
Condensation Return Unit

"High and Dry"

Here is a unit that returns the condensate to the heating boiler efficiently and surely.

No need to subject the condensation pump to the grease, water and dirt usually found in the boiler room pit.

Powerful suction lift, even when handling HOT water enables the Burks Super Turbine to perform effectively when mounted on TOP of the receiver tank.

Will Not Steambind!

Ability to pump air alone, or air mixed with water, to the full pressure rating of the pump, means that the Burks pump will not steambind. Pump capacities range from 150 gph to 1,000 gph against boiler pressures up to 100 lbs. per square inch, and will take care of up to 12,000 sq. ft., of radiation per unit.

Construction Features

Only one moving part—the impeller—and this one part does not contact with metal at any stage of operation.

Self-priming and fully automatic. Impeller and raceway of cast bronze.

Shaft of stainless, non-corroding steel, impervious to mild acids, and carried in oversize ball bearings.

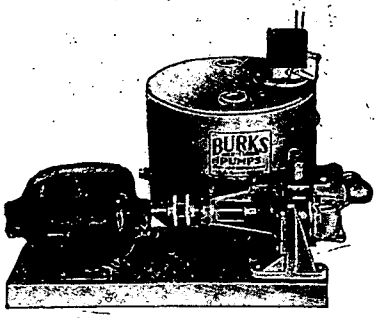
Tank of copper-bearing steel, $\frac{3}{16}$-in. shell; $\frac{1}{4}$-in. top and bottom, welded construction.

Hydraulically Balanced

These pumps are hydraulically balanced and cannot be made to pound or hammer under any condition of operation.

All Burks Turbine pumps start under "no load" conditions.

Ask for new Catalog No. 31, which furnishes complete information.



Series 41100
Condensation Return Unit

CHICAGO PUMP COMPANY

SEWAGE-CONDENSATION-CIRCULATING
BILGE-FIRE-HOUSE-VACUUM

2330 Wolfram Street - BRUnswick 4110 - Chicago

PRODUCTS—Vacuum and Boiler Feed Pumps, Condensation, House, Booster, Fire Pumps, Circulating, Brine, Sewage, Bilge, Sludge, Pneumatic and Tankless Water Systems.

Condensation Pump and Receiver

for Low, Medium and High Pressures and Systems up to 50,000 Sq. Ft. Radiation

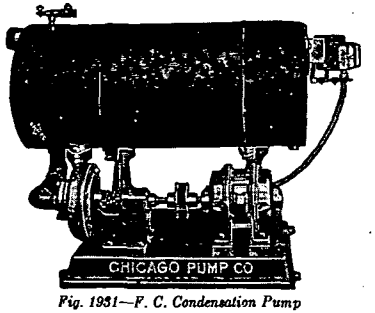


Fig. 1931—F. C. Condensation Pump

"Chicago" Condensation Pumps are built for systems ranging from 3000 up to 50,000 sq. ft. of radiation, and for boiler pressures up to 200 lbs. *Units* are built in either single or duplex—the duplex being alternated in their operation by the Automatic Alternator. *For tables and complete description ask for Bulletin 129.*

Vertical Condensation Pump

for Low and Medium Pressure for Systems up to 40,000 Sq. Ft. Radiation

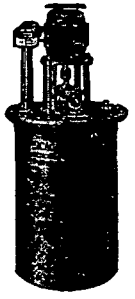


Fig. 1940 Vertical Condensation Pump

The vertical condensation pump is designed to receive returns from lowest radiation. The receiver is placed underground—an ordinary hole sufficing if necessary — and requires very little floor space. Unit is shipped complete, easy to install, assembled so as to prevent steam leaks. Special bearings will stand up under hot water for several years. A special float mechanism is guaranteed not to leak or stick in stuffing box. *Complete data and description in Bulletin 133.*

"Sure-Return" Condensation Pump

for Low and Medium Pressure, and Systems up to 35,000 Sq. Ft. Radiation

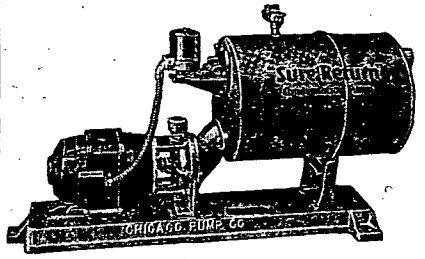


Fig. 1946

"Sure Return" Condensation Pumps and Receivers are built for systems up to 35,000 sq. ft. of direct radiation and for low and medium pressures. Built in either single or duplex units. Duplex units are alternated in their operation by the Automatic Alternator. *Complete data in Bulletin 133.*

Horizontally Split Pumps

for all Services

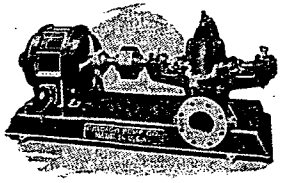


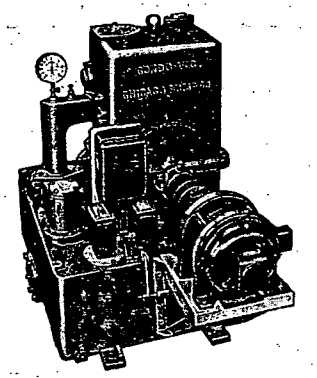
Fig. 1881—Single Stage Type "D" Pump

For any service (such as boiler feed, water supply, tank filling, circulating, fire protection, etc.). Chicago Pump Co. builds a line of horizontally split case centrifugal pumps in both single and multistages. Completely bronze fitted (except where special fittings are required) ball bearings, internal water seal, oil is filtered. "Chicago" Horizontal Pumps are built for efficient performance and long life.

"CONDO-VAC"

Return Line Vacuum and Boiler Feed Pump

Full Water Capacity 200° F. Plus



10″ Vacuum and Full Air Capacity 180° F. Plus

Fig. 2100—Single "Condo-Vac"

No vacuum on stuffing boxes, ample clearance in rotating member. It costs less to operate a Condo-Vac. Condo-Vac reduces corrosion in piping and boiler to minimum—because pump does not take in air from atmosphere and entirely eliminates all air coming back from system. Condo-Vac is quiet, has a low inlet, entirely automatic, fool-proof, easy to maintain. *Ask for Bulletin 137*, learn more about the modern vacuum pump with the long life principle of operation.

CAPACITY TABLE—1720 R. P. M.—10 Lbs. Pressure

PUMPS RATED WITH AIR AND WATER TEMPERATURE AT 180° F.

Size	Sq. Ft. Direct Radiation	H. P. Motor — 10 Lbs. Press.	Air Capacity Cu. Ft. per Min. per Pump 10 In. Vacuum	Water Pump Capacity G. P. M. per Pump	Size Return Inlet in Inches	Pump Discharge in Inches	Receiver Capacity in Gallons—Single	G. P. M. Radiation Listed Will Condense	Approximate Shipping Weight Single Unit	Approximate Shipping Weight Duplex Unit
T	2,500	½	3	5	1½	1	18	1¼	650	1200
U	5,000	¾	3	10	1½	1	18	2½	750	1400
A	8,000	1	5	12	2	1¼	30	4	1225	2400
V	10,000	1½	6	15	2	1¼	30	5	1275	2500
B	16,000	1½	9	24	3	1¼	40	8	1400	2800
C	26,000	2	15	39	3	1½	52	13	1650	3350
D	40,000	3	19	60	4	2	70	20	1900	4000
E	65,000	7½	34	96	4	2	88	32	2250	4550
F	100,000	7½	44	140	6	3	122	52	2700	5300

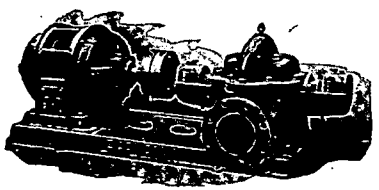
Economy Pumping Machinery Co.

3431 West 48th Place, **Chicago, Ill.**

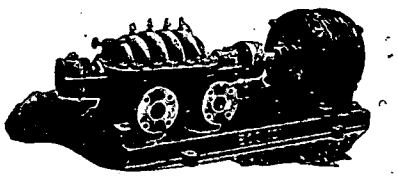
District Sales Offices

BALTIMORE, MD.—W. I. Collier & Co., 522 Park Ave.
BOSTON, MASS.—Thermal Engineering Co., 45 Bromfield St.
CINCINNATI, OHIO—Geo. R. Murphy, 309 Main St.
CLEVELAND—Tomlinson-MacLachlan, 1603 St. Clair Ave.
DALLAS, TEX.—Smith & Whitney, 2017 Cedar Springs
DENVER, COLO.—Crane O'Fallon Co., 1631 Fifteenth St.
DES MOINES, IOWA—Globe Machinery & Supply Co., 205 W. Court Ave.
DETROIT, MICH.—H. J. Clemens, 517 E. Larned St.
FT. WAYNE, IND.—P. & H. Supply Co., 225 E. Columbia St.
HARTFORD, CONN.—Earl Sexton, 647 Main St.
JACKSONVILLE, FLA.—R. H. Johnson, 660 College St.
KANSAS CITY, MO.—The Ritts Co., 609 Linwood Blvd.
NEW ORLEANS, LA.—E. W. Carr, Inc., 807 Howard Ave.
NEW YORK—Quimby-Ryan Eng. Sales Co., 11 W. 42nd St.
OKLAHOMA CITY—Loeffler Supply Co., 710 N. Hudson St.
PEORIA, ILL.—Robert P. Nailon, 701 Lehmann Bldg.
PHILADELPHIA—Haynes Selling Co., 1518 Fairmount Ave.
PITTSBURGH—J. A. Leiendecker, 450 Lincoln Ave. (Bellevue)
PLYMOUTH, MICH.—Scully Sales Co., 713 Ann St.
PORTLAND, OREGON—Ray Smythe, 301 Park Bldg.
SAGINAW, MICH.—Engineering Sales Co., 2nd Nat. Bk. Bldg.
SAN FRANCISCO, CALIF.—J. Harry Russell Monadnock Bldg.
DOMINION OF CANADA—Crane, Ltd., 1170 Beaver Hall Square, Montreal

Economy Pumps



Single Stage



Multi-Stage

Pumps for Clear Liquids

These pumps are widely used for water supply, boiler feeding, hot water circulation, swimming pool circulation, air washer supply, municipal water works. etc.

The sturdy mechanical design and high efficiency of Economy Pumps makes them particularly suited for heavy mill and power plant service (The efficiencies exceed 80 per cent in the larger capacities and are correspondingly high in the smaller sizes).

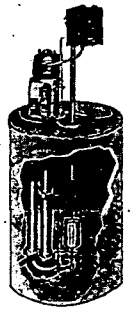
The low-pressure pumps are of the high efficiency single stage, design, as described in Bulletin No. 408. High pressure pumps have many unusual features. They are built for high efficiencies and long life. See Bulletins No. 414 and 415 for description and complete capacity Tables.

CONDENSED SELECTION TABLE—PUMPS FOR CLEAR LIQUIDS

Capacity Gal. per Min.	Total Head in Ft.	Size Disch. and Type of Pump	Motor Hp.	Number of Stages	Approx. Floor Space In.	Capacity Gal. per Min.	Total Head in Ft.	Size Disch. and Type of Pump	Motor Hp.	Number of Stages	Approx. Floor Space In.
10	20	1" SS	¼	1	12x22	400	20	4" DS	3	1	23x54
20	45	1½" SS	¾	1	16x30	400	70	4" DS	10	1	23x54
20	70	1¼" MS	1	2	20x38	400	100	4" DS	15	1	23x56
20	160	1¼" MS	3	4	20x55	400	150	3" DS	25	1	26x62
20	375	1¼" MS	7½	3	20x48	400	200	3" DS	40	1	30x68
50	20	1½" SS	½	1	16x30	800	20	6" DS	7½	1	28x60
50	70	1½" SS	2	1	19x34	800	40	6" DS	10	1	28x60
50	200	1¼" MS	5	6	20x60	800	70	5" DS	20	1	25x58
50	400	1½" MS	15	6	24x64	800	110	6" DS	30	1	28x66
100	30	2" DS	1½	1	22x46	800	160	4" DS	50	1	25x73
100	100	2" DS	5	1	22x51	800	200	5" DS	75	1	32x81
100	200	1½" DS	10	1	24x44	1200	30	6" DS	15	1	34x70
100	425	2½" MS	20	7	24x70	1200	60	6" DS	25	1	34x75
160	20	2½" DS	2	1	20x48	1200	100	6" DS	40	1	34x75
160	60	2½" DS	5	1	20x53	1200	200	5" DS	100	1	32x86
160	100	2½" DS	7½	1	20x55	2000	30	8" DS	25	1	40x82
160	200	1½" DS	15	1	24x47	2000	60	8" DS	50	1	40x85
160	375	2½" MS	25	8	24x73	2000	130	8" DS	100	1	42x106
160	500	3" MS	40	6	34x87	2000	170	8" DS	125	1	48x112
160	750	3" MS	60	8	34x97	2000	200	8" DS	150	1	48x112

DS—Indicates Double Suction Single Stage. SS—Indicates Single Suction Single Stage. MS—Indicates Multi-Stage.
The above is only a partial list of sizes. Complete engineering information is contained in Catalogs.

Sump Pumps

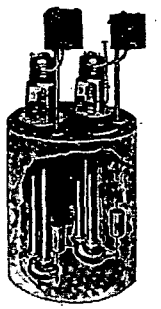


Single

Economy Sump Pumps and Sewage Ejectors are made in all capacities from 5 G.P.M. to 7500 G.P.M., both in clear water design and in non-clogging design. The smaller sizes are extensively used for sub-basement drainage in buildings—the larger sizes for drainage of sub-divisions, highway grade crossings and similar engineering projects.

The Non-Clogging Pumps handle sewage, rags, stones, etc., which are encountered in unscreened sewage.

See Bulletins No. 407, and 413 for the submerged design and Bulletin No. 412 for the dry chamber design.



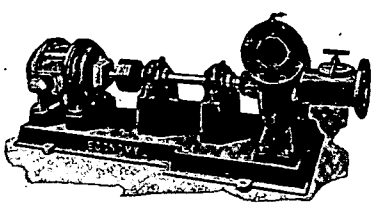
Duplex

CONDENSED CAPACITY TABLE—SUMP PUMPS

Capacity Gallons per Minute Each Pump	Pump Size	Size of Solids Which Pump will Handle	Minimum Recommended Sump Diameter, Inches		Size of Motors Required for Various Heads				Motor Speeds
			Single Pump	Duplex Pump	15 Feet	25 Feet	35 Feet	50 Feet	
15	1"	....	18	30	¼	½	¾	1	1750
50	1½"	....	30	42	½	¾	1½	2	1150–1750
100	3"	2¼"	42	48	1	2	3	5	850–1150
150	3"	2¼"	48	54	1½	2	3	7½	850–1150
200	4"	2½"	48	60	2	3	5	7½	850–1150
300	4"	2½"	54	72	3	5	5	10	850–1150
500	4"–6"	2½"–3¾"	60	72	5	7½	10	15	850–1150
1000	6"	3¾"	72	96	7½	10	15	20	570–1150
2000	8"	5"	96	120	15	20	30	50	570–850
3000	10"	7"	120	180	20	30	50	60	490–850

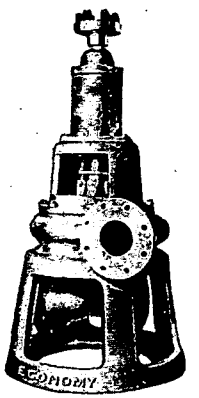
The above table is condensed from over 600 ratings which are shown in the Economy Catalog.

Non-Clogging Centrifugal Pumps



Horizontal

These pumps are widely used for pumping raw sewage, industrial waste, paper pulp, wood pulp, etc. They are also used in municipal sewage stations and in place of conveyors in idustrial plants. Capacities range up to 20,000 G.P.M.



Vertical Open Shaft

The illustrations show only the pumps, but we are in a position to furnish complete sewage pumping equipment, consisting of tanks, valves, fittings, piping, electric motors, automatic control, etc., all factory assembled and ready for erection.

Our Engineering Department will be pleased to submit layout sketches of such equipment, whether for buildings, industrial establishments or municipalities.

Economy Non-Clogging Pumps have several important patented features which makes for longer life and lower maintenance cost.

CONDENSED CAPACITY TABLE—NON-CLOGGING PUMPS

Capacity Gallons per Minute	Pump Size	Size of Solids Which Pump will Handle	Size of Motors Required for Various Heads					Revolutions per Minute	Floor Space Horizontal Pumps, Inches
			15 Feet	25 Feet	35 Feet	50 Feet	75 Feet		
150	4"	2½"	1½	2	3	7½	10	860–1750	27x67
300	4"	2½"	3	5	5	10	15	860–1750	27x71
500	4"–6"	2½"–3¾"	5	7½	10	15	25	860–1750	32x75
1000	6"	3¾"	7½	10	15	20	40	570–1150	32x85
1500	8"	5"	10	20	25	40	50	570–1150	36x98
2500	8"–10"	5"–7"	20	30	40	60	75	490–860	40x105
4000	12"	9"	25	40	60	75	125	275–860	40x120
7000	14"	10"	50	75	100	150	200	275–860	48x130
10000	14"	10"	60	100	125	200	250	275–860	48x140

Complete tables of dimensions and capacities will be sent upon request.

Goulds Pumps, Inc.

Seneca Falls, New York

NEW YORK, 16 Murray St. & 19 Park Place | TULSA.....213 E. Archer St. | PITTSBURGH.....636 H. W. Oliver Bldg.
PHILADELPHIA.....111 N. Third St. | CHICAGO.....12-14 S. Clinton St. | ATLANTA..Citizen and Southern Bank Bldg.
BOSTON.....194 Congress St. | CLEVELAND..Union Trust Bldg. | HOUSTON.....2113 Second Nat'l. Bank Bldg.

Manufacturers of Pumps for Every Service

PRODUCTS—Centrifugal Pumps for all purposes—Single and Double Suction, Sump, Fire, Single and Multistage, Horizontal and Vertical. Triplex Pumps.

Single and Double Acting, Deep Well, Power Rotary, Pressure Pumps, etc.

Goulds Pumps, manufactured since 1848, comprise a line of hand and power pumps, including types and sizes for practically all pumping services.

Every Gould Pump sold is guaranteed to give reliable, satisfactory service under the conditions for which it is recommended.

The power pumps can be furnished for belt, chain, gear or direct drive from all types of drivers.

Condensation Return Pump and Receiver

For handling returns which come back at or below the floor line of boiler room. Will handle returns from 2,000 to 25,000 sq. ft. of radiation; good for pressures up to 28 pounds. Outfits shipped from stock completely assembled.

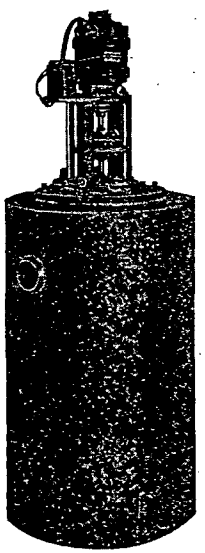


Fig. 3354

Pump—Ball bearing centrifugal type, two stage, bronze fitted. Requires no lubrication.

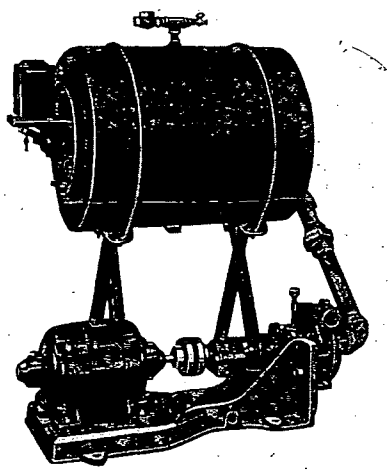
Pump Shaft and Float Rod—Operate through stuffing boxes to prevent leaks. This enables outfit to be used under pressure. Float Rod cannot bind.

Tank—Heavy, galvanized, welded steel, 24 in. in diameter by 40 in. high. Tank has two inlets both tapped for 3 in. pipe, one 8 in. the other 14 in. below top of tank. Tapped for vent connection, and fitted with drain opening. 1-in. discharge from pump to boiler.

Motor—1750 r.p.m., 110-220 volt, 60 cycle repulsion induction motor.

Fig. 3354 has ½ hp. motor; Fig. 3356 has 1 hp. motor.

Capacity—Pumps are suitable for Maximum Direct Radiation, 25,000 sq. ft.; Maximum Discharge Pressure, 28 lb.; Height Over-all, 64⅜ in.; Weight 350 lb.



Horizontal Condensate Return Receiver

The unit consists of a horizontal, galvanized, corrosion-resistant, welded steel receiver tank, in 20 gallon or 40 gallon capacity, with float and automatic switch mounted upon two strong welded steel supports.

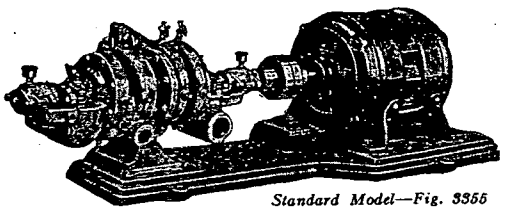
By means of piping it can be connected

and used with Goulds Figs. 3012, 3004, 3057, 3058, 3357, 3480 (1½" and 2½") and 3470 (3") centrifugal pumps; or with Fig. 1678 and 1741 reciprocating pumps.

These units are suitable for radiations up to 40,000 sq. ft. and for pressures to 150 lbs. maximum.

Four-Stage Centrifugal Pump

This New Standard Model is a 4-stage vertical split



Standard Model—Fig. 3556

ball bearing pump for direct connection to electric motors. It is made in two sections with two pairs of opposed impellers which balance the thrust.

This pump covers an extremely wide range of capacities and heads making it suitable for use in connection with humidifying systems, for boiler feeding, as a house booster pump, for circulating brine, for handling gasoline and light oils, and other equipment requiring a circulating pump.

Bronze Fitted Pumps—Have bronze impellers, stainless steel shaft, bronze water seal rings and bronze bushings.

All Iron Pumps—Have all parts coming in contact with liquid of iron, except stainless steel shaft.

Pump size is 1 in.; r.p.m. from 1750 to 3450; capacities from 5 to 80 gal. per minute according to head; motors ¾, 1, 5 and 7½ hp.; domestic shipping weight 200 lb.; for bedplate for 5 and 7½ hp. motors add 30 lb.

Automatic Cellar Drainers

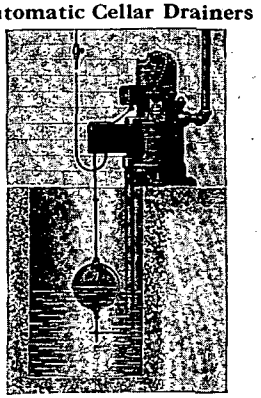


Fig. 1776

Vertical Self Priming Type—Fig. 1776. Capacities up to 25 gal. per minute. Heads up to 23 ft. For pit depths of from 1½ to 5 ft. Shipping weight 107 lb.

Pump has cast iron casing and priming chamber. Bronze impeller with stainless steel shaft working in bronze bearings. 1 in. discharge.

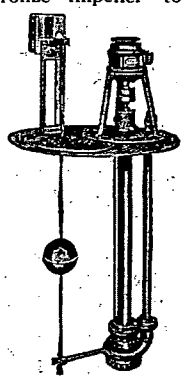
Motor is ¼ hp. mounted on pit cover. Furnished for 25 or 60 cycle A.C. or for D.C. circuits. Equipped with motor protecting Sentinel Breaker and 8 ft. of cord with plug. Double pole type switch. Copper float with brass rod.

Horizontal Self Priming Type—Fig. 3034. Two sizes, capacities 1 in. size up to 30 gal. per minute; 1½ in. size up to 50 gal. per minute. Heads up to 20 ft. Approximate weight, 100 and 250 lb.

This type is equipped with special priming chamber making it entirely automatic for pit depths of 3½ ft. Minimum diameter drainage pit, 1 in. size, 13½ in.; 1½ in. size, 16 in.

Pump is bronze fitted. Discharge 1 in. or 1½ in. Pump shaft is connected to motor shaft by flexible coupling. Motor is repulsion induction type. Double pole type switch. Copper float with brass rod.

Centrifugal Sump Pump—Fig. 3047. Electrically driven, directly connected to motor. Single stage, single suction. Used to elevate drainage in buildings to street level, where basement floors, boilers and elevator pits are below sewer level, and for any other service where liquid accumulates in a catch basin, pit or tank. Furnished with non-clogging bronze impeller to prevent corrosion during idle periods. Outfit includes pump, motor and control completely assembled and shipped from stock. Built in 1½, 2, 3, and 4 inch sizes for capacities up to 650 G. P. M.; heads up to 70 feet. Motors ½, ¾, 1, 1½, 2, 3, 5, and 7½ carried in stock with automatic control. All pumps may be furnished for pit depths up to 14 ft. Duplex units also available.



Centrifugal Sump Pump Fig. 3047

The Nash Engineering Company

Plant and General Offices

South Norwalk, Conn., U. S. A.

Sales Offices

Atlanta	152 Nassau Street, N.W.	Minneapolis	808 La Salle Avenue
Birmingham	2224 Comer Bldg.	Montreal	927 University Tower
Boston	25 Huntington Avenue	New Orleans	505 Queen and Crescent Bldg.
Buffalo	317 Chamber of Commerce	New York, N. Y.	Graybar Bldg.
Butte, Montana	910 Arizona Street	Oklahoma City, Okla.	125 West 2nd Street
Chattanooga	1104 James Bldg.	Omaha	Baum Bldg.
Chicago	925 Monadnock Block	Philadelphia	254 South 15th Street
Cleveland	1600 Union Trust Bldg.	Pittsburgh	1430 Oliver Bldg.
Dallas	1117 Mercantile Bldg.	Portland, Ore.	224 Pine Street
Denver	1226 California Street	Richmond	301 American National Bank Bldg.
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Kansas City, Mo.	314 W. Tenth Street	San Francisco	Sharon Bldg.
Los Angeles	1224 S. San Pedro Street	Seattle	518 Fourth Avenue
Louisville	901 Realty Bldg.	Toronto	1123 Bay Street
Memphis	422 Exchange Bldg.	Vancouver	410 Homer Street
Miami	P. O. Box 2017	Washington, D. C.	601 American Security Bldg.
		Wichita, Kan.	3101 East English Avenue

Return line and air line vacuum heating pumps. Condensation pumps. Standard centrifugal pumps. Suction (self-priming) centrifugal pumps.

Sewage ejectors. Sump pumps. Sewage pumps. Compressors and vacuum pumps for air and gases.

Return Line Vacuum Heating Pump

Removes air and condensation from the return lines of vacuum steam heating systems; discharges the air to the atmosphere and returns the water to the boiler.

Two independent units are combined in a single casing—an air unit and a water unit. Impellers of both are mounted on the same shaft. The pump is bronze fitted throughout.

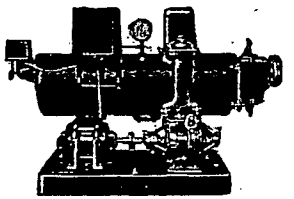
The air unit exhausts air and vapors and delivers these to the atmosphere without back pressure. The water unit removes condensation and pumps it directly into the boiler. Horsepower is saved, with a proportionate reduction in cost of current.

Supplied either direct connected to standard electric motors, for belt drive, or for steam turbine drive. For continuous or automatic operation against pressures up to 40 lb.

Capacities of Jennings Vacuum Heating Pumps

Pump Size	Equiv. Direct Rad. Sq. Ft.	Water Capacity G.P.M.	Air Capacity Cu. Ft. per Minute.	MOTOR H. P. 10 lb.	20 lb.	30 lb.	40 lb.
T	2500	4	3	⅛	½	1	1½
U	5000	9	3	⅛	½	1	1½
V	10,000	14	6	1	1	1½	2
B	16,000	22	9	1½	2	3	5
C	26,000	35	15	2	3	5	5
D	40,000	60	19	3	5	5	7½
E	65,000	90	34	5	5	7½	10
F	100,000	140	50	7½	10	15	15
*G	150,000	200	102	10	15	upon request	
*H	300,000	400	171	....	upon request		

*The last two sizes are not of the manifold type.

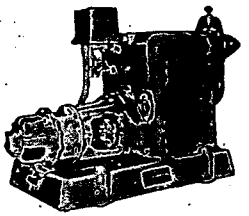


Jennings Motor-driven Return Line Vacuum Heating Pump

Condensation Pump and Receiver

Removes condensation from radiators in return-line steam heating systems and pumps condensation back to the boiler.

Compactness is secured by making the pump casing a part of the returns tank, and bolting the motor base to the tank. The pump can be installed in a corner against the wall.

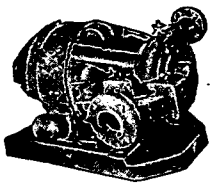


Jennings Motor-driven Condensation Pump

Jennings Condensation pumps are furnished in standard sizes with capacities ranging from 4 to 200 g.p.m. of water. For serving up to 150,000 sq. ft. of equivalent direct radiation.

Centrifugal Pump

For circulating hot and cold water; boosting city water pressure; handling water in air washing and conditioning; removing condensate from heating systems, blow-down from soot blowers and superheaters, exhaust drips from steam ejector air pumps and other auxiliaries; pumping screen wash water, oil engine jacket water, ash sluicing water, etc.



Jennings Centrifugal Pump

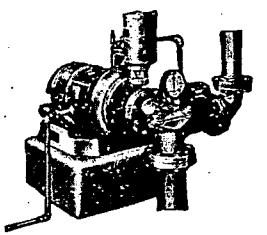
Compact—motor armature and pump impeller are mounted on the same shaft. Simplified—no bearings in pump casing, only one stuffing box. Accessible—pump impeller can be removed without breaking pipe connections, or disturbing shaft alignment.

Supplied in 1¼, 1½, 2, 3, 4 and 6 in. sizes for handling up to 2000 g.p.m. Heads up to 300 ft.

Suction Sump and Sewage Pumps

The Jennings Suction Sump Pump is a self-priming centrifugal pump for handling seepage water and liquids reasonably free from solids. The Suction Sewage Pump is fitted with a non-clog type impeller. Both pumps are mounted entirely above the sump. Only the suction pipe is submerged. Quickly and conveniently accessible, these pumps can be located either near to or removed from the pit.

There are only two moving parts, centrifugal impeller and vacuum priming pump rotor. Both rotate without metal-to-metal contact in the casing. Both are mounted on the same shaft that carries the rotor of the driving electric motor, making possible a single compact assembly.

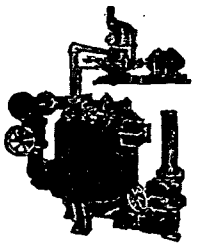


Jennings Suction (self-priming) Sewage Pump

Furnished in sizes and capacaties to meet all the usual requirements.

Sewage Ejector

For pumping unscreened sewage or drainage from basements below the street sewer level; handling crude sewage from low level districts; pumping effluent, sludge and other heavy liquids.



Jennings Pneumatic Sewage Ejector

The Jennings Sewage Ejector is of the pneumatic type. A Nash Hytor Compressor is used as the motive power to pump the accumulated sewage from a pot to the sewer.

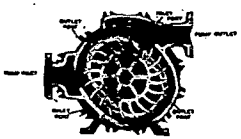
Air is compressed, delivered, and used *only when* required. There are no air storage tanks, reciprocating air compressors, or screens. Air valves are avoided.

Furnished in standard sizes for handling from 30 to 1500 g.p.m. Heads up to 50 ft.

Compressors and Vacuum Pumps for Air and Gases

The rotor, consisting of a cylindrical hub around the periphery of which are chambers formed by heavy shrouds cast integrally, revolves in an elliptical casing filled with water.

As the rotor turns, it carries the water with it. The water under the influence of centrifugal force, follows the contour of the casing, and alternately enters and leaves the rotor chambers.



Sectional View of the Nash Hytor Compressor or Vacuum Pump, Showing the Unique Principle of Hydro-Turbine Operation

As the water recedes from the rotor, air is drawn into the chambers through the inlet ports. As the water is forced back into the rotor, the air is compressed and then discharged through the outlet ports.

A separator frees the compressed air of entrained moisture.

Supplied in standard sizes for handling up to 5000 cu. ft. of air per minute. For discharge pressures up to 20 lb.; vacuums up to 20 in. of mercury column.

Bulletins

No. 10. Nash Hytor Compressors.
No. 11. Nash Hytor Vacuum Pumps.
No. 85. Jennings Return-Line Vacuum Heating Pumps, manifold type.
No. 87. Jennings Vacuum Heating Pumps, unit manifold type.
No. 97. Jennings Suction Sump Pumps.
No. 99. Jennings Condensation Pumps.
No. 103. Jennings Sewage Ejectors, Type B.
No. 108. Jennings Sewage Ejectors, Type A.
No. 155. Jennings Centrifugal Pumps.
No. 161. Jennings Suction Sewage Pumps.

Skidmore Corporation

St. Joseph, Mich.

Sales and Service Offices

Atlanta, Ga.	Chicago, Ill.	Houston, Texas	New Orleans, La.	San Francisco, Calif.
Baltimore, Md.	Cincinnati, Ohio	Indianapolis, Ind.	New York, N. Y.	Seattle, Wash.
Boston, Mass.	Cleveland, Ohio	Kansas City, Mo.	Oklahoma City, Okla.	Spokane, Wash.
Bridgeport, Conn.	Dallas, Texas	Little Rock, Ark.	Omaha, Nebr.	St. Louis, Mo.
Buffalo, N. Y.	Denver, Colo.	Los Angeles, Calif.	Philadelphia, Pa.	Tacoma, Wash.
Butte, Mont.	Des Moines, Iowa	Memphis, Tenn.	Pittsburgh, Pa.	Tampa, Fla.
Charlotte, N. C.	Detroit, Mich.	Milwaukee, Wis.	Portland, Ore.	Toledo, Ohio
Chattanooga, Tenn.	Glens Falls, N. Y.	Minneapolis, Minn.	Rochester, N. Y.	Tulsa, Okla.
	Grand Rapids, Mich.	Nashville, Tenn.	Rockford, Ill.	

Canadian Representatives and Manufacturers—DARLING BROS., LTD., Montreal, Que.

Skidmore Vacuum Pumps—Designed for return line heating systems. Unit is of the rotor type and is made of cast iron with bronze fittings. Base acts as receiver allowing low returns to be drained by gravity. The design of the unit calls for no close clearances between moving parts thus wear is practically eliminated and "Maintained Efficiency" results.

Skidmore Condensation Pumps—Built to fill the needs of the heating field with a pump and receiver of highest quality and efficiency. The receiver is cast iron and the impeller is of the bronze enclosed type. Any part of the centrifugal pump can be inspected without disturbing piping. The novel impeller assembly gives low return connection by gravity, and places the motor above most flood waters.

Send for Bulletin 6

Send for Bulletin 7

10-in. Vacuum, 10 and 20 lb. Pressure

Size of Pump	Capacity Sq. Ft. of Radiation	Gals. of Water per Min.	Motor H.P. 10 Lb.	Motor H. P. 20 Lb.	Size of Companion Flanges for Returns	Size of Discharge to Boiler
0	5,000	8	¾	1	1½"	1"
1	8,000	11	1	1½	2"	1¼"
2	16,000	22	1½	2	2"	1¼"
3	26,000	35	2	3	3"	1½"
4	40,000	60	3	3	3"	2"
5	65,000	90	5	7½	5"	2"
6	100,000	150	7½	10	5"	2½"
7	150,000	200	10	15	5"	3"

R. P. M. 1800 for all sizes. Data on pumps for higher discharge pressure furnished on request.

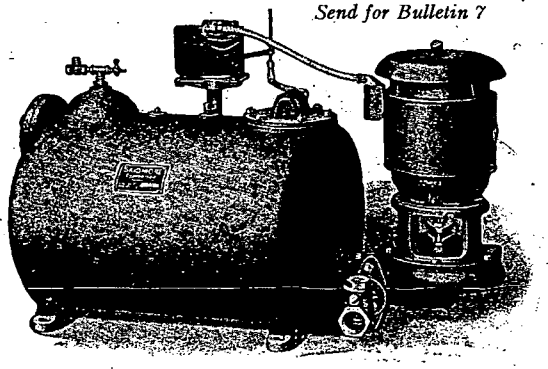


Illustration of Skidmore Condensation Pump

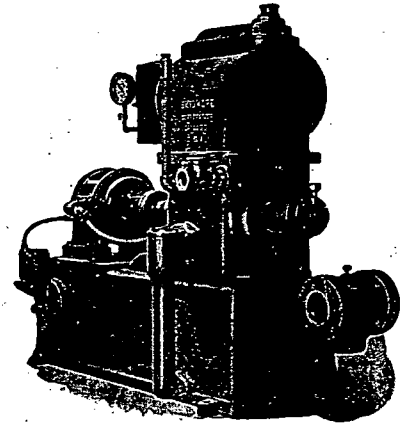


Illustration of a Skidmore Automatic Vacuum Pump

Size	Capacity Sq. Ft.	H. P. Motor 10 Lb.	H. P. Motor 20 Lb.	Gallons Between Float Stops	Gallons Per Minute Pumped	Inlet Disc.		Weight 10#	Weight 20#
C 21	2,000	⅛	...	9	4	2"	1"	325	...
C 22	2,000	...	½	9	4	2"	1"	...	350
C 41	4,000	⅛	...	9	6	2"	1"	325	...
C 42	4,000	...	½	9	6	2"	1"	...	350
C 61	6,000	⅛	...	9	8	2"	1"	325	...
C 62	6,000	...	½	9	8	2"	1"	...	350
C 81	8,000	⅛	...	9	11	2"	1¼"	325	...
C 82	8,000	...	½	9	11	2"	1¼"	...	350
C101	10,000	⅛	...	18	13	2½"	1¼"	440	...
C102	10,000	...	½	18	13	2½"	1¼"	...	460
C121	12,000	½	...	18	16	2½"	1¼"	460	...
C122	12,000	...	¾	18	16	2½"	1¼"	...	470
C161	16,000	½	...	18	22	2½"	1¼"	460	...
C162	16,000	...	¾	18	22	2½"	1¼"	...	470
C261	25,000	¾	...	25	35	3"	1½"	495	...
C262	26,000	...	1	25	35	3"	1½"	...	515
C401	40,000	1½	...	25	60	3"	2"	525	...
C402	40,000	...	2	25	60	3"	2"	...	550

The Weinman Pump Mfg. Co.

Columbus, Ohio

NEW YORK OFFICE
39 Cortlandt Street
Telephone—Cortlandt 7-6541

PITTSBURGH OFFICE
210 Second Avenue
Telephone—Court 3533

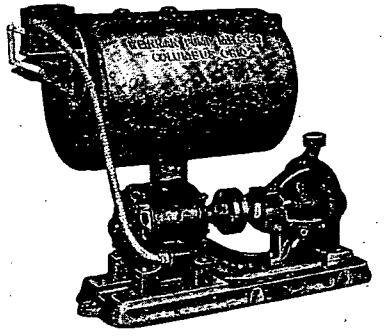
Pumping Machinery for All Purposes

There is a Weinman Pump for every service, representing more than 50 years' experience in the building of pumps, and assuring satisfactory performance. This line of pumps deserves careful consideration before making your next pump specification.

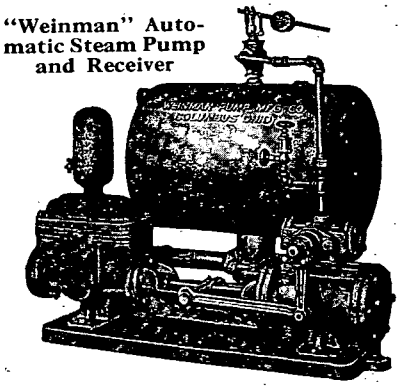
Automatic Pump and Receiver Units

These units are standardized sizes designed for returning to the boiler hot condensate from radiating surfaces of steam heating systems, dry kilns, cookers, or other devices of like nature. Each unit is a complete self contained outfit, requiring only the necessary connections to make them ready for operation. No special foundation is required. May be set on any smooth floor surface.

"Weinman" Type "H" Electric Automatic Centrifugal Pump and Receiver



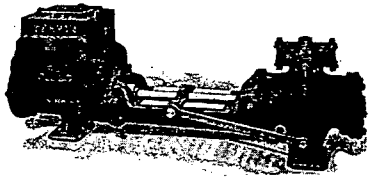
"Weinman" Automatic Steam Pump and Receiver



Advantages—Low elevation of returns; minimum floor space requirement; small maintenance cost; quiet and economical operation.

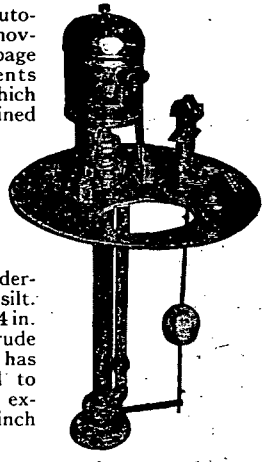
"Weinman" Steam Driven Vacuum Pump

Designed for operation under a maximum vacuum at suction inlet of 20 in. For vacuum greater than 20 in., special construction, in which reduced clearances in the water cylinder, special valves, and water-sealed stuffing-box, must be employed.



"Weinman" Vertical Centrifugal Sump Pump

Designed for automatically removing the seepage from basements and pits which cannot be drained by gravity flow directly into a sewer. All sizes will handle hot water or water containing a moderate amount of silt. Sizes 3 in. and 4 in. will handle crude sewage which has been screened to exclude solids exceeding a 1 inch sphere in size.



Write for Special Bulletin on Pump in which you are interested

W. P. Whittington, Inc.

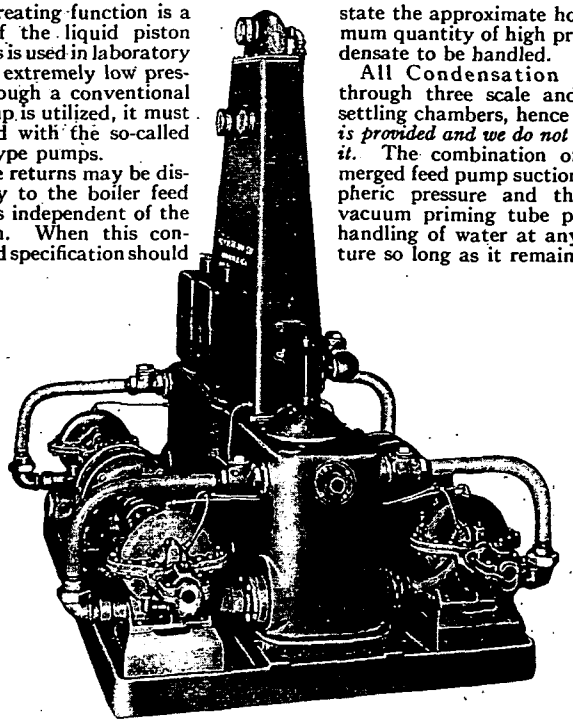
Main Office and Factory
Indianapolis, Ind.

VACUUM HEATING PUMP

The Vacuum creating function is a development of the liquid piston principle such as is used in laboratory work to obtain extremely low pressures, and although a conventional centrifugal pump is utilized, it must not be confused with the so-called jet or ejector type pumps.

High pressure returns may be discharged directly to the boiler feed chamber as it is independent of the vacuum system. When this connection is desired specification should state the approximate hourly maximum quantity of high pressure condensate to be handled.

All Condensation must pass through three scale and sediment settling chambers, hence *no strainer is provided and we do not recommend it.* The combination of the submerged feed pump suction at atmospheric pressure and the positive vacuum priming tube permits the handling of water at any temperature so long as it remains liquid.



Duplex Unit

STANDARD RATING
to 27 In. Vacuum at Shut-off

Sq. Ft. Radiation	Size	10" Vacuum		Water Capacity G.P.M. 210°	Receiver Capacity Gal.	Motor H.P. 1750-R.P.M.	
		Air Capacity C.F.M.	Diam. Orifice			20 Lb.	30 Lb.
5000	VV	3	1/16	9	10	1	1½
10,000	V	5	9/64	12	15	2	2
10,000	A	7	5/32	15	15	2	3
20,000	B	12	7/32	27	20	3	5
30,000	C	17	17/61	39	20	5	5
40,000	D	21	19/61	51	52	5	7½
65,000	E	34	3/8	81	52	7½	10
100,000	F	50	7/16	125	68	10	15

For Duplex Specification add prefix (X) to Size Letter. 2 motors of the same H.P. are required.
Data on Special Pumps for Larger Capacities and Higher Pressures on Application.

Heintz Manufacturing Company

Front Street and Olney Avenue — **Philadelphia, Pa.**

MANUFACTURERS OF CABINET AND CONCEALED RADIATORS

The Heintz Radiator Unit is built of tubing, fins and headers.

No part of the core is less than ⅛ in. thick. The end headers are drop forgings having integral ferrules.

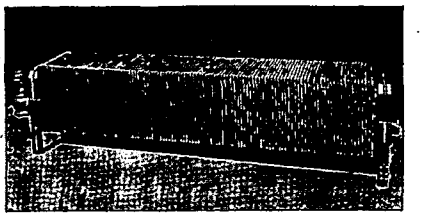
The core is welded together by means of the recently developed "atomic hydrogen" process which gives the most homogeneous and ductile weld so far produced.

The fins are applied by hydraulic pressure and the whole unit is then hot galvanized inside and out.

The Heintz Radiators, while much lighter than cast iron radiators, are very sturdy, and with ordinary care, the danger of becoming damaged during installation is remote.

The tappings at the ends are 1½ in., permitting them to be connected exactly the same as is customary with cast iron.

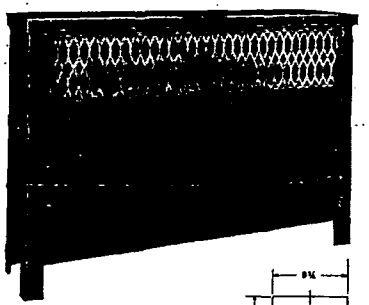
Every radiator is tested before shipment.



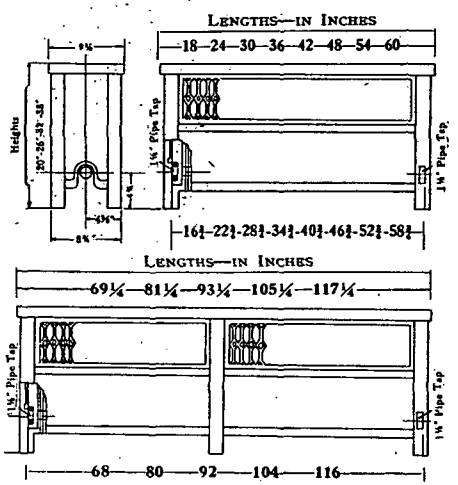
The Heintz Radiator Unit for Vapor, Steam or Water

The ratings of radiators shown are conservative condensation ratings. It is deemed advisable to continue to rate Heintz Radiators on this basis until such time as an acceptable method of testing and rating has been determined upon which will include heating effect.

Roughing-in Diagram of Standard Cabinet Radiator



Standard Cabinet Radiator



Drawing at right shows roughing-in dimensions of the Double Cabinet Radiator

Ratings in Sq. Ft. for Standard Radiators

Lengths	Heights			
	20"	26"	32"	38"
18"	16¾	18¾	20¼	22
24"	22¾	26½	29¼	31¾
30"	29	34½	38	41¼
36"	35¼	42	46¾	51¼
42"	41¼	49¾	55½	61
48"	47½	57½	64½	70½
54"	53¾	65	73¼	80¼
60"	59¾	73	82¼	90

Ratings in sq. ft. for Double Cabinet Radiators

Lengths	Heights			
	20"	26"	32"	38"
69¼"	70½	84	93½	102½
81¼"	82½	99½	111	122
93¼"	95	115	129	141
105¼"	107½	130	146½	160½
117¼"	119½	146	164½	180

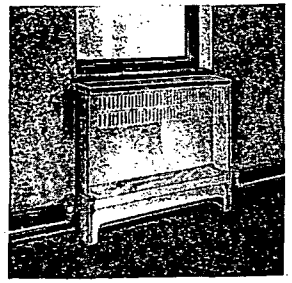
Heintz Cabinet and Concealed Radiators are available in 3 widths and in various types.

The Trane Company

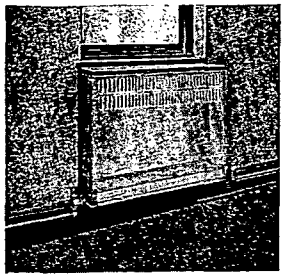
La Crosse, Wis.

See Unit Heaters, pages 666-667; Heating and Ventilating Units, page 678; Heating Specialties, page 824

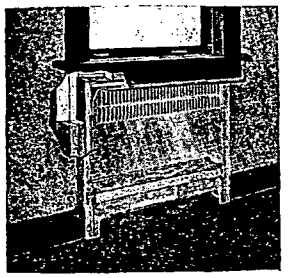
BRANCHES IN ALL PRINCIPAL CITIES



Phantom View of Trane Convection Heat Cabinet



Phantom View of Wall Hung Cabinet



Phantom View of Completely Concealed Cabinet Installed with Wood Window Stool

TRANE CONCEALED CONVECTION HEATERS

Modern Heat Distributors for Modern Buildings

Developments in Trane Concealed Heaters since their announcement six years ago has been primarily in sheet metal enclosure design to meet the structural requirements of buildings.

The heating element is essentially the same in construction. It was developed as a laboratory product and the correctness of design as regards heat transfer has been adequately demonstrated by the fact that it has a heat capacity per pound of material that is unsurpassed by other similar types of heaters.

Trane Convection Heaters have been so perfected that it is possible to select a size and type to fit the requirements of all types of buildings without major changes in structural design. It is impossible to give complete information relative to Trane Concealed Convection Heaters in this book but detailed data is available and will be sent on request to interested architects, engineers, contractors, or prospective builders.

Illustrated on these two pages are six of the general types of Trane Convection Heaters. Although data on all types will be sent immediately to interested parties we are giving below the general applications of each individual type.

The total installed cost of any of these types compares favorably with the ordinary radiator system.

Convection Heat Cabinets are used principally in place of old style radiators in modernizing existing building or on installations where the location of the heat distributors in the room is not objectionable. Easy

TRANE HUMIDIFIERS

In localities where humidity is desired it is recommended that a Trane Humidifier assembly be installed in a sufficient number of Convection Heaters to provide proper moisture for the air content of the building. The smallest humidifier will take care of installations up to 15,000 cu. ft. On larger installations, additional or larger humidifiers should be used. The Trane Humidifier is of the convection type. A series of special composition T-shaped fibre surfaces supply moisture to the heated air. Trane Humidifiers are also furnished in cabinet type for installation on any two-pipe steam or hot water heating system. Catalogs and complete data on request.

and economical to install, the Convection Heat Cabinets give all the positive advantages of Concealed-in-the-wall types.

Wall Hung Cabinets are particularly adaptable for use in hospitals, office, apartment, school and public buildings where the wall construction does not permit concealment.

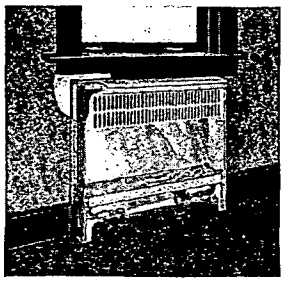
Completely Concealed Cabinets give one of the two ideal types of installation for all classes of buildings because of the extremely low cost. Front metal panel is quite unobtrusive when finished to conform with room decorations.

Partially Concealed Cabinets are usually used where the condition or thickness of the wall structure does not allow sufficient depth for concealment. This type of installation is applicable to either commercial or residential structures of all kinds.

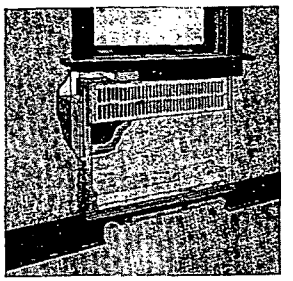
Plaster Front Cabinets give an ideal installation where the utmost in beauty is desired. The cabinet is installed in the wall as usual but the front metal panel which connects the inlet and outlet grille frames is recessed sufficiently to allow a coat of plaster of the ordinary thickness to be carried cross the opening between the frames. This type of installation is used primarily on apartment and residential buildings.

Plaster Front Installations Without Cabinets can be made under certain building conditions where it is practical to eliminate the metal wall enclosure and use the recessed panel with grille frames in connection with a recess framed either in the masonry or structural members of the building. This recess is lined with wallboard.

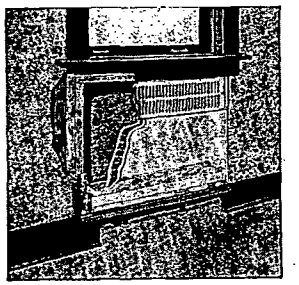
Other types of installation are fully described in Trane Concealed Heater Data which may be secured from the nearest Trane Branch Office.



Phanton View of Partially Concealed Type Cabinet Installed with Wood Window Stool



Cutaway Phantom View of Plaster Front Cabinet with Outlet Frame



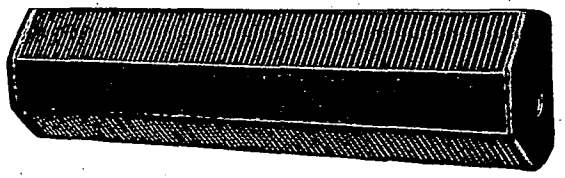
Cutaway Phantom View of Plaster Front with Outlet Frame

Automatic Florzone Heating Co.

Conshohocken, Pennsylvania

MANUFACTURERS OF FLORZONE RADIATORS AND NEW-DAY GAS BOILERS

FLORZONE RADIATORS



Adaptable to any room. Can be attached to baseboard, recessed to plaster line or stud line, or fully recessed.

3½″ fin—¾″ pipe:

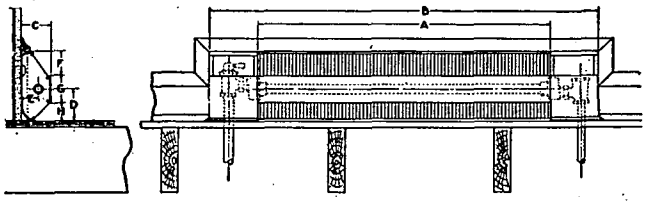
18″ section rated at 10 sq. ft.
36″ section rated at 20 sq. ft.

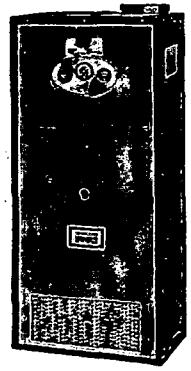
4″ fin—1″ pipe:

18″ section rated at 12 sq. ft.
36″ section rated at 24 sq. ft.

For One Pipe Steam Work 1¼″ Pipe with 4″ Fin is furnished with same rating as 3½″ fin and ¾″ pipe.

A—36″
B—46″
C—3⅝″
D—3 1/16″
E—2 1/16″
F—3″
G—3¼″
H—2¼″





New-Day Gas Fired Boiler Aqua-Force Heating System

An automatically controlled orifice system of forced hot water heating.

Combines the **New-Day** Boiler with **Florzone** Radiators: small piping and flow correctly proportioned to each radiator.

The **New-Day Boiler** measures 21″ x 22″ x 45″. Gas and water connections are 1¼″. Stack size 7″.

Is fully automatic with all controls and automatic pump built in.

Nocare Electric Radiator Corporation

1 East 42nd Street, New York City, N. Y.

NOCARE

AUTOMATIC
ELECTRIC
STEAM
RADIATORS

NOCARE Automatic Electric Steam Radiators are standard steam radiators equipped with a NOCARE automatic dual control, and a NOCARE heating element.

Automatic Dual Control—The NOCARE automatic dual control is the combination of the NOCARE pressurestat and the NOCARE thermostat.

Pressurestat—The NOCARE pressurestat operates on a high pressure of 10 lb. and a low pressure of 1 lb.

Thermostat—The NOCARE thermostat operates on room temperature. It has a range of approximately 45 deg. F. 40 is low and 80 to 85 is high.

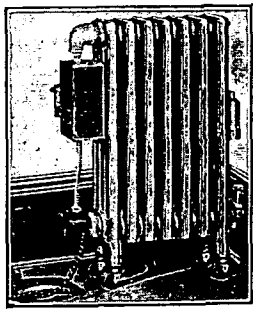
When the NOCARE pressurestat has succeeded in raising the room temperature to the desired or predetermined degree, the NOCARE thermostat being connected in series with the NOCARE pressurestat breaks the circuit and does not reestablish the circuit connection until the room temperature has dropped 1 or 2 degrees below the desired temperature.

Economical in Use of Current—The NOCARE automatic dual control makes it possible to maintain any desired degree, within its range, with a minimum use of the electric current.

Each NOCARE Automatic Electric Steam Radiator is a complete portable steam heating plant.

They operate on A.C. or D.C. 110 or 220 volts.

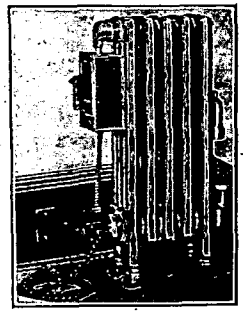
Auxiliary or Complete Heat—NOCARE Automatic Electric Steam Radiators may be used wherever heat is needed and electric current (110 or 220 volts) is available. They may be used as auxiliary heat or as the complete heating system.



This is the NOCARE "General Utility" Federal Model 7194. 14 sq. ft. 1000 watts.
A good heater for general purposes in providing auxiliary heat and in many cases for providing complete heat.

Test and Inspection—They are fully inspected and tested for pressure and temperature before they leave the NOCARE plant.

Safety—A fusible plug is installed as a safety. It is guaranteed to blow at 1 lb. minus or plus 20 lb. pressure.



This is the NOCARE Federal Model 6194; 10 sq. ft. 750 watts.
A good heater for the average bathroom, dressing room, small office, theatre ticket booth, etc. May be used as an auxiliary. It is portable and mounted on casters.

NOCARE Automatic Electric Steam Radiators

Federal Models	Rating Sq. Ft.	Heating Element	Radiator Wt. Lbs.	Shipping Wt. Lbs.
5194	10	750 W.	48	55
7194	14	1000 W.	57	68
10194	19	1250 W.	77	88
10224	22	1500 W.	103	124
12224	27	2000 W.	118	141
6203	13	1250 W.	77	92
6234	20	1500 W.	109	124
8235	30	2500 W.	156	186
10235	40	3000 W.	195	229

Black type indicates H. D. Models.

The NOCARE Model Number indicates the dimensions of the radiator. The last number indicates the number of tubes, the next two the height in inches and the remaining figures, the number of sections. Federal Models are 4⅞″ wide; H. D. 3 tubes are 5¼″ wide, 4 tubes are 6⅞″ wide, and 5 tubes are 8½″ wide.

Add 8″ to the radiator length for the NOCARE equipment.

For further information write to the main office: NOCARE ELECTRIC RADIATOR CORPORATION, 1 East 42nd Street, New York City.

UNITED STATES RADIATOR CORPORATION

GENERAL OFFICES: DETROIT, MICHIGAN

Manufacturers of Capitol Boilers and Radiators

Branches and Sales Offices

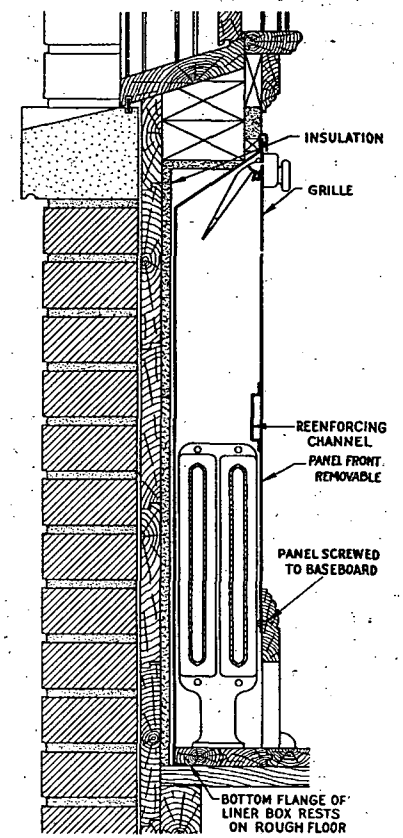
*Atlanta, Ga.
*Baltimore, Md.
*Birmingham, Ala.
*Boston, Mass.
Buffalo, N. Y.
*Cambridge, Mass.
*Chicago, Ill.
*Cincinnati, Ohio
*Cleveland, Ohio
*Columbus, Ohio
*Davenport, Iowa
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Detroit, Mich.
*Harrison, N. J.
*Indianapolis, Ind.
*Kansas City, Mo.
*Louisville, Ky.
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*Milwaukee, Wis.
*New Haven, Conn.
*New Rochelle, N. Y.
New York, N. Y.
*Omaha, Neb.
*Philadelphia, Pa.
*Pittsburgh, Pa.
*Portland, Me.
*Providence, R. I.
*Reading, Pa.
*Rochester, N. Y.
*San Francisco, Cal.
*Seattle, Wash.
*Springfield, Mass.
*St. Louis, Mo.
*St. Paul, Minn.
*Troy, N. Y.
Washington, D. C.

*Assembling Plants located at points indicated by asterisk

Manufacturing Plants Located in Following Cities

Bristol, Pa.; Corry, Pa.; Detroit, Mich.; Dunkirk, N.Y.; Edwardsville, Ill.; Geneva, N.Y.; Waukegan, Ill.; West Newton, Pa.

THE PACIFIC STEEL BOILER CORPORATION—Division of the United States Radiator Corporation, builds steel heating boilers for large and small installations—business buildings, factories, schools, hotels, residences and apartments.



Cut showing how Capitol Cast-Iron Concealed Radiator is placed in 2 x 4 studs

CAPITOL CAST-IRON CONCEALED RADIATORS

Exhaustive tests prove that cast iron is a most desirable metal for any form of radiator.

A scientific development of a radiator to be enclosed.

Can be placed in 2 x 4 studs.

Satisfactory operation in combination with exposed radiators.

Now balanced heating results may be obtained by the combination of Capitol Concealed and Capitol Tube Radiators, both cast iron.

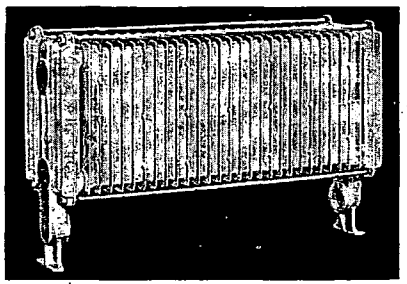
An ideal hot water radiator.

Capitol Cast-Iron Concealed Radiators operate perfectly on all kinds of heating systems—one pipe or two pipe steam, hot water, vapor or vacuum.

Ribs cast integral—no attached fins.

A sturdy radiator to handle and can be used for temporary heat without danger of damage.

All output ratings on Capitol Cast-Iron Concealed Radiators represent actual performance. For complete performance data see catalog.



Capitol Cast-Iron Concealed Radiator with inside header connections

Healy-Ruff Company

Manufacturers of E-Z Radiator Hangers, Lavatory Hangers and Concrete Inserts

791 Hampden Avenue, St. Paul, Minnesota

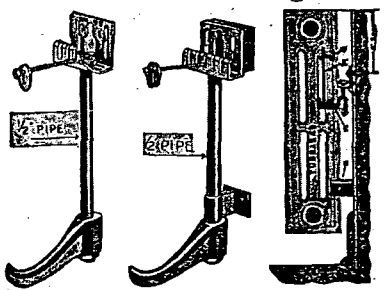
PRODUCTS

E-Z One-Bolt Radiator Hanger or Bracket, for hanging all makes of wall and tube radiation.

E-Z Lavatory Hangers, an Adjustable Hanger for lavatories and sinks.

E-Z Concrete Inserts, for all pipe hangers.

E-Z Radiator Hangers



Style "R" *Style "H"* *Style "C"*

Style "R" places radiator 1½ in. from wall, but is not adjustable for baseboard adjustment.

All Style "R" hangers convertible, with parts No. 4 and No. 8, into Style "H".

Both styles are made for wall, column and tube radiation.

All parts made of pressed steel except bottom hook support.

All column and tube radiation is held in at the top with an invisible washer.

Advantages

Easy to clean under the radiator.

Anchor bolts can be placed in walls during contruction. No accurate measurements required since hangers have both horizontal and vertical adjustments. (Vertical adjustments on Styles H and R made with ½ in. pipe).

Only one bolt in the wall for each hanger.

Expansion cannot affect anchor bolts in wall.

Entire hanger invisible when installed.

Adjustable for any height of baseboard.

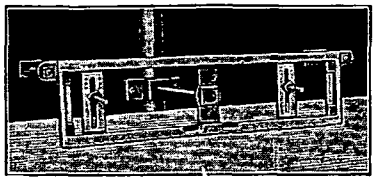
Saves time and labor.

Applicable to walls of wood, brick, tile or of any other material.

Style "C" hanger will hang tube radiation, wall radiation, and the new "fantom" radiation. Fully adjustable horizontally and vertically and has adjustments for irregular walls. Can be furnished for hanging either 1½ or 2½ in. from wall.

Style "C" is a complete hanger, no nipples being required. All parts made of pressed steel.

E-Z Lavatory Hanger



Easy, quick and economical to install. Can be fastened securely to form rigid hanger either with or without clamping to vent pipe. Gives firm, substantial support permanently—cannot slip or come loose from wall. No lavatory pedestal, legs or other support necessary.

Installed in wall without extra frame of wood or other material. Can be built into wall during construction or after, as desired. It is not absolutely necessary to attach to vent pipe, but preferable when possible.

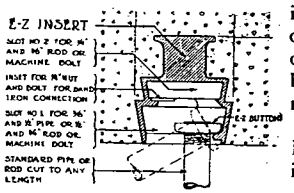
E-Z Lavatory hanger fits all size lavatories and meets all conditions. It is fully adjustable both horizontally and vertically. Exact position need not be figured when setting.

E-Z Concrete Inserts (7 In 1)

An insert with special features making it adaptable to all sizes of pipe hangers, whether supported by pipe, bolt, rod or band iron.

Advantages—Made in just one size, and this one size accommodates ¼, ⅜, ½ in. pipe ¼, ⅜, ½, ⅝ and ¾ in. rod or bolt. Ball and socket connection between insert and hanger.

Fully Adjustable—Allows play to compensate for expansion and inaccurate alignment of inserts. E-Z Button turns in the insert — no couplings or turnbuckles needed. "Make Pipe Hanging Easy."



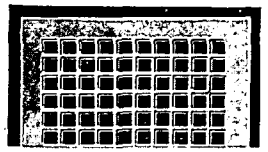
The Auer Register Co.

Cleveland, Ohio

MANUFACTURERS OF REGISTERS, FACES AND GRILLES FOR HEATING AND VENTILATING; WROUGHT METAL GRILLES FOR CONCEALING AND PROTECTING RADIATION

Cold Rolled Steel, Sheet Aluminum, Brass, and Bronze any Size

¼" Thick and Lighter Steel in all Standard Finishes, 12 Gauge most popular



Square Lattice

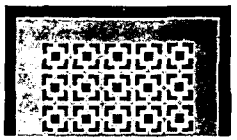
Design No.	Holes, in. sq.	Bars, in.
8A	½	⅛
5A	¾	⅛
3A	⅞	⅛
9A	1	⅛
10A	1¼	⅛

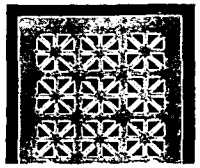
Design No. 5A inch multiples work best to all daylight and over-all sizes. Best adapted for louver registers.

Square Link No. 35A

Squares, in.	Bars, in.	Multiples, in. sq.
1¾	¼	2

All grilles are roller level straightened after perforating.





Union Jack Design

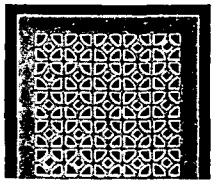
No.	Squares, in.	Bars, in.	Multiples, in. sq.
12A	2½	¼	2¾
12A	2½	½	3
14A	3	⅜	3⅜
14A	3	½	3½
20A	4⅛	⅛	4½

State whether daylight opening or over-all measurement.

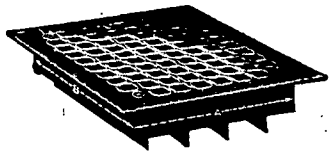
Moorish Design No. 4A

Squares, in.	Bars, in.	Multiples, in. sq.
1¾	¼	2

Invisible access to valve doors can be incorporated in all designs.



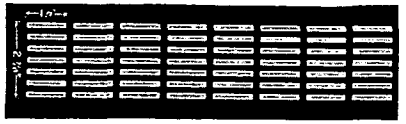
Louver Register



Heavy gauge steel, Aluminum, Brass or Bronze Face, having attached thereto steel louvers. Can also be equipped with lock, or with pulleys, or with pole operating lever.

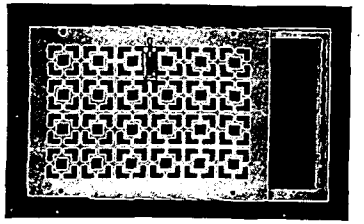
No. 31A Window Stool Grille

Perforations 1½ x ⅝ in. Bars ⅝ in. Made any size.

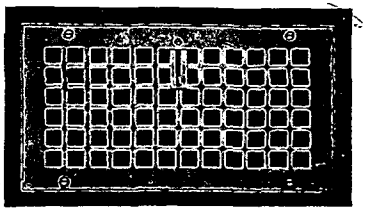


AIR CONDITIONING

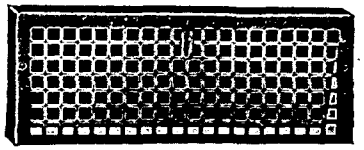
and Forced Air Heating Registers and Intakes.



Louver Register in Frame. Made with, also without Louver, Metal Frame, side or return flanges. Any required size, finish, or design.



Finish flush into wall. The duct or box is bent back over the edge of our metal frame and results in a non-streak installation. The frame is recessed to receive the face plate.



Baseboard Register having 1" return and side flanges to fit base to. Made with, also without louver or deflector. Any required size, finish or design, although square lattice in pearl gray finish for subsequent decorating is most practical and popular.

Hart & Cooley Mfg. Co.

General Sales Office:

61 W. Kinzie Street, **Chicago**

Wm. Highton & Sons Division

Nashua, N. H.

NEW YORK, 101 Park Ave. PHILADELPHIA, 1600 Arch St. BOSTON, 75 Portland St. NEW BRITAIN, CONN.

Factories in

HOLLAND, MICH. NEW BRITAIN, CONN. NASHUA, N. H.

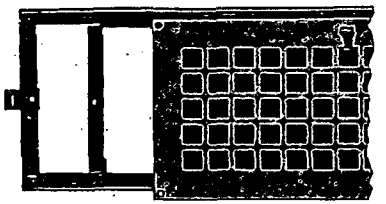
PRODUCTS—Registers for all purposes, including the H & C-HIGHTON Volume-Control Register (McKnight Patent Application) for quickly and perfectly balancing large ventilating jobs. Also a complete line of perforated and cast ornamental grilles.

A Complete Line of Registers

Built Specifically for Air Conditioning

H & C Air-Conditioning Registers are not simply an adaptation of the ordinary gravity type register. On the contrary, they are designed and constructed to meet the particular requirements which air conditioning imposes. They are free from whistles, leaks and rattles, occupy a minimum of wall space, and provide several installation advantages.

No. 3351 Sidewall Register Designed to Set Flush With the Plaster

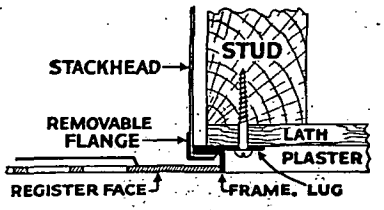


PATENTS PENDING

The 3-piece construction of this register assures an exceptionally neat, very secure and quickly made installation. Note the accompanying installation sketch. The frame, which has a depth of ⅜", and removable flange are installed when the stackhead is placed—the plaster is brought flush with the frame, providing a very pleasing effect—and any time after plastering the job is completed in just a jiffy by screwing the face into position. The removable flange automatically smooths out any unevenness in the stackhead, thus eliminating any possibility of valve interference and providing absolutely tight contact between stackhead and frame, thus making it impossible for any dust to leak out around the edge to soil the wall. Face and valve are removable for cleaning or redecorating.

This register and our No. 3151 Baseboard Register which employs essentially the same construction, are ideal for new house work.

Our one-piece line, which is somewhat less expensive, is designed primarily for old



house work and is also thoroughly adaptable to new work where flush installation and removable face are not essential. The complete line contains Baseboard Return Air Intakes to match the registers. Sizes range from 10" x 4" to 30" x 8". Available in any finish desired. Write for complete details, including chart for easily determining the correct size register for every condition.

Independent Register & Mfg. Co.

ESTABLISHED 1898

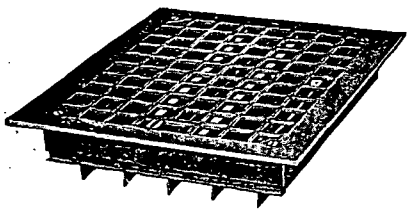
3753 East 93rd Street, **Cleveland, Ohio**

WROUGHT STEEL REGISTERS, REGISTER FACES, VENTILATORS AND GRILLES

The Independent Line consists largely of Register Specialties, each designed to perform unusually well, some particular service in connection with heating and ventilating.

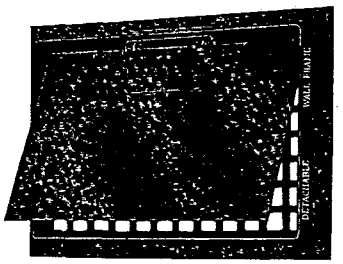
The complete line consists of Wrought Steel Registers and Faces, Wrought Steel and Bronze Grilles, "Fabrikated" Register Faces and Grilles, Adjustable Ceiling and Wall Ventilators, Pipeless Furnace Gratings, and Floor Borders.

If products shown here do not meet with your specifications, please send for full information and catalog covering our complete line.



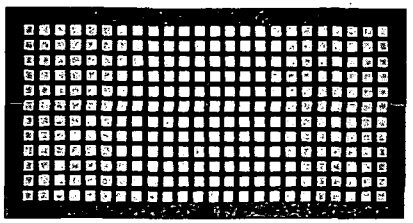
Register with Multiple Valves

For floor, wall or ceiling. Practically any size can be supplied promptly.



Wall Register with Single Valve (Rear View)

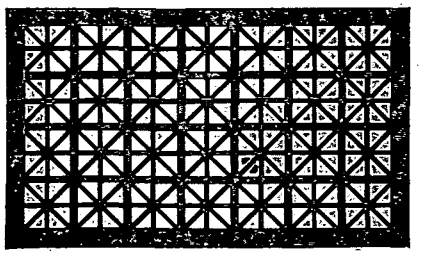
Furnished in wide range of sizes.



Plain Lattice Grilles

½ in., ¾ in., ⅞ in., and 1 in. square openings.

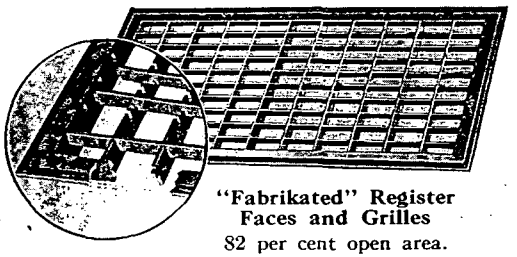
Made of Wrought Steel, Brass and Bronze, in any size.



Grecian Design Grilles

One of many designs.

Made of Wrought Steel, Brass and Bronze.



"Fabrikated" Register Faces and Grilles

82 per cent open area.

Especially suitable for use in the floor.

"Fabrikated" construction is strong and rigid because it uses material to secure the utmost supporting strength. The outer frame is welded to form a solid piece and the grille is made up of steel strips set on edge.

"Fabrikated" Faces and Grilles *can be furnished not only* in all standard sizes, but in practically any size and finish, usually with but little delay.

Tuttle & Bailey Mfg. Co.

ESTABLISHED 1846

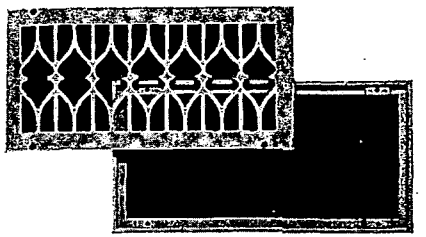
155 East 44th Street, **New York City, N. Y.**

Branch Offices IN BOSTON, MASS., CHICAGO, ILL., AND LOS ANGELES, CALIF.

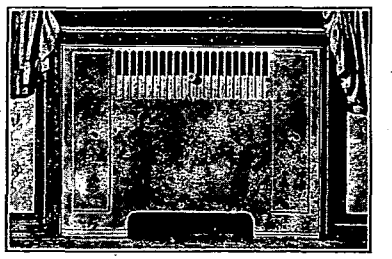
In Canada

TUTTLE & BAILEY MFG. CO. OF CANADA, LTD., BRIDGEBURG, ONT.

PRODUCTS—Ferrocraft Cast Grilles, Stamped Metal Grilles, Ventilators, Registers, Radiator Cabinets, Fronts and Shields.



T & B Design Grille No. 612 for Air Conditioning Work



Controlling Heat from the T&B Vertical Sliding Damper Front

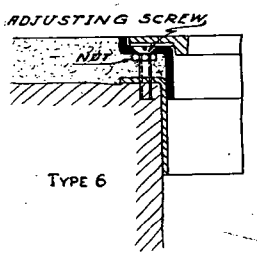
Grilles, Registers, Etc.—

A complete line of Registers, Grilles and Ventilators in cast or stamped metals for all types of heating and ventilating work—fully described with methods of fastening in our specially prepared Architects' and Engineers' Catalog "Grilles."

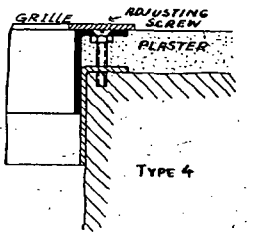
T & B Design No. 612 (illustrated above) is a Ferrocraft Grille of cast iron designed for Air Conditioned Residence Work of today. Grille is placed above breathing line and air (register velocity 200 ft. per min.) is controlled in Basement or at Baseboard. Made in two sizes for duct openings of 6⅜ x 14 in. and 6⅜ x 30 in. The Wallcraft Frame (Method No. 8) is suggested to assure a perfect installation.

Gordon Adjustable Frame—

(Patented)



A Welded Angle Iron Frame, set into duct opening on completion of sheet metal work. Screw-adjusting feature aligns grille with finished face of wall. Method of attaching grille permits removal without damage to wall. Plaster fill-in seals completely in either plaster or marble walls—there is no leakage between duct and frame or frame and grille. Made in any required size. Also used for installing Inspection Doors. (Literature on request).



Radiator Enclosures—

Every type enclosure required for concealing radiators.

Fronts for Radiators or heating units placed in the wall.

"The Coverton," constructed for radiators partly in wall.

"The Undersill" for radiators suspended beneath the window sill, and—

A full line of custom built Radiator Cabinets and Shields for radiators out of the wall.

The illustration above pictures the latest type Vertical Sliding Damper Front, easy to install and easy to remove if necessary. Damper controls perfectly the flow of heat and other patented features assure a snug installation. This front can also be ordered—without damper and with or without hand hole doors. (Complete details on request).

Uni-Flo Grille Corporation

Grilles and Registers for Forced Air Heating, Air Conditioning and Concealed Radiation.

4646 Lawton Avenue **Detroit, Mich.**

UNI-FLO, fin and bar type Grilles and Registers are designed to meet the requirements of Forced Air Heating, Air Conditioning, Ventilating and Concealed Radiation systems.

They offer only 5 per cent reduction of air flow, which is made possible by the design of the grille face.

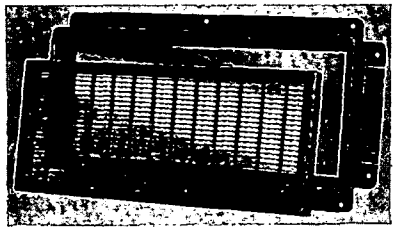
The grille is made of hard rolled spring tempered steel fins (.020) twenty thousandths of an inch thick having a depth of ½ in. and spaced ¼ in. apart. They are supported by vertical bars 1/16 in. by ¼ in. wide and assembled with the narrow edge of the bar to the front of the grille in order that they may offer the least amount of air resistance. The narrow spacing of the fins, in addition to their depth, prevents vision into the stack head or concealed heat chamber. This construction also prevents the entrance of foreign objects into the ducts or concealed chambers, which advantage is immediately recognized in school and office building installations.

Direction of Air Flow

The flow of air from UNI-FLO Grilles and Registers is delivered in a blanket like form, as opposed to a pencil beam sharpness. This result is accomplished by the small diffusers which have been formed at the edge of the horizontal fins. This UNI-FLO feature provides a comfortable zone of air flow, especially, when grille installations are made in a room at the breathing line.

Strength of UNI-FLO Grilles

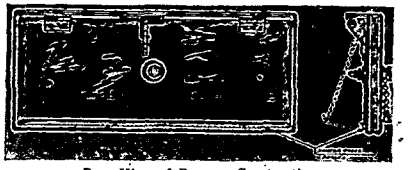
Laboratory tests were conducted to determine the strength of the grille face. A 12 in. x 12 in. grille was supported at the outer edges and a 5 in. plate placed upon the center of the grille face. A pressure was then applied up to 1000 lbs., resulting in no noticeable distortion of the grille face.



UNI-FLO Grille with "SNAP-IN" Roughing-in Frame

UNI-FLO Damper Control

Dampers used on UNI-FLO Registers are spring actuated. The spring holds the damper in an open position, and, is closed,



Rear View of Damper Construction

or, adjusted, by means of a flexible control cord. It is held in the adjusted position, or, closed, by inserting the control cord into the swivel lock busing.

UNI-FLO "Snap-Lock" Roughing-in Frames

Roughing-in Frames were designed for the purpose of insuring and maintaining the Architect's and Engineer's desired grille opening after the lathing and plastering is completed; thereby, preventing the necessity of ordering special size grilles and registers, or, the delay occasioned until the plastering is completed to determine the size of grille required to fill the opening.

The Roughing-in Frame flange has flexible fastening lugs which conform to the shape of the masonry or studding when applied, so as to not cause distortion of the grille opening. Lath fastening holes are also provided.

UNI-FLO "Snap-Lock" Roughing-in Frames were designed for use with UNI-FLO one-piece grilles or registers, which snap lock into the roughing-in frame. No screws are necessary to hold the grille or register in place in the frame. There are no loose parts, or, springs to become damaged, lost or in-operative through clogging with plaster, furnace cement, etc., as the locking device is the grille frame which has been so designed as to create a spring tension which snap locks into the engaging lugs in the Roughing-in Frame and can be easily removed when desired.

UNI-FLO Grilles of this type are designed for plastering in flush with the wall.

Armstrong Machine Works

851 Maple Street **Three Rivers, Mich.**

District Sales Offices in 42 Cities

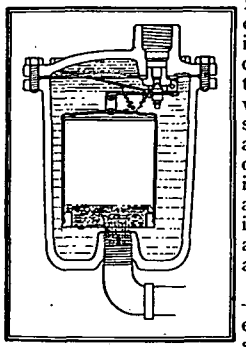
Exclusive Manufacturers of Armstrong Inverted-Bucket Steam Traps

ARMSTRONG TRAPS FOR UNIT HEATER SERVICE

One of the biggest reasons for unsatisfactory unit heater performance is removed when Armstrong Inverted-Bucket traps are used to keep condensate and air out of the steam.

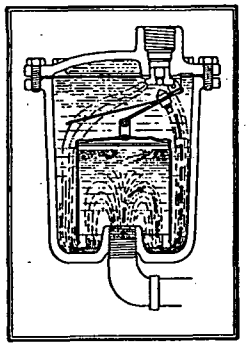
Quick Relief of Condensate—Maximum heat delivery depends on the effective use of all the steam space—all the time. The ideal trap therefore must not only be certain to discharge condensate but it must operate as soon as any condensate forms. With the Armstrong design, the water drains immediately to the trap and discharges as soon as the amount in the trap is enough to drop the bucket. The discharge valve remains open until all the water in the line leading to the trap has drained out. This trap handles condensate at steam temperatures so it is not necessary to wait for the water to cool.

Vents Air Automatically—The effective use of all the steam space also depends on the constant elimination of air. As shown in the accompanying sketch, air or other incondensible gas passes up through the vent hole in the top of the bucket and passes out ahead of the condensate at the next discharge. Air-binding is impossible.

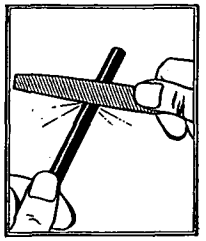


Even if no condensate is reaching the trap, air collecting at the top will force water higher inside the bucket and therefore cause it to lose its buoyancy and drop, opening the valve and releasing the air.

No Clogging—Dirt or sludge entering an Armstrong trap has no chance to collect and obstruct the operation. All condensate enters at the bottom under the bucket and when the trap discharges, this water passes around the lower edge of the bucket at high velocity, scouring out any sediment. Oil or grease cannot clog this trap because it rises to the top and passes out ahead of the water. For these reasons it is seldom necessary to clean an Armstrong trap.



Hardened Valve Parts Prevent Leaking—The advantage of a steam trap over a cracked valve in draining condensate without losing steam is largely lost if the trap valve leaks because of scoring or wire-drawing. The intermittent action of the Armstrong trap and the water seal over the valve minimize wiredrawing. But in addition as a positive safeguard, all Armstrong valve parts are of chrome steel heat treated to file hardness which makes them extremely resistant to wear.



ARMSTRONG TRAPS FOR GENERAL SERVICE

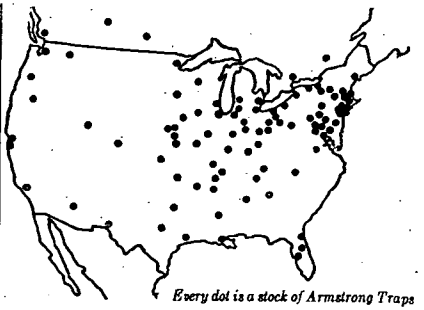
Much the same reasons that have led to the adoption of Armstrong traps for unit heater service apply to the selection of traps for draining steam headers, steam purifiers, steam heated drying and processing equipment such as used in laundries, hotel and restaurant kitchens, canneries, etc.

The principal troubles with steam traps as indicated by replies to a recent questionnaire by a heating and ventilating magazine are leaky valves, air-binding, and plugging up with dirt or oil. The features of Armstrong traps described above either eliminate or minimize all these troubles. It is natural therefore that there should be more of them in service than of any other mechanically operated trap and that engi-

neers quite generally should recognize the dependability of Armstrong traps over long periods of time.

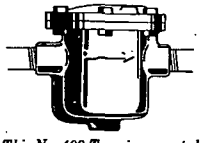
Easy Installation—Except in unusual cases, it is practical to install any standard Armstrong Trap with no support other than the pipe line in which the trap is used.

Service Organization—Armstrong Traps are sold and serviced by 43 district representatives in the United States and Canada. Stocks of Armstrong Traps are carried in nearly one hundred leading cities and representatives are responsible for the satisfactory operation of all Armstrong Traps installed in their respective territories.



Every dot is a stock of Armstrong Traps

DETERMINING THE SIZE OF ARMSTRONG TRAP REQUIRED



This No. 100 Trap is connected like any valve

For unit heaters (when maximum condensate is known)—In most cases, the information regarding the amount of steam condensed by a unit heater is furnished by the manufacturer and it is a simple matter to select the trap by referring to the capacity table. Since the capacity table shows continuous discharge figures at the full pressure differential indicated, it follows that allowances must be made for intermittent trap operation as well as for drop in pressure through the heater and through the trap. If adequate sized steam lines are used, the drop in pressure through the unit heater should not exceed 25 per cent of the initial pressure but at times the pressure in the heater itself and at the trap will be practically equal to the initial pressure. For this reason, any trap selected must have a discharge orifice for operation at the maximum pressure but sufficient capacity at the minimum differential pressure so that it will not be discharging more than one-half of the time. In other words, the continuous discharge capacity of the trap at 75 per cent of the maximum pressure should be at least twice the maximum amount of condensate that is expected from the heater. Another way of stating the same rule is that at the full pressure differential the trap should be able to handle at least two and a quarter times the maximum amount of condensate that will be expected from the heater under normal operating conditions.

When amount of condensate is not known—The amount of condensate from heating coils or other forms of direct radiation can be quickly determined by referring to table A showing the weight of steam condensed per hour per lineal foot of bare pipe or per square foot of heating surface. When the radiation is in greenhouses or dry kilns, multiply the above figures by two and when used for drying wet material such as brick and pottery, multiply by three. If blowers circulate air over the radiation, the figures should be multiplied by five. This will give the amount of condensate that will be obtained after the radiation has been brought up to temperature, so before selecting a trap as outlined in the preceding section, allowances should be made for the extra amount of steam condensed in bringing the radiation up to temperature.

General Service Cast-Iron Traps

PRESSURES TO 300 LBS.

Trap Size		No. 100	No. 30	No. 31	No. 2	No. 25	No. 3	No. 4
Pipe connections		½"	½"	½"	½" or ¾"	1"	1" or 1¼"	1½" or 2"
List prices		$7.00	$9.25	$15.00	$20.75	$29.00	$38.00	$55.00
Telegraph Code		Alder	Oak	Red	Ash	Hickory	Fir	Elm
Height of trap		3⅞"	4¾"	6¼"	10"	12½"	14"	16¾"
Diameter		3¼"	5⅝"	5⅞"	6¼"	7½"	8½"	10"
Weight		3½ lbs.	5½ lbs.	7½ lbs.	18 lbs.	33 lbs.	45 lbs.	74 lbs.
Maximum pressure		125 lbs.	125 lbs.	150 lbs.	300 lbs.	300 lbs.	300 lbs.	300 lbs.
Capacity in pounds of water per hour at these pressures	5	450	799	1043	1692	4172	6770	21097
	10	550	1121	1465	2289	5862	9159	29638
	15	600	979	1763	2753	7054	11013	28216
	20	660	817	1541	3268	8056	13072	24654
	25	370	698	1226	2810	6796	11240	19739
	30	385	768	1348	3074	7428	12297	21572
	40	420	691	1120	2763	6130	11052	24550
	50	450	424	1238	2336	4954	9344	19074
	60	475	459	1337	2534	4181	7352	20672
	70	500	343	1116	1956	3541	7825	17850
	80	520	362	937	2065	3748	6082	18953
	90	450	245	564	1586	2989	6345	15687
	100	460	257	571	1605	3153	5257	16455
	125	500	282	625	1817	2507	4514	14200
	150	...	...	471	1210	1959	4840	10755
	160	...	...	...	1245	2020	3811	11062
	240	...	...	...	811	1865	3285	7474
	300	...	...	...	614	1593	2579	6371

The capacity figures given above are continuous discharge figures at the differential indicated. The actual pressure at the trap inlet and back pressure in the return line should be used to obtain the pressure differential.

TABLE A

Condensate per Hour per Running Foot of Pipe

Gauge Pressure Pounds	Temperature Diff. Degrees F.	Pipe Sizes in Inches										Flat Surface or Larger Pipe Per Sq. Foot
		1	1½	2	3	4	5	6	8	10	12	
5	153	0.16	0.21	0.25	0.3	0.45	0.54	0.64	0.82	1.01	1.19	0.34
50	223	0.28	0.38	0.45	0.63	0.79	0.97	1.14	1.47	1.80	2.13	0.62
100	263	0.36	0.41	0.59	0.84	1.05	1.28	1.51	1.94	2.39	2.82	0.82
150	291	0.43	0.59	0.71	1.00	1.26	1.54	1.82	2.35	2.89	3.40	0.99
200	313	0.50	0.68	0.81	1.16	1.45	1.74	2.09	2.69	3.30	3.91	1.14

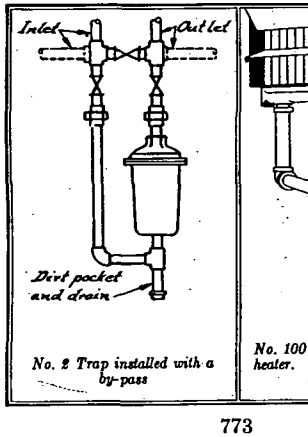
Installation of Armstrong Traps

Whenever possible, Armstrong Traps should be installed below the radiation drained by the trap. This is of particular importance when traps are used on unit heaters. Small traps such as the Nos. 100, 30 and 31 are usually installed without a by-pass whereas the larger sizes generally are furnished with by-passes to facilitate the removal or examination of the traps. The by-pass should always be installed above the trap to prevent loss of prime in case the by-pass valve should develop a leak.

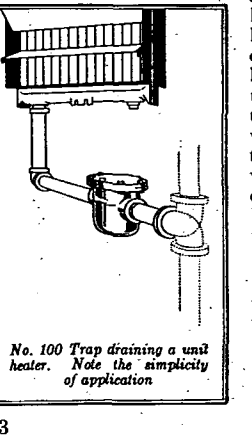
Individual Traps—Best results will be obtained by using a trap on each steam heated unit. Even a slight difference in terminal pressure between two units will cause one to fill up with air or water unless individual traps are used.

Quick Vent Air Valves—Since Armstrong Traps automatically vent air, no quick relief air valves are absolutely necessary except in the case of large heaters when immediate temperature rise is imperative. The air handling capacity of the Nos. 30 and 31 Armstrong Traps is further increased by means of a thermic spring designed to hold the valve away from the seat as long as the trap is cold. When steam reaches the trap, the thermic spring straightens out and allows the valve to seat in the normal manner. Thermic springs can be furnished in all other sizes at slight extra cost.

Whenever manufacturers recommend that their heaters be installed with a quick vent air valve, these recommendations should be followed to the letter. However, once the heater has been brought up to temperature no more air will pass through the quick vent valve as air that comes to the heater along with the steam will pass out through the Armstrong Trap at temperatures too high to cause the air relief valve to function.



No. 2 Trap installed with a by-pass



No. 100 Trap draining a unit heater. Note the simplicity of application

AMERICAN RADIATOR COMPANY

40 West 40th Street, New York, N. Y.

Division of AMERICAN RADIATOR & STANDARD SANITARY CORPORATION

AMERICAN RADIATOR PRODUCTS

● ACCESSORIES

Radiator Valves

A Complete Line of Packed and Packless Radiator Valves



Packless—Leak-proof, require no packing, will not stick. They open with one smooth turn. Furnished in either round or lever handle—made in angle, corner, gate and globe patterns for steam, water, vapor or vacuum. No. 999 series for steam; No. 901 series for water.

Packed—Detroit Radiator Valves are made with metal well distributed—strong and heavy where strength is needed. No. 72 Angle, No. 32 R. H. Corner, No. 37 L. H. Corner, No. 57 Globe, No. 373 Union Gate. No. 101 H. W. with swinging plate design which assures easy turning.

AIR VALVES



Airid—The Airid No. 500 all metal—non-adjustable. One of the most dependable and popular external air valves on the market. No. 510 Vac Airid for vacuum jobs.

In-Airid—The invisible air valve which fits inside the radiator. No. 1 for steam; No. 2 for vacuum.



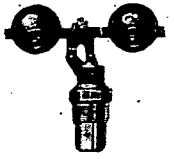
VENT VALVES



A complete line of popularly priced valves for venting mains and risers. No. 815 Ideal Quick Vent (¾") No. 820 Ideal Quick Vent (⅜") No. 821 Ideal Float Quick Vent (¾") No. 822 Ideal Vac Vent (¾" for Vacuum). Also No. 816 Ideal Air Line Valves and No. 817 Vento Vent for Blast Coils.

● ACCESSORIES

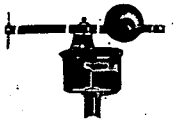
Damper Regulators



ARCO WATER REGULATORS

No. 800 is for damper control on hot water heating boilers, adjustable for temperature between 100 and 220 degrees Fahrenheit. The Arco Water Regulator is made entirely of metal. Within the bulb is an expansion metallic bellows, surrounding which is volatile liquid. As the water temperature in the system increases, the liquid vaporizes and compresses the bellows, forcing the thrust rod upward which closes the drafts. As the water cools the gas pressure is relieved and the counterweight opens the drafts. There are no perishable parts. No. 801 Water Regulator is for hot water supply heaters and small boilers.

ARCO STEAM REGULATORS



Arco Steam Regulator No. 905 is for damper control on steam boilers —pressure up to 15 lbs. Finely finished in black baked-on enamel. Connection to boiler, 1 inch male thread. The design is such that the steam pressure is applied *outside* of the bellows. This insures the bellows expanding and contracting evenly in all folds and makes for long life and sensitive accuracy. No. 305 for small steam boilers.

A Complete Line of Arco Accessories for Every Heating Requirement

AMERICAN RADIATOR COMPANY

40 West 40th Street, New York, N. Y.

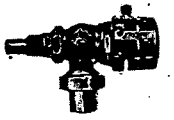
Division of AMERICAN RADIATOR & STANDARD SANITARY CORPORATION

AMERICAN RADIATOR PRODUCTS

● ACCESSORIES

Arco Radiatherm

Automatic Radiator Control for Two-Pipe Steam and Vapor Systems

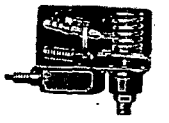


The Arco Radiatherm makes it possible to automatically maintain the heat in individual rooms at any temperature between 35° and 80°, according to individual comfort demands. It is a simple combination of thermostat and valve for independently controlling the steam supply to each radiator on two-pipe steam, vapor or vacuum systems. And just as long as an adequate heating system is in operation, the Arco Radiatherm automatically keeps the temperature at whatever degree it is set.

Arco Radiatherms are the symbols of this automatic age—they reflect the modern trend of refinement. They eliminate hand regulation and the necessity of opening windows—saving fuel otherwise wasted in overheating. They can be installed as easily and quickly as an ordinary radiator valve in old or new buildings.

Arco Radiatherms can be installed in a single room or an entire building, each unit operating entirely independent of the others. This assures personal comfort for the occupants because they can have exactly the warmth they want. It is a protection to health, too, because it prevents over-heated or chilly rooms. And no matter what the weather may be, the Arco Radiatherm acts quickly, automatically and dependably to maintain the temperature at the degree desired. It operates on the patented "hot chamber" principle which permits compact and pleasing design. Made in four types for enclosed or exposed radiators—close coupled and remote control.

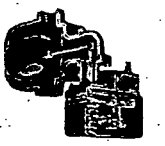
● MERCOID CONTROLS



For Temperature Pressure or Vacuum

All Mercoid Controls employ the Mercoid Switch which carries the full line current at 110 or 120 volts without an exposed arc or corroding of contacts. Mercoid instruments give automatic control of temperature, pressure or vacuum. Electrically operated units such as motors and heating elements are controlled direct by a Mercoid. Units using steam, air, gas or water are controlled by a Mercoid operating a motor valve in the line.

Combination Pressure Control and Low Water Cut-Out



Mercoid No. 612 is an inexpensive, rugged, dependable Low Water Cut-Out and Pressure Control combined in one unit. It positively safeguards against firing a dry boiler.

THERMOSTAT



The No. 855 Mercoid Thermostat is especially adapted for use with Unit Heaters—starting or stopping the fan as the air temperature changes. This control has a range from 45 to 72 degrees—wide enough to meet the requirements of buildings in which both low and normal temperatures are desired.

A Complete Line of Arco Accessories for Every Heating Requirement

Barnes & Jones

INCORPORATED

The Sign of Quality

128 Brookside Avenue, Jamaica Plain, Boston, Mass.

New York Office: 101 Park Avenue

Barnes & Jones Improved Modulation Vapor and Vacuum Systems of Steam Heating; Modulating Radiator Valves; Metering Orifice Supply Valves; Thermostatic Radiator Traps; Thermostatic Traps for medium and high pressures; Condensators (Boiler Return Traps); Blast Traps; Drip Traps; Vent Traps; Strainers; Damper Regulators; Gages.

Barnes & Jones Service

BARNES & JONES offer an advisory and consulting service, believing the manufacturer of a heating system often is in the best position to give practical assistance in the solution of heating problems. On request, our staff will consult with and advise engineers, contractors or users as to the most advantageous manner in which BARNES & JONES apparatus can be installed and operated. When desired, our Service Department will furnish installation details and work with engineers, contractors or users to gain the best results in installation or operation.

Modulation Valves

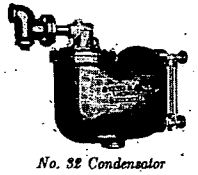
Made in the angle type, in sizes from ½ to 1½ in. Renewable disc seat.



Size Valve	Cap. Sq. Ft.
½"	30
¾"	60
1"	100
1¼"	180
1½"	250

Condensators

For returning water of condensation to boiler from open return line systems independently of boiler pressure, without change in operating conditions, air binding, or admitting steam to return side. Simple in construction, but positive in operation. Its few moving parts are wholly enclosed. Connections are large to eliminate friction and insure an easy and sensitive working apparatus under all conditions. All working parts are of best bronze metal.



No. 32 Condensator

No.	Capacity in Sq. Ft.
31	700
32	1,600
33	3,500
34	6,000
35	10,000
36	16,000
37	32,000

Vent Traps

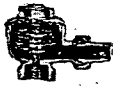
Equipped with float valve to prevent discharge of water, and ball check valve to allow free discharge of air, but prevent return into system, enabling B. & J. Vapor Systems to operate under vacuum conditions, saving fuel.



Vent Trap

Thermostatic Radiator Traps

Made in ½, ¾, 1 and 1¼ in. sizes.



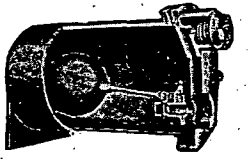
Size Valve	Lbs. Water per Hour	Sq. Ft. Coils	Sq. Ft. C.I. Rad.
½"	30	100	125
¾"	80	240	320
1"	200	600	800
1¼"	400	1200	1600

Blast Drip Traps, Type BD



For use on drips from supply mains and risers and on returns from water heaters and indirect stacks. Float-controlled valve governs discharge of water; thermostatically-controlled valve allows passage of all air but prevents passage of steam. Made with 1¼" tappings.

Blast Traps



Combination float and thermostatic traps with an air and water capacity large enough to take care of the condensation from the largest vento-stacks, dry kiln coils, hot water heaters and other units condensing large quantities of steam at low pressures. Made in sizes from 1 to 2½ in. Capacities to 5,000 lbs. of water per hour.

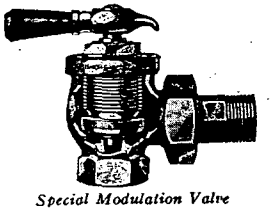
The Bishop & Babcock Sales Co., Cleveland, Ohio

4901-4915 Hamilton Avenue, N.E.

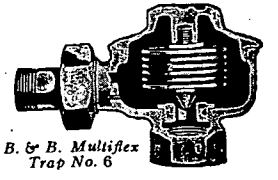
Branch Offices and District Representatives

CALIFORNIA, LOS ANGELES	MASSACHUSETTS, BOSTON	NEW YORK, BUFFALO	PENNSYLVANIA, PHILADELPHIA
CALIFORNIA, SAN FRANCISCO	MICHIGAN, DETROIT	NEW YORK, NEW YORK CITY	PENNSYLVANIA, PITTSBURGH
CONNECTICUT, BRIDGEPORT	MINNESOTA, DULUTH	NEW YORK, SYRACUSE	TEXAS, DALLAS
FLORIDA, ORLANDO	MINNESOTA, ST. PAUL	NORTH CAROLINA, WINSTON-SALEM	TEXAS, SAN ANTONIO
GEORGIA, ATLANTA	MISSOURI, KANSAS CITY	OHIO, CANTON	UTAH, SALT LAKE CITY
ILLINOIS, CHICAGO	MISSOURI, ST. LOUIS	OHIO, CINCINNATI	WASHINGTON, SEATTLE
INDIANA, INDIANAPOLIS	MONTANA, BOZEMAN	OHIO, CLEVELAND	WASHINGTON, SPOKANE
KANSAS, WICHITA	NEBRASKA, LINCOLN	OKLAHOMA, OKLAHOMA CITY	WASHINGTON, D. C.
MARYLAND, BALTIMORE			JAPAN, TOKYO

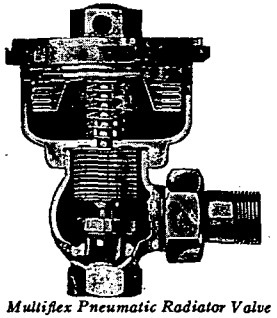
Heating Specialties—Temperature Control—Ventilating Equipment—Unit Heaters



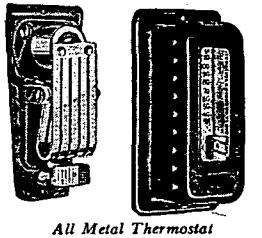
Special Modulation Valve



B. & B. Multiflex Trap No. 6



Multiflex Pneumatic Radiator Valve

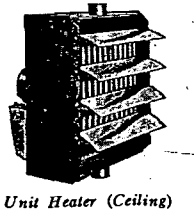


All Metal Thermostat

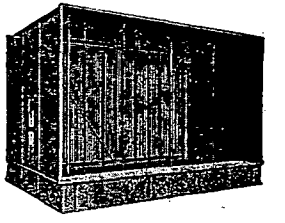
Bishop & Babcock manufactures a complete line of Heating and Ventilating Equipment. Its products comprise all devices and apparatus used in up-to-date vacuum and vapor Heating Systems, Temperature Control and Ventilating Systems. It is entirely practical for an engineer and architect to standardize with **Bishop & Babcock** apparatus, thus insuring a uniformity in design and operation not to be found in equipment of varied manufacture.

Bishop & Babcock has been manufacturing heating, ventilating and temperature control apparatus for many years; its installations including many of the most prominent buildings in all parts of the country.

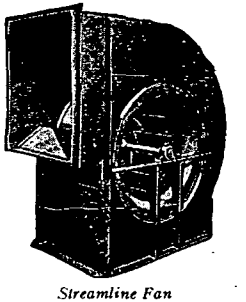
Catalogs will be mailed upon request.



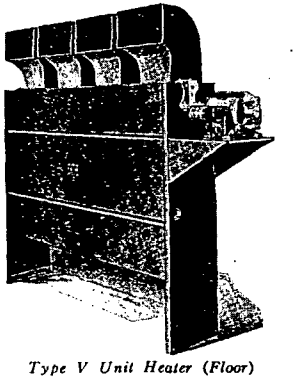
Unit Heater (Ceiling)



Type B Massachusetts Air Washer



Streamline Fan



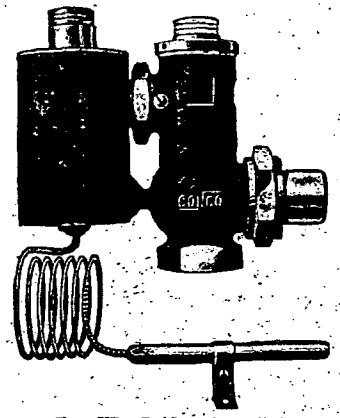
Type V Unit Heater (Floor)

Bohn Aluminum & Brass Corporation

Capitol Brass Division

2306 Franklin Street **Detroit, Mich.**

CONCO



TYPE XB—*For Concealed Radiation*

Temperature Control Valves

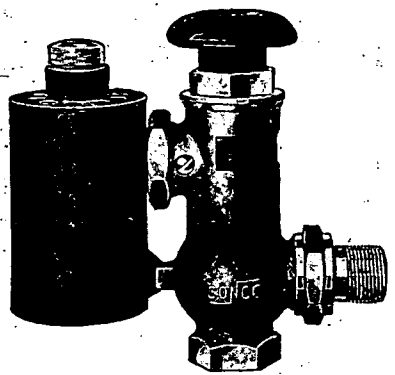
Installed like an ordinary radiator valve. Can be used to replace practically any type of radiator valve without changing pipe work. **CONCO** valves have established an enviable record for accurate, uniform and dependable control of room temperatures.

The **CONCO** Temperature Control Valve is a Graduated Packless Supply Valve, having a temperature control unit, that automatically controls room temperatures within a maximum range of 2 degrees. For use on two-pipe Heating Systems.

The **CONCO** Temperature Control Valve is actuated or caused to open or close only by the actual temperature of the air in the location where the Valve is installed. The Thermostatic Element is completely insulated from radiant and conducted heat.

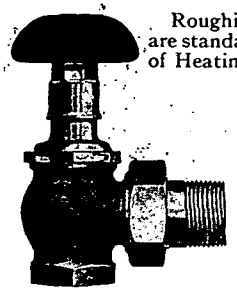
The "XB" Type Valve is identical in construction and operation to the regular Type "I" CONCO Valve, with the exception that the Thermostatic Element is extended through approximately 4½ feet of Capillary Tubing to a Bulb which should be located in the air current under the radiator at the floor line. The Housing for the Thermostatic Element is constructed of Brass in lieu of the Bakelite housing used on the Type "I" Valve. For this method of controlling.

The simplicity in construction and operation makes the CONCO Valve a most practical and economical method for the control of room temperatures. Each CONCO Valve is a self-contained, complete and dependable temperature control system.



TYPE I
For Exposed Radiation

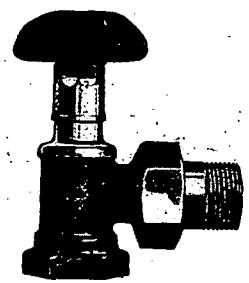
Roughing-in-measurements on all valves are standard and conform to American Society of Heating and Ventilating Engineers' Code.



No. 23 Sta-Pak Valve for Steam and Vapor (Packless Type)

Capitol Radiator Valves

Capitol Sta-Pak Valves (Packless Type), Nos. 23, 24 and 29, are so constructed that they will never need repacking and they will not leak around the stem. The steam valves have an extremely high lift and one complete turn of the handle opens or closes the valve. The No. 24 Sta-Pak Valve is a real hot water valve with the packless feature.



No. 24 Sta-Pak Hot Water Valve (Packless Type)

Cochrane Corporation

3120 North 17th Street, **Philadelphia, Pa.**

Branch Offices

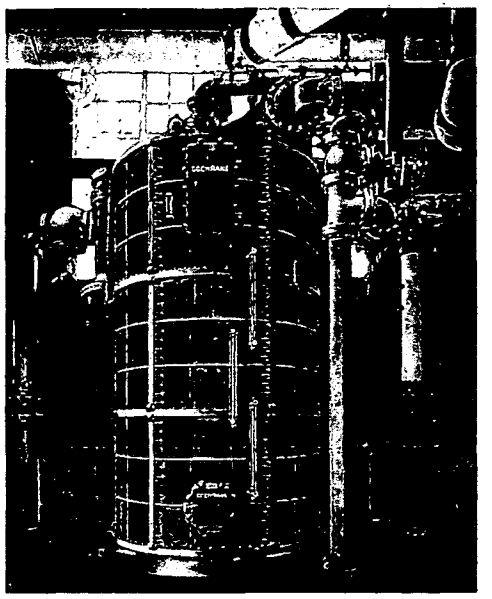
ALBUQUERQUE, N. M.	CLEVELAND, OHIO	INDIANAPOLIS, IND.	PITTSBURGH, PA.	SEATTLE, WASH.
ATLANTA, GA.	DALLAS, TEXAS	KANSAS CITY, MO.	PORTLAND, ORE.	SYRACUSE, N. Y.
BALTIMORE, MD.	DENVER, COLO.	LOS ANGELES, CALIF.	RICHMOND, VA.	TORONTO, ONT.
BIRMINGHAM, ALA.	DETROIT, MICH.	MEMPHIS, TENN.	ROCHESTER, N. Y.	MONTREAL, QUE.
BOSTON, MASS.	EASTON, PA.	MINNEAPOLIS, MINN.	ST. LOUIS, MO.	HALIFAX, N. S.
CHARLOTTE, N. C.	HARRISBURG, PA.	NEW ORLEANS, LA.	SALT LAKE CITY, UTAH	CALGARY, ALBERTA.
CHICAGO, ILL.	HAZLETON, PA.	NEW YORK, N. Y.	SAN FRANCISCO, CALIF.	WINNIPEG, MAN.
CINCINNATI, OHIO	HOUSTON, TEXAS	PHOENIX, ARIZ.	SCRANTON, PA.	HAVANA, CUBA

PRODUCTS—Open Feed Water Heaters; Metering Heaters; Storage Heaters; Closed Heaters; Deaerating Heaters; Deaerating Hot Water Generators; Hot Process Water Softeners; Cold Process Water Softeners; Pressure Filters; Steam and Oil Separators; Steam Purifiers; Back Pressure Valves; Drainers or Traps; Dischargers; Boiler Blow-off Valves; Flow Meters for steam or water in pipes; V-Notch Meters; Continuous Boiler Blow-off Systems, Etc.

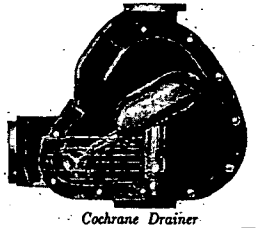
The Cochrane Deaerating Hot Water Generator for Building Service—Banishes pipe corrosion and "red water." It supplies hot water that contains no dissolved oxygen, and which, therefore, cannot cause rust in piping and boilers. Iron or steel piping can be used throughout, instead of more costly metals.

Live or exhaust steam is used, the temperature of the heated water being held constant automatically.

Cochrane Deaerating Heaters—Save fuel by heating the boiler feed water to the exact temperature of the steam supplied to them and protect economizers, boilers and turbines against corrosion by eliminating all trace of dissolved oxygen. They have the usual open heater accessories, including automatic make-up regulator, oil separator and over-flow trap, and in weight, space requirements and cost are comparable to ordinary open heaters.



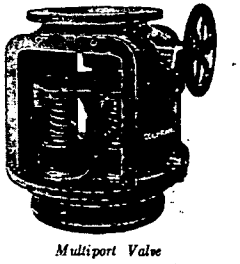
Deaerating Hot Water Generator installed to prevent piping corrosion by zeolite softened water



Cochrane Drainer

Multiport Back Pressure Valves

Differ from the ordinary back pressure valves in that a number of small disks are used instead of one large disk, reducing the size, weight and travel of the disks and insuring silence and absolute safety.



Multiport Valve

Traps, Drainers and Dischargers

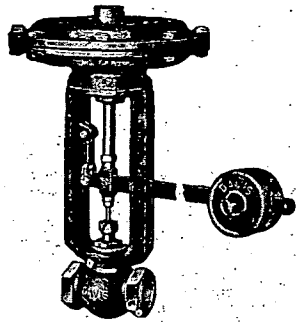
Remove condensate or drips from low or high pressure heating or drying coils, radiators, jackets, steam and oil separators, steam purifiers, etc.

Davis Regulator Company

2549 South Washtenaw Avenue :-: Chicago, Ill.

New York Office, 71 Fulton Street

Manufacturers of Automatic Valve Specialties for Pressure and Flow Control

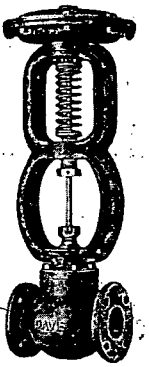


No. 185 Vacuum Pump Governor

No. 185 Vacuum Pump Governor—A counterweighted diaphragm type of balanced governor. The diaphragm head screws into the yoke and may be had in sizes 8 in., 10 in., 13 in., 16 in., and 20 in. for any amount of vacuum specified. Made in sizes ½ in. to 4 in.

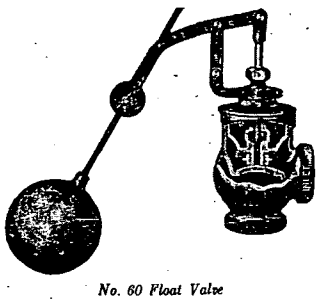
No. 14 Pressure Regulator—A spring loaded diaphragm type of Regulator having double seated balanced disc. The size of the diaphragm is properly proportioned for the pressure specified.

Applicable for reduced pressures of 1 to 150 lbs. Made in sizes 2 in. to 6 in.



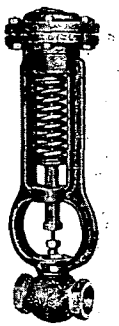
No. 14 Pressure Regulator

No. 60 Float Valve—A pilot operated, single seated, tight closing Valve for use on make-up line to open tank. Has renewable composition or metal disc suitable for hot or cold water or other fluids. Sizes 3 in. and smaller, all bronze; 4 in. and larger, iron body bronze trim. Globe and angle patterns.



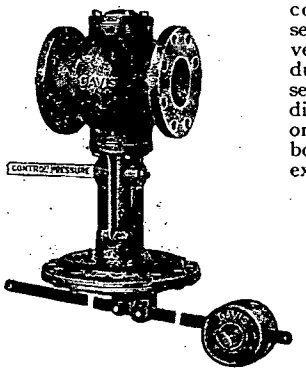
No. 60 Float Valve

No. 180 Constant Pressure Pump Governor—The same basic design as the No. 14 Regulator, but smaller. Sizes 1½ in. and less. Both the No. 180 and No. 14 may be used either as constant pressure pump governors or pressure reducing valves. Excess pressure pump governors are of the same design with provision for pressure connection on both sides of the diaphragm.



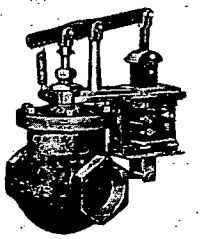
No. 180 Constant Pressure Pump Governor

No. 15 Pressure Regulator—A counterweighted diaphragm, double seated, balanced type of valve, universally used on heating systems for reducing high pressure steam down to a low service pressure. Has interchangeable diaphragm heads, with deep water seal on diaphragm and no packing box. Sizes ½ in. to 14 in., also expanded outlet sizes.



No. 15 Pressure Regulator

No. 93 Solenoid Valve—A single seated, tight closing, electrically operated flow control valve. Suitable for 250 lbs. pressure or less of steam, water, air, gas or other fluids. May be had either normally open or closed with A. C. or D. C. continuous duty solenoid for any voltage up to 550.



No. 93 Solenoid Valve

Julian d'Este Company

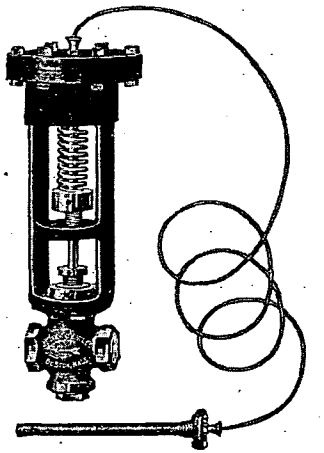
ESTABLISHED 1870

6 Spice Street, Charlestown Dist.

Boston, Mass.

TRADE-MARK

Manufacturers of Curtis Engineering Specialties, Pressure Regulators, Steam Traps, Thermostats and Tank Valves

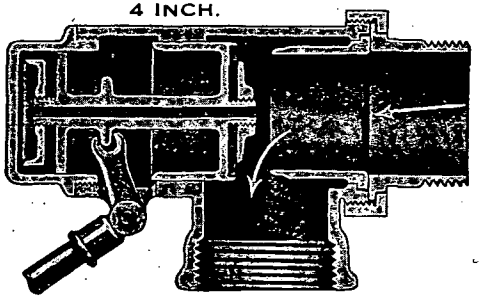


d'Este Temperature Regulator

Self contained bellows and bulb type. Does not require air or water for operating medium. Ruggedly designed with minimum cost of installation and upkeep.

Sizes: ½ in. to 6 in., inclusive.

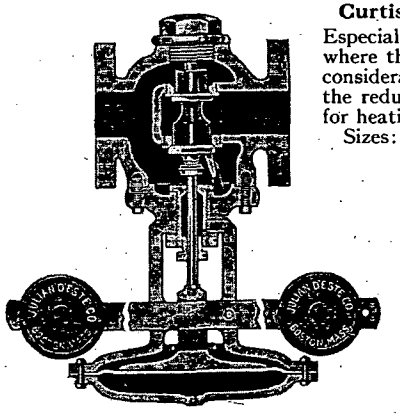
4 INCH.



U. S. Tank Valve

All cast bronze. Will automatically maintain a constant water level in tank. Single seated, shuts against pressure, and is positive in action. Valve is fully balanced, hence operates equally well on high or low pressure. Noiseless in operation and absolutely tight under pressure. For cold water service.

Eight sizes: ¾ in. to 4 in., inclusive.



Curtis Type K Regulator

Curtis Type K Regulator

Especially adapted to conditions where the initial pressure varies considerably or may drop below the reduced pressure. Excellent for heating work.

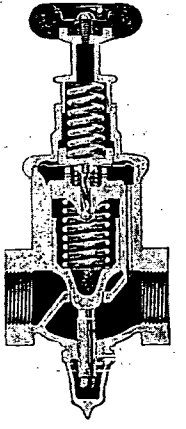
Sizes: ½ in. to 8 in., inclusive.

Curtis Steam Regulator

Simple, compact, self-contained. Pilot actuated. A standard Reducing Valve of long standing.

Sizes: ½ in. to 1¼ in.—all bronze screwed ends.

Sizes: 1½ in. to 4 in.—iron body with bronze mountings.



Curtis Steam Regulator Type D

C. A. Dunham Company

General Offices: Dunham Bldg., 450 East Ohio St., **CHICAGO, ILL.**

Factories: Marshalltown, Iowa, Michigan City, Indiana, U. S. A., and Toronto, Ont., Canada

Eastern Division Offices
101 Park Avenue, New York

Foreign Division Offices
101 Park Avenue, New York
(Japan) Uchida Trading Co., Tokyo and New York
(China)—except Darien—Pacific Trading Co., Shanghai

Western Division Offices
232 Monadnock Building,
San Francisco, Calif.

SALES OFFICES

EASTERN DIVISION

Albany, N. Y., 304 Home Savings Bank Bldg.
Allentown, Pa., 1846 Hamilton St.
Baltimore, Md., 218 Water St.
Bangor, Maine, 104 Exchange St.
Boston, Mass., 10 High St.
Buffalo, N. Y., 232 Delaware Ave.
Caldwell, Ohio, 827 West St.
Clarksburg, W. Va., 300 Stealey Ave.

Atlanta, Ga., 809 Forsyth Bldg.
Birmingham, Ala., 447 Martin Bldg.
Charlotte, N. C., 1815 Queens Road
Chattanooga, Tenn., 1201-03 Volunteer Bldg.

Glen Cove, L. I., N. Y., Glen St. and Hendricks Ave.
Harrisburg, Pa., 2216 N. Fifth St.
Huntington, W. Va., 714-716 Union Bank Bldg.
Kingston, Pa., 302 Kingston Corners Bldg.
Mt. Vernon, N. Y., 245 N. Terrace Ave.
Newark, N. J., 972 Broad St.

SOUTHEASTERN DIVISION

Greenville, S. C., 317 Walker Bldg. (P. O. Box 563)
Little Rock, Ark., 201 E. Markham St.

New Haven, Conn., 42 Church St.
New York, N. Y., 101 Park Ave.
Philadelphia, Pa., 1500 Walnut St.
Pittsburgh, Pa., 3002 Grant Bldg.
Poughkeepsie, N. Y., 50 Market St.
Providence, R. I., 49 Westminster St.
Rochester, N. Y., 972 Mercantile Bldg.
Syracuse, N. Y., 306 O. C. S. B. Bldg.
Trenton, N. J., 219 E. Hanover St.
Washington, D. C., 327 Munsey Bldg.

Memphis, Tenn., 244 Madison Ave.
New Orleans, La., 1666 Abundance St.
Tampa, Fla., 8304 Semmes Ave., Sulphur Springs

CENTRAL DIVISION

Special Sales Office, 450 East Ohio Street, Chicago, C. E. Roscoe

Akron, Ohio, 225 W. Exchange St.
Chicago, Ill., 450 E. Ohio St.
Cincinnati, Ohio, 1231 Union Trust Bldg.
Cleveland, Ohio, 430 Terminal Tower Bldg.
Colorado Springs, Colo., 115 E. Washington St.
Columbus, Ohio, 85 E. Gay St.
Dallas, Texas, 408 Dallas Bank & Trust Bldg.
Davenport, Iowa, 305 Security Bldg.
Denver, Colo., 414 W. Colfax Ave.

El Paso, Texas, 401 N. Santa Fe St. (P. O. Box 512)
Kalispell, Mont., Whipps Block
Los Angeles, Calif., 617 W. Seventh St.

Des Moines, Iowa, 710 Old Colony Bldg.
Detroit, Mich., 2988 E. Grand Blvd.
Duluth, Minn., 316 Glencoe Bldg.
Grand Rapids, Mich., 425 Murray Bldg.
Houston, Texas, 312 Caroline St.
Indianapolis, Ind., 325-326 Board of Trade Bldg.
Joliet, Ill., 309 Sterling Ave. (P. O. Box 1086)
Kansas City, Mo., 615 City Bank Bldg.

Louisville, Ky., 1342 Starks Bldg.
Milwaukee, Wis., 1148 Empire Bldg.
Minneapolis, Minn., 132 South 10th St.
Oklahoma City, Okla., 710 N. Hudson St.
Omaha, Neb., 724-725 Union State Bank Bldg.
St. Louis, Mo., 3605 Laclede Ave.
San Antonio, Texas, 3005 Smith-Young Tower
Toledo, Ohio, 1914 Vermont Ave.
Wichita, Kans., 1100 E. Douglas Ave.

WESTERN DIVISION

Portland, Ore., 1000 Guardian Bldg.
Salt Lake City, Utah, 204 Dooly Bldg.
San Francisco, Calif., 232 Monadnock Bldg.

Seattle, Wash., Exchange Bldg.
Spokane, Wash., Sun Life Assurance Bldg.

C. A. Dunham Co., Ltd.,
1523-41 Davenport Road,
Toronto, 4, Ont., Canada.
Sales Offices: Calgary, Alberta; Halifax, N. S.; Montreal, Que.; Ottawa, Ont.; Toronto, Ont.; Winnipeg, Man.; Vancouver, B. C.; Quebec, Que.; St. Johns, Newfoundland.

C. A. Dunham Co., Ltd.,
(of the United Kingdom)
18 St. Thomas St., London, S.E., 1, England.
Agents: Birmingham, Eng.; Cardiff, Wales; Leeds, Eng.; Liverpool, Eng.; Newcastle-on-Tyne, Eng.; Glasgow, Scotland; Belfast, Ireland; Paris, France; Munich, Germany; Copenhagen, Denmark; Gothenburg, Sweden; Wellington, New Zealand; Melbourne, Australia; Sydney, Australia.

The Dunham Differential Vacuum Heating System and individual parts of the apparatus used in that system are fully protected by United States Patents Nos. 1,644,144, 1,706,401, 1,727,965, 1,761,819, 1,771,077, 1,792,213, 1,802,383 and 1,802,384 and Canadian Patents Nos. 282,193, 282,194, 282,195, 292,558, 308,943 and 291,134 (British). Additional patents in the United States, Canada and foreign countries are now pending.

The Dunham Heating Service

Over eighty sales offices in the United States, Canada and the United Kingdom bring Dunham Heating Service as close to you as your telephone. Dunham heating engineers are available for counsel at every one of these offices and the accumulated knowledge of the entire Dunham organization is put at the disposal of the architect or engineer in scientifically and economically laying out any Dunham Heating System.

The Dunham Systems of Heating, types of adapted to different classes or building are as follows:

The Dunham Differential Vacuum Heating System.

The Dunham Vacuum Return Line Heating System.

The Dunham Return Heating System.

The Dunham Home Heating System.

Each of these several designs is a complete two-pipe system, the great efficiency of which is made possible by the use of the Dunham Radiator Trap, which is installed at the return outlet of each radiator or pipe coil, where it stands guard against waste of steam and constantly relieves the radiation of the enemies of heating efficiency—air and water.

THE DUNHAM DIFFERENTIAL VACUUM HEATING SYSTEM

This system is a two-pipe system in which steam is supplied to the radiators at sub-atmospheric pressures and in quantities varying with the need for heat. It is so designed that a relatively constant difference in vacuum is maintained automatically between the radiators and the return piping (the vacuum in the return line being slightly higher), thereby assuring a circulation of steam to and within the radiators whenever there is demand for heat.

It is simple in its component parts, requiring that:

(1) A properly controlled vacuum pump having capacity to create high vacuums economically be provided.

(2) The traps function under vacuums as high as 25 in.

(3) The radiator valves be of the all metal packless type and be equipped with regulating plates having the proper size orifice for the amount of radiation.

(4) The temperature controlling equipment be selected to meet the requirements of the individual installation.

The system is flexible in operation resulting in comfortable and economical warmth for occupants in the milder months of early Fall and Spring as well as the extreme cold months of Winter. This is accomplished by increasing the vacuum (which is synonymous with "cooler steam") during the mild weather and by lowering the vacuum or if necessary operating under slight pressure (which is synonymous with "hotter steam") during the extreme cold weather. During very mild weather the radiators are only partly filled with steam under high vacuum.

The average system of heating is ordinarily designed with sufficient radiation to heat a building to 70 degrees when the outside temperature is at the lowest for the season. However, since the low or minimum temperature is reached or approached only on a few days during the heating season it follows that the system has too much heating capacity during the average weather condition, and since no provision is made to vary sufficiently the temperature of the steam supplied to the radiators, the rooms become uncomfortably overheated.

The Dunham Differential Vacuum Heating System prevents this heat waste which amounts to 25 to 50 per cent of the steam consumption for the heating season.

Heating with Steam of Variable Temperatures—Cool Steam (133°F.) Warm Steam (133° to 212°F.) Hot Steam (above 212°F.)

It is generally agreed that there is a large amount of heat wasted in mild weather because buildings are overheated. The cause is that the heating system is operated on and limited in its operation to pressures above atmospheric, even in mild weather. Steam pressures ranging from a few ounces to 2 or 3 lb. afford but a small operating range of steam temperatures to meet changes in weather conditions. That is, steam at a relatively constant pressure is usually supplied to the radiators regardless of what the outside weather may be. The heat output of the radiators will therefore be entirely too high in mild and moderate weather, when only a fraction of the radiation installed would actually be required to balance the heat loss of the building and maintain the desired and comfort giving room temperature.

Daily weather reports show that the temperature rises and falls quite rapidly over the greater portion of the country. Temperature changes of 40 deg. per day occur each winter in the Chicago area, while daily changes of 20 deg. are but slightly higher than normal. To this variation in heat demand must be added the cooling effect of wind, if a true picture of the great fluctuations in heating requirements is wanted.

This statement of the great variation in weather conditions from day to day is simply to point out that the ideal in heating is to have output of the system just equal to the heat loss from the building if uniform room temperature is to be maintained and heat waste through overheating is to be eliminated, and the accompanying excessive open window heat loss is to be prevented.

The Dunham Differential Vacuum Heating System accomplishes this without any complicated or delicate equipment, or any greater variety of appliances than is used by the ordinary Vacuum Return Line Heating System.

Easily Adaptable to Change-over From Existing Vacuum Return Line Systems—An ordinary, well-designed, Vacuum Return Line System can be changed over to the Dunham Differential System. Radiation does not have to be disturbed and in most instances existing piping may be used with only slight changes.

Steam Furnished at Variable Temperatures is the Secret of Comfortable, Economical Heat—Steam is supplied from the boiler direct or through controlled valves in the steam main, to the radiators at variable temperatures ranging from 133 deg. up to 212 deg. and higher if so required. The 133 deg. temperature corresponds to 25 in. of vacuum (at sea level), and 212 deg. to zero on the gauge. By furnishing steam at this wide range of temperatures, it is possible to vary the heat output of the radiation, thus preventing overheating. For instance, in mild weather, steam is supplied at a low temperature, therefore the radiator will give off only a slight amount of heat (in fact one can hold his hand on the radiator). As the weather gets colder higher temperature steam is furnished until finally in severe weather there may be a pressure on the radiation instead of the high vacuum used in mild weather.

The fundamental differences of operation that distinguish the Differential Vacuum Heating System are the use of high vacuum on supply as well as return side of the system, and the accurate control of steam pressures and vacuum.

The Differential System meets the practical requirements of temperature control effectively and efficiently because it is designed to operate on the wide range of sub-atmospheric steam pressures from 25 inches of vacuum to 0 or 1 or 2 lbs. gauge, supplying steam at a temperature volume and quantity that meets the heat requirements of the moment. This flexibility, sufficient to meet all variations in weather, provides constant room temperature control, eliminates overheating, and thus delivers uniform comfort and remarkable economy.

The temperature of steam depends upon the pressure. By lowering the pressure the temperature is lowered over a wide range. As the temperature decreases the specific volume increases.

For example, at 2 lb. gauge pressure one pound of steam will occupy a space of 23.78 cu. ft. The temperature of the steam will be 218.5°F. By reducing to a pressure of 10 in. vacuum the same pound of steam will now have a temperature of 191.19°F. and will fill 39.16 cu. ft. of space.

Further reducing the pressure to 15 in. vacuum the pound of steam will have a temperature of 178.91°F. and will have a volume of 51.3 cu. ft. The volume of the pound of steam at this pressure (vacuum) is more than double the volume of the pound of steam at 2 lb. gauge pressure.

This relation of steam temperatures and volume may be carried on up the range and at 25 in. vacuum it will have a temperature of 133.22°F. with a volume of 145 cu. ft. or over six times greater than that at 2 lb.

The same pressure conditions are duplicated in the boiler and system of the Differential Vacuum Steam Heating System. The temperature of the steam is governed by the Dunham control equipment and the Dunham Differential Vacuum Pump, which removes the air from the system, thereby reducing the pressure on the water in the boiler, or causing the steam to expand through Reducing Valves when they are used.

The term "Differential" is applicable because a relatively constant difference in pressure between the supply lines, the radiator and the return is maintained, so that the air and water will constantly flow out of the radiators. Due to this "Differential" complete circulation is obtained and the radiators throughout the building are heated uniformly.

Fuel Saving of 25 per cent or More Compared with Ordinary Types of Steam Heating Systems—On buildings changed over to the Dunham Differential Vacuum System the owners' performance records show actual fuel savings of 25 per cent or more compared with previous system. Thus the heat from 75 tons of fuel results in heating comfort for the same space that required 100 tons or more under the old method. This saving is accomplished with greater heat comfort to the occupants of the space heated with a resultant greater rental value to the owner.

GENERAL DESCRIPTION OF PARTS AND OPERATION

The Dunham Differential Vacuum Heating System is a two-pipe system using steam at pressures less or greater than atmospheric pressure as required by the weather. The parts are very similar to those used with the well known vacuum return line heating system of which this is a further development.

On an average size installation, the system will have Dunham Sub-atmospheric Reducing Valves to supply steam to maintain the desired temperature of the

radiation; a properly designed system of steam piping; a Dunham Packless Radiator Valve, with regulating plate in the inlet of each radiator; a Dunham Thermostatic Trap on the outlet of each radiator; a system of return piping; a Dunham Differential Vacuum Pump with Differential Controller. This controller is governed by the pressure difference existing between the radiation and return piping.

Any Good Piping Job Is Sufficient—The piping is assembled so as to remain tight over a long period of years, *just the same as is required for any other good job.* The same quality of workmanship which is used to assemble the hot water supply piping is easily sufficient if proper provision is made for the slightly greater expansion.

Control of Steam Supply—In smaller installations steam is supplied at the same vacuum (absolute pressure) at which it is to be used in the heating system by controlling the rate of heat generation at the boiler. On larger installations and on central station installations steam is furnished at a higher pressure than is required by the system and is reduced by means of Dunham Sub-atmospheric pressure reducing valves to the desired vacuum or absolute pressure. These valves may either be manually or thermostatically controlled.

Wide Range of Flexibility—Heating systems are seldom operated for 24 hours per day except in very severe weather, so the building is usually below the required temperature when the heating plant is started up each morning. The building may be brought up to temperature slowly, or rapidly, as desired, by circulating steam, at say a 10 in. vacuum or even on pressures above atmosphere. When the building is up to the desired temperature on manually controlled systems the engineer can set the pressure reducing valve for the vacuum required to maintain the room temperature; on automatic installation the thermostat will govern. The amount of steam to be supplied under this vacuum will, naturally, depend on the rate of heat loss from the building at the time. The system affords an excellent means of regulating the steam consumption during the heating up period, when steam rate will be excessive unless properly controlled. The Dunham Differential Control has been developed for this purpose.

System May be Manually or Automatically Controlled—There are three distinct methods of heat control:

(a) Manual Control, using Dunham Sub-atmospheric Reducing Valves, adjusting these so as to furnish a uniform and sufficient flow of Sub-atmospheric Steam.

(b) Automatic Control, by the function of Dunham Sub-atmospheric control valves controlled from one or more Room Thermostats.

(c) Automatic operation, as used in the system for heating residences and small buildings.

The room thermostats are electrically connected to the motor of the valve through a control panel, arranged so that the steam in the system may be either automatically controlled or manually controlled when special conditions may demand it.

The Zoning System—In larger buildings or where the use of their several parts is more varied, it has been found that more economical means of satisfactory heating will be obtained by using a multiple system called zoning.

THE "D" SERIES DIFFERENTIAL SYSTEM

The "D" series Dunham Differential Vacuum System is for the heating of office buildings, hotels, apartment houses, schools and groups of buildings with more than 3000 sq. ft. of equivalent direct radiation.

In this system the boiler serves as a heat storage unit from which steam is supplied according to the demand of the Sub-atmospheric Pressure Reducing Valves.

Central Station Heating—The Dunham Differential Vacuum Heating System is especially adapted to Central Station Steam Supply, both from the standpoint of the Central Station Company and the Consumer. It offers great economy of steam consumption, low condensate temperatures, complete circulation even though the pressure carried on the distributing mains from the boiler plant is low. It is the means of reducing the demand rate by regulating the flow of steam into the system.

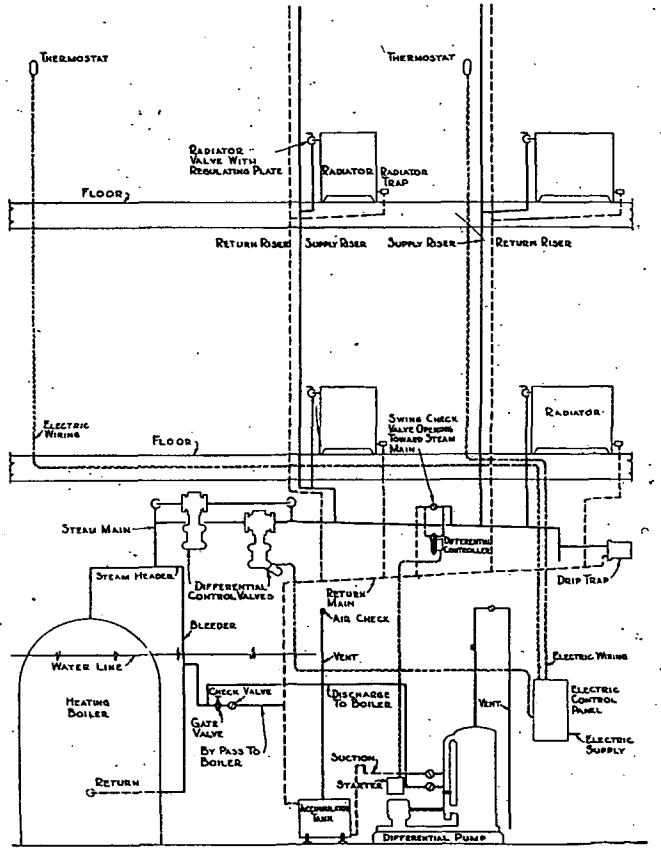
Exhaust Steam—Exhaust steam may be circulated under vacuum, thus saving steam formerly wasted. Greater economy and greater capacity of engines or pumps is also secured. The application of this system reduces the back pressure to a vacuum and greater power output will be obtained at reduced steam consumption.

Process Work—In installations where high steam pressures and temperatures are necessary for process work the building heating system can be operated more economically by applying the differential principle. By reducing the high steam pressure through reducing valves the heat input may be controlled and the over-all economy of the plant improved.

Dunham Differential Vacuum Pump—The Dunham Differential Vacuum Pump operates on the Jet Exhauster principle. The Dunham Exhauster is a special design

and has great air and vapor handling capacity. Under high pressures, water is supplied from the receiving tank to the exhauster by a motor driven enclosed impeller type centrifugal pump of high efficiency. The pump exhausts air and water from return piping under very high vacuums and discharges condensate to the boiler. It is a complete assembled compact unit ready for piping and wiring connections.

Dunham Thermostatic Radiator Traps and Drip Traps—All traps used in connection with the Dunham Differential Vacuum Heating System are known as "D" Series. They function uniformly over a wide range of pressures and temperatures from 25 in. of vacuum to 25 lb. gauge pressure.



Schematic illustration of the "D" Series Dunham Differential System. This drawing does not give actual piping details, but shows the principle of application

Dunham Packless Radiator Valve—Dunham Packless Radiator Valves equipped with Regulating Plate are used on all radiators to secure proper balance. The valve is made packless by means of the bellows construction. The plate orifice is calibrated to the number of feet of radiation in each radiator.

Pipe Sizes—Steam mains and steam risers should be slightly larger than for a Vacuum Return Line System, because of the larger volume of steam to be circulated in mild weather, although a smaller weight of steam is circulated. Ample grade of all pipes must be provided to insure free circulation. Experience proves that a Differential System using vacuum return line pipe sizes will secure a fuel saving up to 25 per cent over vacuum return line operation. Experience also proves that a system using Differential pipe sizes will secure fuel savings from 25 per cent to 40 per cent or more.

Drips—The steam mains are dripped direct to boiler return header and drip mains vented through a "D" Series Trap to the return main on systems operating without reducing valves. The pressure in the boiler, radiators and supply piping will in such cases be the same, permitting condensate to enter boiler by gravity. Should a higher pressure be carried in boiler than in the system (where a Reducing Valve is used for admitting Sub-atmospheric steam into the system) then "D" Series Float and Thermostatic Traps are used on mains and connected to returns leading to Differential Pump. The same applies

Heating Specifications
"D" Series, Dunham Differential Vacuum Heating System

1. GENERAL CONDITIONS.—The general conditions governing this work shall be those established as standard by the American Institute of Architects which shall apply hereto.

2. CONSTRUCTION AND MATERIAL.—The heating apparatus, proposed herewith includes the furnishing, delivery and erection on the premises of all necessary material and labor, which shall be first class in all particulars, and in accordance with the specifications and plans.

3. INSPECTION.—The Heating Contractor must at all times allow the C. A. Dunham Company's Representative to come on the job for the purpose of inspection and must lend any assistance necessary to expedite and complete the work. Any instructions given by the C. A. Dunham Company's Representative and confirmed in writing regarding changes to make system conform to plans or specifications and details shall be considered a part of this specification.

4. BOILER.—The steam boiler shall be a..... with guaranteed rating for.....sq. ft. of radiation installed upon suitable foundation, and equipped with all necessary connections and trimmings, including a safety valve set to blow at 10 lb. pressure, a Dunham Compound Gauge 15 lb. x 30 in. vacuum and a 7-in. Dunham Damper Regulator. (Omit Regulator on gas fired and automatic oil *fired installations*).

5. SMOKE PIPE.—Connect boiler to chimney with suitable black iron smoke pipe gauge..... Size to be as recommended by Boiler Manufacturer. Smoke pipe must be provided with hand stop damper. (Omit stop damper on gas fired installation).

6. PRESSURE AND TEMPERATURE CONTROL.—On all systems not equipped with full automatic control of fire, install Dunham Sub-Atmospheric Control Valves of size shown on plans, with necessary gate valves. Install Dunham 15 lb. x 30 in. compound gauges where directed. If Thermostats and Dunham Control Panels are to be used, Heating Contractor shall furnish, install and wire these, all in accordance with manufacturer's details and instructions.

7. PIPE AND FITTINGS.—Furnish and erect with tight connections all necessary piping of sizes shown on plans and run as indicated, supported and properly graded to insure free and noiseless circulation. Use fittings of cast-iron of standard quality. The ends of all pipes shall be reamed or filed. Proper provision must be made for expansion. Use graphite and oil for making up all pipe joints applied to male thread only. Provide for expansion of mains and risers by loop type expansion joints and swing connections in mains wherever possible. In other cases provide approved all-metal packless expansion joints. Piping to be properly anchored.

8. All steam tappings in boiler shall be connected full size of tapping into a steam header which shall be dripped to the return header through a bleeder. All spring pieces to steam and return mains shall be taken off the top of mains at 45 deg. On down-feed systems, take the spring pieces from the bottom of steam main at 90 deg.

9. The end of each steam main and each drip point shall be drained, through a gate valve, Dunham Strainer, and "D" Series Dunham Trap as indicated on plans.

No lift connections shall be used at drip points.

10. Grade steam mains, return mains and drip mains ½ in. in 10 ft. All steam supply branches such as spring pieces, offsets in steam risers and runouts to radiators shall in each case be installed one size larger than the vertical pipes to which they connect and shall be given as much grade as possible ½ in. per ft. is preferable.

11. Return mains shall be connected together into the accumulator tank of Dunham Differential Vacuum Pump as shown in detail furnished by manufacturer. Lift connections must not be used except between pump and accumulator tank.

12. Risers are to be run concealed or in the open as directed by the architect. Each down-feed steam riser must be dripped into the return through a "D" Series Dunham Trap. Install traps as instructed by manufacturer. All concealed piping must be tested and made tight at 15 lb. water pressure before being concealed and covered.

13. All union connections, flanges, packing nuts on gate and globe valves and on gauge glass of boiler must be drawn up tight so as to prevent air leaking into system when under a high vacuum. This work must be performed after system is completed and while it is working with a vacuum in both steam and return lines.

14. FLOOR PLATES, SLEEVES—Furnish approved floor and ceiling plates, protecting sleeves on all pipes passing through floors or finished partitions.

15. DIFFERENTIAL VACUUM PUMP.—Furnish and install one or several (as indicated on plans) Dunham Differential Vacuum Pumps of "D" series size ..... having a differential rating of.....sq. ft. of equivalent direct radiation. The pump (or pumps) shall be installed, connected and wired in accordance with manufacturer's instructions and local regulations.

15A. DOMESTIC HOT WATER AND BLAST HEATER.—Condensation from this equipment shall be returned to boiler by other means than Dunham Differential Vacuum Pump.

16. CHECK VALVES.—Check valves shall be horizontal swing type with brass disc, best grade obtainable. They shall be installed where called for by the plans, and in accordance with accompanying details. They shall be tested for tightness.

17. RADIATION.—Furnish and install radiation as shown on the plans. There shall be.....sq. ft. of direct radiation of approved make. All radiators must be provided with top inlet tapping. Furnish ½-in. eccentric *bushing in the return tapping. All air valve tappings shall* be plugged.

18. RADIATOR TRAPS AND VALVES.—Each radiator shall be provided with a Dunham "D" Series Radiator Trap of suitable capacity. A Dunham Packless Radiator Valve with Dunham Regulating Plate shall be installed at inlet connection according to manufacturer's instructions.

19. PAINTING.—All exposed piping in finished rooms shall be given a priming coat of flat paint and thereafter painted or enameled as directed by architect. Radiators shall be painted as directed by architect. All pipe joints and all uncovered piping in basement, front and other exposed parts of boiler shall be painted one coat of black asphaltum when the system is hot and under a vacuum. The finishing coat of paint must be applied when the entire system is under vacuum, so that paint will fill up small leaks.

20. COVERING.—Cover all steam mains and spring pieces with four-ply, 1 in. thick asbestos sectional covering and fittings with asbestos cement. Cover all steam and return risers and other piping run concealed in outside walls with two-ply, ½ in. thick asbestos sectional covering. Cover boiler as specified by boiler manufacturer.

21. FINISHING UP.—After system has been in operation two weeks, thoroughly blow down and clean out system as follows:

Remove the safety valve and connect a temporary blow-off pipe to the safety valve tapping, extending it outside or to some suitable drain. Shut off all radiator valves or valves in main. Fill the boiler with water to top of gauge glass. Build a very hot fire and blow steam and water out through the safety valve tapping and pipe connected thereto. Fire hard with not more than 10 lb. pressure on the boiler. Supply cold water constantly in at bottom of the boiler. Continue this for six hours. At the end of the period, close the water feed valve, draw the fire quickly, open blow-off at bottom of boiler and entirely drain the boiler, replace the safety valve. Fill the boiler slowly after it becomes cold.

Remove the cover of each trap and wipe off grease and dirt accumulation. Replace trap cover tightly on body.

22. TEST.—The System when finished and cleaned shall be tested for tightness as directed by C. A. Dunham Company's Representative. Contractor shall furnish labor and material for performing test.

23. GUARANTEE.—The Heating Contractor shall guarantee the apparatus installed to circulate steam thoroughly through every radiator without noise, with a vacuum of 15 in. in steam main. If the apparatus shall fail to accomplish this guarantee by reason of any defect developing within the period of one full heating season and that defect is due to faulty material or poor workmanship, the Heating Contractor shall remedy such defect at his own cost within reasonable time after notice thereof.

24. FINALLY.—Nothing herein contained can be construed to relieve the Heating Contractor from making good and perfect work in all usual details of construction, and he will be held responsible to provide and furnish necessary material and to perform all necessary labor and to bear all expenses incidental to the satisfactory completion of the work.

when steam piping is too low for gravity return to boiler. No lift connections can be used.

Individual Temperature Control for Sections of Buildings or Groups of Buildings—Different parts of buildings require different quantities of heat at different times due to class of occupancy of various parts of building, sun and wind effect on the different sides, and buoyancy of the heated air as in very tall buildings. All large buildings should therefore be "zoned" to secure maximum conservation of steam and correct heating of all sections.

The Dunham Zone Temperature Control in conjunction with the Dunham Differential Vacuum Heating System provides remote electrical control of the steam supply as required by each zone.

Controlling Factors in Designing a Zoning System—

(1) Buoyancy—Heated air rises within the building due to flue effect. This causes the upper floors of tall buildings to be overheated after the system is full of steam.

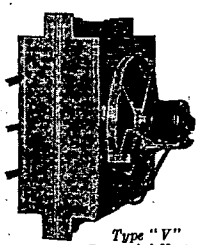
(2) Exposure—Sunshine, wind and other weather conditions cause variable heat demands on different sides of buildings.

(3) Type of Occupancy—Sections of the same building may require different degrees of heat due to their particular uses, such as storage, manufacturing, office space, etc., or periods of occupancy.

No particular rule can be given for the zoning of a building, as each is an individual problem and should be studied as such. The experience of Dunham engineers is at the service of architects and engineers when heating system layout for a zoned system is being studied. A general description of the problem will enable the Dunham engineering staff to advise you.

DWYER UNIT HEATERS

Dwyer Unit Heaters are manufactured in four distinct types in a range of sizes broad enough to meet all requirements.

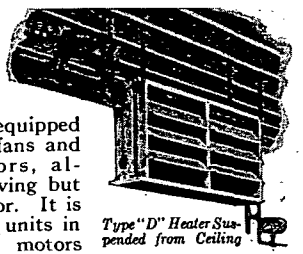


Type "V" Suspended Heater

Type "V" is a simple compact design, in sizes up to 1132 square feet of equivalent direct radiation. The all-aluminum fan mounted directly on the motor shaft forces the room air through the radiator, and the warmed air is deflected up or down by individually adjustable louvers.

Light in weight, the unit may be hung from the roof joists by ordinary pipe hangers, from the wall with wall brackets, or from a column or post. When equipped with a recirculating duct the heating efficiency is greatly increased. The cooler air near the floor is drawn into the units allowing the warmer air to settle down into the working zone.

Speed control of the electric motors, which is available for all current characteristics, particularly adapts the Type "V" Unit to retail stores, offices, showrooms, etc., in addition to an unlimited application for small factories, garages, and lofts.

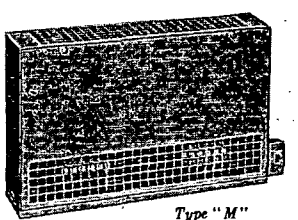


Type "D" Heater Suspended from Ceiling

Type "D" is equipped with two fans and two motors, although having but one radiator. It is really two units in one. The motors may be connected, if so desired, to operate independently instead of simultaneously. With only one motor in operation, the capacity of the unit is approximately 60 per cent of the full rated capacity. Type "D" units are manufactured in sizes up to 2360 square feet of equivalent direct rediation, yet require only one steam supply and one return connection.

Every Dunham-built Dwyer Unit Heater is built around the time-proven Dwyer Radiator, constructed of seamless drawn copper tubes to which continuous helical copper fins are metallically attached. The tubes are assembled into semi-steel cast headers at each end by means of brass clamping nuts, forming screwed ground joints. This feature permits of the removal and replacement of any tube or number of tubes (in the event of damage) without breaking any piping connections.

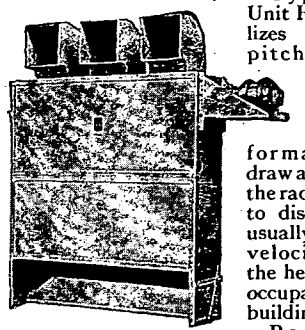
Type "M" is a compact cabinet-type heating unit, quiet in operation, efficient and soundly constructed for lifetime service. Its pleasing appearace and self-contained operating parts, its



Type "M" Cabinet Unit Heater

silent yet positive action, adapt it to offices, stores, showrooms and basements, where a maximum quantity of heat is required in a minimum amount of space available.

The unit is universal in application, and may be installed on the floor, inverted and attached to the wall, or it may be installed behind the walls, breathing the air through grilles. Type "M" Unit Heaters range in size from 100 to 300 square feet of equivalent direct radiation.



Type "R" Unit Heater

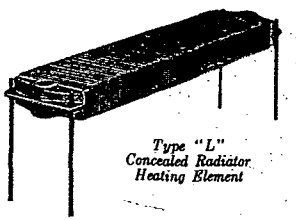
Type "R" Unit Heater utilizes backward pitched, centrifugal housed fans in tandem formation to draw air through the radiator, and to discharge it, usually at a high velocity, over the heads of the occupants of the building.

Ranging in size up to 3350 square feet of equivalent direct radiation, these units are primarily intended for larger industrial buildings. By controlling the speed of fans, they become ideal for ventilating and heating offices, auditoriums, and gymnasiums.

All parts are instantly accessible. The electric motor, self-aligning, dust-proof ball bearings, and flexible coupling, are installed outboard. The radiator slides in and out through either end, like a drawer. The complete fan assembly is removable through the top of the unit.

Discharge cowls are square and may be set in any of the four directions. The unit may be installed on the floor, hung on the wall upright, or inverted, or flat against the ceiling. Only one steam supply and one return connection are required.

TYPE "L" CONCEALED RADIATOR



Type "L" Concealed Radiator Heating Element

Type "L" Concealed Radiator replaces the bulky, antiquated, cast-iron heater, so unsightly in any room. Installed behind the walls of a home or office building, it allows the space formerly occupied (and made unusable) by the cast-iron radiator to become as utilitarian as the other parts of a room.

The radiators are made in a complete range of sizes, to meet every condition. They are designed throughout along the most advanced scientific lines. A choice of grille designs and radiator enclosures will appeal to the architect and builder.

Orifice regulation of the steam supply is a necessity for the modern circulation system, so a special *adjustable* regulating fitting is available for the Type "L" Concealed Radiator. This fitting is easily adjusted, and may also be used as a valve to close off the steam supply when the trap is being cleaned.

Pipe connections are greatly simplified, and every precaution has been taken to aid the steam fitter in his work.

The Heating Element is built for lifetime service. It consists of seamless drawn copper tubes and pure copper fin sheets metallically attached. This feature assures permanence of heating capacity as no dirt, dust, or oxidization can insulate the contact between tube and fin. The tubes are airfoil in shape, to offer the least resistance to the convection of air. They are individually brazed into an extra heavy die-pressed copper tube sheet which is swaged and then brazed over a one piece reinforced bronze casting. The result is a homogeneous structure. Each element is given careful inspection and a steam and hydraulic test before shipment from the factory.

Heating elements are removable from the enclosure (in case of necessity) through the air inlet opening.

Enclosures are built of heavy sheet steel, substantially reinforced; and of proper design to offer the least impedance to air flow. Metal panel fronts of highly finished furniture steel, and panels for plaster front are available with or without recess linings. Grilles are of heavy perforated metal welded to one-piece bar frames. Dampers to control the air flow as desired are optional.

The appearance of the complete installation, and the application of the panel for plaster front, with recess lining and damper, are shown in special bulletins, copies of which will be sent on request. An inlet grille may be substituted for the cut-out removable baseboard section shown.

GRINNELL COMPANY INC.

Heating, Industrial and Power Plant Piping, Fittings, Hangers, Valves, Pipe Bending, Welding, Piping Supplies, Etc.

Executive Offices: **Providence, R. I.**

Exclusive Distributors of Thermoflex Traps and Heating Specialties

For data on other Grinnell Products, see pages 707-713

Thermoflex Specialties

The heart of all Thermoflex Traps is the Hydron Bellows.

The Hydron Bellows is formed under hydraulic pressure. This powerful internal pressure locates any weakness of any nature in the tubing. Such hydraulic pressure is many times more severe than any pressure the Trap will ever be called upon to control. Every Thermoflex Trap, therefore, is practically indestructible.

Thermoflex Traps have an exceptionally large orifice. This large orifice combined with high lift, insures fast action and freedom from clogging.

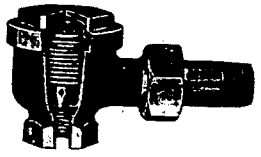
We supply Thermoflex Traps guaranteed for steam pressures up to 25 lb. and to 125 lb. Complete information and details of typical installations will be gladly sent on your request.

Each Thermoflex Trap is tested, certified, and tagged by the Pittsburgh Testing Laboratory.

Valves, Traps, Gauges, Etc.

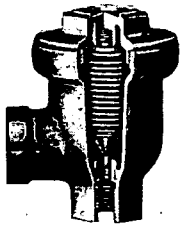
The Thermoflex line includes: Radiator Traps, Offset Traps, Blast Traps, Drip Traps, High Pressure Traps, Vent Traps, High-grade Packless Inlet Valves, and the Thermoflex Alternator, Thermoflex Compound Gauge, Thermoflex Damper Regulator.

No. 12 Thermoflex Radiator Trap



The full eight-fold Thermoflex-Hydron Bellows is the best bellows ever made. Because of the Hydron-forming process every bellows is absolutely perfect. Body is heavy bronze construction throughout, using a forging for the cap and spudnut. Fully nickel-plated with highly polished trimmings. The No. 12 is made in angle pattern only, with ½ in. inlet and ½ in. outlet tappings. The inlet neck is double thick to allow for expansion strains. Guaranteed for steam pressures up to 25 lb.

Thermoflex High Pressure Traps



The No. 100 Thermoflex Trap is guaranteed for steam pressures from 25-125 lb. Must not be used where the steam temperature exceeds 400 deg. Fahr.

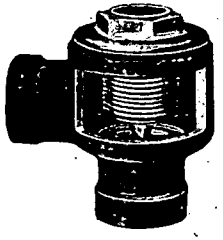
For use with all types of process work, Laundry Machinery, Kitchen Equipment, Hospital Sterilizers, Vulcanizers, Dry Kilns, Unit Heaters, Street Steam Service, etc., in fact any place that a trap is desired for service at the above pressures.

Small, compact and inexpensive in comparison to the usual float or bucket trap.

Extra heavy body with stainless steel renewable seat. Valve on bellows is of nitrided steel which will not rust and resists wear.

Regularly furnished without unions, plain nickel finish. Can be furnished with unions, polished nickel or chromium plated at extra cost.

No. 4 Thermoflex Drip Traps



For dripping mains, risers, coils and unit heaters, we offer this type of trap. Cast iron body, bronze cap and inserted renewable bronze seat, angle pattern only, without unions. Can be used for any general purpose where a finished, nickel-plated trap is not necessary, and at a lower cost. Guaranteed for steam pressures up to 25 lb.

William S. Haines & Company

12th and Buttonwood Sts., **Philadelphia, Pa.**

Manufacturers of Equipment for Vapor and Vacuum Heating Systems

Haines Radiator Traps.

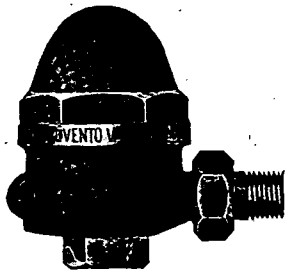
Haines Medium Pressure Thermostatic Traps.

Haines High Pressure Thermostatic Traps.

Haines Float and Thermostatic Blast Traps.

Haines Vent Traps.

Haines Modulating Valves.



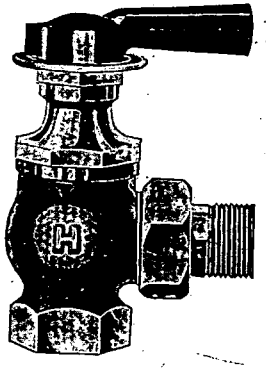
All HAINES traps, whether designed for pressures below atmosphere or pressures in excess of 100 lbs. per sq. in., employ as their operating member a specially constructed bourdon tube—the principle that actuates the steam gauge.

The tube is of tempered steel. It is charged with a volatile fluid and hermetically sealed. It is the expansion and contraction of the fluid, under varying temperatures, that furnishes the operating power.

The tube is mounted vertically on a horizontal valve motion. The end opposite the valve is anchored so that the travel of the tube either opens or closes the valve piece.

The thermostatic member is outboard the valve seat and closes the valve against the flow of steam. This arrangement prevents fouling of the trap due to scale or other foreign matter and permits a thorough draining of the unit to which it is attached.

HAINES thermostatic traps are made in sizes from ½ in. to 1½ in. All traps are factory tested and adjusted before shipment.



HAINES modulating valves never need repacking. They seat tightly and open on less than a full turn of the lever or wheel handle.

Made in sizes from ½ to 2 in. in angle, globe, or corner pattern.

HAINES VENTO TRAPS

No. of Trap	Center to Inlet	Center to Outlet	Capacity Sq. Ft.
1	2⅞″	1⅜″	125
2	3¼″	1⅝″	200
2E	3⅝″	1⅝″	250
3	3⅝″	1⅝″	400
3E	3⅞″	1⅝″	500

HAINES MODULATING VALVES

Size of Valve	Center to Inlet	Center to Outlet
½″	1⅞″	2⅛″
¾″	1⅞″	2⅛″
1″	1⅞″	3″
1¼″	1⅞″	3⅝″
1½″	2¼″	4¼″
2″	2¼″	4⅝″

Hoffman Specialty Co., Inc.

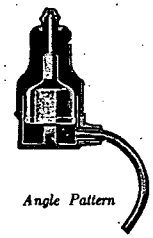
Main Office and Factory, **Waterbury, Conn.**

General Sales Department, Chrysler Building, **New York**

Sales Representatives in Principal Cities

VENTING VALVES FOR ONE-PIPE SYSTEMS

ALL METAL—NON-ADJUSTABLE—THERMOSTATIC



Angle Pattern

The Airport—An efficient venting valve, made and guaranteed by Hoffman, for jobs where initial cost is a factor. It is small and attractive in appearance. Base and threaded connection is a one piece hot brass forging. Valve pin is of nickel silver. An adaptation of the double shell construction—exclusively Hoffman—assures perfect operation should water flood the valve.

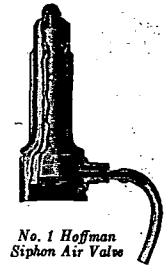
Made in Angle, or Straightshank pattern for fin type units. Radiator connection—⅛ in. Maximum guaranteed operating pressure—10 lbs.



Straight Shank

The No. 1 Hoffman Siphon Air Valve is designed for systems of the one-pipe gravity type, to vent all air from radiators without loss of steam. After contact of water with the valve the siphon drains all water from the valve and venting occurs without the slightest "spit" even if the radiator is under pressure.

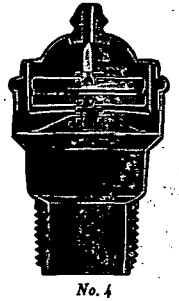
Radiator connection, ⅛ in. Maximum guaranteed operating pressure, 10 lb.



No. 1 Hoffman Siphon Air Valve

The No. 4 is used in venting mains, risers, vento stacks, coils, etc. All air is freely vented through a ⅛ in. vent port without steam loss, but valve does not close against water.

Standard connection, ¾ in., can also be supplied with ¼ in. connection. Maximum guaranteed operating pressure, 10 lb.

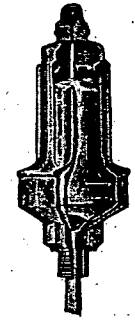


No. 4

The No. 5 is particularly adapted for use in venting: Ends of steam or dry return mains; Indirect radiators; Blast or "Vento" stacks; Hot-water generators; Dryers and drums, etc.

The basic principle is the same as the No. 1 Valve, having separate channels for air and water which are only found in Hoffman Valves.

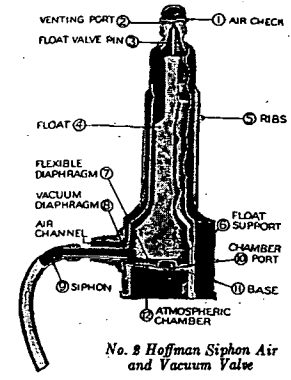
Pipe connection, ⅜ in.; vent port for less than 3 lb. is 3/16 in.; for 3 lb. and over is 1/16 in. Unless otherwise ordered, will be shipped with 1/16 in. port. Maximum guaranteed operating pressure, 10 lb.



No. 5

Write for Descriptive Circular—The Watchman of the Coal Pile

VENTING VALVES FOR ONE-PIPE VACUUM SYSTEMS



No. 2 Hoffman Siphon Air and Vacuum Valve

In construction, the No. 2 Valve is similar to the No. 1 with the addition of a vacuum diaphragm in the base and an air check over vent port.

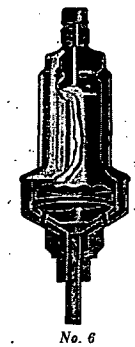
Upon steam contact, float diaphragm (7) expands, closing port (2). When pressure goes below atmosphere vacuum diaphragm (8) follows up contracting float diaphragm, maintaining port closed against air intake.

Air check (1) functions only in the case of a half-hot radiator when float diaphragm (7) is not expanded by steam contact. With a cessation of steam generation, air check holds port closed against air intake until pressure goes below atmosphere and when a 1 in. vacuum forms diaphragm (8) expands, closing port, relieving air check of any further function.

The superiority of the diaphragm controlled port compared with valves having air check only is indicated by the fact that the total pressure exerted in holding vent port closed is approximately 20 times greater than that exerted in maintaining an air check closed.

This greater pressure, exerted by the vacuum diaphragm holds the valve pin more tightly against its seat and also aids in crushing or pushing away dirt particles which might be caught between the valve pin and its seat.

Radiator Connection ⅛ in. Maximum guaranteed operating pressure 10 lb.



No. 6

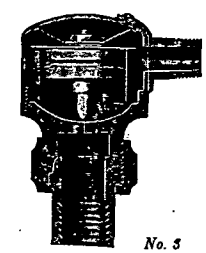
The No. 6 Float Air and Vacuum Valve is similar in design and application to the No. 5 with the additional feature of the air check or vacuum starter above vent port and vacuum diaphragm in base. Used for venting ends of mains, vento stacks, etc., where water is liable to be present.

Pipe connection, ⅜ in.; vent port for less than 3 lb. is 3/16 in.; for 3 lb. and over is 1/16 in. Unless otherwise ordered, will be shipped with 1/16 in. port. Maximum guaranteed operating pressure, 10 lb.

The No. 16 Air and Vacuum Valve is used for venting ends of steam and dry return mains. Valve is 3⅜ in. high overall, permitting installation in lines close to ceiling. It has the special Hoffman feature, the combined air check and vacuum diaphragm for preventing return of air to system. Pipe connection, ¾ in. Vent port 1/16 in. dia. Maximum operating pressure, 10 lb.



No. 16



No. 3

The No. 3 Hoffman Air Line Valve is specially designed for Air Line, or as they are frequently termed "Paul" Systems. It is sensitive in action and closes the instant steam fills the radiator.

Radiator connection, ⅛ in.; Air Line connection, ¼ in. Maximum guaranteed operating pressure, 10 lb.

THE HOFFMAN VALVE LOCK

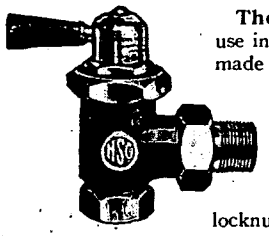
Prevents theft of No. 1 and No. 2 valves in public buildings, etc. No extra tapping is required as lock is easily applied when valve is inserted in radiator. By using set screws, valve is locked in position and can only be removed by a special key.



Hoffman Valve Lock

Write for Descriptive Circular—Locking the Door Against the Heat Thief

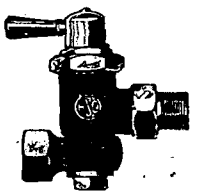
HOFFMAN VAPOR AND VACUUM SPECIALTIES



No. 7—Hoffman Adjustable Modulating Valve

The No. 7 Hoffman Adjustable Modulating Valve—For use in Vapor, Vapor Vacuum or Forced Hot Water Systems, is made in ¾ in. size, angle or swivel pattern, having a range of adjustment up to 200 sq. ft. of direct cast-iron radiation.

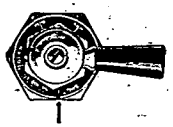
After installation, whether the system is in operation or cold, the port of each valve is adjusted for size of the radiator to which it is attached. Adjustment is simple; loosen a locknut; turn valve handle until proper number of graduations are visible on the dial plate; then tighten locknut. The valve handle may then be moved to admit sufficient steam to heat a quarter, half, three-quarter, or entire radiator. The valve stem stuffing box has a frictionless metallic fibre packing that will last indefinitely and require no attention, giving at the same time, a valve action so free that the pressure of only one finger is required to open the valve.



No. 7 Swivel Conn.

The No. 7 Hoffman Modulating Valve provides a most convenient and accurate method of balancing steam distribution throughout vapor or vacuum systems and control of the output of each heating unit.

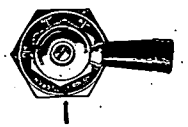
TOP DIAL PLATE ADJUSTMENT



Dial set for 200 sq. ft.



Port Area for 200 sq. ft. Radiator



Dial set for 50 sq. ft.

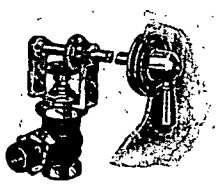


Port Area for 50 sq. ft Radiator

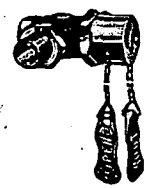
The visible adjustment aids the designing engineer by enabling heating contractor to make a final accurate adjustment which compensates for slight irregularities in pipe sizes, failure to ream pipe, installation of extra fittings not foreseen in original layout, etc. The advantages of an adjustable port in forced hot water systems to secure proper balance makes the **No. 7 Valve** especially adaptable for such use.

NO. 7 VALVE ATTACHMENTS

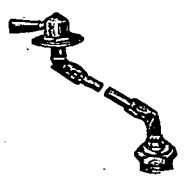
Special attachments for the No. 7 Valve are illustrated below. The use of the Bevel Gear attachment and Offset or Straight Extension Stem make the valve handle readily accessible when the valve is installed on concealed units.



Bevel Gear



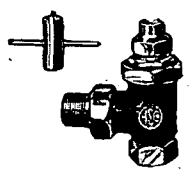
Chain Pull



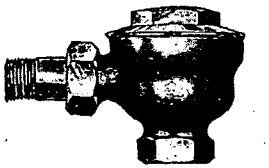
Offset Extension Stem



Straight Extension Stem



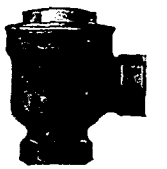
Lock Shield



No. 8-A

The New 8-A and 9-A Traps are actuated by a Bellows Thermostat, formed and tested-in-the-making by a new hydraulic process. Through this process, the folds of the bellows maintain a uniform metal thickness and crystalline structure and are unimpaired by tool marks, both requisite for long life.

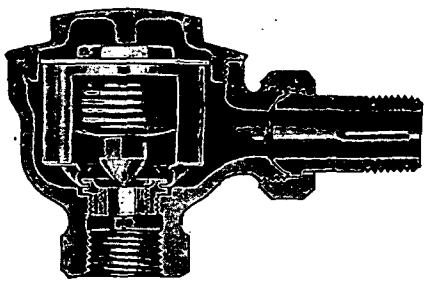
A novel feature of the Nos. 8-A and 9-A Traps is the combination of all vital parts—bellows, valve pin and valve seat—into a single unit as illustrated. This unit threads into the body and the joint is sealed by a soft copper gasket which also facilitates removal of the unit if ever necessary.



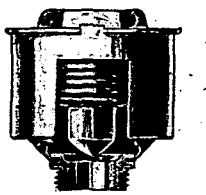
No. 9-A

An important factor in trap operation is the durability of the seating surfaces of the port. In these Traps, the valve pins and renewable seats are of a special nickel-silver alloy having exceptional wear resisting qualities.

The No. 8-A has ½ in. connections and is available in Angle or Swivel Pattern. Nominal capacity under pressures below 1 lb.—300 sq. ft. of radiation. Capacities at various temperature drops and pressure differences are given in table below. Valve port—⅜ in. diameter. Bellows—8 convolutions, 1½ in. diameter.



No. 8-A Sectional View



Type of Thermal Member used in the Nos. 8-A and 9-A

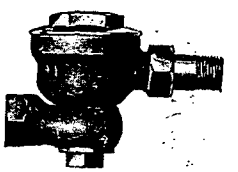
The No. 9-A has ¾ in. connections (without union) made in Angle Pattern only. Nominal capacity under pressures below 1 lb.—700 sq. ft. of radiation. Valve port—$\frac{7}{16}$ in. diameter. Bellows—12 convolutions—1½ in. diameter.

Maximum guaranteed operating pressure of No. 8-A and 9-A is 25 lbs. Furnished for pressures up to 50 lbs. on special order at no extra charge.

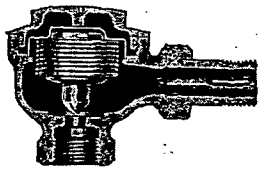
Roughing-in measurements comply with standards adopted by Heating & Piping Contractors National Association.

Average Capacities in Pounds of Condensate per Hour—Nos. 8-A and 18-A Traps

Pressure Difference Lbs. Sq. In.	TEMPERATURE DROP—DEG. FAHR.						
	4°	5°	6°	7°	8°	8°	10°
1	126	130	135	141	147	152	160
2	129	134	139	145	151	157	167
3	133	138	143	149	156	163	174
4	138	142	147	154	162	170	182
5	142	146	151	159	168	178	190
6	147	151	157	166	176	186	198
7	153	158	164	174	184	194	206
8	159	166	173	181	192	202	214
9	166	174	182	190	200	211	222
10	175	184	192	200	209	220	230



No. 8-A Swivel Pattern

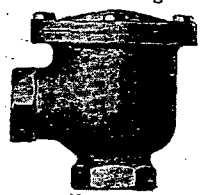


No. 18-A Angle Pattern

The New No. 18-A Radiator Trap contains the "tested-in-the-making" hydraulically formed bellows. It is similar in every respect to the No. 8-A, except the valve seat is cut in the body and is not removable.

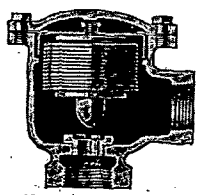
Connections, ½ in. Angle or Swivel Patterns. Nominal capacity under pressures below 1 lb.—300 sq. ft. of radiation. For capacities at various temperature drops and pressure differences, see Table on Page 795. Valve port, ⅜ in. diameter. Bellows—8 convolutions—1½ in. diameter. Maximum guaranteed operating pressure—25 lbs.

The No. 10-A Iron Body Steam Trap, with bellows thermal member, has a nominal capacity of 2800 sq. ft. of radiation and is suitable for any heavy duty service where a cooling leg (for temperature drop) can be installed. Particularly adapted for systems having Unit Heaters, indirect radiators, small water heaters, etc.



No. 10-A

The thermal member is a $2\frac{7}{16}$ in. bellows, 13 convolutions, hydraulically formed. Corrosion and wear resisting nickel-silver alloy is used in valve pin and removable seat.

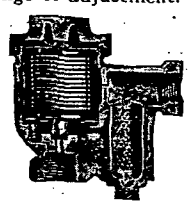


No. 10-A Sectional View

Connections, 1 in. (without union). Angle pattern only. Maximum guaranteed operating pressure—25 lbs. Thermal members are interchangeable in No. 10-A bodies without adjustment.

Nos. 20 and 21 Hoffman Thermostatic Steam Traps—Pressure Range—0 to 100 lbs. without change or adjustment.

The Trap bodies are of strong, rugged, all bronze construction. The hydraulically formed bellows is so constructed as to be water-hammer proof. Valve pin and renewable seat are of a wear resisting nickel silver alloy. A strainer is built into the trap body and is readily removed and cleaned. Thermal members are interchangeable in bodies of the same size without adjustment and the cage, supporting the bellows, has a stop which permits removal of the thermal member while steam hot without damage to the bellows.



Nos. 20 and 21

The valve port is normally wide open for the free discharge of air and initial condensation. No hand operated by-pass for venting the unit is required.

The discharge capacity is dependent on differences between the temperature of the condensate delivered to the trap and the steam temperature—the greater the difference, the larger the capacity of the trap. Capacities for various temperature drops and steam temperatures are given below.

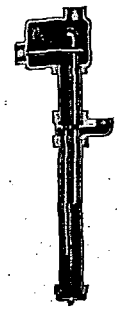
	NO. 20 TRAP						NO. 21 TRAP					
Pressure, lbs. per sq. in.	10	30	50	70	90	100	10	30	50	70	90	100
Temperature Drop 20°	275	550	715	820	900	925	375	725	925	1085	1190	1225
Temperature Drop 35°	725	1075	1380	1675	1830	1860	950	1410	1860	2250	2490	2550

No. 20 Trap has ½ in. pipe connections, ⅛ in. port. Weight 3¼ lb.
No. 21 Trap has ¾ in. pipe connections, ¼ in. port. Weight 3¾ lb.

Write for Descriptive Circulars

HOFFMAN "CONTROLLED HEAT" EQUIPMENT

HOFFMAN DIFFERENTIAL LOOP



Hoffman Differential Loop

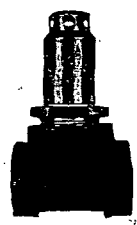
The Differential Loop is the safety device for maintaining a steady water line in vapor and vapor vacuum systems. It is entirely automatic, non-adjustable and has no moving parts to stick at a critical moment.

In operation the water rises in the return main **only** to a certain predetermined height. The loop then functions, blowing over a small quantity of steam which closes the No. 15 Valve used for venting the system and compresses the air which is "bottled up" in the return main, building up a pressure which prevents further rise of water in the vertical part of the return beyond the predetermined height. As soon as this is accomplished, and the action is almost instantaneous, the loop reseals and no more steam is blown over until the differential pressure is slightly reduced. It will be readily seen that, by the alternate blowing over and resealing of the loop, a constant differential pressure will be maintained between the steam main and return main. Also by the maintenance of this differential no matter how high the boiler pressure goes, circulation will start in a radiator as soon as the inlet valve is opened even though the return main vent is closed through loop action.

Standard Differential Loops are made in four sizes, to handle systems up to 15,000 sq. ft. of radiation. For larger systems the No. 04 Loops can be installed in a battery.

No. 01 and No. 02 Loops should not be used where the low point in the dry return is less than 24 in. above boiler water line; with the No. 03 and No. 04 Loops this distance must be at least 30 in.

NO. 15 VALVE

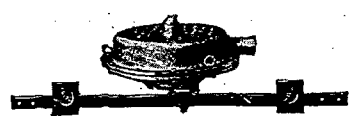


No. 15

In conjunction with the Loop a special valve for venting the entire system is used—the No. 15 Hoffman Vacuum Valve—which permits free venting of air through its ¾ in. vent port and prevents air returning to the system by means of a light check, which is thoroughly reliable in fulfilling its requirements.

The No. 15 Valve is intended for use only in connection with Hoffman Differential Loops.

HOFFMAN DAMPER REGULATOR



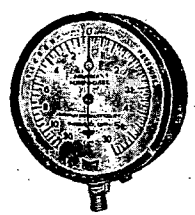
Hoffman Damper Regulator

One of the most important features of the Hoffman Damper Regulator is the accurate pressure control and resultant fuel economy.

It is extremely sensitive in its action and controls so efficiently that when inlet valves are turned on or off, the fire is accelerated or retarded to meet the change in demand for vapor. A low constant pressure is always maintained so that vapor enters the radiator as soon as a valve is turned on.

A compensating plate presents the accumulation of water on the diaphragm when it is depressed, maintaining perfect balance at all times. Connections, 1 in.

HOFFMAN KOMPO-GAGE

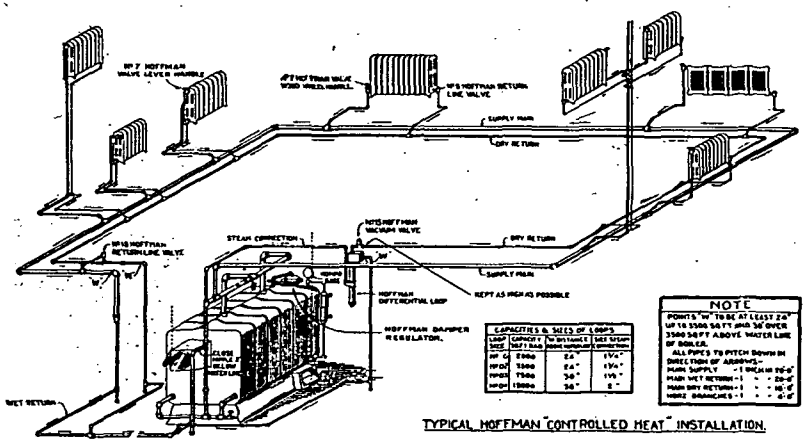


Hoffman Kompo-Gage

Measures pressure up to 30 lb., vacuum to 30 in. Pressure is registered in ounces up to 5 lb. Vacuum is shown in half inches up to 10 in.

Used in Hoffman "Controlled Heat" installations or in one-pipe gravity vacuum systems equipped with No. 2 valves; indicates efficiency of the apparatus when a warm house is maintained with vapor at temperatures considerably below 212 deg.

TYPICAL INSTALLATION
HOFFMAN "CONTROLLED HEAT" EQUIPMENT



TYPICAL HOFFMAN "CONTROLLED HEAT" INSTALLATION.

NOTE.—Loop discharges into high end of return main. This results in venting air from high point in return instead of low point. Point "W" should be at least 24 in. above water line with Nos. 0 and 02 loops and 30 in. with Nos. 03 and 04.

The above drawing shows the typical application of Hoffman Products to a vapor-vacuum system—Hoffman "Controlled Heat."

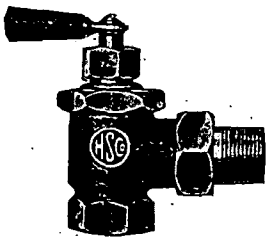
The features of the No. 7 Adjustable Modulating Valve for balancing steam distribution and radiator output and the accuracy of No. 8-A or 18-A Traps in controlling flow of condensation and air from the radiators without steam loss, positively control the room temperature to meet the requirements of the occupant.

The basement specialties automatically control fuel consumption and protect the boiler from loss of water through the returns, without thought or attention on the user's part.

"Controlled Heat" is adaptable and economically suited to any building where the required water line difference is available.

The No. 11 Vapor Vacuum Valve is used for venting the return mains of vapor-vacuum systems or for other conditions where return of air through vent port must be prevented. The vent port is ¾ in. in diameter.

Pipe connection—¾ in. Maximum guaranteed operating pressure—15 lbs.



No. 19 Hoffman Radiator Valve

No. 19 Quick Opening Radiator Valve is of the semi-packless type for vacuum pump installations or for vapor systems where modulation is not required. Made in ¾ in. size only. Capacity—200 sq. ft. of radiation.

Regularly furnished with lever handle. Wood wheels or Lock Shields on special order at no extra charge. Offset or straight extended stems for concealed units on order at small extra charge. Angle pattern only.



No. 11

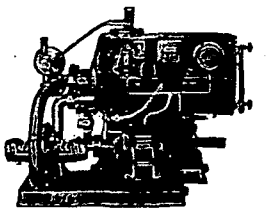
HOFFMAN-ECONOMY RETURN LINE VACUUM PUMPS

The jet type vacuum producer used in these pumps is one of the simplest and best known methods for exhausting air and vapors. *It has no moving parts and avoids close* clearances so that loss of efficiency, due to wear, is reduced to a minimum. Pumps will handle extremely hot water and are smooth and quiet in operation.

All units of 16,000 sq. ft. and over have horizontal split case pumps with enclosed, double suction, bronze impellers. Units of 12,000 sq. ft. and under have vertically split volute pumps, with enclosed impeller, removable bronze stand bearing and outboard ball bearing. Operation is controlled by float switch and vacuum regulator.

All sizes furnished in Duplex Units.

When returns are below pump inlet an auxiliary accumulator tank will permit operation on *float control* only. All units completely assembled and wired ready for installation.



Capacity Table—Vacuum Pumps

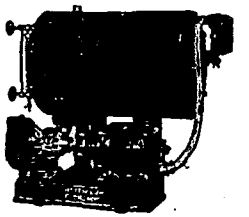
Pump No.	Capacity Sq. Ft. Dir. Cast Iron Rad.	Water Cap. G. P. M.	Air Cap. C. F. M.	Motor H. P. 20. lb. Press.
SV-0	1,500	3	1	½*
SV-1A	3,500	7	3	¾
SV-2	5,000	9	3	1
SV-2A	7,000	13	4	1
SV-3A	12,000	18	7	1½
SV-4	16,000	22	9	2
SV-5	20,000	28	12	3
SV-6	26,000	35	15	5
SV-7	40,000	60	21	5
SV-8	65,000	90	34	7½
SV-9	100,000	140	50	10
SV-10	150,000	210	102	15
SV-11	250,000	350	130	25

*Discharge pressure SV-0, 10 lbs. All other standard pumps, 20 lbs.

HOFFMAN-ECONOMY HORIZONTAL CONDENSATION PUMPS

Horizontal Condensation Pumps are made in Styles "A"—0 to 20 lb. pressure—"B"—"C" and "D" for 35 to 100 lb. pressure. All units have bronze fitted, enclosed impellers. Styles A-B and C have vertically split case—Style D horizontal split case. Style A pumps have outboard ball bearing and self-lubricating, renewable bronze stand bearing. Style B and C have double outboard bearings, ring oiling at driving end and ball bearing at opposite end, both readily renewable. Style D has double outboard ring oiling bearings, both easily renewable.

Float switch mechanism is positive with bronze float arm supported by two liberal bearings. All units are completely assembled and wired, ready for installation.



Style "A"

Capacity Table—Condensation Pumps—60 Cycle and Direct Current

Pump and Style No.	Capacity Sq. Ft. Dir. C. I. Radiation	Disc. Press. Lbs. Sq. In.	Pump Cap. G.p.m.	Motor H. P.	Speed R.p.m.	Pump and Style No.	Capacity Sq. Ft. Dir. C. I. Radiation	Disc. Press. Lbs. Sq. In.	Pump Cap. G.p.m.	Motor H. P.	Speed R.p.m.	Pump and Style No.	Capacity Sq. Ft. Dir. C. I. Radiation	Disc. Press. Lbs. Sq. In.	Pump Cap. G.p.m.	Motor H. P	Speed R.p.m.
10A	1,000	10	2	¼	1,750	100A	10,000	10	20	¼	1,750	200A	20,000	10	40	½	1,750
						101A	10,000	15	20	½	1,750	201A	20,000	15	40	¾	1,750
30A	3,000	10	5	¼	1,750	102A	10,000	20	20	¾	1,750	202A	20,000	20	40	1	1,750
31A	3,000	15	5	½	1,750	103B	10,000	25	20	1	1,750	203B	20,000	25	40	1½	1,750
32A	3,000	20	5	¾	1,750	104B	10,000	30	20	1½	1,750						
						105B	10,000	40	20	1½	1,750	205B	20,000	40	40	2	1,750
60A	6,000	10	12	¼	1,750	105C	10,000	40	20	1½	3,500	205C	20,000	40	40	2	3,500
61A	6,000	15	12	½	1,750	106B	10,000	50	20	2	1,750	207B	20,000	60	40	3	1,750
62A	6,000	20	12	¾	1,750	106C	10,000	50	20	2	3,500	207C	20,000	60	40	3	3,500
64B	6,000	30	12	1	1,750	107B	10,000	60	20	3	1,750	209C	20,000	100	40	5	3,500
65B	6,000	40	12	1½	1,750	107C	10,000	60	20	3	3,500						
						109C	10,000	100	20	5	3,500	300A	30,000	10	53	½	1,750
65C	6,000	40	12	1½	3,500	151A	15,000	15	30	½	1,750	301A	30,000	15	53	¾	1,750
66B	6,000	50	12	2	1,750	152A	15,000	20	30	¾	1,750	302A	30,000	20	53	1	1,750
66C	6,000	50	12	2	3,500	153B	15,000	25	30	1	1,750	303A	30,000	25	53	1½	1,750
67B	6,000	60	12	3	1,750	155B	15,000	40	30	2	1,750						
67C	6,000	60	12	3	3,500	155C	15,000	40	30	2	3,500	304A	30,000	30	53	2	1,750
68C	6,000	75	12	3	3,500	157B	15,000	60	30	3	1,750	307C	30,000	60	53	5	3,500
69C	6,000	100	12	5	3,500	157C	15,000	60	30	3	3,500	308C	30,000	75	53	7½	1,750
						159C	15,000	100	30	5	3,500	309B	30,000	100	53	10	1,750

Complete Tables and Specifications for Pumps up to 70,000 sq. ft. capacity, Given in Our General Catalogue

HOFFMAN-ECONOMY VERTICAL UNDERGROUND COND. PUMP

Where return lines are located below the floor, or otherwise too low for Horizontal Condensation Pumps, the Vertical Underground Pump should be used. No concrete pit is required as receiver is of heavy cast-iron suitable for underground use.

Ball bearing pump shaft is mounted in dust proof housing. Lower bearing is self lubricating and renewable without removing impeller from shaft or dismantling pump. Can be furnished in duplex unit or for high pressure by addition of horizontal booster pump. Float switch mechanism same as in Horizontal pumps.

Completely assembled and wired, ready for installation.



Capacity Table—Vertical Underground Condensation Pumps

Pump No.	Capacity Sq. Ft. Dir. C. I. Rad.	Pump Cap. G. P. M.	H. P. 10 lb. Dis. Pr.	Recvr. Dim. Ins.	Pump No.	Capacity Sq. Ft. Dir. C. I. Rad.	Pump Cap. G. P. M.	H. P. 10 lb. Dis. Pr.	Recvr. Dim. Ins.
U-30	3000	6	¼	16 x 30	U-120	12,000	24	½	24 x 36
U-50	5000	10	¼	16 x 30	U-200	20,000	40	½	24 x 36
U-80	8000	16	¼	18 x 30	U-300	30,000	60	1	30 x 36

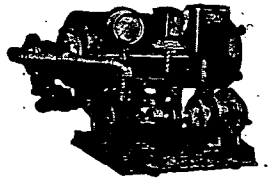
HOFFMAN-ECONOMY AIR LINE VACUUM PUMPS

Capacity Table—Air Line Pumps

Pump No.	Capacity Sq. Ft. Direct Radiation	Air Capacity Cu. Ft. per Min.	Motor H. P.
AL-1	4800	1¾	¾
AL-2	8000	4	1
AL-3	12,000	6	1½
AL-4	20,000	10	2
AL-5	30,000	15	3
AL-6	40,000	20	5
AL-7	60,000	30	5
AL-8	80,000	40	7½
AL-9	150,000	70	10

Hoffman-Economy Air Line Pumps are used for rapid removal of air from gravity installations using No. 3 Hoffman or "Paul" type air line valves. Does not handle condensate nor act as boiler feed pump.

Made in single or duplex units with capacities from 4,000 to 150,000 sq. ft. radiation.

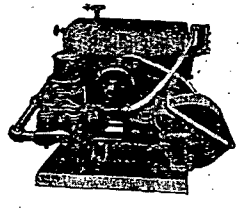


HOFFMAN-ECONOMY RECIPROCATING COND. PUMP

Hoffman-Economy Reciprocating Condensation Pumps are widely used in laundries, cleaning and dyeing establishments, etc., where steam pressures of 50 to 100 lb. are carried. These units are low in cost but are not as quiet as Centrifugal type, due to the slight pulsation at end of stroke and chain drive. Standard sizes range from 1,000 to 10,000 sq. ft. of radiation with discharge pressures of 50 and 100 lb. in each size.

Capacity Table—Reciprocating Pumps

Pump No.	Capacity Sq. Ft. Direct Radiation or Equiv.	Discharge Pressure Lbs. per Sq. In.	Pump Capacity Gals. per Min.	Motor H. P.	Receiver Capacity Gals.
R- 11	1,000	50	2	½	9
R- 12	1,000	100	2	¾	9
R- 31	3,000	50	5	½	13
R- 32	3,000	100	5	¾	13
R- 61	6,000	50	10	½	20
R- 62	6,000	100	10	1	20
R-101	10,000	50	16	1	26
R-102	10,000	100	16	2	26

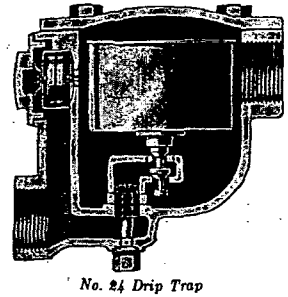


SALES AND SERVICE

Hoffman Products including Hoffman-Economy Pumps, are sold by Wholesalers of heating and plumbing supplies, assuring a convenient source of supply for the heating contractor.

The Hoffman Specialty Co. maintains trained representatives in the field who will gladly assist in the selection of equipment suitable for various services.

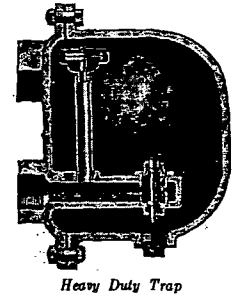
FLOAT AND THERMOSTATIC TRAPS



No. 24 Drip Trap

The new Hoffman Float and Thermostatic Traps are made in sizes from ¾" to 2" for every service where condensate in large quantities and air must be quickly and continuously discharged. Their wide capacity range adequately meets the requirements for proper drainage of risers, steam mains, unit heaters, blast coils, hot water generators and similar apparatus.

These traps contain a balanced double seated valve which permits the use of a direct acting float, making possible two very desirable features—compactness and large capacity.



Heavy Duty Trap Nos. 25, 26, 27 and 28

The double valve is assembled into a single unit screwed into the outlet casting. This permits easy removal for cleaning or renewal of seats. Access to the valve may be had without breaking pipe connections. The ports are deeply water sealed at all times and in addition a slight variation in the area of the upper seat insures a tight valve closure when required. Steam loss into the return, therefore, does not occur.

The discharge ports are located a considerable distance above the bottom of the trap body, permitting the accumulation of a quantity of scale and dirt before interfering with valve operation. In addition, the valves close against sharp edge seats minimizing the effect of dirt which may reach the ports.

Initial and entrained air is vented above the water line directly to the returns through a separate passage controlled by a sensitive thermal member.

Materials and workmanship are Hoffman quality throughout. The bodies and cover are of cast-iron, valve discs of wear resisting nickel alloy and seats of bronze.

The No. 24 Drip Trap has ¾" inlet and outlet connections. It is used for dripping risers, steam mains, unit heaters and other apparatus where a cooling leg is not practical or desirable. Designed for pressures up to 15 lbs. per square inch.

No. 25, No. 26, No. 27 and No. 28 Heavy Duty Traps have 1", 1¼", 1½" and 2" connections respectively. These traps are designed for all services requiring the use of a trap having large water and air capacity under pressures up to 30 lbs. per square inch.

Special folder, giving capacities, dimensions, etc., furnished on request.

Hoffman Specialty Co. of California, Ltd.

Pasadena, Calif.

Originators of the Electric Heater with a Fan

HOFFMAN THERMADOR ELECTRIC HEATERS

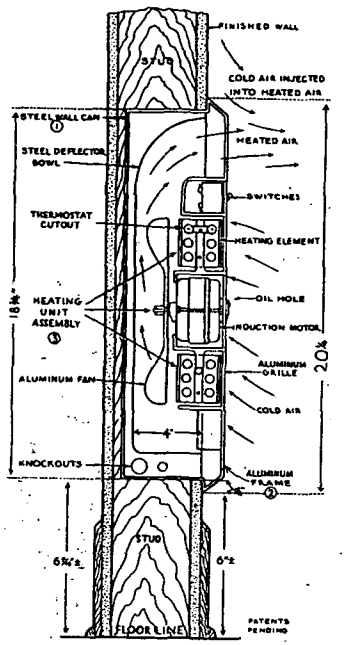
The Thermador embodies the fan-principle of electric heating, drawing in the cold air from the floor and redistributing warmed air quickly and gently throughout the entire zone. The Thermador successfully solves the problem of maintaining the greater amount of warmed air in the lower strata of the room atmosphere (the living zone) by the distribution of fan-circulated warmed air to every corner of the room. It likewise provides for cooler air circulation in the summertime.

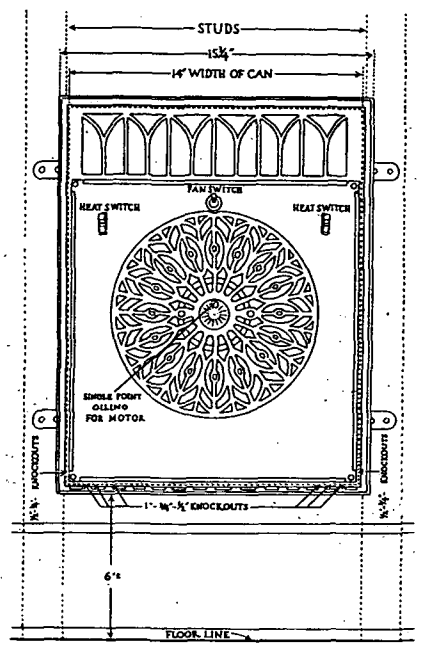
Thermador offers a most economical form of manually controlled electric heat because of its heat-speed and efficiency. Even greater heating economy may be realized with Thermador Thermostatic Control which will maintain temperatures within a two-degree limit. There is no over-heating waste, no under-heating inefficiency with Thermador Thermostatic Control.

The structural design of the Wall Insert Thermador is remarkably simple, permitting easy accessibility and installation. The unit consists of three parts: (1) the can; (2) the frame; (3) the heating unit assembly.

As the external dimensions of all three parts are the same regardless of the K. W. rating of the heating unit, heaters of any capacity may be interchanged in the frame. In very large rooms, requiring more than one heater, this also permits using heaters of uniform appearance.

Thermador Electric Heaters are listed by the Underwriters' Laboratories established and maintained by the National Board of Fire Underwriters.





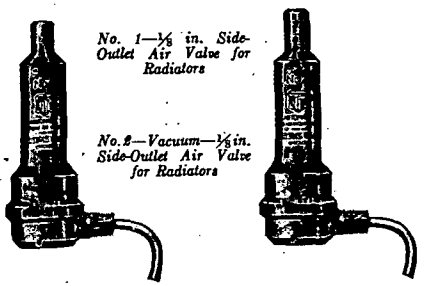
Manufactured complete by

Kelly Brass Works

226-232 West Ontario Street **Chicago, Ill.**

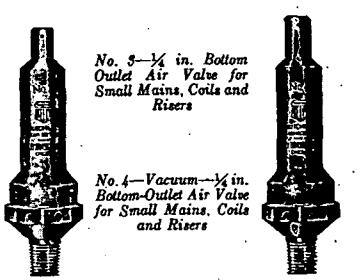
"Kelly" Non-Adjustable Automatic Steam, Air and Vacuum Valves

A complete line of 7 Automatic Non-Adjustable Valves that will fill every Air Valve Requirement for a Gravity One-Pipe Atmospheric or Vacuum Type Heating System.



No. 1—¼ in. Side-Outlet Air Valve for Radiators

No. 2—Vacuum—¼ in. Side-Outlet Air Valve for Radiators



No. 3—¼ in. Bottom Outlet Air Valve for Small Mains, Coils and Risers

No. 4—Vacuum—¼ in. Bottom-Outlet Air Valve for Small Mains, Coils and Risers

The outer shell of every "KELLY" VALVE is threaded into a **drop forged brass base** and the valves are substantially constructed of the best grade of materials throughout.

"KELLY" VALVES come in two types—"KELLY" Air Valves, scientifically designed to close against the escape of steam or water, and "KELLY" Vacuum Valves which in addition to closing against escape of steam or water have a special vacuum feature which prevents the intake of cold air and forms a vacuum in the radiator when the steam goes down, thus assuring quicker response to boiler temperatures.

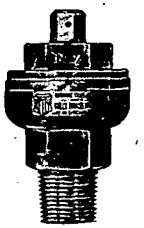
All "KELLY" VALVES are subjected to practical steam and vacuum tests before shipping and are

Guaranteed for Five Years



No. 5—⅜ in. Bottom-Outlet Quick Vent Air Valve for Large Mains and HV Stacks

NOTE.—Contains Float—will close against water.



No. 7—¾ in. Bottom-Outlet Quick Vent Air Valve for Large Mains and HV Stacks

NOTE.—Will not close against water.

No. 6—Vacuum—⅜ in. Bottom-Outlet Quick Vent Air Valve for Large Mains and HV Stacks

NOTE.—Contains Float—will close against water.



Send for complete descriptive circular

Illinois Engineering Company

General Offices and Factory: CHICAGO

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Boston	Denver	Houston	Minneapolis	Pittsburgh	Scranton
Buffalo	Des Moines	Indianapolis	Nashville	Portland	Seattle
Charlotte	Detroit	Kansas City	New Orleans	Providence	South Bend
Chattanooga	El Paso	Knoxville	New York City	Richmond (Va.)	Spokane
Cincinnati	Erie	Little Rock	Oklahoma City	Rochester	Syracuse
Cleveland	Evansville	Los Angeles	Omaha	St. Louis	Toronto
Columbus	Grand Rapids				Youngstown

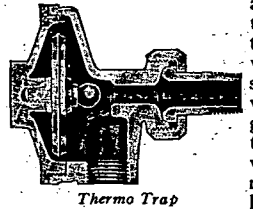
PRODUCTS—Illinois Heating Systems—Eclipse Steam Specialties

Illinois Heating Systems

Successfully installed in thousands of buildings—the result of over 30 years of special work in this line, and the ultimate in efficiency and economy.

Illinois Thermo Trap

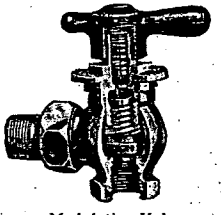
The original vertical seat trap. Dirt does not lie on seat—self-cleaning, non-adjustable, positive in operation; durable, will stand 50 lb. steam pressure which shows the great strength of the diaphragm, which is the reason for the long life and durability of these Traps. Thousands in operation for over 15 years without diaphragm replacements.



Thermo Trap

Illinois Modulating Supply Valve

Quick Opening—only a half turn of handle from open to closed position. Packless, Bakelite handle, steam tight on 50 lbs. pressure. Large diameter of thread spool and machine cut threads make valve easy of operation. The improved Bakelite handle insulates the hand from heat.



Modulating Valve

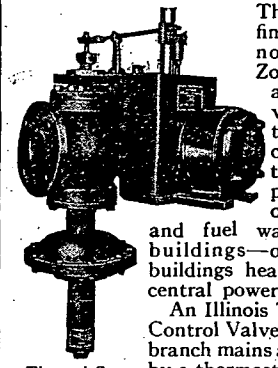
The graduated dial shows the open or closed or any position of the valve.

Furnished with Lock Shield and Key, or with Bakelite Wheel handle, upon order.

Illinois Vapor Systems

Illinois Vapor Systems are capable of operating automatically on any pressures possible in a low pressure heating system—from 10 lb. to 20 in. of vacuum. Our improved equipment actually insures operation under vapor—less than atmospheric pressure—with only two or three firing periods per 24 hrs. The advantages are healthful, modulated heat, and a *fuel saving of 25-30 per cent* over other systems of heating.

Illinois Thermal-Zone Control



Thermal-Zone Control

The added refinement of Illinois Thermal-Zone control to an Illinois vacuum system is the logical answer to the problem of preventing overheating and fuel waste in large buildings—or groups of buildings heated from one central power plant.

An Illinois Thermal-Zone Control Valve is installed in branch mains and controlled by a thermostat in the zone or section heated by such mains. The valve will shut off when zone is up to temperature and open when temperature at thermostat falls.

This stops all overheating and steam waste by controlling the steam not only in the radiator but *also on the piping*—therefore effecting an additional saving over systems controlling only the radiators.

Buildings may be zoned as to occupancy; as to time (Program and Cycle); geographic location; exposure, wind and sun; and so on.

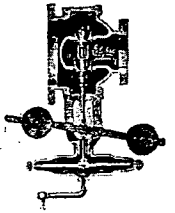
The system in addition can be arranged to control the operation of fuel burner and vacuum pump. It is entirely automatic in operation. No adjustments are required by engineer for varying pressures or temperatures. The installation is regular, the apparatus simple, as all zones are operated from *one* pump and not a separate pump on each zone. Write for Bulletin 61.

ILLINOIS PRODUCTS—Eclipse Steam Specialties

Eclipse Steam Specialties

The old John Davis Co. Eclipse Steam Specialties have been on the market for over 40 years, and embody the improvements and refinements suggested by this long period of service. These Specialties are quality products, having bronze and monel metal pistons, seat rings and valve parts, the bodies are extra heavy, and every piece of apparatus is carefully steam tested—under working pressure where same is given—before shipment.

Pressure Reducing Valves, for all pressures and services.
Back Pressure, and *Atmospheric Relief Valves.*
Separators, Oil and *Steam, Cast-Iron* and *Steel.*
Steam Traps, all pressures.
Non-Return or *Stop* and *Check Valves.*
Pump Governors, Balanced Valves.
Float Valves, Expansion Joints, Pipe Strainers.



Reducing Valve

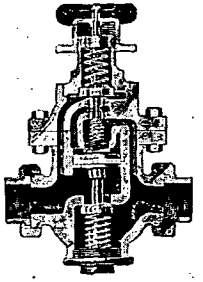
Reducing Valves. In general use on Vacuum or low pressure Heating Systems. Will reduce to 4 oz. pressure from even 150 lb. initial pressure.

The large diaphragm insures sensitive operation.

Made in both straight-way and expanded outlet bodies.

Sizes ¾ in. to 12 in.

Eclipse Master Reducing Valve

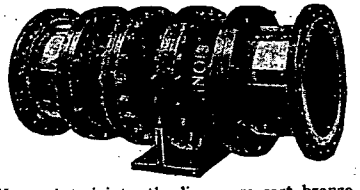


A pilot type valve will reduce from any pressure up to 250 lb. down to 10 lb. and hold reduced pressure constant at all times—even against a "dead end" pipe.

Made of Bronze with monel valves and trimmings.

Sizes ½ in. to 6 in.

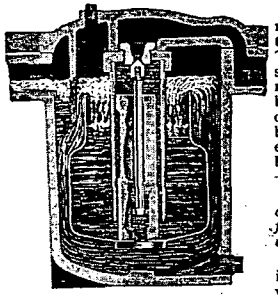
Illinois Expansion Joints - Single and Double Traverse



Heavy duty joints, the liners are cast bronze—not brass tubing. The bolts are through bolts, no stud bolts used.

Tapped for service connections in anchor section if desired.

Eclipse Steam Trap



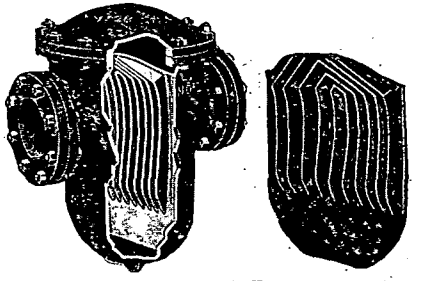
Something new in Steam trap design. The valve and stem are separate from the bucket and only operated by the bucket at its extreme top and bottom travel —*Result*—

Valve is always either full open or tight closed.

No wire drawing or cutting of valve and seat, which are of monel metal. Steam tight and long lasting.

Bulletin No. 34 describes in detail.

Horizontal Oil Separator

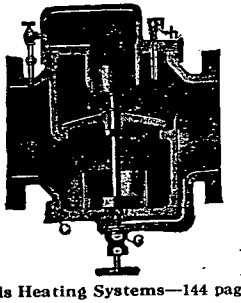


These Separators have a baffle removable without disturbing the piping. Occasional cleaning is necessary for proper elimination of oil.

The port areas are over 3 times the diameter of the pipe area, hence these separators are effective.

Eclipse Back Pressure and Combination Relief Valves

Made in Vertical and Horizontal types, straight-way or angle pattern, for condensing and non-condensing engines.



It is noiseless and works equally well on pressure or vacuum, air cushioned by back pressure in dashpot. Constructed entirely of metal with no springs; wearing parts of special bronze.

Size 4 in. to 36 in.

Catalog and Bulletins—Illinois Heating Systems—144 pages

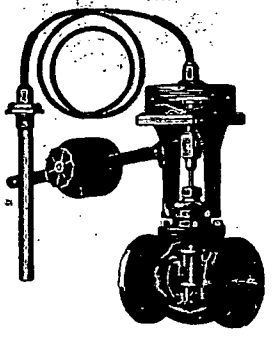
BULLETINS

No. 14—Heating Specialties.
No. 22—Vapor System Details.
No. 45—Non-Return Valves.
No. 61—Thermal-Zone Control.
No. 105—Pressure Reducing Valves.
No. 204—Back Pressure, and Relief Valves, Exhaust Heads.
No. 34—Steam Traps.
No. 54—Separators—Oil and Steam.
No. 204—Float and Balanced Valves.

Klipfel Manufacturing Co.

2641-2659 West Harrison Street :-: Chicago, Ill.

Manufacturers of Automatic Valve Specialties

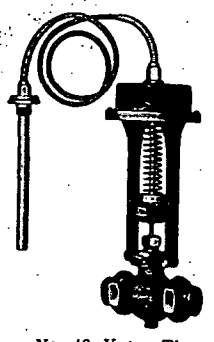


No. 48 Vapor Thermostat, Lever Type

Sizes: ½ to 8 in., inclusive. Bronze bodies in sizes 1½ in. and under, union connections only. Iron bodies in sizes 2 in. and above, flanged ends only.

No. 48 Vapor Thermostats.—Automatically maintain hot water in steam heated tanks at any desired temperature between 140° and 180°; but can be made special for other temperatures. A complete operating unit within itself—it is self-contained. No compressed air, water, electrical, or other auxiliary power required. Lever of lever type is fitted with roller bearings to insure frictionless operation.

The sensitive all-metal bellows will move the inner valve farther on a given temperature-pressure change than any competing bellows of the same diameter and length.



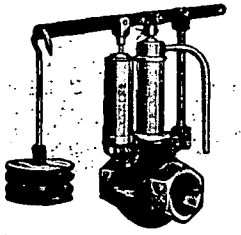
No. 49 Vapor Thermostat, Spring Type

Sizes: ½ to 2½ in., inclusive. Bronze bodies in sizes 1½ in. and under, union connections only. Iron bodies in sizes 2 in. and above, flanged ends only.

No. 49 Vapor Thermostats.—Similar to the No. 48 Vapor Thermostat, except that a spring is used instead of a lever and weight. The spring type may be used where space does not permit the use of the lever type and where extreme sensitiveness and a wide range of temperature adjustment are not required. The semi-balanced, bevel seated, bronze inner valve is normally held open by a spring. An increase of temperature of a volatile fluid hermetically sealed within the temperature sensitive bulb, which is installed in contact with the medium, causes the bellows to expand and operate the inner valve.

No. 1 Pressure Regulators.—Automatically reduce any initial steam, air or water pressure to any desired reduced pressure down to 2 lb. and maintain reduced pressure constantly regardless of fluctuations in initial pressure, or changes in the demand for steam. When specified for the control of air or water, the piston is provided with special leather cup packing.

Can be furnished with expanded outlet in sizes 1x2 to 12x24 in., inclusive.

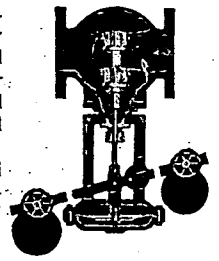


No. 1 Pressure Regulator, Piston Type

Sizes: ⅜ to 14 in., inclusive. Bronze bodies in sizes 1½ in. and under, screwed ends only. Iron bodies in sizes 2 in. and above; 2 to 6 in., inclusive, screwed or flanged ends, but screwed ends will be furnished unless otherwise specified; sizes 7 in. and above, flanged ends only

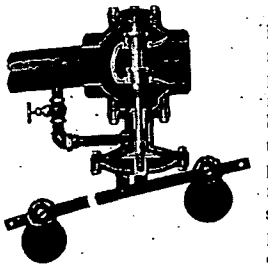
No. 38 Pressure Regulators.—Intended for use with steam, air, water or gas where accurate and dependable very low reduced pressures are required. Particularly suited for reduced pressures below atmosphere. Will constantly maintain reduced pressure regardless of initial pressure fluctuations or changes in the demand for steam. Inner valves and seats are made of bronze and are bevel seated.

Can be furnished with expanded outlet in sizes 1x2 to 12x24 in., inclusive.



No. 38 Pressure Regulator, Diaphragm Type

Sizes: ⅜ to 14 in., inclusive. Bronze bodies in sizes 1½ in. and under, screwed ends only. Iron bodies in sizes 2 in. and above; 2 to 6 in., inclusive, screwed or flanged ends, but screwed ends will be furnished unless otherwise specified; sizes 7 in. and above, flanged ends only.

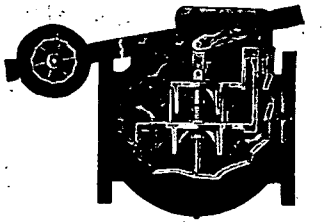


No. 3 Pressure Regulator, Diaphragm Type

Sizes: ⅜ to 14 in., inclusive. Bronze bodies in sizes 1½ in. and under, screwed ends only. Iron bodies in sizes 2 in. and above; 2 to 6 in., inclusive, screwed or flanged ends, but screwed ends will be furnished unless otherwise specified; sizes 7 in. and above, flanged ends, only.

No. 3 Pressure Regulators—Automatically reduce any initial steam pressure to any desired reduced pressure, either below atmosphere or up to 5 lb. above atmosphere, and constantly maintain reduced pressure regardless of initial pressure fluctuations or changes in the demand for steam. Includes no packing box, thus eliminating leakage and friction on valve stem. Inner valves and seats are bronze, bevel seated.

Can be furnished with expanded outlet.

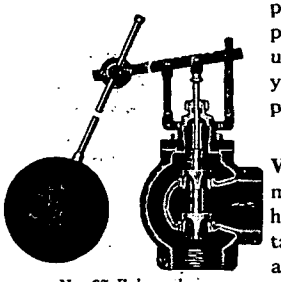


No. 28 Noiseless Back Pressure Valve

Sizes: 2 to 24 in., inclusive. All sizes made with iron bodies and with flanged ends; sizes 2 to 8 in., inclusive, also made with screwed ends. Unless otherwise specified, sizes 6 in. and under will be shipped screwed ends; sizes 8 in. and above with flanged ends.

No. 28 Noiseless Back Pressure Valves.—Automatically and noiselessly maintain any desired back pressure on exhausts of non-condensing engines. Because of the patented construction, inner valve is effectively stabilized and can not pulsate in unison with the stroke of the engine. Operated in either horizontal or vertical position. Preferable installation is in horizontal pipe line. Iron bodies, bronze inner valves and trimmings.

No. 27 Balanced Float Valves.—Automatically control the supply of cold water to open tanks, so as to maintain a practically constant water level. The inner valve consists of two perfectly balanced bronze plunger discs, and is unaffected by the water pressure. Can be furnished with bevel seated valves at an extra price. Angle and globe patterns, with seamless copper float, for working pressures up to 200 lb. Swivel guide yoke can be turned to any position.

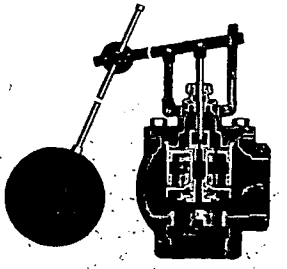


No. 27 Balanced Float Valve

Sizes: ⅜ to 20 in., inclusive. Bronze bodies in sizes 1½ in. and under, screwed ends only. Iron bodies in sizes 2 in. and above; 2 to 6 in., inclusive, screwed or flanged ends, but screwed ends will be shipped unless specified otherwise; sizes 7 in. and above, flanged ends, only. All sizes 14 in. and under made angle or globe patterns, but angle pattern will be shipped unless specified globe. Sizes 16 in. and above made globe patterns, only.

No. 7 Single Seated Float Valves.—Automatically maintain a constant level of hot or cold water in open tanks. Single seated, auxiliary operated. Seat equal to pipe size. Swivel guide yoke allows the float to be turned to any position. Includes a packing box with gland to prevent leakage past the valve stem.

Angle and globe patterns, with seamless copper float, for working pressures up to 200 lb.



No. 7 Single Seated Float Valve

Sizes: ¾ to 12 in., inclusive. Bronze bodies in sizes 1½ in. and under, screwed ends only. Iron bodies in sizes 2 in. and above; 2 to 6 in., inclusive, screwed or flanged ends, but screwed ends will be shipped unless specified otherwise; size 8 in., flanged ends only. Sizes 8 in. and under made angle or globe patterns, but angle pattern will be shipped unless specified globe. Sizes 10 and 12 in. made to order, flanged ends, globe pattern only.

Kieley & Mueller, Inc.

Manufacturers of Specialties for Steam, Water, Air, Oil and Gas

34 West 13th Street — **Agents in all Principal Cities** — New York City

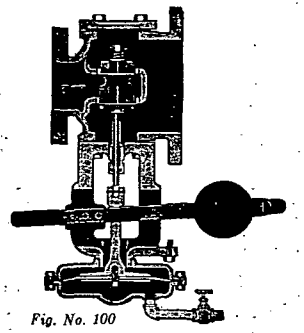


Fig. No. 100

No. 100 Diaphragm Lever and Weight Pressure Reducing Valve for all services and normal pressures. Single or double seated in sizes ⅜″ to 16″. Also made spring weighted.

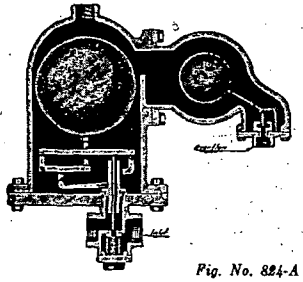


Fig. No. 824-A

No. 824-A Duplex Water Feeder—A feeder of large capacity with Direct to Boiler principal. Constructed with integral Strainer and monel metal valve parts for trouble-free performance. Simplex type for small boilers is No. 800, for large boilers No. 816.

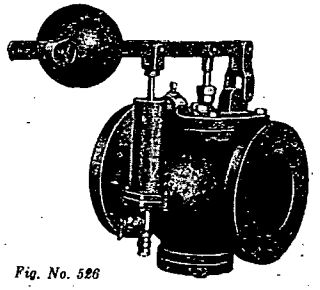


Fig. No. 526

No. 526 Back Pressure and Atmospheric Relief Valve—This valve may be used where the plant is operated either condensing or non-condensing. An outside air dash pot insure noiseless operation. Made horizontal or vertical lever and weight or spring operated.

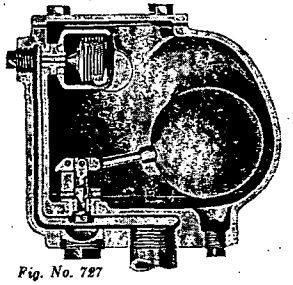


Fig. No. 727

No. 727 Thermostatic Float Operated Steam Trap—*This is a trap of large* capacity with an automatic air vent which makes air binding impossible. Open bucket traps without automatic air vent are available for any pressure.

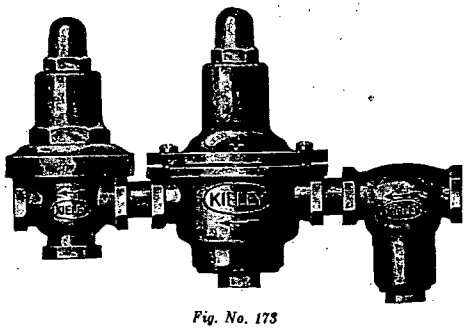


Fig. No. 173

No. 173 Hot Water System Control Unit—A closed system without an expansion tank is made possible with this unit. Economy and better performance result from its use. The Reducing Valve is made with full opening and will quickly fill the system when first installed. The Relief Valve is sealed to prevent tampering. The Strainer protects both valves from foreign matter.

J. E. Lonergan Co.

207 Florist Street, **Philadelphia, Pa.**

Pop Safety Valves; Relief Valves; Steam Gauges; Hydraulic Gauges; Air Gauges; Water Gauges; Pressure and Temperature Gauges; Test Gauges; Gauge Boards; Oil Gauges; Clocks; Counters; Gauge Cocks; Steam Gauge Syphons; Lubricating Specialties.

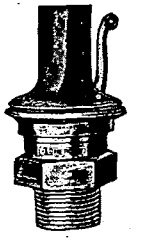


Model "GLP"

Low Pressure, Iron Body, Brass Mounted.

Set to blow off at 10, 15, 20, 25 or 30 lb.

Five sizes—2½ to 4½ in.



Model "HHU"

Pop Safety Valve A.S.M.E. "House Heating Boiler."

Standard pressures, 5. 10 and 15 lb.



Model "WRV"

Water Relief Valve for tank service.

Sizes ⅜, ½ and ¾ in.



Model "VAK"

Special valve for vacuum breaking.

Six sizes, ½ to 2 in.



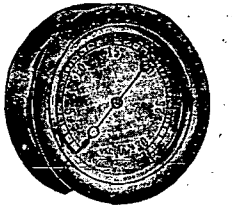
Model "U"

Relief Valve.

Snifter, Water or Cylinder—Bronze.

Recommended for steam engines, pumps, pipe lines, etc.

Ten sizes, ½ to 4 in.

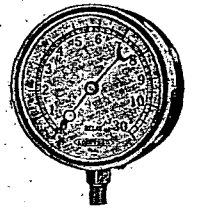


Model "GV"

Vacuum Gauge.

Gauges graduated to 30 in. vacuum.

Ten sizes, 2½ to 10 in. dial.



Model "BLGR"

Gauge for indicating height of water in feet.

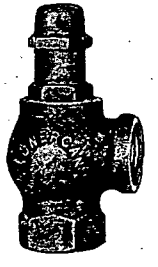
Graduation 70 ft.

Three sizes, 3½, 4½ and 5 in dial.

Model "ORV"

Oil Relief Valve.

Sizes ⅜ to 2 in.



Model "GOZ"

Vapor Gauge.

Graudated to 5 lb. by ounces.

Two sizes, 4½ and 5 in. dial.

Model "BLGB"

Tank in basement type of gauge for closed heating systems.

Made in two- and three-story calibrations only.

One size, 3½ in. dial.

Model "BLGW"

For either pressure or altitude, or combination of both.

Graduation 30 lb., 70 ft.

Two sizes, 3½ and 4½ in. dial.

Model "BLGA"

Pressed steel case gauge for indicating height of water in feet. Graduation 70 ft.

Three sizes, 3½, 4½ and 5 in. dial.

CATALOGUE

Write for our new 100-page catalogue, describing and illustrating the complete "Lonergan Line" or ask us about specialties in which you are interested.

Mason Regulator Company

Dorchester Center

Boston, Massachusetts

Branches in Principal Cities

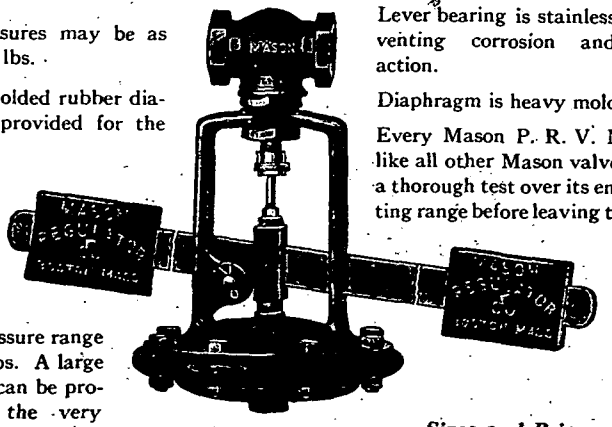
Mason Lever-and-Weight P. R. V. No. 236-A

Application—

Mason No. 236-A Pressure Reducing Valve is widely employed in heating systems requiring accurate regulation at low pressures.

Initial pressures may be as high as 150 lbs.

A special molded rubber diaphragm is provided for the reduced pressure range of 2 to 15 lbs. A large diaphragm can be provided for the very delicate regulation, in ounces, of reduced pressures below 3 lbs.



All castings are heat treated to prevent distortion.

Stuffing box and valve stem are designed for minimum friction.

Lever bearing is stainless steel, preventing corrosion and sluggish action.

Diaphragm is heavy molded rubber.

Every Mason P. R. V. No. 236-A, like all other Mason valves, is given a thorough test over its entire operating range before leaving the factory.

Operation—

Mason P. R. V. No. 236-A is particularly adapted for low pressure systems in which the initial pressure may at times fall below the set reduced pressure. The valve is normally open; it closes only when the reduced pressure rises to the set limit and, working against the diaphragm, balances the weight-and-lever system.

Construction—

Main valve, valve seats, and valve body made of hard steam bronze, machined to extremely close limits to assure permanent alignment and fit. Positive clearance.

Sizes and Prices

Sizes	7⅝ In. Diaphragm for Reduced Pressures 2 to 15 Lbs.	11 In. Diaphragm for Reduced Pressures 0 to 3 Lbs.
½"	$28.50	$35.50
¾"	31.00	38.00
1"	35.50	42.50
1¼"	39.50	46.50
1½"	44.00	51.00
2" to 6"	On Application	On Application

Send for Catalogs—

For complete descriptions of Mason P. R. V. No. 236-A and other Mason reducing and vacuum regulating valves, address the factory, or your Mason distributor.

JAS. P. MARSH & COMPANY

FOUNDED IN 1865

2073 Southport Avenue, **Chicago, Ill.**

Branches

551 Fifth Avenue, New York, N. Y.
Bendix Building, Los Angeles, Cal.
2539 Pennsylvania Ave., Washington, D. C.

In Canada: The Jas. Morrison Brass Mfg. Co., Ltd., Toronto, Ont.

Sales Offices in Principal Cities

Marsh Units | Marsh Systems | Marsh Instruments

The Company

Jas. P. Marsh & Company have been manufacturers of heating equipment and precision instruments for 66 years. These pages include brief descriptions of the Marsh System Units for installation on the heating systems noted on this page; medium pressure specialties, gauges and instrument panels.

The Marsh Weather Compensating System

Marsh Weather Compensating System of Heating

The Marsh Weather Compensating System of Heating is based upon well known principles. Modern apparatus and application of these principles comprise the means of effecting absolute control of heat output as required. (1) Temperature at which water boils depends entirely on the pressure exerted upon it. Likewise, volume of steam depends upon pressure, whether from an outside source or its own generation. The amount of heat required to generate steam and the consequent heat output of a given volume of steam varies with the pressure (or vacuum). (2) A radiator or other condensing unit can assume steam only as the air and non-condensable gases, which accumulate are purged. By controllably limiting the flow of these gases from the radiator the amount of steam entering the radiator is varied in proportion to the increase or decrease of pressure (or vacuum) in the system. The Marsh Weather Compensating System has such flexible features that the volume and temperature of steam delivered to the radiators are directly proportioned to correspond with the heat demand required for prevailing weather conditions. In its construction aspects, it is similar to the two-pipe vacuum system. Steam is supplied either by means of a boiler or from an outside source. A vacuum pump is employed to create circulation and to withdraw air and condensate.

The Marsh Compensating Supply Control is placed in the supply mains. This control governs the pressure (or vacuum) and regulates the amount and temperature of the steam distributed throughout the system.

Each radiator is controlled by a Marsh Compensating Radiator Trap. This trap operates to pass all water of condensate and to retain within the radiator, steam at all temperatures and pressures and to controllably limit the portion of the radiator available for steam by entraining the air and non-condensable gases in quantities which are varied by the pressures (vacuum) within the radiator.

The Marsh Standard Vacuum System of Heating

The Marsh Standard Vacuum System of Heating is a two-pipe system especially adaptable to larger buildings. It circulates steam at low pressures from a boiler, central station or by utilizing exhaust steam. Rapid circulation is secured by a mechanically created vacuum in the return. Large or small condensing units may be used with appropriate Marsh System Units.

The Marsh Vapor System

The Marsh Vapor System of Heating is a two-pipe system which rapidly circulates vapors at low pressures. In mild weather steam at a few ounces of pressure or under vacuum is sufficient to care for heat requirements. Circulation is maintained by the Marsh System Unit Equalizer and Boiler Return Trap.

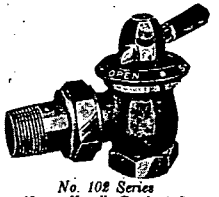
The Marsh One-Pipe System

The Marsh System Unit Radiator Valve, together with the Marsh Air and Vacuum Valve, make the Marsh One-Pipe System ideal for small installations, eliminating many weaknesses heretofore inherent in one-pipe systems.

MARSH SYSTEM UNIT RADIATOR VALVES

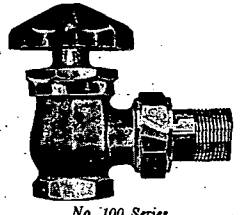
Description

The Marsh System Unit Radiator Valve combines beauty with mechanical perfection. Now, radiator fittings as well as radiators themselves may be worked into interior design and be in keeping with the finest of furnishings.

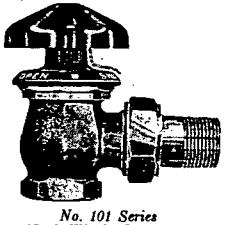


No. 102 Series
(Lever Handle Graduated)

This New Marsh Radiator Valve is modern in design. The simplicity of its lines, the two-tone polished and satin chrome or nickel body finish, crowned by a control wheel or lever of bakelite of distinctive proportions, places this heating necessity abreast of modern trend.



No. 100 Series
(Oval Wheel Packless)



No. 101 Series
(Oval Wheel—Graduated)

The Marsh System Unit Radiator Valve is truly packless. Its packless feature is not subject to deterioration, wear or cracking. We have confidence in the principles upon which it has been designed. These principles have proven as sound as they are new.

In the Marsh System Unit Graduated Type Packless Radiator Valve a means is provided whereby the total capacity of the valve is adjusted in proportion to the size of the radiator, operating the valve so as to limit the flow through the valve in graded quantities. The flexcone valve disc, together with the valve seat, form an orifice arrangement which as the flexcone valve disc is raised and lowered modulate the area through which the steam or liquid can flow and in that way graduate the capacity of the valve.

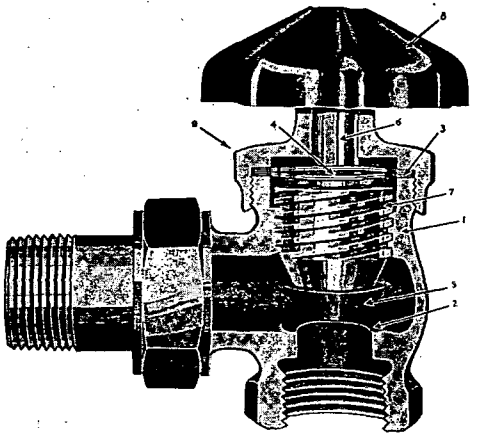
An indicator and dial act to guide the operator of the valve as to the proper setting for the desired flow.

Laboratory tests of Marsh System Unit Valves calculated definitely to prove the efficiency and perfection of the unique construction, have subjected these units to service many times that of normal operation.

Patterns and Sizes

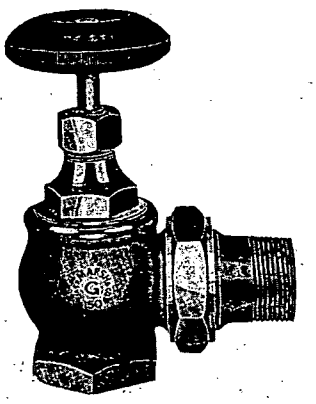
Marsh System Unit Radiator Valves are made in three series: No. 100 series oval wheel packless; No. 101 Series oval wheel graduated and No. 102 series lever handle graduated. All three series are made in sizes ½ in., ¾ in., 1 in., 1¼ in., 1½ in. and 2 in. in the following patterns: angle, right hand corner, left hand corner, globe and back offset. Extensions and other valve accessories on next page.

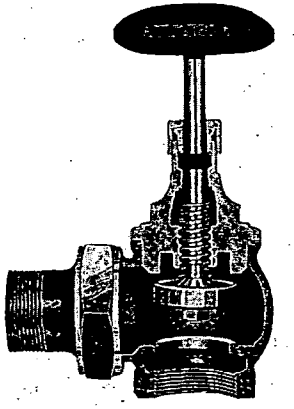
Construction



The body of the valve (1) is a steam bronze casting accurately machined and tested to 125 pounds pressure. The valve seat (2) is built integrally into the valve body and in combination with the Flexcone valve disc (5) permits a large, full capacity flow through the valve. The lift thread in which the thrust screw (7) operates is cut integrally into the main body casting, allowing a large deep thread and adding strength to the body casting. The patented Flexcone valve (5) is a drawn monel metal spring cup permanently riveted to the thrust screw. Integrally incorporated in the valve stem is a perfectly machined stem collar (4) which in conjunction with the Metalflex sealing discs (3) serve to make the valve perfectly packless. These sealing discs consist of two sets of thin metal diaphragms. The valve bonnet (9) is screwed onto the valve body around the valve stem (6), lining up the latter and at the same time compressing the upper set of Metalflex discs against the lower set, forming a perfect seal. The valve wheel (8) is made of bakelite.

MARSH TYPE G 150 STEAM RADIATOR VALVE





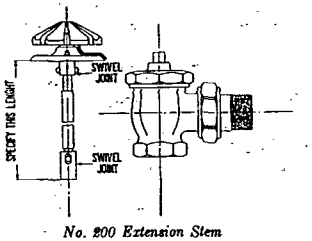
Government Pattern

The Marsh Type G 150 radiator valve is a heavy 150 lb. construction steam radiator valve. As shown by the illustration this valve is of rugged construction. The body and bonnet castings are of steam bronze and wall thicknesses throughout are much heavier than usually found in valves of this type. The stem is of large diameter and the operating thread is perfectly machined and is of design to give lasting, smooth operation. The packing gland, follower and nut are of ample proportion and make provision for a lasting joint for service on pressures or vacuum. When the valve is screwed full open a tight joint is formed between the top of the disc holder and the inside surface of the valve bonnet, permitting repacking of the valve under pressure or vacuum without leakage. This also prevents any possibility of the valve jamming or sticking in the open position.

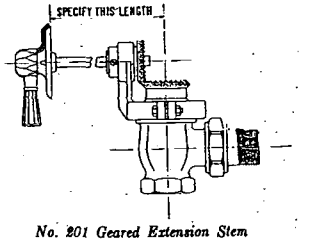
The Marsh Type G 150 steam radiator valve is standard in angle pattern only, and in 1 in., 1¼ in., 1½ in. and 2 in. sizes, but can be manufactured in other patterns.

We also manufacture a complete line of standard low pressure steam and hot water radiator valves and union ells.

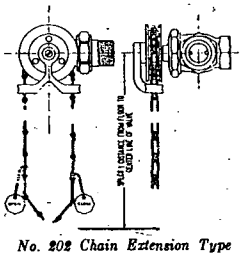
RADIATOR VALVE ACCESSORIES



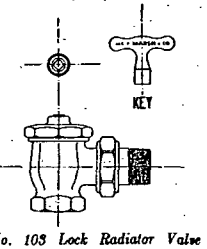
No. 200 Extension Stem



No. 201 Geared Extension Stem



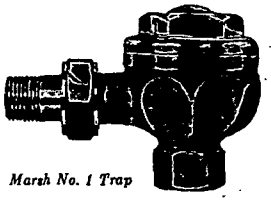
No. 202 Chain Extension Type



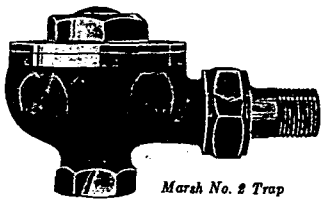
No. 103 Lock Radiator Valve

MARSH SYSTEM UNIT THERMOSTATIC RADIATOR TRAPS

Like Marsh System Unit Valves, these traps are made in two-tone lustrous polished and satin finish in either chrome or nickel. It is the function of the Marsh System Unit Radiator Trap, installed at the outlet of the radiator, to retain steam within the radiator until it has given up its heat units. It is equally essential that all water of condensate, air and gases be passed out of the radiator into the return system. This is dependent upon the sensitive operation of the thermostatic diaphragm within ranges where steam, water and air are at temperatures varying only slightly from each other.



Marsh No. 1 Trap



Marsh No. 2 Trap

Installed upon the radiator it has a second important function; that of automatically maintaining the necessary difference in pressure or vacuum between supply and return systems, assuring circulation throughout the heating system.

Marsh System Unit Thermostatic Traps are manufactured in two styles: The Marsh No. 1 Series, made in ½ in. connection size only, and the No. 2 Series, made in three sizes, ½, ¾, and 1 in. The No. 1 Series is obtainable in the following patterns: Angle, Straightway, Right Hand, Left Hand and Back Offset. The same patterns are supplied in the ½ in. No. 2 Series. The ¾ and 1 in. sizes of No. 2 Series have the following patterns: Angle, Right Hand, Left Hand and Back Offset.

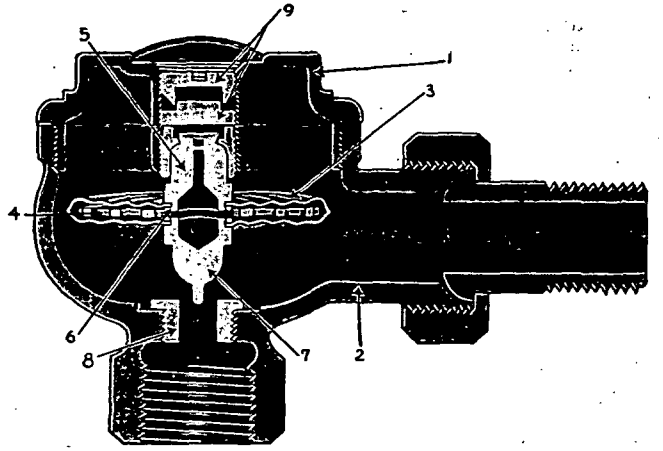
CAPACITIES

No. 1 Series Radiator Trap

Sizes	Sq. Ft. C. I. Radiation
½" x ½" connection	150

No. 2 Series Radiator Trap

Sizes	Sq. Ft. C. I. Radiation
½" x ½" connection	200
¾" x ¾" connection	500
1" x 1" connection	1000

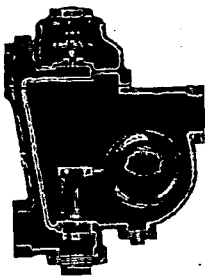


The body (2) is a steam bronze casting accurately machined and tested to 125 pounds working pressure. Modern methods of machining on all parts, including the body (2) and bonnet (1) are employed, gauged by micrometer scale with a tolerance of .007 inches. The traps are built with renewable seat (8) made of a hard brass screw machine part.

The expansible portion of the thermostatic diaphragm assembly consists of an upper and lower wafer of tinned phosphor bronze, drawn and spun to perfection of temper. The lower wafer is fastened to the valve needle (7) which consists of a tinned brass screw machine part spun and sweated to the diaphragm wafer. The upper diaphragm wafer is spun and sweated to the adjustment screw assembly consisting of two parts combined to form the adjustment screw (5) and swivel. When the two wafers are assembled, projection on both the upper post (5) and the valve needle (7) combine to form a matched fit when the diaphragm is completely compressed. An interior reinforcement arrangement (4) forms a perfect inner ring reinforcement between the upper and lower wafers.

MARSH SYSTEM UNIT TRAPS

Marsh No. 8 Drip Trap

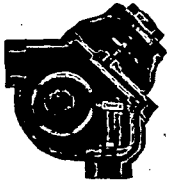


This trap is continuous in discharge and is designed to quickly remove condensation and air from drip points on steam mains, steam risers, steam coils, or blast heaters or for any like service within the capacity of the trap. The design permits a deep water seal on the discharge. The thermostatic bypass member is the same as in the Marsh No. 1 Radiator Trap. Body of trap is provided with one 1¼ in. tapped inlet and two 1¼ in. outlet openings. It may be suspended directly in the piping.

Capacities

Steam Pressure, lb.	Capacities Water per Hour, lb.
½	500
1	900
2	1400
3	1600
4	1800
5	2000
10	3200
15	4000

Marsh No. 12 Drip Trap



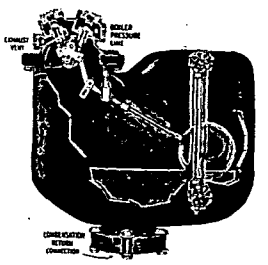
Designed for removal of air and condensation from short steam mains, branches or risers, unit heaters, steam coils, etc. Condensation is removed through a float operated valve located at the lowest point inside the body. Air removal is located in a thermostatic bypass in the cap of the trap. The thermostatic member is interchangeable with the member of the standard No. 1 Radiator Trap.

Capacities

Steam Pressure, lb.	Capacities Water per Hour, lb.
½	350
1	600
2	800
3	1200
4	1400
5	1600
10	2000
15	2800

Marsh No. 10 System Unit Equalizer and Boiler Return Trap

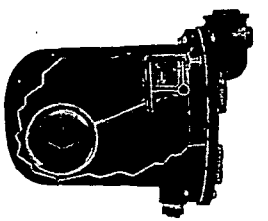
This unit, installed on Marsh Vapor Systems, performs the two functions of equalizing the vacuum between the supply and return piping and returning water to the boiler. It eliminates the installation of additional piping and guarantees protection to the boiler. This trap is made in sizes up to 10,000 sq. ft. capacity and can be installed in series for large installations.



Equalizer and Boiler Return Trap

Marsh System Unit Air Trap

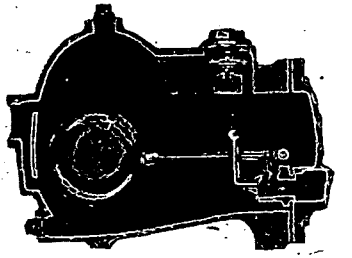
This unit vents the air from return piping of Marsh Vapor Systems. It also vents air and exhaust vapor from the return trap. A ball float mechanism permits the escape of air and prevents the leakage of water.



This trap is made in one size to handle installations up to 10,000 sq. ft. of radiation.

Marsh System Unit No. 14 Heavy Duty Trap

The Marsh No. 14 Float and Thermostatic Heavy Duty Trap is designed to handle very large volumes of water and air and for service on air heating coils, hot water and storage heaters, steam headers, large steam mains, etc.

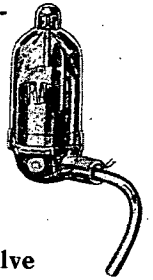


Capacities

Size	1 lb.	3 lb.	5 lb.	10 lb.	15 lb.	20 lb.	25 lb.
1 in.	1900	3260	4180	5800	7100	8000	9200
1¼ in.	4180	7140	9170	12000	14600	17700	19700
1½ in.	6200	8400	12000	18400	24000	29450	34800
2 in.	8200	14500	19000	26500	34900	38400	44700

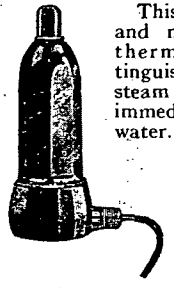
MARSH AIR VENTS

Marval Syphon Automatic Air Valve



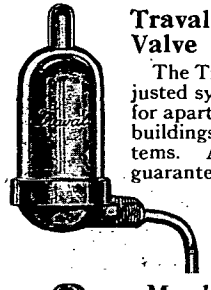
This is a popular priced dependable, all-metal, factory adjusted valve. Will vent air rapidly, closes for steam and shuts off to water. Furnished in ⅛ in. angle and straight shank in ⅛, ¼ and ¾ in. sizes.

No. 1 Syphon Air Valve



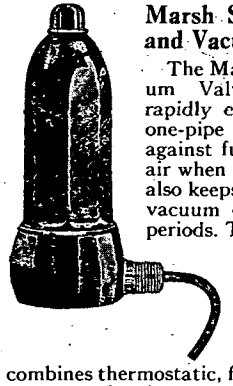
This valve assures positive and noiseless venting. The thermostatic action distinguishes instantly between steam and heated air. It closes immediately to steam and water. It is especially adapted to cast-iron radiation and is suitable for copper radiation. Furnished in angle and straight shank types, ⅛ in. and also straight shank in ¼ and ¾ in.

Travall Syphon Air Valve



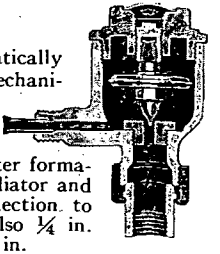
The Travall is a factory adjusted syphon valve designed for apartment and residential buildings with gravity systems. A low priced valve guaranteed to function satisfactorily. Supplied in ⅛ in. angle type and ⅛ and ¼ in. straight shank.

Marsh System Unit Air and Vacuum Valve



The Marsh Air and Vacuum Valve functions to rapidly eliminate air from one-pipe systems and seal against further intrusion of air when pressure drops. It also keeps the system under vacuum during heating-up periods. This permits steam to circulate under low pressures or vacuum, the radiators retaining heat for a much longer period. It combines thermostatic, flotation and vacuum operation in one operative part. It is fully guaranteed. Made in ⅛ in. angle pattern, ⅛, ¼ and ¾ in. straight pattern.

No. 3 Air Line Valve



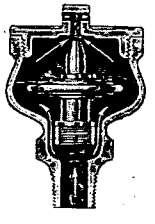
Operates automatically with or without mechanical suction. Passes all air, closes instantly to steam. No pockets for water formation. ⅛ in. to radiator and ¼ in. union connection to return air line. Also ¼ in. x ⅜ in. and ⅜ x ⅜ in.

No. 5 Rapid Vent



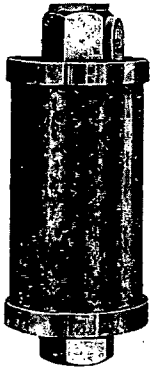
For installation at ends of steam mains, return mains, tops of risers where large volumes of air require rapid venting without escape of steam or water. Also operates to close on vacuum and to prevent re-entry of air. On vapor systems this vent is placed at ends of steam mains. Operates up to 10 lbs. pressure. ⅜ and ¾ in. connections.

No. 6 Quick Vent



Made without float, does not close against water. Cannot blow shut on air pack. Vents at the slightest pressure. Has large air port. Factory tested for 10 lbs. pressure. Shipped without vacuum top unless otherwise specified. ¼ or ⅜ in. male bottom connection.

No. 7 Air Eliminator

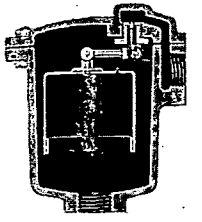


Designed for return main use. Vents all the air at any temperature. Has vacuum top. Assures free and unlimited vent of all air, hot or cold. Cannot water-log does not spit or leak water. Closes instantly to steam or vapor. Adjusted and tested at factory to work automatically from below atmosphere to 10 lbs. steam pressure. Made in ¾ or 1 in. connection.

MARSH MEDIUM PRESSURE STEAM TRAPS

No. 500 Steam Trap, Inverted Bucket Type

Ideal for use on equipment handling large volume of condensate up to 125 lbs. pressure. Self-venting, combined with large water capacity gives unusually high efficiency. Simple in construction and operation.

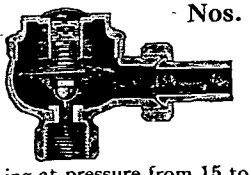


Capacities in Pounds per Hour at Various Pressure Differentials

Size Inlet and Outlet	5 lb.	10 lb.	25 lb.	50 lb.	75 lb.	100 lb.	125 lb.
½ in.	800	1125	1000	670	530	425	400
¾ in.	2800	4200	4000	3000	2500	2000	1450
1 in.	6000	11000	8700	6200	5700	4000	3800

To convert above capacities to square feet of equivalent direct radiation each trap will handle per hour, multiply capacities given in table by three. To convert these capacities to lineal feet of 1 in. pipe multiply by nine.

Thermostatic Steam Traps Nos. 501 and 502

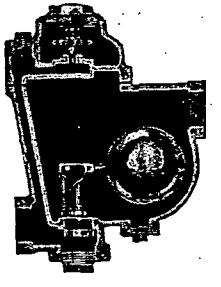


Used to discharge air and condensate from heating coils and apparatus working at pressure from 15 to 100 lbs. Body of heavy cast-brass with union nut and tail piece. Nos. 501 and 502 standard in angle pattern only. Other patterns on order.

Nos. 501 and 502 Thermostatic Steam Traps

No.	Size, In.	Capacities, pounds condensation per hour at given pressure differential			
		35 lb.	50 lb.	80 lb.	100 lb.
501	½	90	110	115	130
502	½	140	160	200	260
502	¾	300	450	490	580
502	1	700	925	1100	1260

No. 508 Steam Trap

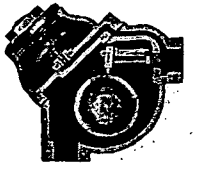


Similar in design to No. 8 trap previously described but constructed for working pressures from 25 to 60 lbs. Specify highest working pressure.

No. 508 Float and Thermostatic Medium Pressure Trap—1¼-in. Inlet and Outlet

Pressure differential	40 lb.	60 lb.
Capacities—pounds condensation per hour	690	827

No. 512 Steam Trap

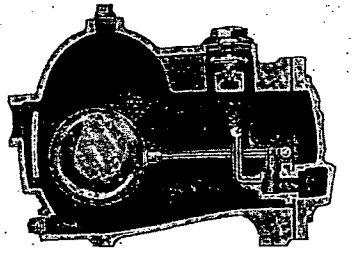


Similar in design to No. 12 trap previously described but constructed for working pressures from 30 to 100 lbs. Specify highest working pressure.

No. 512 Float and Thermostatic Medium Pressure Trap—¾-in. Inlet and Outlet

Pressure differential	30 lb.	50 lb.	75 lb.	100 lb.
Capacities — pounds Condensation per hour	600	425	360	400

No. 514 Steam Trap



No. 514 Steam Trap

Size Inlet and Outlet	30 lb.	80 lb.
1 in.	4750	3860
1¼ in.	7600	6800
1½ in.	11450	9700
2 in.	13500	12240
Size Inlet and Outlet	**100 lb.**	**125 lb.**
1 in.	2460	1380
1¼ in.	5275	3260
1½ in.	7490	5400
2 in.	9230	8140

MARSH GAUGES AND INSTRUMENT PANELS

Instrument Panels

Marsh Panels can be furnished in a wide range of materials. They may be specified of electrical, ribbon or Monson slate, white and pink Tennessee or Alabama marble, woods of all kinds, asbestos ebony or steel.

Marsh Instrument Panels may also be designed to include other types of instruments such as flow meters, recording thermometers, electrical, temperature regulation instruments and switches. Panels can be furnished with electric lighting fixtures.

Instruments

Marsh Gauges are available in these finishes: Chromium plated brass case and ring, chromium plated ring with black enameled case, nickel plated brass case and ring, nickel plated ring with black enameled case, polished brass case and ring, polished brass ring with black enameled case, black enameled case and ring, white or colored case and ring. They are equipped with oven baked, white enameled metal dials having dead black numerals, lettering and graduations, with silver dials having black figures and graduations, or black dials having white figures and graduations. Marsh Gauges are made with case and ring so assembled as to insure a dust and moisture-proof instrument. All gauges are made for either surface mounting or flush mounting for gauge board application.



Single Spring Pressure Gauge

Marsh Single Spring Pressure Gauges are made in sizes from 2½ to 16 in., suitable for pressure not to exceed 3000 lb. per sq. in. Drawn steel case, cast-iron case or cast-brass case with bronze or nitralloy movement.

Double Spring Pressure Gauge

Manufactured in pressure ranges from 60 to 3000 lb. per sq. in. Plain case and ring, sizes 4½ to 5 in., inclusive, larger sizes up to 16 in. in flanged case, flared ring for larger equipment.

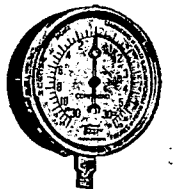




Marsh Clocks

Constructed with a choice of several high grade clock movements: Seth Thomas, Chelsea and Telechron Electric. Sizes 6¾, 8½, 10 and 12 in. and in all types and finishes.

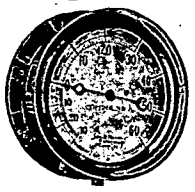
Low Pressure Ounce Graduated Retard Gauges



Compound construction indicates even first ounce of pressure. Graduated in 1 oz. divisions up to 5 lb. with retard travel from 5 to 30 lb. On vacuum side graduated in ½ in. divisions up to 10 in. and retarded from 10 to 30 in. Manufactured in 3½ to 12 in. sizes.

Standard Compound Gauge

Standard pressures 0 to 15 lb. x 0 to 30 in. up to 600 lbs. x 30 in. Sizes 2½, 3, 3½, 4½ and 5 in. in plain case and ring for application to equipment for close reading. In larger sizes to 16 in. in flanged case, flared ring for larger equipment.



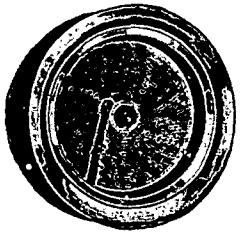
Standard Vacuum Gauge



Dial graduated 0 to 30 in. in 1-in. divisions and 5-in. numerical intervals. Sizes 2½, 3, 3½, 4½ and 5 in. in plain case and ring where instruments are accessible for close reading. Larger sizes to 16 in. in flanged case, flared ring for larger equipment.

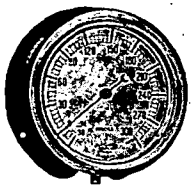
Recording Gauges

Marsh Recording Gauges give an exact record of either pressure or vacuum. These gauges are equipped with a high grade Seth Thomas eight-day clock movement and 24-hour chart. Can be furnished in cast-iron case, polished brass case, nickel plated case or chrome plated case and in sizes 6¾ in., 8½ in., 10 in. and 12 in.



The Marsh Combined Indicating and Recording gauge is very similar to the pressure recorder, except that, in addition to the recording pen, it is also equipped with indicating hand.

Refrigeration Gauges



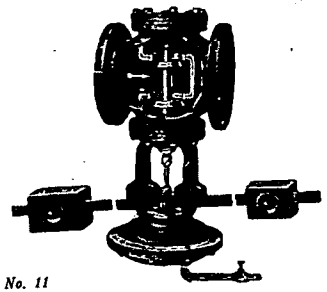
Manufactured in both high pressure and low pressure graduations to indicate pressures in both suction and compression side. Sizes 2½, 3, 3½, 4½ and 5 in. in plain case and ring instruments accessible for close reading. Larger sizes to 16 in. for larger equipment.

Mueller Steam Specialty Co., Inc.

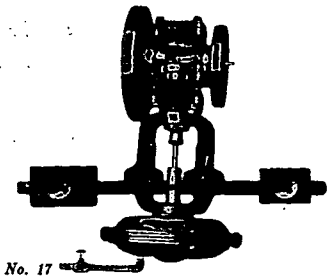
349-351 West 26th Street, New York City

Steam, Water, Air, Oil and Gas Specialties for Heating and Power Plants

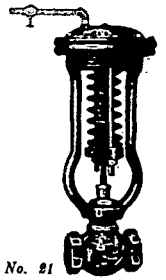
Pressure Reducing Valves—Straight Pattern and With Increased Outlet



No. 11



No. 17



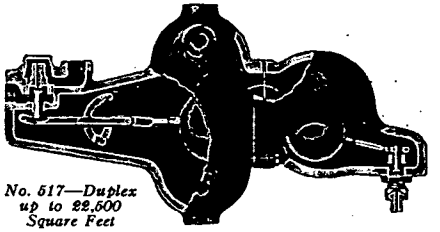
No. 21

No. 11—For Vacuum, Vapor and Low Pressure Heating Systems. Initial Pressures, up to 200 lb.; Reduced Pressures, 0 to 10 lb.

No. 17 and 21—For automatic control of reduced pressures on dead-end service, requiring a tight closing valve, such as tank heaters, kitchen utensils, sterilizing apparatus, laundry equipment, kettles, cookers, driers, etc. Initial Pressures up to 200 lb. Reduced Pressures 0 to 150 lb.

Constructed with full globe bodies. Center guide eliminates the wings on discs, and increases efficiency, assures minimum noise and prolongs the life of the seats and discs. Lever and weight operates on a steel roller bolt, assuring a most sensitive valve. Spring type furnished with special long springs for sensitive operation and wide ranges of reduced pressures.

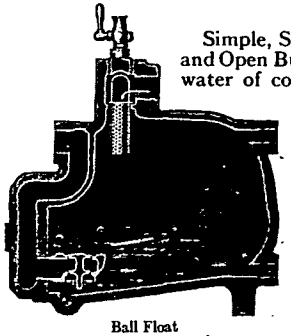
Automatic Water Feeders



No. 517—Duplex up to 22,600 Square Feet

With a powerful leverage to control the water line in steam boilers, etc. They supply make up water to compensate for evaporation, leaks, steam utilized in process work and condensation wasted. Where condensation held up in the system eventually returns in large quantities, our Duplex type protects the boiler against flooding. All working parts of non-corrosive metal, are accessible without breaking pipe connections. Provided with an integral strainer. For steam pressures up to 100 lb., water pressures up to 120 lb.

Steam Traps



Ball Float

No. 219—Up to 50 lb.
No. 221—Up to 160 lb.

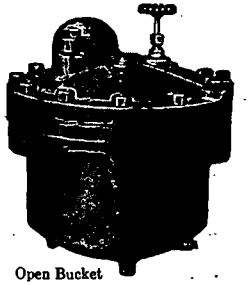
Simple, Sturdy and Compact Ball Float and Open Bucket Steam Traps for draining water of condensation from steam apparatus and steam mains.

Powerful leverage enables them to take care of large quantities of condensation.

Equipped with strainer, water gages, air cocks, blow off and integral by-pass valve, when desired.

All working parts are accessible without disturbing any pipes.

Valves are sealed with several inches of water, making the escape of steam impossible.



Open Bucket

No. 229—Up to 30 lb.
No. 231—Up to 150 lb.
No. 233—Up to 250 lb.

Sizes from ½ to 3 inches.

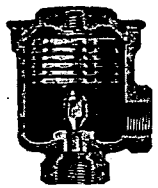
CATALOGUE and BULLETINS covering our COMPLETE LINE gladly furnished on application.

W. H. Nicholson & Co.

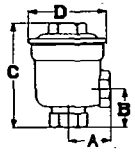
143 Oregon Street **Wilkes-Barre, Pa.**

MANUFACTURERS OF MACHINERY AND STEAM SPECIALTIES

Nicholson Industrial Trap



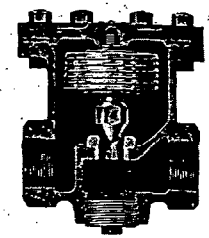
Style "A"



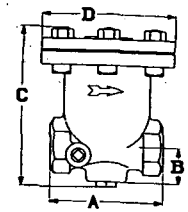
Style "A"

Recommended for draining Unit Heaters, Pipe Coils, Ironers, Presses, Sterilizers, Autoclaves, Blanket Warmers, Milk Pasteurizers, Coffee and Hot Water Urns, *Dish Heaters, Kettles, Steam Tables,* High Pressure Drips, Blast Coils, Dry Kilns, Dryers of all kinds, etc., etc.

The Style "A" Trap is constructed of bronze, the Style "B" of cast iron, and both are aluminum painted and are suitable for pressures from vacuum to 100 lbs. They have several times the capacities of other makes, as will be noted from the capacity list. The bellows operates on the balanced pressure principle and is made of phosphor bronze discs instead of soft copper, giving it a powerful and positive intermittant action. Valve and Seat are interchangeable and made of Nitralloy insuring long life.

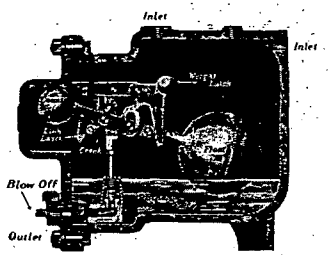


Style "B"



Style "B"

PRICES		DIMENSIONS				CAPACITY IN LBS. PER HOUR			
Sizes	List Price	A	B	C	D	0 Lbs.	5 Lbs.	40 Lbs.	100 Lbs.
Style "A"									
¼" ⅜" ½" ¾"	$13.25	1-⅝"	1-⅜"	4-⅛"	3"	300	1005	2770	4230
	14.00	2"	1-⅞"	4-½"	3"	345	1155	3185	4865
Style "B"									
½"	$21.00	4-¼"	1-⅜"	6-⅜"	5-⅛"	560	1885	5190	7950
¾"	21.00	4-¼"	1-⅜"	6-⅜"	5-⅛"	560	1885	5190	7950
1"	25.00	5-½"	1-⅞"	7-⅛"	5-⅝"	1135	3840	10520	16100
1¼"	25.00	5-½"	1-⅞"	7-⅛"	5-⅝"	1135	3840	10520	16100
1½"	37.00	7-¼"	1-¾"	8-⅛"	7-¾"	2070	6980	19200	29500
2"	37.00	7-¼"	1-¾"	8-⅛"	7-¾"	2070	6980	19200	29500



Nicholson Weight Operated Trap

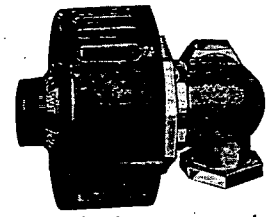
These traps are of Cast Iron Construction and suitable for all pressures up to 200 lbs. Sizes ½ in. to 2 in. Have an intermittant discharge and large capacity. Will discharge into a vacuum line. Write for bulletins.

Sterling Engineering Co.

3734 N. Holton Street **Milwaukee, Wis.**

Representatives in all Principal Cities

The Thermotrol

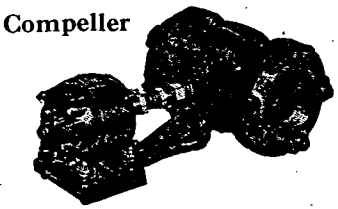


An automatic self-contained, thermostatic type of regulating supply valve applicable to two-pipe steam, vapor, vacuum or hot water heating systems, that will control room temperature accurately. Hand adjustable or loose key type of operation.

Right or Left Hand Corner or Angle type of valve body.

½" Capacity 60 sq. ft. C. I. Radiation.
¾" Capacity 100 sq. ft. C. I. Radiation.
1" Capacity 200 sq. ft. C. I. Radiation.
1¼" Capacity 275 sq. ft. C. I. Radiation.
1½" Capacity 300 sq. ft. C. I. Radiation.

The Compeller



For stimulating circulation in hot water heating systems or domestic hot water or ice water circulating systems.

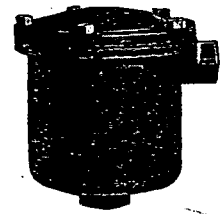
No. 1½—With globe pattern body, screwed ends for 1½" or 2" pipe.

No. 2½—With globe pattern body, flanged ends for 1½", 2" or 2½" pipe.

No. 4—With angle pattern body, flanged ends for 3", 3½" or 4" pipe.

No. 6—With angle pattern body, screwed ends for 5" or 6" pipe.

No. 73 Unit Heater Trap

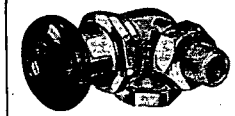


A combination float and thermostatic trap for unit heaters, blast coils and dripping steam mains and risers.

Non air binding.
Cannot freeze.
No cooling leg required.

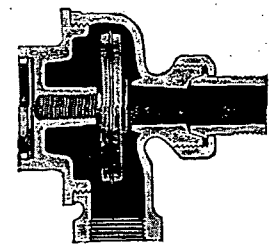
Drains completely when cold.
Tapped for ¾" or 1" pipe connections.

The Thermotype Valve



A packless valve that has the same body and interior mechanism as the body on the Thermotrol, but is furnished with a bonnet and hand wheel. At any later date the automatic feature can be added to the system by removing the hand wheel and attaching the housing section of the Thermotrol, which contains the Thermostatic members. Pipe connections need not be detached, neither is it necessary to scrap a complete hand valve. Made in Right or Left Hand Corner or Angle type. Capacities same as for Thermotrol.

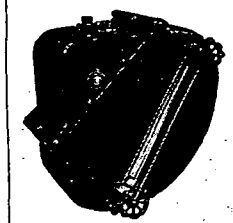
Thermostatic Trap



An all brass trap for vapor and vacuum heating systems.

½" Capacity 200 sq. ft. C. I. Radiation.
¾" Capacity 500 sq. ft. C. I. Radiation.

Return Trap



To drain return lines of vapor heating systems, eliminate air without loss of vapor and return water to boiler against pressure.

Size No.	Capacity Sq. Ft. Radiation	Pipe Connections	Steam Connections	Vent Connections
27	3000	1½"	¾"	½"
29	6000	2"	¾"	½"

Sarco Company, Inc.

MANUFACTURERS OF STEAM SPECIALTIES

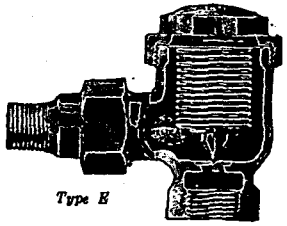
183 Madison Ave., New York, N. Y.

Branches in all Principal Cities

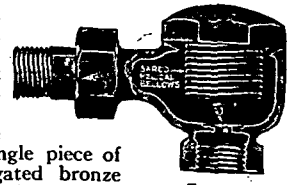
SARCO CANADA LIMITED, FEDERAL BLDG., TORONTO, ONT.

PRODUCTS—Sarco Radiator Traps, Steam Traps, Packless Inlet Valves, Air Eliminators, Alternating Receivers, Float Traps, Temperature Regulators and Self-Cleaning Strainers.

SARCO RADIATOR TRAPS



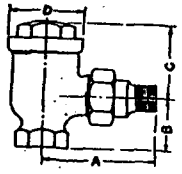
Type E



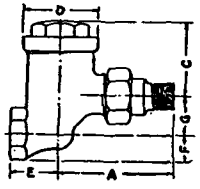
Type H

For vacuum, vapor and gravity heating systems, pressures up to 25 lbs. Available in angle, right and left offset and straightway patterns. Special features are the flexible bellows, made from a single piece of seamless, helically corrugated bronze tubing of large diameter and heavy wall. Also the self-aligning valve head which assures perfect seating. The valve has a full ¼" lift, securing exceptionally large capacity. The body is of heavy brass, nickel plated with polished trimmings.

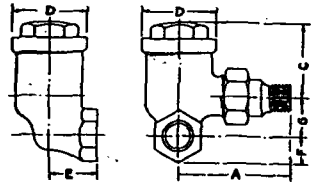
Angle



Straightway



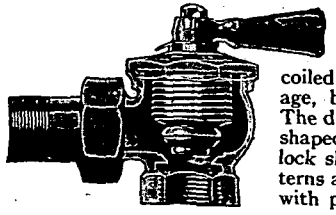
Corner-Offset



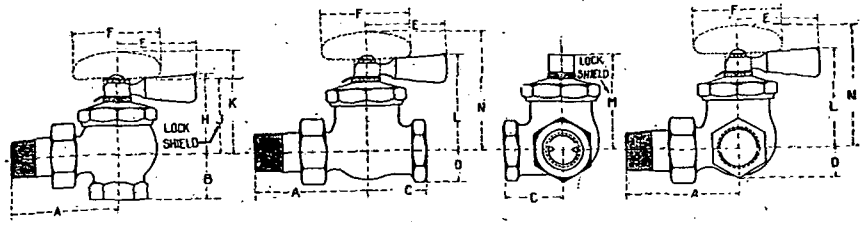
ROUGHING-IN DIMENSIONS

Type	Size	Dimensions							Capacity		List Price
		A	B	C	D	E	F	G	Vacuum	Vapor	
H	½"	3¼"	1½"	1⅝"	2"	1⅜"	⅝"	1⅛"	125 sq. ft.	100 sq. ft.	$5.00
E	½"	3¼"	1½"	2⅛"	2¼"	1⅜"	⅝"	1⅛"	250 sq. ft.	200 sq. ft.	6.00
E	¾"	3¼"	1½"	2⅛"	2¼"	1⅜"	¾"	1⅛"	800 sq. ft.	600 sq. ft.	8.00
E	1"	3½"	2"	2¼"	2½"	....	....	....	1800 sq. ft.	1500 sq. ft.	15.00

SARCO BELLOWS-PACKLESS VALVES

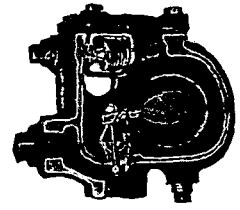


These valves are of the truly packless, quick-opening type. The valve stem is sealed to the cap by a flexible bellows made of the same seamless, helically coiled tubing, used in Sarco Traps. No possibility of leakage, binding or sticking—no attention or maintenance. The disc is of high temperature asbestos composition, cone shaped and fully protected. Lever or round handles, or lock shield furnished. Angle, straightway or corner patterns available. The body is of heavy brass, nickel plated with polished trimmings.



ROUGHING-IN DIMENSIONS

Size	Dimensions, Inches													List Prices	
	A	B	C	D	E	F	H	J	K	L	M	N	Capacities, Feet Direct Radiation	Angle	Offset or Straightway
½	2¼	1¼	1⅝	⅝	2⅛	2⅛	2⅝	2	2⅝	2⅝	2½	3⅝	0–25	$5.50	$6.50
¾	3	1¼	1⅝	⅝	2⅛	2⅛	2⅝	2	2⅝	2⅝	2½	3⅝	26–75	6.00	7.00
1	3⅜	1½	1¾	1	2⅛	2⅛	2⅝	2⅛	2⅝	2⅝	2½	3⅝	75–125	7.50	8.50
1¼	3½	1⅝	....	....	2⅛	2⅛	2⅝	2⅜	3⅛	....	....	....	126–200	9.50	10.50
1½	3¾	1¾	....	....	2⅛	2⅛	2⅝	2⅜	3½	....	....	....	201–300	12.00	13.00

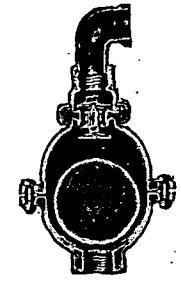


SARCO FT FLOAT AND THERMOSTATIC TRAPS

For dripping ends of mains, risers, stacks, unit heaters, hot water tanks, etc. Have internal thermostatic air by-pass. Valves are underslung for large capacity and to reduce clogging. Made in two sizes: FT-1, 1¼" and FT-2, 2" inlet and outlet.

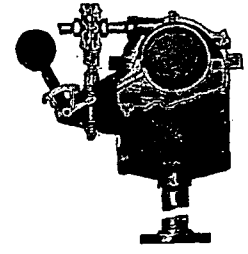
List prices, FT-1, $25.00. FT-2, $60.00.

SARCO NO. 11 AIR ELIMINATOR



For venting air from Vapor Systems at one central point in basement. Has two separate check valves, one to prevent air from entering system when operating below atmospheric pressure, and the other to prevent water from escaping. Capacity sufficient to vent air from 15,000 sq. ft. of radiation in 20 minutes. 1" I. P. S.

SARCO ALTERNATING RECEIVER



For automatically returning condensate to boiler in Vapor Systems. Insures prompt return of water to boiler under all pressure conditions.

For all heating specialties, write for Catalog HV-40.

SARCO TEMPERATURE REGULATOR

A simple, self-contained automatic valve for regulating temperature of water in storage heaters, for room or kiln control. Made in sizes ½" to 6" for temperatures 30-300° F.

Write for Catalog HV-70.

SARCO STRAINERS

Strainers in pipe lines are effective insurance against interruption in service, injury to valves and expensive breakdowns. Suitable for steam, water and oil lines.

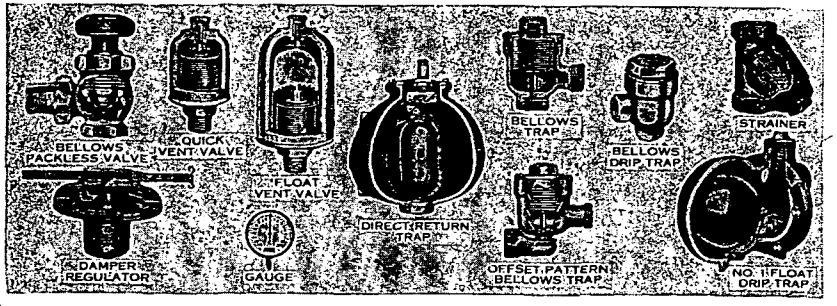
Write for Booklet HV-100.

The Trane Company

La Crosse, Wis.

See Unit Heaters, pages 666-667; Heating and Ventilating Units, page 678; Concealed Radiation, pages 760-761

BRANCHES IN ALL PRINCIPAL CITIES



TRANE HEATING SPECIALTIES

Trane Heating Specialties are constructed of the finest material and workmanship—guaranteed for one year.

Trane Bellows-Packless Valves, ideal for homes, office buildings, apartments, churches, hospitals. Range of sizes of ½" to 2". The No. 30 packless series are of slightly different construction.

Trane Bellows Traps, used extensively on office buildings, apartments, homes, industrial plants, churches, etc. Sizes range from ½" to 1¼" in angle pattern. Made for both high and low pressures. Low pressure range any vacuum to 25 lbs. High pressure 25 to 100 lbs., steam pressure. Thermostatic Drip Traps have same pressure range.

Trane Direct Return Trap used extensively on all installations for insuring return of condensate back to boiler.

Trane Float Drip Trap is an ideal trap for industrial unit application used in factories, garages, creameries, warehouses. Size range for any installation.

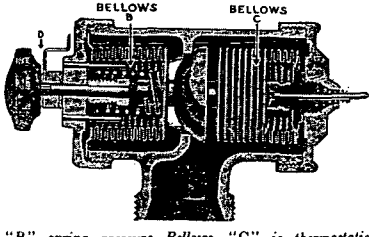
Trane Float and Quick Vents are installed in houses, office buildings, industrial plants. Float Vents close against water and steam—quick vents against steam only—keeps system free from air constantly.

Trane Damper Regulator provides positive pressure control of boiler. Diaphragm is sensitive to an ounce change of boiler pressure which is sufficient to reverse the position of draft and check dampers.

Trane Strainer for installation in pipe lines to keep dirt and sediment out of traps, etc. Installed in either vertical or horizontal pipe lines.

Trane Gauges are furnished compound vapor-vacuum with scale reading from 18 inches of vacuum to 30 pounds pressure, and vacuum only with scale reading from zero to 30 inches vacuum.

THE TRANE TEMPERATURE CONTROL VALVE



"B" spring pressure Bellows—"C" is thermostatic Bellows—"D" Temperature adjusting knob

The Trane Temperature Control Valve is of constant changing orifice type with remote control. For each degree variation in temperature on the control bulb, there is a corresponding change in the valve orifice. This type of valve will maintain exceptionally close temperatures and with the control bulb placed on the floor line where temperature changes are most quickly reflected, engineers and architects can be assured of highly satisfactory temperature regulation.

Can be installed in place of ordinary valves without changing the piping. Supplied in ¾", 1", 1¼" and 1½" sizes.

Vapor Engineering Company

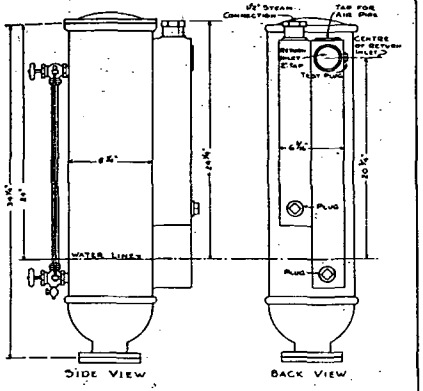
489 Fifth Avenue
New York City
Chas. E. Scott—R. C. Willis

10 South 18th Street
Philadelphia, Pa.
J. W. Glassey—M. S. Buck

VECO VAPOR SPECIALTIES

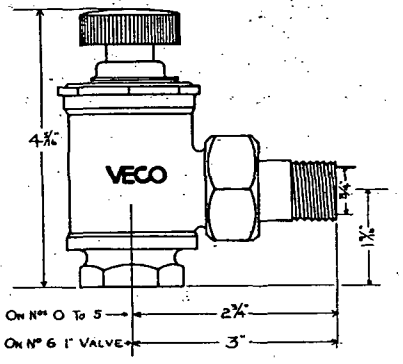
Non Mechanical and Positive in Operation

Engineers for the design of "open-to-atmosphere" vapor heating systems for factory, public and residential buildings, regardless of size, construction or location. Veco Vapor specialties are the result of 25 years of specialization in vapor heating work



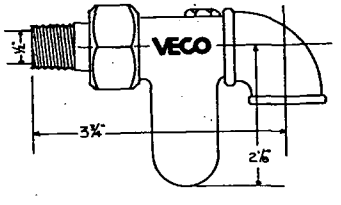
VECO GOVERNOR

Combining, Safety Valve, Air Eliminator and positive control of Boiler draft, Gas supply valve, or Oil Burner



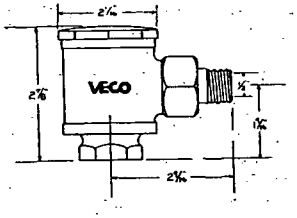
VECO SUPPLY VALVE

Packless, Leakless, Graduated.
¾ in. Nos. 0 to 5 up to 139 sq. ft. inclusive.
1 in. No. 6 up to 140 to 150 sq. ft. inclusive.



VECO RETURN SEAL

No moving parts. For all standard vapor work



VECO THERMOSTATIC TRAP

For Central Plant work, Ventilating Units, etc.

Full cooperation is offered to Architects, Engineers and Contractors in the planning of Veco Systems which are fully Guaranteed as to material—and satisfactory operation.

ESTABLISHED 1888

WARREN WEBSTER & COMPANY

Pioneers of the Vacuum System of Steam Heating

Camden, N. J. Branches in over 60 Cities

Webster – since 1888 – Systems of Steam Heating

Manufacturers of Webster Systems of Steam Heating, Webster Heating System Controls, Webster System Equipment, Webster Series "78" Traps for "Process" Steam Pressures.

"78" – for users of process steam

PRODUCTS AND SERVICES

Improved Webster Systems of Steam Heating.
Webster Vacuum and Type "R" Systems of Steam Heating.
Webster HYLO Variator Control.
Webster MODERATOR Control.
Modernization of Obsolete and Faulty Heating Systems.
Webster System Equipment used as needed in Webster Systems of Steam Heating and including the following:
Radiator Supply Valves; Metering Orifices; Thermostatic Traps; Drip Traps; Heavy Duty Traps; Dirt Strainers; Dirt Pockets; Boiler Return Traps; Vent Traps and Vent Valves; Damper Regulators; Boiler Protectors; Lift Fittings; Expansion Joints; Separating Tanks; Steam and Oil Separators, Vacuum Pump Governors.
Webster Series "78" Traps for use at process pressures (10 to 125 lbs. per sq. in.).

A Heating System for Every Need and Purpose

Warren Webster & Company have developed an entire group of Webster Systems of Steam Heating together with effective central controls, each built to meet certain conditions; each a combination of service, experience, equipment and engineering methods for the various heating requirements of the individual installation.

Improved Webster Systems of Steam Heating

The Improved Webster Systems are basic two-pipe systems of steam circulation *with the addition* of accurately-sized metering orifices at radiator supply connections and, when required, intermediate metering orifices at points in branch mains. Metering orifices effect even distribution of steam to all parts of the heating system and permit the successful application of a centralized, gradual acting control.

How Even Distribution is Accomplished—*All radiators get steam at the same time and substantially in proportion to the need for steam.* In Fig. 1 it can be seen that the metering orifice in radiator A is quite small. When steam reaches this radiator the amount that can enter is therefore restricted. As a result the remaining steam quickly flows on through the piping to the next radiator B. Here the opening is slightly larger because the pressure of the steam by the time it reaches radiator B is lower. So it goes, radiator by radiator to the farthest point. The "pressure drop" to each radiator has been equalized or balanced by installation of the correctly-sized metering orifice. The result is that each radiator receives the required amount of steam.

Vacuum or Gravity Operation—Improved Webster Systems are available for both gravity and vacuum operation. The Webster Vacuum System employes a vacuum pump on the return piping to facilitate steam circulation, to eliminate air from the system and to return water of condensation to the boiler. If steam is supplied from an outside source such as street steam lines, air is vented through a Webster Vent Trap, the condensate being discharged to sewer or into returns by a condensate pump. Steam-driven or motor-driven vacuum pumps are used with Webster Vacuum Systems.

Many Webster Systems operate with

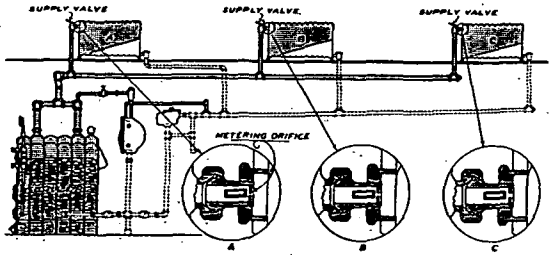


Fig. 1 How "pressure drop" is equalized or balanced in an Improved Webster System by use of Webster Metering Orifices in the radiator supply connection.

gravity returns. When low pressure boilers are used, Webster Type "R" System basement equipment is employed. This consists of a Vent Trap and Vent Valve for discharge of air from the return piping and a Webster Boiler Return Trap to assure positive return of condensation to the boiler. A typical arrangement of Webster Type "R" System equipment is illustrated in Fig. 2.

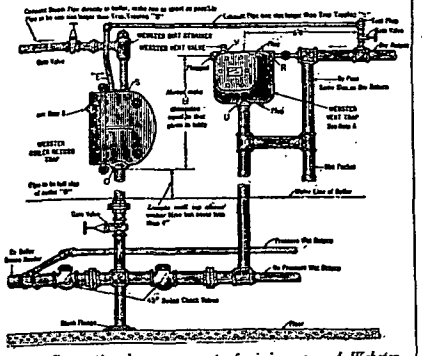


Fig. 2 Conventional arrangement of piping around Webster Basement Equipment for the Webster Type "R" System

Webster HYLO Vacuum Variator Control

The Webster HYLO Vacuum Variator is a central, manual throttling control used with Improved Webster Vacuum Systems. It provides a means for manually varying the amount of steam supplied to the entire heating system. The HYLO Variator has a lever arm provided with sliding weights which are adjusted manually by the operator. The position of the weights on the scales determines the difference in pressure maintained between the supply and return lines and thus controls the amount of steam delivered to the system. The HYLO Variator will vary the steam supply for heat requirements from 33 % to 140 % of normal.

The HYLO Vacuum Variator is especially desirable for small and medium sized buildings and where the additional first cost may not warrant installation of Webster MODERATOR Control. HYLO Variator Control can be applied either to new buildings or to vacuum systems in existing buildings.

Webster Key-Room Thermostat Control—Applied to pressure reducing valve in supply main of Improved Webster Systems. Closes valve when desired key-room temperature is reached. Applicable where simple on-and-off control is adequate and as supplementary automatic control with Webster HYLO Variator (Manual) Control.

Webster MODERATOR Control

Webster MODERATOR Control is applicable to all types of Webster Systems (5,000 sq. ft. and upward). The advantages of MODERATOR Control are obtained in:

(1) Improved heating service at the radiator.
(2) Centralized control and operation.
(3) Reduced steam consumption, maintenance and operation expense.

Solves the overheating problem by providing: fully automatic variation for changes in outdoor temperature; shutting off or turning on radiation; variation of steam pressure, variation in vacuum; convenient manual variation for changes in weather conditions other than temperature and for quick heating-up and night load conditions.

Properly operated, this system varies the supply of steam to the entire heating system and to all parts of it in accordance with changes in demand resulting from changes in weather and occupancy conditions. Webster MODERATOR Control does not control the temperature in each room, but *moderates* the excesses of overheating and underheating.

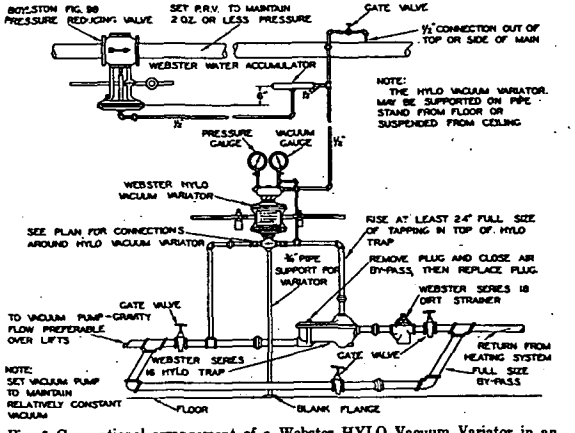


Fig. 3 Conventional arrangement of a Webster HYLO Vacuum Variator in an Improved Webster Vacuum System.

Equipment—The basic MODERATOR Control equipment consists of a Roof Thermostat, Control Panel, Air Compressor Unit and Main Steam Control Valve. Full details on request.

Webster Supply Valves

Furnished in angle, right and left corner off-set or straightway bodies. Also with Metering Orifices integrally in supply valve nipple for use in Improved Webster Systems. All-bakelite wheel handles are standard. Also supplied in lever, lock-shield, chain wheel and flush type handles. Extended stems for concealed radiation.

Webster Type "W" Modulation Valves—Highest quality, quick-opening radiator supply valve with *modulating feature*. With the exception of the disc and handle, all parts are of high-grade steam brass. Outside is nickeled and has satin finish.

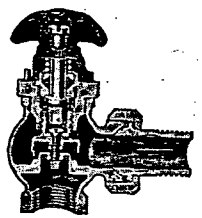


Fig. 7 Webster Type "W" Valve

Webster "Three-Point" Valves—Highest quality, quick-opening valve. Includes sleeve orifice fitting into the seat opening and easily changed if radiation or occupancy changes require a new orifice size. Valve may be set at "Shut," "Normal," or "Excess" position, the latter giving 140 per cent of normal steam requirements. Especially desirable for hospitals, hotels, etc., where extreme flexibility is desired.

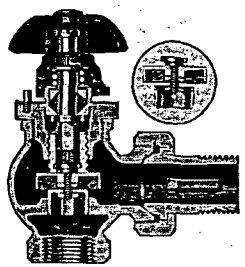


Fig. 8. Webster "Three-point" Valve. Inset shows replaceable orifice sleeve

Webster Sylphon Packless Valves—Quick-opening. Use the well-known Sylphon bellows completely enclosing stem as packless feature. Body is of steam brass and valve disc is of special composition.

Webster Type "B" Valves—Simple in design but of good quality. Quick-opening, non-rising stem, molded ring packing. The composition disc is assembled with shake-proof washer to permit easy renewal.

Webster Traps

Webster Sylphon Traps—Genuine seamless *Sylphon* bellows; factory-adjusted 60° cone valve piece; sharp-edged, renewable seat, cast steam brass body, forged brass cap and nut, nipple turned from bar stock. Normal operating pressure up to 5 lbs. per sq. in.

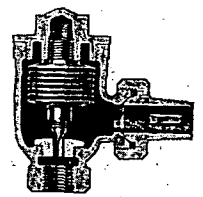


Fig. 4 Webster Sylphon Trap

Webster Series "7" Traps—Phosphor-bronze diaphragm, triple-sealed. Other features same as Sylphon Trap. Normal operating pressures up to 5 lbs. per sq. in.

Webster Series 7-M Traps—Same as Series "7" except for heavy gauge *Monel metal* diaphragm, valve piece and seat insert. For normal operating pressures up to 15 lbs. per sq. in.; occasional pressures to 25 lbs. per sq. in.

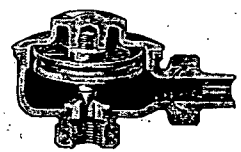


Fig. 5 Webster Series "7" Trap

Webster 026 Drip Traps (Fig. 6)—A compact heavy duty trap suited for drips of mains, blast radiation, unit heaters, etc. Has thermostatic vent for elimination of air. Maximum working pressure 15 lbs. per sq. in.

Webster Heavy Duty Traps—Used to remove large quantities of condensation and air in mains, hot water generators, vent heater coils, etc. Operates on the float principle for discharge of condensation. Air discharged through thermostatic by-pass. Maximum working pressure 15 lbs. per sq. in.

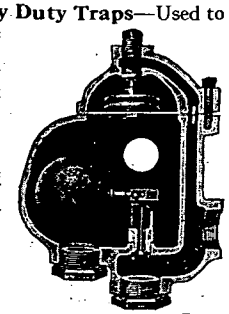


Fig. 6 Webster Drip Trap

Webster Series "78" Traps—Sturdy thermostatic traps for heating coils and any apparatus using steam at process pressures, i.e., 10 to 125 lbs. per sq. in.

Exhaust Heads
Water Columns
Pump Governors

Wright-Austin Co.

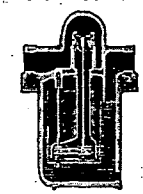
409 Griswold St., **Detroit, Mich.**

Representatives in Principal Centers

Made to order
Separators
Air Traps

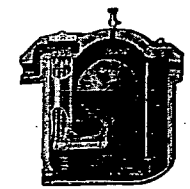
"Airxpel" Bucket Type Steam Trap 0 to 300 lb.

This is a "double duty" trap expelling entrained air and condensate automatically. Unusually large capacity. Has exceptionally long life without repairs. All parts are accessible. Horizontal pipe connection; easy to install; hangs on the pipe line like a valve.



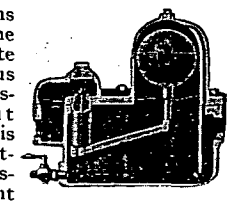
"Emergency" Float Type Steam Trap 0 to 250 lb.

Three valve trap with large capacity at high loads and no wire drawing at low loads. No change of valves or adjustments from 0 to 200 lbs. Strong nickel float. An exceptionally reliable trap for use in inaccessible places.



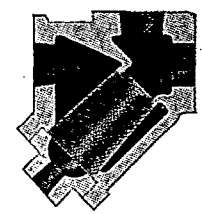
"Victor" Low Pressure Steam Trap 0 to 20 lb.

The valve opens outward with the flow of condensate giving enormous capacity. Will discharge without pressure which is valuable in starting up a cold system. An excellent oil and grease trap. Used also on vacuum returns in which case the trap is provided with a thermostatic air vent.



"Tuway" Straight Way or Angle Strainer—0 to 300 lbs.

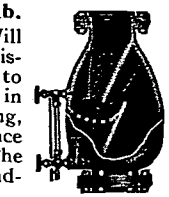
An alternate inlet enables this strainer to be used either as an angle or straightway type in horizontal or vertical pipe line. The perforated brass screen has 400 holes per sq. inch but can be made to suit requirements. The screen is easily removable for cleaning or the strainer may be blown down without removing the screen.



The three Separators illustrated here are part of one of the most complete lines of types and sizes in the world. These include cast semi-steel Separators, cast steel, riveted steel and welded steel Separators made in all sizes for all classes of service for steam, air and gas.

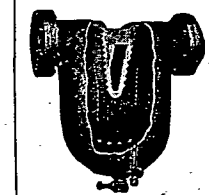
Type "A" Vertical Steam Separator 0 to 250 lb.

For average service. Will eliminate dirt and moisture from steam down to ½ of 1 per cent; cast in one piece and self-cleaning, requiring no maintenance after installation. The Type "A" has been standard for 35 years.



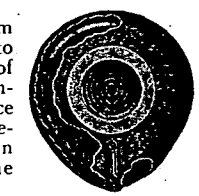
Type "B" Horizontal Steam Separator 0 to 250 lb.

Can be placed close to walls or ceiling, because body of Separator hangs below pipe line. Self-cleaning, cast in one piece, no maintenance required. Will remove moisture down to ½ of 1 per cent.



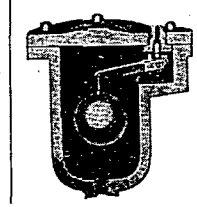
Type "S" Horizontal Oil Separator 0 to 50 lb.

Will remove oil from exhaust steam down to a very small fraction of 1 per cent. Self-cleaning, cast in one piece requiring no maintenance. Thousands in use throughout the world.



Air Trap for Relieving Air from Hot and Cold Water Systems.

Extreme simplicity and reliability characterizes this air trap. There is nothing to it but a float, a lever and a valve. No overflow needed, ample valve opening. Seven inches high by 6 inches diameter.



Webster Tallmadge & Co., Inc.

50 Church Street, New York, N. Y.

THE TALLMADGE ZONE HEATING SYSTEM

With Simplified Orifice Distribution and Remote Electrical Control

The Tallmadge Zoned Heating System increases building comfort and saves the steam usually wasted in overheating in ordinary system operating without control.

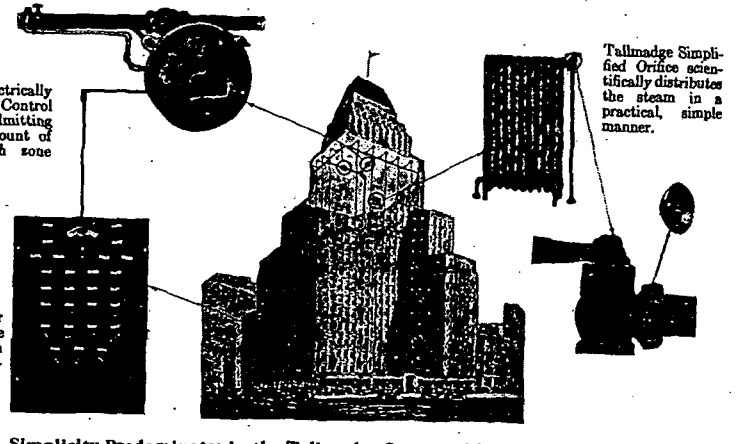
In the application of the Tallmadge control the heating system is divided into separate systems or *zones*, each zone consisting of the radiators serving the same general building exposure or type of occupancy. A *control valve and mechanism* is placed on the steam supply to each zone and is electrically connected to a central control board. An *orifice* or restricted opening is placed in the entrance to each radiator. The *continuous (not intermittent) steam flow* to the radiators of a zone is then controlled (automatically or by hand from central control board) in accordance with the requirements of weather or occupancy affecting the steam demand of each zone which varies with relation to that of other zones and with every change in weather, thus saving additional steam on zones exposed to the sun or protected from the wind.

Radiator orifices are sized in proportion to the size of each radiator; fit in any make of radiator valve; *no orifices in mains or risers*, hence no unbalancing of steam distribution when radiators are changed or turned off.

The *valve control mechanism* automatically increases or decreases the continuous steam supply to the zone as radiators are turned on or off. It opens slowly to prevent noise usually resulting from too quick starting up and closes slowly to prevent blowing of the boiler safety valve; reduces peak demand on district steam supply; is motor-driven, taking current from the lighting circuit; operates on any initial pressure thus eliminating reducing valves and permitting smaller mains supplying steam to the control valve; prevents more than full steam flow entering any radiator hence *radiator traps* and *vacuum are unnecessary* regardless of the height or size of the building. Valve can be hand-operated. Operating mechanism can be removed without shutting off steam. No by-pass required.

No special pipe sizes required as those used in good standard practice for steam and return are satisfactory. Unnecessary to zone the returns as they may be common to all zones.

Low initial cost, low installation cost in new or old system due to simplicity of few devices used. Cost often offset by elimination of equipment otherwise necessary. Depreciation and maintenance practically nil due to few moving parts, hence efficiency does not decrease with age or use.



Tallmadge electrically operated Zone Control Valve for admitting the proper amount of steam to each zone separately.

Tallmadge Simplified Orifice scientifically distributes the steam in a practical, simple manner.

Control Center of Tallmadge System. Can be placed anywhere.

Simplicity Predominates in the Tallmadge System of Zoned Heating

The devices illustrated above are the only ones used

Barber-Colman Company

Rockford **Illinois**

An ELECTRIC System of Temperature Control

Distributed By

Barber-Colman Company....221 N. LaSalle St., Chicago, Ill.
Barber-Colman Company of Wisconsin, Inc., 2561 N. Downer Avenue, Milwaukee, Wis.
Barber-Colman Company of Mass......Framingham, Mass.
Preferred Utilities Co., Inc. 33 W. 60th St., New York City
Culbert-Whitby Co., 2019 Rittenhouse St., Philadelphia, Pa.
Edwin J. Richard, 527 Union Central Bldg., Cincinnati, Ohio
Harrison Sales Co., 314 Ninth Ave., North, Seattle, Wash.
Herbert.-Moore Machinery Company, 140 First Street, San Francisco, Calif.
Crane Co., 321 East Third Street, Los Angeles, Calif.



Thermostats — Low-voltage, three-wire, open-contact type. Moulded phenolic resin base and cover. External or internal adjustment on Room, Two-Temperature, Duplex and Compound types. With or without detents on all types. Differential without detent on all types except Insertion and Immersion, 1½° F.; with detent, 2° F. Ranges shown in table are ones most commonly used. Thermostats with special ranges supplied on order. Thermometers on cover optional for all types except Insertion and Immersion.

Type	Range ° F.	No. of Elements	Temperature Limits, ° F.
Room Thermostat	60–80	1	.....
Two-Temperature Thermostat	50–70 60–80	2	.....
Duplex Thermostat	60–80	2	.....
Compound Thermostat	60–80	1	.....
Insertion & Immersion Thermostat	20–120	1	0–250
Do. (Special)	120	1	250–500

Packless Valves—Positive-acting motor-operated only. Globe pattern with screwed ends. Angle, straightway, right-hand and left-hand patterns with radiator union and nut. Rough body, finished trim, nickel plated all over. Locked covers, special disk for gas, on order. Static and differential pressure capacity, 10 lbs. per sq. in. gauge on all types and sizes.

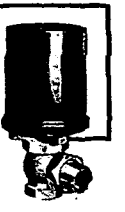
Packed Valves—Positive-acting motor-operated only. Globe or angle pattern with screwed ends, flanged ends without companion flanges, or radiator union and nut. Rough body, finished trim. Radiator style nickeled. Locked covers, special disk for gas, special camshaft and spring assembly on order. Moulded or metal covers optional.

Differential Pressure Capacities of Packed Valves

Static Pressure—125 Lbs. per Sq. In. Gauge

SIZE	½"	¾"	1"	1¼"	1½"	2"
Steam Tight	125	75	65	45	30	10
Water Tight	125	90	75	55	35	15

Line Valves—Globe or angle pattern, screwed or flanged ends. Cast iron body. Bronze seat, composition disk. Motor-operator either positive or reversing. The 5 in., 6 in., and 8 in. sizes in balanced or semi-balanced types, double disc, globe pattern only.



Type	Rating Volts	Rating Cycles	Input Amps.	Input Watts	Minimum Operating Voltage	Shading Coil Current Amps.	Camshaft Torque lb. in.	Pressure on Valve Seat, lbs.	Avg. Secs. per Stroke
Positive	25	60	2.2	28.5	20	..	370	300	75
Reversing	25	60	2.5	35	20	0.6	500	300	275

Differential Pressure Capacities of Line Valves

Static Pressure—150 Lbs. per Sq. In. Gauge

SIZE	2"	2½"	3"	3½"	4"
Tight	40	30	20	15	10
Throttling Service	60	40	30	20	10

Damper Controllers—Type aYCg for dampers up to 15 sq. ft. in area; and type eYCc, for dampers up to 50 sq. ft. in area. Positive or reversing. Reversing types have fixed or adjustable speed regulation, and two position or multi-position styles. Metal case, filled with oil and sealed. Type aYCg, positive, fixed speed, available air cooled (no oil). Special camshaft assembly on order.

Types and Models	Rating Volts	Rating Cycles	Input Running Amps.	Input Running Watts	Input Idle Amps.	Input Idle Watts	Shaft Torque lb. in.	Seconds per 360° at No Load	Shading Coil Current Amps.
Type aYCg Positive	25	60	2.0	29	0	0	100	200	..
Type aYCg Reversing	25	60	2.3	27	2.4	22	60	250–1100	0.45
Type eYCc Positive	25	60	2.1	28	0	0	150	120	..
Type eYCc Reversing	25	60	2.5	36	2.0	15	220	280–3000	0.60

Johnson Service Company

General Offices and Factory

Milwaukee, Wisconsin

Albany, N. Y.	Denver, Colo.	Minneapolis, Minn.
Atlanta, Ga.	Des Moines, Ia.	New York City, N. Y.
Baltimore, Md.	Detroit, Mich.	Philadelphia, Pa.
Boston, Mass.	Greensboro, N. C.	Pittsburgh, Pa.
Buffalo, N. Y.	Indianapolis, Ind.	Portland, Oregon
Chicago, Ill.	Kansas City, Mo.	Salt Lake City, Utah
Cincinnati, O.	Los Angeles, Calif.	San Francisco, Calif.
Cleveland, O.	Milwaukee, Wis.	St. Louis, Mo.
Dallas, Texas		Seattle, Wash.

JOHNSON TEMPERATURE REGULATING CO. OF CAN., LTD.,
97 Jarvis St., Toronto, Ont., Can.

Montreal, Que. Winnipeg, Man. Calgary, Alb. Vancouver, B. C.

Products and Services

Engineers and contractors for the control of temperature or humidity for any purpose and over every range used in manufacturing purposes or buildings, furnishing and installing:

Temperature Controlling Apparatus for any and all kinds of heating and ventilating systems.

Temperature Controlling Apparatus for any industrial process requiring the medium of heat.

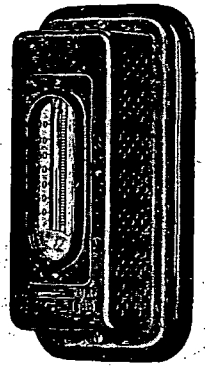
Control of humidity in industrial processes requiring artificial humidification.

Dual or two-temperature systems of temperature control for entire buildings.

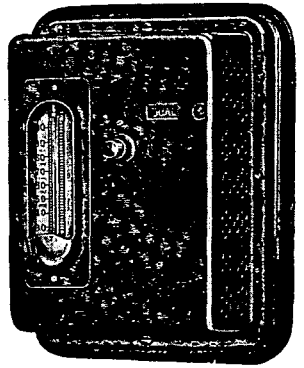
Manufacturers of thermostats and other apparatus for the control of temperature and humidity.

Johnson All-Metal Thermostats

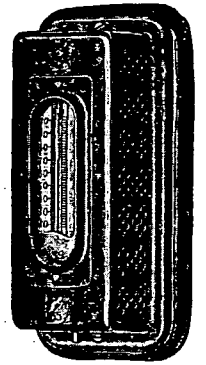
Every Johnson Thermostat is ALL-METAL throughout, having no soft or hard rubber parts to deteriorate and become inoperative. Every thermostat exquisitely made and thoroughly tested for accuracy, efficiency and durability.



Model "P" Lever Shutoff Lever Adjustment



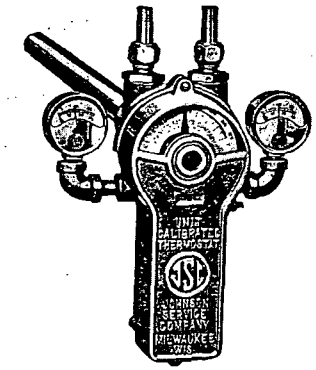
Dual Thermostat with Push Button



Model "P" Dial Adjustment

Johnson Intermediate or Graduated Action Thermostat

This thermostat gives a true graduated motion to mixing dampers and valves. It holds them in an intermediate position to maintain the temperature of the room accurately within one degree above or below the setting of the thermostat. This thermostat is best suited for all systems of heating and ventilating except the single pipe gravity steam system. The Johnson positive movement is manufactured for use in connection with single pipe gravity systems.



Unit Calibrated Thermostat

Johnson Dual or Two-Temperature Thermostat

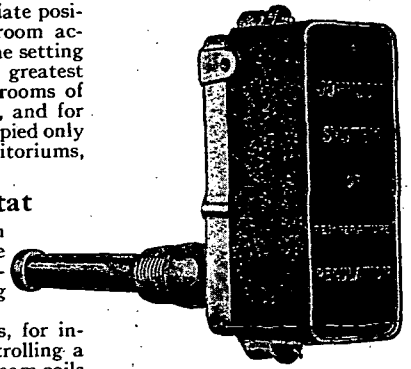
The Dual, or two-temperature thermostat provides for a daylight temperature (usually 70 deg.) and a night-time temperature (35 to 50 deg.) as desired, for all or some of the rooms in a building, simply by the manipulation of a single push button by the engineer or other person in authority. It is an all-metal thermostat and operates valves and dampers with a gradual motion, holding them in an intermediate position to maintain the temperature of the room accurately within one degree above or below the setting of the thermostat. It is a factor for the greatest economy in school buildings, a number of rooms of which are occupied at night as well as day, and for buildings in which some of the rooms are occupied only at certain times, such as churches, auditoriums, masonic temples and lodges.

Johnson Insertion Thermostat

Designed to control temperatures within closed air chambers or ducts and tanks. The body of thermostat is a dust-proof case containing the two working parts and extending outside the chamber.

Designed, in the case of hot water tanks, for insertion through 1 in. tapped hole and controlling a diaphragm valve on the supply pipe to the steam coils in the tank. It can be used to control the temperature of any liquid, either hot or cold. It is especially adaptable for controlling the temperature of water in hot water heating plants.

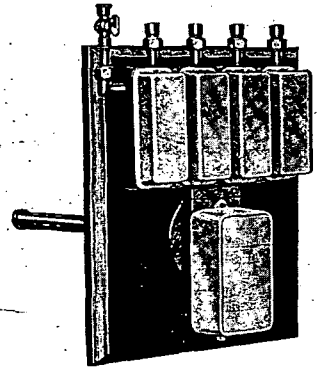
Adaptable for use in bake ovens for enamels, japans, etc.; drying rooms for paints, varnishes, patent leather, etc.; storage rooms for tobacco, rubber or similar goods; sterilizers or pasteurizers, cold-storage rooms, fur vaults, etc.; refrigerator machine control; humidity control for air washers; flue gas tempered control; hot blast heating plants; combination tempered ventilation and hot blast systems; greenhouses, Turkish bath rooms, etc.; tempered ventilation for buildings.



Liquid Insertion Thermostat

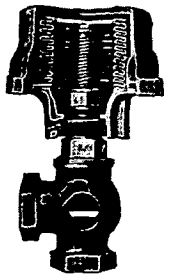
Multiple Insertion Thermostat

Similar to the insertion duct thermostat, excepting that one multiple thermostat takes the place of a number of separate duct thermostats set for different temperatures. The 4-point multiple thermostat shown will operate four separate diaphragm valves at as many different temperatures. It has become very popular with heating engineers for the control of heating and tempering coils where it is desired to have these coils turn on at different temperatures.

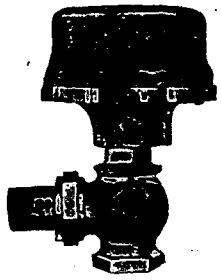


Four-Point Multiple Thermostat

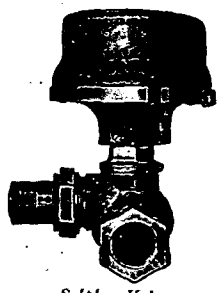
Johnson Metal Diaphragm Valve



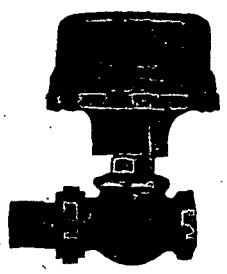
Sylphon Valve Sectional View



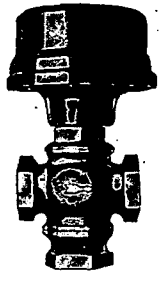
Sylphon Valve Angle



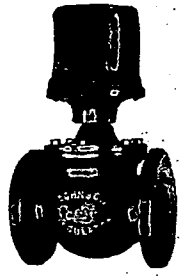
Sylphon Valve Offset Corner



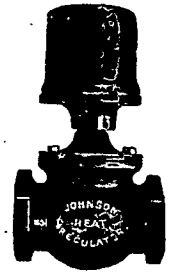
Sylphon Globe Valve



Sylphon Valve Brass Three-Way



Flanged Globe Coil Valve



Screwed Globe Coil Valve

Pneumatic Switch Control

Remote valve and damper control plays, by means of our pneumatic switches, a very important part in the economical operation of the modern heating plant, especially in schools. It saves the janitor's time for other duties, and makes it possible to accomplish results in the operation of the heating plant which can not be obtained in any other way. It makes it easy to operate the fresh air, return air and vent dampers. It also makes possible and facilitates the control of risers in office buildings in accordance with the latest practices for the economical use of steam.

Different types of pneumatic switches:

Lever handle switches.

Push button switch.

Indicating switch to open and close dampers partially as desired.

Electro pneumatic switch to open and close dampers automatically—with the starting and stopping of fan motors.

Humidostats and Humidifiers

The humidostat automatically controls the supply of moisture delivered to the air by a humidifier and maintains a constant percentage of relative humidity. It operates a diaphragm valve on the steam coils in the pan humidifier. The pan is provided with float box to maintain constant water level and is located in the ventilating air duct leading throughout the building. Steam jet and water spray types of humidifiers are also furnished.

Specifications

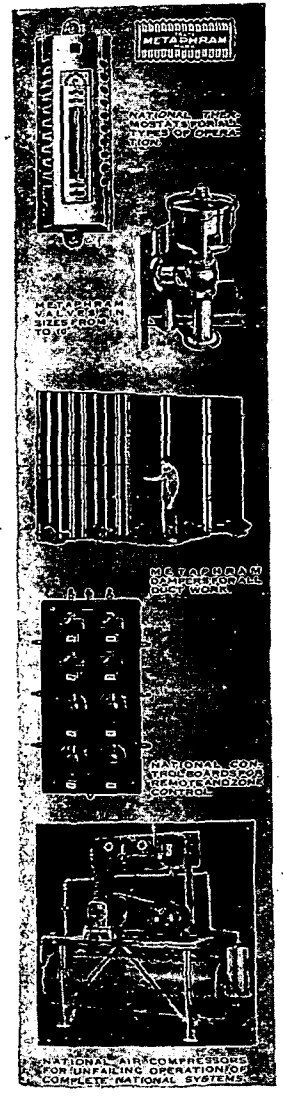
The Johnson System of Temperature Regulation to be erected and assembled by trained mechanics employed by the manufacturer, the Johnson Service Co.

The Johnson Service Company maintains an engineering organization in each of its branch offices competent to render complete information regarding application of the equipment, location of thermostats, capacity of air compressors, humidifiers, etc., and layouts of air piping. Our engineering department should be consulted regarding specifications.

National Regulator Co.

2311 Knox Avenue, **Chicago, Illinois**

National Systems for Control of Temperature, Humidity, Ventilation and Air Conditioning. Metaphram Damper Regulators for Domestic Heating Boilers. A-Jacks High Pressure Steam Damper and Combustion Control. Metaphram Damper Regulators for Domestic Boilers.



A National Control System for temperature, humidity, ventilation or air conditioning comprises coordinated equipment easily understood by local operating engineers. Each system is planned to meet the requirements of the individual building to assure proper regulation.

National Thermostats (Room Type)—Air operated; simple, two-temperature and compound types for direct radiation, direct radiation and unit ventilating machines, straight blast heating, ventilating fan units and dampers.

National Thermostats (Duct Type)—Air operated; for ventilating duct or blast heating control and hot water tanks.

National Thermostats (Industrial) for control of industrial and process temperatures.

Metaphram Valves—Air operated; for direct radiation, steam lines, hot water tanks, humidifiers and accumulator control.

Metraphram Dampers—Air operated by Metaphram motors; for accurate automatic control of ventilation and blast heating. Built in round, double or louvre types, of black or galvanized steel or special metals.

National Control Boards—Located in engineers room or central place for remote or zone control of pneumatic or electric-pneumatic switches in connection with two-temperature and zone control systems under manual or time-clock operation; operating valves or steam lines, radiation, or ventilating fan units and dampers.

National Air Compressors—Self contained, automatic units for unfailing operation of National apparatus and equipment.

Metaphram Damper Regulators for all domestic hot water or low pressure heating boilers, gas, oil or coal fired.

A-Jacks Control for high pressure boilers (15 lbs. to 300 lbs. pressure) giving synchronized control to boiler pressure and fuel consumption.

Catalogs and Bulletins—Thoroughly illustrated bulletins are available on all products. Engineering assistance will be rendered without obligation.

Minneapolis-Honeywell Regulator Company

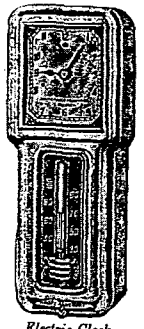
Executive Offices: 2711 Fourth Avenue, S., **Minneapolis**

Factories: Minneapolis, Minn, and Wabash, Ind.

Branch and Distributing Offices: New York, Chicago, Philadelphia, Boston, Detroit, Indianapolis, Cleveland, Providence, Newark, St. Louis, Cincinnati, Milwaukee, Pittsburgh, Baltimore, Washington, D. C.; Buffalo, Syracuse, Rochester, N. Y.; St. Paul, Denver, Salt Lake City, Louisville, Los Angeles, San Francisco, Portland, Seattle, Hartford, New Haven, Springfield, Worcester, Mass. *In Canada: Halifax, N. S.; St. John, N. B.;* Montreal, Toronto, Windsor, Winnipeg, Calgary, Vancouver. Agencies in almost every city.

Manufacturers of Temperature, Pressure and Safety Combustion Controls for all Types of Residence and Industrial Heating Systems, Including Oil Burners, Gas Burners, Coal Stokers, Automatic Blowers and District Steam. Service Departments Maintained by all Branch Offices and Agencies. Complete Systems of Control for Schools and other Public Buildings.

THERMOSTATS—Oil, Gas, Coal or District Steam Heat Control

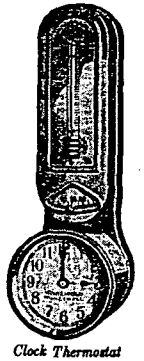


Electric Clock Thermostat

Electric Clock Thermostat operates from the house lighting circuit. The clock movement is a synchronous type and in the event of power failure it restarts itself when power is resumed. At night it automatically lowers the thermostat setting and raises it to the day time setting early in the morning. It is available for 60 cycle operation only.

8-Day Clock Thermostats—give differential day and night temperature control for residences or commercial buildings unoccupied at night so lower night temperature is desirable. Types available for motor valve or relay operation.

With Week-end Shut-off—Permits the clock to skip performance of its normal function of raising the temperature in the morning of any day or days that the building is unoccupied, maintaining the "night" temperature throughout the week-end or holiday; but automatically restores the warmer temperature on the morning of the day that the building is again occupied.



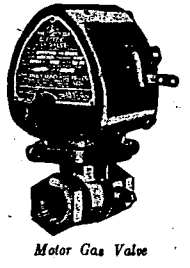
Clock Thermostat

Plain Thermostats (low voltage)—are used where one temperature is required at all hours or where irregular temperature regulation or group or master clock control is necessary. Available for motor valve or relay operation.

110 Volt Thermostats (Mercury Switch Type)—for use where most accurate operation is not essential, such as in garages, storage warehouses, etc. No transformers or relays are needed.

THERMOSTAT GUARDS—Fitted and locked over thermostats to prevent tampering with the setting or mechanism.

LIMIT CONTROLS—Important safety units which prevent overheating of boiler or furnace. They prevent overruns of temperature and economize in fuel consumption. Models suitable for all types of heating plants: The Aquastat for hot water systems; Pressuretrol for steam systems; Vaporstat for vapor systems, and the Warm Air Limit Control for warm air plants.

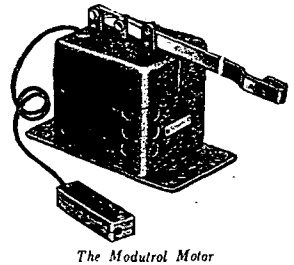


Motor Gas Valve

PROTECTORELAY—Complete line for full automatic control of all types of oil burner installations. Available for 110 or 220 volt, 25, 30, 40, 50 or 60 cycle A. C. and 110 or 220 volt D. C. Listed as standard by Underwriters' Laboratories, Inc.

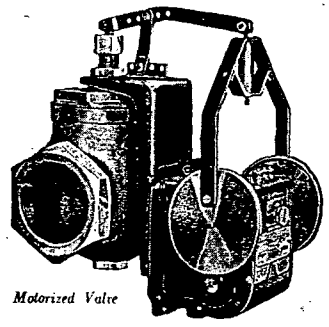
GAS VALVES—Minneapolis-Honeywell motorized gas valves for automatically controlling gas supply operated by low voltage series 10 thermostats. Gas valves for use in connection with Pyrostat or Protectostat also available. Provide positive operation at all times with safety combustion protection by the use of a thermal cutout switch. Available in sizes ¾, 1, 1¼, 1½, 2 and 2½ in.

Minneapolis-Honeywell Complete Control Systems are designed to meet the requirements, no matter how specialized, of large or small factories and buildings of all types, in maintaining accurate and automatic control of temperatures. Not only are there control systems for the automatic control of heating systems, but for air conditioning systems as well. There are listed here a few of the typical Minneapolis-Honeywell systems of automatic control.



The Modutrol Motor

Unit Heater Control System—There are Minneapolis-Honeywell Controls suitable for the control of single unit heater or batteries of unit heaters. This system includes, depending upon the installation, line voltage or low voltage thermostats, single or polyphase, high or low voltage relays, and Unifan Controls that prevent the heater from operating when the heating coils are cold.

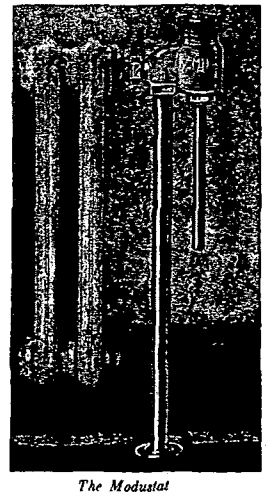


Motorized Valve

Zone or Sectional Control Systems—A wide variety of controls is used to provide any desired degree of complete automatic control. A system of this type includes thermostats and motorized valves that control the supply of heat to the various zones of control.

The Modustat—This self-contained modulating radiator valve automatically controls the temperature of individual rooms. It can be used successfully on direct or concealed radiators. It is often employed as part of a complete Zone Control System.

The Low Limit Control System—By keeping the radiators or warm air ducts always slightly warmer than room temperatures air stratification due to lack of air circulation is prevented, and the condition known as Cold 70° is eliminated. This system is adaptable to any type of heat burning any kind of fuel.



The Modustat

Summer-Winter Control System—This system enables an automatic coal, gas, or oil burner to provide domestic hot water supply economically by means of an indirect heater throughout the entire year.

The Modutrol System—This system provides automatic modulating control of dampers, louvers, valves, etc., used in connection with air conditioning and ventilation systems, and Unit Ventilators.

Complete catalogs fully describing and illustrating any of the instruments or systems mentioned above, will be gladly sent upon request.

GENERAL ELECTRIC

HEAT REGULATOR

PENN HEAT CONTROL CO., National Distributors, Franklin Trust Bldg.,

Philadelphia, Pa., U. S. A.

District Sales Offices

NEW YORK CITY, N. Y. BOSTON, MASS. DETROIT, MICH. CHICAGO, ILL. SAN FRANCISCO, CALIF.

Canada

THE CANADIAN GENERAL ELECTRIC COMPANY

Distributors in all Principal Cities

PRODUCT—General Electric Heat Regulator is a new, improved heat regulator for the automatic control of temperature, in homes, apartments, schools, churches, business establishments, factories and other buildings equipped with some form of heating apparatus.

Uses—For all hand-fired furnaces, oil burners, gas heaters, and central plant heat.

Mechanics—There are two principal parts of the General Electric Heat Regulator—a thermostat, installed in the upper quarters of the home or building, and a regulator, installed with the heating apparatus in the basement. The thermostat is comprised, essentially, of a bimetallic blade, or blades, with an adjustable dial for temperature setting. Adjustment can be made over a range of thirty degrees—from 50 degrees to 80 degrees Fahrenheit. The regulator differs in construction depending upon the type of heat employed. For hand-fired furnaces it is equipped with two arms, from which chains are run to the damper doors. The regulator, controlled by responses of the thermostat, operates these arms, so that they open the damper and close the check-draft when heat is required, and close the damper opening the check-draft, when the temperature selected on the thermostat has been reached.

With gas heaters, these arms operate the gas valves and air supply, adjusting the flame to the temperature requirements.

With central plant heat, the amount of steam fed into the basement from the main supply is regulated according to temperature requirements.

The General Electric Heat Regulator for oil burners differs entirely in mechanical construction and operation. It governs the ignition and combustion of the oil in the burner, and regulates starting and stopping cycles to conform exactly with temperature requirements.

Improvements—General Electric Heat Regulator for hand-fired furnaces. Devices hitherto on the market have controlled heating only insofar as they have taken the actual regulation of the furnace out of the hands of a human attendant. When a need for heat was transmitted from the thermostat to the control unit, the damper was opened entirely and the furnace set to generating heat to its full capacity. This was continued until the room temperature had reached the degree indicated on the thermostat, at which point the control unit completely shut the damper. But the excess heat, resulting from full operation of the furnace, continued to raise the temperature and consequently overheat the house. Since this additional heat demanded an excessive amount of fuel, a loss in economy was inevitable.

In the new General Electric Heat Regulator, this uneven heating has been eliminated by a "floating" damper control. This does away with extreme operation; the doors are moved to positions between open and closed—three-quarters, a half, a quarter, a tenth open—at which full value is derived, every hour of the day and night, from every bit of fuel used. Draft is graduated, and once the furnace has generated enough heat to raise the temperature to the desired degree, it is given only sufficient draft to keep it there. This assures even heating and economy.

In the room thermostat is a small resistance coil, termed a preheat coil, which receives energy when the thermostat calls for heat, and builds the temperature within the thermostat two degrees higher than the actual room temperature during draft periods. Thus, as the temperature approaches the degree selected on the thermostat, it is anticipated, and the furnace is slowed down. This prevents overshooting of the room temperature,

within its consequent waste of fuel—and eliminates subsequent temperature fluctuation.

A special safety device, called the fail-safe, closes the damper if the electric current supply fails and the regulator is thus rendered powerless to operate. With ordinary heat controls, such a power failure exposes the owner to the danger of an excessive generation of heat in his furnace, or of steam in his boiler, for, if the thermostat is calling for heat, and the damper door has been opened, the regulator is powerless to close it, and the fire continues at full blast.

With General Electric Heat Regulator, the damper door can be regulated by hand until the power is restored—when, without further attention the regulator again assumes control. The chains from the control box to the damper doors do not, at any time, have to be removed.

For Oil Burners—The control unit for oil burners has the advantage of an electric timer—as in the GE Clock—for the control of day and night temperature changes and the starting operation of the burner.

A positive recycling mechanism, driven by the electric timing motor, repeats itself five times if the flame is not established, and then shuts itself off.

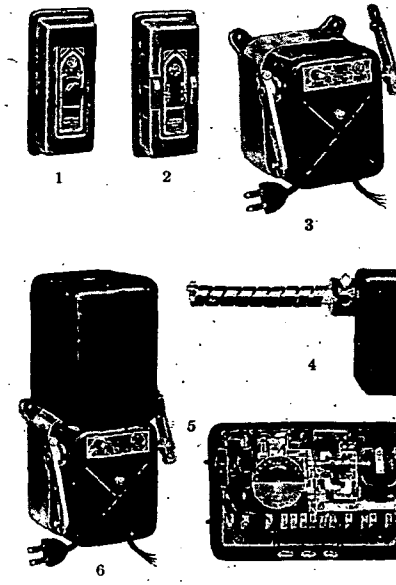
A supersensitive ignition cut-off works with two to four second operation, insuring absolute safety under all operating conditions.

65 oil-burner manufacturers already are using General Electric Heat Regulator. 12 are standardizing on it.

Installation—General Electric Heat Regulator is easily installed on present heating system. No intricate wiring is necessary. The installation of the cable between the thermostat in the living quarters and the regulator in the basement is the major operation required. The regulator is then put in operation simply by plugging into the regular electric house current.

General Electric Consultation—Specialists in the installation and use of this equipment are available at any time. They will gladly co-operate with you in arranging for satisfactory heat regulation, in homes, schools, churches or business establishments.

Standard Models—General Electric Heat Regulator comes in two models, a single-range model, selling for $85, completely installed, and a double-range model, with electric timing, for making day and night temperature changes automatically—at $125. With the single-range model, manual attention is necessary whenever the temperature is to be changed. The double-range model, as explained, is regulated by an electric timer, operating in the control box in the basement. The two dials on this thermostat, one for day, the other for night temperature, are set at the desired degrees and, without further attention, the regulator secures the right temperatures morning and night.



1. Single-range thermostat, with $85 model of damper regulator. Radio-type dial. Rugged, compact. Neatly unobtrusive on any wall.
2. Double-range thermostat, with $125 model of damper regulator. Day and night dials. Same size and finish as single-range thermostat.
3. Closed view of control unit with single-range model of damper regulator. Chains extend from the arms to furnace dampers (or heat supply valves, with gas or central plant heat).
4. The stack control, a switch mechanism operated by a spiral thermostatic element, for use with systems of oil burner heat regulator.
5. A special type of General Electric Heat Regulator is made for oil burners. Illustration shows control unit of oil burner regulator with cover removed. GE Electric Timer—same as used in GE Electric Clocks.
6. Closed view of control unit with double-range model of damper regulator. Electric timer makes day and night changes automatically.

THE POWERS REGULATOR CO.

Over 40 years of specialization in temperature control

General Offices and Factory—2719 GREENVIEW AVENUE, CHICAGO, ILL.

General Eastern Offices—231 EAST 46th STREET, NEW YORK CITY

THE CANADIAN POWERS REGULATOR CO., LTD., TORONTO, ONT.

List of Branch Offices of The Powers Regulator Co.

Atlanta, Ga.	Columbus, Ohio	Milwaukee, Wis.	San Francisco, Calif.
Baltimore, Md.	Dallas, Texas	Minneapolis, Minn.	Seattle, Wash.
Birmingham, Ala.	Denver, Colo.	Nashville, Tenn.	St. Louis, Mo.
Boston, Mass.	Detroit, Mich.	New Orleans, La.	Syracuse, N. Y.
Buffalo, N. Y.	El Paso, Texas	Philadelphia, Pa.	
Butte, Mont.	Houston, Texas	Pittsburgh, Pa.	Calgary
Charlotte, N. C.	Indianapolis, Ind.	Portland, Ore.	Halifax
Chattanooga, Tenn.	Kansas City, Mo.	Reading, Pa.	Montreal
Cincinnati, Ohio	Los Angeles, Calif.	Rochester, N. Y.	Vancouver
Cleveland, Ohio	Memphis, Tenn.	Salt Lake City, Utah	Winnipeg

Products

Automatic Temperature Controlling Systems, applying them, under the supervision of Powers engineers, to the heating plants, new or old, in residences, offices, factories, schools, institutions, and to any other conditions of artificial heating where uniform temperature is desired.

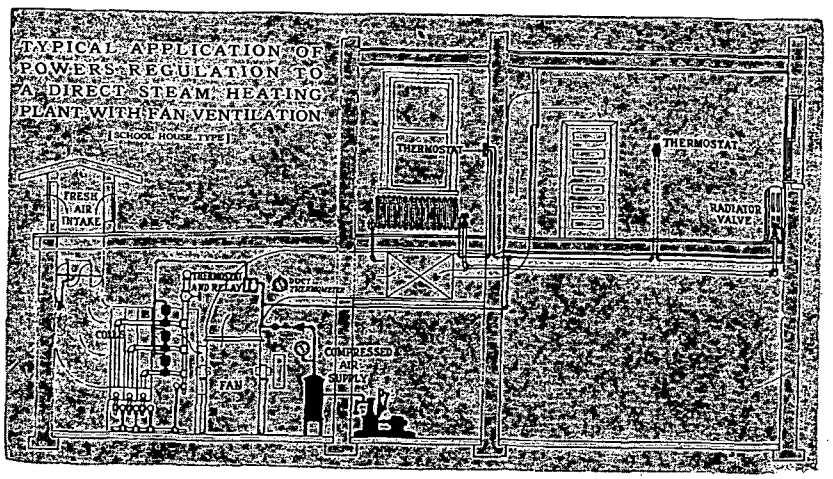
Automatic Regulators for ACCURATELY controlling temperature of Liquids, Gases and Air, Pressure Reducing Valves, High Pressure Steam Traps, Humidity Control Devices, Shower Mixing Valves, Etc.

Temperature Controlling Appliances

Powers thermostats are accurate in their working and will maintain their adjustment. They are of the vapor disc type, exclusive with Powers regulators, and are not thrown out of adjustment by extremes of temperature or long disuse. For over 40 years the accurate control obtained by this method has been the standard of thermostatic control by which all other methods are measured. In design, Powers thermostats are second to none in beauty and perfection of finish; in size, as small as is consistent with the reliability so necessary in such instruments; in operation, sure, with gradual or positive action, as conditions require.

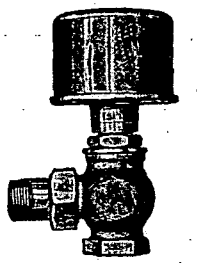
Diaphragm radiator valves, diaphragm motors, mixing dampers and other equipment are especially rugged in construction, dependable and durable: built regardless of expense, for efficiency and long service.

Motive power used in these systems is compressed air. The company builds its own air compressors, operated by steam, or electricity, and characterized by their reliability, noiseless operation, perfect control and long life.





Powers Type D Thermostat



The Powers All-Metal Radiator Valve

Installations

Installations of Powers systems are invariably made by the company. At each branch office is maintained a competent engineering and erecting force, sparing no expense to maintain the highest efficiency. Powers special devices, however, are easily installed by any engineer or contractor.

Prices

Price for Powers regulation covers the system installed complete, and is only named after a careful study of the requirements. Our price is not lowest, but no other system will be found so efficient and economical. Customers are served with the sole aim of getting results for them; and experience shows that **satisfactory service from a temperature controlling system is of much more importance than its first cost.**

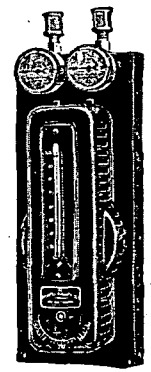
Specifications

Heating systems, and the requirements for temperature control, vary widely in detail. Much of the dissatisfaction experienced with some systems of temperature regulation is due to the attempt to force a ready-made inflexible system or device to meet special requirements, taking no account of the conditions peculiar to the situation to be treated.

For these reasons we believe special study should be given each case. We shall be glad to submit to any Architect or Engineer a detailed specification, accompanied by a guaranteed price, to cover complete system of temperature control installed, the price to hold if specification is used. This guarantees full protection to the client against advantage being taken of a close specification. This company will gladly collaborate with Architect or Engineer in preliminary plans. As specialists in temperature control, The Powers Regulator Company has unusual facilities for solving problems in this particular field.

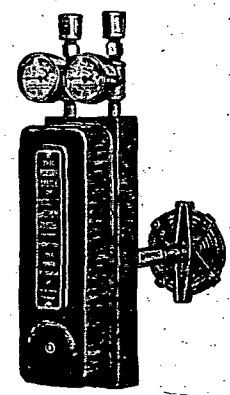
Catalogs

Engineers, Architects, and others who wish further information regarding the Powers System, will find it in the following books: *Elimination of Heat Waste* shows applications in schools, churches, and other public buildings, residences, etc.; *Shop and Office Temperatures* shows applications in shops, offices and workrooms, also presents proof of fuel savings and increased production due to its use.



Powers Type K Heavy Duty Thermostat

Write for Bulletin No. 251



Powers Type K Duct Thermostat

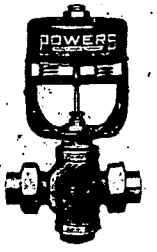


Powers Hygrostat for Humidity Control

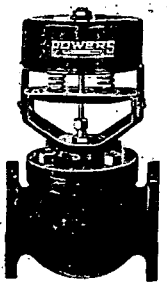
POWERS ALL-METAL DIAPHRAGM VALVES



Low Pressure All-Metal Valve



High Pressure All-Metal Valve



L. P. Iron Body Valve Flanged



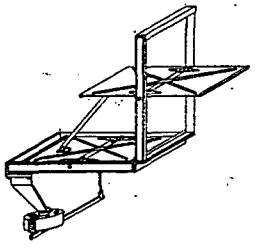
Brine Control All-Metal Valve



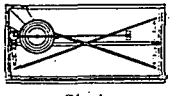
Three-Way All-Metal Valve

Write for Bulletin No. 244

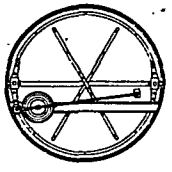
POWERS DAMPERS



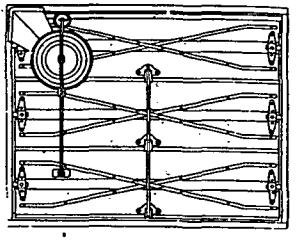
Mixing



Single



Round

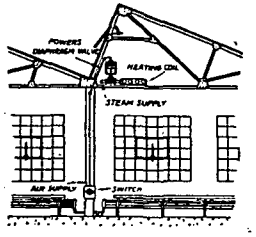


Louver

Write for Bulletin No. 244

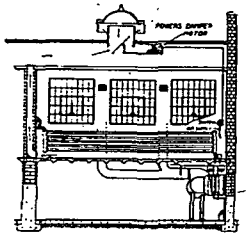
POWERS PNEUMATIC SWITCH FOR REMOTE CONTROL

of Diaphragm Valves and Dampers



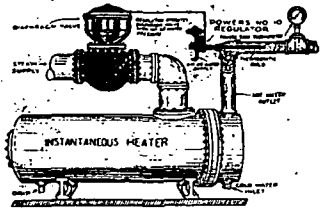


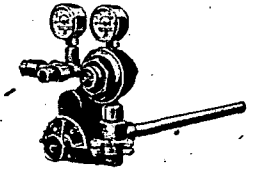
Write for Bulletin No. 257



NO. 10 REGULATOR

operated by Compressed Air or Water Pressure

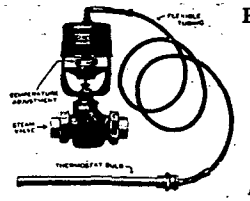




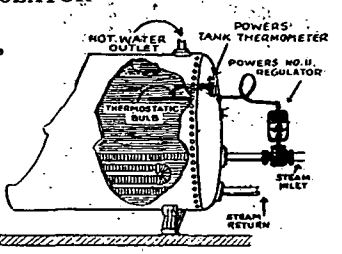
Write for Bulletin No. 216

POWERS SELF OPERATING REGULATORS

POWERS NO. 11 REGULATOR

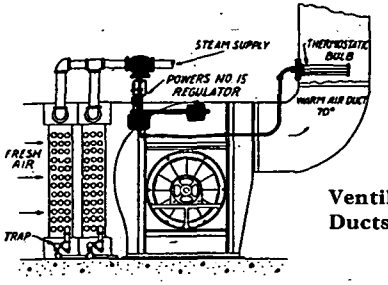


For Hot Water Heaters, Feed Water Heaters, Fuel Oil Heaters, Drinking Water Systems, Etc.



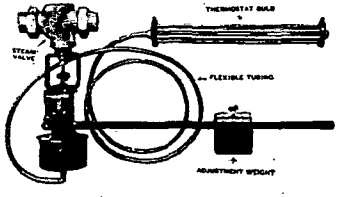
Write for Bulletin No. 229

POWERS NO. 15 REGULATOR



For Drying Rooms

Ventilating Ducts, Etc.

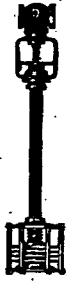


Write for Bulletin No. 238

POWERS NO. 16 REGULATOR



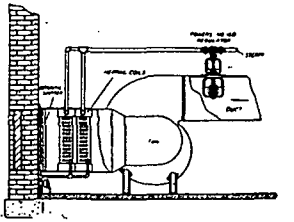
Style A

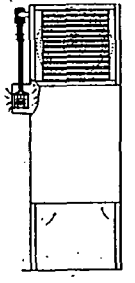


Style B

For Unit Heaters

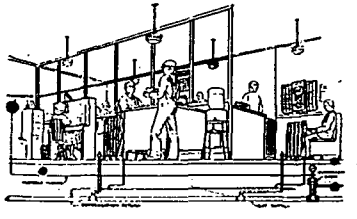
Ventilating Ducts, Brine Coil Control, Etc.





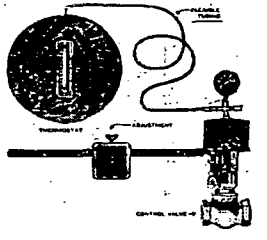
Write for Bulletin No. 246

POWERS NO. 18 REGULATOR



Installed on direct heating system in an office.

For Storage Rooms Offices and Factories



Write for Bulletin No. 245

F. I. Raymond Company

629 West Washington Boulevard, Chicago, Ill.

AUTOMATIC HEAT REGULATION SYSTEMS

Controlled by the Outdoor Temperature

Raymond Duo-Stat For Steam

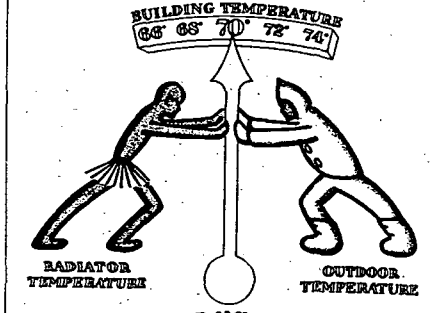
The Duo-Stat for Steam Heating Systems, shown in Figure 1, contains a mercury switch which is opened or closed by changes in the combined temperature of THREE metal bulbs filled with liquid. Two of these bulbs are attached to the last radiator on the longest steam line and the other is placed outdoors. The outdoor bulb changes the temperature at which the radiator bulbs open and close the switch. When the Duo-Stat is used to control the heating plant, the radiators are therefore maintained at a steady temperature which is proportional to the outdoor temperature.

Raymond Duo-Stat For Hot Water

The Duo-Stat for Hot Water Heating Systems is like the Duo-Stat for Steam except that the volumes of the metal bulbs are different and there are only TWO bulbs instead of three. One bulb is attached to a large flow main and the other is placed outdoors. Under its control an oil burner or any other automatic burner will maintain the water at a temperature which is proportional to the outdoor temperature.

Dimensions of The Duo-Stats

Overall dimensions of the case of all Duo-Stats are:—5 in. wide, 7½ in. high and 3¾ in. deep. All Duo-Stats are provided with 10 ft. of flexible tubing connecting the outdoor bulb to the Duo-Stat and with 20 ft. of flexible tubing connecting the radiator or boiler bulbs to the Duo-Stat. Duo-Stats for steam are provided with 2 ft. of tubing between the radiator bulbs. A recess is provided in the back of the Duo-Stat in which any excess of tubing is left coiled up. All bulbs are ⅜ in. in outside diameter and from 4 in. to 10 in. in length.



THE RAYMOND
DUO-STAT

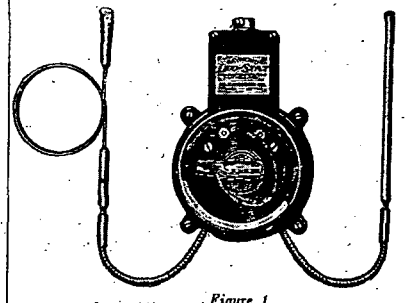


Figure 1
The Raymond Duo-Stat for Steam

OPERATING SCHEDULE OF RAYMOND DUO-STATS

TYPE DUO-STAT	OUTDOOR TEMPERATURE (Degrees Fahrenheit)									
	70	60	50	40	30	20	10	0	−10	−20
	WATER TEMPERATURE (Hot Water Duo-Stats)									
C-1	100	110	120	130	140	150	160	170	180	190
C-1¼	90	102	115	127	140	152	165	177	190	202
C-1½	75	90	105	120	135	150	165	180	195	210
	RADIATOR TEMPERATURE (Steam Duo-Stats)									
C-1¾	70	87	105	122	140	157	175	192	210	227
C-2	70	90	110	130	150	170	190	210	230	
C-2½	70	95	120	145	170	195	220			
C-3	70	100	130	160	190	220				
C-4	70	110	150	190	230					

All Duo-Stats are adjustable to 30° F. above or below the schedule shown.

Applications of The Raymond Duo-Stat

How to Use The Duo-Stat For Controlling Steam Heating Systems

Referring to Figure 2, the essentials of the Duo-Stat installation with a steam heating system are:—

1. Trace the steam mains from the boiler to find the last radiator on the longest steam line.
2. Mount the Duo-Stat on a wall or in a box not more than 20 feet from this last radiator.
3. Clamp one of the radiator bulbs to this last radiator near the top.
4. Clamp the other radiator bulb to this last radiator near the bottom.
5. Mount the outdoor bulb outdoors, not more than 10 feet from the Duo-Stat.
6. Fasten the Duo-Stat tubing to the wall. Leave any excess coiled up in the Duo-Stat.
7. Run electric wires from the Duo-Stat to the automatic oil burner, gas burner or coal stoker, or to the automatic steam valve, which ever the case may be. Electric connections for the Duo-Stat are the same as for a thermostat.

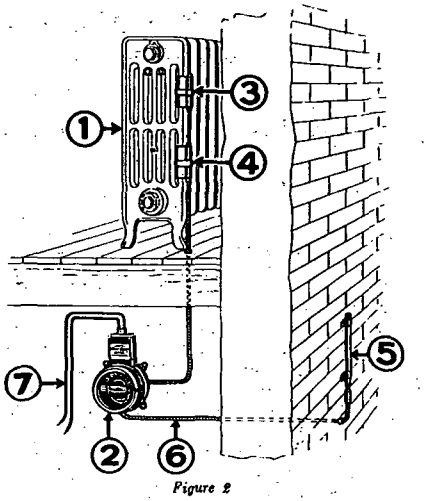


Figure 2

How to Use The Duo-Stat For Controlling Hot Water Heating Systems

Application of the Duo-Stat for controlling hot water heating systems is similar to that shown in Figure 2, for steam heating systems. The only difference is that the boiler bulb of the Duo-Stat is clamped onto a large flow main as close as possible to the boiler instead of to a radiator.

Designing A Steam Heating Plant For Duo-Stat Control

Duo-Stat control does not require any special heating layout but the installation can be simplified by keeping certain points in mind when making the piping layout. The radiator to which the Duo-Stat is applied must not be turned off. Therefore, the piping should be so arranged that the last radiator will be one in a hallway or in some room where there will be no occasion to turn the radiator off. For example, the last radiator should not be in a bedroom or in a small office with only one radiator. Preferably it should be in a hall where the attendant can have access to the Duo-Stat and the radiator without entering a tenant's quarters.

Where the entire system is controlled as a unit, it will be desirable to have the outdoor bulb of the Duo-Stat located on the north side of the building. Therefore, the piping should be arranged so as to bring the last radiator near the north side of the building.

Designing A Zoned Steam Heating System For Duo-Stat Control

Duo-Stat control eliminates high differential between the supply and return lines of a vacuum return line heating system. Therefore, all zones may be connected to the same vacuum pump.

Any good vacuum return line heating system with the standard size vacuum pump is all that is required. The piping should be laid out to supply the different exposures from separate branch mains and each one of these branches should be provided with any standard make of motorized valve.

Heating plans may be sent to our home office for suggestions without obligation. We do not make heating plans, but we are often able to give worth while suggestions to consulting engineers, in connection with our equipment.

Heating and Ventilating

THE INDUSTRIAL PRESS, PUBLISHERS

140 Lafayette Street, **New York City**

Founded 1904



Heating and Ventilating accepted as the authoritative publication in the field of heating, ventilating and air conditioning, is edited by engineers who know their subject and who know the needs of the specialists in the field.

Voluntary renewal of over 76 per cent of subscriptions testifies to the reader interest in Heating and Ventilating and to the value of the timely articles.

Editorials on the planning, installation and operation of heating, ventilating and air conditioning systems in public buildings of all kinds, in offices, factories, schools, hospitals and homes, keep subscribers abreast of the latest development in these fields.

Constant striving to promote better understanding of the problems that arise in the development and application of equipment has enabled Heating and Ventilating to play its part in the progress manifested in this field.

Heating and Ventilating also helps manufacturers of heating, ventilating and air conditioning equipment to maintain constant contact with the technicians and with the men who specify, buy and install these systems for major projects.

Here is a list of some of the articles published in recent issues of Heating and Ventilating. These contributions, like all others to follow, are from men of wide practical experience:

A Study of Oil-Fired Heating Boilers.

Ventilating a University Laboratory.

Calculations for Radiant Heating.

Cooling Railway Cars with Steam.

Operation of an Air Conditioning Plant in a Large Office Building.

Designing Water Supply Piping for Building.

Heating and Cooling for a Modern Bank and Office Building.

Clean Air necessary for Proper Ventilation of Homes.

Setting the Thermostat Back at Night.

An Electrically Heated Office Building.

Radiant Heating Studied in Britain by Using Scaled Models.

What Thickness Insulation for Gas Heated Buildings?

Problems of Library Heating and Ventilation.

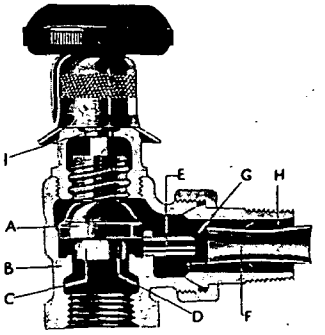
Sample copies of Heating and Ventilating on request. Subscription Price $2.00 a year.

D. G. C. Trap and Valve Company, Inc.

1 E. 43 Street **New York** **Murray Hill 2-7320**

Makers of Cryer Radiator Control Valves, Radiator Traps and Steam Traps

Distributors in All Principal Cities

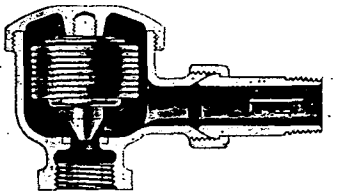


Cryer Radiator Control Valve

A Control Valve which gives to steam heating systems the same operating economies, and the same medium temperatures in the radiator afforded by hot water heating systems.

The Cryer Control Valve mixes the steam with air already in the radiator, and circulates this humid mixture of air and steam through all sections of the radiator.

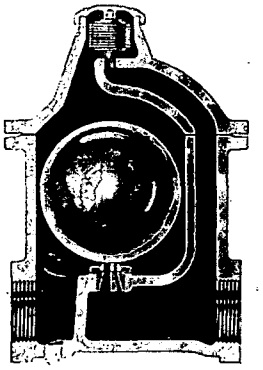
The temperature of the whole radiator may be varied at will from the low temperatures usual only with hot water, to the full steam effect.



Cryer Radiator Trap

A Thermostatic Radiator Trap constructed to endure as well as to operate efficiently. The bellows is made of a special bronze alloy, the seat of stainless steel, the spud, nut and cap are bronze forgings, and the body is a heavy bronze casting. Made to standard dimensions.

Suitable for low pressure, vacuum or vapor heating.



Cryer Condensation Trap

A heavy duty Condensation trap for Unit Heaters, Ventilating Stacks, Hot Water Heaters and other large units. Compact design, small enough to be used anywhere, but of large capacity. Cannot air-bind.

The Cryer Condensation Trap is of the unattached ball float type, with a thermostatic air by-pass. The valve seats are stainless steel, the float seamless copper nickel-plated, the bellows of bronze alloy, and the body of heavy cast-iron.

The pressure limit is 10 lbs.

Catalogues on Request

The Direct Control Valve Company

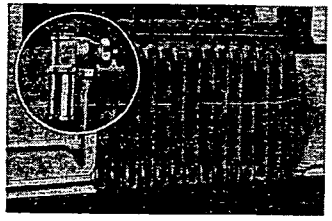
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St. Paul	Edmonton	Tulsa
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Montreal	Newark	Vancouver

DIRECT CONTROL VALVE

It is a thermostatically operated, hydraulic, quick opening, packless radiator valve, controlling the steam to the radiator so as to automatically maintain room temperature at any required degree.

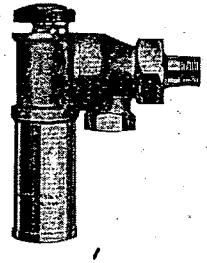


Self Contained Unit

The Direct Control Valve is a tried and perfected method of individual radiator control. It is a complete, self contained unit requiring no outside attachments or power of any kind. It is as easily installed as a hand valve. It costs only a fraction of the usual temperature control system. It automatically regulates the amount of steam to the radiator. The saving in fuel alone usually repays its cost in about 3 years.

It may be applied to any building, new or old, which is equipped with a two-pipe heating system—vacuum, vapor, or atmospheric steam.

The degree of temperature at which the room is to be maintained may be controlled by the occupant of the room. Or the valve can be equipped with a lock to be operated only by the building operator.



Advantages

Reduced Fuel Cost—Maintains constant, healthful temperature with large savings in steam and fuel. *The savings in fuel alone return complete installation costs together with interest on the investment in about 3 years.*

THE DIRECT CONTROL VALVE COMPANY

Low Maintenance Cost—There is practically no maintenance cost. The Direct Control Valve is a self contained unit requiring no outside accessories or attachments, no complicated piping systems, no delicate wall mounted thermostats. *The First Cost is the Last Cost.*

Low Initial Cost—It requires no more labor installation cost than an ordinary hand valve. The simplicity of design and the sturdy construction assures uninterrupted temperature control within the prescribed control limits with practically no upkeep costs. The valve is of all metal construction, guaranteed for 3 years, and built to give indefinitely long service.

Description

Thermostatic Unit—The thermostatic unit, 3½ in. long, is ruggedly built to withstand abuse. Utilizes hydraulic pressure for valve operation. Is positive and powerful, fulfilling test of 2500-3000 lbs. per sq. in. The hydraulic pressure is constant and effective. It is unaffected by evaporation or chemical change—once filled and sealed it remains in its original condition developing constantly the necessary power to firmly seat the valve.

Standard Type—Occupies a minimum of space. Height over all 7 in.

Sizes—Furnished in ¾, 1, 1¼, 1½ and 2 in. sizes.

Recessed Radiators—For concealed or recessed radiators, valves can be furnished with extension stems, and operates in radiator enclosures.

Specification

On each radiator, furnish and install a self-contained thermostatic radiator valve, designed to control room temperature within one degree above or below a predetermined room temperature.

These valves shall be actuated by means of hydraulic thermostat and shall be so arranged that each valve can be shut off by hand or not, as desired.

These valves shall be designed to control at an average room temperature of ..... deg. fahr.

Valves shall be nickel-plated finish and shall be of the following sizes:

For radiators up to 80 sq. ft. ¾ in. valve
For radiators 80 to 140 sq. ft. 1 in. valve
For radiators 140 to 250 sq. ft. 1¼ in. valve
For radiators 250 to 350 sq. ft. 1½ in. valve
For radiators 350 sq. ft. and above 2 in. valve

Standard Guarantee

The Direct Control Valve Company guarantees that a Direct Control Valve or Valves, when properly installed on sufficient radiation to properly heat the room, will maintain a room temperature within the limits of 1 deg. fahr. above and 1 deg. fahr. below the point of adjustment.

Write for catalogue showing all dimensions.

A Few Notable Recent Installations:

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Minneapolis

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Philadelphia

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New York City

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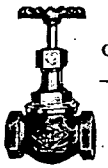


Fig. 106-Bronze Globe, Screwed

PRODUCTS

Jenkins Globe, Angle, Cross, Check, Hose, Blow-Off, Safety and Gate Valves; Radiator Valves. Rapid Action Valves; Steam Traps; Gage Cocks; Marine Valves; Needle Valves; Valve Discs; Jenkins '96 and Jenarco Sheet Packing, Gaskets; Pump Valves; Compressed Asbestos Jointing; Moncrieff Scotch Gauge Glasses.



Fig. 106-A Bronze Globe, Screwed. One-piece screw-over bonnet, slip-on, stay-on disc holder

Renewable Disc, Bronze and Iron Body Valves

Jenkins Bronze and Iron Body Valves of the globe, angle, cross and check types in standard, medium and extra heavy patterns have renewable discs and disc holders. The renewable, resilient disc, first introduced by Jenkins many years ago, assures absolute tightness. For steam use, the discs are made of hard composition, which becomes pliable in service. For water, gas and air, softer compounds are furnished.

New advantages for valve users are to be found in Jenkins Standard Bronze Valves with the one-piece screw-over bonnet and the slip-on stay-on disc holder. Fig. 106-A, globe, screwed, is shown at the left. This line also includes angle, cross, horizontal and angle check types, screwed and flanged.

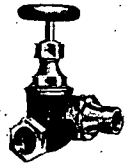


Fig. 180 Bronze Offset Corner, Radiator with Union

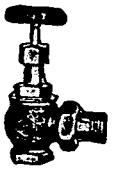


Fig. 168 Radiator Angle, with Union

Radiator Valves

Regularly furnished with black composition wheels, or, if desired, with bronze, wire or iron wheels. Furnished in the new low-bonnet patterns or the regular pattern as supplied for years.

Lock shield valves, to be operated with key, designed to prevent tampering. Supplied in all patterns.

Corner valves are made in two patterns—regular and offset. Regular styles of finish follow:

Rough body, finished trimmings, No. 1 screwed, No. 6 with union.

Finished and polished all over, No. 2 screwed, No. 7 with union.

Rough body, nickel-plated trimmings, No. 3 screwed, No. 8 with union.

Rough body, nickel-plated all over, No. 4 screwed, No. 9 with union.

Finished and nickel-plated all over, No. 5 screwed, No. 10 with union.

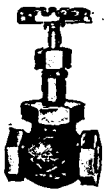


Fig. 801-Bronze Globe Valve, Screwed, with renewable composition disc and renewable seat rings, for 250 lbs. steam working pressure.

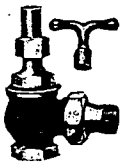


Fig. 170 Bronze Lock Shield Radiator Angle, with Union



Fig. 352-Bronze Swing Check Valve

A catalog of all the Jenkins valves, giving sizes, styles and list prices, mailed on request.

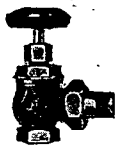


Fig. 853-Low Bonnet Radiator Angle, Male Union

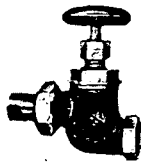


Fig. 859-Low Bonnet Radiator Offset Globe, Male Union

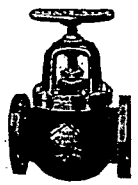


Fig. 148-Iron Body Globe, Flanged

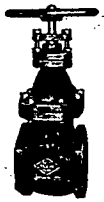


Fig. 385-Iron Body Gate, Screwed



Fig. 370-Bronze Gate, Screwed

Marsh Valve Company

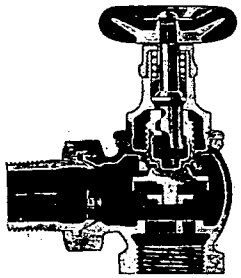
Plant and General Offices: **Dunkirk, New York**

We specialize on high-grade Radiator Valves and make the largest line of any company in the world.

The re-enforced packless feature of our Packless and Modulated lines, both steam and water, and the upper seat features of our Union Bonnet, Special and Gate lines are distinctive, scientific, mechanical principles, used with these lines exclusively.

MARSH RE-ENFORCED PACKLESS FLAT DISC RADIATOR VALVES

Oval Wheel or Lock Shield



Flat-Disc

All sizes and patterns Globes, Angles Corner and Back Offsets

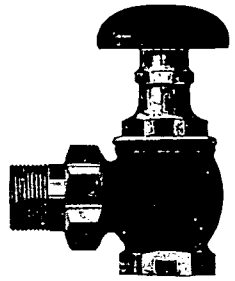


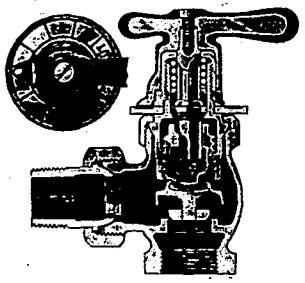
Fig. 155

We call particular attention to the scientific mechanical construction of the Re-enforced Cone Metal Packless Feature of our Modulated and Packless Valves, in which the Packless feature is re-enforced and protected against leakage due to wear or cracks of so-called Packless parts and **Guaranteed** against wear or defects of Packless construction and leakage through bonnets.

Quick Opening

A three-fourths turn will fully open a ¾ in. valve, and from this up to one and one-quarter turns for balance of line through 2 in. These valves, account of low pitch of thread due to large diameter of cylinder, will seal and lock against any pressure.

MARSH RE-ENFORCED MODULATED LEVER HANDLE RADIATOR VALVES



Flat-Disc

These Valves may be had with Oval Wheel in place of Lever Handle same as Fig. 147

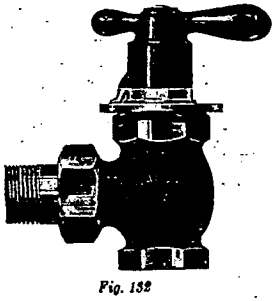
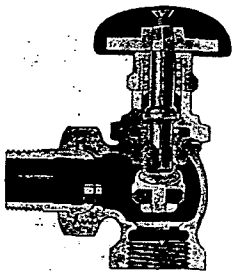


Fig. 152

The Modulation or Graduation is accomplished by a cone disc nut, regulating volume of steam, according to pressure, until indicator registers valve about two-thirds open, when the further turning of lever handle until indicator registers open, will give full valve capacity; a feature of material value in a valve in which volume or capacity for modulating purposes is choked down, and to meet extreme weather conditions, full pipe capacity is required.

MARSH RE-ENFORCED PACKLESS CONE DISC RADIATOR VALVES

Oval Wheel or Lock Shield



Cone-Disc

These Discs will not crack or leak through valve seat. No clogging or water hammer from return condensation

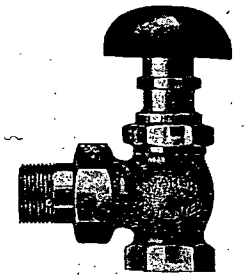
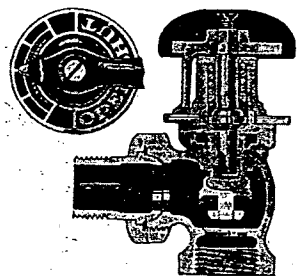


Fig. 141

Marsh Composition Cone Discs are without question one of the greatest improvements in radiator valve construction in the past fifty years or since the composition disc replaced the old style metal-to-metal disc and seat.

These Discs are **Guaranteed** not to warp or crack, and Valve Seat through bevel to wash free from scale and afford perfect drainage for a one pipe job.

MARSH RE-ENFORCED MODULATED CONE DISC RADIATOR VALVES



Cone-Disc Mod.

Oval Wheel, Lever Handle or Lock Shield

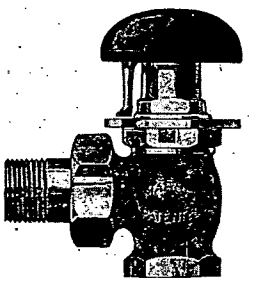


Fig. 147

The Modulation feature of our Cone Disc Line is the same as with our union bonnet flat disc Fig. 132.

Our Cone Disc Modulated valves unless otherwise ordered are fitted with Oval Wheel. When Lever Handle is preferred, Fig. No. is 148.

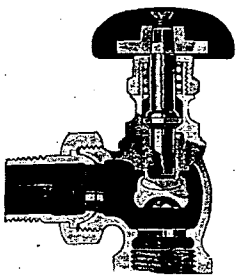
With our Oval Wheel Handle user has the same dial and indicator control as with Lever handle and a much stronger and more serviceable **Construction** than is possible with a Wood wheel as this composition won't break or split as will wood.

Further, this wheel is removable and interchangeable with our Lever handle, effecting a material advantage to customer in matter of convenience of changing from one to the other on job if for any reason change is desired.

HOT WATER HEATING

MARSH RE-ENFORCED PACKLESS WATER RADIATOR VALVES

Oval Wheel or Lock Shield



Packless

A Genuine Packless Water Valve Guaranteed to hold any pressure required for forced circulation

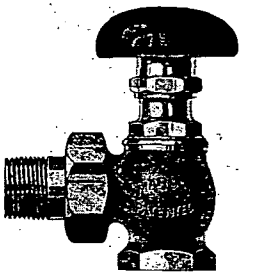
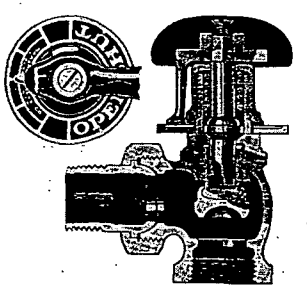


Fig. 157

These valves are quick opening, full pipe capacity, and are **Guaranteed not to Stick at any Time, or Leak at any Pressure** that a cast-iron boiler and radiation will stand.

We believe they are the only Packless valves which will hold high pressure forced circulation and also protect against taking in of air around stem in a sealed system, *two very necessary requirements* for satisfactory service and cost but little more than the cheap competition valves.

MARSH RE-ENFORCED GRADUATED WATER RADIATOR VALVES



Water Graduated

Oval Wheel, Lever Handle or Lock Shield

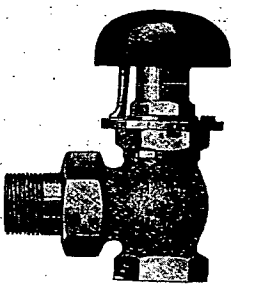


Fig. 159

SOMETHING ENTIRELY NEW IN WATER HEAT REGULATION

We have made a special study of hot water heat regulation and control and are pioneers in the matter of individual radiator control, through a graduated valve, employing the same principle as with steam.

Further, water circulation for each radiator, graduating for same or *balancing of system*, can be increased from nothing to full pipe capacity, and *held or locked at any intermediate point*, if desired, by simply turning dial so that stop on same will register against indicator or pointer and locking dial in this position, preventing further opening of valve or turning of wheel or lever handle to the left.

These valves cost but little more than our regular water valves and much less than steam modulated valves.

New York Air Valve Corporation

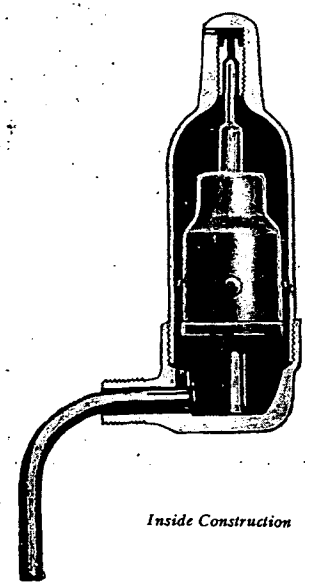
476-478 Broome Street
New York

THE "AIR-OUT" LINE

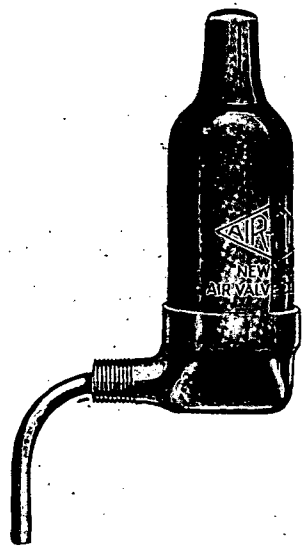
SYPHON THERMOSTATIC NON-ADJUSTABLE

"Air-Out" valves, for eliminating air from steam radiators, operate by the expansion of a phosphor bronze diaphragm, soldered on the bottom of a brass float, containing a volatile liquid. This float is large in size, allowing ample capacity for the necessary pressure to operate the diaphragm.

The seating pin at the top of float is made from nickel silver, as called for in United States Government specifications for Air Valves. Verdigris will not form on nickel silver—corrosion at the vent post is therefore reduced to a minimum.



Inside Construction



We do not use a "stamped out" base. Our bases are heavy bronze castings, in one piece, with no soldered parts to break off.

Made also in straight pattern, threaded ⅛, ¼ and ¾ in. for quick venting of cellar mains and risers.

The best valve money and experience can produce and sold at reasonable prices.

OTHER SPECIALTIES

Carbon Post Automatic Air Valves.
Key and Wood Wheel Air Valves.
Adjustable Floor and Ceiling Plates.
Steam and Altitude Gauges.
Water Gauges.
Pop Safety Valves.

"Air-Out" Valves Guaranteed for Five Years

W. F. Hirschman Co., Inc.

Main Office: Buffalo, N.Y. **Works: Le Roy, N.Y.**

New York, N. Y., 205 East 42nd St. Philadelphia, Pa., 1338 Spring Garden St. Baltimore, Md., 330 St. Paul Place
Boston, Mass., 37 Pearl St. Chicago, Ill., 2539 East 73rd St. Detroit, Mich., 97 W. Warren Ave.

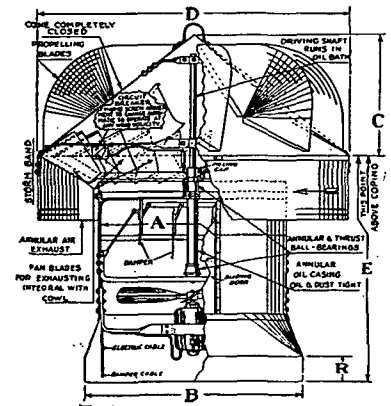
MANUFACTURERS ROOF VENTILATORS

Principle of Operation of Wind-Electric Ventilator—When the wind is blowing sufficiently to remove the desired amount of air from the building being ventilated, the electric motor is still. Instantly, when the wind turbine moves below a previously determined number of revolutions, the electric motor starts automatically and carries the load. The entire apparatus is noiseless.

Special Advantages—Besides the regular automatic operation the motor may also be so connected as to give a maximum exhaust capacity (running full speed) by manual control.



Effico Rotary Ball Bearing Ventilator Installation, Wind Driven (only) The Effico Wind Electric Also Has the Same Artistic Lines and Pleasing Appearance. Lowest in Height of Rotary Ventilators by Over 50 per cent Average.



Detail of Effico Wind Electric Rotary Ball Bearing Ventilator Full Automatic

Note.—Details of Wind Driven (only) Ventilator are Identical with Exception of Motor Unit.

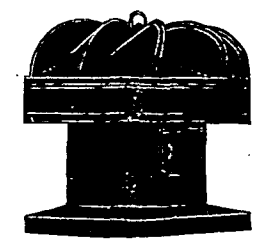
CAPACITIES OF EFFICO ROTARY BALL BEARING VENTILATORS
Both Wind Electric and Wind Driven (only)—Cubic Feet of Air Exhausted per Minute

Wind Velocity, Miles per Hour	*Bold Type is Regularly Furnished Wind-Electric Capacity*											
	Temperature Difference in Degrees Fahrenheit in Building and Outside											
	0	10	20	30	0	10	20	30	0	10	20	30
	12-In. Ventilator				18-In. Ventilator				24-In. Ventilator			
5	350	440	515	560	600	850	950	1040	1020	1600	1780	1900
10	430	525	600	625	910	1050	1200	1300	1490	1900	2100	2300
	30-In. Ventilator				36-In. Ventilator				42-In. Ventilator			
5	1560	2300	2690	2900	2300	3400	3810	4100	3150	4500	5010	5500
10	2300	3210	3490	3600	3250	4200	4720	5050	4390	5700	6300	6800
	48-In. Ventilator				54-In. Ventilator				60-In. Ventilator			
5	4000	5900	6700	7400	5100	7300	8450	9500	6500	9300	10600	11900
10	5900	7900	8900	9050	7850	9900	11000	11500	9200	12500	14000	14500

Effico Wind Electric Ventilator Dimensions

Ventilator Sizes Corresponding to Those in Table Opposite	Dimensions in Inches—(See Diagram Above)					Thickness of Metal			Hp. of Motor
	A	B	C	D	E	Gauge G. I.		Copper, Oz.	
	Actual Size of Ventilator for Wind Elec. Type	Base	Height of Blades	Diam. of Storm Band	Height to Propeller Blades	Cowl	Base		
12	14	20	8	21¾	32	24	22	16	1/30
18	19	26	10	28½	32	24	22	18	
24	25	38	14	40	40	24	20	18	
30	31	40	14	50	42	24	20	20	
36	37	44	18	60	45	22	18	24	1/6
42	43	50	22	68	51	22	18	24	
48	49	56	24	76	51	22	18	24	
54	55	62	24	86	51	22	18	24	1/4
60	61	66	24	98	55	22	18	24	

This apparatus is adjustable to exhaust various quantities of air within the limits of given sizes and is regularly supplied at capacities of 5 miles per hour wind and 10 deg. temperature difference rating. *The Wind-Electric will exhaust minimum volume regardless of temperature difference or wind velocity.* Other capacity can be supplied and the ventilator is adjustable to any constant capacity after installation.



Effico Wind-Electric Ventilator, Automatic

Patented May 20, 1922; March 20, 1928; August 21, 1928.

The Effico Wind Electric Ventilator, Full Automatic

Recommended for those installations which require a definite minimum exhaust at all times or which may require an unusually heavy exhaust at intermittent periods. This is the regular Effico equipped with an auxiliary electrically operated fan placed in the ventilator throat just below the regular fan. The throat is slightly enlarged to allow for the motor.

For F Electric Ventilator Non-Automatic see second page following:

"Effico" Wind-Driven Roof Ventilators

The Effico Ventilator consists of a wind-driven head to which suction blades are permanently connected (on the underside) making an efficient exhaust fan. Rotation of the head creates an exhaust suction in the throat of the ventilator. There are no moving parts.

Bearings.—Effico Bearings are full ball bearings, are solidly enclosed and oil-flooded (also dust and acid proof). They are as sturdy as the best automobile bearings, and will run in a dry state for years, but we oil-flood them as an extra precaution.

Effico Internal Louver Unit Ventilators

The Effico internal louver unit comprises the Effico rotary ball bearing ventilator head constructed with a specially short base, or neck. In this base is built a circular multiple blade louver damper. The damper is carefully balanced and heavily constructed. The blades lap and are fitted in a circular frame. It is adaptable for manual control, but is intended for a thermostatic control system. The roof base is very low, is part of this unit and is supplied with either the square or round base.

The roof base and the ventilator head are connected by means of angle iron companion rings, which give solidity and facilitate the taking down of the ventilator when required. Each ventilator neck has also a tight fitting door to give free access to the louvers and to the operating motor. The operating motor is suspended underneath the damper to a cross brace. The object of the specially low base and the low roof base is to make the entire unit as low to the roof as possible.

Effico Louver Dampers

Made of stretcher leveled sheet steel. The pneumatic damper motor is supplied and installed with these units unless not desired. (Note specifications below).

Electric Remote Control

Also supplied to operate any of our dampers.

Effico Louver Unit

Low Height. The Effico louver unit sets very low (note dimensions at right).

Height above Coping

Louver Unit "C" dimension should be above coping. Note above.

Heads Only. Effico Heads without dampers are also supplied.

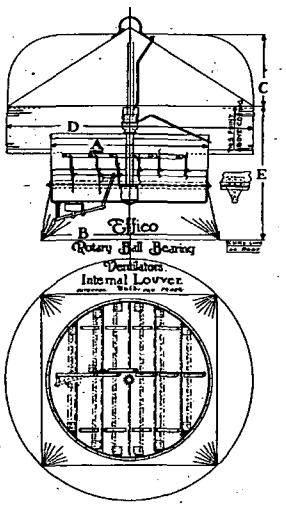
Suggested Specifications

The roof ventilators shall be of the sizes as shown in plans, [square base] [round base] style to be made of [Toncan] [Copper]. [Electric damper motor to be supplied with these units]. They shall be the Effico Internal Louver Unit Ventilators as manufactured by the W. F. HIRSCHMAN CO., INC., Buffalo, N. Y.

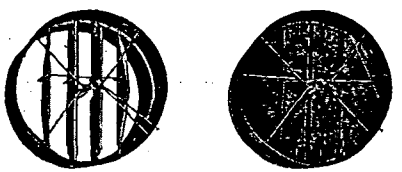
Effico Louver Unit Sizes and Dimensions

Dimensions, Inches					Galvanized Steel Gauge		Net Wght., Lb.	Copper, Oz.	Code for Telegraphy
A	B	C	D	E	Cowl	Base			
18	20	10	28½	23	24	24	90	16	vale
24	30	14	40	30	22	22	140	18	valet
30	36	14	50	32	22	20	190	20	vive
36	42	18	60	32	22	18	225	24	varve
42	48	22	68	43	22	18	350	24	vetch
48	54	24	76	43	22	18	400	24	vax
54	60	24	86	43	22	18	600	24	vaid
60	66	24	98	43	20	18	710	24	valor
66	72	30	103½	49	20	18	800	24	vamp
72	80	30	114	54	20	18	880	24	vane
84	92	36	130	54	18	16	1050	24	vang
96	116	45	153	54	18	16	1200	24	van

For round bases, "E" dimension remains the same.
For capacities note preceding page.



Patented May 20, 1922; March 20, 1928.



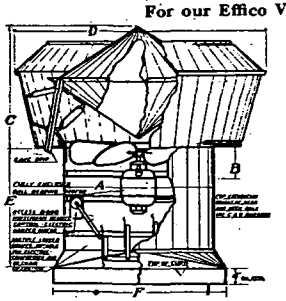
Open *Closed*

The Multiple Circular Louver Damper in Neck of Ventilator

CAPACITY—Exhaust capacity same as Effico Head—note opposite page, for F Electric Ventilator see next page.

Hirschman's S E and F Roof Ventilators

For our Effico Ventilator see preceding pages



F Electric Ventilator Non-Automatic (Patented) *With Electric Damper*

Recommendation of F Electric Ventilator—Is a high class ventilator where a high exhaust velocity is required at certain periodical times or resistance (static pressure) is encountered. Where our **Effico** Rotary Head, or the **Effico** Wind-Electric Automatic Ventilator, due to obstructed location or its moderate, even capacity is not required, then we recommend the Hirschman F Ventilator.

Dampers—Chain, pneumatic or electrically operating; close fitting damper supplied with all sizes if required. Fire Damper—with fusing link furnished if required. **There are no outside louvers to freeze or blow shut.**

Motor—Condenser Motor, Brushless, Cummutatorless, Variable Speed, fully enclosed, very quiet running, are furnished at extra cost when above characteristics are essential.

DIMENSIONS OF HIRSCHMAN F. VENTILATORS

Dimensions, in Inches					Thickness of Metal			
					Ga. Galvan.		Oz. Copper	
A	C	D	E	F	Head	Base	Head	Base
12	9½	22	24	16	24	24	16	16
18	14¼	32	24	22	24	24	16	16
24	18	42	30	30	24	22	16	18
30	22½	52	30	36	22	20	18	20
36	27	61½	30	42	22	18	20	24
42	31⅞	71	30	48	20	18	20	24
48	36	81	36	54	18	18	20	24
54	39¾	91	36	60	18	18	20	24
60	45¼	101	36	66	18	16	24	24
66	52	110	36	72	18	16	24	32
72	60	120	36	78	18	16	24	32
84	65	140	36	92	18	16	24	32

CAPACITIES HIRSCHMAN F ELECTRIC VENTILATORS

Size of Stack Inches	Fan Speed R.P.M.	Horse-Power	Capacities—C.F.M. Static Pressure in Inches of Water				Type of Motor	Shipping Weight	O Quiet X Silent
			⅛" or Less	¼"	⅜"	½"			
12	1750	1/20	725	400			S.D.	100	O
	1150	1/50	250				S.D.		X
18	1750	⅛	1500	900			S.D.		O
	1100	1/6	1500	900	520	200	S.D.		X
	850	1/20	820				S.T.D.		X
24	1100	¼	3000	2200	1600	1000	S.D.	225	O
	1150	⅓	4800	4200	3800	3000	S.D.		
	825	¼	2600	1500	920		S.T.D.		X
30	1080	½	5000	4000	2700	2000	S.D.	300	
	860	½	4000	2900	1900		S.D.		X
36	1080	½	6000	5400	4600		S.D.		O
	680	½	5500	4600	3600		S.T.D.		X
42	680	½	6200	5000			S.D.	525	O
	465	⅓	9000	6600	5700	4000	S.T.D.	575	O
48	680	1½	14000	9000			S.T.D.		O

"F," Electric Ventilators furnished also in 54", 60" and 10" sizes.

Prefix letters in Motor Column indicate kind of current for which the motors are available.

("S" *Alternating*—single-phase, 60 cycle). ("T", two or three-phase, 60 cycle). ("D", *direct current*).

"X", Very silent suitable for Talkie Movies.

"O", Silent for schools, theatres; auditoriums and other quiet running requirements.

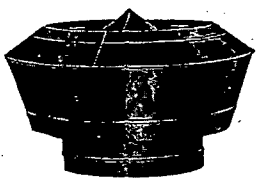
REMEMBER—With the Hirschman F Ventilator you still have a good ventilator when the motor is not running.

As an Exhaust Head

FOR EXHAUST FAN

SE Ventilator design is such that air driven 1200 ft. velocity through the head, registers only .015 water gauge static pressure a performance of unequalled merit. Thus for a fan or high heat exhaust head, it is highly effective. When so used and the fan is cut off the ventilator still operates as a syphon ventilator. **There are no shutters to blow or freeze shut.**

Is also vision-proof, will resist back drafting during a five mile wind against an adverse temperature difference of 10 deg. fahr. Also during the same wind velocity will not back-draft unless a greater than static pressure resistance of .025 water gauge. For information on wind pressure causing down draft in the angle of U or L buildings, write us.



SE Ventilator

The head of the "F" Electric Ventilator sold separate—makes an excellent Syphon Ventilator.

THE LINDE AIR PRODUCTS COMPANY

Unit of Union Carbide and Carbon Corporation

126 Producing Plants — UCC — 627 Warehouse Stocks

IN CANADA, DOMINION OXYGEN COMPANY, LTD., TORONTO

District Offices

Atlanta	Detroit	New York
Baltimore	El Paso	Philadelphia
Birmingham	Houston	Pittsburgh
Boston	Indianapolis	St. Louis
Buffalo	Kansas City	Salt Lake City
Chicago	Los Angeles	San Francisco
Cleveland	Milwaukee	Seattle
Denver	Minneapolis	Tulsa

LINDE OXYGEN · PREST-O-LITE ACETYLENE · OXWELD APPARATUS AND SUPPLIES · UNION CARBIDE



Linde Oxygen

Plants and warehouses in all industrial centers make Linde Oxygen, in the familiar Grey and Green cylinders, available everywhere at minimum transportation cost. The standard Linde cylinder contains 220 cu. ft. of oxygen.

Prest-O-Lite Acetylene

Prest-O-Lite Dissolved Acetylene, the standard for well over a quarter of a century, is a uniformly high quality gas in an easily portable and economical form. It is readily available from Prest-O-Lite plants and warehouses everywhere. Prest-O-Lite "WK" cylinders contain approximately 300 cu. ft. of acetylene.

Oxweld Apparatus and Supplies

Suitable Oxweld blowpipes, regulators, welding rods and supplies are available for every welding and cutting operation. Complete stocks and service stations are located in all principal cities. Oxweld low-pressure injector type blowpipes, high test welding rods and other supplies represent maximum values in oxy-acetylene welding and cutting equipment.

Union Carbide

Careful expansion of distributing facilities has made Union Carbide available from over 255 warehouse stocks. It gives highest acetylene yield per pound and is always uniform and dependable. Union Carbide is packed in 100-lb. Blue and Grey non-returnable steel drums. It will keep indefinitely in its original double sealed drums.

OXWELDED PIPING

The demand for permanency and uninterrupted operation has focused the attention of engineers and architects upon the oxy-acetylene welded pipe joint. The oxwelded pipe joint is permanently tight, strong and compact. It eliminates leakage and reduces friction, radiation losses and maintenance. After testing, it may be forgotten. There is no necessity to use joint compounds or other means to prevent leakage. It assures increased serviceability and operating efficiency.

Oxy-acetylene welding greatly simplifies design and materially speeds up the installation of piping. Where bends, valves and special fittings have been located, little consideration need be given to exact connecting lengths. Equipment that does not conform to drawings and last minute changes do not retard the installation schedule. It is easy to cut from random lengths and weld in the right length of pipe during construction.

Under Linde Process Service, available to users of Linde products, welded piping construction may be undertaken with the same confidence in a satisfactory result as older methods, and with further assurance of increased economy and serviceability. Thousands of Linde customers benefit by the assistance and advice of this service regularly. The Linde organization focuses its pioneer background of scientific research and unequalled field experience upon their individual problems and translates proved methods into actual operations. Linde Process Service is available everywhere.

Any welded piping system, even in its most complicated form, is a combination of a few fundamental welding design details. A handbook on fundamental designs, titled, "Design Standards for Oxwelded Steel and Wrought Iron Piping", will be sent upon request. Address the nearest Linde District Office.

Index to Modern Equipment

AMERICAN SOCIETY *of* HEATING *and* VENTILATING ENGINEERS GUIDE, 1932

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Linde Air Products Co., The 858

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American Air Filter Co., Inc. 572-573
American Blower Corp. 657
American Foundry & Furnace Co. 569
Bayley Blower Co. 631
Bishop & Babcock Sales Co., The 777
E. W. Bliss Co. 555
Buffalo Forge Co. 633
Burt Air Filter Corp. 571
Carrier Engineering Corp. 556-558
Carrier-Lyle Corp. 680-681
Coppus Engineering Corp. 647
Dail Steel Products Co. 679
General Iron Works Co., The 682-683
Ilg Electric Ventilating Co. 638
Lakeside Co. 643
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E. W. Bliss Co. 555
Buffalo Forge Co. 633
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Carrier-Lyle Corp. 680-681
Carrier-York Corp. 658-659
Clarage Fan Co. 635
Cooling & Air Conditioning Corp. The 559
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General Iron Works Co., The 682-683
Ilg Electric Ventilating Co. 638
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American Air Filter Co., Inc. 572-573
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Burt Air Filter Corp. 571
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Clarage Fan Co. 635
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ASBESTOS PRODUCTS (*See Insulation*)

AUTOMATIC SHUTTERS (*See Shutters, Automatic*)

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Crane Co. 580-581
Grinnell Co., Inc. 707-713, 790
National Pipe Bending Co., The 703
Parks-Cramer Co. 566-567
Whitlock Coil Pipe Co., The 704-705
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American Blower Corp. 657
American Foundry & Furnace Co. 569
Bayley Blower Co. 631
Buckeye Blower Co., The 632
Buffalo Forge Co. 633
Carling Turbine Blower Co. 644-645
Champion Blower & Forge Co., The 634
Clarage Fan Co. 635
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American Blower Corp. 657
American Foundry & Furnace Co. 569
Bayley Blower Co. 631
Bishop & Babcock Sales Co., The 777
Buckeye Blower Co., The 632
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L. J. Mueller Furnace Co. 613
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Niagara Blower Co. 563-565
Skinner Bros. Mfg. Co., Inc. 664-665
Thermidaire Corp. 668
L. J. Wing Mfg. Co. 640-642

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Buckeye Blower Co., The 632
Buffalo Forge Co. 633
Carling Turbine Blower Co. 644-645
Champion Blower & Force Co., The 634
Clarage Fan Co. 635
DeBothezat Impeller Co., Inc. 636
General Electric Co. 739
General Iron Works Co., The 682-683
W. F. Hirschman Co., Inc. 855-857
Ilg Electric Ventilating Co. 638
Nash Engineering Co., The 754-755
New York Blower Co., The 639
L. J. Wing Mfg. Co. 640-642

BLOWERS, Turbine
Buffalo Forge Co. 633
Carling Turbine Blower Co. 644-645
Coppus Engineering Corp. 647
General Electric Co. 739
New York Blower Co., The 639
L. J. Wing Mfg. Co. 640-642

BLOWERS, Warm Air Furnace
American Blower Corp. 657
Buffalo Forge Co. 633
Champion Blower & Forge Co., The 634
Clarage Fan Co. 635
DeBothezat Impeller Co., Inc. 636
Lakeside Co. 643
Meyer Furnace Co., The 685
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BLOWPIPES, Welding and Cutting
Linde Air Products Co., The 858

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BOILER COVERING (*See Covering, Pipes and Surfaces*)

BOILER FEEDERS (*See Feeders, Boiler*)

BOILER FEED PUMPS (*See Pumps, Boiler Feed*)

BOILERS, Cast Iron
American Radiator Co. 578-579, 774-775
B-Line Boiler Co. 612
Burnham Boiler Corp. 577
Crane Co. 580-581
Molby Boiler Co. 582
L. J. Mueller Furnace Co. 613
Pierce, Butler & Pierce Mfg. Corp. 583
Richmond Radiator Co., Inc. 584-585
Spencer Heater Co. 586-587
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American Radiator Co. 578-579, 774-775
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BOILERS, Heating
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Monitor Boiler Co. 608-609
Orr & Sembower, Inc. 610-611
Pierce, Butler & Pierce Mfg. Corp. 583
Richmond Radiator Co., Inc. 584-585
Spencer Heater Co. 586-587
Titusville Iron Works Co., The 607
United States Radiator Corp. 764

BOILERS, Magazine Feed
American Radiator Co. 578-579, 774-775
Babcock & Wilcox Co., The 589
Molby Boiler Co. 582
Spencer Heater Co. 586-587
Weil-McLain Co. 588

BOILERS, Oil Burning
American Radiator Co. 578-579, 774-775
Babcock & Wilcox Co., The 589
Bigelow Co., The 590-591
Burnham Boiler Corp. 577
Crane Co. 580-581
Fitzgibbons Boiler Co., Inc. 592-595
A. D. Granger Co. 606
Heggie-Simplex Boiler Co. 597-599
Kewanee Boiler Corp. 600-605
Leader Boiler & Heater Co. 684
Monitor Boiler Co. 608-609
Orr & Sembower, Inc. 610-611
Petroleum Heat & Power Co. 618-621
Pierce, Butler & Pierce Mfg. Corp. 583
Richmond Radiator Co., Inc. 584-585
Spencer Heater Co. 586-587
Titusville Iron Works Co., The 607
United States Radiator Corp. 764
Weil-McLain Co. 588

BOILERS, Steel
American Radiator Co. 578-579, 774-775
Babcock & Wilcox Co., The 589
Bigelow Co., The 590-591
Burnham Boiler Corp. 577
Farrar & Trefts, Inc. 596
Fitzgibbons Boiler Co., Inc. 592-595
A. D. Granger Co. 606
Heggie-Simplex Boiler Co. 597-599
Kewanee Boiler Corp. 600-605
Leader Boiler & Heater Co. 684
Monitor Boiler Co. 608-609
Orr & Sembower, Inc. 610-611
Pierce, Butler & Pierce Mfg. Corp. 583
Spencer Heater Co. 586-587
Titusville Iron Works Co., The 607
United States Radiator Corp. 764

BOILERS, Water Tube
Babcock & Wilcox Co., The 589
Bigelow Co., The 590-591
Burnham Boiler Corp. 577
Fitzgibbons Boiler Co., Inc. 592-595
Foster Wheeler Corp. 700
A. D. Granger Co. 606
Monitor Boiler Co. 608-609
Orr & Sembower, Inc. 610-611
Spencer Heater Co. 586-587

BREECHINGS AND CHIMNEYS
Farrar & Trefts, Inc. 596
Fitzgibbons Boiler Co., Inc. 592-595
A. D. Granger Co. 606
Kewanee Boiler Corp. 600-605
Titusville Iron Works Co., The 607
Whitlock Coil Pipe Co., The 704-705

Numerals following Manufacturers' Names refer to pages in the Catalog Data Section

BURNERS, Coal, Automatic (*See Coal Burners*)

BURNERS, Gas (*See Gas Burners*)

BURNERS, Oil (*See Oil Burners*)

CALCIUM CARBIDE
Linde Air Products Co., The 858

CIRCULATORS, Hot Water Heating
Chicago Pump Co. 748-749
Economy Pumping Machinery Co. 750-751
Hoffman Specialty Co., Inc. 792-801
Nash Engineering Co., The 754-755
Rochester Circulator Co., The 627
Sterling Engineering Co. 821
H. A. Thrush & Co. 695

***COIL* BURNERS, Automatic**
Babcock & Wilcox Co., The 589
Combustioneer, Inc. 623
Iron Fireman Mfg. Co. 624-625
Motor Stoker Corp. 626
Orr & Sembower, Inc. 610-611
Westinghouse Elec. & Mfg. Co. 740

COILS, Ammonia
E. W. Bliss Co. 555
Bush Mfg. Co., The 652
Crane Co. 580-581
Frick Company 560
McCord Radiator & Mfg. Co. 660-661
National Pipe Bending Co., The 703
Unit Heater & Cooler Co., The 669
Whitlock Coil Pipe Co., The 704-705
York Ice Machinery Corp. 568

COILS, Pipe, Copper
E. B. Badger & Sons Co. 630
Bayley Blower Co. 631
Clarage Fan Co. 635
Crane Co. 580-581
McCord Radiator & Mfg. Co. 660-661
National Pipe Bending Co., The 703
Parks-Cramer Co. 566-567
Rome-Turney Radiator Co., The 654
Whitlock Coil Pipe Co., The 704-705
Wolverine Tube Co. 656

COILS, Pipe, Iron
Babcock & Wilcox Co., The 589
Bayley Blower Co. 631
E. W. Bliss Co. 555
Crane Co. 580-581
Frick Company 560
McCord Radiator & Mfg. Co. 660-661
National Pipe Bending Co., The 703
Parks-Cramer Co., 566-567
Whitlock Coil Pipe Co., The 704-705

COILS, Tank
Babcock & Wilcox Co., The 589
Davis Engineering Corp. 699
Frick Company 560
Kewanee Boiler Corp. 600-605
National Pipe Bending Co., The 703
Whitlock Coil Pipe Co., The 704-705
York Ice Machinery Corp. 568

COMPOUNDS, Boiler
Vinco Co., Inc. 575
Woodward Wanger Co. 696

COMPOUNDS, Boiler and Radiator Sealing
Vinco Co., Inc. 575

COMPOUNDS, Underground Conduit Sealing
Ric-wiL Co., The 735

COMPRESSORS, Air
American Air Filter Co., Inc. 572-573
E. W. Bliss Co. 555
General Electric Co. 739
Johnson Service Co. 832-834
Nash Engineering Co., The 754-755
Powers Regulator Co. 840-843

CONCRETE INSERTS (*See Inserts, Concrete*)

CONDENSERS
Alberger Heater Co. 697
E. W. Bliss Co. 555
Bush Mfg. Co., The 652
Farrar & Trefts, Inc. 596
Foster Wheeler Corp. 700
Frick Company 560
G. & O. Mfg. Co., The 653
Johns-Manville 733
National Pipe Bending Co., The 703
Rome-Turney Radiator Co., The 654
Schutte & Koerting Co. 655
Westinghouse Elec. & Mfg. Co. 740
Whitlock Coil Pipe Co., The 704-705

CONDUITS, Underground Pipe
Ric-wiL Co., The 735

CONTROLLERS AND CONTROL EQUIPMENT (*See also Temperature Control*)
American Radiator Co. 578-579, 774-775
Bristol Co., The 714
D. & T. Mfg. Co. 692
Foster Wheeler Corp. 700
General Electric Co. 739
Johnson Service Co. 832-834
James P. Marsh & Co. 811-818
Mason Regulator Co. 810
Minneapolis-Honeywell Regulator Co. 836-837
Motor Wheel Corp. 686-687
Mueller Steam Specialty Co., Inc. 819
Penn Heat Control Co. 838-839
F. I. Raymond Co. 844-845
Webster Tallmadge & Co., Inc. 830
Taylor Instrument Cos. 716-717
Westinghouse Electric & Mfg. Co. 740

COOLING EQUIPMENT, Oil and Water (*See also Air Cooling and Dehumidifying Apparatus*)
Aerofin Corp. 649-651
Alberger Heater Co. 697
American Radiator Co. 578-579, 774-775
Bell & Gossett Co. 698
E. W. Bliss Co. 555
Bush Mfg. Co., The 652
Carrier-Lyle Corp. 680-681
O. E. Frank Heater & Engineering Co., Inc. 701
Frick Company, 560
G. & O. Mfg. Co., The 653
National Pipe Bending Co., The 703
York Ice Machinery Corp. 568

COVERING, Ammonia Pipe
Armstrong Cork & Insulation Co. 628, 720-721
Johns-Manville 733
Keasbey & Mattison Co. 734
Mundet Cork Corp. 629
York Ice Machinery Corp. 568

COVERING, Pipes and Surfaces
American Radiator Co. 578-579, 774-775
Armstrong Cork & Insulation Co. 628, 720-721
Johns-Manville 733
Keasbey & Mattison Co. 734
Mundet Cork Corp. 629
Ric-wiL Co., The 735

CUTTING AND WELDING APPARATUS (*See Welding and Cutting Apparatus*)

DAMPERS
American Foundry & Furnace Co. 569
Buckeye Blower Co., The 632
Buffalo Forge Co. 633
Clarage Fan Co. 635
D. & T. Mfg. Co. 692
W. F. Hirschman Co., Inc. 855-857
Johnson Service Co. 832-834
National Regulator Co. 835
Powers Regulator Co. 840-843

DAMPER REGULATORS, Boiler and Furnace
American Radiator Co. 578-579, 774-775
Barber-Colman Co. 831
D. & T. Mfg. Co. 692
Davis Regulator Co. 780
C. A. Dunham Co. 782-789
W. F. Hirschman Co., Inc. 855-857
Illinois Engineering Co. 804-805
Johnson Service Co. 832-834
Kieley & Mueller, Inc. 808
Leader Boiler & Heater Co. 684
James P. Marsh & Co. 811-818
Mason Regulator Co. 810
Minneapolis-Honeywell Regulator Co. 836-837
National Regulator Co. 835
Powers Regulator Co. 840-843
F. I. Raymond Co. 844-845
Sarco Co., Inc. 822-823
Trane Co., The 666-667, 678, 760-761, 824

Numerals following Manufacturers' Names refer to pages in the Catalog Data Section

Vapor Engineering Co. 825
Warren Webster & Co. 826-828
L. J. Wing Mfg. Co. 640-642

DEAERATORS
Cochrane Corp. 779
Frick Company 560

DIFFUSERS (*See Ventilators, Floor and Wall*)

DRAFT APPARATUS, Mechanical
American Radiator Co. 578-579, 774-775
American Blower Corp. 657
Bayley Blower Co. 631
Buckeye Blower Co., The 632
Buffalo Forge Co. 633
Carling Turbine Blower Co. 644-645
Clarage Fan Co. 635
W. L. Clayton, Inc. 646
Ilg Electric Ventilating Co. 638
L. J. Wing Mfg. Co. 640-642

DRYING EQUIPMENT
Bayley Blower Co. 631
E. W. Bliss Co. 555
Buckeye Blower Co., The 632
Buffalo Forge Co. 633
Carrier Engineering Corp. 556-558
Carrier-York Corp. 658-659
A. D. Granger Co. 606
Maryland Air Conditioning Corp. 561
Skinner Bros. Mfg. Co., Inc. 664-665
Trane Co., The 666-667, 678, 760-761, 824
L. J. Wing Mfg. Co. 640-642

DRY KILNS (*See Kilns, Dry*)

DUST SEPARATORS (*See Air Cleaning Equipment*)

EXHAUST HEADS
A. D. Granger Co. 606
W. F. Hirschman Co., Inc. 855-857
Illinois Engineering Co. 804-805
Kieley & Mueller, Inc. 808
Skinner Bros. Mfg. Co., Inc. 664-665
Wright-Austin Co. 829

EXPANSION JOINTS
Alberger Heater Co. 697
E. B. Badger & Sons Co. 630
Crane Co. 580-581
Foster Wheeler Corp. 700
Illinois Engineering Co. 804-805
Warren Webster & Co. 826-828
Whitlock Coil Pipe Co., The 704-705

FAN DRIVES, Constant Speed Multi-Belt
Horton Manufacturing Co. 648

FAN DRIVES, Variable Speed
Horton Manufacturing Co. 648

FANS, Furnace
Buckeye Blower Co., The 632
Buffalo Forge Co. 633
Carling Turbine Blower Co. 644-645
Champion Blower & Forge Co., The 634
Clarage Fan Co. 635
DeBothezat Impeller Co., Inc. 636
Ilg Electric Ventilating Co. 638
Lakeside Co. 643
New York Blower Co., The 639
Trane Co., The 666-667, 678, 760-761, 824
L. J. Wing Mfg. Co. 640-642

FANS, Supply and Exhaust
American Blower Corp. 657
Bayley Blower Co. 631
Bishop & Babcock Sales Co., The 777
Buckeye Blower Co., The 632
Buffalo Forge Co. 633
Carrier-York Corp. 658-659
Century Electric Co. 738
Champion Blower & Forge Co., The 634
Clarage Fan Co. 635
Coppus Engineering Corp. 647
DeBothezat Impeller Co., Inc. 636
Diehl Mfg. Co. 637
General Electric Co. 739
W. F. Hirschman Co., Inc. 855-857
Ilg Electric Ventilating Co. 638
Lakeside Co. 643
J. H. McCormick & Co. 562
New York Blower Co., The 639
Skinner Bros. Mfg. Co., Inc. 664-665
Thermidaire Corp. 668
Westinghouse Electric & Mfg. Co. 740
L. J. Wing Mfg. Co. 640-642

FEEDERS, Boiler
Kieley & Mueller, Inc. 808
McDonnell & Miller 576
Mueller Steam Specialty Co., Inc. 819
Schutte & Koerting Co. 655
Warren Webster & Co. 826-828
Wright-Austin Co. 829

FEEDERS, Water
Decatur Pump Co. 747
Kieley & Mueller, Inc. 808
McDonnell & Miller 576
Mueller Steam Specialty Co., Inc. 819

FEED WATER HEATERS (*See Heaters, Feed Water*)

FEED WATER REGULATORS (*See Regulators, Feed Water*)

FILTERS, Air (*See Air Cleaning Equipment*)

FILTERS, Water
Cochrane Corp. 779
Radi-Ion Corp. 744-745
Staynew Filter Corp. 574

FITTINGS, Pipe, Flanged
Crane Co. 580-581
Frick Company 560
Grinnell Co. Inc. 707-713, 790
Molby Boiler Co. 582
Stockham Pipe & Fittings Co. 741

FITTINGS, Pipe, Screwed
Crane Co. 580-581
D. & T. Mfg. Co. 692
Frick Company 560
Grinnell Co., Inc. 707-713, 790
Molby Boiler Co. 582
Stockham Pipe &Fittings Co. 741

FURNACE HEATING SYSTEMS (*See Heating Systems, Furnace*)

FURNACES, Electric
General Electric Co. 739
Westinghouse Electric & Mfg. Co. 740

FURNACES, Warm Air
Carrier-Lyle Corp. 680-681
Dail Steel Products Co. 679
Leader Boiler & Heater Co. 684
Meyer Furnace Co., The 685
Motor Wheel Corp. 686-687
L. J. Mueller Furnace Co. 613
New York Blower Co., The 639
Payne Furnace & Supply Co., Inc. 688-691
Richmond Radiator Co., Inc. 584-585

GAS BURNERS
Anthony Co., The 616
National Airoil Burner Co. 622

GAS HEATERS (*See Heaters, Gas*)

GASKETS, Asbestos
Jenkins Bros. 850
Johns-Manville 733
Keasbey & Mattison Co. 734
McCord Radiator & Mfg. Co. 660-661

GASKETS, Cork
Armstrong Cork & Insulation Co. 628, 720-721
McCord Radiator & Mfg. Co. 660-661
Mundet Cork Corp. 629

GASKETS, Metallic
Jenkins Bros. 850
McCord Radiator & Mfg. Co. 660-661

GASKETS, Rubber
Jenkins Bros. 850
Johns-Manville 733
McCord Radiator & Mfg. Co. 660-661

GAS STEAM RADIATORS (*See Radiators, Gas Fired*)

GAUGE BOARDS
Consolidated Ashcroft Hancock Co., Inc. 715
Frick Company 560
J. E. Lonergan Co. 809
James P. Marsh & Co. 811-818
Warren Webster & Co., 826-828

GAUGE GLASSES
American Radiator Co. 578-579, 774-775
Crane Co. 580-581
Jenkins Bros. 850
James P. Marsh & Co. 811-818

Numerals following Manufacturers' Names refer to pages in the Catalog Data Section

GAUGES, Altitude
American Radiator Co. 578-579, 774-775
Consolidated Ashcroft Hancock Co., Inc. 715
Crane Co. 580-581
J. E. Lonergan Co. 809
James P. Marsh & Co. 811-818
New York Air Valve Corp. 854
Pierce, Butler & Pierce Mfg. Corp. 583
Taylor Instrument Cos. 716-717

GAUGES, Ammonia
Bristol Co., The 714
Consolidated Ashcroft Hancock Co., Inc. 715
J. E. Lonergan Co. 809
James P. Marsh & Co. 811-818
New York Air Valve Corp. 854
York Ice Machinery Corp. 568

GAUGES, Draft
Bristol Co., The 714
Consolidated Ashcroft Hancock Co., Inc. 715
Taylor Instrument Cos. 716-717

GAUGES, Hot Water
American Radiator Co. 578-579, 774-775
Bristol Co., The 714
Consolidated Ashcroft Hancock Co., Inc. 715
D. & T. Mfg. Co. 692
James P. Marsh & Co. 811-818
New York Air Valve Corp. 854

GAUGES, Pressure
American Radiator Co. 578-579, 774-775
Bohn Aluminum & Brass Corp. (Capitol Brass Division) 778
Bristol Co., The 714
Consolidated Ashcroft Hancock Co., Inc. 715
Crane Co. 580-581
C. A. Dunham Co. 782-789
Kainer & Co. 693
J. E. Lonergan Co. 809
James P. Marsh & Co. 811-818
Petroleum Heat & Power Co. 618-621
Taylor Instrument Cos. 716-717
Trane Co., The 666-667, 678, 760-761, 824

GAUGES, Steam
American Radiator Co. 578-579, 774-775
Bohn Aluminum & Brass Corp. (Capitol Brass Division) 778
Bristol Co., The 714
Consolidated Ashcroft Hancock Co., Inc. 715
Crane Co. 580-581
C. A. Dunham Co. 782-789
Hoffman Specialty Co., Inc. 792-801
J. E. Lonergan Co. 809
James P. Marsh & Co. 811-818
New York Air Valve Corp. 854
Pierce, Butler & Pierce Mfg. Corp. 583
Webster, Tallmadge & Co., Inc. 830
Trane Co., The 666-667, 678, 760-761, 824
Warren Webster & Co. 826-828

GAUGES, Vacuum
American Radiator Co. 578-579, 774-775
Bohn Aluminum & Brass Corp. (Capitol Brass Division) 778
Bristol Co., The 714
Consolidated Ashcroft Hancock Co., Inc. 715
Crane Co. 580-581
C. A. Dunham Co. 782-789
William S. Haines & Co. 791
Hoffman Specialty Co., Inc. 792-801
Illinois Engineering Co. 804-805
J. E. Lonergan Co. 809
James P. Marsh & Co. 811-818
New York Air Valve Corp. 854
Webster Tallmadge & Co., Inc. 830
Taylor Instrument Cos. 716-717
Trane Co., The 666-667, 678, 760-761, 824
Warren Webster & Co. 826-828

GAUGES, Vapor
American Radiator Co. 578-579, 774-775
Bristol Co., The 714
Consolidated Ashcroft Hancock Co., Inc. 715
Crane Co. 580-581
William S. Haines & Co. 791
Hoffman Specialty Co., Inc. 792-801
Illinois Engineering Co. 804-805
J. E. Lonergan Co. 809
James P. Marsh & Co. 811-818
New York Air Valve Corp. 854
Webster Tallmadge & Co., Inc. 830
Trane Co., The 666-667, 678, 760-761, 824
Vapor Engineering Co. 825
Warren Webster & Co. 826-828

GAUGES, Water
American Radiator Co. 578-579, 774-775
Bohn Aluminum & Brass Corp. (Capitol Brass Division) 778
Bristol Co., The 714
Consolidated Ashcroft Hancock Co., Inc. 715
J. E. Lonergan Co. 809
James P. Marsh & Co. 811-818
New York Air Valve Corp. 854
W. H. Nicholson & Co. 820
Wright-Austin Co. 829

GOVERNORS, Pump
Davis Regulator Co. 780
C. A. Dunham Co. 782-789
Illinois Engineering Co. 804-805
Klipfel Mfg. Co. 806-807
Mason Regulator Co. 810
Mueller Steam Specialty Co., Inc. 819
Petroleum Heat & Power Co. 618-621
Warren Webster & Co. 826-828
Wright-Austin Co. 829

GRATES FOR BOILERS AND FURNACES
American Radiator Co. 578-579, 774-775
Babcock & Wilcox Co., The 589
W. L. Clayton, Inc. 646
Farrar & Trefts, Inc. 596
Fitzgibbons Boiler Co., Inc. 592-595
Kewanee Boiler Corp. 600-605
Titusville Iron Works Co., The 607

GRILLES, REGISTERS AND ORNAMENTAL METAL WORK
American Foundry & Furnace Co. 569
Auer Register Co., The 766
C. A. Dunham Co. 782-789
Hart & Cooley Mfg. Co. 767
Independent Register & Mfg. Co. 768
L. J. Mueller Furnace Co. 613
Tuttle & Bailey Mfg. Co. 769
Uni-Flo Grille Corp. 770

HANGERS, Pipe
Crane Co. 580-581
Farley Sleeve & Hanger Co. 742
Grinnell Co., Inc. 707-713, 790
Woodward Wanger Co. 696

HANGERS, Radiator
American Radiator Co. 578-579, 774-775
Burnham Boiler Corp. 577
Crane Co. 580-581
Farley Sleeve & Hanger Co. 742
Grinnell Co., Inc. 707-713, 790
Healy-Ruff Co. 765

HEAT CABINETS (*See Heaters, Cabinet*)

HEATERS, Air
Aerofin Corp. 649-651
Babcock & Wilcox Co., The 589
Buffalo Forge Co. 633
Carrier-York Corp. 658-659
G. & O. Mfg. Co., The 653
J. H. McCormick & Co. 562
Motor Wheel Corp. 686-687
New York Blower Co., The 639
Niagara Blower Co. 563-565
Rome-Turney Radiator Co., The 654
Skinner Bros. Mfg. Co., Inc. 664-665
Unit Heater & Cooler Co., The 669
Westinghouse Electric & Mfg. Co. 740
Whitlock Coil Pipe Co., The 704-705
L. J. Wing Mfg. Co. 640-642
Young Radiator Co. 670

HEATERS, Automatic Hot Water
American Radiator Co. 578-579, 774-775
Automatic Burner Corp. 614-615
Cochrane Corp. 779
Crane Co. 580-581
McDermott Water Heaters, Inc. 702
Westinghouse Electric & Mfg. Co. 740

HEATERS, Blast
Aerofin Corp. 649-651
Bayley Blower Co. 631
Clarage Fan Co. 635
G. & O. Mfg. Co., The 653
McCord Radiator & Mfg. Co. 660-661
New York Blower Co., The 639

Numerals following Manufacturers' Names refer to pages in the Catalog Data Section

Rome-Turney Radiator Co., The 654
Skinner Bros. Mfg. Co., Inc., 664-665
Thermidaire Corp. 668
Trane Co., The 666-667, 678, 760-761, 824
L. J. Wing Mfg. Co. 640-642

HEATERS, Cabinet
Aerofin Corp. 649-651
American Radiator Co. 578-579, 774-775
Automatic Burner Corp. 614-615
Buckeye Blower Co., The 632
Carrier-Engineering Corp. 556-558
Carrier-Lyle Corp. 680-681
Carrier-York Corp. 658-659
Clarage Fan Co. 635
G. & O. Mfg. Co., The 653
Heintz Mfg. Co. 759
Hoffman Specialty Co. of California, Ltd. 802
J. H. McCormick & Co. 562
Unit Heater & Cooler Co., The 669

HEATERS, Electric
General Electric Co. 739
Hoffman Specialty Co., Inc. 792-801
Hoffman Specialty Co. of California, Ltd. 802
Nocare Electric Radiator Corp. 763
Trane Co., The 666-667, 678, 760-761, 824
Westinghouse Electric & Mfg. Co. 740

HEATERS, Feed Water
Alberger Heater Co. 697
Cochrane Corp. 779
Davis Engineering Corp. 699
Foster Wheeler Corp. 700
O. E. Frank Heater & Engineering Co., Inc. 701
A. D. Granger Co. 606
McDermott Water Heaters, Inc. 702
National Pipe Bending Co., The 703
Patterson-Kelley Co., The 706
Whitlock Coil Pipe Co., The 704-705

HEATERS, Gas
American Radiator Co. 578-579, 774-775
B-Line Boiler Co. 612
Carrier-Lyle Corp. 680-681
Meyer Furnace Co., The 685
Payne Furnace & Supply Co., Inc., 688-691

HEATERS, Hot Water Service
Alberger Heater Co. 697
American Radiator Co. 578-579, 774-775
Automatic Burner Corp. 614-615
Burnham Boiler Corp. 577
Cochrane Corp. 779
Davis Engineering Corp. 699
Foster Wheeler Corp. 700
O. E. Frank Heater & Engineering Co., Inc. 701
Heggie-Simplex Boiler Co. 597-599
Kewanee Boiler Corp. 600-605
McCord Radiator & Mfg. Co. 660-661
McDermott Water Heaters, Inc. 702
National Pipe Bending Co., The 703
Orr & Sembower, Inc. 610-611
Patterson-Kelley Co., The 706
Unit Heater & Cooler Co., The 669
Whitlock Coil Pipe Co., The 704-705

HEATERS, Indirect
Aerofin Corp. 649-651
Alberger Heater Co. 697
American Radiator Co. 578-579, 774-775
Bell & Gossett Co. 698
Carrier-Lyle Corp. 680-681
Carrier-York Corp. 658-659
Davis Engineering Corp. 699
McDermott Water Heaters, Inc. 702
National Pipe Bending Co., The 703
Patterson-Kelley Co., The 706
Whitlock Coil Pipe Co., The 704-705

HEATERS, Refuse Burning
American Radiator Co. 578-579, 774-775
Heggie-Simplex Boiler Co. 597-599
Kewanee Boiler Corp. 600-605
Richmond Radiator Co., Inc. 584-585

HEATERS, Storage
Alberger Heater Co. 697
American Radiator Co. 578-579, 774-775
Automatic Burner Corp. 614-615
Cochrane Corp. 779
Davis Engineering Corp. 699
O. E. Frank Heater & Engineering Co., Inc. 701
A. D. Granger Co. 606
Kewanee Boiler Corp. 600-605
Leader Boiler & Heater Co. 684
McDermott Water Heaters, Inc. 702
National Pipe Bending Co., The 703
Patterson-Kelley Co., The 706
Whitlock Coil Pipe Co., The 704-705

HEATERS, Tank
Alberger Heater Co. 697
American Radiator Co. 578-579, 774-775
Burnham Boiler Corp. 577
Davis Engineering Corp. 699
O. E. Frank Heater & Engineering Co., Inc. 701
Kewanee Boiler Corp. 600-605
McDermott Water Heaters, Inc. 702
Molby Boiler Co. 582
L. J. Mueller Furnace Co. 613
National Pipe Bending Co., The 703
Pierce, Butler & Pierce Mfg. Corp. 583
Richmond Radiator Co., Inc. 584-585
United States Radiator Corp. 764
Weil-McLain Co. 588
Whitlock Coil Pipe Co., The 704-705

HEATERS, Unit
Aerofin Corp. 649-651
American Blower Corp. 657
Bayley Blower Co. 631
Bishop & Babcock Sales Co., The 777
Buckeye Blower Co., The 632
Buffalo Forge Co. 633
Carrier-Lyle Corp. 680-681
Carrier-York Corp. 658-659
Champion Blower & Forge Co., The 634
Clarage Fan Co. 635
DeBothezat Impeller Co., Inc. 636
C. A. Dunham Co. 782-789
G. & O. Mfg. Co., The 653
Grinnell Co., Inc. 707-713, 790
Ilg Electric Ventilating Co. 638
McCord Radiator & Mfg. Co. 660-661
J. H. McCormick & Co. 562
Multicell Radiator Corp. 662-663
Herman Nelson Corp., The 672-673
John J. Nesbitt, Inc. 674-677
New York Blower Co., The 639
Niagara Blower Co. 563-565
Peerless Unit Ventilation Co., Inc. 671
Rome-Turney Radiator Co., The 654
Skinner Bros. Mfg. Co., Inc. 664-665
Thermidaire Corp. 668
Trane Co., The 666-667, 678, 760-761, 824
Unit Heater & Cooler Co., The 669
L. J. Wing Mfg. Co. 640-642
Wolverine Tube Co. 656
Young Radiator Co. 670

HEATERS, Unit, Gas Fired
American Blower Corp. 657
Buffalo Forge Co. 633
General Iron Works Co., The 682-683
Payne Furnace & Supply Co., Inc. 688-691

HEATING SYSTEMS, Air
American Radiator Co. 578-579, 774-775
Bayley Blower Co. 631
Carrier Engineering Corp. 556-558
Carrier-Lyle Corp. 680-681
Clarage Fan Co. 635
Cooling & Air Conditioning Corp. The 559
Dail Steel Products Co. 679
General Iron Works Co., The 682-683
Hoffman Specialty Co. of California, Ltd. 802
Ilg Electric Ventilating Co. 638
J. H. McCormick & Co. 562
Meyer Furnace Co., The 685
Motor Wheel Corp., 686-687
N. Y. Blower Co., The 639
Niagara Blower Co. 563-565
Skinner Bros. Mfg. Co., Inc. 664-665
Staynew Filter Corp. 574
Thermidaire Corp. 668
L. J. Wing Mfg. Co. 640-642

Numerals following Manufacturers' Names refer to pages in the Catalog Data Section

HEATING SYSTEMS, Furnace
American Foundry & Furnace Co. 569
Carrier-Lyle Corp. 680-681
Cooling & Air Conditioning Corp., The 559
Dail Steel Products Co. 679
Leader Boiler & Heater Co. 684
Meyer Furnace Co., The 685
Motor Wheel Corp. 686-687
L. J. Mueller Furnace Co. 613
New York Blower Co., The 639
Payne Furnace & Supply Co., Inc. 688-691
Skinner Bros. Mfg. Co., Inc. 664-665

HEATING SYSTEMS, Gas Fired
Carrier-Lyle Corp. 680-681
Dail Steel Products Co. 679
General Iron Works Co., The 682-683
Leader Boiler & Heater Co. 684
J. H. McCormick & Co. 562
Meyer Furnace Co., The 685
L. J. Mueller Furnace Co. 613
Payne Furnace & Supply Co., Inc. 688-691

HEATING SYSTEMS, Hot Water
American Radiator Co., 578-579, 774-775
Automatic Florzone Heating Co. 762
D. & T. Mfg. Co. 692
Davis Engineering Corp. 699
Foster Wheeler Corp. 700
Grinnell Co., Inc. 707-713, 790
Leader Boiler & Heater Co. 684
Mueller Co. 694
L. J. Mueller Furnace Co. 613
Parks-Cramer Co. 566-567
H. A. Thrush & Co. 695
Titusville Iron Works Co., The 607
United States Radiator Corp. 764

HEATING SYSTEMS, Steam
American Radiator Co. 578-579, 774-775
Barnes & Jones 776
Bishop & Babcock Sales Co., The 777
D. G. C. Trap & Valve Co., Inc. 847
Direct Control Valve Co., The 848-849
C. A. Dunham Co., 782-789
Hoffman Specialty Co., Inc. 792-801
Ilg Electric Ventilating Co. 638
Leader Boiler & Heater Co. 684
James P. Marsh & Co. 811-818
L. J. Mueller Furnace Co. 613
Nocare Electric Radiator Corp. 763
Parks-Cramer Co. 566-567
F. I. Raymond Co. 844-845
Sarco Co., Inc. 822-823
Thermidaire Corp. 668
Trane Co., The 666-667, 678, 760-761, 824
United States Radiator Corp. 764
Warren Webster & Co. 826-828

HEATING SYSTEMS, Vacuum
American Radiator Co. 578-579, 774-775
Barnes & Jones 776
D. G. C. Trap & Valve Co., Inc. 847
C. A. Dunham Co. 782-789
William S. Haines & Co. 791
Hoffman Specialty Co., Inc. 792-801
Illinois Engineering Co. 804-805
James P. Marsh & Co. 811-818
Parks-Cramer Co. 566-567
F. I. Raymond Co. 844-845
Sarco Co., Inc. 822-823
Sterling Engineering Co. 821
Webster Tallmadge & Co., Inc. 830
Trane Co., The 666-667, 678, 760-761, 824
United States Radiator Corp. 764
Warren Webster & Co. 826-828
W. P. Whittington, Inc. 758

HEATING SYSTEMS, Vapor
American Radiator Co. 578-579, 774-775
Barnes & Jones 776
Bishop & Babcock Sales Co., The 777
D. G. C. Trap & Valve Co., Inc. 847
C. A. Dunham Co. 782-789
William S. Haines & Co. 791
Hoffman Specialty Co., Inc. 792-801
Illinois Engineering Co. 804-805
James P. Marsh & Co. 811-818
F. I. Raymond Co. 844-845
Sarco Co., Inc. 822-823
Sterling Engineering Co. 821
Webster Tallmadge & Co., Inc. 830
Trane Co., The 666-667, 678, 760-761, 824
United States Radiator Corp. 764
Vapor Engineering Co. 825
Warren Webster & Co. 826-828

HEAT SURFACE, Fan System
Aerofin Corp. 649-651
American Radiator Co. 578-579, 774-775
Carrier-Lyle Corp. 680-681
Clarage Fan Co. 635
G. & O. Mfg. Co., The 653
Multicell Radiator Corp. 662-663
Rome-Turney Radiator Co., The 654
Thermidaire Corp. 668
Trane Co., The 666-667, 678, 760-761, 824
L. J. Wing Mfg. Co. 640-642
Young Radiator Co. 670

HOT WATER HEATING SYSTEMS (*See Heating Systems, Hot Water*)

HUMIDIFIERS
American Radiator Co. 578-579, 774-775
Buffalo Forge Co. 633
Carrier Engineering Corp. 556-558
Carrier-Lyle Corp. 680-681
Clarage Fan Co. 635
Cooling & Air Conditioning Corp., The 559
Crane Co. 580-581
General Iron Works Co., The 682-683
Grinnell Co., Inc. 707-713, 790
Ilg Electric Ventilating Co. 638
Johnson Service Co. 832-834
Lakeside Co. 643
Maryland Air Conditioning Corp. 561
J. H. McCormick & Co. 562
Meyer Furnace Co., The 685
Motor Wheel Corp. 686-687
L. J. Mueller Furnace Co. 613
Parks-Creamer Co. 566-567
Trane Co., The 666-667, 678, 760-761, 824
York Ice Machinery Corp. 568

HUMIDIFIERS, Unit
Carrier Engineering Corp. 556-558
Carrier-Lyle Corp. 680-681
Carrier-York Corp. 658-659
Clarage Fan Co. 635
Cooling & Air Conditioning Corp., The 559
Dail Steel Products Co. 679
J. H. McCormick & Co. 562
Parks-Cramer Co. 566-567
York Ice Machinery Corp. 568

HUMIDITY CONTROL
Barber-Colman Co. 831
Bishop & Babcock Sales Co., The 777
E. W. Bliss Co. 555
Bristol Co., The 714
Carrier Engineering Corp. 556-558
Carrier-Lyle Corp. 680-681
Consolidated Ashcroft Hancock Co., Inc. 715
Cooling & Air Conditioning Corp., The 559
Grinnell Co., Inc. 707-713, 790
Johnson Service Co. 832-834
Klipfel Mfg. Co. 806-807
J. H. McCormick & Co. 562
Minneapolis-Honeywell Regulator Co. 836-837
Motor Wheel Corp. 686-687
National Regulator Co. 835
Parks-Cramer Co. 566-567
Powers Regulator Co. 840-843
York Ice Machinery Corp. 568

INCINERATORS
Kewanee Boiler Corp. 600-605

INSERTS, Concrete
Grinnell Co., Inc. 707-713, 790
Healy-Ruff Co. 765

INSTRUMENTS, Indicating and Recording
Bristol Co., The 714
Builders Iron Foundry 737
Cochrane Corp. 779
Consolidated Ashcroft Hancock Co., Inc. 715
General Electric Co. 739
James P. Marsh & Co. 811-818
Penn Heat Control Co. 838-839
Powers Regulator Co. 840-843
Taylor Instrument Cos. 716-717
Westinghouse Electric & Mfg. Co., 740

INSULATION, Building
Armstrong Cork & Insulation Co., 628, 720-721
Samuel Cabot, Inc. 719
Celotex Co., The 722-723
Flax-li-num Insulating Co. 724
Insulite Co., The 725
International Fibre Board, Ltd. 726

Numerals following Manufacturers' Names refer to pages in the Catalog Data Section

Johns-Manville 733
Mundet Cork Corp. 629
Stewart Inso Board Corp. 727
Upson Co., The 728-729
Wood Conversion Co. 730-731
Wood-Fibre Board Corp., The 732

INSULATION, Pipes and Surfaces (*See Covering, Pipes and Surfaces*)

INSULATION, Sound Deadening
Armstrong Cork & Insulation Co. 628, 720-721
Samuel Cabot, Inc. 719
Celotex Co., The 722-723
Flax-li-num Insulating Co. 724
Insulite Co., The 725
International Fibre Board, Ltd. 726
Johns-Manville 733
Mundet Cork Corp. 629
Stewart Inso Board Corp. 727
Upson Co., The 728-729
Wood Conversion Co. 730-731
Wood-Fibre Board Corp., The 732

INSULATION Ventilating Ducts
Armstrong Cork & Insulation Co. 628, 720-721
Samuel Cabot, Inc. 719
Flax-li-num Insulating Co. 724
Insulite Co., The 725
Johns-Manville 733
Keasbey & Mattison Co. 734
Mundet Cork Corp. 629
Stewart Inso Board Corp. 727
Wood Conversion Co. 730-731

KILNS, Dry
American Blower Corp. 657

LOUVRES
American Foundry & Furnace Co. 569
Auer Register Co., The 766
Buffalo Forge Co. 633
Carling Turbine Blower Co. 644-645
Carrier Engineering Corp. 556-558
Champion Blower & Forge Co., The 634
Clarage Fan Co. 635
Diehl Mfg. Co. 637
W. F. Hirschman Co., Inc. 855-857
Powers Regulator Co. 840-843

MECHANICAL DRAFT APPARATUS (*See Draft Apparatus, Mechanical*)

METERS, Air
Builders Iron Foundry 737
Cochrane Corp. 779

METERS, Feed Water
Builders Iron Foundry 737
Cochrane Corp. 779

METERS, Flow
Builders Iron Foundry 737
Cochrane Corp. 779
Petroleum Heat & Power Co. 618-621

METERS, Steam
Builders Iron Foundry 737
Cochrane Corp. 779

METERS, Water
Builders Iron Foundry 737
Cochrane Corp. 779

MOTORS, Electric
Century Electric Co. 738
Diehl Mfg. Co. 637
General Electric Co. 739
Minneapolis-Honeywell Regulator Co. 836-837
Westinghouse Electric & Mfg. Co. 740

NOZZLES, Spray (*See Spray Nozzles*)

OIL BURNER EQUIPMENT
Anthony Co., The 616
Automatic Burner Corp. 614-615
Minneapolis-Honeywell Regulator Co. 836-837
Mueller Co. 694
Penn Heat Control Co. 838-839
Petroleum Heat & Power Co. 618-621

OIL BURNERS
Anthony Co., The 616
Automatic Burner Corp. 614-615
Babcock & Wilcox Co., The 589
Crystal Oil Burner Corp. 617
Motor Wheel Corp. 686-687
National Airoil Burner Co. 622
Petroleum Heat & Power Co. 618-621
Schutte & Koerting Co. 655

OXYGEN
Linde Air Products Co., The 858

OZONE APPARATUS
Radi-Ion Corp. 744-745

PACKING
Crane Co. 580-581
Jenkins Bros. 850
Johns-Manville 733
Keasbey & Mattison Co. 734
McCord Radiator & Mfg. Co. 660-661
Woodward Wanger Co. 696

PANELS, Access
Auer Register Co., The 766
Higgin Mfg. Co., The 736

PIPE BENDING
Crane Co. 580-581
Frick Company 560
Grinnell Co., Inc. 707-713, 790
National Pipe Bending Co., The 703
Parks-Cramer Co. 566-567
Whitlock Coil Pipe Co., The 704-705
York Ice Machinery Corp. 568

PIPE, Brass
Crane Co. 580-581
Foster Wheeler Corp. 700
Wolverine Tube Co. 656
Woodward Wanger Co. 696

PIPE, Cast-Iron
American Radiator Co. 578-579, 774-775
Crane Co. 580-581
Molby Boiler Co. 582

PIPE COILS, (*See Coils, Pipe*)

PIPE CONDUITS, (*See Conduits, Underground Pipe*)

PIPE COVERING (*See Covering, Pipes and Surfaces*)

PIPE FITTINGS (*See Fittings, Pipe*)

PIPE HANGERS (*See Hangers, Pipe*)

PIPE, Return Bends
Crane Co. 580-581
Grinnell Co., Inc. 707-713, 790
York Ice Machinery Corp. 568

PIPE SLEEVES, Adjustable
Farley Sleeve & Hanger Co. 742
Knowles Pipe Sleeve Co. 743

PIPE, Steel
Crane Co. 580-581

PIPE, Wrought Iron
Crane Co. 580-581

PITOT TUBES (*See Air-Measuring and Recording Instruments*)

PRESSURE REDUCING VALVES (*See Regulators, Pressure*)

PSYCHROMETERS (*See Air-Measuring and Recording Instruments*)

PULLEYS, Variable Speed
Horton Manufacturing Co. 648

PUMP GOVERNORS
Julian d'Este Co. 781
C. A. Dunham Co. 782-789
Illinois Engineering Co. 804-805
Kieley & Mueller, Inc. 808
Klipfel Mfg. Co. 806-807
Mason Regulator Co. 810
Mueller Co. 694
Mueller Steam Specialty Co., Inc. 819
Petroleum Heat & Power Co. 618-621
Wright-Austin Co. 829

PUMPS, Air and Gas
Anthony Co., The 616
Nash Engineering Co., The 754-755
Skidmore Corp. 756

Numerals following Manufacturers' Names refer to pages in the Catalog Data Section

PUMPS, Ammonia
Chicago Pump Co. 748-749
Economy Pumping Machinery Co. 750-751
Frick Company 560
Goulds Pumps, Inc. 752-753
York Ice Machinery Corp. 568

PUMPS, Boiler Feed
Buffalo Pumps, Inc. 746
Chicago Pump Co. 748-749
Decatur Pump Co. 747
Economy Pumping Machinery Co. 750-751
Goulds Pumps, Inc. 752-753
A. D. Granger Co. 606
Nash Engineering Co., The 754-755
Trane Co., The 666-667, 678, 760-761, 824
Weinman Pump Mfg. Co., The 757

PUMPS, Brine
Buffalo Pumps, Inc. 746
Chicago Pump Co. 748-749
Decatur Pump Co. 747
Economy Pumping Machinery Co., 750-751
Frick Company 560
Goulds Pumps, Inc. 752-753
Nash Engineering Co., The 754-755
Weinman Pump Mfg. Co., The 757

PUMPS, Centrifugal
Buffalo Pumps, Inc. 746
Chicago Pump Co. 748-749
C. A. Dunham Co. 782-789
Economy Pumping Machinery Co. 750-751
Foster Wheeler Corp. 700
General Electric Co. 739
Goulds Pumps, Inc. 752-753
Hoffman Specialty Co., Inc. 792-801
Nash Engineering Co., The 754-755
Skidmore Corp. 756
Trane Co., The 666-667, 678, 760-761, 824
Weinman Pump Mfg. Co., The 757

PUMPS, Circulating
Buffalo Pumps, Inc. 746
Chicago Pump Co. 748-749
Decatur Pump Co. 747
Economy Pumping Machinery Co. 750-751
Foster Wheeler Corp. 700
Goulds Pumps, Inc. 752-753
Hoffman Specialty Co., Inc. 792-801
Nash Engineering Co., The 754-755
Rochester Circulator Co., The 627
H. A. Thrush & Co. 695
Trane Co., The 666-667, 678, 760-761, 824
Weinman Pump Mfg. Co., The 757

PUMPS, Condensation
Buffalo Pumps, Inc. 746
Chicago Pump Co. 748-749
Decatur Pump Co. 747
C. A. Dunham Co. 782-789
Economy Pumping Machinery Co. 750-751
Foster Wheeler Corp. 700
Goulds Pumps, Inc. 752-753
Hoffman Specialty Co., Inc. 792-801
Nash Engineering Co., The 754-755
Skidmore Corp. 756
Sterling Engineering Co. 821
Trane Co., The 666-667, 678, 760-761, 824
Weinman Pump Mfg. Co., The 757

PUMPS, Oil
Anthony Co., The 616
Buffalo Pumps, Inc. 746
Goulds Pumps, Inc. 752-753
National Airoil Burner Co. 622
Petroleum Heat & Power Co. 618-621
Schutte & Koerting Co. 655
Weinman Pump Mfg. Co., The 757

PUMPS, Steam
Buffalo Pumps, Inc. 746
Goulds Pumps, Inc. 752-753
A. D. Granger Co. 606
Hoffman Specialty Co., Inc. 792-801
Petroleum Heat & Power Co. 618-621
Weinman Pump Mfg. Co., The 757

PUMPS, Sump
Buffalo Pumps, Inc. 746
Chicago Pump Co. 748-749
Economy Pumping Machinery Co. 750-751
Goulds Pumps, Inc. 752-753
Hoffman Specialty Co., Inc. 792-801
Nash Engineering Co., The 754-755
Weinman Pump Mfg. Co., The 757

PUMPS, Turbine
Chicago Pump Co. 748-749
Economy Pumping Machinery Co. 750-751
Goulds Pumps, Inc. 752-753
A. D. Granger Co. 606
Hoffman Specialty Co., Inc. 792-801
Nash Engineering Co., The 754-755
Petroleum Heat & Power Co. 618-621
Skidmore Corp. 756
Weinman Pump Mfg. Co., The 757

PUMPS, Vacuum
Anthony Co., The 616
Chicago Pump Co. 748-749
C. A. Dunham Co. 782-789
Economy Pumping Machinery Co. 750-751
Foster Wheeler Corp. 700
General Electric Co. 739
Goulds Pumps, Inc. 752-753
A. D. Granger Co. 606
Hoffman Specialty Co., Inc. 792-801
Nash Engineering Co., The 754-755
Skidmore Corp. 756
Weinman Pump Mfg. Co., The 757
W. P. Whittington, Inc. 758

RADIATION, Aluminum, Brass, Copper, Steel, Etc., Plain and Extended Surface
Aerofin Corp. 649-651
American Radiator Co. 578-579, 774-775
Automatic Florzone Heating Co. 762
Buckeye Blower Co., The 632
Bush Mfg. Co., The 652
Carrier-Lyle Corp. 680-681
Carrier-York Corp. 658-659
C. A. Dunham Co. 782-789
G. & O. Mfg. Co., The 653
Heintz Mfg. Co. 759
Hoffman Specialty Co. of California, Ltd. 802
Herman Nelson Corp., The 672-673
John J. Nesbitt, Inc. 674-677
New York Blower Co., The 639
Richmond Radiator Co., Inc. 584-585
Rome-Turney Radiator Co., The 654
Trane Co., The 666-667, 678, 760-761, 824
Unit Heater & Cooler Co., The 669
L. J. Wing Mfg. Co. 640-642
Wolverine Tube Co. 656
Young Radiator Co. 670

RADIATION, Cast-Iron
American Radiator Co. 578-579, 774-775
Burnham Boiler Corp. 577
Crane Co. 580-581
Molby Boiler Co. 582
Pierce, Butler & Pierce Mfg. Corp. 583
Richmond Radiator Co., Inc. 584-585
Unit Heater & Cooler Co., The 669
United States Radiator Corp. 764
Weil-McLain Co. 588

RADIATOR AIR VALVES (*See Valves, Air*)

RADIATOR ENCLOSURES AND SHIELDS
American Radiator Co. 578-579, 774-775
Auer Register Co., The 766
Hart & Cooley Mfg. Co. 767
Rome-Turney Radiator Co., The 654
Tuttle & Bailey Mfg. Co. 769
United States Radiator Corp. 764

RADIATOR HANGERS (*See Hangers, Radiator*)

RADIATORS, Cabinet and Concealed
American Radiator Co. 578-579, 774-775
Buckeye Blower Co., The 632
Bush Mfg. Co., The 652
C. A. Dunham Co. 782-789
G. & O. Mfg. Co., The 653
Heintz Mfg. Co. 759

Numerals following Manufacturers' Names refer to pages in the Catalog Data Section

Hoffman Specialty Co. of California, Ltd. 802
McCord Radiator & Mfg. Co. 660-661
Herman Nelson Corp., The 672-673
Thermidaire Corp. 668
Trane Co., The 666-667, 678, 760-761, 824
Unit Heater & Cooler Co., The 669
United States Radiator Corp. 764
Weil-McLain Co. 588
Young Radiator Co. 670

RADIATORS, Electric, Automatic

Nocare Electric Radiator Corp. 763

RECEIVERS, Air

Babcock & Wilcox Co., The 589
Farrar & Trefts, Inc. 596
Kewanee Boiler Corp. 600-605
Parks-Cramer Co. 566-567
Whitlock Coil Pipe Co., The 704-705
York Ice Machinery Corp. 568

RECEIVERS, Condensation

Babcock & Wilcox Co., The 589
Hoffman Specialty Co., Inc. 792-801
Rome-Turney Radiator Co., The 654
Sarco Co., Inc. 822-823
Trane Co., The 666-667, 678, 760-761, 824
Whitlock Coil Pipe Co., The 704-705

REFRIGERATING MACHINERY

American Radiator Co. 578-579, 774-775
E. W. Bliss Co. 555
Carrier Engineering Corp. 556-558
Carrier-Lyle Corp. 680-681
Cooling & Air Conditioning Corp., The 559
Foster Wheeler Corp. 700
Frick Company 560
McCord Radiator & Mfg. Co. 660-661
York Ice Machinery Corp. 568

REGISTERS (*See Grilles, Registers, Etc.*)

REGULATORS, Damper

American Radiator Co. 578-579, 774-775
Barber-Colman Co. 831
Bishop & Babcock Sales Co., The 777
D. & T. Mfg. Co. 692
Davis Regulator Co. 780
Julian d'Este Co. 781
C. A. Dunham Co. 782-789
Hart & Cooley Mfg. Co. 767
W. F. Hirschman Co., Inc. 855-857
Hoffman Specialty Co., Inc. 792-801
Illinois Engineering Co. 804-805
Kainer & Co. 693
Kieley & Mueller, Inc. 808
James P. Marsh & Co. 811-818
Mason Regulator Co. 810
Minneapolis-Honeywell Regulator Co. 836-837
Penn Heat Control Co. 838-839
Petroleum Heat & Power Co. 618-621
Powers Regulator Co. 840-843
F. I. Raymond Co. 844-845
Sarco Co., Inc. 822-823
H. A. Thrush & Co. 695
Trane Co., The 666-667, 678, 760-761, 824
Vapor Engineering Co. 825
Warren Webster & Co. 826-828
L. J. Wing Mfg. Co. 640-642

REGULATORS, Feed Water

Babcock & Wilcox Co., The 589
Kainer & Co. 693
Kieley & Mueller, Inc. 808
McDonnell & Miller 576
Minneapolis-Honeywell Regulator Co. 836-837
Mueller Steam Specialty Co., Inc. 819
Wright-Austin Co. 829

REGULATORS, Humidity (*See Humidity Control*)

REGULATORS, Pressure

American Radiator Co. 578-579, 774-775
Bell & Gossett Co. 698
Bristol Co., The 714
Consolidated Ashcroft Hancock Co., Inc. 715
Crane Co. 580-581
Davis Regulator Co. 780
Julian d'Este Co. 781
C. A. Dunham Co. 782-789
Illinois Engineering Co. 804-805
Jenkins Bros. 850
Kainer & Co. 693
Kieley & Mueller, Inc. 808
Klipfel Mfg. Co. 806-807
Linde Air Products Co., The 858
Mason Regulator Co. 810
Minneapolis-Honeywell Regulator Co. 836-837
Mueller Co. 694
Mueller Steam Specialty Co., Inc. 819
Petroleum Heat & Power Co. 618-621
Powers Regulator Co. 840-843
Schutte & Koerting Co. 655
Taylor Instrument Cos. 716-717
H. A. Thrush & Co. 695
Vapor Engineering Co. 825

REGULATORS, Temperature (*See Temperature Control*)

RELIEF VALVES (*See Valves, Relief*)

SAFETY VALVES, (*See Valves, Safety*)

SEPARATORS, Dust (*See Air-Cleaning Equipment*)

SEPARATORS, Oil

Bell & Gossett Co. 698
E. W. Bliss Co. 555
Cochrane Corp. 779
Crane Co. 580-581
Frick Company 560
Illinois Engineering Co. 804-805
Kieley & Mueller, Inc. 808
National Pipe Bending Co., The 703
Patterson-Kelley Co., The 706
Warren Webster & Co. 826-828
Wright-Austin Co. 829

SEPARATORS, Steam

Bell & Gossett Co. 698
Cochrane Corp. 779
Crane Co. 580-581
A. D. Granger Co. 606
Illinois Engineering Co. 804-805
Kieley & Mueller, Inc. 808
W. H. Nicholson & Co. 820
Warren Webster & Co. 826-828
Wright-Austin Co. 829

SHUTTERS, Automatic

American Foundry & Furnace Co. 569
Auer Register Co., The 767
Buffalo Forge Co. 633
DeBothezat Impeller Co., Inc. 636
Diehl Mfg. Co. 637
Ilg Electric Ventilating Co. 638
L. J. Wing Mfg. Co. 640-642

SOFTENERS, Water

Cochrane Corp. 779
Crane Co. 580-581

SOUND DEADENING

Samuel Cabot, Inc. 719
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Knowles Pipe Sleeve Co., 41 North Moore St., New York, N. Y.	743
Lakeside Company, Hermansville, Mich.	643
Leader Boiler & Heater Co., 176 West Adams St., Chicago, Ill.	684
Linde Air Products Co., The, 30 East 42nd St., New York, N. Y.	858
J. E. Lonergan Co., 207 Florist St., Philadelphia, Pa.	809
J. P. Marsh & Co., 2073 Southport Ave., Chicago, Ill.	811–818
Marsh Valve Company, Dunkirk, N. Y.	851–853
Maryland Air Conditioning Corp., Clarkson, McComas, Donaldson and Race Sts., Baltimore, Md.	561
Mason Regulator Co., Dorchester Center, Boston, Mass.	810
McCord Radiator & Mfg. Co., 2587 E. Grand Blvd., Detroit, Mich.	660–661
J. H. McCormick & Co., Williamsport, Pa.	562
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McDonnell & Miller, Wrigley Bldg., Chicago, Ill.	576
Meyer Furnace Co., The, Peoria, Ill.	685
Minneapolis-Honeywell Regulator Co., 2711 Fourth Ave., S., Minneapolis, Minn.	836–837
Molby Boiler Co., Graybar Bldg., Lexington Ave. and 43rd St., New York, N. Y.	582
Monitor Boiler Co., 1505 Race St., Philadelphia, Pa.	608–609
Motor Stoker Corp., 250 Park Ave., New York, N. Y.	626
Motor Wheel Corp., 701-735 E. Saginaw St., Lansing, Mich.	686–687
Mueller Company, Decatur, Ill.	694
L. J. Mueller Furnace Co., 338 S. Second St., Milwaukee, Wis.	613
Mueller Steam Specialty Co., Inc., 349-351 West 26th St., New York, N. Y.	819
Multicell Radiator Corp., Lockport, N. Y.	662–663
Mundet Cork Corp., 450 Seventh Ave., New York, N. Y.	629
Nash Engineering Co., The, South Norwalk, Conn.	754–755
National Airoil Burner Co., 1327 Girard Ave., Philadelphia, Pa.	622
National Pipe Bending Co., The, 104 River St., New Haven, Conn.	703
National Regulator Co., 2311 Knox Ave., Chicago, Ill.	835
Herman Nelson Corp., The, Moline, Ill.	672–673
John J. Nesbitt, Inc., State Road and Rhawn St., Holmesburg, Philadelphia, Pa.	674–677
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New York Blower Co., The, 3169 Shields Ave., Chicago, Ill.	639
Niagara Blower Co., 6 East 45th St., New York, N. Y.	563–565
W. H. Nicholson & Co., 143 Oregon St., Wilkes-Barre, Pa.	820
Nocare Electric Radiator Corp., 1 East 42nd St., New York, N. Y.	763
Orr & Sembower, Inc., Reading, Pa.	610–611

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Parks-Cramer Company, Fitchburg, Mass.	566–567
Patterson-Kelley Co., The, 99 Park Ave., New York, N. Y.	706
Payne Furnace & Supply Co., Inc., 338 N. Foothill Road, Beverly Hills, Calif.	688–691
Peerless Unit Ventilation Co., Inc., 776-778 Union Ave., Bridgeport, Conn.	671
Penn Heat Control Co., Franklin Trust Bldg., Philadelphia, Pa.	838–839
Petroleum Heat & Power Co., Stamford, Conn.	618–621
Pierce, Butler & Pierce Mfg. Corp., 41 East 42nd St., New York, N. Y.	583
Powers Regulator Co., The, 2719 Greenview Ave., Chicago, Ill.	840–843
Radi-Ion Corporation, 54 W. Illinois St., Chicago, Ill.	744–745
F. I. Raymond Co., 629 W. Washington Blvd., Chicago, Ill.	844–845
Richmond Radiator Co., Inc., 1480 Broadway, New York, N. Y.	584–585
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Rome-Turney Radiator Co., The, Rome, N. Y.	654
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Sterling Engineering Co., 3734 N. Holton St., Milwaukee, Wis.	821
Stewart Inso Board Corp., St. Joseph, Mo.	727
Stockham Pipe & Fittings Co., Birmingham, Ala.	741
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Taylor Instrument Companies, 95 Ames St., Rochester, N. Y.	716–717
Thermidaire Corp., 2441-45 Charlotte St., Kansas City, Mo.	668
H. A. Thrush & Co., Peru, Ind.	695
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Tuttle & Bailey Mfg. Co., 155 East 44th St., New York, N. Y.	769
Uni-Flo Grille Corp., 4646 Lawton Ave., Detroit, Mich.	770
Unit Heater & Cooler Co., The, Wausau, Wis.	669
United States Radiator Corp., Detroit, Mich.	764
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Vinco Company, Inc., The, 75 Vesey St., New York, N. Y.	575
Warren Webster & Co., Camden, N. J.	826–828
Weil-McLain Co., 641 W. Lake St., Chicago, Ill.	588
Weinman Pump Mfg. Co., The, 290 Spruce St., Columbus, Ohio	757
Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.	740
Whitlock Coil Pipe Co., The, Hartford, Conn.	704–705
W. P. Whittington, Inc., 311 N. Alabama St., Indianapolis, Ind.	758
L. J. Wing Mfg. Co., 59 Seventh Ave., New York, N. Y.	640–642
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Wood Conversion Co., Cloquet, Minn.	730–731
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Wright-Austin Co., 409 Griswold St., Detroit, Mich.	829
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Roll of Membership

AMERICAN SOCIETY *of* HEATING *and* VENTILATING ENGINEERS

1932

Contains Lists of Members Arranged Alphabetically and Geographically, also Lists of Officers and Committees, Past Officers and Local Chapter Officers

Corrected to January 1, 1932

Published at the Headquarters of the Society

51 Madison Avenue, New York, N. Y.

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AMERICAN SOCIETY *of* HEATING *and* VENTILATING ENGINEERS
51 Madison Ave., New York, N. Y.

1932

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1931-32

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Headquarters, Cleveland
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Secretary, R. G. DAVIS
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4246 Forest Park Boulevard
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170 Beaumont Avenue

Roll of Membership

AMERICAN SOCIETY *of* HEATING *and* VENTILATING ENGINEERS

1931-32

HONORARY MEMBERS

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Arranged Alphabetically—All Grades

(Asterisk indicates authorship of papers)

(*M* 1923; *A* 1918; *J* 1916) indicates, Election as Member 1923; Associate 1918; Junior 1916.
(Pres. 1923) indicates, Elected President in 1923 and is now a Presidential Member.

A

ABBOUD, Alfred (*M* 1930; *A* 1930; *J* 1924), Pres. (for mail), Alfred Abboud & Co., Inc., 45 Bromfield St., Boston, and 4467 Washington St., Roslindale, Mass.
ABEL, D. Morgan (*J* 1928), Research Engr. (for mail), Carrier Research Corp., 750 Frelinghuysen Ave., Newark, and 1030 Sheridan Ave., Elizabeth, N. J.
ABRAHAMSON, P. (*M* 1927), Secy. (for mail), Advance Htg. Co., 117 N. Desplaines St., and 1440 Rosemont Ave., Chicago, Ill.
ABRAMS, Abraham (*M* 1927; *J* 1924), Pres., Abbey Heating Co., Inc., 77 Centre Ave., and (for mail), 100 Clove Rd., New Rochelle, N. Y.
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ACKERMAN, Reynold H. (*J* 1930), Room 803, Heymann Bldg., 213 S. Broad St., Philadelphia, Pa.
ADAMS, Benjamin (*M* 1919), Dist. Mgr. (for mail), American Blower Corp., 612 Otis Bldg., and 3006 W. Coulter St., Queen Lane Manor, Philadelphia, Pa.
ADAMS, Charles W. (*M* 1920), Treas. (for mail), The Daly Co., 1635 Blake St., and Denver Athletic Club, Denver, Colo.
ADAMS, Harold Eugene (*M* 1930), Chief Engr. (for mail), Nash Engrg. Co., Wilson Rd., S. Norwalk, and Merrill Heights, Norwalk, Conn.
ADAMS, N. D. (*M* 1929; *A* 1925; *J* 1922), Supt., Franklin Htg. Sta., 220 Second Ave., S. W., and (for mail), 836 Eighth Ave., S. W., Rochester, Minn.
ADAMS, William Herbert (*S* 1930), Box 25, Middletown, Conn.
ADDAMS, Homer (*Charter Member*), (*Presidential Member*), (Pres., 1924; 1st Vice-Pres., 1923; Treas., 1915-1922; Council, 1915-1925), Pres. (for mail), Kewanee Boiler Co., Inc., 570 Seventh Ave., New York, N. Y.
ADLER, Alphonse A.* (*M* 1921), Consulting Engr. (for mail), 10 Murray St., New York, N. Y., and 35 Stewart Ave., Arlington, N. J.
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AHEARN, William J. (*M* 1929), The Downey Co., 99 W. Dedham St., Boston, Mass.
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ALCOTT, William L. (*A* 1929), 945 Liberty Ave., Pittsburgh, Pa.
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ALLEN, Harry D. (*M* 1917), Htg. Contractor (for mail), 2940 W. Lake St., and 1640 N. Luna Ave., Chicago, Ill.
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ANDERSON, F. Paul* (*M* 1921), (*Presidential Member*), (Pres., 1927; 1st Vice-Pres., 1926; 2nd Vice-Pres., 1925; Council, 1924-1928), Dean (for mail,) College of Engineering, University of Kentucky, and 499 E. Main St., Lexington, Ky.

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ARENBERG, Milton K. (*A* 1920), Chicago Sales Mgr. (for mail), Ilg Elec. Vtg. Co., 182 N. LaSalle St., Chicago, and 362 Oakland Dr., Highland Park, Ill.

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ARMAGNAC, Arthur S. (*M* 1914; *A* 1907), 375 Upper Mountain Ave., Upper Montclair, N. J.

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ARMSPACH, O. W.* (*M* 1919), Chief Engr., Theatre Div., Carrier Engrg. Corp., Paramount Bldg., New York, and (for mail), 3721-80th St., Jackson Heights, L. I., N. Y.

ARMSTRONG, Asher D. (*M* 1931), Mgr., Heating Dept. (for mail), Crane Co., 400 Third Ave., N., and 4200 Aldrich Ave., S., Minneapolis, Minn.

ARMSTRONG, Harold Melotte (*A* 1928), (for mail), American Radiator Co., 1344 Broadway, and 2921 Webb Ave., Detroit, Mich.

ARMSTRONG, John A. (*A* 1930), Salesman, A. M. Byers Co., Box 83, Pittsburgh, Pa.

ARNOLD, Robert S. (*A* 1926; *J* 1922), Dist. Sales Mgr. (for mail), Carrier-York Corp., 1541 Sansom St., Philadelphia, and Rogers Lane, Wallingford Hills, Wallingford, Pa.

ARNOLDY, William F. (*A* 1930), New England Br. Mgr. (for mail), Minneapolis-Honeywell Regulator Co., 285 Columbus Ave., Rm. 705, Boston, and 75 Westminster Rd., Newton Center, Mass.

ARONSON, Henry H. (*J* 1929), Asst. Mgr. (for mail), H. A. Aronson & Son, 1015 Chestnut St., and 4740 Pine St., Philadelphia, Pa.

ARTHUR, Harry W. (*A* 1920), Genl. Supt., J. T. Evans, Inc., 245 W. Market St., Wilkes-Barre, and (for mail), 44 N. Dorrence Ave., Kingston, Pa.

ARTHUR, John M., Jr. (*M* 1923), Supt., Comml. Light and Steam Sales (for mail), Kansas City Power & Light Co., 1330 Baltimore, Kansas City., Mo., and 3311 State Ave., Kansas City, Kan.

ASBURY, Norman B. G. (*J* 1929), Carrier-York Corp., 149 Broadway, New York, N. Y.

ASCHER, Norman C. (*A* 1928), U. S. Radiator Corp., 516 Board of Trade Bldg., Indianapolis, Ind.

ASHENHURST, Harold S.* (*A* 1926), Consulting Engr., 6519 Algonquin Ave., Chicago, Ill.

ASHLEY, Carlyle M. (*M* 1931), (for mail), Carrier Research Corp., 750 Frelinghuysen Ave., Newark, and 7 Girard Place, Maplewood, N. J.

ASHLEY, Edward E. (*M* 1912), P. O. Box 188, Noroton Heights, Conn.

ASHTON, David W. (*M* 1929), Htg. Contractor and Engr. (for mail), D. W. Ashton Co., 1529 Main St., and 206 Linden Ave., Buffalo, N. Y.

ASTON, James (*M* 1919), A. M. Byers Co., 235 Water St., Pittsburgh, Pa.

ATHERTON, G. R. (*M* 1930), Asst. Gen. Mgr. of Sales (for mail), American Radiator Co., 40 West 40th St., New York, and 10 Brook Lane, Scarsdale, N. Y.

ATKINS, Thomas J. (*M* 1931), 16 Arsdale Terrace, East Orange, N. J.

ATKINSON, Kenneth B. (*J* 1930), Personnel Mgr., Carrier Corp., 850 Frelinghuysen Ave., Newark, N. J., and (for mail), Box 26, Media, Pa.

ATWATER, Lyman W. (*M* 1923), Htg. Engr., 552 Rugby Rd., Brooklyn, N. Y.

AUSTIN, Frank L. (1914), Archt., 240 College St., Burlington, Vt.

AUSTIN, William E. (*M* 1909), Branch Mgr. (for mail), National Radiator Corp., 3032 Norfolk St., and 107 Overbrook Rd., Richmond, Va.

AXEMAN, James E. (*J* 1925), Sales Engr., Spencer Heater Co., Williamsport, Pa., and (for mail), 170 Hillendale St., Rochester, N. Y.

AXTHELM, Fred G. (*A* 1930), 648 N. Forest Ave., Webster Groves, Mo.

B

BABBITT, Edward C. (*M* 1923), 135 N. Ardmore Rd., Columbus, O.

BABBITT, William D. (*S* 1930), P. O. Box 200, Carnegie Inst. of Technology, Pittsburgh, Pa., and (for mail), R. F. D. No. 1, Taunton, Mass.

BACHLER, Harry C. (*M* 1927; *J* 1921), Member of Firm (for mail), C. F. Bachler & Son, 139 N. Fourth St., Philadelphia, and 836 Kenmore Rd., Overbrook, Philadelphia, Pa.

BACHLER, Leonard J. (*M* 1918), Engr., Molby Boiler Co., 420 Lexington Ave., and (for mail), 304 East 41st St., New York, N. Y.

BACKSTROM, Russell E. (*J* 1928), Insulation Specialist (for mail), National Committee on Wood Utilization, Dept. of Commerce, and 2707 Adams Mill Rd., Apt. 200, Washington, D. C.

BACKUS, Theodore H. L. (*M* 1916), Schumacher & Backus, 200-208 Hill St., Ann Arbor, Mich.

BAETZ, Henry (*M* 1919), 5854 Etzel Ave., St. Louis, Mo.

BAHNSON, Frederic F. (*M* 1917), Vice-Pres. and Chief Engr. (for mail), The Bahnson Co., 1001 S. Marshall St., and Pres., Southern Steel Stampings, Inc., and 28 Cascade Ave., Winston-Salem, N. C.

BAILEY, Edward P., Jr. (*M* 1925), 221 Central Ave., Johnstown, Pa.

BAILEY, George B. (*M* 1930), 45 Bromfield St., Boston, Mass.

BAILEY, James L. (*J* 1930), Engr. (for mail), Parks-Cramer Co., and 230 S. Torrance St., Charlotte, N. C.

BAILEY, Joseph H. (*M* 1928; *A* 1927; *J* 1923), Sales Engr. (for mail), Carrier Engrg. Corp., 1032 Burnham Bldg., and 1613 Farwell Ave., Chicago, Ill.

BAILEY, W. Mumford (*M* 1930), Managing Director, (for mail), Mumford Bailey & Preston, Ltd., Newcastle House, Clerkenwell Close, London, E. C. 1, and Daines Way, Thorpe Bay, Essex, England.

BAIRD, Floyd E., (*M* 1929), Mgr., Atlanta Branch (for mail), Trane Co., 405-6 Southeastern Trust Bldg., Atlanta, and 900 Church St., Marietta, Ga.

BAKER, Clyde H. (*M* 1928), 195 Cortland Ave., Detroit, Mich.

BAKER, H. W. H. (*M* 1918), Director, Merritt, Ltd., 9 Avenue Edward VII, Shanghai, China.

BAKER, Howard C. (*M* 1921), Pres. (for mail), Howard C. Baker Co., 128 S. St. Clair St., and 4604 Manorwood Dr., Toledo, O.

BAKER, Roland H. (*M* 1928; *A* 1924), Pres-Treas. (for mail), R. H. Baker Co., Inc., 145 Broadway, and 19 Garden St., Cambridge, Mass.

BALDWIN, William Howard (*M* 1921), Branch Sales Mgr., Br. No. 23 (for mail), C. A. Dunham Co., 2988 E. Grand Blvd., and 2662 W. Grand Blvd., Detroit, Mich.

BAMPTON, C. Morton (*M* 1919), Vice-Pres. (for mail, Gates Htg. Co., Inc., 915 Gates Ave., Brooklyn, and 70 Huron Rd., Bellrose, L. I., N. Y.

BARKER, Arthur Henry* (*M* 1906), Consulting Engr. (for mail), 100 Victoria St., S. W. 1, Westminster, and Oakhill House, Beckenham, Kent, England.

BARKER, Charles M. (*M* 1930), Office Mgr. (for mail), B. F. Sturtevant Co., 706 Hollingsworth Bldg., and 129 S. Norton Ave., Los Angeles, Calif.

BARNARD, M. Everett (*J* 1929), Sales Engr. (for mail), Carrier-York Corp., 1541 Sansom St., Philadelphia, and 7115 Radbourne Rd., Upper Darby, Pa.

BARNES, Elmer Raymond (*M* 1928), Estimator, Eichler Htg. Co., 2010 Railway Exchange Bldg., and (for mail), 4444 Beethoven, St. Louis, Mo.

BARNES, Ralph B. (*M* 1927), Owner, Ralph B. Barnes, Htg. Contractor, 212 S. Marion St., and (for mail), 800 Carpenter Ave., Oak Park, Ill.

BARNETT, Stephen J. (*A* 1931), Senior Partner (for mail), Barnett Bros., 1282 Abbott Rd., and 40 Paul Place, Buffalo, N. Y.

BARNUM, Marvin C. (*M* 1930; *A* 1928), Sales Mgr., Humidifier Div., Wilcolator Co., 17 Nevada St., Newark, N. J., and (for mail), 4115–51st St., Woodside, L. I., N. Y.

BARNUM, Willis E., Jr. (*J* 1930), Sales Engr., York Ice Mchy. Corp., 5051 Santa Fe Ave., Los Angeles, Calif.

BARR, George W. (*M* 1905), (Board of Governors 1910), Dist. Mgr., Aerofin Corp., 1822 Land Title Bldg., Philadelphia, and (for mail), Willow Burn and Deep Dene Roads, Villanova, Pa.

BARROWS, C. E. (*A* 1921), Mgr., Chicago Br., (for mail), Crane Co., 156 N. Jefferson St., Chicago, and 1041 Ridge Ave., Evanston, Ill.

BARRY, Curtis P. (*M* 1929), 401 Ashland Ave., Park Ridge, Ill.

BARRY, Patrick I. (*M* 1920), Managing Director (for mail), M. Barry, Ltd., 4 Marlboro St., and Hazeldene, The Marina, Cork, Ireland.

BARTH, Herbert E. (*M* 1920), Sales Mgr., American Blower Corp., 6000 Russell St., Detroit, Mich.

BARTLETT, Amos C. (*M* 1919), Dist. Mgr. (for mail), B. F. Sturtevant Co., 89 Broad St., Boston, and 30 Hollingsworth Ave., Braintree, Mass.

BARTLETT, C. Edwin (*M* 1922), Pres. (for mail), Bartlett & Co., Inc., 1938 Market St., and 3111 W. Coulter St., Philadelphia, Pa.

BARTON, Royal Elton (*M* 1922), Engr. (for mail), McLean & Cousens Co., 65 Chandler St., Boston, and 49 St. Agatha Rd., E. Milton, Mass.

BASSLER, Edwin M.* (*M* 1923), Mech. Engr., 603 Franklin St., Wausau, Wis.

BASTEDO, Albert E. (*M* 1919), Burnham Boiler Corp., Irvington, N. Y.

BAUM, Albert L. (*M* 1916), Member of Firm (for mail), Jaros & Baum, 1350 Broadway, and 601 West 113th St., New York, N. Y.

BAUMGARDNER, Carroll Miles (*M* 1928), Br. Mgr., U. S. Radiator Corp., 228 N. La Salle St., Chicago, and (for mail), 602 Michigan Ave., Evanston, Ill.

BAYSE, Harry V. (*M* 1923), American Furnace Co., 2725 Morgan St., St. Louis, Mo.

BEAHM, Robert B. (*M* 1924; *A* 1919), 445 Berkley Rd., Haverford, Pa.

BEASOM, George R. (*M* 1927), Dir. of Sales, Heggie Simplex Boiler Co., 222 Scott St., and (for mail), 119 Second Ave., Joliet, Ill.

BEATY, Guy M., Jr. (*S* 1930), P. O. Box 1368, Charlotte, N. C.

BEAURRIENNE, Auguste* (*M* 1912), 25 Rue des Marguettes, Paris, France.

BEAVERS, George R. (*M* 1929), Engr., Canadian Blower & Forge Co., Ltd., and (for mail), 30 Sterling Ave., Kitchener, Ont., Canada.

BEEBE, Frederick E. W. (*A* 1915), Sales Engr. (for mail), Johnson Service Co., Inc., 28 East 29th St., New York, N. Y., and 20 Denman Place, Elizabeth, N. J.

BEERY, Clinton E.* (*M* 1913), Pres. (for mail), Stoker Engrg. Corp., 100 N. La Salle St., and 4414 N. Paulina St., Chicago, Ill.

BEGGS, William E. (*M* 1927), Vice-Pres., University Plbg. & Htg. Co., and (for mail), 3639 Palatine Ave., Seattle, Wash.

BEIGHEL, Howard Atlee (*A* 1927), Sales Repr. (for mail), The Herman Nelson Corp., 2424 W. Liberty Ave., Pittsburgh, and 3338 Latonia Ave., Dormont, Pittsburgh, Pa.

BEIRN, John U. (*J* 1928), 210 Voorhees Ave., Buffalo, N. Y.

BEITZELL, Albert E. (*J* 1930), 1339 Girard St., N. W., Washington, D. C.

BELING, Earl H. (*A* 1930; *J* 1925), Research Htg. and Vtg. Engr., Herman Nelson Corp., and (for mail), 2428–13th St., Moline, Ill.

BELT, Newton O. (*M* 1929), Engr. (for mail), Armstrong Cork Co., and *Armstrong Manor*, Lancaster, Pa.

BEMAN, Myron C. (*M* 1926), (for mail), Beman & Candee, 374 Delaware Ave., and 55 Granger Place, Buffalo, N. Y.

BENDER, Charles P. (*M* 1923), Co-Partner (for mail), C. & J. Bender, 1734 Flatbush Ave., and 2045 East 19th St., Brooklyn, N. Y.

BENEDICT, Everett R. (*M* 1926), Pres. (for mail), United District Htg., Inc., 4400 Perkins Ave., and 2544 Overlook Rd., Cleveland, O.

BENNETT, Edwin A. (*J* 1929), Sales Engr. (for mail), American Blower Corp., 401 Broadway, New York, and 51 Chatfield Rd., Bronxville, N. Y.

BENNETT, George Garman (*M* 1928), 1106 Springfield Ave., Urbana, Ill.

BENNETT, Irving T. (*M* 1928; *A* 1928; *J* 1927), Sales Promotion Mgr. (for mail), Revere Copper & Brass, Inc., and 705 N. Madison Ave., Rome, N. Y.

BENNETT, Ralph E. (*A* 1928), Genl. Sales Mgr. (for mail), Thermax Corp., 228 N. LaSalle St., Chicago, and 670 Hinman Ave., Evanston, Ill.

BENNITT, George E. (*M* 1918), Consolidated Gas Co., 130 East 15th St., New York, N. Y.

BENSON, John C. (*J* 1930), 6128 Nassau Rd., Overbrook, Pa.

BENSON, Maurice A. (*J* 1929), Johnson Service Co., 1238 Irwin Ave., Pittsburgh, Pa.

BENTZ, Harry (*M* 1915), 18 Holland Ter., Montclair, N. J.

BERCHTOLD, Edward W. (*M* 1927; *A* 1925), Engr. (for mail), Boston Consolidated Gas Co., 100 Arlington St., Boston, and 20 Randolph St., S. Weymouth, Mass.

BERG, A. Herman (*M* 1919), Pres., Berg Engrg. Corp., Box Y, Huntington Park, Calif.

BERGHOEFER, Victor A. (*J* 1926), Supt., Sterling Engrg. Co., 3738 N. Holton St., and (for mail), 3850 N. Morris Blvd., Milwaukee, Wis.

BERMAN, Louis K. (*M* 1908), Pres. (for mail), Raisler Htg. Co., 129 Amsterdam Ave., and 101 Central Park West, New York, N. Y.

BERMEL, Alfred H. (*J* 1928), Mech. Engr., The Austin Co., 326 Frelinghuysen Ave., Newark, and (for mail), 16 Pershing Pl., N. Arlington, N. J.

BERNHARD, George (*A* 1929), Pres-Treas. (for mail), Geo. Bernhard Engrg. Corp., 145-08 Jamaica Ave., Jamaica, and 18 Lismore Road, Lawrence, L. I., N. Y.

BERNSTROM, Bert (*M* 1930), Engr. (for mail), Lakeside Co., and P. O. Box 92, Hermansville, Mich.

BERRINGER, Sidney H. (*M* 1926), Sales Engr., Dist. Repr., Hoffman Specialty Co., Waterbury, Conn.

BERTHET, Edward E. (*A* 1930), Pittsburgh Dist. Mgr., Skinner Bros. Mfg Co.., Inc., 901 Oliver Bldg., and (for mail), 544 Gettysburg St., Pittsburgh, Pa.

BETTS, Howard M. (*M* 1927), Senior Mech. Engr. (for mail), Dept. of Bldgs., City of Minneapolis, 213 City Hall, and 4923 Russell Ave., S., Minneapolis, Minn.

BETZ, Harry D. (*M* 1928), Gen. Mgr. (for mail), Betz Unit Air Cooler Co., 6 W. Ninth St., Kansas City, Mo., and 5110 Paseo Blvd., Kansas City, Kans.

BEVIL, Alexander T. (*J* 1927), Asst. Htg. Engr., Crane Co., 254 Court Ave., and (for mail), 353 Walker Ave., Memphis, Tenn.

BEVINGTON, Warren C. (*M* 1928), Pres., (for mail), Bevington-Williams, Inc., 1134-39 K. of P. Bldg., and 3419 Pennsylvania St., Apt. D 2, Indianapolis, Ind.

BIDWELL, R. E. (*A* 1924), 6253 Southwood Ave., St. Louis, Mo.

BILYEU, William F. (*M* 1927), Sales Mgr., Radiator Div., John J. Nesbitt, Inc., Holmesburg Philadelphia, Pa., and (for mail), 710 Thomas Ave., Riverton, N. J.

BINDER, Charles G. (*M* 1920), Mgr., Htg. Dept., Warren Webster & Co., 17th and Federal Sts., Camden, and (for mail), 115 Oak Ter., Merchantville, N. J.

BINFORD, Wilmer M. (*J* 1930), 419 N. Poinsettia Pl., Los Angeles, Calif.

BIRCH, Herbert R. (*M* 1922), Sales Engr. (for mail), U. S. Radiator Corp., 370 Lexington Ave., New York, and 28 Caryl Ave., Yonkers, N. Y.

BIRKHOLZ, H. E. (*A* 1925), Novelaire Corp., 1114 Bardstown Rd., Louisville, Ky.

BIRRELL, Allan L. (*A* 1925), Equipment Engr. (for mail), Chapman & Oxley, 372 Bay St., Toronto 2, and 93 Kingsway, Old Mill P. O., Ont., Canada.

BISCH, Bernard J. (*M* 1931), Chief Engr., St. Mary of the Woods College, St. Mary of the Woods, Ind.

BISHOP, Charles R. (*Life Member*; *M* 1901), 413 Locust St., Lockport, N. Y.

BISHOP, Frederick R. (*M* 1921), Mgr. of Sales, Furnace Fans Dept., The Brundage Co., 246 W. Kalamazoo Ave., Kalamazoo, and (for mail), 4018 Pingree Ave., Detroit, Mich.

BJERKEN, Maurice H. (*A* 1927), Sales Repr. (for mail), Hoffman Specialty Co., 533 S. Seventh St., and 4952–17th Ave., S., Minneapolis, Minn.

BLACK, Edgar Newbold III, (*M* 1922), Philadelphia Mgr., Kewanee Boiler Co., Inc., 803 Land Title Bldg., Philadelphia, and (for mail), 111 Woodside Road, Haverford, Pa.

BLACK, F. C. (*M* 1919), Pres. (for mail), F. C. Black Co., 622 W. Randolph St., and 4535 N. Ashland Ave., Chicago, Ill.

BLACK, George E. (*M* 1915), 709 Broad St., Sewickley, Pa.

BLACK, Harry G. (*M* 1917), Prop. (for mail), P. Gormly Co., 155 N. Tenth St., and 927 North 65th St., Philadelphia, Pa.

BLACK, John J. A. (*A* 1925; *J* 1922), Pres. (for mail), John Black & Sons, Inc., 216 Alexander St., and Princeton-Kingston Rd., Princeton, N. J.

BLACKBURN, Edwin C., Jr. (*M* 1929), Mech. Engr., Crow, Lewis & Wick, 200 Fifth Ave., New York, and (for mail), 141 Crowell St., Hempstead, L. I., N. Y.

BLACKHALL, Wilmot R. (*M* 1922), Partner, McKellar & Blackhall, 1104 Bay St., and (for mail), 332 Waverley Road, Toronto, Ont., Canada.

BLACKMAN, Alfred O. (*M* 1911), Consulting Engr. (for mail), 1540 Broadway, New York, N. Y., and Suburban Club, Stamford, Conn.

BLACKMORE, F. H. (*M* 1923), Mgr., Operating Dept. (for mail), U. S. Radiator Corp., Box 686, and 2322 Tuxedo Ave., Detroit, Mich.

BLACKMORE, George C. (*Charter Member*), Edgewood, Pittsburgh, Pa.

BLACKMORE, J. J.* (*Charter Member*), 32 West 40th St., New York, N. Y.

BLACKMORE, James S. (*J* 1931), Sales Engr., Automatic Gas Steam Rad. Co., 301 Brushton, Ave., Pittsburgh, Pa.

BLACKMORE, Norman L. (*M* 1928), Secy. (for mail), Automatic Gas Steam Radiator Co., 301 Brushton Ave., and 103 Biddle Ave., Pittsburgh, Pa.

BLACKSHAW, J. L.* (*J* 1929), Research Engr., A. S. H. V. E. Laboratory, U. S. Bureau of Mines, 4800 Forbes St., and (for mail), 3752 Beechwood Blvd., Pittsburgh, Pa.

BLAKE, Albert Henry (*M* 1926), Br. Mgr. (for mail), Sheldons, Ltd., 119 W. Pender St., and 3261 W. Second Ave., Vancouver, B. C., Canada.

BLANDING, George H. (*M* 1919), Salesman, Johnson Service Co., 1355 W. Washington Blvd., Chicago, and (for mail), 800 N. Lombard Ave., Oak Park, Ill.

BLANEY, Charles A. (*M* 1914), Secy. and Gen. Mgr. (for mail), Wheeler-Blaney Co., 249 N. Burdick St., and 301 Douglas Ave., Kalamazoo, Mich.

BLANKIN, Merrill F. (*M* 1927; *A* 1926; *J* 1919), Pres. (for mail), Haynes Selling Co., 1518 Fairmount Ave., and 3328 W. Penn St., Philadelphia, Pa.

BLESSED, William A. (*A* 1929; *J* 1927), Mech. Engr., Mueller Brass Co., and (for mail), 1526 Howard St., Port Huron, Mich.

BLITZ, Emmanuel (*M* 1931), Engr., Andrew J. Thomas, 2 West 42nd St., and (for mail), 2846 Marion Ave., New York, N. Y.

BLOMFELDT, Allen A. (*M* 1914), Pres. (for mail), Texo Heater & Mfg. Corp., 220-230 Madison Ave., Covington, and 100 Mayo Circle, Clifton, Ky.

BLOOM, Samuel C.* (*M* 1915), Prop. (for mail), S. C. Bloom & Co., 53 W. Jackson St., and 1953 East 72nd St., Chicago, Ill.

BLUME, Frederick J., Jr. (*J* 1929), Sales Engr., American Radiator Co., 40 West 40th St., New York, N. Y., and (for mail), Box 433, Emerson, N. J.

BOALES, William G. (*A* 1923), Mfrs. Repr., McDonnell & Miller, 1226 Marquette Drive, Detroit, Mich.

BOCK, Bernard (*A* 1929; *J* 1927), 425 Beech St., Arlington, N. J.

BODDINGTON, William P. (*M* 1927), Mgr. (for mail), The Powers Regulator Co., Ltd., 106 Lombard St., and 280 Clendenan Ave., Toronto, Ont., Canada.

BODINGER, Jacob H. (*M* 1931), Pres. (for mail), J. H. Bodinger Co., Inc., 439 West 38th St., New York, and 1429 East 19th St., Brooklyn, N. Y.

BOGATY, Hermann S. (*M* 1921), Designing Engr., Proctor & Schwartz, Inc., Seventh St. and Tabor Rd., and (for mail), 5230 North 15th St., Philadelphia, Pa.

BOLLING, Esten (*M* 1921; *J* 1918), Consulting Publicity Engr., Mountain Lakes, N. J.

BOLSINGER, Raymon C. (*M* 1916), Pres. (for mail), Automatic Florzone Htg. Co., Conshohocken, Pa., and 238 E. Madison Ave., Collingswood, N. J.

BOLTE, Edward E. (*A* 1929), 1502 East 69th Pl., Chicago, Ill.

BOLTON, Reginald Pelham* (*Life Member*; *M* 1897), (*Presidential Member*), (Pres., 1911; 1st Vice-Pres., 1905-1910; 2nd Vice-Pres., 1903; Board of Governors, *1901, 1905, 1910, 1911,* 1912, 1913), Consulting Engr., Pres. (for mail), The R. P. Bolton Co., Bolton Bldg., 116 East 19th St., and 638 West 158th St., New York, N. Y.

BOND, Horace A. (*M* 1930), 12 Ramsey Pl., Albany, N. Y.

BONDY, Winfield S. (*M* 1930; *A* 1930; *J* 1926), Sales Engr., Clarage Fan Co., 40 West 40th St., New York, N. Y., and (for mail), 1349 Elm Ter., W. Englewood, N. J.

BOON, George (*M* 1915), Pres. (for mail), Boon & Sample, Inc., 3008-10 Ludlow St., and 6428 Morris Park Rd., Philadelphia, Pa.

BOOTH, C. A. (*M* 1917), Vice-Pres. and Sales Mgr. (for mail), Buffalo Forge Co., 490 Broadway, and 142 Summit Ave., Buffalo, N. Y.

BOOTH, Harry N. (*M* 1924; *A* 1917), Vice-Pres., Sales Dept. (for mail), U. S. Radiator Corp., Room 1056, First National Bank Bldg., and 688 Taylor Ave., Detroit, Mich.

BORNEMANN, Walter A. (*M* 1924; *J* 1923), (for mail), Carrier Engrg. Corp., 1726 Land Title Bldg., Philadelphia, and 123 W. Wharton Ave., Glenside, Pa.

BOSTAIN, James C. (*M* 1923), *Williamson* Heater Co., 337 W. Fifth St., and (for mail), 3469 Evanston Ave., Cincinnati, Ohio.

BOSWIN, George A. (*M* 1917), Pres. (for mail), Boswin Engrg. Corp., 228 N. La Salle St., and 902 Diversey Pkwy., Chicago, Ill.

BOUEY, Angus J. (*J* 1930), Sales Engr., The B. F. Sturtevant Co., 706 Hollingsworth Bldg., Los Angeles, Calif.

BOWERS, Arthur F. (*A* 1919), Pres. (for mail), Industrial Htg. & Engrg. Co., 828 N. Broadway, and 2853 N. Hackett Ave., Milwaukee, Wis.

BOWERS, J. Sylvan (*M* 1921), *Owner (for mail)*, J. Sylvan Bowers Sales Co., 3805 Page Blvd., and 2525-A W. St. Louis Ave., St. Louis, Mo.

BOWLES, Potter (*A* 1928), Treas. (for mail), Hoffman Specialty Co., Inc., Chrysler Bldg., New York, and 964 Highland Ave., Pelham Manor, N. Y.

BOYD, Spencer W. (*J* 1931), Consult. Engr. (for mail), Newcomb & Boyd, 808 Walton Bldg., and 895 Myrtle St., Atlanta, Ga.

BOYD, William R. (*A* 1926; *J* 1924), Turner Supply Co., 8 W. Sixth St., Chester, Pa.

BOYDEN, Davis S.* (*M* 1909), (*Council* 1917; 1930; 1931), Dept. Supt. (for mail), Edison Elec. Illuminating Co. of Boston, 39 Boylston St., Boston, and 1496 Commonwealth Ave., Brighton, Mass.

BOYNTON, Daniel Wilcox (*A* 1927), International Heater Co., 77 Franklin St., Boston, Mass.

BOZEMAN, Richard W. (*J* 1929), Service Mgr. (for mail), Carrier-York Corp., 1541 Sansom St., Philadelphia, and 531 Dudley Ave., Narberth, Pa.

BRAATZ, Chester J.* (*M* 1930), Engr., Barber-Colman Co., and (for mail), 1622 Camp Ave., Rockford, Ill.

BRABBÉE, Dr. Charles W.* (*M* 1925), Director, Inst. of Thermal Research, American Radiator Co., 675 Bronx River Road, Yonkers, N. Y.

BRACKEN, John Henry (*M* 1927), Industrial Uses Dept., The Celotex Co., 919 N. Michigan Ave., and (for mail), 447 Oakdale Ave., Chicago, Ill.

BRADFIELD, Paul E. (*M* 1930), Htg. Engr., Crane Co., 321 E. Second St., and (for mail), 1643 Shenandoah, Los Angeles, Calif.

BRADFIELD, William W. (*M* 1926), 909 Michigan Trust Bldg., Grand Rapids, Mich.

BRADFORD, H. H. (*A* 1927), 4701 Blaisdell Ave., S., Minneapolis, Minn.

BRADLEY, Eugene P. (*M* 1906), Pres. (for mail), Hester-Bradley Co., 2835 Washington Ave., St. Louis, and 6935 Pershing Ave., University City, Mo.

BRADLEY, Royal H. (*M* 1915), Kelsey Htg. Co., 277 James St., Syracuse, N. Y.

BRAEMER, William G. R. (*M* 1915), Mgr. and Consultant, Niagara Blower Co., Lafayette Bldg., Philadelphia, Pa., and (for mail), 732 Mt. Vernon St., Haddonfield, N. J.

BRAKENRIDGE, Charles E. (*A* 1930), 3817 Johnson Ave., Western Springs, Ill.

BRANDELES, H. J. (*M* 1921), Vice-Pres. (for mail), Hudson-Brandeles, Inc., 1600 Lincoln Ave., and 66 Prospect St., Utica, N. Y.

BRANDI, O. H. (*M* 1930), (for mail), Carrier Lufttechnische Gesellschaft, Savignyplatz, 3, and Hohenzollerndamm, 35, Wilmersdorf, Berlin, Germany.

BRANDT, Ernst Hamilton, Jr. (*M* 1928), Partner, Chas. W. Christian Co., and (for mail), P. O. Box 292, Charlotte, N. C.

BRASSINGTON, Arthur F.* (*A* 1918), 505-507 West 45th St., New York, N. Y.

BRAUER, Roy (*M* 1926), Sales Engr. (for mail), The Ventilating Equipment Corp., Bessemer Bldg., Pittsburgh, and 2880 Glenmore Ave., Dormont, Pa.

BRAUN, Louis T. (*M* 1921), Executive Secy. (for mail), Chicago Master Steamfitters Assn., 228 N. LaSalle St., and 6739 N. Greenview Ave., Chicago, Ill.

BRAYTON, William M. (*M* 1926), Engr. (for mail), Robt. Gordon, Inc., 22 W. Austin Ave., Chicago, and Cary, Ill.

BRECKENRIDGE, L. P.* (*M* 1920), Prof. Emeritus, Mech. Engrg., Yale University, New Haven, Conn., and (for mail), N. Ferrisburg, Vt.

BREDESEN, Bernhard P. (*A* 1931), Sales Engr., Herman Nelson Corp., 501 Essex Bldg., and (for mail), 3119 Knox Ave., N., Minneapolis, Minn.

BREEN, Joseph W. (*M* 1916), Htg. Engr. and Contr., Jos. W. Breen & Sons, Wyalusing Ave., and Fallon St., and (for mail), 957 N. Fallon St., Philadelphia, Pa.

BREITENBACH, George Charles (*J* 1928), Mgr., Govt. Service Div. (for mail), The Trane Co., 726 Investment Bldg., and 2801 Adams Mill Rd., N. W., Washington, D. C.

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BRENEMAN, Robert B. (*J* 1927), Sales Engr. (for mail), Armstrong Cork & Insulation Co., 232 W. Seventh St., and 1557 *Addington* Place, Cincinnati, Ohio.

BREWSTER, Donald R.* (*M* 1926), Dist. Mgr. (for mail), National Lumber Mfrs. Assn., 1339 Bk. of Commerce Bldg., and 349 Hawthorne St., Memphis, Tenn.

BRIDE, W. T. (*M* 1928; *A* 1928; *J* 1925), Supervising Engr. (for mail), Bride, Grimes & Co., 9 Franklin St., and 116 E. Haverhill St., Lawrence, Mass.

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BRILL, Joseph W. (*J* 1931), 105 Canister St., Hornell, N. Y.

BRINTON, Joseph W. (*M* 1920), Boston Dist. Mgr. (for mail), American Blower Corp., 1003 Statler Bldg., Boston, and 51 Gleason St., W. Medford, Mass.

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BROGAN, James J. (*A* 1917), Senior Partner (for mail), Brogan & Co., 810 Race St., and 6142 Lebanon Ave., Philadelphia, Pa.

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BROOM, Benjamin Alexander (*M* 1914), Sales Promotion Engr. (for mail), Weil-McLain Co., 641 W. Lake St., and 7440 Malvern Ave., Chicago, Ill.

BROWN, Alfred P. (*M* 1927), (for mail), B. F. Reynolds & Co., 609 N. LaSalle St., Chicago, and 551 Hill Terrace, Winnetka, Ill.

BROWN, Aubrey I.* (*M* 1923), Associate Prof. of Htg. and Vtg. (for mail), Ohio State University, and 169 Richards Rd., Columbus, O.

BROWN, Foskett* (*M* 1926), Vice-Pres. (for mail), Gray & Dudley Co., 222 Third Ave. N., and 2314 West End Ave., Nashville, Tenn.

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BROWN, Robert H. (*M* 1926), Research Engr. (for mail), Parks-Cramer Co., 1102 Old South Bldg., Boston, and 45 Pierpont Rd., Roxbury, Mass.

BROWN, Thomas (*A* 1931), Htg. Contractor, 41 Glenholme Ave., Toronto, Ont., Canada.

BROWN, Tom (*M* 1930), Sales Engr. and Mfrs. Repr. (for mail), B. F. Reynolds & Co., 487 W Alexandrine Ave., and 14292 Camden Ave., Detroit, Mich.

BROWN, W. Chester (*A* 1928), Pres. (for mail), The Brown Co., 1055 W. Baltimore Ave., and 1053 W. Baltimore Ave., Detroit, Mich.

BROWN, W. Maynard (*A* 1930), Asst. Secy. (for mail), Warren Webster & Co., 17th and Federal Sts., Camden, and 48 Colonial Ridge Drive, Haddonfield, N. J.

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BRYANT, Percy J. (*M* 1915), Chief Engr. (for mail), Prudential Insurance Co., Newark, and 530 Hanford Pl., Westfield, N. J.

BRYCE, Stephen D. (*M* 1921), Partner (for mail), Bryce Htg. & Vtg. Co., 2014-16 North 14th St., and 2907 Rockwood Pl., Toledo, O.

BUCHER, Harry G. (*J* 1930), 210 Copeland St., McKees Rocks, Pa.

BUCK, Lucien (*M* 1928), Pres. (for mail), Buck Dryer Corp., Manchester, and 488 E. Center St., South Manchester, Conn.

BUCKLEY, Martin B. (*A* 1930), 910 Grand Ave., Kansas City, Mo.

BUDER, Charles G.* (*M* 1919), Stoker Dept. (for mail), *Butler Mfg. Co., 13th and Eastern Ave.*, Kansas City, and 2000 Urban Ave., Brentwood, Mo.

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BUENSOD, Alfred Charles (*M* 1918), Sales Engr., Carrier Engrg. Corp., 39 Cortlandt St., and (for mail), 1 Fifth Ave., New York, N. Y.

BULKELEY, Claude A.* (*M* 1923), Chief Engr. (for mail), Niagara Blower Co., 6 East 45th St., and Tudor Tower, 25 Prospect Place, New York, N. Y.

BULLEIT, Charles R. (*J* 1930), 1630 S. Grand Ave., Evansville, Ind.

BULLOCK, Thomas A. (*M* 1930), Densmore, LeClear & Robbins, 31 St. James Ave., Boston, Mass.

BUNKER, Kenneth S. (*A* 1930), Sales Engr. (for mail), Union Tank & Pipe Co., Ltd., 2801 Santa Fe Ave., and 323 N. Genesee St., Los Angeles, Calif.

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BURKE, Fletcher H. (*M* 1925), Professional Engr. (for mail), 677 Ellicott Sq., Buffalo, and Orchard Park, N. Y.

BURKE, George B. (*M* 1926), Vice-Pres. (for mail), Sarco Co., Inc., 205 W. Wacker Dr., Chicago, and 611 Ninth St., Wilmette, Ill.

BURKE, James (*J* 1930), (for mail), Carrier Engrg. Corp., 850 Frelinghuysen Ave., Newark, and Tudor Court Apt., A-9, Pingry Place, Elizabeth, N. J.

BURNAP, Charles W. (*M* 1922), Herman Nelson Corp., 724 Commercial St., Emporia, Kans.

BURNETT, Earle S. (*M* 1920), Mech. Engr., U. S. Helium Production Plant, Box 2025, and (for mail), 4223 West 11th Ave., Amarillo, Tex.

BURNS, Edward J. (*M* 1923), Supt. (for mail), H. Kelly & Co., 948-950 N. W. Bk. Bldg., and 4716 Aldrich Ave., S., Minneapolis, Minn.

BURNS, Willard A. (*M* 1924), Pres. (for mail), Burns Htg. Co., 6900 N. Clark St., and 1728 Farwell Ave., Chicago, Ill.

BURRITT, Charles G. (*A* 1916), Johnson Service Co., 922 Second Ave. S., Minneapolis, Minn.

BUSCH, Philip J. (*A* 1931), Salesman, American Radiator Co., 111 Benjamin, S. E., Grand Rapids, Mich.

BUSHNELL, Carl D. (*A* 1921), Bushnell Machinery Co., 1501 Grant Bldg., Pittsburgh, Pa.

BUTLER, C. W. (*M* 1929; *A* 1929; *J* 1927), Sales Engr. (for mail), B. F. Sturtevant Co., 423 Dwight Bldg., and 4509 Roanoke Parkway, Kansas City, Mo.

BUTLER, Peter D. (*M* 1922), Salesman, U. S. Radiator Corp., 370 Lexington Ave., New York, N. Y., and (for mail), 127 Edgewater Ave., Grantwood, N. J.

BUTT, Roderick E. W. (*J* 1930), Sales Engr., Carrier Engrg. Corp., Ltd., 24 Buckingham Gate, and (for mail), 3 Orme Court, London, England.

BYNUM, Otis W. (*A* 1930), Engr., Carrier Engrg. Corp., 1032 Burnham Bldg., Chicago, Ill.

BYRNES, Emmet F. (*A* 1930), 609 Free Press Bldg., Detroit, Mich.

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CALLON, Harry, Jr. (*A* 1928), Office Mgr. (for mail), Callon Bros., 24 S. Alabama St., and 3001 East 38th St., Indianapolis, Ind.

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CAMPBELL, F. B. (*A* 1927), Pres., F. B. Campbell Corp., 10 Murray St., New York, N. Y.

CAMPBELL, John M. (*A* 1919), R 2 Plymouth, Plymouth, Mich.

CAMPBELL, Ray W. (*M* 1930), Sales Engr., L. J. Mueller Furnace Co., 1138 S. Cardiff St., Los Angeles, Calif.

CAMPBELL, Thomas F. (*M* 1928), Distributor (for mail), Minneapolis-Honeywell Regulator Co., 1013 Penn Ave., Wilkinsburg, and 580 Oakwood St., Pittsburgh, Pa.

CAMPBELL, Walter E. (*M* 1931), 803 Montrose Ave., South Pasadena, Calif.

CANDEE, Andrew H.* (*M* 1930), Railway Engr. (for mail), Westinghouse Elec. & Mfg. Co., East Pittsburgh, and Forest Hill Road, Bryn Mawr Farms, Wilkinsburgh, Pa.

CANTWELL, John DeM. (*M* 1930), Br. Mgr. (for mail), The Trane Co., 8316 Woodward Ave., and 417 N. Philip Ave., Detroit, Mich.

CAREY, James A. (*M* 1928), Vice-Pres. (for mail), Carrier-York Corp., 1541 Sansom St., Philadelphia, and Villanova, Pa.

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CAREY, Thomas H. (*M* 1931), Dist. Mgr., Herman Nelson Corp., Moline, and (for mail), 622 Jefferson Ave., Defiance, Ohio.

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CARLSON, Everett E. (*A* 1929), Br. Mgr. (for mail), The Powers Regulator Co., 1010 Loudermman Bldg., and 6652 Washington Ave., St. Louis, Mo.

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CARNAHAN, Glen C. (*M* 1924), 5412 Woodlawn Ave., Chicago, Ill.

CARPENTER, R. H. (*M* 1921), (Council, 1931), Mgr., New York Office (for mail), Nash Engrg. Co., Graybar Bldg., 420 *Lexington* Ave., New York, and 10 Jefferson Ave., White Plains, N. Y.

CARR, Maurice L. (*M* 1931), Staff Engr. (for mail), Pittsburgh Testing Lab., P. O. Box 1115, and Keystone Athletic Club, Pittsburgh, Pa.

CARRASCO, Saturnino (*J* 1928), Monedo 944, Casilla 2405, Santiago, Chile, South America.

CARRIER, Earl G. (*J* 1929), Estimating Engr., Carrier Engrg. Corp., 39 Cortlandt St., New York, N. Y., and (for mail), 38 N. Burnett St., East Orange, N. J.

CARRIER, Willis H.* (*M* 1913), (*Presidential Member*), (Pres., 1931; 1st Vice-Pres., 1930; 2nd Vice-Pres., 1929; Council, 1923-1931), Chairman of the Board (for mail), Carrier Corp., 850 Frelinghuysen Ave., Newark, and Rensselaer Road, Essex Fells, N. J.

CARROLL, W. J. (*A* 1925), Br. Mgr., Kewanee Boiler Corp., 402½ Michigan Trust Bldg., and (for mail), 339 Burton St., S. E., Grand Rapids, Mich.

CARSON, Clifford C. (*M* 1930), Chief Engr. (for mail), Texo Htr. & Mfg. Corp., 220 Madison St., and 9 E. Martana Apts., Covington, Ky.

CARSTEIN, W. H. (*M* 1923), Majestic Furnace & Mfg. Co., 1723 Westlake Ave., N., Seattle, Wash.

CARTIER, C. Ernest (*M* 1930), Associate (for mail), Clinton S. Robison & Associates, 208 W. Washington St., and 7416 Rogers Ave., Chicago, Ill.

CASE, Walter G. (*A* 1930), Tech. Mgr. (for mail), National Radiator Co., Ltd., "Ideal" House, Gt. Marlborough St., London, W I, and 66 The Ridgeway, Kenton, Middlesex, England.

CASEY, Byron L. (*M* 1921), Sales Engr. (for mail), Ilg Elec. Vtg. Co., 182 N. LaSalle St., Chicago, and 423 N. Prospect Ave., Park Ridge, Ill.

CASEY, Huntley F. (*M* 1931), 756 E. River St., Anderson, S. C.

CASH, Tidie T. (*A* 1925), Grinnell Co., 240 Seventh Ave., S., Minneapolis, Minn.

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CASTIN, Laurence N. (*M* 1927), 1212 Michigan Ave., Buffalo, N. Y.

CATLIN, Byron J. (*A* 1929), House-Htg. Engr. (for mail), New Haven Gas Light Co., 70 Crown St., and 181 W. Rock Ave., New Haven, Conn.

CAVILEER, James V. (*A* 1921), (for mail), York Htg. & Vtg. Corp., 1541 Sansom St., and 7124 Ogontz Ave., Philadelphia, Pa.

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CHALLMAN, Samuel A. (*M* 1919), Director of School Bldgs., State Dept. of Education, State Capitol, St. Paul, Minn.

CHANDLER, Clark W. (*S* 1930), (for mail), Chandler Co., and 624–19th St., S. E., Cedar Rapids, Iowa.

CHAPPELL, Henry D. (*M* 1931), 2359 First National Bank Bldg., Detroit, Mich.

CHAPPELL, Robert E. (*M* 1928), 611 North St., Baton Rouge, La.

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CHASE, Chauncey L. (*M* 1931), 8829 Fort Hamilton Pkway., Brooklyn, N. Y.

CHASE, Louis R. (*J* 1931), Br. Mgr. (for mail), Buffalo Forge Co., 1025 New York Life Bldg., and 4822 Wornall Road, Kansas City, Mo.

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CHERNE, Realto E. (*J* 1929), Engr., Carrier Engrg. Corp., 39 Cortlandt St., New York, N. Y., and (for mail), 435 Westminster Ave., Elizabeth, N. J.

CHERRY, Lester A. (*M* 1921), Industrial Planning Corp., 45 Court St., Buffalo, N. Y.

CHERVEN, Victor W. (*M* 1928; *A* 1920), Chief Engr. (for mail), Holland Furnace Co., and 326 Maple Ave., Holland, Mich.

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CHEYNEY, Charles C. (*A* 1913), Buffalo Forge Co., 490 Broadway, Buffalo, N. Y.

CHITTENDEN, Edwin F. (*A* 1930), 604, Donovan Bldg., Detroit, Mich.

CHOFFIN, C. C. (*M* 1919), Pres-Treas. (for mail), W. J. Scholl & Co., Mahoning Ave. and Hogue St., and 450 Catalina Ave., Youngstown, Ohio.

CHRISTIAN, Charles W. (*M* 1913), Pres. (for mail), Charles W. Christian Co., P. O. Box 292, and 1101 Providence Road., Charlotte, N. C.

CHRISTMAN, William F. (*J* 1931), 5 Prospect Place, New York, N. Y.

CHURCH, Herbert John (*M* 1922), Mgr., Darling Bros., Ltd., Room 902, 137 Wellington, W., Toronto, Ont., Canada.

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CLANCY, Gilbert E. (*M* 1930), Sales Engr., Gay Engrg. Corp. of Calif., 2650 Santa Fe Ave., and (for mail), 2222 West 75th St., Los Angeles, Calif.

CLARE, Fulton Warren (*M* 1927), Prop. (for mail), Clare & Co., 611 Bona Allen Bldg., and 935 Plymouth Road, N. E., Atlanta, Ga.

CLARK, E. Harold (*M* 1922), Mfrs. Agt., 626 Michigan Theatre Bldg. (for mail), Apt. 26, 132 Pingree St., Detroit, Mich.

CLARKE, Samuel S. (*M* 1909), Pres. and Mgr. (for mail), S. S. Clarke & Co., Ltd., 605 Second St. W., and 603 Second St. W., Calgary, Alberta, Canada.

CLARKSON, Robert C. Jr. (*M* 1921), 821 South 49th St., Philadelphia, Pa.

CLARKSON, W. B. (*M* 1919), Vice-Pres., The King Co., 707 N. Cedar St., and (for mail), 251 Broadway, Owatonna, Minn.

CLEGG, Carl (*M* 1922), American Blower Co., 311 Mutual Bldg., Kansas City, Mo.

CLELAND, James E. (*M* 1925), Pres. (for mail), Cleland Engrg. Co., 208 Fifth St., and 73 N. Princeton St., Lynchburg, Va.

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CLUCAS, W. Frank (*M* 1928), 483 Elmwood Ave., Buffalo, N. Y.

COE, Ivan B. (*M* 1918), Pres-Treas. (for mail), Blower Systems Corp., 340 Lyell Ave., and 122 Penhurst St., Rochester, N. Y.

COE, Ralph T. (*M* 1917), Senior Partner (for mail), The R. T. Coe Cos., 907 Gas & Elec. Bldg., and 235 Chili Ave., Rochester, N. Y.

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COLE, Grant E. (*A* 1925), Vice-Pres., Trane Co. of Canada, Ltd., 439 King St., W., and (for mail), 128 Grenadier Road, Toronto, Ont., Canada.

COLEMAN, John B. (*M* 1920), Chief Engr. (for mail), Grinnell Co., Inc., 260 W. Exchange St., and 237 Cole Ave., Providence, R. I.

COLLAMORE, Ralph (*M* 1904), (Board of Governors, 1913), Secy., Smith, Hinchman & Grylls, 800 Marquette Bldg., and (for mail), 679 Pingree Ave., Detroit, Mich.

COLLIER, William I. (*M* 1921), Mech. Engr. (for mail), W. I. Collier & Co., 522 Park Ave., Baltimore, and Ellicott City, Md.

COLLVER, Gordon L. (*J* 1927), Vtg. Engr., Geo. W. Reed Co., Ltd., and (for mail), 49 Mercille Ave., St. Lambert, Que., Canada.

COMSTOCK, Glen Moore (*A* 1926), 154 College Ave., Beaver, Pa.

CONNELL, Richard F. (*M* 1916), Mgr., Capitol Testing Lab. (for mail), U. S. Radiator Corp., 127 Campbell Ave., and 2970 Burlingame Ave., Detroit, Mich.

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CONOVER, Edmond W.* (*M* 1930), 9165 Stoepel Ave., Detroit, Mich.

COOK, Benjamin F. (*M* 1920), Consulting Engr., 713 Linwood Blvd., Kansas City, and (for mail), 1720 Overton Ave., Independence, Mo.

COOK, Chauncey J. (*A* 1930), 409 S. State St., Syracuse, N. Y.

COOK, Chester D. (*M* 1921), 2340-42 Pine St., St. Louis, Mo.

COOK, Ralph P. (*M* 1930), Htg.-Vtg. Engr. (for mail), Eastman Kodak Co., Kodak Park, and 105 Falleson Road, Rochester, N. Y.

COON, Thurlow E. (*M* 1916), Pres. (for mail), The Coon-DeVisser Co., 2051 W. Lafayette and 826 Edison Ave., Detroit, Mich.

COOPER, Albert W. (*A* 1925), Br. Mgr. (for mail), Johnson Service Co., 724 McIntyre Bldg., and 2543 Highland Drive, Salt Lake City, Utah.

COOPER, Frank Irving* (*M* 1911), (Council, 1914-1916), Pres., Frank Irving Cooper Corp., 47 Winter St., Boston, and Wayland, Mass.

COOPER, Frederick D. (*A* 1930), Excelso Products Corp., and (for mail), 17326 Stoepel Ave., Detroit, Mich.

COOPER, John R. (*M* 1931), East. Br. Mgr. (for mail), Thermal Units Mfg. Co., 30 Church St., and 325 Convent Ave., New York, N. Y.

COOPER, John W. (*A* 1925), Buffalo Forge Co., 906 Chemical Bldg., St. Louis, Mo.

COOPER, Thomas R. (*M* 1923), Messrs. John Danks & Son, Ltd., 391 Bourke St., Melbourne, Australia.

COOPER, Thomas W. (*A* 1922), Sales Engr. Haynes Selling Co., 1518 Fairmount Ave., and (for mail, 5117 N. Mervine St., Philadelphia, Pa.

CORBIN, William E. (*J* 1929), Engr. (for mail), C. Stanley Morgan, 445 Larned St., and 676 Charlotte St., Detroit, Mich.

CORLETT, Laurence D. (*M* 1930), 1390 Chalmers St., Detroit, Mich.

CORNELIUS, Frank H. (*M* 1929), 7914 Edgewood Ave., Swissvale, Pa.

CORNELL, Harold A. (*A* 1925), (for mail), Davies Supply Co., 6601 Grand Ave., and 2643 Rosemont Ave., Chicago, Ill.

CORNELL, J. Clarence (*A* 1930), 2823 W. Allegheny Ave., Philadelphia, Pa.

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COTTER, Leonard F. (*J* 1929), 34 Pearl St., Springfield, Mass.

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COUGHLIN, R. J. (*M* 1925), 8215 Maryland Ave., Chicago, Ill.

COUSENS, Walter S. (*M* 1924), 46 Shornecliff Road, Newton, Mass.

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COWARD, Herbert (*M* 1921), Mgr., Washington Office (for mail), Carrier Engrg. Corp., 604 Washington Bldg., and 4344 Forest Lane, Wesley Heights, Washington, D. C.

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COX, William F. (*M* 1924), Sales Engr. (for mail), Crane Co., 1328 West 12th St., and 5212 Rockhill Road, Kansas City, Mo.

COX, William W. (*M* 1923), Pres. and Mgr. (for mail), Heating Service Co., 326 Columbia St., and 6232-31st St., N. E., Seattle, Wash.

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CRAWFORD, William Blake (*M* 1921), Combustion Engr., Seneca Petroleum Co., 439 West 33rd St., and (for mail), 1516 N. Mayfield Ave., Chicago, Ill.

CRESSY, Ralph E. (*J* 1929), Automatic Florzone Heating Co., Conshohocken, Pa., and (for mail), 408 St. Lawrence Ave., Buffalo, N. Y.

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CROSS, Robert E. (*A* 1931), Br. Mgr. (for mail), Minneapolis-Honeywell Regulator Co., 95 State St., and 68 Kimberly Ave., Springfield, Mass.

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ELLIS, Frederic R. (*M* 1913), Sales Engr., Buerkel & Co., Inc., 18-24 Union Park St., Boston, and (for mail), 131 Beacon St., Hyde Park, Mass.
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ELLIS, Wilbur H. (*A* 1927; *J* 1926), Htg. and Vtg. Estimator, J. L. Murphy, Inc., 340 East 44th St., and (for mail), 29 Maple St., Irvington, N. Y.
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ENGLISH, Alpheus T. (*A* 1926), Dist. Mgr., The Columbus Htg. & Vtg. Co., 638 Wabash Bldg., Pittsburgh, Pa.
ENGLISH, Harrold (*M* 1930), 1224 S. San Pedro St., Los Angeles, Calif.
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EVANS, John (*M* 1919), 30 Water St., Galt, Ont., Canada.
EVANS, William A. (*M* 1918), Gen. Mgr., Auditorium Conditioning Corp., 39 Cortlandt St., New York, N. Y., and (for mail), 24 Woodland Road, Maplewood, N. J.
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HAGEDON, Charles H. (*M* 1919), Secy-Treas. (for mail), S. E. Fenstermaker & Co., 937 Architects and Builders Bldg., and 4156 Broadway, Indianapolis, Ind.

HAGERMAN, James J. (*M* 1931), Dist. Mgr., Htg. & Vtg. Div. (for mail), Bishop & Babcock Sales Co., 120 W. Illinois St., and 6008 Glenwood Ave., Chicago, Ill.

HAILEY, Syd Houston (*M* 1925), Asst. Engr., N. C. and St. Louis Railway, 924 Broadway, and (for mail), 3737 Harding Road, Nashville, Tenn.

HAINES, John J. (*M* 1915), Pres. (for mail), The Haines Co., 1931 W. Lake St., Chicago, and 623 17th Ave., Maywood, Ill.

HAKES, Leon Marc (*J* 1929), Sales Engr. (for mail), The R. T. Coe Cos., 907 Gas & Elec. Bldg., and 169 Pierpont St., Rochester, N. Y.

HALE, John F. (*M* 1902), *Presidential Member*), (Pres., 1913; 1st Vice-Pres., 1912; Board of Governors, 1908, 1910, 1912, 1913), Dist. Mgr. (for mail), Aerofin Corp., Room 1531, Burnham Bldg., Chicago, and 408 S. Brainard Ave., La Grange, Ill.

HALEY, Harry S.* (*M* 1914), Consulting Engr. (for mail), Leland & Haley, 58 Sutter St., and 735 21st Ave., San Francisco, Calif.

HALL, C. H. (*M* 1927), Chief Engr., Domestic Stoker Co., 7 Dey St., New York, N. Y., and (for mail), 250 Hamilton Ave., Glen Rock, N. J.

HALLETT, Samuel G. (*M* 1930), 5318 Northland Ave., St. Louis, Mo.

HALLEY, Wilson H. (*M* 1925; *J* 1923), Engr., Langenberg Mfg. Co., 4519 N. Euclid Ave., and (for mail), 6134 W. Park Ave., St. Louis, Mo.

HAMJY, Paul W. (*M* 1924), Htg. Contractor (for mail), General Outdoor Advertising Co., 1158 Mohawk St., and 612 Steel Place, Utica, N. Y.

HAMLIN, Harry A. (*A* 1916), Br. Mgr. (for mail), Johnson Service Co., 427 Brainard St., Detroit, and 120 Winona Ave., Highland Park, Mich.

HAMMOND, Martin J. (*J* 1930), 426 Bath Ave., Long Branch, N. J.

HANBURGER, Fred W. (*M* 1930), Consulting Engr., Hotel Willard, 252 West 76th St., New York, N. Y.

HANCOCK, James Reynolds (*M* 1928; *J* 1926), 131 W. Chestnut St., Jeffersonville, Ind.

HANKIN, Richard (*M* 1898), 279 Main Ave., Passaic, N. J.

HANSEN, Charles C. (*M* 1928), Engr., Erskine Copper Radiator Corp., 1 East 42nd St., New York, N. Y., and (for mail), 428 Prospect St., South Orange, N. J.

HANSON, E. W. (*M* 1922), W. N. Sauer Co., 809 Chestnut St. N. S., Pittsburgh, Pa.

HANSON, Leon C. (*A* 1918), Sec-Treas. and Mgr. (for mail), Bjorkman Bros. Co., 712 Tenth St. S., and 4603 Sunnyside Road, Minneapolis, Minn.

HARBULA, M. G.* (*M* 1921), Consulting Air Conditioning Engr., M. G. Harbula, Inc. (for mail), 693 Park Blvd., Glen Ellyn, Ill.

HARD, Alva L. (*M* 1929), 2987 Tuxedo St., Detroit, Mich.

HARDING, Louis A.* (*M* 1911), (*Presidential Member*), Pres., 1930; 1st Vice-Pres., 1929; 2nd Vice-Pres., 1928; Council, 1922-1931), Pres., L. A. Harding Construction Corp., Prudential Bldg., and 85 Cleveland Ave., Buffalo, N. Y.

HARDINGE, Franklin (*A* 1929), Chairman of Board of Directors (for mail), Hardinge Bros., Inc., 4149 Ravenswood Ave., and 1432 Fargo Ave., Chicago, Ill.

HARE, Edgar S. (*M* 1920), W. Hare's Sons Co., 46–14th St., Wheeling, W. Va.

HARE, W. Almon (*M* 1930), Mgr., Stoker Div., Whitehead & Kales Co., 58 Haltiner St., River, Rouge, and (for mail), 3031 W. Philadelphia Ave., Detroit, Mich.

HARMS, William T.* (*M* 1917), Owner of Business, 1015 Vinewood Ave., Detroit, Mich.

HARNEY, Francis W. (*M* 1930), Upson Co., Lockport, N. Y.

HARPER, Samuel H. (*M* 1929; *A* 1927), Prop., Heating Equipment Co., and (for mail), Oliver Bldg., Pittsburgh, and 223 Dalzell Ave., Ben Avon, Pittsburgh, Pa.

HARRIGAN, Edward M. (*M* 1915), Gen. Mgr. (for mail), Harrigan & Reid Co., 1365 Bagley Ave., and 7450 LaSalle Blvd., Detroit, Mich.

HARRIGAN, Edward R. (*J* 1930), (for mail), Harrigan & Reid Co., 1365 Bagley Ave., and 18688 Pennington Drive, Detroit, Mich.

HARRIGAN, Howard H. (*A* 1930), Dist. Mgr., Consolidated Ashcroft Hancock Co., 514 Morgan Bldg., and (for mail), 15874 Ohio Ave., Detroit, Mich.

HARRINGTON, Charles (*M* 1923), 43 Indian Grove, Toronto, Ont., Canada.

HARRINGTON, Elliott* (*A* 1930), General Elec. Co., Schenectady, N. Y.

HARRIS, Charles R. (*A* 1929), Sales Engr. (for mail), Brunswick-Kroeschell Co., 136 Liberty St., New York, N. Y., and 192 Broadway, Newark, N. J.

HARRIS, Harold R. (*A* 1930), Sales Engr. and Mfrs. Agt. (for mail), 708 Sixth Ave. S., Minneapolis, and 2153 Stanford Ave., St. Paul, Minn.

HARRIS, Henry W. (*A* 1924), Salesman, J. R. Brockman Mfg. Co., 617 N. Second St., and (for mail), 4296 Washington Blvd., St. Louis, Mo.

HARRIS, Jesse Brownell (*M* 1918), Partner (for mail), Rose & Harris, Engrs., 452 N. W. National Life Insurance Bldg., and 3620 Colifax Ave. S., Minneapolis, Minn.

HARRIS, Jesse E. (*M* 1930), 405 Abbottsford Road, Philadelphia, Pa.

HARRISON, Arthur B. (*M* 1931), Multicell Radiator Corp., Lockport, N. Y.

HARRISON, Burt S.* (*M* 1908), Chief Engr., Nichols Products Corp., 122 East 42nd St., New York, and (for mail), 8 Garden Place, Brooklyn, N. Y.

HARRISON, Charles A. (*M* 1931), Multicell Radiator Corp., Lockport, N. Y.

HARRISON, Charles G. (*M* 1930), Sales Engr., Crane Co., 150 Randolph St., and (for mail), 4510 Cortlandt St., Detroit, Mich.

HART, Harry M.* (*M* 1912), (*Presidential Member*), (Pres., 1916; 1st Vice-Pres., 1915; Council, 1914-1917), Pres., L. H. Prentice Co., 1048-50 Van Buren St., Chicago, Ill.

HART, Thomas H (*J* 1927), Chief Engr., Buckeye Incubator Co., and (for mail), 1827 Stratford Place, Springfield, Ohio.

HARTER, B. B. (*J* 1926), Htg. Engr. (for mail), Warren Webster & Co., 549 Washington W. Blvd., Room 506, and 5011½ W. Maypole Ave., Chicago, Ill.

HARTMAN, Frank E.* (*M* 1924), (for mail), Pres. and Dir. of Research, Biological Engrg. Lab., 2704 Pratt Ave., and 6545 N. Mozart St., Chicago, Ill.

HARTMAN, John Milton (*M* 1927), Kewanee Boiler Co., Kewanee, Ill.

HARTPENCE, Charles C. (*M* 1923), Htg. & Vtg. Engr., 309 Third National Bank Bldg., and (for mail), P. O. Box 337, Columbus, Ga.

HARTWELL, Joseph C (*M* 1922), Grinnell Co., Inc., 260 W. Exchange St., Providence, R. I.

HARVEY, Alexander D. (*A* 1928; *J* 1925), Sales Mgr. (for mail), Nash Engrg. Co., S. Norwalk, and New Canaan, Conn.

HARVEY, Lyle C. (*M* 1928), Sales Mgr. (for mail), Bryant Heater & Mfg. Co., 17825 St. Clair Ave., and 3341 Dorchester Road, Cleveland, Ohio.

HASHAGEN, John B. (*M* 1930), Sales Engr., Johnson Service Co., 28 East 29th St., New York, N. Y., and (for mail), 45 Zabriskie St., Jersey City, N. J.

HASKELL, Benjamin E. (*M* 1925), Engr., The Fels Co., 42 Union St., Portland, and (for mail), 539 Brighton Ave., Woodfords, Maine.

HASKETT, Joseph E. (*J* 1930), Carrier Engrg. Corp., 850 Frelinghuysen Ave., Newark, N. J.

HATTIS, Robert E. (*M* 1926), Consulting Mech. Engr. (for mail), 6 N. Michigan Ave., and 4152 N. Mozart St., Chicago, Ill.

HATTON, Albert E. (*M* 1930), 9387 Martindale, N., Detroit, Mich.

HAUPT, Howard F. (*A* 1919), Sales Engr., American Radiator Co., 902 N. Plankington Ave., and (for mail), 614 E. Baumont Ave., Milwaukee, Wis.

HAUSS, Charles F.* (*Charter Member*), Via Domenichino No. 1, Milan, Italy.

HAWES, Herbert R. (*M* 1926), 22 Elmwood St., Worcester, Mass.

HAYDEN, Carl F. (*A* 1930), Br. Mgr. (for mail), Barber-Colman Co., 221 N. La Salle St., Chicago, and 2309 Forest View Road, Evanston, Ill.

HAYES, James J. (*M* 1920), Sales Engr. (for mail), Stannard Power Equipment Co., 926 Monadnock Bldg., and 7443 Jeffrey Ave., Chicago, Ill.

HAYES, Joseph G. (*M* 1908), Pres. and Engr. (for mail), Hayes Bros., Inc., 236 W. Vermont St., and 2849 N. Capitol Ave., Indianapolis, Ind.

HAYMAN, A. Eugene, Jr. (*S* 1930), Student, Carnegie Inst. of Tech., 4929 Forbes St., Pittsburgh, Pa., and 2500 Washington St., Wilmington, Del.

HAYNES, C. V. (*M* 1917), (Council, 1926-1929), Vice-Pres. and Gen. Mgr., Hoffman Specialty Co., 3707-8 Chrysler Bldg., New York, N. Y., and (for mail), 115 Llanfair Road, Ardmore, Pa.

HAYWARD, Ralph B. (*M* 1909), Pres. (for mail), R. B. Hayward Co., 1714 Sheffield Ave., Chicago, and 201 S. Stone Ave., La Grange, Ill.

HEAGLER, John M. (*M* 1922), Engr., American Foundry & Furnace Co., 3138 Snelling Ave., and (for mail), 1646 Iglehart Ave., St. Paul, Minn.

HEARD, John A. E. (*J* 1930), Carrier Engrg. Co., Ltd., Sardar Sujan Singh Block, Connaught Place, New Delhi, India.

HEATH, Frederick R. (*M* 1913), Sales Engr. (for mail), E. B. Badger & Sons Co., 75 Pitts St., Boston, and 89 Trowbridge St., Cambridge, Mass.

HEATH, Samuel C. (*A* 1928), 2345–31st Ave. S., Seattle, Wash.

HEATH, William R. (*M* 1931), 674 Crescent Ave., Buffalo, N. Y.

HECHT, Frank H. (*M* 1930), B. F. Sturtevant Co., 1506 Park Bldg., Pittsburgh, Pa.

HECHT, George L., Jr. (*A* 1921), Chief Engr. (for mail), Garden City Fan Co., 1842 McCormick Bldg., Chicago, Ill.

HECKEL, E. P. (*M* 1918), Vice-Pres. (for mail), Carrier Engrg. Corp., 1032 Burnham Bldg., Chicago, and 314 Cuttriss Place, Park Ridge, Ill.

HECKROTH, Harry H. (*A* 1929), Staff Mgr., Johns-Manville Corp., 292 Madison Ave., New York, N. Y., and (for mail), 4929 N. Marvine St., Philadelphia, Pa.

HEDGES, H. Berkley (*M* 1919), Dist. Sales Mgr. (for mail), Carrier-York Corp., 149 Broadway, New York, N. Y., and 1021 Park Lane, Plainfield, N. J.

HEDLEY, Park S. (*M* 1923), (for mail), Park S. Hedley Co., Curtiss Bldg., Delaware at Tupper, Buffalo, and 31 Westgate Road, Kenmore, N. Y.

HEEBNER, Walter M. (*M* 1922), Sales Engr., Warren Webster & Co., 470 Fourth Ave., New York, N. Y., and (for mail), 282 Highwood St., Teaneck, N. J.

HEIBEL, Walter E. (*M* 1917), Dist Mgr. (for mail), Aerofin Corp., 11 West 42nd St., New York, N. Y.

HEIDENREICH, George (*M* 1928), 325-326 Board of Trade Bldg., Indianapolis, Ind.

HEILMAN, Russell H.* (*M* 1923), Senior Industrial Fellow (for mail), Mellon Institute, and 5637 Wilkins Ave., Pittsburgh, Pa.

HEIM, E. Frank (*M* 1929), Consulting Engr. (for mail), 1800 E St., N. W., Washington, D. C., and 4611 Morgan Drive, Chevy Chase, Md.

HEIMBERGER, Oscar W. (*M* 1930), Mech. Engr. (for mail), Griscom-Russell Co., 285 Madison Ave., New York, and 51 Springhill Ave., West Brighton, S. I., N. Y.

HELBURN, I. B. (*M* 1929; *J* 1927), Junior Partner (for mail), Wyman Engrg. Sales Co., 1101 Chamber of Commerce Bldg., and 2415 Ashland Ave., Cincinnati, Ohio.

HELLSTROM, John (*A* 1929), American Air Filter Co., 215 Central Ave., Louisville, Ky.

HELPHINGSTEIN, Otto (*M* 1919), Pres. and Mgr. (for mail), The Cullyford Co., 810-11 Mississippi St., Amarillo, Tex.

HELSTROM, Herman G. (*M* 1928), (for mail), Kewanee Boiler Corp, 708 Builders Exchange, and 4608 Arden Ave., Minneapolis, Minn.

HELWIG, Gunther Albert (*M* 1927), Dist. Sales Mgr., General Iron Works Co., 4217 Athlone Ave., St. Louis, Mo.

HEMINGWAY, William S. (*M* 1906), 3210 Mountain View Drive, San Diego, Calif.

HENION, Hudson D. (*A* 1923), Sales Mgr. (for mail), C. A. Dunham Co., Ltd., 1523 Davenport Road, and 45 Ridge Drive, Toronto, Ont., Canada.

HENRICH, George A. (*M* 1914), Marcellus, Mich.

HENRICI, Herman C. (*M* 1924), Pres., Henrici Lowry Engrg. Co., 508 Huntzinger Bldg., 114 W. Tenth St., and (for mail), 430 West 58th St., Kansas City, Mo.

HENRY, Alexander S., Jr. (*M* 1930), Mech. Engr., Radio-Keith Orpheum, 1560 Broadway, and (for mail), 300 Central Park West, New York, N. Y.

HEMPHILL, D. A. (*J* 1930), 331 Melwood, Pittsburgh, Pa.

HERENDEEN, Frederick W. (*M* 1920), Secy. (for mail), The Institute of Boiler and Radiator Mfrs., 29 Seneca St., and 815 S. Main St., Geneva, N. Y.

HERLIHY, George F. (*M* 1922), Vice-Pres. (for mail), J. J. Herlihy, Inc., 810 W. Congress St., and 10836 Forest Ave., Chicago, Ill.

HERLIHY, Jeremiah J. (*Life Member*; *M* 1914), Pres., J. J. Herlihy, Inc., 810 W. Congress St., Chicago, Ill.

HERMAN, J., Jr. (*J* 1930), 1349 E. Vernon Ave., Los Angeles, Calif.

HERRICK, Daniel A. (*M* 1923), Mgr. (for mail), Julian D'Este Co., 2 Spice St., Charlestown, and 27 Agassiz St., Cambridge, Mass.

HERRING, Edgar (*M* 1919), Chairman (for mail), I. Jeffreys & Co., Ltd., Barrons Place, Waterloo Road, and 22 Keswick Road, Putney, London, S. W., England.

HERSH, Franklin C. (*J* 1930), Construction Supt., Carrier Engrg. Corp., 2022 Bryan St., Dallas, Texas.

HERSH, G. Willis (*M* 1917), 27 South 18th St., Allentown, Pa.

HERTZ, H. P. (*M* 1924), Engr. (for mail), Routledge & Hertz, Architects and Engrs., 204 Exchange National Bank, and 314 Twelfth Ave., E., Hutchinson, Kans.

HERTZLER, John R. (*J* 1928), (for mail), Air Conditioning Engr., York Ice Machinery Corp., 42nd St. and Second Ave., Brooklyn, and 1 University Place, New York, N. Y.
HESLIP, John C. (*M* 1931), 825 West 75th St., Kansas City, Mo.
HESTER, Thomas J. (*M* 1919), Vice-Pres. and Treas. (for mail), Hester Bradley Co., 2835 Washington Blvd., and 67 Aberdeen Place, St. Louis, Mo.
HEXAMER, Harry D. (*M* 1931), Mgr. of Mfr. (for mail), Excelso Products Corp., 65 Clyde Ave., and 163 E. Delavan Ave., Buffalo, N. Y.
HEYDON, Charles G. (*A* 1923), Mgr., Sales Western Div., Wright Austin Co., 409 Griswold St., and (for mail), 2681 Nebraska St., Detroit, Mich.
HIBBS, Frank C. (*M* 1917), Salesman, The H. B. Smith., 2209 Chestnut St., and (for mail), 846 North 65th St., Philadelphia, Pa.
HICKEY, Daniel W. (*A* 1931), 278 W. Fourth St., St. Paul, Minn.
HICKS, William W. (*A* 1929), *W. W. Hicks & Co., 309 Boyd Bldg., Winnipeg, Manitoba, Canada.*
HIERS, Charles R. (*M* 1929; *A* 1929; *J* 1927), 18 Merritt Ave., Tuckahoe, N. Y.
HIGGINS, Daniel T. (*M* 1928), Vice-Pres. and Htg. Engr. (for mail), McCarthy & Co., 529 S. Cascade Ave., and 330 E. Cachela Poudre, Colorado Springs, Colo.
HIGGINS, Thomas J. (*M* 1927; *A* 1927; *J* 1923), Vice-Pres. and Gen. Mgr. (for mail), Ross Engrg. Co. of Canada, Ltd., New Birks Bldg., and 4384 Sherbrooke St., W., Montreal, P. Q., Canada.
HILL, Charles E. (*A* 1930), Sales Engr., Hoffman Specialty Co., Inc., 533 S. Seventh St., and (for mail), 1445 Lagoon Ave., Minneapolis, Minn.
HILL, E. Vernon* (*M* 1914; *A* 1912), (*Presidential Member*), (1st Vice-Pres., 1919; 2nd Vice-Pres., 1918; Council, 1915-1921), Pres. (for mail), E. Vernon Hill Co., 121 N. Clark St., and 1126 Farwell Ave., Chicago, Ill.
HILL, Fred M. (*M* 1930), 225 E. Ave. 39, Los Angeles, Calif.
HILL, Newell J. (*M* 1916), Consulting Engr. (for mail), 708 Architects Bldg., and 19567 Stratford Road, Detroit, Mich.
HILLEN, A. G. (*J* 1929), Salesman (for mail), Carrier Engrg. Corp., 1032 Burnham Bldg., and 6832 N. Ashland Ave., Chicago, Ill.
HILLEN, William G. (*A* 1929), Chief Engr. (for mail), Oriental Carrier Engrg. Co., Ltd., Sanshin Bldg., Kojimachi-Ku, and Yoyogi, Hommura 739, Tokyo, Japan.
HILLIARD, Charles E. (*J* 1927), Htg. and Vtg. Engr. (for mail), 27 B St., S. Boston, and 1301 Washington St., S. Braintree, Mass.
HILLIARD, Forrest H. (*A* 1930), Br. Mgr. (for mail), U. S. Radiator Corp., 2120 East 25th St., and 2500 S. Hobart Blvd., Los Angeles, Calif.
HILLS, Arthur H. (*M* 1924), Mgr., Westchester Office, C. A. Dunham Co., 245 N. Terrace Ave., Mt. Vernon, N. Y.
HINCHMAN, E. G. (*M* 1923), 1263 Atlantic Ave., Brooklyn, N. Y.
HINKLE, Edwin C. (*M* 1911), Pres., Atlantic Heating and Engrg. Co., Second National Bank Bldg., and (for mail), 170 Franklin St., Hempstead, N. Y.
HINRICHSEN, A. F. (*M* 1928), *Pres. (for mail),* A. F. Hinrichsen, Inc., 50 Church St., New York, N. Y., and Mountain Lakes, N. J.
HIRES, J. Edgar (*M* 1927), Consulting Engr., 2025 Fidelity-Philadelphia Bldg., Philadelphia, and (for mail), 107 Linwood Ave., Ardmore, Pa.
HIRSCHMAN, William F. (*M* 1929), Pres-Treas., W. F. Hirschman Co., Inc., 220 Delaware Ave., Buffalo, and (for mail), 165 LeBrun Road, Eggertsville, N. Y.
HIRST, James Noble (*M* 1930; *J* 1927), Chief Draftsman (for mail), Carrier-York Corp., 1541 Sansom St., and 2913 Poplar St., Philadelphia, Pa.
HITCHCOCK, Frederick P. (*M* 1917), Sales Repr. (for mail), Buckeye Blower Corp., 213-214 Lathrop Bldg., and 4938 Forest Ave., Kansas City, Mo.
HITCHCOCK, Paul C. (*M* 1931), 4939 Girard Ave. S., Minneapolis, Minn.
HJERPE, Clarence A., Jr. (*J* 1931), 73 Arch St., New Britain, Conn.
HOBBS, J. Clarence (*M* 1920), 60 Wood St., Painesville, Ohio.
HOCHULI, Henry W. (*M* 1925), Sales Engr., Richardson & Boynton Co., 244 Madison Ave., *New York, N. Y., and (for mail),* 113 Chester Ave., Bloomfield, N. J.
HODEAUX, W. L. (*M* 1931), Owner, W. L. Hodeaux Plbg. & Htg. Co., 2 Lakeview Arcade, and (for mail), 310 Tenth St., West Palm Beach, Fla.
HODGDON, Harry A. (*M* 1919), Engr., Stone-Underhill Co., 171 Harrison Ave., Boston, and (for mail), 153 Norfolk St., Wollaston, Mass.
HODGES, George S., Jr. (*A* 1930), Detroit *Stoker Co., 3–120 General Motors Bldg., Detroit,* Mich.
HOERSTING, Frank J. (*M* 1921), Pres. (for mail), The Hoersting & Holtmann Co., 1133 W. Third St., and 2045 Philadelphia Drive, Dayton, Ohio.
HOFFMAN, Charles S. (*M* 1924), Vice-Pres. (for mail), Baker Smith & Co., Inc., 576 Greenwich St., and 25 Central Park, West, New York, N. Y.
HOFFMAN, George D. (*M* 1906), Pres., Hoffman Specialty Co., *Inc., Waterbury, Conn., and (for* mail), Box 240, Pasadena, Calif.
HOFFMAN, James D.* (*M* 1903), (*Presidential Member*), (Pres., 1910; 1st Vice-Pres., 1908; Board of Governors, 1911-1912), Prof. of Practical Mechanics, Head of Dept., Director of Practical Mech. Lab. (for mail), Purdue University, and 323 University St., W. Lafayette, Ind.
HOFT, Paul J. (*M* 1925; *A* 1924), Prop. (for mail), *Paul J. Hoft Plbg. & Htg. Co., 245 S. Eighth St.,* and 1119 Wyoming Ave., Philadelphia, Pa.
HOGABOOM, Henry Raymond (*M* 1929), Heating Engr., 1529–33rd Ave., Seattle, Wash.
HOGAN, Edward L.* (*M* 1911), Consulting Engr. (for mail), American Blower Corp., 6000 Russell St., and 700 Seward Ave., Detroit, Mich.
HOIER, William V. (*M* 1917), Wm. V. Hoier Co., 701 N. Wells St., Chicago, Ill.
HOLBROOK, Frank M.* (*M* 1923), 84 Park St., Montclair, N. J.
HOLLISTER, Edmund W. (*J* 1931), 88 Oak St., Hudson Falls, N. Y.
HOLTON, John H. (*M* 1927), Secy. (for mail), Carrier Research Corp., 750 Frelinghuysen Ave., Newark, and 41 Harding Drive, South Orange, N. J.
HONIBALL, Charles R.* (*M* 1911), 156 Boundary St., Liverpool, England.
HOOD, Leslie A. (*A* 1929), Trane Co., 439 King St. W., Toronto, Ont., Canada.
HOOD, O. P. (*Honorary Member*, 1929), (for mail), Chief, Technologic Br., U. S. Bureau of Mines, 17th and F St., N. W., and 1831 Irving St., N. W., Washington, D. C.
HOOK, C. Howard (*M* 1915), Pres. (for mail), Hook Heater Co., Sharpesburg P. O. Sta., Pittsburgh, and 6949 Thomas Blvd., Pittsburgh, Pa.
HOOPER, Vernon F. (*M* 1929), 61 Eastern Ave., *Ossining, N. Y.*
HOOVER, H. Earl (*A* 1922), The Hoover Co., 2300 Willoughby Tower, Chicago, Ill.
HOPKIN, William E. (*M* 1919), Pres-Treas. (for mail), Charles E. Hopkin Co., 107 Bethlehem Pike, and 514 Wyndmoor Ave., Chestnut Hill, Philadelphia, Pa.
HOPSON, William T. (*M* 1915), The Hopson & Chapin Mfg. Co., New London, Conn.
HORNUNG, John C. (*M* 1914), Engr. (for mail), Central Heat Appliances, 343 S. Dearborn St., Chicago, and 854 Bluff St., Glencoe, Ill.
HORTON, George H. (*M* 1930), 1198 S. San Pedro St., Los Angeles, Calif.

HORTON, Homer F. (*M* 1925), Sales Repr. (for mail), 2301 Knox Ave., Chicago, and 343 Green Bay Road., Glencoe, Ill.
HOSHALL, Robert H. (*M* 1930), Associate (for mail), Thos. H. Allen, Engr., 65 McCall St., and 789 N. Evergreen St., Memphis, Tenn.
HOSKING, Homer L. (*M* 1930), Mgr. (for mail), Pacific Steel Boiler Corp., 370 Lexington Ave., New York, and 18 Barclay Ave., Scarsdale, N. Y.
HOSTERMAN, Charles O. (*M* 1924), Supt., The McMurrer Co., 303 Congress St., Boston, and (for mail), 25 Bateswell Road, Dorchester, Mass.
HITCHKISS, Charles H. B. (*M* 1927), Editor, Heating and Ventilating, 148 Lafayette St., New York, N. Y.
HOUGHTEN, Ferry C.* (*M* 1921), Director (for mail), Research Lab., A.S.H.V.E., U. S. Bureau of Mines, 4800 Forbes St., and 1136 Murray Hill Ave., Pittsburgh, Pa.
HOULISTON, George B. (*A* 1928), Secy. (for mail), The W. C. Green Co., 704 Race St., Cincinnati, Ohio, and 1039 N. Ft. Thomas Ave., Ft. Thomas, Ky.
HOWATT, John (*M* 1915), (Council, 1927-1931), (for mail), Board of Education, 188 W. Randolph St., and 6720 Merrill Ave., Chicago, Ill.
HOWELL, Frank B. (*M* 1920), Tech. Advisor (for mail), American Radiator Co., 40 West 40th St., and 15 Central Park West, New York, N. Y.
HOWELL, Lloyd (*M* 1915), Mgr. (for mail), 2239 W. Lake St., and 7610 Yates, St., Chicago, Ill.
HOYT, Charles W. (*A* 1931), Treas. (for mail), Wolverine Htg. & Vtg. Equip. Co., 80 Bolyston St., Boston, and 45 Thaxter Road, Newtonville, Mass.
HOYT, Leroy W. (*M* 1930), N. Stamford Ave., Stamford, Conn.
HOYT, William B.* (*M* 1919), Pres-Treas. (for mail), The Hoyt-Grant Co., 52 Whitney Ave., New Haven, and 39 Clifford St., Whitneyville, Conn.
HUBBARD, George Wallace* (*M* 1911), Chief Mech. Engr. (for mail), Graham, Anderson, Probst & White, 1417 Railway Exchange, Chicago, and 710 Bonnie Brae, River Forest, Ill.
HUBBARD, Nelson B. (*M* 1919), Consulting Engr. (for mail), Room 500, 1346 Broadway, and 2985 Blaine Ave., Detroit, Mich.
HUCH, A. J. (*M* 1919), Gen. Mgr. of Sales (for mail), Central Supply Co., 312 S. Third St., and 4037 Harriet Ave., Minneapolis, Minn.
HUCKER, Joseph H. (*M* 1921), Partner, Hucker-Pryibil Co., 1700 Walnut St., Philadelphia, and (for mail), 715 Stanbridge St., Norristown, Pa.
HUGHES, Willard C. (*M* 1921), Pres. (for mail), Wicks-Hughes & Co., 224 Genesee St., and 16 Cottage Place, Utica, N. Y.
HUMPHREY, Dwight E.* (*M* 1921), Htg. and Vtg. Engr. (for mail), Goodyear Tire & Rubber Co., Akron, and 2499 Sixth St., *Cuyahoga Falls,* Ohio.
HUMPHREYS, A. E. (*M* 1911), Mgr., O'Mara Htg. Co., 504 Victoria Bldg., St. Louis, Mo.
HUMPHREYS, Clark M. (*M* 1931), Asst. Prof. of Htg. and Plbg. (for mail), Carnegie Institute of Technology, Schenley Park, and 932 Flemington Ave., Pittsburgh, Pa.
HUMPHREYS, James (*M* 1930), Pres. (for mail), Wolverine Copper Radiator Corp., of N. Y., 420 Lexington Ave., and 315 East 68th St., New York, N. Y.
HUNGER, Robert F. (*M* 1927), (for mail), Davidson & Hunger, 810 Land Title Bldg., and 4618 Chester Ave., Philadelphia, Pa.
HUNGERFORD, Leo (*M* 1930), Supervisor of Construction, Fox West Coast Theatres, Washington and Vermont Sts., Los Angeles, Calif.
HUNT, Phil M. (*M* 1922), Sales Engr., Hoffman Specialty Co., 557 Market St., and (for mail), 1245 Francisco St., San Francisco, Calif.
HUNT, Richard B. (*M* 1912), Sales Engr., 414 S. Fourth Ave., Mt. Vernon, N. Y.
HURLEY, Joseph C. (*M* 1915), (for mail), Petroleum Fuel Engrg. Co., 4028-32 Filbert St., Philadelphia, and 134 Lansdowne Court, Lansdowne, Pa.
HUSBAND, Edward Woods (*M* 1922), 9 Savings St., Providence, R. I.
HUSTOEL, Arnold M. (*A* 1930), 2623 N. Ballou St., Chicago, Ill.
HUTTON, William (*M* 1919), Pres. (for mail), The Hutton Bros. Co., 9 Union St., and 28 Spring St., Winsted, Conn.
HUTZEL, A. F. (*M* 1916), Partner (for mail), Hutzel & Co., 119 E. Washington St., and 2115 Wallingford Road, Ann Arbor, Mich.
HUTZEL, Hugo F. (*M* 1918), Plant Mgr., Multicell Radiator Corp., Lockport, and (for mail), 64 N. Long St., Williamsville, N. Y.
HUTZEL, Max H. (*M* 1923), Hutzel Bldg., Muncie, Ind.
HUTZEL, Victor C. (*M* 1923), Hutzel & Co. Hutzel Bldg., Muncie, Ind.
HUZZARD, Edward C. (*A* 1924), 710 New Holland Ave., Lancaster, Pa.
HUOSLEF, Fredrik W. (*M* 1931; *A* 1921), Htg. Research Engr. (for mail), Kohler Co., and 523 Audubon Road, Kohler, Wis.
HYMAN, Wallace M. (*M* 1920), Vice-Pres. (for mail), Reis & O'Donovan, Inc., 255 West 28th St., and 210 West 70th St., New York, N. Y.
HYNES, Lee P.* (*M* 1919), Pres. (for mail), Hynes Elec. Heating Co., 240 Cherry St., and 4311 Spruce St., Philadelphia, Pa.

I

ICKERINGILL, John (*M* 1923), Salesman, Spencer Heater Co., 1718 Fairmount Ave., and (for mail), 235 Rector St., Roxborough, Philadelphia, Pa.
ILLIG, Walter R. (*A* 1927), Mgr., Plbg. Dept., The Jennison Co., 17 Putnum St., and (for mail), 18 Mechanic St., Fitchburg, Mass.
INE, Frank H. (*A* 1930), 699 Layton Blvd., Milwaukee, Wis.
INGALLS, F. D. B. (*M* 1906), Heating Engr., 1 Hopkins St., Reading, Mass.
INGELS, Margaret* (*M* 1923; *J* 1918), (for mail), Carrier-Lyle Corp., 850 Frelinghuysen Ave., Newark, and Hotel East Orange, 101 N. Grove St., East Orange, N. J.
INNIS, Helen R.* (*M* 1921; *J* 1918), Largent, W. Va.
ISSERTELL, Henry G.* (*M* 1913; *A* 1912), Commercial Engr. (for mail), General Elec. Co., 120 Broadway, and 270 Seaman Ave., New York, N. Y.

J

JACKES, Herman D. (*M* 1915), 160 Williamson Ave., Bloomfield, N. J.
JACKSON, Charles H. (*M* 1923), Sales Engr. (for mail), Bayley Blower Co., 1938 S. Fourth St., and 2706 N. Farwell Ave., Milwaukee, Wis.
JACKSON, Charles J. (*A* 1912), Vice-Pres., Jenkins Bros., 646 Washington Blvd., Chicago, Ill.
JACKSON, George O. (*A* 1928), Pres. (for mail), Jackson Engrg. Co., 936 Architects and Builders Bldg., and 132 East 44th St., Indianapolis, Ind.
JACKSON, Jonathan William (*A* 1927), Pierce Co., 41-43 W. Spring St., Gainesville, Ga.
JACKSON, Marshall S. (*M* 1919), Repr. (for mail), Powers Regulator Co., 232 Delaware Ave., and 108 Larchmont Road, Buffalo, N. Y.
JACOBS, Barrett (*A* 1928), Pres. (for mail), Jacobs Htg. Corp., 122 East 42nd St., and 255 Haven Ave., New York, N. Y.
JACOBUS, Dr. David S. (*M* 1916), Advisory Engr., The Babcock & Wilcox Co., 85 Liberty St., New York, N. Y.
JALIEN, John J. (*M* 1922), Engr., American Gas Products Corp., Chrysler Bldg., and (for mail), 80 Arden St., New York, N. Y.

JALONACK, Irwin G. (*S* 1930), Student (for mail), Carnegie Inst. of Technology, Box 229, Pittsburgh, Pa., and 2423 E. Fayette St., Syracuse, N. Y.

JAMES, Hamilton R. (*M* 1931), Ind. Engr., United Engrs. & Constructors, Inc., 112 N. Broad St., Philadelphia, and (for mail), 55 W. Drexel Ave., Lansdowne, Pa.

JANET, Harry L. (*M* 1920), Engr. (for mail), Carrier Engrg. Corp., 850 Frelinghuysen Ave., Newark N. J., and 688 Decatur St., Brooklyn, N. Y.

JARDINE, Douglas C. (*M* 1929; *A* 1926), Pres. (for mail), Jardine & Knight Plbg. & Htg. Co., 312 Custer Ave., and 1326 N. Wahsatch Ave., Colorado Springs, Colo.

JARRATT, Paul R. (*A* 1931), 117 Fifth Ave., N., Nashville, Tenn.

JAYNES, Eubertis L. (*M* 1918), Pres. (for mail) Michigan Warming & Vtg. Co., 363 Houseman Bldg., and 862 Ardmore St. S. E., Grand Rapids, Mich.

JELLETT, Stewart A.* (*Honorary Member*, 1929), (*Charter Member*; *Presidential Member*), (Pres., 1895; Board of Mgrs., 1896-1899; Secy., 1898), Pres. (for mail), Stewart A. Jellett Co., 1200 Locust St., Philadelphia, and 6701 Lincoln Drive, Mt. Airy, Philadelphia, Pa.

JENKINS, Harry E. (*A* 1923), Sales Mgr., Radiator Div. (for mail), Winchester Repeating Arms Co., and 436 Whalley Ave., New Haven, Conn.

JENNINGS, Irving C. (*M* 1924), Nash Engrg. Co., S. Norwalk, Conn.

JENNINGS, Warren G. (*A* 1930), Resident Vice-Pres. (for mail), Minneapolis-Honeywell Regulator Co., 2065 Daily News Bldg., and 2738 Pine Grove Ave., Chicago, Ill.

JENNINS, Henry H. (*M* 1901), E. Oldroyd & Co., Ltd., Black Bull St., Leeds, England.

JENS, Jens (*J* 1930), Mech. Engr. (for mail), Carrier Lufttechnische Gesellschaft, Savigny, Platz 3, Berlin, Germany.

JENSON, Jean S. (*M* 1912), 431 S. Dearborn St., Chicago, Ill.

JOHN, Victor P. (*M* 1931), Dist. Mgr., American Blower Corp., 822 White Bldg., and (for mail), 312 Hartwell Road, Buffalo, N. Y.

JOHNS, Charles F. (*A* 1931), Heating Engr., Enterprise Foundry Co., Ltd., Sackville, New Brunswick.

JOHNS, Harold B.* (*M* 1928; *J* 1927), Mgr., House Htg. Div. (for mail), Peoples Gas Co., 122 S. Michigan Ave., Chicago, and 543 N. Elmwood Ave., Oak Park, Ill.

JOHNSEN, Henry (*M* 1927), Plbg. and Htg. Contractor, 173 Jewett Ave., Port Richmond, S. I., N. Y.

JOHNSON, Carl E. (*J* 1930), Heating Engr. (for mail), Holland Furnace Co., 2001 N. Broad St., Philadelphia, Pa., and "The Maples," Main St., Riverton, N. J.

JOHNSON, Carl E. (*M* 1930), Pres., Sterling Elec. Motors, Inc., 5401 Telegraph Road, Los Angeles, and (for mail), 1505 Virginia Road, Pasadena, Calif.

JOHNSON, Carl W. (*M* 1912), Pres. (for mail), C. W. Johnson, Inc., 211 N. Desplaines St., and 1809 Morse Ave., Chicago, Ill.

JOHNSON, Clarence W. (*J* 1931), 1418 Majestic Bldg., Milwaukee, Wis.

JOHNSON, Edgar E. (*M* 1926), Sales Engr. (for mail), Buffalo Forge Co., 490 Broadway, and 103 University Ave., Buffalo, N. Y.

JOHNSON, Edward B. (*M* 1919), Sales Engr., Staten Island Supply Co., 1390 Richmond Ter., and (for mail), 154 Wardwell Ave., W. New Brighton, S. I., N. Y.

JOHNSON, Fred W. (*M* 1916), Vice-Pres. (for mail), Johnson, Larsen & Co., 6530 Beaubein St., Detroit, and R. F. D. No. 4, Birmingham, Mich.

JOHNSON, Helge S. (*J* 1927), Repr. Engr. (for mail), Buffalo Forge Co., 414 Standard Bldg., and 20 Fleetwood Ave., Albany, N. Y.

JOHNSON, James M. (*A* 1928), Sales Engr., Bryant Gas Htg. Inc., 152 North 15th St., and (for mail), 825 North 24th St., Philadelphia, Pa.

JOHNSON, L. H. (*M* 1931), 918 LaSalle Ave., Minneapolis, Minn.

JOHNSON, Leslie O. (*J* 1930), 3307 Berteau Ave., Chicago, Ill.

JOHNSON, Paul H. (*A* 1914), E. H. Sheldon & Co., 205 Washington Ave., Muskegon, Mich.

JOHNSON, Tracy R. (*M* 1924), Mgr., Heating Specialties Dept., The Trane Co., and (for mail), 628 S. Fourth St., Apt. 2, La Crosse, Wis.

JOHNSON, Walter F. (*M* 1929), Mgr. (for mail), American Radiator Co., 374 Delaware Ave., and 969 Amherst St., Buffalo, N. Y.

JOHNSTON, James A. (*M* 1912), Mech. Engr., Carneal, Johnston & Wright, 806 Electric Bldg., Richmond, Va.

JOHNSTON, James H. (*A* 1930), Br. Mgr. (for mail), U. S. Radiator Corp., Davis and Central Aves., Harrison, and 399 Lincoln Ave., Orange, N. J.

JOHNSTON, Robert Elliott (*M* 1929; *A* 1926), Consulting Engr., 3342–33rd Ave., W., Vancouver, British Columbia.

JOHNSTON, William B. (*M* 1921; *A* 1916), Vice-Pres-Treas. (for mail), Ideal Furnace Co., 2995 E. Grand Blvd., and 19450 Gloucester Drive, Palmer Woods, Detroit, Mich.

JOHNSTON, William H. (*M* 1924), Pres. (for mail), Johnston Htg. Co., 306 East 26th St., New York, and Larchmont, N. Y.

JONES, Alfred (*M* 1928), Chief Consulting Engr. (for mail), Armstrong Cork Co., P. O. Box 565 and 402 President Ave., Lancaster, Pa.

JONES, Alfred L. (*M* 1926), Plbg. and Htg. Contractor (for mail), 21 Church St., Greenwich, and Breezemont Ave., Riverside, Conn.

JONES, Bernard G. (*M* 1928), Mgr., Acme Fan & Blower Co., 868 Arlington St., Winnipeg, Manitoba, Canada.

JONES, Charles R. (*A* 1928), Mgr., Jones Supply Co., 917-921 St. Nicholis Ave., Siloam Springs, Ark.

JONES, Edwin (*J* 1924), Box 582, Tulsa, Okla.

JONES, Edwin A. (*M* 1919), Engr., Gas Div. (for mail), L. J. Mueller Furnace Co., 339 S. Second St., and 5906 Bay Ridge Ave., Milwaukee, Wis.

JONES, Edwin F. (*M* 1923), Consulting Engr. (for mail), 116 E. Fourth St., and 220 Montrose Place, St. Paul, Minn.

JONES, Harold L. (*M* 1920), W. W. Farrier Co., 44 Montgomery St., Jersey City, N. J.

JONES, Morris P. (*A* 1925), Mgr., Fan Sales Div., New York Blower Co., 3155 Shields Ave., and (for mail), 5430 Crystal St., Chicago, Ill.

JONES, Raymond E. (*M* 1919), Mgr. (for mail), Thermo-Service, Inc., Lafayette Bldg., Philadelphia, Pa., and 39 West End Ave., Haddonfield, N. J.

JONES, W. T. (*M* 1915), (2nd Vice-Pres., 1931; Council, 1925-1931), Barnes & Jones, 128 Brookside Ave., Jamaica Plain, Boston, and (for mail), 1886 Beacon St., Waban, Mass.

JUNG, John S. (*M* 1930; *A* 1923), Htg. and Vtg. Contractor, 1516 S. Layton Blvd., Milwaukee, Wis.

JUNKERS, Prof. Hugo (*M* 1925), Prof. (for mail), Junkers-Werke, Kaiserplatz 21, and Albrechtstr. 109, Dessau, Germany.

JUTTNER, Otto J. (*M* 1915), Pres. (for mail), Juttner Htg. Co., 814 N. Milwaukee St., and Elks Club, Milwaukee, Wis.

K

KAGEY, Isaac B. (*J* 1929), Junior Sales Engr. (for mail), Carrier Engrg. Corp., 39 Cortlandt St., New York, N. Y.

KALLOCH, Parker Cromwell, Jr. (*A* 1930), Pres., Fintube Radiator Co., Inc., 44-02–11th St., Long Island City, N. Y.

KAMMAN, Arnold R. (*A* 1925; *J* 1921), (for mail), Chippewa Plbg. Co., 279 Chicago St., Buffalo, and 3 E. Parkway, Wanakah, Erie Co., N. Y.

KAMMERER, W. C. (*M* 1923), Mech. Engr. (for mail), Hadlow, Hughes, Hick & Conrad, Inc., 1301 Citizens Bldg., Cleveland, and 13963 Clifton Blvd., Lakewood, Ohio.

KAPPEL, George W. A. (*M* 1921), Pres-Treas. (for mail), Camden Htg. Co., 8 Market St., Camden, and 347 W. Kings Highway, Haddonfield, N. J.

KAPPLER, Herman C. (*M* 1927), 185 McLean Ave., Detroit, Mich.

KARLSON, Alfred F. (*M* 1918), Chief Engr. (for mail), Parks-Cramer Co., 970 Main St., Fitchburg, and 186 Prospect St., N. Leominster, Mass.

KATSUMOTO, Eijiro (*M* 1926), Pres. (for mail), Katsumoto & Co., Ginza St., Dairen, S. Manchuria, China, and 50 2-chome Matsubara-dori, Nishinari-Ku, Osaka, Japan.

KEASBEY, A. P. (*M* 1922), Pres. and Gen. Mgr. (for mail), Robert A. Keasbey Co., 141 West 19th St., and 45 Gramercy Park, N., New York, N. Y.

KEEFE, Edmund T. (*M* 1931), 75 Pitts St., Boston, Mass.

KEELING, Harry B. (*M* 1930; *A* 1930), Salesman (for mail), American Blower Corp., 305 Union Ins. Bldg., and 816 S. Wooster Ave., Los Angeles, Calif.

KEENAN, P. Frank (*A* 1921), Pres. (for mail), Leo Flush Valve Co., 331 Madison Ave., New York, and 283 Burns St., Forest Hills, L. I., N. Y.

KEENEY, Frank P. (*A* 1915), Pres., Engineering Publications, Inc., 1900 Prairie Ave., Chicago, Ill.

KEHM, August (*M* 1901), (1st Vice-Pres., 1909, Board of Governors, 1908-1911), Pres. (for mail), Kehm Bros. Co., 51 E. Grand Ave., and 3160 Sheridan Road, Chicago, Ill.

KEHM, Horace Stevens (*M* 1928), Vice-Pres. (for mail), Kehm Bros. Co., 51 E. Grand Ave., and 2339 Commonwealth Ave., Chicago, Ill.

KEIST, Walter E. (*A* 1931), Sales Engr., Penna. Furnace & Iron Co., and (for mail), 908 Stuart St., Edgewood, Birmingham, Ala.

KEITH, Lewis H. (*J* 1930), Sales Engr., Piere-Perry Co., 236 Congress St., Boston, and (for mail), 180 Main St., Bridgewater, Mass.

KELBLE, Frank R. (*M* 1928), Mgr. and Htg. Engr. (for mail), The Huffman-Wolfe Co., 11 W. Rittenhouse St., Philadelphia, and Box A-34, Glenside, Pa.

KELLEY, Arthur D., Jr. (*J* 1930), Sales Engr., York Htg. & Vtg. Corp., 149 Broadway, New York, N. Y.

KELLEY, James J. (*A* 1924), 535 Commonwealth Ave., Boston, Mass.

KELLOGG, Alfred (*M* 1916), (Council, 1920-1921; 1923-1924), Consulting Engr. (for mail), 585 Boylston St., Boston, and 6 Hawthorne St., Belmont, Mass.

KELLOGG, H. D. (*Life Member*; *A* 1916), Philadelphia, Pa.

KELLOGG, Thomas M. (*M* 1929; *A* 1923), Mgr. N. Y. Br. (for mail), The Bishop & Babcock Sales Co., 105 East 18th St., New York, and 23 Roxbury Road, Scarsdale, N. Y.

KELLY, Charles J. (*M* 1931), Sales Engr., Jas. P. Marsh & Co., 551 Fifth Ave., New York, N. Y., and (for mail), 151 Highland Ave., Jersey City, N. J.

KELLY, Hugh (*M* 1927), 10041-101 A. Ave., Edmonton, Alberta, Canada.

KELLY, Jerome J. (*M* 1930), Vice-Pres., Wisconsin Equipment Co., 307 Loan and Trust Bldg., Milwaukee, Wis.

KELLY, John G. (*A* 1919), 374 Park Ave., Yonkers, N. Y.

KELLY, Joseph A. (*A* 1931), 3042 N. Franklin St., Philadelphia, Pa.

KENDALL, Edwin H. (*J* 1930), 1224 S. San Pedro St., Los Angeles, Calif.

KENNEDY, Maron (*J* 1930), Sales Engr. (for mail), York Ice Mchy. Corp., 5051 Santa Fe Ave., Los Angeles, and 2541 Santa Anna Ave., Walnut Park, Calif.

KENT, James King (*J* 1928), Pres. (for mail), J. King Kent & Co., 124 N. Main St., and 1030 Commodore Drive, St. Louis, Mo.

KENT, Laurence F. (*A* 1927; *J* 1924), Moncrief Furnace Co., P. O. Box 1673, Atlanta, Ga.

KEPLINGER, William L. (*M* 1929), Carrier Engrg. Corp., 39 Cortlandt St., New York, and 140 Fulton Ave., Hempstead, L. I., N. Y.

KEPPNER, Harry W. (*M* 1930), 1310 South 56th Ave., Cicero, Ill.

KERN, Raymond T. (*M* 1927), Chief Engr., Jennison Co., Fitchburg, and (for mail), 51 Claflin St., Leominster, Mass.

KERNEY, Thomas F. (*A* 1930; *J* 1925), Engr., H. Berkeley Hackett, 901 Architects Bldg., and (for mail), 4524 N. Reese St., Philadelphia, Pa.

KERSHAW, Melville G. (*A* 1926; *J* 1921), Ventilating Engr. (for mail), E. I. du Pont de Nemours & Co., Wilmington, Del., and 7313 North 21st St., Philadelphia, Pa.

KERSJES, William (*M* 1922), 728 Clinton St., Kalamazoo, Mich.

KEYES, Robert E. (*M* 1913), Chief Engr., The Cooling & Air Conditioning Corp., 11 West 42nd St., New York, N. Y.

KEYS, George Walter (*A* 1927), 518 Van Kirk St., Crescentville, Philadelphia, Pa.

KICE, Murray S., Jr. (*M* 1920), Asst. Chief Engr. (for mail), American Blower Corp., 6000 Russell St., Detroit, and P. O. Box 451, Birmingham, Mich.

KIEFER, Carl J. (*M* 1922), Consulting Engr., 902 Schmidt Bldg., Cincinnati, Ohio.

KIEFER, E. J., Jr. (*J* 1928), Mgr. (for mail), H. C. Archibald Co., 8 S. Sixth St., and 108 N. Sixth St., Stroudsburg, Pa.

KIESLING, Justin A. (*M* 1930), Pres. (for mail), Robischung-Kiesling, Inc., Box 1295, and 1806 Holman Ave., Houston, Texas.

KIEWITZ, Arthur A. (*M* 1912), 23-80–28th St., Astoria, L. I., N. Y.

KIEWITZ, Conway (*M* 1907), Engr., New York Board of Education, Flatbush Ave. Ext. and Concord St., Brooklyn, and (for mail), 70 King St., Floral Park, L. I., N. Y.

KILBY, Roger E. (*M* 1926), Pres. (for mail), Northwestern Htg. & Plbg. Co., 1465 Sherman Ave., and 1112 Grove St., Evanston, Ill.

KILLIAN, Maurice A. (*M* 1922), Glanz & Killian Co., 1761 Forest Ave. W., Detroit, Mich.

KILNER, John Saunders (*M* 1929), Partner (for mail), Kilner-Mills Co., 3-266 General Motors Bldg., and 1091 Seminole Ave., Detroit, Mich.

KIMBALL, Charles W. (*M* 1915), Richard D. Kimball Co., 6 Beacon St., Boston, Mass.

KIMBALL, Dwight D.* (*M* 1908), (*Presidential Member*), (Pres., 1915; 2nd Vice-Pres., 1914; Board of Governors, 1912-1916), Consulting Engr. (for mail), Kimball & Cucci, 205 East 42nd St., New York, and 230 23rd St., Jackson Heights, L. I., N. Y.

KINGSLEY, Edwin A. (*M* 1926), Consulting Mech Engr. (for mail), 370 Lexington Ave., New York, and 25 Overhill Place, Sherwood Park, Yonkers, N. Y.

KINNER, J. E. (*M* 1924), The Bryant Heater & Mfg. Co., 17825 St. Clair Ave., Cleveland, Ohio.

KINNEY, William H. (*M* 1931), Bureau of Subways, 20 N. Wacker Drive, Chicago, Ill.

KINTZ, Leslie H. (*M* 1930), Sales Engr. (for mail), Johnson Service Co., 427 Brainard St., and 210 Highland Ave., Detroit, Mich.

KIPE, J. Morgan (*M* 1919), Br. Mgr., Spencer Heater Co., 1718 Fairmount Ave., Philadelphia, and (for mail), 801 Homestead Ave., Beechwood, Delaware Co., Pa.

KIRK, Charles D. (*M* 1909), Mgr., Chas. D. Kirk & Co., Cor. Sargent and Colleen Sts., Winnipeg, Manitoba, Canada.

KIRK, George H. (*Life Member*; *M* 1906), 6711 Wentworth Ave., Chicago, Ill.

KIRK, Leonard G. (*M* 1923), Pres. (for mail), Kirk & Story, 12 Waverly Place, New York, N. Y., and 829 Boulevard, East, Weehawken, N. J.

KIRKPATRICK, Arthur H. (*J* 1931), Specialty Engr., Ilg Elec. Vtg. Co., 2850 N. Crawford Ave., and (for mail), 4251 Irving Park Blvd., Chicago, Ill.

KITAURA, Shigeyuki (*M* 1918), Monoply Bureau, Dept. of Finance, Tokyo, Japan.

KITCH, Stanley B. (*M* 1928; *A* 1928; *J* 1925), Chief Engr., Oscar Mayer & Co., 1241 Sedgewick St., and (for mail), 2024 Berwyn Ave., Chicago, Ill.

KITCHELL, Herbert N. (*A* 1926), 4528 Circle Ave., Cincinnati, Ohio.

KITCHEN, Francis A. (*A* 1927; *J* 1923), Pres. (for mail), American Warming & Vtg. Co., 1514 Prospect Ave., and 2910 Ludlow Road, Shaker Heights, Cleveland, Ohio.

KITCHEN, John H. (*M* 1906), (for mail), John H. Kitchen & Co., 1016 Baltimore Ave., and 5015 Westwood Terrace, Kansas City, Mo.

KLEIN, Albert (*M* 1920), Managing Director (for mail), Carrier Lufttechnische Gesellschaft, Archivstrasse 14, and Panoramastrasse 23, Stuttgart, Germany.

KLEIN, Edward W. (*M* 1917), Dist. Mgr. (for mail), Warren Webster & Co., 152 Nassau St. N. W., and 456 Peachtree Battle Ave., Atlanta, Ga.

KLEINE, Robert E. (*S* 1930), Student (for mail), Univ. of Cincinnati, and 5831 Ridge Ave., Cincinnati, Ohio.

KLIE, Walter (*M* 1915), Pres-Treas. (for mail), The Smith & Oby Co., 6107 Carnegie Ave., and 18411 S. Woodland Road, Cleveland, Ohio.

KLONOWER, Arthur A. (*M* 1920), J. S. Cassedy Co., 132 Austin St., Cambridge, Mass.

KLUBE, John O. (*J* 1929), (for mail), Carrier Engrg. Corp., 604 Washington Bldg., and 3221 Connecticut Ave., N. W., Washington, D. C.

KNAB, Edward A. (*M* 1930; *A* 1927), Htg. Contractor, 1575 N. Cramer St., Milwaukee, Wis.

KNECHT, Charles H. (*A* 1930), Vice-Pres. (for mail), Harry Knecht & Co., Inc., 415 Richie Ave., W. Collingswood, and Rudderrow and Burl Ave., East Merchantville, N. J.

KNEE, J. Stuart (*M* 1931), Pres., Knee Heating Co., 706-708 Wealthy, S. E., and (for mail), 836 Pinecrest, S. E., Grand Rapids, Mich.

KNIBB, Alfred E. (*M* 1930), Heating Eng., J. F. Stephens Co., P. O. Box 1027, Portsmouth, Ohio.

KNOX, James R. (*M* 1930), Heating Engr., Lord & Burnham Co., 2 Main St., and (for mail), 20 South E St., Irvington, N. Y.

KOCH, Harry O. (*M* 1916), 212 Centre St., Tamaque, Pa.

KOETZ, Lester (*J* 1929), Sales Engr. (for mail), Zion Institutions and Industries, 2633 Sheridan Road, and 3110 Elm Ave., Zion, Ill.

KOITHAN, William S. (*M* 1913), Koithan & Pryor, 39 Cortlandt St., New York, N. Y.

KORN, Charles B. (*M* 1922), 1022 S. Eighth St., Allentown, Pa.

KOZU, Tamiichro (*M* 1930), Chief Engr. (for mail), Daiwa Kogyo Co., Ltd., First Mutual Bldg., Kyobashi, and 1, 701 Shimo-ochiai, Ochiai-machi, Tokyo, Japan.

KRATZ, Alonzo P.* (*M* 1925), Research Prof. (for mail), Dept. of Mech. Engrg., University of Illinois, and 1003 Douglas Ave., Urbana, Ill.

KRATZ, Robert W. (*M* 1930), 5451 Marathon St., Hollywood, Calif.

KREISSL, Hans George (*M* 1925), Mgr., Vento and Arcoblast Div. (for mail), American Radiator Co., 816 S. Michigan Ave., and 718 Gordon Terrace, Chicago, Ill.

KREITNER, William (*J* 1926), 108 Linden St., Brooklyn, N. Y.

KRIEBEL, Arthur E. (*M* 1920), Sales Engr. (for mail), Haynes Selling Co., 1518 Fairmount Ave., Philadelphia, and Berwyn, Chester Co., Pa.

KRUEGER, Bill (*A* 1931), 91 Tremont, Kenmore, N. Y.

KRUEGER, James I. (*M* 1921), Factory Repr. (for mail), 357 Ninth St., and 1920 Sacramento St., San Francisco, Calif.

KRUSE, Robert W. (*A* 1930), Pres. (for mail), Kruse Co., 353 West 16th St. Place, and 133 East 19th St. Indianapolis, Ind.

KUEHNERT, Albert C. (*A* 1930), 301 Station St., McDonald, Pa.

KUEMPEL, Leon L. (*J* 1929), Sales Engr. (for mail), Minneapolis-Honeywell Regulator Co., and 4917 Garfield Ave., S., Minneapolis, Minn.

KUHLMANN, Rudolf (*M* 1928), Pres., Thermo-Service, Inc., 101 Park Ave., New York, N. Y.

L

LABOV, Milton (*S* 1930), Benj. F. Labov (for mail), 212 Adriatic Ave., and 215 S. Vermont Ave., Atlantic City, N. J.

LAGODZINSKI, Harry J. (*A* 1927; *J* 1920), 3628 N. Tripp Ave., Chicago, Ill.

LAMB, Edward A. (*M* 1919), 244 Second Ave., S., Minneapolis, Minn.

LAMMERS, Cornelius (*A* 1931), 236 Winter Ave., Grand Rapids, Mich.

LaMONTAGNE, John M. (*A* 1930), Westinghouse Elec. & Mfg. Co., 420 S. San Pedro St., Los Angeles, Calif.

LANCE, Joseph F. (*M* 1923), Supt. (for mail), Harrigan & Reid Co., 1365 Bagley Ave., and 14816 Ashton Road, Detroit, Mich.

LANDERS, John J. (*M* 1930; *A* 1930; *J* 1924), Sales Engr. (for mail), Pacific Steel Boiler Corp., 303 Crosby Bldg., Buffalo, and 411 Highland Ave., Hamburg, N. Y.

LANGDON, J. D. (*M* 1920), 2030 Fifth Ave., Pittsburgh, Pa.

LANGENBERG, E. B. (*M* 1914), (Council, 1926-1931), Pres. (for mail), Langenberg Engrg. Co., 3800 W. Pine Blvd., and 6625 Waterman Ave., St. Louis, Mo.

LANGLEY, Frank P. (*M* 1931; *A* 1926), Dist. Mgr. (for mail), The Trane Co., 624 Genesee Bldg., Buffalo, and 26 Berryman Drive, Snyder, N. Y.

LANNING, E. K. (*A* 1927), Asst. Secy. and Sales Mgr. (for mail), Warren Webster & Co., Camden, and Clayton, N. J.

LANOU, J. Ernest (*M* 1931), 90 St. Paul St., Burlington Vt.

LARIMER, William McCoy (*M* 1922), Mgr. Htg. Dept. (for mail), Crane O'Fallon Co., 1625 15th St., and 159 W. Second Ave., Denver, Colo.

LARSON, G. L.* (*M* 1923), (Council, 1929-1931), Prof. Steam and Gas Engrg. and Chairman of Dept., of Mech. Engrg., University of Wisconsin, Madison, Wis.

LARSON, J. M. (*M* 1924), National Regulator Co., 2301 Knox Ave., Chicago, Ill.

LaSALVIA, James J. (*M* 1930), Htg. and Vtg. Engr., The Ideal Mfg. Co., 323 East 12th St., and (for mail), 3764 Aylesboro Ave., Cincinnati, Ohio.

LATHAM, George (*M* 1924), Engr. and Supt. of Plant (for mail), Edmonton Public School Board, 518 Civic Block, and 11317 91st St., Edmonton, Alberta, Canada.

LATHERS, Victor M. (*A* 1929), Dist. Repr. (for mail), Rome Brass Radiator Corp., 354 Paul Brown Bldg., and 1949 Alfred St., St. Louis, Mo.

LATHROP, Dr. Elbert C. (*M* 1926), Director of Research (for mail), The Celotex Co., 919 N. Michigan Ave., and 2320 East 70th Place, Chicago, Ill.

LAU, Anton S. (*M* 1926), Consulting Engr., A. S. Lau, 101 Park Ave., New York, N. Y., and (for mail), 35 Woodland Road, Bloomfield, N. J.

LAUER, Harold B. (*M* 1930), Vice-Pres. (for mail), English & Lauer, Inc., 1224 S. San Pedro St.; and 1121 S. Hayworth Ave., Los Angeles, Calif.

LAUTENSCHLAGER, Fred (*M* 1915), Vice-Pres-Treas., Kroeschell Boiler Co., 4211 Diversey Ave., and (for mail), 3846 Alta Vista Terrace, Chicago, Ill.

LAWLER, Matthew M. (*J* 1930), Cooling and Air Conditioning Corp., 706 Hollingsworth Bldg., Los Angeles, and (for mail), Beverly Hills, Calif.

LAWSON, William Irvin (*A* 1929), Sales Mgr., The New York Blower Co., 3155 Shields Ave., Chicago, Ill., and (for mail), 67 W. Dunedin Road, Columbus, Ohio.

LAWTON, Frank C. (*M* 1928), 145 Buena Vista Ave., Hawthorne, N. J.

LEACH, Thomas F. (*J* 1930), 212 Aberdeen Ave., Wayne, Pa.

LeBEAU, John F. (*M* 1924), Pres., John F. LeBeau & Co., Inc., 103 Park Ave., New York and (for mail), 158-21-84th Drive, Jamaica, L. I., N. Y.

LECOMPTE, William G. (*A* 1914), Vice-Pres. (for mail), Jenkins Bros., 80 White St., and 124 East 84th St., New York, N. Y.

LEEK, Walter (*M* 1903), Managing Director (for mail), Leek & Co., Ltd., 1111 Homer St., and 4769 W. Second Ave., Vancouver, British Columbia.

LEES, Herbert K. (*M* 1924; *J* 1912), Secy-Treas. (for mail), William Lees, Inc., 548 Washington Blvd., and 6318 N. Irving Ave., Chicago, Ill.

LEES, William D. (*M* 1930), Elec. Engr., Dept. of Public Works, Province of Alberta, and (for mail), 12050–93rd St., Edmonton, Alberta, Canada.

LEILICH, Roger L. (*M* 1922), Baltimore Htg. Corp., 419 St. Paul Place, Baltimore, Md.

LEINROTH, J. Paul (*M* 1929), Gen. Industrial Fuel Repr. (for mail), Public Service Elec. & Gas Co., 80 Park Place, Newark, and 22 Hillside Ave., Caldwell, N. J.

LEITCH, Arthur S. (*M* 1908), Pres. and Managing Director (for mail), The Arthur S. Leitch Co., Ltd., 1123 Bay St., and 421 Russell Hill Road, Toronto, Ont., Canada.

LELAND, Warren B. (*M* 1929), Sales Engr., The H. B. Smith Co., Westfield, and (for mail), P. O. Box, 1522, Springfield, Mass.

LELAND, William E. (*M* 1915), Partner (for mail), Leland & Haley, 58 Sutter St., San Francisco, and 704 The Alameda, Berkeley, Calif.

LEMMERMAN, Clarence W. (*A* 1927), Engr. (for mail), Keasbey-Mattison Co., 31 Farnsworth St., Boston, and 61 Rangeley Road, West, Newton, Mass.

LENNON, Joseph O. (*M* 1929), New York Mgr. (for mail), Ilg Elec. Vtg. Co., 15 Park Row, and 180 West 59th St., New York, N. Y.

LENONE, J. M. (*M* 1919), Designing Engr., Wilson & Co., 41st and Ashland Ave., and (for mail), 4808 Dorchester Ave., Chicago, Ill.

LEONARD, J. H. (*M* 1931), 405 Tribune Bldg., Winnipeg, Manitoba, Canada.

LEVY, Marion I. (*J* 1931), Research Engr., Bishop & Babcock Sales Co. (for mail), 4901 Hamilton Ave., N. E., Cleveland, and 2368 Euclid Heights Blvd., Cleveland Heights, Ohio.

LEWIS, Carroll E. (*M* 1930), Pres. (for mail), Lewis Air Conditioners, Inc., 829 Second Ave., S., Minneapolis, and 1454 Chelmsford Ave., St. Paul, Minn.

LEWIS, Edward B. (*M* 1924), 2283 Commonwealth Ave., St. Paul, Minn.

LEWIS, George C. (*M* 1919), American Htg. & Vtg. Co., 1505 Race St., Philadelphia, Pa.

LEWIS, J. Clifford (*M* 1913), Pres., Circulair Heat Co., Inc., Louisville, and (for mail), Anchorage, Ky.

LEWIS, John G. (*M* 1926), Prop. (for mail), John G. Lewis Plbg. & Htg. Co., 412 East 31st St., and 3522 Campbell St., Kansas City, Mo.

LEWIS, John P. (*M* 1931), 39 Hanover St., Lebanon, N. H.

LEWIS, L. L.* (*M* 1918), Secy. (for mail), Carrier Engrg. Corp., 850 Frelinghuysen Ave., Newark, and 724 Carlton Ave., Plainfield, N. J.

LEWIS, Milton (*A* 1930), 1221 Hollingsworth Bldg., Los Angeles, Calif.

LEWIS, Samuel R.* (*M* 1905), (*Presidential Member*), (Pres., 1914; 2nd Vice-Pres., 1910; Board of Governors, 1909, 1910, 1912; Council, 1914-1915), Consulting Engr. (for mail), 1615 Old Colony Bldg., 407 S. Dearborn St., and 4737 Kimbark Ave., Chicago, Ill.

LEWIS, Thornton* (*M* 1919), (*Presidential Member*), (Pres., 1929; 1st Vice-Pres., 1928; 2nd Vice-Pres., 1927; Council, 1923-1930), Exec. Vice-Pres. (for mail), Carrier Corp., 850 Frelinghuysen Ave., Newark, N. J., and 327 Llandrillo Road, Cynwyd, Pa.

LEWIS, Will (*M* 1931), Munroe Furnace Supply Co., 1718 Cass St., and (for mail), 1484 Lathrop St., Omaha, Neb.

LICHTY, C. P. (*M* 1920), Pres. (for mail), C. P. Lichty Engrg. Co., Inc., 400½ South 21st St., Birmingham, and 125 Windsor Drive, Hollywood, Birmingham, Ala.

LILLARD, Walter S. (*A* 1930), 185 E. Sixth St., Peru, Ind.

LINER, John J. (*A* 1916), Pres. (for mail), Philadelphia Asbestos Co., 2010 N. Tenth St., Philadelphia, Pa., and Berlin, N. J.

LINN, Homer R. (*M* 1914), Engr., American Radiator Co., 816 S. Michigan Ave., Chicago, and (for mail), 321 S. Ashland Ave., La Grange, Ill.

LINTON, John P. (*M* 1927), Managing Director (for mail), The Garth Co., 50 Craig St., W., and 247 Brock Ave., N., Montreal, P. Q. Canada.

LIPPMAN, Orville S. (*A* 1920), Vice-Pres. (for mail), Fix-Lippman Co., 5259 Northwest Highway, and Midland Club, 172 W. Adams St., Chicago, Ill.

LITTLE, Edwin R. (*M* 1916), Pres-Treas. (for mail), The E. R. Little Co., Inc., 1805 Ford Bldg., Detroit, and 447 Rivard Blvd., Grosse Point, Village, Mich.

LLOYD, Edward C. (*M* 1927), (for mail), Armstrong Cork & Insulation Co., and 429 W. Walnut St., Lancaster, Pa.

LOEFFLER, Frank X. (*M* 1914), Pres. (for mail), 710 N. Hudson St., and 320 West 26th St., Oklahoma City, Okla.

LOH, Nan-Shee (*J* 1927), Salesman, Andersen Meyer & Co., Ltd., and (for mail), 337 Rue Lafayette, Shanghai, China.

LONG, David Raymond (*M* 1927), Director of Development (for mail), Congoleum-Nairn, Inc., Kearny, and 117 Christopher St., Montclair, N. J.

LOUCKS, David W. (*A* 1930), Power and Steam Salesman (for mail), Duquesne Light Co., 435 Sixth Ave., Pittsburgh, and 506 North Ave., Wilkinsburg, Pa.

LOVE, Clarence H. (*M* 1919), Mfrs. Agent (for mail), Nash Engrg. Co., 317 Chamber of Commerce, and 289 Norwalk Ave., Buffalo, N. Y.

LOVE, Harold G. (*M* 1930), Engr. (for mail), Weiss & Neistadt, 343 S. Dearborn St., and 7443 Ridge Blvd., Chicago, Ill.

LOVEGREN, Harvey M. (*M* 1929; *A* 1927), 112 26th St., Milwaukee, Wis.

LOWNSBERY, Benjamin F. (*M* 1920), 21 S. Sycamore St., Wilmington, Del.

LUCE, George D., Jr. (*M* 1919), Consulting Engr., Burnham Bros., Inc., Room 1900, 160 N. La Salle St., and (for mail), 3633 N. Harding Ave., Chicago, Ill.

LUCK, Alexander W. (*M* 1919), Pres. and Gen. Mgr. (for mail), Reading Heater & Supply Co., Church and Woodward Sts., Reading, and Reiffton, Pa.

LUCKE, Charles Edward (*M* 1924), Stevens Prof. of Mech. Engrg. (for mail), Columbia University, and 845 West End Ave., New York, N. Y.

LUNDQUIST, Ralph A. (*J* 1931), 6 Highland Place, Boston, Mass.

LUTZ, James H., Jr. (*M* 1928), (for mail), 140 Paxton St., and 1601 Forster St., Harrisburg, Pa.

LUTZ, Paul R. (*J* 1929), Mech. Engr. (for mail), Badenhusen Co., Cornwells, and 2512 S. Lloyd St., Philadelphia, Pa.

LYLE, Ernest T. (*M* 1919), Carrier Engrg. Corp., 39 Cortlandt St., New York, N. Y.

LYLE, J. Irvine* (*M* 1911), (*Presidential Member*), (Pres., 1917; Council, 1917-1918), Pres. (for mail), Carrier Corp., 850 Frelinghuysen Ave., Newark, and 1200 W. Seventh St., Plainfield, N. J.

LYMAN, Samuel E. (*A* 1924), Carrier Engrg. Corp., 850 Frelinghuysen Ave., Newark, and (for mail), Elm Court Apts., Apt. 3-D, 47 Elm St., Elizabeth, N. J.
LYNCH, William L. (*M* 1928), Pres. (for mail), Rome-Turney Radiator Co., and 312 N. James St., Rome, N. Y.
LYON, P. S. (*M* 1929), Chief Engr. (for mail), Hall Elec. Htg. Co., Inc., 1429 Walnut St., and 3416 Warden Drive, Philadelphia, Pa.

M

MacDADE, Ambrose H. (*M* 1923), Sales (for mail), Burnham Boiler Corp., S. E. Cor. 31st and Jefferson Sts., Philadelphia, Pa., and 225 Haddon Ave., Westmont, N. J.
MACDONALD, Donald B. (*M* 1930), Br. Mgr. (for mail), C. A. Dunham Co., Kingston Corners Bldg., and 101 S. Walnut St., Kingston, Pa.
MacDOUGALL, Burgess W. (*M* 1923), 219 Netherwood Ave., Plainfield, N. J.
MacKENZIE, Donald W. (*J* 1930), Follansbee Bros. Co., Third and Liberty Aves., Pittsburgh, Pa.
MacKENZIE, John J. (M 1925), Heating Engr., McNaughton & MacKenzie, 1029 Shaw St., and (for mail), 664 Shaw St., Toronto, Ont., Canada.
MACKIE, James (*M* 1917), Owner (for mail), James Mackie, 357 Langside St., and 254 Montrose St., Winnipeg, Manitoba, Canada.
MacKINNON, Daniel A. (*J* 1930), 1224 S. San Pedro St., Los Angeles, Calif.
MADISON, Richard D. (*M* 1926), Buffalo Forge Co., 490 Broadway, Buffalo, N. Y.
MAGINN, Peter F. (*Life Member*; *M* 1908), 207 Fulton Bldg., Pittsburgh, Pa.
MaGIRL, Willis James (*J* 1927), MaGirl Foundry & Furnace Works, 401-413 E. Oakland Ave., Bloomington, Ill.
MAGNEY, Gottlieb R. (*M* 1931), 104 So. Ninth St., Minneapolis, Minn.
MAHONEY, David John (*A* 1926), Br. Mgr. (for mail), Johnson Service Co., 503 Franklin St., and 703 W. Ferry St., Buffalo, N. Y.
MAIER, George M. (*M* 1921), (for mail), Mfg. Dept., American Radiator Co., 40 West 40th St., and Peldean Court, Pelham, N. Y.
MAIER, Herman F. (*M* 1926), 7124 Morgan St., Chicago, Ill.
MALLIS, William (*M* 1914), 330 Lyon Bldg., Seattle, Wash.
MALONE, Dayle G. (*M* 1929; *A* 1925), Vice-Pres. and Gen. Mgr., Hardin-Lavin Co., 121-31 W. Pershing Road, and (for mail), 7729 Essex Ave., Chicago, Ill.
MALVIN, Ray C. (*M* 1929), Pres. (for mail), Malvin & May, 332 S. Michigan Ave., and 7310 Ridgeland Ave., Chicago, Ill.
MANDEL, Henry J. (*A* 1929), Heating Engr. and Comml. Mgr. (for mail), Indiana Gas Utilities Co., Cherry St., and 15 Jackson Blvd., Terre Haute, Ind.
MANDEVILLE, Edgar W. (*M* 1914), Treas., E. W. Mandeville, Inc., 623 Parkside Ave., and (for mail), 1171 East 37th St., Brooklyn, N. Y.
MANN, Arthur R. (*M* 1930), Owner (for mail), Mann & Co., Archts. and Engrs., 722 R. W. Bldg., and 122 West 15th St., Hutchinson, Kan.
MANN, Lee B. (*J* 1930), Engr. (for mail), Carrier Engrg. Corp., 850 Frelinghuysen Ave., and Tudor Court Apts., Apt. A-9, 19 Pingry Place, Elizabeth, N. J.
MANNING, Walter M. (*M* 1930), Heating Engr., Wigman Co., 313 Perry St., and (for mail), 1901 Palmetto St., Sioux City, Iowa.
MARKS, Alexander A. (*A* 1930), Asst. Sales Mgr., Richmond Radiator Co., 2241 N. American St., and (for mail), 3441 W. Queen Lane, Philadelphia, Pa.
MARKUSH, Emery U. (*M* 1931), Mech. Engr., Secy. (for mail), Weitbeer Plbg. Corp., 446 East 72nd St., New York, and 8918-89th Ave., Woodhaven, L. I., N. Y.
MARQUET, Clyde M. (*M* 1930), Htg. and Vtg. Engr. (for mail), 316 E. Eighth St., and 1502 Reid St., Los Angeles, Calif.
MARSCHALL, Peter J. (*M* 1930; *A* 1930; *J* 1927), Secy. (for mail), E. V. Hill Co., 121 N. Clark St., and 8228 Langley Ave., Chicago, Ill.
MARSH, Arthur B. (*J* 1930), Carrier Engrg. Corp., 850 Frelinghuysen Ave., Newark, N. J.
MARSH, Thomas A. (*M* 1931), Pres. (for mail), Modern Coal Burner Co., 3733 N. Lincoln Ave., and 6839 East End Ave., Chicago, Ill.
MARSHALL, H. Hall (*M* 1923), Consulting Engr. (for mail), 37 West 43rd St., New York, and 63 Pine St., Garden City, N. Y.
MARSHALL, Orville D. (*A* 1931), 514 Anderson Bldg., Grand Rapids, Mich.
MARTENIS, John V. (*M* 1918), Associate Prof., Mchy. Design (for mail), University of Minnesota, and (for mail), 114 Melbourne Ave., S. E., Minneapolis, Minn.
MARTIN, Albert B. (*M* 1917), Res. Mgr. (for mail), Kewanee Boiler Corp., 1858 S. Western Ave., Chicago, and 997 Vine St., Winnetka, Ill.
MARTIN, George W.* (*M* 1911), Supervising Engr. (for mail), U. S. Realty Improvement Co., 57th St. and Madison Ave., New York, N. Y., and 314 Prospect St., Ridgewood, N. J.
MARTINEZ, Juan Jose (*J* 1929), Miguel Schulz, No. 26, Mexico City, Mexico.
MARTY, Edgar O. (*M* 1916), Vice-Pres. and Gen. Mgr., Sherman Coal Corp., and (for mail), Howard Ave. at 18th St., Pottsville, Pa.
MARUM, Otto (*M* 1931), Plant Engr. (for mail), Agfa Ansco Corp., 29 Charles St., and 61 Bigelow St., Binghamton, N. Y.
MASON, Ray B. (*M* 1925), Asst. Br. Mgr. (for mail), Kewanee Boiler Co., 2014 Wyandotte St., and Villa Serena Hotel, 321 Ward Pkwy., Kansas City, Mo.
MATCHETT, James C. (*M* 1923), Vice-Pres. and Gen. Mgr. (for mail), Illinois Engrg. Co., Racine Ave. at 21st St., and 9936 S. Winchester Ave., Chicago, Ill.
MATHER, Harry H. (*A* 1929), Philadelphia Elec. Co., 1000 Chestnut St., Philadelphia, Pa.
MATHEY, Nicholas J. (*M* 1915), Prop. Mathey Plbg. & Htg. Co., 31 Third Ave., N. E., Le Mars, Iowa.
MATHIS, Eugene* (*M* 1922), New York Blower Co., 32nd and Shields Ave., Armour P. O. Sta., Chicago, Ill.
MATHIS, George A. (*A* 1931), 418 Rockefeller Bldg., Cleveland, Ohio.
MATHIS, Henry (*M* 1921), 10317 Oakley Ave., Chicago, Ill.
MATHIS, Julien W. (*A* 1921), (for mail), New York Blower Co., 3155 Shields Ave., and 7929 Bishop St., Chicago, Ill.
MATTHEWS, Charles R. (*M* 1924), Htg. Engr. (for mail), Warren Webster & Co., 76 Summer St., Boston, and 91 Trowbridge St., Cambridge, Mass.
MATTHIESSEN, H. G. F. (*M* 1923), Mech. Engr., McQuillan & Chave, Inc., 198 Eleventh Ave., New York, and (for mail), 1487 East 37th St., Brooklyn, N. Y.
MATZEN, Harry B. (*M* 1919), Vice-Pres. and Dist. Mgr. (for mail), Carrier Engrg. Corp., 1824 Union Trust Bldg., Cleveland, and 3115 Chadbourne Road, Shaker Heights, Ohio.
MAUER, William J.* (*M* 1919), (for mail), C. A. Dunham Co., 450 E. Ohio St., Chicago, and 2525 Colfax St., Evanston, Ill.
MAURER, Edward D. (*M* 1921), 1527 Mars Ave., Lakewood, Ohio.
MAUTSCH, Robert Henri (*A* 1928), Compagnie Gen. Met., 97, Avenue Louise, Brussels, Belgium.
MAY, A. O. (*J* 1928), Sales Engr. (for mail), Stannard Power Equipment Co., 53 W. Jackson Blvd., Chicago, and 4827 Lee St., Niles Center, Ill.
MAY, Edward M. (*M* 1931), 1023 S. Seventh St., Goshen, Ind.
MAY, Edwin A. (*M* 1906), 171 N. Kenilworth Ave., Oak Park, Ill.

MAY, Maxwell F. (*M* 1929), Secy-Treas. (for mail), Malvin & May, 332 S. Michigan Ave., Chicago, and Palos Park, Ill.
MAYER, Robert S. (*M* 1911), Mfrs. Agt, 1223 W. Eighth St., and (for mail), R. F. D. No. 1, Erie, Pa.
MAYETTE, Charles E. (*M* 1926), Service Equipment Engr. (for mail), United Engrs. & Constructors, Inc., 112 N. Broad St., Philadelphia, and 204 Harding Ave., Manoa, Pa.
MAYNARD, J. Earle (*M* 1931), 827 Middle Ave., Elyria, Ohio.
McCAFFREY, H. Grattan (*M* 1922), Sales Mgr. (for mail), Sheldons, Ltd., Grand Ave., S., and 23 Rich Ave., Galt, Ont., Canada.
McCANN, Frank G. (*M* 1903), (Council, 1914-1915), Chief of Htg. and Vtg. Div. (for mail), Board of Education, 131 Livingston St., and 1616 E. Tenth St., Brooklyn, N. Y.
McCARTHY, Bernard J. (*M* 1925), Sales Engr. Yelton-Weaver Supply Co., 215 N. Eighth St., and (for mail), 624 S. Fifth St., Springfield, Ill.
McCARTHY, Charles J. (*M* 1919), Plbg. and Htg. Contractor (for mail), Chas. J. McCarthy, 3419 Haverford Ave., and 533 South 55th St., Philadelphia, Pa.
McCAULEY, James H. (*M* 1921), Pres., James H. McCauley, Inc., 5321 West 65th St., Chicago, and 707 William St., River Forest, Ill.
McCLANAHAN, Luther C. (*M* 1930), Sales Engr. (for mail), Buffalo Forge Co., 927 Union Trust Bldg., and 1113 Lancaster St., Pittsburgh, Pa.
McCLELLAN, James E. (*M* 1922), Br. Mgr. (for mail), American Blower Corp., 228 N. La Salle St., Chicago, and 4918 Mulford St., Miles Center, Ill.
McCLELLAND, Harvey S. (*A* 1930), 1928 S. Compton Ave., Los Angeles, Calif.
McCLENATHAN, Robert (*M* 1927), Board of Education, Central High School, Akron, Ohio.
McCLINTOCK, A., Jr. (*M* 1928; *J* 1920), Htg. Engr. (for mail), A. McClintock & Sons, 1937 Ridge Ave., Philadelphia, and 121 Rochelle Ave., Wissahickon, Philadelphia, Pa.
McCLINTOCK, A., Sr. (*M* 1917), Pres., A. McClintock & Sons, 1937 Ridge Ave., Philadelphia, Pa.
McCLINTOCK, John L. (*M* 1917), Htg. Engr. (for mail), A. McClintock & Sons, 1937 Ridge Ave., Philadelphia, and 933 E. Rittenhouse St., Germantown, Philadelphia, Pa.
McCOLL, Jay R.* (*M* 1916), (*Presidential Member*), (Pres., 1922; 1st Vice-Pres., 1921; 2nd Vice-Pres., 1920; Council, 1920-1923), 2304 Penobscot Bldg., Detroit, Mich.
McCONACHIE, L. L. (*A* 1928), Co-Partner, McConachie & Reid, 8817 Mack Ave., and (for mail), 1415 Harvard Road, Detroit, Mich.
McCONNER, Charles R. (*A* 1925; *J* 1922), Gen. Sales Mgr. (for mail), Clarage Fan Co., and 1904 Waite Ave., Kalamazoo, Mich.
McCORMACK, Edward T. (*A* 1923), Dist. Mgr. (for mail), Pierce, Butler & Pierce Mfg. Corp., 41 East 42nd St., New York, N. Y., and Stanton, N. J.
McCOY, Thomas F. (*M* 1924), Mgr. (for mail), The Powers Regulator Co., 125 St. Botolph St., Boston, and Glen Road, Wellesley Farms, Mass.
McCREA, Lester W. (*M* 1920), West 27th and Sisson Sts., Baltimore, Md.
McCREARY, Julian Ledrew (*A* 1928), Room 11, Prince Theater Bldg., Ambridge, Pa.
McCREERY, Hugh Joseph (*M* 1922), Mech. Engr., Combustion Engrg. Corp., 530 Standard Bank Bldg., Vancouver, British Columbia.
McCULLOCH, Laurence (*M* 1931), Mgr. (for mail), Richardson & Boynton Co., 144 Kensington Ave., Buffalo, and 79 Kenton Road, Kenmore, N. Y.
McCULLOUGH, John L. (*M* 1930), Northwestern Life Ins. Co., 1812 Clark Bldg., Pittsburgh, Pa.
McCUNE, Byron V. (*M* 1928), Sales Engr. (for mail), 101 W. Yakima Ave., and 2310 W. Yakima Ave., Yakima, Wash.
McDONALD, John J. (*M* 1927), Mgr., Albert Pick-Barth Co., John Van Range Co., 85 Kneeland St., Boston, and (for mail), 26 Chestnut St., Malden, Mass.
McDONNELL, Everett N. (*M* 1923), Pres. (for mail), McDonnell & Miller, Wrigley Bldg., 400 N. Michigan Ave., Chicago, and 815 Forest Ave., Evanston, Ill.
McELGIN, John W. (*J* 1931), 180 Rowland Park, Cheltenham, Pa.
McELLROY, G. S. (*M* 1925), R. D. 2, Glenshaw, Pa.
McFARLAND, William P. (*A* 1923), Salesman, Powers Regulator Co., 2720 Greenview Ave., and (for mail), 1258 Pratt Blvd., Chicago, Ill.
McGEORGE, R. H. (*M* 1927), Mgr. Detroit Office (for mail), McCord Radiator & Mfg. Co., and 14565 Brace St., Detroit, Mich.
McGINNESS, J. E. (*M* 1903), Pres., McGinness, Smith & McGinness Co., 527 First Ave., Pittsburgh, Pa.
McGLENN, G. Raymond (*M* 1915), Secy., American Warming & Vtg. Co., 259 Lormore St., Elmira, N. Y.
McGRAIL, Thomas Ernest (*M* 1926), Mgr., Htg. Dept., Crane, Ltd., Beaver Hall Hill, and (for mail), 3465 Belmore Ave., Montreal, P. Q., Canada.
McGREGOR, George H. (*M* 1920), Mgr. (for mail), Western Htg. Co., 2250 N. Cicero Ave., Chicago, and 500 Leonard St., Park Ridge, Ill.
McGREGOR, Robert F. (*J* 1929), Carrier Mfg. Corp., Gamble Plant, Old Emaus Road, Allentown, Pa.
McGUIGAN, L. A. (*A* 1919), Salesman (for mail), National Radiator Corp., 1508 Arrott Bldg., and 724 Hastings St., Pittsburgh, Pa.
McHENRY, Robert W. (*M* 1921), Sales Engr., National Radiator Corp., 672 Dupont St., and (for mail), 236 Eglinton Ave. E., Toronto, Ont., Canada.
McILVAINE, John H.* (*M* 1929), Pres-Treas. (for mail), McIlvaine Burner Corp., 749 Custer Ave., Evanston, and Lake Forest, Ill.
McINDOE, James F. (*A* 1931), 1534 First Ave., S., Seattle, Wash.
McINTIRE, James F. (*M* 1915; *A* 1914), (Council, 1926-1928), Vice-Pres. (for mail), U. S. Radiator Corp., P. O. Box 686, 1056 First National Bank Bldg., and 3261 Sherbourne Road, Detroit, Mich.
McINTOSH, Fabian C. (*M* 1921; *J* 1917), (Treas., 1930; Council, 1929-1931), Br. Mgr. (for mail), Johnson Service Co., 1238 Irwin Ave., and 3334 Portola St., Pittsburgh, Pa.
McKELVEY, David M. (*M* 1930), 60 East 42nd St., New York, N. Y.
McKENNA, William N. (*Life Member*; *M* 1912), Treas. (for mail), William N. McKenna Co., 79 Chestnut St., and 21 W. Cedar St., Boston, Mass.
McKIEVER, William H. (*M* 1897; *J* 1896), Pres. (for mail), William H. McKiever, Inc., 247 West 13th St., New York, and 479 Eighth St., Brooklyn, N. Y.
McLAIN, Roland D. (*M* 1921), 716 Vernon Ave., Williamsport, Pa.
McLAUGHLIN, Joseph D. (*A* 1930; *J* 1928), Mgr. (for mail), Braley & McLaughlin, 166 Aborn St., and 45 Roslyn Ave., Providence, R. I.
McLEAN, Dermid (*M* 1917), Consulting Engr. (for mail), McColl, Snyder & McLean, 2348 Penobscot Bldg., and 12651 Birwood Ave., Detroit, Mich.
McLEAN, Ivory D. (*M* 1924), Pres., McLean & Cousens Co., 65 Chandler St., Boston, Mass.
McLEISH, William Scott (*J* 1928), Mech. Engr. (for mail), The Ric-wil Co., Union Trust Bldg., Cleveland, and 1646 Wagar Ave., Lakewood, Ohio.
McMAHON, Thomas W. (*M* 1928), Br. Mgr. (for mail), American Blower Corp., 1005-6 American Bldg., and 2830 Harrison Ave., Cincinnati, Ohio.
McMORRAN, Francis J. (*M* 1917), Chief Engr. (for mail), Black & Servant Mfg. Co., 2951 N. Market St., and 230 E. Argonne Drive, Kirkwood, Mo.

McMURRAY, John (*M* 1920), Iron City Htg. Co., 843 Jackson St., N. S., Pittsburgh, Pa.

McMURRER, Louis J. (*M* 1928; *J* 1924), Pres., The McMurrer Co., 303 Congress St., Boston, Mass.

McNAIR, E. E. (*M* 1915), (2nd Vice-Pres., 1923; Council, 1921-1923), Vice-Pres., U. S. Radiator Corp., and Pres. Pacific Steel Boiler Corp., 1056 First National Bank Bldg., Detroit, Mich.

McNAMARA, William (*A* 1930), Sales Engr. (for mail), the Trane Co., 722 Plymouth Bldg., Minneapolis, and 1355 Como Ave., St. Paul, Minn.

McPHERSON, William A. (*M* 1929), Chief Htg. and Vtg. Div., Dept. of School Bldgs., City of Boston, 11 Beacon St., Boston, and (for mail), 10 Codman St., Dorchester, Mass.

McTERNAN, Felix J. (*A* 1931), 1523 Main St., Buffalo, N. Y.

MEAD, Edward A. (*M* 1926), Asst. Sales Mgr. (for mail), Nash Engrg. Co., Wilson Ave., South Norwalk, and 5 Thames St., Norwalk, Conn.

MEFFERT, George H. (*J* 1930), (for mail), Carrier Engr. Corp., 1032 Burnham Bldg., and 925 Glengyle Place, Chicago, Ill.

MEHAFFEY, William Chambers (*M* 1922), Engr., Chambersburg Construction Co., Chambersburg, Pa.

MEHNE, Carl A. (*M* 1929), 244 Madison Ave., New York, N. Y.

MEHRING, George (*Charter Member*), Pres., Mehring & Hanson Co., 162-166 N. Clinton St., Chicago, Ill.

MEIER, Konrad (*M* 1916), Rychenbergstrasse 57, Winterthur, Switzerland.

MEISEL, Carl L. (*J* 1931), 245 West 107th St., New York, N. Y.

MELLON, James T. J. (*M* 1911), (Council, 1915), (for mail), Mellon Co., 4415-21 Ludlow St., and 431 North 63rd St., Philadelphia, Pa.

MELONEY, Edward J. (*M* 1930), Consulting Engr. (for mail), Bower Bros. Co., 2015 Sansom St., Philadelphia, and 100 E. Stewart Ave., Lansdowne, Pa.

MENSING, Frederick D. (*M* 1920), (Treas., 1931), *Consulting Engr. (for mail)*, Mensing & Co., 1520 Locust St., and 2845 Frankford Ave., Philadelphia, Pa.

MERKEL, Fred P. (*M* 1924), 204–11th Ave., Belmar, N. J.

MERRILL, Carle J. (*M* 1919), Treas., C. J. Merrill, Inc., 54 St. John St., Portland, Maine.

MERRITT, Cecil James (*M* 1925), Director, Merritt, Ltd., 9 Avenue Edward VII, Shanghai, China.

MERTZ, Walter A. (*M* 1919), Secy. (for mail), Kehm Bros. Co., 51 E. Grand Ave., and 3753 N. Keeler Ave., Chicago, Ill.

MERWIN, Glle E. (*M* 1924; *J* 1923), Htg. Engr., Rockford Brass Works, and (for mail), 1236 Garrison Ave., Rockford, Ill.

METCALF, Ralph H. (*J* 1929), Sales Engr., C. A. Dunham Co., 3605 Laclede Bldg., St. Louis, Mo.

MEWSHAW, James P. (*M* 1923), Sales Engr. (for mail), James P. Mewshaw & Co., 915-16 Barr Bldg., and 2700 35th Place, N. W., Washington, D. C.

MEYER, Charles L. (*M* 1930), Sales Engr., L. J. Wing Mfg. Co., 154 West 14th St., New York, and (for mail), 198-25 Foothill Terrace, Hollis, L. I., N. Y.

MEYER, Frank L. (*J* 1928), Treas., The Meyer Furnace Co., and (for mail), 2900 Knoxville Road, Peoria, Ill.

MEYER, Henry C., Jr. (*M* 1898), (Council, 1915-1916), 101 Park Ave., New York, N. Y.

MEYER, John W. (*M* 1921), Mgr., Order and Credit Depts. (for mail), American Blower Corp., 6000 Russell St., and 700 Seward Ave., Detroit, Mich.

MEYER, John W. (*A* 1929), (for mail), Mgr., Steam Heat Sales Div., The Philadelphia Elec. Co., 1000 Chestnut St., and 5000 Pine St., Philadelphia, Pa.

MICHIE, D. Fraser (*A* 1930), 14 B., 553 Wardlaw Ave., Winnipeg, Manitoba, Canada.

MICKIEWICZ, Stanley J. (*J* 1928), 14 Mt. Hope Place, New York, N. Y.

MILES, James C.* (*M* 1914), Vice-Pres. and Chief Engr. (for mail), The Warm Air Furnace & Fan Co., 6545 Carnegie Ave., and 1865 Crawford Road, Cleveland, Ohio.

MILLAR, Rowland J. (*M* 1925), Vice-Pres. and Gen. Mgr. (for mail), Pease Foundry Co., Ltd., 118 King St. E., and 53 Oakmont Road, Toronto, Ont., Canada.

MILLARD, Junius W. (*M* 1929), Dist. Sales Mgr. (for mail), Carrier-York Corp., 410 Asylum St., Hartford, and 32 Maplewood Ave., West Harford, Conn.

MILLER, Alan A. (*A* 1926), Richardson & Boynton Co., Terminal Commerce Bldg., 13th and *Callowhill* St., Philadelphia, and (for mail), 731 Cornell Ave., Drexel Hill, Pa.

MILLER, Bruce R. (*A* 1930), Consulting Mech. Engr., 1533 N. W. 25th St., Oklahoma City, Okla.

MILLER, Charles A. (*A* 1917), Salesman (for mail), H. B. Smith Co., 10 East 41st St., and 2178 University Ave., New York, N. Y.

MILLER, Charles W. (*M* 1919; *J* 1908), Pres. (for mail), The Rado Co., 338 S. Second St., Milwaukee, and R 1, Box 62, Menomonie Falls, Wis.

MILLER, Edgar S. (*M* 1931), 609 Manufacturers' Exchange, Kansas City, Mo.

MILLER, Floyd A. (*M* 1911), 477 Federal Bldg., Chicago, Ill.

MILLER, Harry M. (*M* 1920), Htg. and Vtg. Engr., 6089-91 Plankington Bldg., and (for mail), 3938 N. Stowell Ave., Milwaukee, Wis.

MILLER, Harvey N. (*M* 1921), 1850 Gidding Ave., S. E., Grand Rapids, Mich.

MILLER, Henry F. (*A* 1928), Dist. Mgr. (for mail), Keasbey & Mattison Co., 1001 Liberty Trust Bldg., Philadelphia, and 11 S. Swarthmore Ave., Ridley Park, Pa.

MILLER, James E. (*M* 1914; *J* 1912), C. W. Johnson, Inc., 211 N. Desplaines St., Chicago, Ill.

MILLER, John F. G. (*M* 1916), American Blower Co., 6004 Russell St., Detroit, Mich.

MILLER, L. B. (*M* 1926), Special Repr. (for mail), Time-O-Stat Controls Div., Minneapolis-Honeywell Regulator Co., and 1420 Lawndale Road, Elkhart, Ind.

MILLER, Merl William (*J* 1926), Trane Co., La Crosse, Wis.

MILLER, Robert A. (*M* 1931), Tech. Sales Engr., (for mail), Pittsburgh Plate Glass Co., 2200 Grant Bldg., Pittsburgh, and 1121 Carlisle St., Tarentum, Pa.

MILLER, Robert B. (*M* 1922), Pres., Miller & Brady, Inc., 210 East 38th St., New York, N. Y.

MILLER, Robert T. (*A* 1927), Chief Engr. (for mail), Masonite Corp., 2037 Conway Bldg., and 5737 Kenmore Ave., Chicago, Ill.

MILLER, Tolbert G. (*A* 1929; *J* 1921), Supt., Herre Bros., Seventh and Emerald Sts., Harrisburg, and (for mail), 11 N. Second St., Wormleysburg, Pa.

MILLIKEN, J. H.* (*M* 1923), (for mail), American Air Filter Corp., 20 N. Wacker Drive, Chicago, and 1021 Ridge Court, Evanston, Ill.

MILLIKEN, Vincent D. (*A* 1930), Sales Mgr. (for mail), Skidmore Corp., and 1927 Forres Ave., St. Joseph, Mo.

MILLIS, Linn W. (*M* 1918), Secy., Security Store & Mfg. Co., 1630 Oakland St., and (for mail), 3534 Wabash Ave., Kansas City, Mo.

MILWARD, Robert King (*A* 1920), Mgr. (for mail), U. S. Radiator Corp., 517 Dime Bank Bldg., and 2675 Tuxedo Ave., Detroit, Mich.

MITCHELL, Andrew J. (*J* 1930), Sales Engr. (for mail), Carrier Engrg. Corp., 1824 Union Trust Bldg., and 11119 Lake Ave., Apt. 204, Cleveland, Ohio.

MITCHELL, Charles H. (*M* 1924), 179 Thatcher St., Mattapan P. O., Milton, Mass.

MODIANO, René (*M* 1925), Continental Sales Engr., Carrier Engrg. Co., Ltd., 4 Rue d'Aguesseau, Paris 8eme, and (for mail), 55 Blvd. Beauséjour, Paris 16eme, France.

MOFFETT, William S. (*M* 1907), Staunton, Va.

MOFFITT, Roy M. (*A* 1930), Br. Mgr. (for mail), L. J. Mueller Furnace Co., 211 W. Wacker Drive, Chicago, Ill.

MOLER, William H. (*M* 1927; *J* 1923), Sales Engr. (for mail), Carrier Engrg. Corp., 2022 Bryan St., and 6811 Casa Loma St., Dallas, Texas.

MOLLER, Robert C. (*J* 1930), Br. Mgr. (for mail), Carrier-Lyle Corp., 708 Statler Bldg., and 108 St. Botolph St., Boston, Mass.

MONAGHAN, T. H. (*M* 1914), Pres. (for mail), Robert Gordon, Inc., 22 W. Austin Ave., and Deming Place, Chicago, Ill.

MONDAY, Charles E. (*M* 1920), (for mail), Chas. E. Monday & Co., 1323 Fairmount Ave., Philadelphia, Pa., and 15 N. Chelsea Ave., Atlantic City, N. J.

MONROE, Harry E. (*A* 1928), 1907 East 78th St., Chicago, Ill.

MONROE, L. O. (*A* 1925; *J* 1917), Gen. Mgr., Nichols Products Corp., 12953 Greeley Ave., Detroit, Mich.

MONROE, Raymond R. (*A* 1929), Sales Engr. (for mail), Nash Engrg. Co., Wilson Ave., South Norwalk, and 8 W. Rooks Road, Norwalk, Conn.

MONTGOMERY, W. Ray (*A* 1923), Montgomery Bros., 500 N. Dearborn St., Chicago, Ill.

MOON, L. Walter (*M* 1915), Pres. (for mail), Bradley Htg. Co., 3834 Olive St., and 5412 Cabanne Ave., St. Louis, Mo.

MOOR, Rhea F. (*A* 1929), Room 1, Reliance Bldg., 4915 Wabash St., Kansas City, Mo.

MOORE, H. Lee (*M* 1919), (Council, 1927-1928), Buffalo Forge Co., 927 Union Trust Bldg., and 7065 Flaccus Road, Ben Avon, Pittsburgh Pa.

MOORE, H. S. (*A* 1923), Sales Mgr., 107 Clendenan Ave., Toronto, Ont., Canada.

MOORE, Raymond F. (*A* 1926), Architect (for mail), 415-18 O. R. C. Bldg., and 1714 Park Ave., Cedar Rapids, Iowa.

MOORE, Robert Edwin (*A* 1928), Mgr., B. & G. Heater Div., Bell & Gossett Co., 3000 Wallace St., Chicago, and (for mail), 744 Dobson St., Evanston, Ill.

MORAN, Frank E. (*M* 1922), Pres. (for mail), F. E. Moran, Inc., 6850 Grand Ave., Chicago, and 3034 S. Maple Ave., Berwyn, Ill.

MORGAN, C. Stanley (*A* 1919), Owner (for mail), 445 W. Larned St., Detroit, and 1036 Devonshire Road, Grosse Pointe Park, Mich.

MORGAN, Francis H. (*M* 1912), Pres-Treas., J. F. Morgan & Son., Inc., 67 Blake St., Lynn, Mass.

MORGAN, Glenn C. (*M* 1911), Partner (for mail), Morgan-Gerrish Co., 307 Essex Bldg., and 4308 Fremont Ave., S., Minneapolis, Minn.

MORGAN, Robert C. (*M* 1915), Chief Engr. (for mail), Stewart A. Jellett Co., 1200 Locust St., and 314 W. Seymour St., Germantown, Philadelphia, Pa.

MORRILL, Frank B. (*M* 1930), James Hunter Machine Co., and (for mail), 15 Montana St., N. Adams, Mass.

MORRILL, Raleigh Dudley (*M* 1928), Prof., Experimental Engrg., New York University, University Heights, New York, N. Y.

MORRIS, C. Raymond (*M* 1921), Vice-Pres. (for mail), A. & J. Friedman Supply Co., Inc., 55 Central Ave., Passaic, and 69 Elm Place, Nutley, N. J.

MORRIS, Edward J. (*S* 1931), Estimator, Modern Engrg. Co., 107 E. Pleasant St., and (for mail), 3414 Gwynn's Falls Pkwy., Baltimore, Md.

MORRIS, F. I. (*A* 1912), (for mail), Grinnell Co., Inc., 5203 Hamilton Ave., and 1233 East 125th St., Cleveland, Ohio.

MORRISON, Chester B. (*M* 1931), York Shipley, Inc., 21 Jinkee Road, Shanghai, China.

MORSE, C. T. (*M* 1921), Vice-Pres. and Sales Mgr. (for mail), American Blower Corp., 6004 Russell St., and 16222 Shaftsbury Ave., Detroit, Mich.

MORTON, Charles H. (*A* 1931), 524 Murray Bldg., Grand Rapids, Mich.

MORTON, Harold S. (*M* 1931), 231 S. Exchange St., St. Paul, Minn.

MOSHER, Clarence H. (*A* 1919), Mfrs. Agt., C. H. Mosher & Co., 423 Ashland Ave., Buffalo, N. Y.

MOSHER, Roy Bradford (*A* 1927), Mgr. (for mail), Modine Mfg. Co., 125 South 10th St., and 3236 Irving Ave. S., Minneapolis, Minn.

MOSS, Edward (*M* 1920), 1130 Atlantic Ave., Brooklyn, N. Y.

MOULDER, Albert W.* (*M* 1917), Mgr., Htg. Power and Industrial Piping Div. (for mail), Grinnell Co., Inc., 260 W. Exchange St., Providence, R. I.

MOULTON, David (*M* 1926), Mech. Engr. (for mail), Monks & Johnson, 99 Chauncy St., Boston, and 35 Glen St., Melrose, Mass.

MOWER, William P. (*M* 1924), Warren Webster Co., 76 Summer St., Boston, Mass.

MUELLER, Harold C. (*A* 1930), The Powers Regulator Co., 2720 N. Greenview Ave., Chicago, Ill.

MUIR, George A. (*M* 1917), Consulting Engr., 168 N. Michigan Ave., Chicago, and (for mail), 234 S. Scoville Ave., Oak Park, Ill.

MUNDER, John F., Jr. (*M* 1927; *J* 1924), Mgr., Trade Dept. (for mail), American Blower Corp., 401 Broadway, New York, N. Y., and 81 Joyce Road, Tenafly, N. J.

MUNIER, Leon L. (*M* 1919; *J* 1915), Secy-Treas. (for mail), Wolff & Munier, Inc., 222 East 41st St., New York, and 356 N. Fulton Ave., Mt. Vernon, N. Y.

MUNRO, Edward A. (*Charter Member*; *Life Member*), Htg. and Vtg. Engr., 118-66 Farmers Ave., St. Albans, L. I., N. Y.

MUNSON, Morris G. (*M* 1925), Herman Nelson Corp., Moline, Ill.

MURPHY, Edward T.* (*M* 1915), Pres. (for mail), Carrier Engrg. Corp., 850 Frelinghuysen Ave., Newark, N. J., and 241 Central Park, West, New York, N. Y.

MURPHY, Howard C.* (*M* 1923), Vice-Pres. (for mail), American Air Filter Co., 215 Central Ave., Louisville, and Lightfoot Road, Green Hills, Louisville, Ky.

MURPHY, Joseph R. (*A* 1925), Gen. Sales Mgr., Taco Heaters, Inc., 342 Madison Ave., New York, N. Y., and (for mail), Riverside Terrace, Riverside, Conn.

MURPHY, William A. (*M* 1926), Gen. Sales Mgr., McDonnell & Miller, 5936 Grand Central Terminal Bldg., New York, N. Y.

MURPHY, William R. (*M* 1911), 226 Valley Road, Merion Sta., Pa.

MURPHY, William W. (*M* 1930), 171 Chestnut St., Springfield, Mass.

MURRAY, Thomas F. (*M* 1923), Engr., State Architect, and (for mail), 300 Washington Ave., Albany, N. Y.

MURRAY, Woodworth N. (*M* 1931), 724 Statler Bldg., Boston, Mass.

MUSSON, Joseph R. (*A* 1929), 240 W. Walnut Lane, Apt. C-110, Germantown, Philadelphia, Pa.

MYERS, Eddie V. (*A* 1931), 816 Clark St., Willard, Ohio.

MYERS, George W. F. (*M* 1930; *A* 1928; *J* 1923), Dist. Sales Mgr. (for mail), Carrier-York Corp., 1514 Chemical Bldg., St. Louis, and 476 Pasadena Ave., Webster Groves, Mo.

MYERS, Joseph E. (*A* 1929), Sales Engr., Marine-Galligan Co., 14 South 20th St., Philadelphia, and (for mail), 98 W. Marshall Road, Lansdowne, Pa.

MYRICK, James W. H. (*M* 1909), New England Air Conditioning Co., 53 Devonshire St., Boston, Mass.

N

NACEY, Harry M. (*M* 1908), Pres. and Gen. Mgr. (for mail), P. Nacey Co., 927 S. State St., Chicago, Ill.

NAGELSEN, Lou M. (*M* 1930), Sales Mgr., Unit Heater & Cooler Co., Wausau, Wis.

NAROWETZ, Louis L., Jr. (*M* 1929; *A* 1912), Secy., Narowetz Htg. & Vtg. Co., 1711-1717 Maypole Ave., Chicago, Ill.

NASON, George Lewis (*M* 1929; *A* 1929; *J* 1927), 31 N. Franklin St., Holbrook, Mass.

NASS, A. F. (*M* 1927), Secy-Treas. (for mail), McGinness-Smith-McGinness Co., 527 First Ave., Pittsburgh, and Elmhurst and Hillcrest Road., Greentree Boro, R. D. 8, Crafton P. O., Pa.

NATHAN, John M (*A* 1931), 318 *Sanders Road*, Buffalo, N. Y.

NATKIN, Benjamin* (*M* 1909; *J* 1907), Pres. (for mail), Natkin Engrg. Co., 314 W. Tenth St., and 5211 Rockhill Road, Kansas City, Mo.

NAYLOR, Charles L. (*M* 1931), Supt., Heat, Light & Power Dept., Atlantic Refining Co., 3144 Passyunk Ave., Philadelphia, Pa.

NEAL, Harry W. (*M* 1928), Neal Furnace Co., 2705-7 Northwestern Ave., and 3906 Graceland Ave., Indianapolis, Ind.

NEALE, Laurance I. (*A* 1927), Vice-Pres. (for mail), Atlantic Gypsum Products Co., 60 East 42nd St., and 49 West 57th St., New York, N. Y.

NEFF, Charles J. (*S* 1930), Canfield, Ohio.

NEIDECK, Albert A. (*J* 1927), Engr., Peter Sinnott Htg. Co., 621 Tiffany St., and (for mail), 2134 *Wallace Ave., Bronx, N. Y.*

NEILER, Samuel G. (*M* 1898), Senior Member (for mail), Neiler & Rich Co., 431 S. Dearborn St., Chicago, and 737 N. Oak Park Ave., Oak Park, Ill.

NELSON, Chester L. (*J* 1929), Engr. (for mail), Carrier Engrg. Corp., 39 Cortlandt St., New York, N. Y., and 191 North 17th St., Bloomfield, N. J.

NELSON, D. W.* (*M* 1928), Asst. Prof. of Steam & Gas Engrg. (for mail), Engineering College, University of Wisconsin, and 4006 Council Crest, Nakoma, Madison, Wis.

NELSON, George Augustus (*M* 1928), Sales Engr. (for mail), Skinner Bros. Htg. & Vtg. Co., 949 *Broadway*, and 2336 *University Ave.*, New York, N. Y.

NELSON, George O. (*M* 1923), Carstens Bros., Ackley, Iowa.

NELSON, Harold A. (*M* 1926), 236 S. La Pere St., Beverley Hills, Calif.

NELSON, Herman W. (*M* 1909), Pres. and Gen. Mgr. (for mail), The Herman Nelson Corp., 1824 Third Ave., and 2500–11th St., Moline, Ill.

NELSON, J. Fred (*A* 1930), Estimator (for mail), Southern Asbestos & Magnesia Corp., P. O. Box 366, Wilmington, and 2306 W. Montezuma Ave., Alhambra, Calif.

NELSON, Ralph L. (*M* 1917; *J* 1913), Pres., Heating Assurance, Inc., 121-123 Normandie St., and (for mail), N. 3823 Normandie St., Spokane, Wash.

NELSON, Richard H. (*J* 1928), Production Mgr., Herman Nelson Corp. (for mail), 1303–30th St., Moline, Ill.

NENTWIG, Ray J. (*A* 1930), Murray W. Sales & Co., 801 W. Baltimore Ave., Detroit, Mich.

NESBITT, Albert J.* (*M* 1921; *J* 1921), Secy-Treas. (for mail), John J. Nesbitt, Inc., State Road and Rhawn St., Holmesburg, and 304 Evergreen Road, Jenkintown, Pa.

NESBITT, John J. (*M* 1923), Pres., State Road and Rhawn St., Holmesburg, and Rockfield Farm, Ambler, Pa.

NESBITT, John J., Jr. (*J* 1930), (for mail), John J. Nesbitt, Inc., State Road and Rhawn St., *Holmesburg, and Rockfield Farm*, Ambler, Pa.

NESDAHL, Eilert (*M* 1915), Fosston, Minn.

NESMITH, O. Earl (*A* 1928), 107 Warner Ave., Bloomington, Ill.

NESS, William H. C. (*M* 1931), 1323 Channing St., Los Angeles, Calif.

NESSI, André (*M* 1930), Ingénieur des Arts et Manufactures (for mail), Établissement Nessi Frères & Cie., 43 Rue de la Vanne, Montrouge (Seine), France, and 1 Avenue du Président Wilson, Paris (VIII), France.

NEWCOMB, Raymond (*M* 1927; *A* 1927; *J* 1924), 570 Seventh Ave., New York, and (for mail), 25 Putnam Ave., White Plains, N. Y.

NEWMAN, Charles T. (*A* 1931), Owner of Business (for mail), 2729 Hooper Ave., and 125 S. Wetherly Drive, Los Angeles, Calif.

NEWPORT, Charles F.* (*M* 1906), Engr., Weil-McLain Co., Michigan City, Ind., and (for mail), 10001 Longwood Drive, Chicago, Ill.

NICELY, John Eyster (*A* 1925), Sales Repr., American Radiator Co., 123 N. Eighth St., and (for mail), 1208 Marion St., Reading, Pa.

NICHOLLS, Percy *M 1920), Supervising Engr., Fuel Section (for mail), U. S. Bureau of Mines, Pittsburgh, Pa.

NICHOLS, George B.* (*M* 1915), (Council, 1919-1920), Engr., 1050 Ocean Ave., Brooklyn, N. Y.

NICOL, Norman C. (*M* 1923), C. H. Sta., Box 542, *New York, N. Y.*

NIESTRATH, Walter H. (*A* 1921), Sales Repr., Jas. P. Marsh & Co., 2073 Southport Ave., Chicago, Ill., and (for mail), 3324 S. Jefferson Ave., St. Louis, Mo.

NIGHTINGALE, George Frederick (*A* 1931), Contract Sales Mgr., Hart & Cooley Mfg. Co., 61 W. Kinzie St., Chicago; and (for mail), 1142 S. Maple Ave., Oak Park, Ill.

NILSON, Andrew (*M* 1917), 5407 *Wayne Ave.*, Chicago, Ill.

NILSON, Karl A. (*A* 1930; *J* 1926), Secy-Treas. (for mail), Nilson Bros., Inc., 3222 N. Halsted St., and 5407 Wayne Ave., Chicago, Ill.

NOBBS, Walter W. (*M* 1919), 50 Fairhazel Gardens, London, N. W. 6, England.

NOBIS, Harry M. (*M* 1914), 1827 Stanwood Road, East Cleveland, Ohio.

NOLAN, James Joseph, Jr. (*J* 1929), Engr. (for mail), Carrier Engrg. Corp. 604 Washington Bldg., and 3221 Connecticut Ave., Washington, D. C.

NOLAND, Lloyd U. (*M* 1915), Pres., Noland Co., Inc., Newport News, Va.

NOLAND, Ralph Waldo (*M* 1914), Consulting Engr., R. W. Noland, M. E. (for mail), 408 Cal-Wayne Bldg., and 3722 Fairfield Ave., Ft. Wayne, Ind.

NOLL, William F. (*M* 1924), (for mail), The Paul E. Mueller Co., 232 W. Bruce St., and 2850 North 47th St., Milwaukee, Wis.

NORDHEIMER, C. L. (*S* 1931), 622 Mellon St., Pittsburgh, Pa.

NORDINE, Louis F. (*M* 1914), Vice-Pres., The Herman Nelson Corp., and (for mail), 1170 *25th St., Moline, Ill.*

NORRIS, William D. (*M* 1930), 1314 Forest Ave., *Wilmette, Ill.*

NORTHON, Louis (*M* 1929), Heating Engr., 143 Prospect Ave., Mt. Vernon, N. Y.

NOTTBERG, Henry J. (*M* 1919), Secy-Treas. (for mail), U. S. Engrg. Co., 914-16 Campbell St., and 213 S. Bales, Kansas City, Mo.

NOVOTNEY, Thomas A. (*M* 1928), Mgr., Research Dept., National Radiator Corp., and (for mail), 207 Leila St., Johnstown, Pa.

NOWITZKY, Herman S. (*A* 1931), *Head of* Construction, Maintenance and Repairs, Wilmer & Vincent Circuit, and (for mail), 151 10th St., Norfolk, Va.

NOYES, George T. (*M* 1928), Treas. and Engr., The Allen Plbg. Co., 283 Main St., and (for mail), 27 Church St., Presque Isle, Maine.

NUSBAUM, Lee* (*M* 1915), (for mail), Pennsylvania Engrg. Co., 1119-21 N. Howard St., Philadelphia, and 315 Carpenter Lane, *Germantown, Philadelphia*, Pa.

O

OAKS, Orlon O. (*M* 1917), Chief Engr. (for mail), American Radiator Co., 40 West 40th St., New York, N. Y., and 119 Oak Ridge Ave., Summit, N. J.

OATES, Walter A. (*M* 1931), 20 Ocean Terrace, Lynn, Mass.

O'BANNON, Lester Severance* (*M* 1928), Prof. of Heat Engrg., University of Kentucky, Lexington, Ky.

OBERT, Casin W.* (*M* 1916), Consulting Engr., Union Carbide & Carbon Research *Lab., Thompson* Ave. and Manley St., Long Island City, and (for mail), 122 N. Columbus Ave., Mt. Vernon, N. Y.

O'BRIEN, J. H. (*M* 1923), Divisional Sales Mgr. (for mail), American Blower Corp., 228 N. La Salle St., and 6525 Glenwood Ave., Chicago, Ill.

O'CONNELL, Michael* (*J* 1927), 1722 Crosby Ave., New York, N. Y.

O'CONNELL, Presly M. (*M* 1916), Mech. Engr., Seattle School Dist., 810 Dexter Ave., and (for mail), 5749–31st Ave., N. E., Seattle, Wash.

O'DONNELL, Thomas J. (*M* 1920), Secy-Treas. (for mail), William H. McKiever, Inc., 247 West 13th St., New York, and 927 Central Ave., Woodmere, L. I., N. Y.

ODROBINA, Stephen R. (*M* 1927), 2533–36th St., Long Island City, N. Y.

OFFEN, Ben (*M* 1928), *Owner and Mgr.*, B. Offen & Co., 608 S. Dearborn St., Chicago, Ill.

OFFNER, Alfred J. (*M* 1922), Consulting Engr., 1182 Broadway, New York, N. Y.

O'HAVER, Hubert M. (*J* 1931), Sales Engr. (for mail), American Blower Corp., 305 Union Ins. Bldg., and 1758 West 42nd St., Los Angeles, Calif.

OLSEN, Carlton F. (*A* 1825; *J* 1920), 6238 Evans Ave., Chicago, Ill.

OLSEN, Gustav E. (*M* 1930), 6809 Amstel Blvd., Arverne, L. I., N. Y.

OLSON, Arvid E. (*M* 1925), 3554 Dickens Ave., Chicago, Ill.

OLSON, Bernhard (*A* 1929), Mgr. (for mail), National Gas Heating, Inc., 122 S. Michigan Ave., and 5122 N. Kimball Ave., Chicago, Ill.

OLSON, Gilbert E. (*M* 1930), Vice-Pres. (for mail), Olson Bros., 2612 Leavenworth St., and 2512 North 53rd St., Omaha, Neb.

OLSON, Robert G. (*M* 1923), Dist. Mgr., American Blower Corp. (for mail), 1302 Sweetland Bldg., and 1802 East 13th St., Cleveland, Ohio.

OLSTAD, Martin H. (*J* 1931), Niagara Blower Co., 673 Ontario St., Buffalo, N. Y.

OLVANY, William J. (*M* 1912), 100 Charles St., New York, N. Y.

O'NEILL, James W. (*M* 1929; *A* 1927; *J* 1925), Chief Engr., Trane Co. of Canada, Ltd., 439 King St. W., and (for mail), 8 Springmount Ave., Toronto, Ont., Canada.

O'NEILL, Peter (*M* 1920), Treas. (for mail), Bartley-O'Neill Co., 240-242 Blvd. of The Allies, and 2448 Charles St., N. S., Pittsburgh, Pa.

OREAR, Andrew G. (*M* 1930), Br. Mgr. (for mail), Ilg Elec. Vtg. Co., 406 S. Main St., Los Angeles, and 1015 Raleigh St., Glendale, Calif.

ORMSBY, H. Kingsley, Jr. (*M* 1930; *A* 1930; *J* 1928), Dist. Repr. (for mail), Hoffman Specialty Co., 1538 E. Genesee St., and 102 Cumberland Ave., Syracuse, N. Y.

ORR, Fred B. (*M* 1924), Illinois Maintenance Co., 72 W. Adams St., Chicago, Ill.

ORR, H. B. (*M* 1928), Dist. Mgr. (for mail), Carrier-York Corp., 2215 Koppers Bldg., and 281 Lebanon Ave., Mt. Lebanon, Pittsburgh, Pa.

ORR, Merrill J. (*M* 1917), 513 Jackson St., Sioux City, Iowa.

OSBORN, Wallace J. (*A* 1927), Eastern Mgr. Engineering Publications, Inc., 110 East 42nd St., New York, N. Y., and (for mail), 599 Old Post Road, Fairfield, Conn.

OSBORNE, Gurdon H. (*M* 1922), Gen. Mgr., The Vtg. & Blow Pipe Co., Ltd., 714 St. Maurice St., and (for mail), 836 Pratt Ave., Outremont, Montreal, P. Q., Canada.

OSBORNE, Maurice Machado (*M* 1925) Partner, Osborne & Powell, 755 Boylston St., and (for mail), 367 Beacon St., Boston, Mass.

OSMUNDSEN, H. B. (*M* 1930), 129 Haddon Place, Montclair, N. J.

OSTER, George R. (*A* 1930), Sales Repr. (for mail), American Air Filter Co., 921 Hollingsworth Bldg., and 147 N. Edgemont St., Los Angeles, Calif.

OSTRANDER, Lewis F. (*M* 1923), 701 Lake Drive, Milwaukee, Wis.

OTIS, Gerald E.* (*M* 1922), The Herman Nelson Corp., Moline, Ill.

OTT, Rush C. (*M* 1931), (for mail), Peerless Unit Ventilator Co., Inc., 776 Union Ave., Bridgeport, and R. D. 1, Westport, Conn.

OTT, O. W. (*M* 1925), Consulting Mech. Engr. (for mail), 1100 Washington Bldg., and 123 S. Virgil Ave., Los Angeles, Calif.

OTTO, R. W. (*M* 1912), Mech. Engr., Toltz, King & Day, Builders Exchange, and (for mail), 2147 Carroll Ave., St. Paul, Minn.

OURUSOFF, Leon (*M* 1931), 411 10th St., N. W., Washington, D. C.

OVERTON, Sidney Harold (*M* 1929), Wheeler & Sons, Ltd., 34 Church St., Kensington, London, W. 8, England.

P

PADGINTON, George (*M* 1919), Consulting Engr., 1119 Genesee Bldg., and (for mail), 73 Huntington Ave., Buffalo, N. Y.

PAETZ, Herbert E. (*M* 1922), American Blower Co., 2539 Woodward Ave., Detroit, Mich.

PAGE, Harry W. (*M* 1923), 119 Warren Ave., Wauwatosa, Wis.

PANCOAST, Henry B., Jr. (*A* 1930), 950 N. Front St., Philadelphia, Pa.

PARK, Clifton D. (*M* 1929), Dist. Sales Mgr., Carrier Engrg. Corp., 708 Statler Bldg., Boston, and (for mail), 22 Otis St., Needham, Mass.

PARK, J. Frank (*J* 1930), Sales Engr. (for mail), Carrier Engrg. Corp., 832 Folsam St., and 1935 Franklin St., Apt. 307, San Francisco, Calif.

PARKER, Philip (*M* 1915), 8 Middle St., Woburn, Mass.

PARKS, W. N. (*A* 1927), Br. Mgr. (for mail), U. S. Radiator Corp., 688 Hampden Ave., St. Paul, and 5348 First Ave. S., Minneapolis, Minn.

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PEACOCK, Herbert (*M* 1930), Sales Engr. (for mail), Carrier Engrg. Corp., Union Trust Bldg., Cleveland, and 3320 Grenway Road, Shaker Heights, Ohio.

PEACOCK, James K. (*M* 1921), Br. Mgr. (for mail), Hoffman Specialty Co., Chrysler Bldg., New York, and 440 Fowler Ave., Pelham Manor, N. Y.

PECKHAM, Randolph R. (*M* 1919), c/o R. P. Peckham, 650 Baltimore, W., Detroit, Mich.

PEEBLES, John K., Jr. (*A* 1925; *J* 1924), Peebles & Ferguson, 733 Law Bldg., Norfolk, Va.

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PETERSEN, Adolph J. (*J* 1929), Service Engr., Philadelphia & Reading Coal & Iron Co., 332 S. Michigan Ave., Chicago, Ill.

PETERSON, Clarence O. (*S* 1930), Sales Mgr., Majestic May Corp., 89 Asylum St., and (for mail), 333 Jefferson St., Hartford, Conn.

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PETERSON, Sterling D. (*A* 1930), 5051 Prince St., Seattle, Wash.

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PHELPS, Harold R. (*J* 1927), Mech. Engr., American Blower Corp., 6000 Russell St., and (for mail), 16262 Appoline St., Detroit, Mich.

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PHILLIPS, William J. (*A* 1929), 1103 Forestdale Road, Royal Oak, Mich.

PHIPPS, Frederick G. (*M* 1930), Heating Engr., Engrg. Equip. Co., Ltd., 420 New Birks Bldg., and (for mail), 2054 Mercier Ave., Montreal, P. Q., Canada.

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PICKETT, Clinton A. (*A* 1923), Br. Mgr. (for mail), Herman Nelson Corp., 1609 Arcade Bldg., Eighth and Olive Sts., and 7300 Melrose Ave., St. Louis, Mo.

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PITCHER, Lester J. (*M* 1929; *A* 1928; *J* 1924), Sales Engr., Illinois Engrg. Co., 21st St. and Racine Ave., and (for mail), 8129 Dante Ave., Chicago, Ill.

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PITTOCK, Louis B. (*M* 1930), Sales and Htg. Engr., L. B. Pittock (for mail), 938 Oliver Bldg., and 80 Berry St., Pittsburgh, Pa.

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PLASS, Charles Webster (*M* 1928), Vice-Pres. (for mail), Combustioneer, Inc., and 1026 N. Main St., Goshen, Ind.

PLAYFAIR, George Alexander (*A* 1924), Mgr. (for mail, Johnson Temperature Regulating Co. of Canada, Ltd., 97 Jarvis St., and 7 Highland Crescent, West Hill, Toronto, Ont., Canada.

PLEWES, Stanley E. (*M* 1917), 2853 North 12th St., North Philadelphia, Sta. 8, Philadelphia, Pa.

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POEHNER, Robert E. (*M* 1928), Vice-Pres-Secy., W. H. Johnson & Son Co., 330 E. St. Joe St., and (for mail), 2308 Coyner Ave., Indianapolis, Ind.

POGALIES, Louis H. (*M* 1931), 4102 Archwood Ave., Cleveland, Ohio.

POHLE, Kenneth F. (*A* 1930), W. F. Hirschman Co., Inc., 37 Pearl St., Boston, Mass.

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POOL, Sterling H. (*M* 1913), 22 Market St., Lynn, Mass.

POOLE, Ernest F. (*M* 1921), Engr. (for mail), F. P. Sheldon & Son, 1009 Hospital Trust Bldg., and 74 Farragut Ave., Providence, R. I.

POPE, S. Austin (*M* 1917), 26 N. Jefferson St., Chicago, Ill.

POPE, William A. (*M* 1906), (for mail), 26 N. Jefferson St., Chicago, and 612 Keystone Ave., River Forest, Ill.

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PORTER, Richmond C. (*J* 1930), Research Asst. Engr. Dept., (for mail) University of Kentucky, Lexington, and Clinton, Ky.

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POSEY, James (*M* 1919), James Posey, Consulting Engr. (for mail), 1755 Baltimore Trust Bldg., and 4005 Liberty Heights Ave., Baltimore, Md.

POWERS, Edgar C. (*J* 1931), Sales Engr., Rome Radiation Co., 1108 Architects Bldg., Philadelphia, and (for mail), 110 Elgin Ave., Westmont, N. J.

POWERS, Fred I. (*M* 1920), Factory Repr. (for mail), Box 324, Bozeman, Mont.

POWERS, F. W. (*M* 1911), Pres. and Gen. Mgr. (for mail), The Powers Regulator Co., 2720 Greenview Ave., and 900 Castlewood Terrace, Chicago, Ill.

POWERS, Lowell G. (*J* 1930), Sales Engr., Carrier Engrg. Corp., 1824 Union Trust Bldg., Cleveland, Ohio.

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PRESDEE, Cliff W. (*A* 1926), Heating and Ventilating, 148 Lafayette St., New York, N. Y.

PRICE, Lewis C. (*A* 1930), L. C. Price Co., 136 Federal St., Boston, Mass.

PRICE, William H., Jr. (*M* 1927), Vice-Pres. in Charge of Sales (for mail), Carrier Engrg. Corp., 850 Frelinghuysen Ave., Newark, N. J., and Windsor Ave. and Farm Road, Wayne, Pa.

PROBST, A. H. (*M* 1919), Morgan-Gerrish Co., 307 Essex Bldg., Minneapolis, Minn.

PROHASKA, Ernest C. (*A* 1929), 1752 N. Monticello Ave., Chicago, Ill.

PROX, Robert F. (*M* 1923; *J* 1922), Vice-Pres. (for mail), Frank Prox Co., 1201 S. First St., and 1608 S. Fourth St., Terre Haute, Ind.

PRYOR, Frederick L. (*M* 1913), Consulting Engr. (for mail), 5 Colt St., Paterson, and 99 Mt. Prospect Ave., Verona, N. J.

PURCELL, Arthur J. (*M* 1914), Engr. Salesman, 631 New Britain Ave., Hartford, Conn.

PURCELL, Frederick C. (*M* 1926), Dist. Mgr. (for mail), National Regulator Co., 2847 Grand River Ave., Room 410, and Lee Plaza Apts., 2240 W. Grand Blvd., Detroit, Mich.

PURCELL, Robert E. (*M* 1916), Owner, Robert E. Purcell (for mail), 1735 Willis Ave., W., and 4061 Seebaldt Ave., Detroit, Mich.

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PURDY, Ellwood D. (*M* 1930), Sales Engr., Automatic Heat Corp., 5840 Second Blvd., and (for mail), 17310 Kentucky Ave., Detroit, Mich.

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PURINTON, Dexter J. (*A* 1923), 101 Park Ave., New York, N. Y.

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RAISLER, Robert K. (*J* 1930), Treas., Raisler Htg. Co., 129 Amsterdam Ave., and (for mail), 25 East 77th St., New York, N. Y.

RALSTON, Louis T. M. (*M* 1926), Vice-Pres. (for mail), Chelva Heat, Inc., Chrysler Bldg., and 25 East 77th St., New York, N. Y.

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RANK, David J. (*M* 1930), Chief Engr., Grant Bldg., Inc., 310 Grant St., and (for mail), 530 Grandview Ave., Mt. Washington, Pittsburgh, Pa.

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RASMUSSEN, Robert P. (*M* 1931), Pres. (for mail), Economy Equipment Co., Inc., 6835 Wentworth Ave., and 1243 East 46th St., Chicago, Ill.

RATHER, Max F. (*M* 1919), Mgr., Cleveland Office (for mail), Johnson Service Co., 2142 East 19th St., and 3098 Huntington Road, Shaker Heights, Cleveland, Ohio.

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RECK, William Ernst (*M* 1927), Vice-Pres. (for mail), The Reck Htg. Co., 15 Esromgade, Copenhagen, and Sundvej 16, Hellerup, Denmark.

REED, John F. (*M* 1927; *A* 1923), Vice-Pres. (for mail), American Air Filter Co., 420 Lexington Ave., New York, and 22 Edgewood Lane, Bronxville, N. Y.

REED, Van Applegate (*M* 1930), Mech. Engr., Federal Engrg. Co., 239 Fourth Ave., Pittsburgh, Pa.

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REESE, Philip R. (*M* 1931), Br. Mgr. (for mail), Herman Nelson Corp., 501 Essex Bldg., and Maryland Hotel, Minneapolis, Minn.

REHLING, Hugo F. (*M* 1928), Sales Engr., Andrews & Goodrich, Inc., 171 Sidney St., Cambridge, and (for mail), 993 South St., Roslindale, Mass.

REID, Henry P. (*A* 1927), Special Engr. (for mail), Universal Atlas Cement Co., Room 1257, 222 W. Adams St., Chicago, and 3507 Oak Park Ave., Berwyn, Ill.

REILLY, Charles Edward (*J* 1928), 4920 City Line Ave., Philadelphia, Pa.

REILLY, J. Harry (*M* 1931; *A* 1931; *J* 1929), American Radiator Co., 402 Broad St., Newark, and (for mail), 14 Watson Ave., E. Orange, N. J.

REINKE, Floyd C. (*A* 1930), Pres. (for mail), Air-O-Cel, Inc., 10-216 General Motors Bldg., and 152 Waverly, Detroit, Mich.

RENTE, Harry W. (*M* 1931), 114 Morris Ave., Buffalo, N. Y.

RENTE, Sidney R. (*A* 1930), Mgr. (for mail), R-O Distributors, Inc., 775 Main St., Buffalo, and 18 Charleston Ave., Kenmore, N. Y.

RETTEW, Harvey F. (*M* 1929), Htg. and Vtg. Engr., Board of Public Education, 19th and Ludlow Sts., and (for mail), 6821 Martins Mill Road, Philadelphia, Pa.

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REYNOLDS, Walter V. (*A* 1928), Pres. (for mail), Janes-Reynolds Co., Inc., 218 East 52nd St., New York, and 87 N. Broadway, White Plains, N. Y.

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RICE, C. J. (*A* 1923), Western Distributor, Modine Mfg. Co., 3738 N. Holton St., Milwaukee, Wis.

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RICE, William W. (*M* 1915), 830 Morgan Ave., Drexel Hill, Delaware County, Pa.

RICH, Calvin G. (*A* 1930), 5020 Los Robles St., Eagle Rock, Calif.

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RICHARDS, S. Frank (*M* 1915), Pres. (for mail), The Richards Corp., 1125 North Ave., Wilkinsburg Br., Pittsburgh, and 335 W. Riverview Ave., Bellevue Br., Pittsburgh, Pa.

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ROBERTS, Edward F., Jr. (*J* 1929), 2622 Columbia Ave., Philadelphia, Pa.

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ROBINSON, Mayes R. (*M* 1930), Pres. (for mail), Vtg. Equipment Co., 1101 Bessemer Bldg., and 424 McCully St., S. H. B., Pittsburgh, Pa.

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RODMAN, Robert W. (*M* 1922), Supt. of Plant Operation (for mail), Board of Education, City of New York, 500 Park Ave., and 175 West 73rd St., New York, N. Y.

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ROTH, Charles F. (*A* 1930), Mgr., International Htg. & Vtg. Exposition, Grand Central Palace, and (for mail), 141 East 36th St., New York, N. Y.

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ROWE, William A. (*M* 1921), (Council, 1929-1931), Chief Engr. (for mail), American Blower Corp., 6004 Russell St., and 140 Burlingame Ave., Detroit, Mich.

ROWLEY, Frank Benjamin* (*M* 1918), (1st Vice-Pres., 1931; Council, 1927-1931), Prof. of Mech. Engrg. and Director of Experimental Engrg. Lab., University of Minnesota, and (for mail), 63 Barton Ave., S. E., Minneapolis, Minn.

ROYER, Earl B. (*M* 1928), Des. Engr., Fosdick & Hilmer, 1703 Union Trust Bldg., and (for mail), 6635 Iris Ave., Cincinnati, Ohio.

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RUGART, Karl (*A* 1924), Br. Mgr. (for mail), Warren Webster & Co., 304 Stephen Girard Bldg., and 5830 Willows Ave., Philadelphia, Pa.

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RUSSELL, Hugh C.* (*M* 1911), U. S. Treas. Dept., Post Office Bldg., Chattanooga, Tenn.

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RUSSELL, W. A. (*M* 1921), Br. Mgr., U. S. Radiator Corp., 1405 West 11th St., and (for mail), 235 Ward Pkwy., Kansas City, Mo.

RUSSELL, William Bradford (*M* 1928), Colorado Ave., R. F. D. 1, Joliet, Ill.

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S

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SACHLEBEN, Edward H. (*A* 1921), E. H. Sachleben & Co., 1923 Washington Ave., St. Louis, Mo.

SADLER, Charles Boone (*M* 1928), Design Draftsman (for mail), Public Works Office, 11th Naval Dist., and 4440 Point Loma Ave., San Diego, Calif.

ST. CLAIR, Charles W. (*A* 1930; *J* 1927), Mgr. (for mail), Domestic Fuel Corp., 1346 West 116th St., Cleveland, and 17225 Clifton Blvd., Lakewood, Ohio.

ST. JOHN, Joseph S. (*J* 1928), Vice-Pres-Secy. (for mail), The Nussbaum Co., 1056 W. Baltimore, and 13571 Turner, Detroit, Mich.

SAITO, Shozo (*M* 1923), Prop., Saito Shozo Tokyo Office (for mail), Sixth Floor, Marunouchi Bldg., and 171 Kitakamata, Tokyo-fu, Japan.

SAKOUTA, Mathieu L. (*M* 1924), Gavan Simanskaia 4, Leningrad, U. S. S. R.

SALISBURY, William C. (*M* 1930), Sales Dept., American Radiator Co., 1344 Broadway, Detroit, and (for mail), 836 Lakeview, Birmingham, Mich.

SAMUELS, Sidney (*A* 1928; *J* 1925), Secy-Treas., Paramount Plbg. & Htg. Supply Corp., 10 East 135th St., New York, N. Y.

SANBERN, E. Nute* (*M* 1923), Engr. (for mail), Mensing & Co., 1520 Locust St., Philadelphia, Pa., and 119 S. Haviland Ave., Audubon, N. J.

SANDS, Clive Chisholm (*M* 1929), Briton Ltd., Dowling St., Waterloo, Sydney, Australia.

SANDS, John S. (*A* 1930), Sales Repr., Westinghouse Elec. & Mfg. Co., 3001 Walnut St., and (for mail), 3479 Bowman St., Philadelphia, Pa.

SANFORD, Arthur L. (*M* 1915), Mech. Engr. (for mail), Board of Education, 811 Broadway, N. E., and 301 East 48th St., Minneapolis, Minn.

SANFORD, Sterling S.* (*M* 1930), Htg. Engr. (for mail), The Detroit Edison Co., 2000 Second Ave., and 1503 Seyburn Ave., Detroit, Mich.

SANTEE, Helen C. (*M* 1930), Asst. to the Architect, Wilkes-Barre City School District, 81 N. Washington St., and (for mail), 900 S. Franklin St., Wilkes-Barre, Pa.

SAUER, Robert L. (*A* 1930), Dist. Mgr. (for mail), Riley Stoker Corp., Foot of Walker St., and 3315 W. Philadelphia, Detroit, Mich.

SAULSON, Saul (*M* 1916), Mech. Engr. (for mail), A. Kahn, Inc., 1000 Marquette Bldg., and 12524 Broadstreet Ave., Detroit, Mich.

SAUNDERS, J. Chester (*M* 1926), Estimator and Engr. (for mail), Crosby & Beard Co., 1550 S. Wabash Ave., and 10921 Oakley Ave., Chicago, Ill.

SAVILLE, Thomas H. (*M* 1924), 2009 N. Wabash Ave., and 1121 Lafayette St., Scranton, Pa., and (for mail), c/o Dean D. E. Carpenter, International Correspondence School, Scranton, Pa.

SAWADE, Carl A. (*A* 1920), Mgr. of Business Promotion (for mail), National Radiator Corp., 221 Central Ave., and 821 Luzern St., Johnstown, Pa.

SAWDON, Will M. (*M* 1920), Prof. Experiment Engrg. (for mail), Cornell University and 1018, E. State St., Ithaca, N. Y.

SAWHILL, R. V. (*A* 1929), Engineering Publications, Inc., 1900 Prairie Ave., Chicago, Ill.

SCANLAN, Chester J.* (*M* 1930), Chief Engr. (for mail), Trane Co., and 2131 Main St., La Crosse, Wis.

SCHAFER, Harry C. (*M* 1930), Dist. Engr. (for mail), B-Line Boiler Co., 1125 Walbridge Bldg., Buffalo, and 197 Union St., Hamburg, N. Y.

SCHALL, Howard S. (*M* 1930), Consulting Engr. (for mail), 327 Jackson Bldg., and 234 Parker Ave., Buffalo, N. Y.

SCHANZE, Augustus Gale (*A* 1925), Salesman, International Engrg. Works, Inc., Framingham, and (for mail), 71 Gilbert Road, Belmont, Mass.

SCHEIDECKER, Daniel B. (*A* 1919), Hunter-Clark Vtg. System, 2800 Cottage Grove Ave., Chicago, Ill.

SCHELLHAMMER, Alfred L. (*M* 1919), Pennsylvania Furnace & Iron Co., Warren, Pa.

SCHERNBECK, Fred H. (*M* 1930), Salesman (for mail), Williams Bros. Boiler & Mfg. Co., Nicollet Island, and 5045 Portland Ave., Minneapolis, Minn.

SCHLEY, Arthur A. (*M* 1920), Schley & Nash Co., 709 Columbia Bank Bldg., Pittsburgh, Pa.

SCHLEYER, Emil F. (*A* 1931), Salesman, Trane Co., and (for mail), 1725 East 37th St., Brooklyn, N. Y.

SCHLOSS, Newton L. (*M* 1913), Archt. and Engr. (for mail), 51 East 42nd St., New York, and 347 Lincoln Place, Brooklyn, N. Y.

SCHMIDT, George G. (*M* 1914; *J* 1912), Secy. (for mail), Carrier-Lyle Corp., 50 East 42nd St., New York, and 55 Burns St., Forest Hills, L. I., N. Y.

SCHNEIDER, Charles (*M* 1923), 492 East 163rd St., New York, N. Y.

SCHOENIJAHN, Robert Polk (*M* 1919), Consulting Engr. (for mail), 303-7 Industrial Trust Bldg., and 719 Nottingham Road, Wilmington, Del.

SCHOENOFF, Alfred E. (*S* 1930), 808 Ninth Ave., Menomonie, Wis.

SCHOEPFLIN, Paul H. (*M* 1920), Pres. (for mail), Niagara Blower Co., 6 East 45th St., New York, and 91 Valley Road, Larchmont, N. Y.

SCHOFIELD, Thomas Johnson (*M* 1928), Sales Engr. (for mail), Schofield Engrg. Co., 713 Hawley Bldg., and Glenwood Heights, Wheeling, W. Va.

SCHOPP, Walter J. (*M* 1922), 711 Lincoln Ave., Palmyra, N. J.

SCHOURUP, Walter E. (*A* 1930), L. J. Mueller Furnace Co., and (for mail), 5450 West Blvd., Los Angeles, Calif.

SCHRADER, Charles C.* (*A* 1925; *J* 1923), Research Engr., Armstrong Cork Co., Research Div., Lancaster, Pa.

SCHROTH, A. H. (*M* 1911), Vice-Pres., Richmond Radiator Co., 1480 Broadway, New York, N. Y., and (for mail), 90 S. Oraton Pkwy., E. Orange, N. J.

SCHUENGEL, George W. (*M* 1930), 1916 Morse Ave., Rogers Park P. O., Chicago, Ill.

SCHULTE, Ross R. (*M* 1931), 1781 Hague Ave., St. Paul, Minn.
SCHULZ, Howard I. (*A* 1915), Mgr. (for mail), Crane Co., 1223 W. Broad St., and 1535 West Ave., Richmond, Va.
SCHULZE, Benedict H. (*M* 1921), Dist. Mgr. (for mail), Kewanee Boiler Corp., 1344 Broadway, and 11203 McKinney Ave., Detroit, Mich.
SCHUNK, Thomas (*M* 1929), Htg. Engr., Baker Bros. & Co., Riverhead, and (for mail), Quogue, L. I., N. Y.
SCHWAB, Quentin D. (*J* 1927), Htg. and Vtg. Engr. (for mail), Atchison, Topeka & Santa Fe Ry., Railway Exchange Bldg., Chicago, and 424 Madison St., Gary, Ind.
SCHWARTZ, Jacob (*J* 1929), Htg. Contractor, Samuel Schwartz & Son, Inc., 30 West 27th St., Bayonne, N. J.
SCHWEIKERT, John N. (*M* 1931), Vice-Pres. (for mail), The Bryant Heater & Mfg. Co., 17825 St. Clair Ave., Cleveland, and 3361 Lansmere Road, Shaker Heights, Ohio.
SCHWEIM, Henry J. (*M* 1928), Chief Engr. (for mail), Gypsum Assn., 211 W. Wacker Drive, Chicago, and 1110 Grove St., Evanston, Ill.
SCOTT, Charles E. (*M* 1907), Pres-Treas. (for mail), Vapor Engrg. Co., 489 Fifth Ave., New York, N. Y., and Meadowbrook Road, Darien, Conn.
SCOTT, Clarence E. (*A* 1929; *J* 1926), Air Conditioning Engr. (for mail), Carrier-York Corp., 1541 Sansom St., Philadelphia, and 730 Wynnewood Road, Ardmore, Pa.
SCOTT, Edwin A. (*M* 1912), E. A. Scott Publishing Co., 45 West 45th St., New York, N. Y.
SCOTT, George McKay (*M* 1915), 108 Wooster St., New York, N. Y.
SCOTT, Leslie O. (*J* 1930), Carrier Engrg. Corp., 748 E. Washington St., Los Angeles, Calif.
SCRIBNER, Eugene D. (*J* 1929), Office Engr. (for mail), Carrier-York Corp., 149 Broadway, New York, N. Y., and 138 Ferris Place, Westfield, N. J.
SEBREE, George M. (*A* 1930), Advertising Mgr. (for mail), Baker Ice Mach. Co., Inc., 3601 North 16th St., and 1029 Park Ave., Omaha, Neb.
SEELBACH, Herman (*M* 1931), Pres. (for mail), Equipment Sales, Inc., 610 Erie County Bank Bldg., Buffalo, and 31 Central Ave., Hamburg, N. Y.
SEELEY, Lauren E.* (*M* 1930), Asst. Prof. (for mail), Yale University, Mason Laboratory, New Haven, and 1227 Whitney Ave., Hamden, Conn.
SEELIG, Alfred E. (*M* 1926), Pres. and Gen. Mgr., L. J. Wing Mfg. Co., 154 West 14th St., and (for mail), 310 Convent Ave., New York, N. Y.
SEELIG, Lester (*M* 1925), Consulting Engr., 5735 Washington Blvd., Chicago, Ill.
SEIDERS, John T. (*M* 1926), 82 S. High St., Room 214, Columbus, Ohio.
SEITER, J. Earl* (*M* 1928), Asst. Mgr. New Business Dept., Steam Sales, Consolidated Gas, Elec. Light & Power Co. of Baltimore, Lexington Bldg., Baltimore, and (for mail), 6 Dixie Drive, Towson, Md.
SEKIDO, Kunisuke (*M* 1903), Consulting Engr., 885 Marunouchi Bldg, and (for mail), 19 Momozono, Nakano, Tokyo, Japan.
SELCH, Homer C. (*A* 1929), Owner, Homer Selch Sheet Metal Works, 844 Virginia Ave., Indianapolis, Ind.
SELLMAN, Nils T. (*M* 1922), Dir. of Sales and Utilization, and Asst. Secy. (for mail), Consolidated Gas Co., 4 Irving Place, and 135 West 183rd St., New York, N. Y.
SENIOR, Richard L. (*M* 1925), Premium Point Park, New Rochelle, N. Y.
SEWARD, Percival H.* (*Charter Member*), 369 Washington Ave., Brooklyn, N. Y.
SEWELL, John M. (*M* 1919), Consulting Engr. (for mail), 1541 Spring Garden St., Philadelphia, and Warren Ave., Berwyn, Pa.
SHANKLIN, Arthur P. (*M* 1929), 1724 Land Title Bldg., Philadelphia, Pa.
SHANKLIN, Jno. A. (*M* 1928), Estimator (for mail), West Virginia Htg. & Plbg. Co., 233 Hale St., and 5 Swathmore Ave., Charleston, W. Va.
SHANKLIN, John R. (*M* 1899), Pres. and Gen. Mgr. (for mail), West Virginia Htg. & Plbg. Co., 233 Hale St., and 1507 Quarrier St., Charleston, W. Va.
SHARP, Floyd H. (*M* 1929), Contracting Htg. Engr. (for mail), Chatfield & Sharp, 304 Pine St., and 512 E. Seventh, Jamestown, N. Y.
SHARPE, Norman (*J* 1930), Engr., Carrier Engrg. Corp. (for mail), 748 E. Washington Blvd., and 1390 West 20th St., Los Angeles, Calif.
SHAVER, Elmer W. (*M* 1930), Coon-DeVisser Co., 2051 W. Lafayette, Detroit, Mich.
SHAVER, Herbert H. (*A* 1929), Asst. Gen. Sales Agent (for mail), The Hudson Coal Co., 424 Wyoming Ave., and 1507 Wyoming Ave., Scranton, Pa.
SHAW, Edgar (*M* 1923), Pres. (for mail), Lynch & Woodward, Inc., 320 Dover St., Boston, and 51 Royal St., Wollaston, Mass.
SHAW, N. J. H. (*M* 1927; *J* 1925), 37 Benjamin Road, Arlington, Mass.
SHAW, R. E. (*M* 1921), Sales Mgr. (for mail), B. F. Sturtevant Co., Hyde Park, Boston, and Wellesley Hills, Mass.
SHAWLIN, Walter C. (*A* 1931), Pres. and Gen. Mgr. (for mail), Northwestern Fan & Blower Co., 647 West Virginia St., and 1545 North 50th St., Milwaukee, Wis.
SHEA, Michael B. (*M* 1930), (for mail), American Radiator Co., 1344 Broadway, Detroit, and 95 Richton Ave., Highland Park, Mich.
SHEARS, Matthew W. (*M* 1922), 39 Sylvan Ave., Toronto, Ont., Canada.
SHEFFIELD, Edward B. (*M* 1921), Sales Engr. (for mail), Armstrong Cork & Insulation Co., 522 King St., W., and 25 Government Road, Lambton Mills, Toronto, Ont., Canada.
SHEFFLER, M. (*M* 1921), Pres. (for mail), Sheffler-Gross Co., Inc., 203-11 Drexel Bldg., and 5451 Lebanon Ave., Philadelphia, Pa.
SHELDON, Nelson E. (*M* 1927), Dist. Sales Mgr. (for mail), Carrier-York Corp., 912 Temple Bldg., and 942 Genesee Park Blvd., Rochester, N. Y.
SHELNEY, Thomas (*M* 1931), Pres., Pierce Blower Corp., 27 Carolina St., and (for mail), 196 W. North St., Buffalo, N. Y.
SHEPARD, John deB. (*J* 1929), Sales Engr., Carrier Engrg. Corp., 1726 Land Title Bldg., Philadelphia, Pa.
SHEPPARD, F. A. (*M* 1918), Salesman (for mail), Johnson Service Co., 411 E. Tenth St., and 27 East 70th St., Kansas City, Mo.
SHEPPARD, William G. (*M* 1922), Sheppard & Abbott, 119 Harbour St., Toronto, Ont., Canada.
SHEPSTONE, Oscar (*M* 1927), Engr., Detroit Edison Co., 2000 Second Ave., and (for mail), 121 N. Phillip Ave., Detroit, Mich.
SHERET, Andrew (*M* 1929; *A* 1925), Pres. (for mail), Andrew Sheret, Ltd., 1114 Blanshard St., and 1030 St. Charles St., Victoria, British Columbia.
SHERRY, Raymond Wilbur (*M* 1927), 601 Peace St., Hazelton, Pa.
SHIELDS, Morton K. (*J* 1930), Carrier Engrg. Corp., 748 E. Washington St., Los Angeles, Calif.
SHIMANSKI, Victor E. (*M* 1931), Dist. Sales Mgr., Trane Co., La Crosse, Wis.
SHINOHARA, Shiro (*M* 1924), Z. Chome Kojimachi, Kojimachikes, Tokyo, Japan.
SHIPP, C. C. (*M* 1923), Owner, C. C. Shipp & Co., 230 E. Ohio St., Room 210, Indianapolis, Ind.
SHIVERS, Paul F. (*M* 1930), Chief Engr., Research and Development Div. (for mail), Minneapolis-Honeywell Regulator Co., W. Canal St., and 472 Falls Ave., Wabash, Ind.
SHODRON, John G. (*M* 1921), Consulting Engr. and Researchist, James Mfg. Co., and (for mail), 419 E. Milwaukee Ave., Ft. Atkinson, Wis.
SHORB, Will A. (*M* 1909), 3 Lincoln Place, Decatur, Ill.

SHREINER, Dewey C. (*A* 1926; *J* 1923), Vice-Pres-Treas. (for mail), Shreiner & Son, Inc., 116 W. High St., and 1240 S. Boulevard, Elkhart, Ind.
SHROCK, J. H. (*M* 1924), Vice-Pres. (for mail), New York Blower Co., and 1524 Michigan Ave., La Porte, Ind.
SHRUM, A. T. (*M* 1928), 712 Louisville Trust Bldg., Louisville, Ky.
SHUELL, Frank W. (*A* 1921), Pres. and Gen. Mgr. (for mail), Ever-Hot Heater Co., 5241 Wesson Ave., Detroit, and Lone Pine Road, Bloomfield Hills, Mich.
SHUFELT, Howard M. (*A* 1928), 7353 Bennett Ave., Chicago, Ill.
SHULTZ, Earle (*A* 1919), Vice-Pres. (for mail), Illinois Maintenance Co., 1136-72 W. Adams St., and 5555 Sheridan Road, Apt. 1411, Chicago, Ill.
SIEBS, Claude T. (*A* 1927), Elec. and Mech. Engr., Western Elec. Co., Inc., 80 John St., New York, N. Y.
SIEGEL, Leo (*M* 1928; *A* 1925; *J* 1924), 1970 East 18th St., Brooklyn, N. Y.
SIMMS, Robert C. (*A* 1929), 3725 Taylor Ave., Drexel Hill, Pa.
SIMONDS, A. H. (*J* 1929), Sales Engr. (for mail), Carrier Engrg. Corp., 748 E. Washington Blvd., and 1128 S. Longwood Ave., Los Angeles, Calif.
SIMPSON, Richard B. (*A* 1929), Sales Engr. (for mail), Armstrong Cork & Insulation Co., 120 W. Illinois St., Chicago, and 428 S. Euclid Ave., Oak Park, Ill.
SIMPSON, William A. (*M* 1925), 1160 Cromwell Ave., New York, N. Y.
SIMPSON, William K. (*M* 1919), Vice-Pres. (for mail), Hoffman Specialty Co., and 9 Sands St., Waterbury, Conn.
SKELLY, John F. (*M* 1921), Pres., John F. Skelly (for mail), 314 Ford St., Ogdensburg, N. Y.
SKIDMORE, John G. (*J* 1930), Student Engr., Carrier Engrg. Corp., 850 Frelinghuysen Ave., Newark, and (for mail), 321 Elmora Ave., Apt. 104, Elizabeth, N. J.
SKILLIN, N. Morton (*A* 1930), Dist. Sales Mgr., Cohoes Rolling Mill Co., 2631 Woodward Ave., Detroit, and (for mail), 860 Beaconsfield Road, Grosse Pointe Park, Mich.
SKINNER, H. W. (*M* 1920), Consulting Mech. Engr. (for mail), P. O. Box 1334, and 3619 Watonga St., Ft. Worth, Texas.
SKLENARIK, Louis (*J* 1928), 305 East 72nd St., New York, N. Y.
SLATER, Jean B. (*M* 1930), Sales Engr., Alberger Heater & Howard Iron Works, 287 Chicago St., Buffalo, and (for mail), 215 Lamarck Drive, Snyder, N. Y.
SLAYTER, Games (*M* 1931), Pres., *Games* Slayter, Inc., 1635 Holden Ave., Detroit, Mich.
SLIGHT, Irvin (*A* 1925), Partner (for mail), Slight Bros., 741 Yorkway Place, Jenkintown, and Hartsville, Pa.
SMAIL, A. Melville (*M* 1931), Chief Engr. (for mail), Wright Junior High School, 3400 N. Austin Ave., and 160 N. Menard Ave., Chicago, Ill.
SMALL, John D.* (*M* 1910), 940-127 N. Dearborn St., Chicago, Ill.
SMALLMAN, Edwin W. (*M* 1920), Engr. (for mail), Veterans Administration, and 705 Shepherd St., N. W., Washington, D. C.
SMALLMAN, William T. (*Life Member*; *M* 1911), Treas. (for mail), Isaac Coffin Co., 52 Sudbury St., Boston, and 127 Rockland Ave., Malden, Mass.
SMITH, C. Warner (*A* 1930), Dist. Mgr. (for mail), Ilg Elec. Vtg. Co., 325 Commercial Trust Bldg., Philadelphia, and 128 Kenilworth Road, Merion, Pa.
SMITH, Elmer G.* (*M* 1929), Asst. Prof. (for mail), Agricultural and Mechanical College of Texas, College Station, Texas.
SMITH, Frank J. (*J* 1930), Junior Engr., Carrier Engrg. Corp., 850 Frelinghuysen Ave., Newark, and (for mail), 1 Fernwood Place, Upper Montclair, N. J.
SMITH, Gard Wentworth (*M* 1927), Markle, Ind.
SMITH, George P. (*M* 1922), Mgr., Chicago Br. (for mail), The Herman Nelson Corp., 520 N. Michigan Ave., and 6851 Paxton Ave., Chicago, Ill.
SMITH, Harold Paul (*M* 1928), Mgr. (for mail), H. Smith Co., Front St. and Maple Ave, Red Bank, and 17 De Normandie Ave., Fair Haven, N. J.
SMITH, John Colbourne (*A* 1929; *J* 1927), Sales Engr., Niagara Blower Co., 673 Ontario St., Buffalo, and (for mail), 95 Columbia Blvd., Kenmore, N. Y.
SMITH, Leslie L.* (*M* 1919), Smith, Hinchman & Grylls, 800 Marquette Bldg., Detroit, Mich.
SMITH, Milton S. (*M* 1919), Vice-Pres. (for mail), Carrier Corp., 850 Frelinghuysen Ave., Newark, and 13 N. Terrace, Maplewood, N. J.
SMITH, Owen J. (*A* 1931), Box 991, Scotts Bluff, Neb.
SMITH, Philip C., Jr. (*M* 1928), Northport, L. I., N. Y.
SMITH, Robert C. (*A* 1930), Columbia Radiator Co., 1411 Union Bank Bldg., Pittsburgh, Pa.
SMITH, Russell J. (*A* 1929), Sales Engr., Modine Mfg. Co., 7557 Buckingham Drive, St. Louis, Mo.
SMITH, Wilbur F. (*M* 1920), 422 Bryn Mawr Ave., Cynwyd, Pa.
SNELL, Ernest (*M* 1920), 3914 Le May Ave., Detroit, Mich.
SNELLING, Louis R. (*M* 1930), Mgr., National Radiator Corp., 259 Delaware Ave., and (for mail), 766 Crescent Ave., Buffalo, N. Y.
SNIDER, L. A. (*M* 1927), Pres. (for mail), L. A. Snider Engrg. Service, Inc., 605 N. Michigan Ave., and 649 Buena Ave., Chicago, Ill.
SNYDER, Allen K. (*J* 1930), Asst. to Sales Promotion Mgr. (for mail), York Ice Mchy. Corp., and 951 Grantley Road, York, Pa.
SNYDER, Jay W. (*M* 1917), McColl-Snyder-McLean, 2304 Penobscot Bldg., Detroit, Mich.
SNYDER, Joseph S. (*A* 1925), Sales Engr., Detroit Lubricator Co., 374 Delaware Ave., and (for mail), 39 Granger Place, Buffalo, N. Y.
SODEMANN, Paul W. (*M* 1926; *A* 1925; *J* 1920), Salesman, Carrier Engrg. Corp. (for mail), 1596 Arcade Bldg., and 4551 Queens Ave., St. Louis, Mo.
SODEMANN, William C. B. (*M* 1919), Pres. (for mail), Sodemann Heat & Power Co., 2306 Morgan St., and 3510-A University St., St. Louis, Mo.
SODERBERG, C. H. (*M* 1919), Consulting Engr., 672 Puritan Road, Birmingham, Mich.
SOMERS, William Stuart (*M* 1928; *J* 1926), *Factory Mgr., Armstrong Furnace Co.*, and (for mail), 1547 Guilford Road, Columbus, Ohio.
SOMMER, Louis J., Jr. (*M* 1922), Pres. (for mail), Louis J. Sommer & Son, Inc., 2436 Brown St., Philadelphia, Pa.
SONNEBORN, Charles (*M* 1930), Vice-Pres. in Charge of Production, Shaw-Perkins Mfg. Co., W. Pittsburgh, and (for mail), R. D. No. 3, New Castle, Pa.
SONNEBORN, Robert H. (*A* 1929), (for mail), Youngstown Sheet & Tube Co., 713 Fisher Bldg., and 3480 Edison Ave., Detroit, Mich.
SOPER, Horace A. (*M* 1916), Vice-Pres. (for mail), American Foundry & Furnace Co., and 1122 E. Monroe St., Bloomington, Ill.
SOULE, Lawrence C.* (*M* 1908), Secy. and Chief Engr. (for mail), Aerofin Corp., 850 Frelinghuysen Ave., Newark, and Gordon and Stewart Roads, Essex Fells, N. J.
SOWERS, Paul E. (*M* 1922), Engr. and Mgr. (for mail), Paul E. Sowers Co., 25 N. Duke St., and 110 N. Finlay St., York, Pa.
SPAFFORD, Allen (*A* 1927), Factory Supt. (for mail), Wood Conversion Co., and 406 Ave. D, Cloquet, Minn.
SPAFFORD, Lewis Burton (*A* 1929), Engrg. Editor (for mail), Heating, Piping and Air Conditioning, 1900 Prairie Ave., Chicago, Ill., and Buchanan, Mich.

SPECKMAN, Charles H. (*M* 1918), 375 The Bourse, Philadelphia, Pa.
SPELLER, Frank N.* (*M* 1908), Dir., Dept. of Metallurgy and Research (for mail), National Tube Co., 1810 Frick Bldg., and 6411 Darlington Road, Pittsburgh, Pa.
SPERZEL, Henry J. (*M* 1919; *A* 1918), Kewanee Boiler Co., 708-10 Builders Exchange, Minneapolis, Minn.
SPIELMANN, Gordon P. (*J* 1923), Vice-Pres. (for mail), Harrison-Spielmann Co., 480 Milwaukee Ave., Chicago, and 730 N. Prospect Ave., Park Ridge, Ill.
SPITZLEY, Ray L. (*M* 1920), Pres. and Gen. Mgr. (for mail), R. L. Spitzley Htg. Co., 1200 W. Fort St., Detroit, and 1050 Yorkshire Road, Grosse Pointe, Mich.
SPOFFORTH, Walter (*M* 1930), 1654 James St., St. Paul, Minn
SPRAGUE, James F. (*M* 1930), 612–39th St., Milwaukee, Wis.
SPROULL, Howard E. (*M* 1920), Div. Sales Mgr. (for mail), American Blower Corp., 1005-6 American Bldg., and 3588 Raymar Drive, Hyde Park, Cincinnati, Ohio.
SPURGEON, Joseph H. (*M* 1924), Sales Engr. (for mail), Jos. H. Spurgeon Co., 5203 General Motors Bldg., and 17215 Pennington Drive, Detroit, Mich.
STACEY, Alfred E., Jr.* (*M* 1914), Wootton Road, Essex Fells, N. J.
STACKHOUSE, Ray M. (*M* 1919; *A* 1908), 1369 East 51st St., Chicago, Ill.
STACY, Stanley C. (*M* 1931), 13 Fitzhugh St., Rochester, N. Y.
STAMMER, Edward L. (*M* 1919), Board of Education, 506-911 Locust St., St. Louis, Mo.
STANDISH, Myles (*M* 1929), 171 Commercial St., Worcester, Mass.
STANFORD, Leland E. (*M* 1921), 445 Hudson Road, R. D. 3, Kent, Ohio.
STANGER, Ralph B. (*M* 1920), Mgr. (for mail), Robinson & Stanger, Empire Bldg., Pittsburgh, and Deer Creek Church Road, Glenshaw, Pa.
STANGLAND, B. F. (*Charter Member*), (2nd Vice-Pres., 1908; Board of Governors, 1905-1906-1909; Board of Mgrs., 1895-1899; Council, 1896-1897), Morton, N. Y.
STANNARD, James M.* (*M* 1906), (Council, 1914-1917; Board of Governors, 1913), Stannard Power Equipment Co., 925-8 Monadnock Block, Chicago, Ill.
STANTON, Gerard W. (*M* 1928), 231 Washington Place, Hasbrouck Heights, N. J.
STAPLES, William H. (*A* 1924), Engr. (for mail), Gillis & Geoghegan, 537 W. Broadway, and 605 West 151st St., New York, N. Y.
STARK, W. Elliott* (*M* 1926), Research Engr., Bryant Heater & Mfg. Co., 17825 St. Clair Ave., Cleveland, and (for mail), 1875 Rosemont Road, East Cleveland, Ohio.
STAUD, Clement J. (*A* 1929), Htg. Engr., Federal Radiator Co., 301 Brushton Ave., Pittsburgh, and (for mail), R. F. D. No. 4, Box 460-A, Milvale, Pa.
STEARNS, Walter I. (*A* 1926), Owner, W. I. Stearns Co., 560 North 16th St., Philadelphia, Pa.
STECKHAN, Louis (*M* 1928; *A* 1928; *J* 1926), Estimator, Crane Co. (for mail), 30 South 16th St., and 3014 Indiana Ave., St. Louis, Mo.
STEDMAN, Charles N. (*M* 1921), C. N. Stedman Co., 610 Wrigley Bldg., Chicago, Ill.
STEELE, Alfred N. (*M* 1930), Gen. Salesman, Trane Co., La Crosse, Wis., and (for mail), 220 S. Maple Ave., Oak Park, Ill.
STEELE, Harry G. (*A* 1931), 200 E. Slauson Ave., Los Angeles, Calif.
STEELE, Maurice G. (*M* 1929), Engr. (for mail), The Rome Radiation Co., and 906 N. Madison St., Rome, N. Y.
STEEN, Joseph M. (*M* 1929), Pres. (for mail), Iron City Htg. Co., 843 Jacksonia St., and 906 Quaill Ave., Bellevue, P. O., Pittsburgh, Pa.
STEIM, Charles J., Jr. (*M* 1923), Br. Mgr. (for mail), C. A. Dunham Co., 11 N. Pearl St., and 1074 Washington Ave., Albany, N. Y.
STEINHORST, Theodore F. (*M* 1919), Engr. and Treas., Emil Steinhorst & Sons, Inc., 612-616 South St., and (for mail), 1664 Brinckerhoff Ave., Utica, N. Y.
STEINKE, George B. (*M* 1924), Pres. (for mail), George B. & B. H. Steinke Co., Inc., 103 Park Ave., New York, N. Y., and 375 North 13th St., Newark, N. J.
STEINMUELLER, John M. (*M* 1925), Mech. Engr. (for mail), Thompson-Starrett Co., Inc., 245 Hunters Point Ave., Long Island City, and 10 Ocean Pkwy., Brooklyn, N. Y.
STE. MARIE, Gaston P. (*M* 1930), Sales and Service Engr., C. A. Dunham & Co., Ltd., Room 1428, University Tower Bldg., and (for mail) 7208 St. Denis St., Montreal, P. Q., Canada.
STEPHEN, Harold M. (*A* 1926), James E. Degan Co., 2130 Franklin St., Detroit, Mich.
STEPHENSON, George A. (*M* 1931), 139 Stratford Road, Buffalo, N. Y.
STEPHENSON, L. A. (*M* 1917), Mgr., Powers Regulator Co., 409 East 13th St., Kansas City, Mo.
STERN, H. Richard (*M* 1923), Pres. (for mail), Johnson & Morris, 233 West 18th St., and 225 West 86th St., New York, N. Y.
STERNBERG, George A. (*M* 1931), Member of Firm, Weather Control Co., 123 White St., and (for mail), 58 East 92nd St., New York, N. Y.
STETSON, Lawrence R. (*M* 1913), 303 Congress St., Boston, Mass.
STEVENS, F. H. (*A* 1924), 455 Norwood Ave., S. E., Grand Rapids, Mich.
STEVENS, Harry L. (*A* 1927; *J* 1924), Secy. (for mail), M. M. Stevens, 108 W. Sherman St., and 7 West 22nd, Hutchinson, Kan.
STEVENSON, Merle E. (*J* 1929), Repr., Stevenson Htg. Co., 1615 E. Main St., and (for mail), 51 South 16th St., Richmond, Ind.
STEVENSON, W. W. (*M* 1928), Steam Htg. Engr. (for mail), Allegheny County Steam Htg. Co., 435 Sixth Ave., and 1125 Lancaster Ave., Pittsburgh, Pa.
STEWART, Charles W. (*M* 1919, *A* 1918), Asst. Gen. Sales Mgr. (for mail), Hoffman Specialty Co., 3707 Chrysler Bldg., and 70 East 96th St. New York, N. Y.
STEWART, Duncan J. (*A* 1930), (for mail), Barber-Colman Co., River and Loomis Sts., and 214 Franklin Place, Rockford, Ill.
STEWART, Earl A. (*J* 1930), P. O. Box 158, Washington, Pa.
STILES, Harry Leroy (*M* 1928), Mech. Engr. (for mail), Edison General Elec. Appliance Co., 5600 W. Taylor St., and 525 N. Austin Blvd., Chicago, Ill.
STILL, F. R.• (*M* 1904), (*Presidential Member*), (Pres., 1918; 2nd Vice-Pres., 1917; Council, 1916-1919), Vice-Pres. and Mgr. of Export Dept. (for mail), American Blower Corp., 401 Broadway, and 1 East End Ave., New York, N. Y.
STITT, Eugene W. (*M* 1917), Sales Engr. (for mail), National Radiator Corp., 221 Central Ave., and 217 Fayette St., Johnstown, Pa.
STITT, Howard B. (*A* 1922), Sales Engr., National Radiator Corp., 431 W. Georgia St., and (for mail), 5355 Broadway, Indianapolis, Ind.
STOCKENBERG, Ruben (*M* 1922), Johnson Service, Co., 1355 W. Washington Blvd., Chicago, Ill.
STOCKWELL, William R. (*M* 1903; *J* 1901), Gen. Mgr., Mfg. Div., Weil-McLain Co., Michigan City, Ind.
STOEVER, George H. (*M* 1930), Chief Engr., John J. Nesbitt, Inc., State Road and Rhawn Sts., Holmesburg, and (for mail), 7014 Cottage St., Tacony, Philadelphia, Pa.
STOKES, Ralph E. (*M* 1920), Htg. and Vtg. Engr., 1337 East 185th St., Cleveland, Ohio.
STONE, Eugene R. (*M* 1913), 171 Harrison Ave., Boston, Mass.
STONE, George F. (*M* 1918), 4520 N. Carlisle St., Philadelphia, Pa.

STORCH, Clemens A. (*M* 1930), Sales Engr. (for mail), Johnson Service Co., 1355 W. Washington Blvd., and 1725 N. Shore Ave., Chicago, Ill.
STRACHAN, George W. (*M* 1930), 1848 Hillsdale Ave., Pittsburgh, Pa.
STRACHAN, John S. (*M* 1928), Consulting Engr., 121 Furman St., Schenectady, N. Y.
STRANDWITZ, William J. (*M* 1919), Pres. (for mail), Strandwitz & Scott, Inc., 537 S. Second St., Camden, and 325 Hawthorne Ave., Haddonfield, N. J.
STRICKLAND, Albert W. (*A* 1929), Supt. of Bldgs., and Chief Engr., Fountain Valley School, Colorado Springs, Colo.
STROCK, Clifford (*A* 1929), Associate Editor Heating and Ventilating, 148 Lafayette St., and (for mail), 72 Barrow St., New York, N. Y.
STRONG, Edward A., Jr. (*A* 1928), 309 N. Alabama St., Indianapolis, Ind.
STROUSE, Sidney B. (*M* 1921), Dist. Mgr. (for mail), Warren Webster & Co., 429 Guarantee Trust Bldg., and 22 S. Illinois Ave., Atlantic City, N. J.
SUITS, George A. (*M* 1923), Service Engr., Hoffman Specialty Co., 26 Stanley Ave. Medford, Mass.
SULLIVAN, Daniel A. (*M* 1923), Engr. and Estimator, Callahan Engrg. Co., Inc., 20 Grove St., White Plains, and (for mail), 3178 Rochambeau Ave., New York, N. Y.
SULLIVAN, Tim J. (*M* 1930), (for mail), Sullivan Valve & Engrg. Co., 910 S. Arizona St., and 1205 W. Park St., Butte, Mont.
SUMMERS, Ernest T. (*A* 1930), Pres. (for mail), Summers-Darling & Co., 386 Donald St., and Suite 12, The Willingdon Apts., Winnipeg, Manitoba, Canada.
SUTCLIFFE, Arthur G. (*M* 1922; *A* 1918), 4146 N. St. Louis Ave., Chicago, Ill.
SWAIN, Wilbur A. (*A* 1926), Jenkins Bros., 80 White St., New York, N. Y.
SWAN, Ernest H. (*M* 1929), Htg. and Vtg. Engr. (for mail), W. A. Swan & Sons, 122 Unley Road, Unley, and 25 Austral Terrace, Malvern, South Australia.
SWANEY, Carroll R. (*M* 1929; *J* 1921), Gilbert Howe Gleason, 25 Huntington Ave., Boston, and 43 Clyde St., Newtonville, Mass.
SWARTWOUT, J. D. (*M* 1917), Secy-Treas., J. D. Swartwout Co., 613 Millard St., and (for mail), 349 S. Weadock Ave., Saginaw, Mich.
SWEENEY, Sylvester H. (*M* 1915), S. H. Sweeney (for mail), 306 East 39th St., and 1916 Loring Place, New York, N. Y.
SWEET, Homer (*A* 1931), 914 Main St., Buffalo, N. Y.
SWENSON, John E. (*A* 1930), Indus. Engr. (for mail), Minneapolis Gas Light Co., 800 Hennipen Ave., and 4153 South 21st Ave., Minneapolis, Minn.
SWIFT, Clement K. (*A* 1928), MacAndrews & Forbes Co., Third St., and Jefferson Ave., Camden, N. J.
SYLVAN, Stig G. (*M* 1930), 102 Kennedy St., Bradford, Pa.
SZEKELY, Ernest (*M* 1920), Chief Engr. (for mail), Bayley Blower Co., 1938 S. Fourth St., and 3104 W. Kilbourn Ave., Milwaukee, Wis.
SZOMBATHY, Louis R. (*A* 1930), Ferguson Sheet Metal Works, Inc., 34 N. Florissant Blvd., Ferguson, Mo.

T

TABY, Joseph C. (*A* 1930), Owner and Mgr., Jos. C. Taby & Co., Second and Walnut Sts., Shamokin, Pa.
TAGGART, Ralph C.• (*M* 1912), 14 Lyon Ave., Menands, Albany, N. Y.
TALIAFERRO, Robert R.* (*M* 1919), Sales Engr. (for mail), Carrier Engrg. Corp., 1726 Land Title Bldg., Philadelphia, and 838 Beechwood Road, Upper Darby, Pa.
TALLMADGE, Webster (*M* 1924), Pres., Webster Tallmadge & Co., Inc., 50 Church St., New York, N. Y.
TARR, Harold M. (*M* 1931), 21 Montague St. Arlington Heights, Mass.
TAVANLAR, E. J.* (*J* 1931), Engr. (for mail), Associated Gas & Elec. System, 89 East Ave., Rochester, N. Y., and Binalonan, Paryasinan, Philippine Islands.
TAVERNA, Frederick F. (*M* 1928; *A* 1927; *J* 1924), Engr., Raisler Htg. Co., 129 Amsterdam Ave., New York, N. Y., and (for mail), 406–12th St., Union City, N. J.
TAYLOR, John H. (*A* 1928), Pres., Hutchison Regulator Sales Corp., 9344–215th Place, Queens Village, L. I., N. Y.
TAYLOR, Kenneth A. (*J* 1930), Carrier-York Corp., 1541 Sansom St., Philadelphia, Pa.
TAZE, Donovan L. (*M* 1931), 604 Building and Loan Bldg., Grand Rapids, Mich.
TEAGUE, William Wallace* (*M* 1929), Research Engr. (for mail), Research Lab., A.S.H.V.E., 4800 Forbes St., and 244 Spahr St., Pittsburgh, Pa.
TEASDALE, Lawrence Aldrich (*M* 1926), Partner, Hollis French, 210 South St., Boston, Mass. (for mail), 20 Ashmun St., and 199 Nicoll St., New Haven, Conn.
TEELING, George A. (*M* 1930), Dist. Engr. (for mail), B. F. Sturtevant Co., 77 South Ave., Room 218, and 29 Probert St., Rochester, N. Y.
TEMPLE, Walter J. (*A* 1931) Engr., J. A. Temple Co., 919 E. Michigan Ave., and (for mail), 1306 Clinton Ave., Kalamazoo, Mich.
TEMPLIN, Charles L. (*M* 1921), Dist. Mgr. (for mail), Carrier-York Corp., 305 Bona Allen Bldg., and 764 Greenwood Ave., N. E., Atlanta, Ga.
TEN BROOK, C. S. (*J* 1930), Sales Engr. (for mail), The Trane Co., La Crosse, Wis., and 1009 W. Fourth St., Duluth, Minn.
TENNANT, Raymond J. J. (*A* 1929), 435 Sixth Ave., Pittsburgh, Pa.
TERRELL, Herbert A. (*M* 1915), Carrier Engrg. Corp., 39 Cortlandt St., New York, N. Y., and (for mail), 19 Hampton Hall, Cranford, N. J.
TETEREVNIKOFF, Nikolas (*M* 1930), 3 Fifth Soviet St., Leningrad, U. S. S. R.
THAIN, Arthur Edgar (*A* 1926), 1109 N. Charles St., and (for mail), 2116 Mt. Holly St., Baltimore, Md.
THATCHER, George S. (*M* 1919), Pres. (for mail), Thatcher Htg. Co., 356 Spicer St., and 665 Nome Ave., Akron, Ohio.
THAYER, Allen J. (*J* 1929), Engr. and Estimator, Carmon-Thompson Co., 12-14 Lincoln St., and (for mail), 182 Summer St., Auburn, Maine.
THEORELL, Hugo C. T.* (*Life Member*; *M* 1902), Consulting Engr., Hugo Theorells Ingenieussbyra, Skoldungagatan 4, Stockholm, Sweden.
THINN, Christian A.* (*M* 1921), Chief Engr., C. A. Dunham Co., 450 E. Ohio St., Chicago, Ill.
THOMAS, Earle E. (*A* 1931), Sales Engr. (for mail), General Electric Co., 5201 Santa Fe Ave., Los Angeles, and 2040 La France Ave., South Pasadena, Calif.
THOMAS, Herbert G. (*M* 1917), Sales Engr., Warren Webster & Co., 549 W. Washington St., Chicago, and (for mail), 2312 Ridge Ave., Evanston, Ill.
THOMAS, Melvern F. (*M* 1909), Consulting Engr., 229 College St., Toronto, Ont., Canada.
THOMAS, Norman A. (*M* 1928), Pres. (for mail), Thomas Htg. Co., 1046 Herrick Ave., and 824 Monroe Ave., Racine, Wis.
THOMAS, R. H. (*M* 1920), Pres. (for mail), Economy Pumping Machinery Co., 3431 West 48th Place, Chicago, and 426 Forest Ave., Oak Park, Ill.
THOMMEN, Adolph A. (*A* 1929), 3400 West 61st Place, Chicago, Ill.
THOMMEN, Arthur R. (*J* 1929), 3400 West 61st Place, Chicago, Ill.
THOMPSON, Charles (*A* 1927), 720–13th St., Sacramento, Calif.
THOMPSON, Nelson S.* (*M* 1917; *J* 1897), 1615 Hobart St., N. W., Washington, D. C.
THOMPSON, Richard C. (*M* 1927), Power Equipment Co., 250 Stuart, St., Boston, Mass.

THOMPSON, William J. (*A* 1929), 11 York St., St. Catharines, Ont., Canada.
THOMSEN, William T. (*M* 1919), 3636 Fillmore St., St. Louis, Mo.
THOMSON, Thomas N.* (*M* 1899), Sanitary and Htg. Engr., Plumbing and Heating Contractors Trade Journal, 515 Madison Ave., New York, and (for mail), 37 Irwin Place, Huntington, N. Y.
THORNBURG, Harold A. (*J* 1929), Carrier Engrg. Corp., 1824 Union Trust Bldg., Cleveland, and (for mail), 1501 Carew Tower, Cincinnati, Ohio.
THORNTON, Frank, Jr. (*A* 1930), Mgr., Association Activities (for mail), Westinghouse Elec. & Mfg. Co., East Pittsburgh, and 166 N. Dithridge St., Pittsburgh, Pa.
THORNTON, Roger T. (*M* 1919), Sales Engr. (for mail), Buffalo Forge Co., 490 Broadway, and 46 Burbank Terrace, Buffalo, N. Y.
THORNTON, William B. (*M* 1931), Br. Engr. (for mail), Carrier-Lyle Corp., 1504 Clark Bldg., and 420 S. Graham St., Pittsburgh, Pa.
THRUSH, Homer A. (*M* 1918), H. A. Thrush & Co., 21-23 E. River St., Peru, Ind.
THUEM, Edward A. (*A* 1927; *J* 1922), Htg. and Vtg. Engr., Board of Education, Flatbush Ave. and Concord St., Brooklyn, and (for mail), 1922 Bogart St., Bronx, N. Y.
THURNESS, Bernard E. (*A* 1929), Dist. Mgr. (for mail), Carrier-York Corp., 1350 Hanna Bldg., and 1929 East 90th St., Cleveland, Ohio.
TIBBETS, John C. (*M* 1920), Htg. and Vtg. Engr., Engrg. Dept., Baltimore & Ohio R. R. Co., Room 1303, B. & O. Central Bldg., Baltimore, and (for mail), P. O. Box 106, Ellicott City, Howard County, Md.
TICHENOR, Leslie R., Jr. (*J* 1930), Member of Firm, L. R. Tichenor & Son, 1259 Robert St., Hillside, N. J.
TIERNEY, Lawrence J. J. (*A* 1930), Owner (for mail), L. J. Tierney Co., 1425 Statler Bldg., Boston, and 17 Oriole St., W. Roxbury, Mass.
TILDEN, Elwyn E. (*M* 1924), Asst. Mgr., N. E. Dist. (for mail), Warren Webster & Co., 76 Summer St., Boston, and Holbrook, Mass.
TILTZ, Bernard E. (*M* 1930), Pres. (for mail), Tiltz Air Conditioning Corp., 480 Lexington Ave., New York, and 24 Barnum Road, Larchmont Gardens, N. Y.
TIMMERMAN, Manford Monroe (*M* 1925; *J* 1921), Supervisor of Works Engrg., Westinghouse Elec. & Mfg. Co., E. Pittsburgh, and (for mail), 859 E. Hutchinson Ave., Swissvale, Pa.
TIMMIS, Pierce (*M* 1920), Service Equipment Engr. (for mail), United Engineers & Constructors, Inc., 112 N. Broad St., Philadelphia, and 202 Midland Ave., Wayne, Pa.
TIMMIS, W. Walter (*A* 1925), Mgr. (for mail), C. A. Dunham Co., 101 Park Ave., New York, and Oak Lane, Glen Cove, N. Y.
TINKER, A. K. (*M* 1927), Br. Mgr., National Radiator Corp., 1511 Investment Bldg., Pittsburgh, and (for mail), 234 Morrison Drive, Mt. Lebanon, Pa.
TINKER, William E. (*A* 1922), National Radiator Co., 121 N. Broad St., Philadelphia, Pa.
TISNOWER, William (*M* 1923), 131 Livingston St., Brooklyn, N. Y.
TITUS, Marvin Sinclair (*M* 1928), 99 Wandle Ave., Bedford, Ohio.
TJERSLAND, Alf (*M* 1916; *J* 1906), Chairman and Managing Director, E. Sunde & Co., Ltd., Oslo, Norway.
TOBIN, George J. (*M* 1905), Owner, Geo. J. Tobin (for mail), 187-191 North Ave., and 510 Grant Ave., Plainfield, N. J.
TOMLINSON, Malcolm C. W.* (*M* 1924), Westtown, Chester County, Pa.
TOOKER, Charles C. (*M* 1918), 116 North 27th St., Billings, Mont.
TOWER, Elwood S. (*M* 1930), Engr. (for mail), American Radiator Co., 310 Second Ave., and 1411 Wightman St., Pittsburgh, Pa.
TRANE, Reuben N.* (*M* 1915), Pres., The Trane Co., and (for mail), 126 South 15th St., La Crosse, Wis.
TRAUGOTT, Mortimer (*A* 1930), Dist. Sales Mgr., Bryant Heater & Mfg. Co., 152 North 15th St., Philadelphia, Pa.
TROSKE, Joseph J. (*A* 1931), 236 Winter Ave., N. W., Grand Rapids, Mich.
TRUE, John E. (*J* 1929), Dist. Mgr. (for mail), Carrier-York Corp., 622 Broadway, Cincinnati, and 1271 Rossmore Ave., Bond Hill, Ohio.
TRUITT, Joseph E. (*M* 1920; *A* 1911), Pres. (for mail), Autovent Fan & Blower Co., 1805-27 N. Kostner Ave., Chicago, and Park Ridge, Ill.
TRULSON, Arthur F. (*M* 1930), Associate Engr., Municipal Architect, Ford Bldg., and (for mail), 1214 Eye St., N. W., Apt. 12, Washington, D. C.
TRUMBO, Silas M. (*A* 1926), Sales Engr. (for mail), Buffalo Forge Co., 15 N. Jefferson St., Chicago, and 921 Franklin St., Downers Grove, Ill.
TUCKER, Frank N. (*M* 1926), 13 Park Row, Room 1108, New York, N. Y.
TULLOSS, Joseph C. (*M* 1930), 2117 O St., N. W., Washington, D. C.
TUPPER, George B. (*A* 1930), Gen. Mgr., Airmaster Corp., 230 W. Huron St., and (for mail), 5921 Kenmore Ave., Chicago, Ill.
TURLAND, Charles H. (*A* 1930), 325 Centennial St., Winnipeg, Manitoba, Canada.
TURNER, John W. (*M* 1930), 115 Myrtle St., Boston, Mass.
TURNER, John W. (*M* 1928), Chief Engr. (for mail), Pacific Steel Boiler Corp., 1056 First National Bank Bldg., and 32 Wellesley Drive, Detroit, and Pleasant Ridge, Royal Oak, Mich.
TURNO, Walter G. W. (*M* 1917; *A* 1912), 71 Lafayette Ave., E. Orange, N. J.
TUSCH, Walter (*M* 1917), 881 Sterling Place, Brooklyn, N. Y.
TUTTLE, J. Frank (*M* 1913), Mgr. (for mail), Warren Webster & Co., 76 Summer St., Boston, Mass.
TWIST, Charles F. (*M* 1921), (for mail), Ashwell-Twist Co., 967 Thomas St., and 2310–10th Ave., Seattle, Wash.
TYLER, Frank T. (*M* 1922), Asst. Sales Mgr. (for mail), Herman Nelson Corp., 1824 Third Ave., and 1615 Eighth Ave., Moline, Ill.
TYLER, Roy Dexter (*M* 1928), Eastern Sales Mgr. (for mail), Modine Mfg. Co., 101 Park Ave., New York, and 31 Highbrook Ave., Pelham, N. Y.
TYSON, Perry W. (*M* 1930), Salesman, James Spear Stover & Heating Co., 1823 Market St., Philadelphia, and (for mail), 109 Kent Road, Springfield, Pa.
TYSON, William Hope (*M* 1923), Mgr. of Engrg. (for mail), Goodyear Tire & Rubber Co., Ltd., and "Kipewa," Codsall Road, Wolverhampton, England.

U

UHL, Edwin J. (*M* 1925), Sales Engr. (for mail), 132 South 10th St., Minneapolis, Minn.
UHL, Willard F. (*M* 1918), 4716 Lyndale Ave., Minneapolis, Minn.
UHLHORN, W. J. (*M* 1920), 733 S. Highland Ave., Oak Park, Ill.
ULLMAN, Herbert G. (*A* 1928), Exec. Secy., Inst. of Thermal Research, American Radiator Co., 675 Bronx River Road, Yonkers, and (for mail), 107 White Road, Scarsdale, N. Y.
UNDERHILL, William W. (*M* 1913), Treas. (for mail), Stone-Underhill Htg. & Vtg. Co., 171 Harrison Ave., Boston, and 15 Kenwood St., Brookline, Mass.
UPDEGRAFF, Lee (*A* 1930), Mfrs. Repr., 405 S. Hill St., Los Angeles, Calif.
URDAHL, Thomas H. (*M* 1930), Consulting Engr. (for mail), Room 107, Jackson Place, N. W., and 1505–44th St., N. W., Washington, D. C.

V

VALE, Henry A. L. (*M* 1929), Company Director and Chief Heating-Mechanical Engr., Vale Co., Ltd., 141-143 Armagh St., Christchurch, P. O. Box 1828, Auckland, New Zealand.

VALIQUET, Harry Howell (*A* 1926), Sales Engr., Allen & Billmyre Co., Inc., 1240 Builders Bldg., 223 N. La Salle St., and (for mail), 6436 N. Albany, Chicago, Ill.
VAN ALEN, Walter T. (*M* 1924), Sales Engr. & Mfrs. Agt., Dole Valve Co., 1501 Grant Bldg., Pittsburgh, and (for mail), 1300 Darlington Road, Beaver Falls, Pa.
VAN ALSBURG, J. H. (*M* 1931), R. F. D. 10, Holland, Mich.
VANCE, Louis G. (*M* 1919), Mfrs. Agt., The Ric-wil Co., 1207 Garret Bldg., and (for mail), 3601 Garrison Blvd., Baltimore, Md.
VAN COURT, Walter G. (*M* 1930), Htg. Engr. and Field Supt., Wm. H. Lutton Co., 267 Kearney Ave., and (for mail), 557 Communipaw Ave., Jersey City, N. J.
VAN METER, B. F. (*J* 1930), Carrier Engrg. corp., 850 Frelinghuysen Ave., Newark, N. J.
VAN NORDEN, Ernest M. (*M* 1923), Civil Engr. (for mail), The New York Edison Co., 130 East 15th St., New York, and 120 Stratford Ave., Garden City, L. I., N. Y.
VAN SICKLE, William B. (*M* 1915), Pres. (for mail), The W. B. Van Sickle Co., 1623 St. Clair Ave., Cleveland, and 1530 Grace Ave., Lakewood, Ohio.
VAN ZANDT, John H. (*M* 1914), (for mail), 408 Dallas Bank & Trust Bldg., and 4416 Bryan St., Dallas, Texas.
VAUX, Noble (*A* 1923), 11 Holmelands Park S., Sunderland, England.
VER HALEN, Edward T. (*A* 1925), (for mail), Edward T. Ver Halen, Inc., 1110 N. Milwaukee St., and 286 Juneau Ave., Milwaukee, Wis.
VERMERE, Earl J. (*M* 1929), Br. Mgr., Trane Co., 2118 Grantwood Drive, Toledo, Ohio.
VERNON, J. Rexford (*M* 1928; *A* 1926), Sales Engr., Johnson Service Co., 1355 Washington Blvd., Chicago, and (for mail), 1020 Austin St., Evanston, Ill.
VETLESEN, G. Ungar (*M* 1930), Secy., Federated Laboratories, Inc., 229 East 38th St., New York, N. Y.
VIESSMAN, Warren (*M* 1930), Mech. and Elec. Engr., 2205 Lake Ave., Baltimore, Md.
VINCENT, Paul J. (*M* 1931), Paul J. Vincent Co., 1010 Chandler Bldg., Washington, D. C., and (for mail), 3807 Beech Ave., Baltimore, Md.
VIVARTTAS, E. Arnold (*M* 1910), 115 Parkside Ave., Brooklyn, N. Y.
VOGEL, Andrew (*M* 1926), Architect and Building Engr. (for mail), General Elec. Co., and 611 Lenox Road, Schenectady, N. Y.
VOGELBACH, Oscar (*M* 1923), Chief Engr., Guilbert & Betelle, Architects, 20 Branford Place, Newark, and (for mail), 23 William St., North Arlington, N. J.
VOGT, J. H. (*A* 1925), Chemical Engr. (for mail), N. Y. State Dept. of Labor, 80 Centre St., New York, and 87 Grant Ave., Brooklyn, N. Y.
VOGT, Joseph B. (*J* 1929), Heating Engr. (for mail), Dept. of Architect, N. Y. State, State Office Bldg., and 49 Summit Ave., Albany, N. Y.
VOISINET, Walter E. (*M* 1930), Sales Repr. (for mail), Herman Nelson Corp., 304 Curtiss Bldg., Delaware at Tupper, Buffalo, and 151 Warren Ave., Kenmore, N. Y.
VOLK, Joseph H. (*M* 1923), Pres-Treas. (for mail, Thos. E. Hoye Htg. Co., 1906 W. St. Paul Ave., and 2965 South 43rd St., Milwaukee, Wis.
VOORHEES, Guy A. (*M* 1922), Engr., Century Htg. Service, 633 S. Delaware St., and (for mail), 3451 Broadway, Indianapolis, Ind.

W

WACHS, Louis J. (*J* 1930), Engr., Carrier Engrg. Corp., 39 Cortlandt St., New York, and (for mail), 1 Chester Court, Apt. 6-A, Brooklyn, N. Y.
WAECHTER, Herman Paul (*A* 1930; *J* 1927), Air Conditioning Engr., York Ice Mchy. Corp., 42nd St., and Second Ave., Brooklyn, and (for mail), 89 Sherman Ave., Tompkinsville, S. I., N. Y.
WAGNER, A. M. (*A* 1921), Mgr., American Radiator Co., 902 N. Plankinton Ave., Milwaukee, Wis.
WAID, Glen H. (*A* 1930), Sales Mgr., Scott Valve Mfg. Co., 3963 McKinley Ave., and (for mail), 2928 Northwestern, Detroit, Mich.
WAITE, Harry (*A* 1929), Secy-Treas., Gray Plumbing Co., 1214 Ogden Ave., and (for mail), 1409 North 17th St., Superior, Wis.
WALKER, Alex. (*A* 1925), Br. Mgr. (for mail), C. A. Dunham Co., Ltd., 1307 Fifth St. W., and 603–13th Ave. W., Calgary, Alberta, Canada.
WALKER, George E. (*M* 1929), Nuroad P. O., North Kinloch, Mo.
WALKER, James H.* (*M* 1916), Supt. of Central Htg. (for mail), Detroit Edison Co., 2000 Second Ave., Detroit, and 432 Arlington Road, Birmingham, Mich.
WALLACE, Bruce (*M* 1930), 5 Eden St., Newmarket, Auckland, New Zealand.
WALLACE, George J. (*M* 1923), Engr. and Contractor, 1006 First Ave., New York, and (for mail), 27-36 Ericsson St., E. Elmhurst, L. I., N. Y.
WALLACE, Kenneth S. (*M* 1931), 231 W. Lockwood, Webster Groves, Mo.
WALLACE, R. Robert (*M* 1930), 313 Huron St., South Haven, Mich.
WALLACE, William M., II (*M* 1929), Vtg. Engr., Charles Hartmann Co., 985 Dean St., Brooklyn, and (for mail), 8908–196th St., Hollis, L. I., N. Y.
WALLICH, A. C. (*M* 1919), (for mail), Wallich Ice Mch. Co., 517 E. Larned St., and 1667 Burlingame St., Detroit, Mich.
WALSH, James A. (*J* 1929), Mgr. (for mail), Rome Radiation Co., 1108 Architects Bldg., Philadelphia, and R. D. 1, Ambler, Pa.
WALSH, Joseph F. (*M* 1928), 1163 Ocean Pkwy., Brooklyn, N. Y.
WALSH, Malcolm (*M* 1924), Vice-Pres. (for mail), Walsh & Wertheim, 504 W. Broadway, New York, and 91 Penbroke Ave., Staten Island, N. Y.
WALTER, William (*J* 1930), Carrier-York Corp., 149 Broadway, New York, N. Y.
WALTERS, Arthur L. (*M* 1926; *A* 1925; *J* 1924), Mgr. (for mail), Langenberg Mfg. Co., 4519 N. Euclid Ave., St. Louis, and 7284 Richmond Place, Maplewood, Mo.
WALTERS, William T. (*M* 1917), Engr., Illinois Engrg. Co., 21st St. and Racine Ave., and (for mail), 8053 Ingleside Ave., Apt. 1, Chicago, Ill.
WALTERTHUM, John J. (*A* 1922), Htg. and Vtg. Contractor, 173 East 62nd St., New York, N. Y., and (for mail), 42nd and Van Reipen Ave., Jersey City, N. J.
WALTHER, Harry J. (*M* 1919), Salesman (for mail), The H. B. Smith Co., 2209 Chestnut St., and 1115 Duncannon Ave., Philadelphia, Pa.
WALTHER, Vernon H. (*M* 1928; *J* 1925), (for mail), Radio Keith Orpheum Corp., 190 N. State St., and 6821 Osceola Ave., Edison Park, Chicago, Ill.
WALTON, Hiram Lessiter* (*M* 1916), Member of Firm (for mail), Smith, Hinchman & Grylls, 800 Marquette Bldg., and 244 Hildale Ave., Detroit, Mich.
WALTON, Louis A. (*J* 1930), Carrier Engrg. Corp., Union Trust Bldg., Cleveland, Ohio.
WANDLESS, Franklin W. (*M* 1925), Chief Engr. (for mail), Haynes Selling Co., Inc., 1518 Fairmount Ave., Philadelphia, and Berwyn, Pa.
WARD, Oscar G. (*M* 1919), Mgr. (for mail), Johnson Service Co., 1230 California St., and 1009 Grant St., Denver, Colo.
WARD, Robert N. (*M* 1930), Office Mgr., Syska & Hennessy, 420 Lexington Ave., New York, and (for mail), 275 Carlton Terrace, Teaneck, N. J.
WARD, William T. (*M* 1930), 18 Castlefield Ave., Toronto, Ont., Canada.
WARE, James E., Jr. (*J* 1930), Carrier Mfg. Corp., Old Emaus Road, Allentown, Pa.
WARREN, Clarence N. (*M* 1919), Vice-Pres., Hayes Bros., Inc., 236 W. Vermont St., and (for mail), 419 East 48th St., Indianapolis, Ind.

WARREN, Frederick A. (*A* 1930), 1074 Crescent Ave., Atlanta, Ga.
WARREN, Harry L. (*M* 1930), 1303 Huntington Drive, S. Pasadena, Calif.
WARREN, Walter J. (*M* 1930), Engr. (for mail), Carrier Engrg. Corp., 1032 Burnham Bldg., Chicago, and 118 Gillick St., Park Ridge, Ill.
WASHINGTON, Laurence W. (*M* 1929), 2301 Knox Ave., Chicago, Ill.
WATERMAN, John H. (*M* 1931), 201 Devonshire St., Boston, Mass.
WATERS, George C. (*A* 1926), Dist. Mgr. (for mail), American Blower Corp., 801 First National Bank Bldg., Pittsburgh, and 52 Vernon Drive, Mt. Lebanon, Pa.
WATSON, John H. (*M* 1925), Engr., Drying Systems, Inc., 1800 Foster Ave., and (for mail), 2045 Farragut Ave., Chicago, Ill.
WATSON, M. Barry (*M* 1928), Consulting Engr., 121 Welland Ave., Toronto, 5, Ont., Canada.
WATTERS, Peter J. (*M* 1921), Mgr., John Watters (for mail), 55 Church St., Port Richmond, and 44 Moody Place, W. New Brighton, S. I., N. Y.
WEAGER, T. A. (1920), Dist. Mgr. (for mail), Buffalo Forge Co., Rockefeller Bldg., and 3124 Berkshire Road, Cleveland, Ohio.
WEBB, John S. (*M* 1920), Consulting Engr., Alfred Kellogg, 585 Boylston St., Boston, and 16 Brookline St., Needham, Mass.
WEBB, John William (*M* 1926), Managing Director, Webb Dust Removing & Drying Co., Ltd., Princess St. and Park St. Works, and (for mail), 6 Meadows Road, Heaton Chapel, Stockport, England.
WEBER, Erwin L.* (*M* 1921), Consulting Engr., 534-5 Lumber Exchange, Seattle, Wash.
WEBSTER, E. Kessler (*M* 1915), Secy. and Asst. Gen. Mgr., Warren Webster & Co., 17th and Federal Sts., Camden, N. J.
WEBSTER, Warren (*M* 1906; *A* 1899), Pres. and Gen. Mgr. (for mail), Warren Webster & Co., 17th and Federal Sts., Camden, and Ocean County, N. J.
WEBSTER, Warren, Jr. (*J* 1927), Vice-Pres-Treas. (for mail), Warren Webster & Co., 17th and Federal Sts., Camden, and Colonial Ridge and Washington Ave., Haddonfield, N. J.
WEGMANN, Albert (*M* 1918), Owner, A. Wegmann Co., 2813 W. Fletcher St., and (for mail), 6206 North 17th St., Philadelphia, Pa.
WEIDER, Frederick J. (*M* 1919), Vice-Pres-Treas. (for mail), Barr & Creelman Co., 74 Exchange St., and 40 Kenwood Ave., Rochester, N. Y.
WEIL, Martin (*A* 1925), Secy., Weil-McLain Co., 641 W. Lake St., Chicago, Ill.
WEIL, Maurice I. (*A* 1928), Pres. (for mail), Chicago Pump Co., 2336 Wolfram St., and 1409 Elmdale Ave., Chicago, Ill.
WEIMER, Fred G. (*A* 1919), Br. Mgr., Kewanee Boiler Corp., 1132 S. Barclay St., and (for mail), 3958 N. Stowell Ave., Milwaukee, Wis.
WEINSHANK, Theodore* (*M* 1906), (Board of Governors, 1913), 2323 Kedzie Blvd., Chicago, Ill.
WEISS, Arthur Paul (*M* 1928), Asst. Treas., Burnham Boiler Corp., Irvington, and (for mail), 124 Farrington Ave., North Tarrytown, N. Y.
WEISS, Carl A. (*A* 1924), Supt., Kornbrodt Kornice Ko., 1811 Troost Ave., and 29 East 68th St., Kansas City, Mo.
WEITZEL, Robert D. (*J* 1929), Htg. Contractor, 2445 N. Fifth St., Harrisburg, Pa.
WEIXEL, Albert L. (*M* 1928), Consulting Engr., 1020 Builders Bldg., 228 N. La Salle St., Chicago, Ill.
WELAMB, Victor N. (*M* 1918), V. N. Welamb Co., 105 N. Watts St., Philadelphia, Pa.
WELCH, Louis A., Jr. (*A* 1929), Owner (for mail), Welch Bros., 443 Second St., and 5001 Campbell Ave., Schenectady, N. Y.
WELDY, Lloyd O. (*M* 1930), (for mail), Powers Regulator Co., 2720 Greenview Ave., and 2850 Marmora Ave., Chicago, Ill.
WELLS, Eric E. (*M* 1930), Civil Engr., Sarco Co., Inc., 183 Madison Ave., New York, and (for mail), 1458–155th St., Beechurst, L. I., N. Y.
WELSH, Harry S. (*M* 1906), Director (for mail), Boiler & Radiator Corp., 404 Atlantic Ave., and 53 Kemphurst Road, Rochester, N. Y.
WENDT, Edgar F. (*M* 1918), Pres., Buffalo Forge Co., 490 Broadway, and 731 Lafayette Ave., Buffalo, N. Y.
WEST, Perry* (*M* 1911), (Council, 1920-1925; Treas, 1924-1925), Consulting Htg., Vtg., Plbg. and Elec. Engr. (for mail), 13 Central Ave., and 445 Ridge St., Newark, N. J.
WHALEY, Ralph S. (*M* 1931), Pres. (for mail), Power Plant Engrg. Co., 1933 Fifth Ave., and 2025 Parkside Drive, Seattle, Wash.
WHEELER, Charles A. (*A* 1931), Sales Repr. (for mail), Herman Nelson Corp., 400 The Ninth Vincent Bldg., and 830 Vincent Ave., Cleveland, Ohio.
WHEELER, Charles W. (*M* 1916), Br. Mgr. (for mail), C. A. Dunham Co., 3002 Grant Bldg., Pittsburgh, and Allison Park, Pa.
WHEELER, Otto J. (*M* 1923), Mgr. and Secy., 548-558 W. Broad St., and (for mail), 2044 Collingwood Road, Columbus, Ohio.
WHELAN, William J. (*M* 1923), Estimator and Purchaser (for mail), Harrigan & Reid Co., 1365 Bagley St., and 3790 Seminole Ave., Detroit, Mich.
WHELLER, Harry S. (*M* 1916), Vice-Pres., L. J. Wing Mfg. Co., 154 West 14th St., New York, N. Y., and (for mail), 725 Union Ave., Elizabeth, N. J.
WHITAKER, Ernest C. (*M* 1925), Supt. of Engrg., Buerkel & Co., Inc., 24 Union Park St., Boston, and (for mail), 35 Sherborn St., Arlington, Mass.
WHITBY, Stephen S. (*A* 1922), Treas., Culbert-Whitby Co., Inc., 2019 Rittenhouse St., and (for mail), 127 E. Upsal St., Germantown, Philadelphia, Pa.
WHITE, C. Ferber (*M* 1929), Htg. and Vtg. Engr., 3434 Friendship St., Philadelphia, Pa.
WHITE, E. A. (*M* 1921), Engrg. Dept., Crane Co., 30 South 16th St., and (for mail), 5244 Nottingham, St. Louis, Mo.
WHITE, Elwood S. (*M* 1912), Pres. (for mail), Taco Heaters, Inc., 342 Madison Ave., New York, N. Y., and Meadowbank Road, Old Greenwich, Conn.
WHITE, James J. (*A* 1930), 6035 Nassau St., Philadelphia, Pa.
WHITELAW, H. Leigh (*M* 1916), Vice-Pres. and Gen. Mgr., American Gas Products Corp., 704 Chrysler Bldg., New York, N. Y.
WHITNAH, C. S. (*M* 1927), Commercial Engr., 3907 Sheridan Blvd., Lincoln, Neb.
WHITTEN, Horace E. (*M* 1924), Pres-Treas. (for mail), H. E. Whitten Co., 9 Federal Court, Boston, and 56 Highland Road, Somerville, Mass.
WHITTINGTON, W. Penrose (*M* 1928), Pres. (for mail), W. P. Whittington, Inc., 311 N. Alabama St., and 79th and White River, Indianapolis, Ind.
WHY, H. Berkeley (*M* 1919), Engr. 640 W. Sedgewick St., Philadelphia, Pa.
WIDDICOMBE, R. A. (*M* 1903), 1120 Lake Shore Drive, Chicago, Ill.
WIEGNER, Henry B. (*M* 1919), Mgr., Boston Office, Johnson Service Co., 20 Winchester St., Boston, and (for mail), 143 Standish Road, Watertown, Mass.
WIERENGA, Peter O. (*A* 1931), 231 Brown St., S. E., Grand Rapids, Mich.
WIERSIG, Robert H. (*A* 1927), Pres. (for mail), Rud Wiersig, Inc., 2311 N. California Ave., and 5660 N. Maplewood Ave., Chicago, Ill.
WIGGS, G. Lorne (*J* 1924), Br. Mgr. (for mail), C. A. Dunham Co., Ltd., 905 University Tower, and 4717 Upper Roslyn Ave., Montreal, P. Q., Canada.

WIGLE, Bruce M. (*A* 1926), Owner, Bruce Wigle Plbg. & Htg. Co., 9117 Hamilton Ave., Detroit, Mich.
WILD, Walter H. (*M* 1927; *A* 1921), Dist. Repr. (for mail), Union Iron Works, Land Title Bldg., Philadelphia, and 122 Cynwyd Road, Bala, Cynwyd, Pa.
WILDE, Ray S. M.* (*M* 1916), Consulting Engr. (for mail), Michigan Theatre Bldg., Detroit, and 194 Connecticut Ave., Highland Park, Mich.
WILDER, Edward L. (*M* 1915), Mgr., Gas Sales (for mail), Utility Management Corp., 120 Wall St., New York, and 459 Webster Ave., New Rochelle, N. Y.
WILEY, Charles S. (*M* 1921), Htg. and Vtg. Engr., Eastman Kodak Co., Kodak Park, Rochester, N. Y.
WILEY, Edgar C. (*M* 1909), Consulting Engr., Wiley & Wilson, Lynchburg, Va.
WILLARD, Arthur C.* (*M* 1914), (*Presidential Member*), (Pres., 1928; 1st Vice-Pres., 1927; 2nd Vice-Pres., 1926; Council, 1925-1929), Prof. Htg. and Vtg. and Head of Dept. of Mech. Engrg. (for mail), University of Illinois, and 1208 W. California St., Urbana, Ill.
WILLETT, William McN. (*J* 1930), 205 E. Third St., Ft. Atkinson, Wis.
WILLIAMS, Allen W. (*A* 1915), Managing Dir. (for mail), National Warm Air Htg. Association, 3440 A. I. U. Bldg., and 51 Meadow Park, Columbus, Ohio.
WILLIAMS, David B. (*J* 1929), Draftsman (for mail), Carrier Engrg. Corp., 1726 Land Title Bldg., Philadelphia, and 206 Springton Manor Apts., Garrett Road, Upper Darby, Pa.
WILLIAMS, Grover M. (*M* 1928), Secy-Treas., Bevington-Williams, Inc., 1134-39 Indiana Pythian Bldg., Indianapolis, Ind.
WILLIAMS, J. McFarland, Jr. (*A* 1928; *J* 1927), Sales Engr., Hotel Bellevue, Washington, D. C.
WILLIAMS, Jesse M. (*A* 1925), Pres., Williams Radiator Co., 1869 W. Cordova St., Los Angeles, Calif.
WILLIAMS, J. Walter (*M* 1915), Pres-Treas., Forest City Plbg. Co., 332 E. State St., Ithaca, N. Y.
WILLIAMS, Leo E. (*J* 1930), Asst. Sales Engr. (for mail), Carrier Engrg. Corp., 1824 Union Trust Bldg., Cleveland, Ohio, and Osceola Mills, Pa.
WILLIAMSON, Fred W. (*M* 1914), Htg. Engr., Saltzer & Weinsier, 175 Cook St., and (for mail), 1418 E. 34th St., Brooklyn, N. Y.
WILLIS, F. H. (*M* 1921), 2461 Bywood Drive, Glendale, Calif.
WILLIS, Roy C. (*M* 1927), Vice-Pres-Secy. (for mail), Vapor Engrg. Co., 489 Fifth Ave., and 145 Audubon Ave., New York, N. Y.
WILMOT, Charles S. (*M* 1919), Engr., Aetna Insulations, Inc., 1213 Wood St., Philadelphia, and (for mail), 406 Essex Ave., Narberth, Pa.
WILSON, Andrew W. (*A* 1930), McKellar & Blackhall, 1104 Bay St., Toronto, Ont., Canada.
WILSON, Arthur C. (*A* 1929), Wilson Bros., 639 Parker Ave., Collingdale, Pa.
WILSON, Benjamin W. (*M* 1922), Htg. and Vtg. Engr. (for mail), The Ballinger Co., S. E. Cor. 12th and Chestnut Sts., Philadelphia, and 5935 Windsor Ave., West Philadelphia, Pa.
WILSON, Charles H. (*M* 1920), Htg. and Vtg. Engr., 1403 Park Blvd., Troy, N. Y.
WILSON, Ernest J. F. (*M* 1923), Partner (for mail), Wiley & Wilson, Consulting Engrs., 801 Main St., and Box 150, Route 4, Lynchburg, Va.
WILSON, George T. (*M* 1925), Tyre Ave., Islington, Ont., Canada.
WILSON, Harry A. (*Charter Member*; *Life Member*), P. O. Box 155, Washington, R. I.
WILSON, William H. (*A* 1923), Mgr. Milwaukee Office (for mail), Johnson Service Co., 507 E. Michigan St., and 2023 E. Olive St., Milwaukee, Wis.
WILSON, William Seath (*A* 1924), Field Engr. (for mail), Algoma Steel Corp., and 210 McGregor Ave., Sault Ste. Marie, Canada.
WINANS, Glen D. (*M* 1929), Engr. of Steam Distribution (for mail), The Detroit Edison Co., 2000 Second Ave. and 16183 Wisconsin, Detroit, Mich.
WINCH, Franklin R. (*M* 1825), Consulting Engr. Franklin R. Winch, (for mail), 1031 S. Broadway, and 1058 Bedford St., Los Angeles, Calif.
WINQUIST, Walter J. (*A* 1930), 294 Nostrand Ave., Brooklyn, N. Y.
WINQUIST, William M. (*A* 1930), 3063 Hull Ave., New York, N. Y.
WINTERBOTTOM, Ralph F. (*M* 1931; *A* 1923), Winterbottom Supply Co., Waterloo, Iowa.
WINTERER, Alfonso V. (*A* 1929), Secy., Reuben L. Anderson, Inc., and Asbestos Products Corp., 1834 St. Clair St., and (for mail), 1580 Race St., St. Paul, Minn.
WINTERER, Frank C. (*M* 1920), 836 Juna St., St. Paul, Minn.
WISE, Mason W. (*M* 1923), Pres. (for mail), M. W. Wise Co., 214 Glenn Bldg., and 1656 Melrose Drive, S. W., Atlanta, Ga.
WITMER, Charles N. (*J* 1930), Air Conditioning Engr. (for mail), Carrier Corp., 1501 Broadway, New York, N. Y., and 321 Elmora Ave., Apt. 104, Elizabeth, N. J.
WITTLEDER, Edward A. (*J* 1926), Engr. (for mail), Western Vtg. & Engrg. Co., 24 S. Clinton St., and 3910 N. Central Ave., Chicago, Ill.
WOLF, J. C. (*M* 1923), Engr., B. F. Sturtevant Co., Sturtevant, and (for mail), 4045 N. Stowell Ave., Milwaukee, Wis.
WOLFF, Oscar H. (*M* 1926), 6232 Oakland Ave., St. Louis, Mo.
WOLFF, Richard A. (*M* 1919; *J* 1915), Pres. (for mail), Wolff & Munier, Inc., 222 East 41st St., New York, and Woodmere, L. I., N. Y.
WOLFSFELD, Charles F. (*M* 1923), Vista Ave., Bayside, L. I., N. Y.
WOOD, Frederick C. (*J* 1931), Sales Engr. (for mail), Westerlin & Campbell Co., 1113 Cornelia Ave., and 7728 N. Ashland Ave., Chicago, Ill.
WOOD, James Sydney (*M* 1926), Estimator (for mail), Bennett & Wright, Ltd., 72 Queen St. E., and 32 Davisville Ave., Toronto, Ont., Canada.
WOODLING, Miner D. (*M* 1926), Owner and Mgr. (for mail), Miner D. Woodling Htg. & Vtg. Co., 811 Midland Bldg., and 1002 Greenway Terrace, Kansas City, Mo.
WOODLOCK, William M. (*A* 1929), Sales Engr., Carrier-York Corp., 149 Broadway, New York, N. Y., and (for mail), 1243 Magnolia Place, Townley, Elizabeth, N. J.
WOOLSTON, Alfred H. (*M* 1919), Vice-Pres-Treas. (for mail), Bowers Bros. Co., 2015 Sansom St., and 4815 North 12th St., Philadelphia, Pa.
WOOLSTON, C. E. (*M* 1924), Treas. (for mail), Smith Twin Tubular Boiler Co., Inc., 1111 Frankford Ave., and 1510 North 28th St., Philadelphia, Pa.
WORM, Amdi (*A* 1924), Flax-li-num Insulating Co., 1425 Grand Ave., and (for mail), 3833 Montgall, Kansas City, Mo.
WORSHAM, Herman (*M* 1925; *J* 1918), Mgr. Sales Office (for mail), Carrier Engrg. Corp., 850 Frelinghuysen Ave., Newark, and 103 N. Walnut St., East Orange, N. J.
WRIGHT, Harris H. (*M* 1917), Mgr. (for mail), C. A. Dunham Co., Pacific Steel Boiler Co., 615 City Bank Bldg., and 808 Greenway Terrace, Kansas City, Mo.
WRIGHT, Kenneth A. (*M* 1921), Br. Mgr. (for mail), Johnson Service Co., 1113 Race St., Cincinnati, Ohio, and 113 Orchard Road, Fort Mitchell, Covington, Ky.

WRIGHT, M. Birney (*J* 1929), Instructor in Mech. Engrg. (for mail), Case School of Applied Science, Cleveland, and 1159 Yellowstone Road, Cleveland Heights, Ohio.
WUNDERLICH, Milton S.* (*M* 1925), 1598 Laurel Ave., St. Paul, Minn.
WYLIE, Howard McW. (*M* 1925; *J* 1917), Vice-Pres. in Charge of Sales, Nash Engr. Co., South Norwalk, Conn.
WYMAN, Dwight M. (*M* 1931), R. F. D. 421, Barrington, R. I.

Y

YAGER, John J. (*M* 1921), 272 Carlton St., Buffalo, N. Y.
YAGLOU, Constantin P.* (*M* 1923), Asst. Prof. in Industrial Hygiene (for mail), Harvard School of Public Health, 55 Van Dyke St., Boston, and 24 Wade St., Brighton, Mass.
YAMASAKI, Kanjiro (*A* 1923), Htg. Engr., Daiwa Kogyo Co., Ltd., First Mutual Bldg., Room 216, No. 5-3 Chome Denmacho, Kyobashi-ku, Tokyo, Japan.
YARDLEY, Ralph W. (*M* 1920), Asst. Architect, Board of Education, City of Chicago, Steuben Bldg., Cor. Randolph and Wells Sts., and (for mail), 817 N. Dearborn St., Chicago, Ill.
YATES, Walter M., I. M. E., (*M* 1902), Governing Dir. (for mail), Matthews & Yates, Ltd., Cyclone Works, and Parksend, Swinton, Manchester, England.
YEOMANS, Paul H. (*M* 1930), Armstrong Cork Co., Floor Div., Lancaster, Pa.
YOCKEL, Thomas J. (*A* 1929), Treas. (for mail), Philip F. Yockel Sons, Inc., 1074 Franklin Ave., and 265 Bedford Park Blvd., New York, N. Y.

Z

ZACK, Hans J. (*M* 1928), Pres. (for mail), The Zack Co., 2311 Van Buren St., and 5924 Race Ave., Chicago, Ill.
ZECK, Alex. (*Life Member*; *M* 1904), Pres., Alex. Zeck & Son Co., 902 University Ave., Morgantown, W. Va.
ZELLWAGER, Louis S. (*J* 1930), 922 Churchill Ave., Utica, N. Y.
ZIBOLD, Carl Edward (*M* 1929), Pres. and Chief Engr. (for mail), Zibold & Donohue Co., Inc., 331 Vanderbilt Ave., Brooklyn, and 78-55–80th St., Glendale, N. Y.
ZIEL, Herbert E. (*M* 1924), Albert Kahn, 1000 Marquette Bldg., Detroit, Mich.
ZIESSE, Karl L. (*A* 1931), Secy-Treas. (for mail), Phoenix Sprinkler & Heating Co., 115 Campau Ave., and 315 Hampton Ave., S. E., Grand Rapids, Mich.
ZIMMERMAN, Alexander H. (*A* 1930), Ventilation Engr., Chicago Health Dept., 704 City Hall, and (for mail), 3748 Irving Park Blvd., Chicago, Ill.
ZINK, David D. (*M* 1931), Sales Engr. (for mail), American Radiator Co., 1021 Grand Ave., Kansas City, Mo.
ZOKELT, C. G. (*M* 1921), Engr., University Plbg. & Htg. Co., 3939 University Way, and (for mail), 2355–16th Ave., S., Seattle, Wash.
ZUHLKE, William Ronald (*M* 1928), Engr., American Radiator Co., 40 West 40th St., New York, and (for mail), 530 McLean Ave., Yonkers, N. Y.

Summary of Membership

(Corrected to January 1, 1932)

UNITED STATES

Alabama	3	Missouri	95
Arkansas	2	Montana	4
California	73	Nebraska	6
Colorado	8	New Hampshire	1
Connecticut	31	New Jersey	134
Delaware	4	New York	427
District of Columbia	19	North Carolina	7
Florida	1	Ohio	94
Georgia	12	Oklahoma	6
Illinois	275	Pennsylvania	308
Indiana	43	Rhode Island	9
Iowa	8	South Carolina	1
Kansas	4	Tennessee	8
Kentucky	13	Texas	15
Louisiana	2	Utah	2
Maine	8	Vermont	4
Maryland	16	Virginia	12
Massachusetts	121	Washington	22
Michigan	168	West Virginia	7
Minnesota	69	Wisconsin	59
			2101

FOREIGN COUNTRIES

Australia	4	Japan	9
Belgium	1	Mexico	2
Canada	82	New Zealand	3
China	6	Norway	1
Denmark	1	South America	1
England	19	Sweden	2
France	6	Switzerland	1
Germany	5	U. S. S. R.	2
India	2		149
Ireland	1		
Italy	1	Total Membership	2250

SUMMARY OF MEMBERSHIP BY GRADES

Honorary Members	2
Presidential Members	20
Members	1515
Associate Members	489
Junior Members	202
Student Members	22
	2250

LIST OF MEMBERS
Geographically Arranged

UNITED STATES

ALABAMA

Birmingham—
Keist, W. E.
Lichty, C. P.

Mobile—
Festorazzi, A. O.

ARKANSAS

Little Rock—
Pettit, E. N., Jr.

Siloam Springs—
Jones, C. R.

CALIFORNIA

Altadena—
Bremser, H. A.

Beverly Hills—
Nelson, H. A.

Burlingame—
Douglass, T. C.

Eagle Rock—
Rich, C. G.

Glendale—
Dougherty, P. J.
Willis, F. H.

Hollywood—
Kratz, R. W.

Huntington Park—
Berg, A. H.

Los Angeles—
Adrianse, P. R.
Anderson, C. S.
Barker, C. M.
Barnum, W. E., Jr.
Binford, W. M.
Bouey, A. J.
Bradfield, P. E.
Bunker, K. S.
Campbell, R. W.
Clancy, G. E.
Earhart, J. S.
Ellingwood, E. L.
English, H.
Gillespie, J. D.
Gunzel, R. M.
Herman, J., Jr.
Hill, F. M.
Hilliard, F. H.
Horton, G. H.
Hungerford, L.
Keeling, H. B.
Kendall, E. H.
Kennedy, M.
LaMontagne, J. M.
Lauer, H. B.
Lewis, M.
MacKinnon, D. A.
Marquet, C. M.
McClelland, H. S.
Ness, W. H. C.
Newman, C. T.
O'Haver, H. M.
Orear, A. G.
Oster, G. R.
Ott, O. W.
Polderman, L. H.
Schourup, W. E.
Scott, L. O.
Sharpe, N.
Shields, M. K.
Simonds, A. H.
Steele, H. G.
Thomas, E. E.
Updegraff, L.
Williams, J. M.
Winch, F. R.

Oakland—
Cummings, G. J.

Pasadena—
Cranston, W. E., Jr.
Gifford, R. L.
Hoffman, G. D.
Johnson, C. E.

Sacramento—
Duncan, G. W.
Thompson, C.

San Diego—
Hemingway, W. S.
Sadler, C. B.

San Francisco—
Haley, H. S.
Hunt, P. M.
Krueger, J. I.
Leland, W. E.
Park, J. F.

Santa Monica—
Lawler, M. M.

South Pasadena—
Campbell, W. E.
Warren, H. L.

West Hollywood—
Armitage, J. B.

Wilmington—
Nelson, J. F.

COLORADO

Colorado Springs—
Higgins, D. T.
Jardine, D. C.
Strickland, A. W.

Denver—
Adams, C. W.
Daly, J. H.
Larimer, W. M.
Walther, V. H.
Ward, O. G.

CONNECTICUT

Bridgeport—
Ott, R. C.

Fairfield—
Osborn, W. J.

Greenwich—
Jones, A. L.

Hartford—
Millard, J. W.
Peterson, C. O.
Purcell, A. J.

Manchester—
Buck, L.

Middletown—
Adams, W. H.

New Britain—
Cadwell, W. H.
Hjerpe, C. A., Jr.

New Haven—
Catlin, B. J.
Hoyt, W. B.
Jenkins, H. E.
Seeley, L. E.
Teasdale, L. A.

New London—
Forsberg, W.
Hopson, W. T.

Noroton Heights—
Ashley, E. E.

Riverside—
Murphy, J. R.

South Norwalk—
Adams, H. E.
Harvey, A. D.
Jennings, I. C.
Mead, E. A.
Monroe, R. R.
Wylie, H. M.

Springdale—
Broderick, J. F.

Stamford—
Hoyt, L. W.

Waterbury—
Berringer, S. H.
Simpson, W. K.

Winsted—
Griffin, P. C.
Hutton, W.

DELAWARE

Wilmington—
Gawthrop, F. H.
Kershaw, M. G.
Lownsbery, B. F.
Schoenijahn, R. P.

DISTRICT OF COLUMBIA

Washington—
Backstrom, R. E.
Beitzell, A. E.
Breitenbach, G. C.
Coward, H.
Febrey, E. J.
Frankel, G.
Gardner, S. F.
Heim, E. F.
Hood, O. P.
Klube, J. O.
Mewshaw, J. P.
Nolan, J. J., Jr.
Ourusoff, L.
Smallman, E. W.
Thompson, N. S.
Trulson, A. F.
Tulloss, J. C.
Urdahl, T. H.
Williams, J. M., Jr.

FLORIDA

West Palm Beach—
Hodeaux, W. L.

GEORGIA

Atlanta—
Alger, R. W.
Baird, F. E.
Boyd, S. W.
Clare, F. W.
Kent, L. F.
Klein, E. W.
Templin, C. L.
Warren, F. A.
Wise, M. W.

Columbus—
Dexter, M.
Hartpence, C. C.

Gainesville—
Jackson, J. W.

ILLINOIS

Berwyn—
Kitch, S. B.

Bloomington—
MaGirl, W. J.
Nesmith, O. E.
Soper, H. A.

Chicago—
Abrahamson, P.
Aeberly, J. J.
Allen, H. D.
Andel, F. J.
Arenberg, M. K.
Ashenhurst, H. S.
Bailey, J. H.
Barrows, C. E.
Beery, C. E.

Bennett, R. E.
Black, F. C.
Bloom, S. C.
Bolte, E. E.
Boswin, G. A.
Bracken, J. H.
Braun, L. T.
Brayton, W. M.
Broom, B. A.
Brown, A. P.
Burke, G. B.
Burns, W. A.
Bynum, O. W.
Callaghan, P. F., Jr.
Carman, G. G.
Carnahan, G. C.
Cartier, C. E., Jr.
Casey, B. L.
Chenoweth, W. H.
Claffey, E. J.
Clow, M. T.
Cornell, H.
Coughlin, R. J.
Crawford, W. B.
Crone, C. E., Jr.
Currier, C. H.
Cutler, J. A.
Cutter, E. H.
Davis, H. H.
DeLand, C. W.
Doherty, R.
Dunham, C. A.
Ebin, L.
Emmert, L. D.
Ensign, R. M.
Faber, G. S.
Finan, E. J.
Finan, J. J., Sr.
Fix, F. W., Jr.
Fleming, J. P.
Foster, T. R.
Frank, J. M.
Gardner, W., Jr.
Gaylord, F. H.
Gemeny, W. J.
Getschow, G. M.
Getschow, R. M.
Gibbs, F. C.
Gifford, E. W.
Gilliam, O. F.
Gilmore, R. E.
Goelz, A. H.
Good, M. S.
Gordon, E. G.
Gossett, E. J.
Graham, W. D.
Graves, C. C.
Graves, W. B.
Grebe, H. W.
Haas, S. L.
Hagerman, J. J.
Haines, J. J.
Hale, J. F.
Hardinge, F.
Hart, H. M.
Harter, B. B.
Hartman, F. E.
Hattis, R. E.
Hayden, C. F.
Hayes, J. J.
Hayward, R. B.
Heck, G. L., Jr.
Heckel, E. P.
Herlihy, G. F.
Herlihy, J. J.
Hill, E. V.
Hillen, A. G.
Hoier, W. V.
Hoover, H. E.
Hornung, J. C.
Horton, H. F.
Howatt, J.
Howell, L.
Hubbard, G. W.
Hustoel, A. M.
Jackson, C. J.
Jennings, W. G.
Jenson, J. S.
Johns, H. B.
Johnson, C. W.
Johnson, L. O.
Jones, M. P.
Keeney, F. P.
Kehm, A.
Kehm, H. S.
Kinney, W. H.
Kirk, G. H.
Kirkpatrick, A. H.
Kreissl, H. G.
Lagodzinski, H. J.
Larson, J. M.
Lathrop, E. C.
Lautenschlager, F.
Lees, H. K.
Lenone, J. M.
Lewis, S. R.
Lippman, O. S.
Love, H. G.
Luce, G. D., Jr.
Maier, H. F.
Malone, D. G.
Malvin, R. C.
Marschall, P. J.
Marsh, T. A.
Martin, A. B.
Matchett, J. C.
Mathis, E.
Mathis, H.
Mathis, J. W.
Mauer, W. J.
May, A.
May, M. F.
McCauley, J. H.
McClellan, J. E.
McDonnell, E. N.
McFarland, W. P.
McGregor, G. H.
Meffert, G. H.
Mehring, G.
Mertz, W. A.
Miller, F. A.
Miller, J. E.
Miller, R. T.
Milliken, J. H.
Moffitt, R. M.
Monaghan, T. H.
Monroe, H. E.
Montgomery, W. R.
Moran, F. E.
Mueller, H. C.
Nacey, H. M.
Narowetz, L. L., Jr.
Neiler, S. G.
Newport, C. F.
Nilson, A.
Nilson, K. A.
O'Brien, J. H.
Offen, B.
Olsen, C. F.
Olson, A. E.
Olson, B.
Orr, F. B.
Pence, M. D.
Petersen, A. J.
Pitcher, L. J.
Pope, S. A.
Pope, W. A.
Powers, F. W.
Prentice, O. J.
Prohaska, E. C.
Rasmussen, R. P.
Raymond, F. I.
Reid, H. P.
Ries, L. S.
Rietz, E. W.
Rottmayer, S. I.
Saunders, J. C.
Sawhill, R. V.
Scheidecker, D. B.
Schuengel, G. W.
Schwab, Q. D.
Schweim, H. J.
Seelig, L.
Shufelt, H. M.
Shultz, E.
Simpson, R. B.
Small, A. M.
Small, J. D.
Smith, G. P.
Snider, L. A.
Spafford, L. B.
Spielmann, G. P.
Stackhouse, R. M.
Stannard, J. M.
Stedman, C. N.
Stiles, H. L.
Stockenberg, R.
Storch, C. A.
Sutcliffe, A. G.
Thinn, C. A.
Thomas, R. H.
Thommen, A. A.
Thommen, A. R.
Truitt, J. E.
Trumbo, S. M.
Tupper, G. B.
Valiquet, H. H.
Walters, W. T.
Warren, W. J.
Washington, L. W.
Watson, J. H.
Weil, M.
Weil, M. I.
Weinshank, T.
Weixel, A. L.
Weldy, L. O.
Widdicombe, R. A.
Wiersig, R. H.
Wittleder, E. A.
Wood, F. C.
Vardley, R. W.
Zack, H. J.
Zimmerman, A. H.

Cicero—
Keppner, H. W.

Decatur—
Shorb, W. A.

Evanston—
Baumgardner, C. M.
Kilby, R. E.
McIlvaine, J. H.
Moore, R. E.
Thomas, H. G.
Vernon, J. R.

Glen Ellyn—
Harbula, M. G.

Joliet—
Beasom, G. R.
Russell, W. B.

Kewanee—
Bronson, C. E.
Dickson, R. B.
Hartman, J. M.
Pursell, H. E.

La Grange—
Eaton, B. K.
Linn, H. R.

Maywood—
Pelletier, A.

Moline—
Beling, E. H.
Munson, M. G.
Nelson, H. W.
Nelson, R. H.
Nordine, L. F.
Otis, G. E.
Tyler, F. T.

Oak Park—
Barnes, R. B.
Blanding, G. H.
May, E. A.
Muir, G. A.
Nightingale, G. F.
Steele, A. N.
Uhlhorn, W. J.

Park Ridge—
Barry, C. P.

Peoria—
Farnsworth, J. G.
Meyer, F. L.
Peterson, L. J.
Robb, J. M.

Rockford—
Braatz, C.
Merwin, G. E.
Richtmann, W. M.
Stewart, D. J.

Springfield—
McCarthy, B. J.

Urbana—
Bennett, G. G.
Kratz, A. P.
Willard, A. C.

Western Springs—
Brakenridge, C. E.

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Norris, W. D.

Winnetka—
Ellis, E. E.

Zion—
Koetz, L.

INDIANA

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Miller, L. B.
Shreiner, D. C.

Evansville—
Bulleit, C. R.

Fort Wayne—
Noland, R. W.

Goshen—
May, E. M.
Plass, C. W.

Indianapolis—
Ammerman, C. R.
Ascher, N. C.
Bevington, W. C.
Callon, H., Jr.
Edwards, R. H.
Fenstermaker, S. E.
Hagedon, C. H.
Hayes, J. G.
Heidenreich, G.
Jackson, G. O.
Kruse, R. W.
Neal, H. W.
Poehner, R. E.
Rotz, J. M.
Selch, H. C.
Shipp, C. C.
Stitt, H. B.
Strong, E. A.
Voorhees, G. A.
Warren, C. N.
Whittington, W. P.
Williams, G. M.

Jeffersonville—
Hancock, J. R.

Lafayette—
Hoffman, J. D.

La Porte—
Shrock, J. H.

Markle—
Smith, G. W.

Michigan City—
Stockwell, W. R.

Muncie—
Hutzel, M. H.
Hutzel, V. C.

Peru—
Lillard, W. S.
Pyle, J. W.
Thrush, H. A.

Richmond—
Stevenson, M. E.

St. Mary-of-the-Woods—
Bisch, B. J.

Terre Haute—
Mandel, H. J.
Prox, R. F.

Wabash—
Shivers, P. F.

IOWA

Ackley—
Nelson, G. O.

Cedar Rapids—
Chandler, C. W.
Moore, R. F.

Le Mars—
Mathey, N. J.

Sioux City—
Hagan, W. V.
Manning, W. M.
Orr, M. J.

Waterloo—
Winterbottom, R. F.

KANSAS

Emporia—
Burnap, C. W.

Hutchinson—
Hertz, H. P.
Mann, A. R.
Stevens, H. L.

KENTUCKY

Anchorage—
Lewis, J. C.

Covington—
Blomfeldt, A. A.
Carson, C. C.

Lexington—
Anderson, F. P.
Evans, H.
O'Bannon, L. S.
Porter, R. C.

Louisville—
Birkholz, H. E.
Hellstrom, J.
Murphy, H. C.
Reed, W. M.
Shrum, A. T.
Sylvan, S. G.

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Chappell, R. E.

Ruston—
Riser, S. P.

MAINE

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Thayer, A. J.

Belfast—
Goodhue, A. P.

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Fels, A. B.
Merrill, C. J.
Partridge, G. A.

Presque Isle—
Noyes, G. T.

Woodfords—
Eaton, P.
Haskell, B. E.

MARYLAND

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Dorsey, F. C.
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Morris, E. J.
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Reeder, C. L.
Vance, L. G.
Thain, A. E.
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Ellicott City—
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Dorfan, M. I.

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Brunett, A. L.

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Seiter, J. E.

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Whitaker, E. C.

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Belmont—
Schanze, A. G.

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Ahearn, W. J.
Arnoldy, W. F.
Bailey, G. B.
Bartlett, A. C.
Barton, R. E.
Berchtold, E. W.
Boyden, D. S.
Boynton, D. W.
Brigham, F. H.
Brinton, J. W.
Brissette, L. A.
Brown, R. H.
Bryant, A. G.
Bullock, T. A.
Clough, L.
Cooper, F. I.
Cummings, C. H.
Drinker, P.
Dusossoit, E. A.
Ehrenzeller, A.
Flemings, J. A.
Foulds, P. A. L.
Franklin, R. S.
Gerrish, G. B.
Gifford, R. F.
Gilmore, F. P.
Gleason, G. H.
Goodrich, C. F.
Heath, F. R.
Hoyt, C. W.
Keefe, E. T.
Kelley, J. J.
Kellogg, A.
Kimball, C. W.
Lemmerman, C. W.
Lundquist, R. A.
Matthews, C. R.
McCoy, T. F.
McKenna, W. N.
McLean, I.
McMurrer, L. J.
Moller, R. C.
Moulton, D.
Mower, W. P.
Murray, W. N.
Myrick, J. W. H.
Osborne, M. M.
Pohle, K. F.
Price, L. C.
Shaw, E.
Shaw, R. E.
Smallman, W. T.
Stetson, L. R.
Stone, E. R.
Swaney, C. R.
Thompson, R. C.
Tierney, L. J. J.
Tilden, E. E.
Turner, J. W.
Tuttle, J. F.
Underhill, W. W.
Waterman, J. H.
Webb, J. S.
Whitten, H. E.
Yaglou, C. P.

Bridgewater—
Keith, L. H.

Cambridge—
Baker, R. H.
Cox, C. J.
Flint, C. T.
Haddock, I. T.
Klonower, A. A.

Charlestown—
Herrick, D. A.

Dorchester—
Brown, M.
Hosterman, C. O.
McPherson, W. A.
Plunkett, J. H.
Richard, I. T.

Fitchburg—
Dolan, W. H., Jr.
Illig, W. R.
Karlson, A. F.

Holbrook—
Nason, G. L.

Hyde Park—
Ellis, F. R.

Lawrence—
Bride, W. T.

Leominster—
Kern, R. T.

Lynn—
Feehan, J. B.
Morgan, F. H.
Oates, W. A.
Pool, S. H.
Reardon, J. A.

Malden—
McDonald, J. J.

Medford—
Cushman, L. D.
Dane, I. S.
Suits, G. A.

Milton—
Mitchell, C. H.

Needham—
Park, C. D.

Newton—
Cousens, W. S.

North Adams—
Morrill, F. B.

Reading—
Ingalls, F. D. B.

Revere—
Foulds, S. T. N.

Roslindale—
Rehling, H. F.

South Boston—
Hilliard, C. E.

Springfield—
Brown, W. M.
Cotter, L. F.
Cross, R. E.
Leland, W. B.
Murphy, W. W.

Taunton—
Babbitt, W. D.

Waban—
Jones, W. T.

Watertown—
Wiegner, H. B.

Wellesley—
Fitch, W. S.

Wellesley Hills—
Gilling, W. F., Jr.

Woburn—
Parker, P.

Wollaston—
Hodgdon, H. A.

Worcester—
Hawes, H. R.
Robinson, H. C.
Standish, M.

MICHIGAN

Ann Arbor—
Backus, T. H. L.
Emswiler, J. E.
Hutzel, A. F.

Birmingham—
Giddey, Y. R. F.
Hadjisky, J. N.
Salisbury, W. C.
Soderberg, C. H.

Detroit—
Akers, G. W.

Armstrong, H. M.
Baker, C. H.
Baldwin, W. H.
Barth, H. E.
Bishop, F. R.
Blackmore, F. H.
Boales, W. G.
Booth, H. N.
Brown, W. C.
Brown, T.
Byrnes, E. F.
Cantwell, J. D.
Chappell, H. D.
Chester, T.
Chittenden, E. F.
Clark, E. H.
Collamore, R.
Connell, R. F.
Conover, E. W.
Coon, T. E.
Cooper, F. D.
Corbin, W. E.
Corlett, L.
Cossaboom, G. C.
Cowan, E., Jr.
Cummings, C. A.
Cummins, G. H.
Darlington, A. P.
Dauch, E. O.
Davis, L. J.
Degan, J. E.
Dolan, H. P.
Donohue, E. S.
Doody, C. A.
Dubry, E.
Eggleston, L. W.
Feely, F. J.
Fortune, J. R.
Fuller, J. L.
Gallarno, C. A.
Gaulin, R. P.
Giguere, G. H.
Glanz, E.
Gordon, R. H.
Green, J. E.
Hamlin, H. A.
Hard, A. L.
Hare, W. A.
Harms, W. T.
Harrigan, E. M.
Harrigan, E. R.
Harrigan, H. H.
Harrison, C. G.
Hatton, A. E.
Heydon, C. G.
Hill, N. J.
Hodges, G. S., Jr.
Hogan, E. L.
Hubbard, N. B.
Johnson, F. W.
Johnston, W. B.
Kappler, H. C.
Kice, M. S.
Killian, M. A.
Kilner, J. S.
Kintz, L. H.
Lance, J. F.
Little, E. R.
McColl, J. R.
McConachie, L. L.
McGeorge, R. H.
McIntire, J. F.
McLean, D.
McNair, E. E.
Meyer, J. W., Jr.
Miller, J. F.
Milward, R. K.
Monroe, L. O.
Morgan, C. S.
Morse, C. T.
Nentwig, R. J.
Paetz, H. E.
Parrott, L. G.
Partlan, J. W.
Peckham, R. R.
Phelps, H. R.
Pittelkow, A. G.
Purcell, F. C.
Purcell, R. E.
Purdy, E. D.
Randall, H. N.
Randall, R. D.
Randall, W. C.
Reinke, F. C.
Rollins, L. E.
Rowe, W. A.
St. John, J. S.
Sanford, S. S.
Sauer, R. L.
Saulson, S.
Schulze, B. H.
Shaver, E. W.
Shea, M. B.
Shepstone, O.
Shuell, F. W.
Slayter, G.
Smith, L. L.
Snell, E.
Snyder, J. W.
Sonneborn, R. H.
Spitzley, R. L.
Spurgeon, J. H.
Stephen, H. M.
Turner, J. W.
Waid, G. H.
Walker, J. H.
Wallich, A. C.
Walton, H. L.
Whelan, W. J.
Wigle, B. M.
Wilde, R. S. M.
Winans, G. D.
Ziel, H. E.

Dowagiac—
Firestone, J. F.

Grand Rapids—
Alexander, C. H.
Bradfield, W. W.
Busch, P. J.
Carroll, W. J.
Jaynes, E. L.
Knee, J. S.
Lammers, C.
Marshall, O. D.
Miller, H. N.
Morton, C. H.
Stevens, F. H.
Taze, D. L.
Troske, J. J.
Wierenga, P. O.
Ziesse, K. L.

Grosse Pointe—
Skillin, N. M.

Hermansville—
Bernstrom, B.

Holland—
Cherven, V. W.
Van Alsburg, J. H.

Kalamazoo—
Blaney, C. A.
Downs, S. H.
Kersjes, W.
McConner, C. R.
Temple, W. J.

Lansing—
Distel, F.

Marcellus—
Henrich, G. A.

Muskegon—
Johnson, P. H.

Pontiac—
Brown, J. L.
Eames, W. R.

Port Huron—
Blessed, W. A.

Plymouth—
Campbell, J. M.

Royal Oak—
Crandall, R. K.
Phillips, W. J.

Saginaw—
Swartwout, J. D.

St. Joseph—
Milliken, V. D.

South Haven—
Wallace, R. R.

MINNESOTA

Cloquet—
Spafford, A.

Duluth—
Foster, C.

Fosston—
Nesdahl, E.

Minneapolis—
Algren, A. B.
Andresen, A. W.
Armstrong, A. D.
Betts, H. M.
Bjerken, M. H.
Bradford, H. H.
Bredesen, B. P.
Brown, J. H.
Burns, E. J.
Burritt, C. G.
Cash, T. T.
Cowles, B. E.
Dahlstrom, G. A.
Dock, C. J.
Eckley, W. A.
Eiss, R. M.
Forfar, D. M.
Gerrish, H. E.
Gordon, E. B. Jr.
Gross, L. C.
Hanson, L. C.
Harris, H. R.
Harris, J. B.
Helstrom, H. G.
Hill, C. E.
Hitchcock, P. C.
Huch, A. J.
Johnson, L. H.
Kuempel, L. L.
Lamb, E. A.
Lewis, C. E.
Magney, G. R.
Martenis, J. V.
McNamara, W.
Morgan, G. C.
Mosher, R. B.
Porter, H. M.
Probst, A. H.
Reese, P. R.
Rowley, F. B.
Sanford, A. L.
Schernbeck, F. H.
Sperzel, H. J.
Swenson, J. E.
Uhl, E. J.
Uhl, W. F.

Owatonna—
Clarkson, W. B.

Rochester—
Adams, N. D.

St. Paul—
Anderson, P. E.
Buenger, A.
Challman, S. A.
Gausman, C. E.
Heagler, J. M.
Hickey, D. W.
Jones, E. F.
Lewis, E. B.
Morton, H. S.
Otto, R. W.
Parks, W. N.
Ruff, D. C.
Schulte, R. R.
Spofforth, W.
Winterer, A. V.
Winterer, F. C.
Wunderlich, M. S.

Winona—
DeLancey, R. W.

MISSOURI

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Szombathy, L. R.

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Kansas City—
Arthur, J. M., Jr.
Betz, H. D.
Buckley, M. B.
Buder, C. G.
Butler, C. W.
Caleb, D.
Campbell, E. K.
Campbell, E. K., Jr.
Chase, L. R.
Clegg, C.
Cox, W. F.
Dawson, T. L.
Dodds, F. F.
Downes, N. W.
Dunlap, R. L.
Fehlig, J. B.
Gillham, W. E.
Haas, E., Jr.
Henrici, H. C.
Heslip, J. C.
Hitchcock, F. P.
Kitchen, J. H.
Lewis, J. G.
Mason, R. B.
Miller, E. S.
Millis, L. W.
Moor, R. F.
Natkin, B.
Nottberg, H. J.
Payson, C. H.
Pines, S.
Russell, W. A.
Sheppard, F. A.
Stephenson, L. A.
Weiss, C. A.
Woodling, M. D.
Worm, A.
Wright, H. H.
Zink, D. D.

Kirkwood—
Graves, R. E.
McMorran, F. J.

North Kinloch—
Walker, G. E.

St. Louis—
Baetz, H.
Barnes, E. R.
Bayse, H. V.
Bidwell, R. E.
Bowers, J. S.
Bradley, E. P.
Carlson, E. E.

Cook, C. D.
Cooper, J. W.
Davis, C. R.
Deppe, F. W.
DuBois, L. J.
Edwards, D. F.
Evleth, E. B.
Falvey, J. D.
Foster, J. M.
Gallaher, A. J.
Gilmore, L. A.
Griffin, J. J.
Grossmann, H. A.
Hallett, S. G.
Halley, W. H.
Harris, H. W.
Helwig, G. A.
Hester, T. J.
Humphreys, A. E.
Kent, J. K.
Langenberg, E. B.
Lathers, V. M.
Metcalf, R. H.
Moon, L. W.
Myers, G. W. F.
Niestrath, W. H.
Picker, F. C.
Pickett, C. A.
Rosebrough, R. M.
Rossman, V. D.
Russell, W. L. A.
Sachleben, E. H.
Smith, R. J.
Sodemann, P. W.
Sodemann, W. C. B.
Stammer, E. L.
Steckhan, L.
Thomsen, W. T.
Walters, A. L.
White, E. A.
Wolff, O. H.

Webster Groves—
Axthelm, F. G.
Gabelman, H. D.
Wallace, K. S.

MONTANA

Billings—
Cohagen, C. C.
Tooker, C. C.

Bozeman—
Powers, F. I.

Butte—
Sullivan, T. J.

NEBRASKA

Lincoln—
Whitnah, C. S.

Omaha—
Lewis, W.
Olson, G. E.
Sebree, G. M.

Scotts Bluff—
Davis, O. E.
Smith, O. J.

NEW HAMPSHIRE

Lebanon—
Lewis, J. P.

NEW JERSEY

Arlington—
Bock, B.

Atlantic City—
Labov, M.
Strouse, S. B.

Bayonne—
Schwartz, J.

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Merkel, F. P.

Bloomfield—
Hochuli, H. W.
Jackes, H. D.
Lau, A. S.

Camden—
Brown, W. M.
Kappel, G. W.
Lanning, E. K.
Rohlin, K. W.
Strandwitz, W. J.
Swift, C. K.
Webster, E. K.
Webster, W.
Webster, W., Jr.

Cranford—
Terrell, H. A.

East Orange—
Atkins, T. J.
Carrier, E. G.
Gombers, H. B.
Grahn, V. F.
Reilly, J. H.
Schroth, A. H.
Turno, W. G. W.

Elizabeth—
Cherne, R. E.
Cornwall, G. T.
Darby, M. H.
Denholm, J. A., Jr.
Lyman, S. E.
Skidmore, J. G.
Wheller, H. S.

Emerson—
Blume, F. J., Jr.

Essex Fells—
Stacey, A. E., Jr.

Glen Rock—
Hall, C. H.

Grantwood—
Butler, P. D.

Haddonfield—
Braemer, W. G.
Dobbs, C. E.

Harrison—
Johnston, J. H.

Hasbrouck Heights—
Goodwin, S. L.
Stanton, G. W.

Hawthorne—
Lawton, F. C.

Hillside—
Tichenor, L. R., Jr.

Irvington—
Freas, R. B.

Jersey City—
Calahan, J. J.
Hashagen, J. B.
Jones, H. L.
Kelly, C. J.
Ritchie, W.
Van Court, W. G.
Walterthum, J. J.

Jobstown—
Allinson, O. H.

Keansburg—
Roske, F. M.

Kearny—
Long, D. R.

Long Branch—
Hammond, M. J.

Lyndhurst—
Ehrlich, M. W.

Maplewood—
Evans, W. A.

Merchantville—
Binder, C. G.

Montclair—
Bentz, H.
Fenn, C. V.
Holbrook, F. M.
Osmundsen, H. B.

Mountain Lakes—
Bolling, E.

Newark—
Abel, D. M.
Alt, H. L.
Anderson, S. W., Jr.
Arko, F. W.
Ashley, C. M.
Bryant, P. J.
Burke, J.
Carey, P. C.
Carrier, W. H.
Crawford, J. H., Jr.
Day, V. S.
Edgar, J. S.
Eilbeck, A. B.
Ernst, C. E.
French, D. E.
Gabelmann, P. E.
Grant, W. A.
Haskett, J. E.
Holton, J. H.
Ingels, M. M.
Janet, H. L.
Leinroth, J. P.
Lewis, L. L.
Lewis, T.
Lyle, J. I.
Mann, L. B.
Marsh, A. B.
Murphy, E. T.
Price, W. H., Jr.
Rachal, J. M.
Smith, M. S.
Soule, L. C.
Van Meter, B. F.
West, P.
Worsham, H.

New Brunswick—
Gillham, J. N.

North Arlington—
Bermel, A. H.
Vogelbach, O.

Oaklyn—
Driggs, L. L.

Palmyra—
Cassell, J. D.
Schopp, W. J.

Passaic—
Hankin, R.
Morris, C. R.

Paterson—
Cox, H. F.
Gunther, R. C.
Pryor, F. L.

Plainfield—
MacDougall, B. W.
Tobin, G. J.

Princeton—
Black, J. J. A.

Red Bank—
Smith, H. P.

Ridgefield Park—
Davis, A. C.

Ridgewood—
Fitts, J. C.
Forgee, F. A.

Riverton—
Bilyeu, W. F.
Brunt, T. B.

Roselle—
Erickson, H. A.

Short Hills—
Fouilhoux, J. A.

South Orange—
Anderson, E. L.
Hansen, C. C.

Summit—
Durkee, M. E.

Teaneck—
Heebner, W. M.
Ward, R. N.

Townley—
Woodlock, W. M.

Union City—
Taverna, F. F.

Upper Montclair—
Armagnac, A. S.
Smith, F. J.

West Collingswood—
Knecht, C. H.

West Englewood—
Bondy, W. S.

Westmont—
Powers, E. C.

West New York—
Decker, E. J.

Woodridge—
Reynolds, T. W.

NEW YORK

Albany—
Bond, H. A.
Johnson, H. S.
Murray, T. F.
Ryan, H. J.
Steim, C. J., Jr.
Taggart, R. C.
Vogt, J. B.

Binghamton—
Folley, E. B.
Greene, A. R.
Marum, O.

Bronxville—
Close, P. D.

Buffalo—
Ahlff, A. A.
Archer, F. S.
Ashton, D. W.
Barnett, S. J.
Beirn, J. U.
Beman, M. C.
Booth, C. A.
Burke, F. H.
Castin, L. N.
Cherry, L. A.
Cheyney, C. C.
Clucas, W. F.
Cressy, R. E.
Criqui, A. A.
Cundall, L. A.
Danforth, N. L.
Dempsey, H. P.
Dyer, O. K.
Evans, C. A.
Farnham, R.
Farrar, C. W.
Frank, O. E.
Fraser, W. G.
Grieves, T. R.
Harding, L. A.
Heath, W. R.
Hedley, P. S.
Hexamer, H. D.
Jackson, M. S.
John, V. P.
Johnson, E. E.
Johnson, W. F.
Kamman, A. R.
Landers, J. J.
Langley, F. P.
Love, C. H.
Madison, R. D.
Mahoney, D. J.
McCulloch, L.
McTernan, F. J.
Mosher, C. H.
Nathan, J. M.
Olstad, M. H.
Padginton, G.
Pendleton, M. E.
Rente, H. W.
Roarke, H. B.
Rodman, M. J.
Roebuck, W., Jr.
Roseberry, J. H.
Rydell, C. A.
Schafer, H. C.
Schall, H. S.
Seelbach, H.
Shelney, T.
Snelling, L. R.
Snyder, J. S.
Stephenson, G. A.
Sweet, H.
Thornton, R. T.
Voisinet, W. E.
Wendt, E. F.
Yager, J. J.

Eggertsville—
Hirschman, W. F.

Elmira—
Davis, B. C.
Frutchy, A. E.
McGlenn, G. R.

Geneva—
Herendeen, F. W.

Herkimer—
Ertman, B. R.

Hornell—
Brill, J. W.

Hudson Falls—
Hollister, E. W.

Irvington—
Bastedo, A. E.
Ellis, W. H.
Knox, J. R.

Ithaca—
Sawdon, W. M.
Williams, J. W.

Kenmore—
Davis, J.
Krueger, B.
Quigley, W. J.
Rente, S. R.
Riley, D. H.
Smith, J. C.

Lockport—
Bishop, C. R.
Gerstung, G. W.
Harney, F. W.
Harrison, A. B.
Harrison, C. A.
Porzel, J.

Larchmont—
Gaylor, W. S.

Millbrook—
Pizie, S. G.

Morton—
Stangland, B. F.

Mount Vernon—
Hills, A. H.
Hunt, R. B.
Northon, L.
Obert, C. W.
Ryan, J. E.

New Rochelle—
Abrams, A.
Dailey, J. F.
Farley, W. F.
Rooney, M. A.
Senior, R. L.

New York City—
Addams, H.
Adler, A. A.
Alvord, A. M.
Ames, C. F.
Armspach, O. W. (Jackson Heights, L. I.)
Asbury, N. B. G.
Atherton, G. R.
Atwater, L. W. (Brooklyn)
Bachler, L. J.
Bampton, C. M. (Brooklyn)
Barnum, M. C. (Woodside, L. I.)
Baum, A. L.
Beebe, F. E. W.
Bender, C. P. (Brooklyn)
Bennett, E. A.
Bennitt, G. E.
Berman, L. K.
Bernhard, G. (Jamaica, L. I.)
Birch, H. R.
Blackburn, E. C., Jr. (Hempstead, L. I.)
Blackman, A. O.
Blackmore, J. J.
Blitz, E.
Bodinger, J. H.
Bolton, R. P.
Bowles, P.
Brassington, A. F.
Brown, W. A.
Browne, A. L.
Buensod, A. C.
Bulkeley, C. A.
Campbell, F. B.
Carpenter, R. H.
Chase, C. L. (Brooklyn)
Christman, W. F.
Cooper, J. R.
Couch, N. H. (College Point, L. I.)
Crone, T. E.
Crutchley, E., Jr. (Brooklyn)
Cucci, V. J.
Cumming, R. W.
Cunningham, N.
Dailey, J. A. (Astoria, L. I.)
Daly, R. E.
Darts, J. A.
Dillon, H. R.
Doherty, J. A. (Brooklyn)
Donnelly, R.
Donnelly, W. C.
Dornheim, G. A. (Long Island City)
Downe, E. R.
Dresen, W. D. (Jackson Heights, L. I.)
Driscoll, W. H.
Duff, K.
Duffield, T. J.
Durand, W. L.
Dwyer, T. F. (Brooklyn)
Eadie, J. G.
Easterbrooks, C. C.
Edmonds, A. S., Jr.
Eells, H. B. (Brooklyn)
Emerson, R. R. (Brooklyn)
Engle, A.
Everetts, J., Jr.
Fansler, P. E.
Fay, F. C.
Feldman, A. M.
Fenner, N. P.
Ferguson, R. R.
Fife, G. D.
Finch, S. B. (Brooklyn)
Fleisher, W. L.
Flink, C. H.
Friedman, A.
Friedman, F. J.
Fritzberg, H. L.
Gardner, B. F. (Brooklyn)
Giannini, A. C.
Glore, E. F.
Goldschmidt, O. E.
Goodnow, W. F.
Gornston, M. H.
Green, R. F.
Griffin, B. H. (Brooklyn)
Grill, G. E.
Grossman, H. E. (Richmond Hill, L. I.)
Hanburger, F. W.
Harris, C. R.
Harrison, B. S. (Brooklyn)
Hedges, H. B.
Heibel, W.
Heimberger, O. W.
Henry, A. S., Jr.
Hertzler, J. R. (Brooklyn)
Hinchman, E. G. (Brooklyn)
Hinkle, E. C. (Hempstead, L. I.)
Hinrichsen, A. F.
Hoffman, C. S.
Hosking, H. L.
Hotchkiss, C. H. B.
Howell, F. B.
Humphreys, J.
Hyman, W. M.
Issertell, H. G.
Jacobs, B.
Jacobus, D. S.
Jalien, J. J.
Johnsen, H. (Port Richmond, S. I.)
Johnson, E. B. (West New Brighton, S. I.)
Johnston, W. H.
Kagey, I. B.
Kalloch, P. C., Jr. (Long Island City)
Keasby, A. P.
Keenan, P. F.
Kelley, A. D., Jr.
Kellogg, T. M.
Keplinger, W. L.
Keyes, R. E.
Kiewitz, A. A. (Astoria, L. I.)
Kiewitz, C.
Kimball, D. D.
Kingsley, E. A.
Kirk, L. G.
Koithan, W. S.
Kreitner, W. (Brooklyn)
Kuhlmann, R.
LeBeau, J. F. (Jamaica, L. I.)
LeCompte, W. G.
Lennon, J. O.
Lucke, C. E.
Lyle, E. T.
Maier, G. M.
Mandeville, E. W. (Brooklyn)
Markush, E. U.
Marshall, H. H.
Martin, G. W.
Matthiessen, H. G. F. (Brooklyn)
McCann, F. G. (Brooklyn)
McCormack, E. T.
McKelvey, D. M.
McKiever, W. H.
Mehne, C. A.
Meisel, C. L.
Meyer, C. L. (Hollis, L. I.)
Meyer, H. C., Jr.
Mickiewicz, S. J.
Miller, C. A.
Miller, R. B.
Morrill, R. D.
Moss, E. (Brooklyn)
Munder, J. F.
Munier, L. L.
Munro, E. A. (St. Albans, L. I.)
Murphy, W. A.
Neale, L. I.
Neideck, A. A.
Nelson, C. L.
Nelson, G. A.
Nichols, G. B. (Brooklyn)
Nicol, N. C.
Oaks, O. O.
O'Connell, M.
O'Donnell, T. J.
Odrobina, S. R. (Long Island City)
Offner, A. J.
Olsen, G. E. (Arverne, L. I.)

Olvany, W. J.
Patorno, S. A. S.
Paulding, L. G.
Peacock, J. K.
Pfuhler, J. L.
(West New Brighton, S. I.)
Phillips, F. W., Jr.
(Brooklyn)
Pihlman, A. A.
Pinder, P. H.
Pine, M.
(Jamaica, L. I.)
Place, C. R.
Presdee, C. W.
Purdy, R. B.
Purinton, D. J.
Quirk, C. H.
Rack, E. C.
Raisler, R. K.
Ralston, L. T. M.
Reed, J. F.
Reynolds, W. V.
Rice, J. A.
(Gibson, L. I.)
Richardson, D. R.
Richardson, H. T.
Riley, C. L.
Ritchie, E. J.
Ritter, A.
Rodman, R. W.
Rogers, V. A.
(Center Moriches, L. I.)
Rosenberg, P.
Ross, J. O.
Roth, C. F.
Rothrock, J. T.
(Douglaston, L. I.)
Waechter, H. P.
(Tompkinsville, S. I.)
Ruggles, R. F.
(Tompkinsville, S. I.)
Ruppert, E. H.
(Brooklyn)
Samuels, S.
Schleyer, E. F.
(Brooklyn)
Schloss, N. L.
Schmidt, G. G.
Schneider, C.
Schoepflin, P. H.
Schunk, T.
(Quogue, L. I.)
Scott, C. E.
Scott, E. A.
Scott, G. M.
Scribner, E. D.
Seelig, A. E.
Sellman, N. T.
Seward, P. H.
(Brooklyn)
Sharp, F. H.
(Jamestown, L. I.)
Siebs, C. T.
Siegel, L.
(Brooklyn)
Simpson, W. A.
Sklenarik, L.
Smith, P. C., Jr.
(Northport, L. I.)
Staples, W. H.
Steinke, G. B.
Steinmuller, J. M.
Stern, H. R.
Sternberg, E.
Stewart, C. W.
Still, F. R.
Strock, C.
Sullivan, D. A.
Swain, W. A.
Sweeney, S. H.
Tallmadge, W.
Taylor, J. H.
(Queens Village, L. I.)
Thomson, T. N.
(Huntington, L. I.)
Thuem, E. A.
Tiltz, B. E.
Timmis, W. W.
Tisnower, W.
(Brooklyn)
Tucker, F. N.
Tusch, W.
(Brooklyn)
Tyler, R. D.
Van Norden, E. M.
Vetlesen, G. U.
Vivarttas, E. A.
(Brooklyn)
Vogt, J. H.
Wachs, L. J.
(Brooklyn)
Wallace, G. J.
(East Elmhurst, L. I.)
Wallace, W. M., II
(Hollis, L. I.)
Walsh, J. F.
(Brooklyn)
Walsh, M.
Walter, W.
Watters, P. J.
(Port Richmond, S. I.)
Wells, E. E.
(Beechurst, L. I.)
White, E. S.
Whitelaw, H. L.
Wilder, E. L.
Williamson, F. W.
(Brooklyn)
Willis, R. C.
Winquist, W. J.
(Brooklyn)
Winquist, W. M.
Witmer, C. N.
Wolff, R. A.
Wolfsfeld, C. F.
(Bayside, L. I.)
Yockel, T. J.
Zibold, C. E.
(Brooklyn)

North Tarrytown—
Weiss, A. P.

Odgensburg—
Skelly, J. F.

Ossining—
Hooper, V. F.

Poughkeepsie—
Doherty, J. J.

Rochester—
Axeman, J. E.
Coe, I. B.
Coe, R. T.
Cook, R. P.
Dobson, G. G.
Grau, E. R.
Hakes, L. M.
Sheldon, N. E.
Stacy, S. C.
Tavanlar, E. J.
Teeling, G. A.
Weider, F. J.
Welsh, H. S.
Wiley, C. S.

Rome—
Bennett, I. T.
Lynch, W. L.
Steele, M. G.

Rye—
Donovan, J. E.

Scarsdale—
Fiedler, H. W.

Schenectady—
Faust, F. H.
Harrington, E.
Strachan, J. S.
Vogel, A.
Welch, L. A., Jr.

Snyder—
Slater, J. B.

Syracuse—
Acheson, A. R.
Bradley, R. H.
Cook, C. J.
Ormsby, H. K., Jr.
Ryen, M.

Tuckahoe—
Hiers, C. R.

Troy—
Wilson, C. H.

Utica—
Brandeles, H. J.
Hamjy, P. W.
Hughes, W. C.
Steinhorst, T. F.
Zellwager, L. S.

White Plains—
Callahan, T. H.
Newcomb, R.

Williamsville—
Hutzel, H. F.

Yonkers—
Brabbée, C.
Goerg, B.
Kelly, J. G.
Rainger, W. F.
Ullman, H. G.
Zuhlke, W. R.

NORTH CAROLINA

Charlotte—
Bailey, J. L.
Beaty, G. M., Jr.
Brandt, E. H.
Christian, C. W.

High Point—
Gray, W. E.

Weldon—
Chappell, T. A.

Winston-Salem—
Bahnson, F. F.

OHIO

Akron—
Humphrey, D. E.
McClenathan, R.
Thatcher, G. S.

Bedford—
Titus, M. S.

Bellefontaine—
Quay, D. M.

Canfield—
Neff, C. J.

Cincinnati—
Bostain, J. C.
Breneman, R. B.
Doyle, W. J.
Green, W. C.
Grier, W.
Helburn, I. B.
Houliston, G. B.
Kiefer, C. J.
Kitchell, H. N.
Kleine, R. E.
LaSalvia, J. J.
McMahon, T. W.
Rooks, A. W.
Royer, E. B.
Sproull, H. E.
Thornburg, H. A.
True, J. E.
Wright, K. A.

Cleveland—
Benedict, E. R.
Bridges, F. G.
Brueggeman, A. R.
Calvert, N. W.
Colby, C. W.
Conner, R. M.
Deex, C. J.
Eaton, V.
Eveleth, C. F.
Farley, J. W.
Fox, O.
Gottwald, C.
Harvey, L. C.
Kammerer, W. C.
Kinner, J. E.
Kitchen, F. A.
Klie, W.
Levy, M. I.
Mathis, G. A.
Matzen, H. B.
McLeish, W. S.
Miles, J. C.
Mitchell, A. J.
Morris, F. H.
Olson, R. G.
Peacock, H.
Pogalies, L. H.
Powers, L. G.
Rather, M. F.
Roemer, J.
St. Clair, C. W.
Schweikert, J. N.
Stokes, R. E.
Thurness, B. E.
Van Sickle, W. B.
Walton, L. A.
Weager, T. A.
Wheeler, C. A.
Williams, L. E.
Wright, M. B.

Cleveland Heights—
Davis, R. G.
Givelber, S. H.

Columbus—
Babbitt, E. C.
Brown, A. I.
Lawson, W. I.
Seiders, J. T.
Somers, W. S.
Wheeler, O. J.
Williams, A. W.

Dayton—
Gibbons, M. J., Jr.
Haas, W.
Hoersting, F. J.
Reese, H. L.

Defiance—
Carey, T. M.

East Cleveland—
Nobis, H. M.
Stark, W. E.

Elyria—
Gray, R. F.
Maynard, J. E.

Kent—
Stanford, L. E.

Lakewood—
Maurer, E. D.

Martins Ferry—
Giffen, J. K.

Painesville—
Hobbs, J. C.

Portsmouth—
Knibb, A. E.

Springfield—
Hart, T. H.

Toledo—
Baker, H. C.
Bryce, S. D.
Rogers, A. C.
Vermere, E. J.

Willard—
Myers, E. V.

Youngstown—
Choffin, C. C.

OKLAHOMA

Oklahoma City—
Dolan, R. G.
Loeffler, F. X.
Miller, B. R.
Patton, R. L.
Rae, T. W.

Tulsa—
Jones, E.

PENNSYLVANIA

Allentown—
Hersh, G. W.
Korn, C. B.
McGregor, R. F.
Ware, J. E., Jr.

Ambridge—
McCreary, J. L.

Ardmore—
Haynes, C. V.
Hires, J. E.

Beaver—
Comstock, G. M.

Beaver Falls—
Van Alen, W. T.

Beechwood—
Kipe, J. M.

Belle Vernon—
Etheridge, G. T., Jr.

Chambersburg—
Mehaffey, W. C.

Cheltenham—
McElgin, J. W.

Chester—
Boyd, W. R.

Collingdale—
Wilson, A. C.

Conshohocken—
Bolsinger, R. C.

Cornwells—
Lutz, P. R.

Cynwyd—
Smith, W. F.

Delaware County—
Ramsey, H. W.

Drexel Hill—
Miller, A. A.
Rice, W. W.
Simms, R. C.

Drexel Park—
Dingleman, C. S.

East Pittsburgh—
Candee, A. H.
Thornton, F., Jr.

Elizabethtown—
Dibble, S. E.

Erie—
Mayer, R. S.

Germantown—
Anderson, C. A.
Duemler, F. C.
Gomersall, W. H.
Musson, J. R.
Whitby, S. S.

Glenshaw—
McEllroy, G. S.

Harrisburg—
Eicher, H. C.
Filson, F. E.
Fisher, E. L.
Geiger, I. H.
Lutz, J. H., Jr.
Weitzel, R. D.

Haverford—
Beahm, R. B., II
Black, E. N., III

Hazelton—
Sherry, R. W.

Holmesburg—
Nesbitt, A. J.
Nesbitt, J. J.
Nesbitt, J. J., Jr.

Jenkintown—
Slight, I.

Johnstown—
Bailey, E. P., Jr.
Novotney, T. A.
Rinkenberger, G.
Sawade, C. A.
Stitt, E. W.

Kingston—
Arthur, H. W.
Dockeray, F.
Macdonald, D. B.

Lancaster—
Belt, N. O.
Grossman, H. M.
Huzzard, E. C.
Jones, A.
Lloyd, E. C.
Schrader, C. C.
Yeomans, P. H.

Lansdowne—
James, H. R.
Myers, J. E.

McDonald—
Kuehnert, A. C.

McKeesport—
Dugan, T. M.

McKees Rocks—
Bucher, H. G.

Media—
Atkinson, K. B.

Merion Station—
Murphy, W. R.

Millvale—
Staud, C. J.

Narberth—
Wilmot, C. S.

New Castle—
Sonneborn, C.

Norristown—
Frost, R. V.
Hucker, J. H.

Overbrook—
Benson, J. C.

Philadelphia—
Ackerman, R. H.
Adams, B.
Anderson, W. M.
Arnold, R. S.
Aronson, H. H.
Bachler, H. C.
Barnard, M. E.
Bartlett, C. E.
Black, H. G.
Blankin, M. F.
Bogaty, H. S.
Boon, G.
Bornemann, W. A.
Bozeman, R. W.
Breen, J. W.
Brogan, J. J.
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Carey, J. A.
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Clarkson, R. C., Jr.
Cooper, T. W.
Cornell, J. C.
Culbert, W. P.
Dambly, A. E.
Davidson, L. C.
Davidson, P. L.
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Eagan, W. H.
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Edgar, A. C.
Eichberg, W. R.
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Erickson, H. H.
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Henion, H. D.
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Ward, W. T.
Watson, M. B.
Wilson, A. W.
Wood, J. S.

Vancouver, B. C.—
Blake, A. H.
Givin, A. W.
Johnston, R. E.
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McCreery, H. J.

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Sheret, A.

Windsor, Ont.—
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Winnipeg, Man.—
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Michie, D. F.
Summers, E. T.
Turland, C. H.

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Butt, R. E. W.
Case, W. G.
Groom, S. L.
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Herring, E.
Nobbs, W. W.
Overton, S. H.
Russell, J. N.

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Chadwick, J. B.
Yates, W.

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Webb, J. W.

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Bur, J. R. C.

Lyon—
Goenaga, R.

Paris—
Beaurrienne, A.
Downe, H. S.
Modiano, R.
Nessi, A.

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Dessau—
Junkers, H.

Stuttgart—
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Klein, A.

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Casperd, H. W. H.

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Treasurer — Judson A. Goodrich
Secretary — Wm. M. Mackay

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R. P. Bolton	Wm. M. Mackay, *Secy.*

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Wm. Kent	Wm. M. Mackay, *Secy.*

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2nd Vice-President — R. P. Bolton
Treasurer — Judson A. Goodrich
Secretary — Wm. M. Mackay

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2nd Vice-President — Robert C. Clarkson
Treasurer — Ulysses G. Scollay
Secretary — Wm. M. Mackay

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Chairman, Andrew Harvey

John Gormly	H. D. Crane
Robert C. Clarkson	A. E. Kenrick
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2nd Vice-President — C. B. J. Snyder
Treasurer — Ulysses G. Scollay
Secretary — Wm. M. Mackay

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C. B. J. Snyder	B. F. Stangland
B. H. Carpenter	J. C. F. Trachsel
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2nd Vice-President — T. J. Waters
Treasurer — Ulysses G. Scollay
Secretary — Wm. M. Mackay

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2nd Vice-President — Wm. G. Snow
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Jas. D. Hoffman, *Vice-Chm.*	John F. Hale
B. F. Stangland	August Kehm
R. C. Carpenter	C. B. J. Snyder
Frank K. Chew	Wm. M. Mackay, *Secy.*

1909

President — Wm. G. Snow
1st Vice-President — August Kehm
2nd Vice-President — B. S. Harrison
Treasurer — Ulysses G. Scollay
Secretary — Wm. M. Mackay

Board of Governors

Chairman, Wm. G. Snow

August Kehm, *Vice-Chm.*	Samuel R. Lewis
John R. Allen	James Mackay
R. C. Carpenter	B. F. Stangland
B. S. Harrison	Wm. M. Mackay, *Secy.*

1910

President ..... Jas. D. Hoffman
1st Vice-President ..... R. P. Bolton
2nd Vice-President ..... Samuel R. Lewis
Treasurer ..... Ulysses G. Scollay
Secretary ..... Wm. M. Mackay

Board of Governors

Chairman, Jas. D. Hoffman

R. P. Bolton, *Vice-Chm.* — John F. Hale
Geo. W. Barr — Samuel R. Lewis
R. C. Carpenter — James Mackay
Judson A. Goodrich — Wm. M. Mackay, *Secy.*

1911

President ..... R. P. Bolton
1st Vice-President ..... John R. Allen
2nd Vice-President ..... A. B. Franklin
Treasurer ..... Ulysses G. Scollay
Secretary ..... Wm. W. Macon

Board of Governors

Chairman, R. P. Bolton

John R. Allen, *Vice-Chm.* — A. B. Franklin
John T. Bradley — Jas. D. Hoffman
R. C. Carpenter — August Kehm
James H. Davis — Wm. W. Macon, *Secy.*

1912

President ..... John R. Allen
1st Vice-President ..... John F. Hale
2nd Vice-President ..... Edmund F. Capron
Treasurer ..... James A. Donnelly
Secretary ..... Wm. W. Macon

Board of Governors

Chairman, John R. Allen

John F. Hale, *Vice-Chm.* — Dwight D. Kimball
Edmund F. Capron — Samuel R. Lewis
R. P. Bolton — Wm. M. Mackay
Jas. D. Hoffman — Wm. W. Macon, *Secy.*

1913

President ..... John F. Hale
1st Vice-President ..... A. B. Franklin
2nd Vice-President ..... Edmund F. Capron
Treasurer ..... James A. Donnelly
Secretary ..... Edwin A. Scott

Board of Governors

Chairman, John F. Hale

A. B. Franklin, *Vice-Chm.* — James A. Donnelly
John R. Allen — Dwight D. Kimball
Edmund F. Capron — Wm. W. Macon
R. P. Bolton — James M. Stannard
Frank T. Chapman — Theodore Weinshank
Ralph Collamore — Edwin A. Scott, *Secy.*

1914

President ..... Samuel R. Lewis
1st Vice-President ..... Edmund F. Capron
2nd Vice-President ..... Dwight D. Kimball
Treasurer ..... James A. Donnelly
Secretary ..... J. J. Blackmore

Council

Chairman, Samuel R. Lewis

E. F. Capron, *Vice-Chm.* — John F. Hale
Dwight D. Kimball — Harry M. Hart
John R. Allen — Frank G. McCann
Frank T. Chapman — Wm. W. Macon
Frank I. Cooper — James M. Stannard
James A. Donnelly — J. J. Blackmore, *Secy.*

1915

President ..... Dwight D. Kimball
1st Vice-President ..... Harry M. Hart
2nd Vice-President ..... Frank T. Chapman
Treasurer ..... Homer Addams
Secretary ..... J. J. Blackmore

Council

Chairman, Dwight D. Kimball

Harry M. Hart, *Vice-Chm.* — Samuel R. Lewis
Homer Addams — Frank G. McCann
Frank T. Chapman — J. T. J. Mellon
Frank I. Cooper — Henry C. Meyer, Jr.
E. Vernon Hill — Arthur K. Ohmes
Wm. M. Kingsbury — J. J. Blackmore, *Secy.*

1916

President ..... Harry M. Hart
1st Vice-President ..... Frank T. Chapman
2nd Vice-President ..... Arthur K. Ohmes
Treasurer ..... Homer Addams
Secretary ..... Casin W. Obert

Council

Chairman, Harry M. Hart

F. T. Chapman, *Vice-Chm.* — Dwight D. Kimball
Homer Addams — Henry C. Meyer, Jr.
Charles R. Bishop — Arthur K. Ohmes
Frank I. Cooper — Fred R. Still
Milton W. Franklin — Walter S. Timmis
E. Vernon Hill — Casin W. Obert, *Secy.*

1917

President ..... J. Irvine Lyle
1st Vice-President ..... Arthur K. Ohmes
2nd Vice-President ..... Fred R. Still
Treasurer ..... Homer Addams
Secretary ..... Casin W. Obert

Council

Chairman, J. Irvine Lyle

A. K. Ohmes, *Vice-Chm.* — Harry M. Hart
Homer Addams — E. Vernon Hill
Davis S. Boyden — James M. Stannard
Bert C. Davis — Fred R. Still
Milton W. Franklin — Walter S. Timmis
Charles A. Fuller — Casin W. Obert, *Secy.*

1918

President ..... Fred R. Still
1st Vice-President ..... Walter S. Timmis
2nd Vice-President ..... E. Vernon Hill
Treasurer ..... Homer Addams
Secretary ..... Casin W. Obert

Council

Chairman, Fred R. Still

W. S. Timmis, *Vice-Chm.* — J. Irvine Lyle
Homer Addams — E. Vernon Hill
William H. Driscoll — Frank G. Phegley
Howard H. Fielding — Fred. W. Powers
H. P. Gant — Champlain L. Riley
C. W. Kimball — Casin W. Obert, *Secy.*

1919

President ..... Walter S. Timmis
1st Vice-President ..... E. Vernon Hill
2nd Vice-President ..... Milton W. Franklin
Treasurer ..... Homer Addams
Secretary ..... Casin W. Obert

Council

Chairman, Walter S. Timmis

E. Vernon Hill, *Vice-Chm.* — Frank G. Phegley
Homer Addams — Fred. W. Powers
Howard H. Fielding — Robt. W. Pryor, Jr.
Milton W. Franklin — Champlain L. Riley
Harry E. Gerrish — Fred R. Still
George B. Nichols — Casin W. Obert, *Secy.*

1920

President ..... E. Vernon Hill
1st Vice-President ..... Champlain L. Riley
2nd Vice-President ..... Jay R. McColl
Treasurer ..... Homer Addams
Secretary ..... Casin W. Obert

Council

Chairman, E. Vernon Hill

C. L. Riley, *Vice-Chm.* — Jay R. McColl
Homer Addams — George B. Nichols
Jos. A. Cutler — Robt. W. Pryor, Jr
Wm. H. Driscoll — W. S. Timmis
A. C. Edgar — Perry West
Alfred Kellogg — Casin W. Obert, *Secy.*

1921

President ..... Champlain L. Riley
1st Vice-President ..... Jay R. McColl
2nd Vice-President ..... H. P. Gant
Treasurer ..... Homer Addams
Secretary ..... Casin W. Obert

Council

Chairman, Champlain L. Riley

Jay R. McColl, *Vice-Chm.* — E. S. Hallett
Homer Addams — E. Vernon Hill
Jos. A. Cutler — Alfred Kellogg
Samuel E. Dibble — E. E. McNair
Wm. H. Driscoll — Perry West
H. P. Gant — Casin W. Obert, *Secy.*

1922

President ..... Jay R. McColl
1st Vice-President ..... H. P. Gant
2nd Vice-President ..... Samuel E. Dibble
Treasurer ..... Homer Addams
Secretary ..... Casin W. Obert

Council

Chairman, Jay R. McColl

H. P. Gant, *Vice-Chm.* — L. A. Harding
Homer Addams — E. E. McNair
Jos. A. Cutler — H. J. Meyer
Samuel E. Dibble — C. L. Riley
Wm. H. Driscoll — Perry West
E. S. Hallett — Casin W. Obert, *Secy.*

1923

President ..... H. P. Gant
1st Vice-President ..... Homer Addams
2nd Vice-President ..... E. E. McNair
Treasurer ..... Wm. H. Driscoll
Secretary ..... C. W. Obert

Council

Chairman, H. P. Gant

Homer Addams, *Vice-Chm.* — E. S. Hallett
W. H. Carrier — Alfred Kellogg
J. A. Cutler — Thornton Lewis
S. E. Dibble — E. E. McNair
Wm. H. Driscoll — Perry West

Casin W. Obert, *Secy.*

1924

President ..... Homer Addams
1st Vice-President ..... S. E. Dibble
2nd Vice-President ..... William H. Driscoll
Treasurer ..... Perry West
Secretary ..... F. C. Houghten

Council

Chairman, Homer Addams

S. E. Dibble, *Vice-Chm.* — W. E. Gillham
F. Paul Anderson — L. A. Harding
W. H. Carrier — Alfred Kellogg
J. A. Cutler — Thornton Lewis
William H. Driscoll — Perry West
H. P. Gant — F. C. Houghten, *Secy.*

1925

President ..... S. E. Dibble
1st Vice-President ..... Wm. H. Driscoll
2nd Vice-President ..... F. Paul Anderson
Treasurer ..... Perry West
Secretary ..... F. C. Houghten

Council

Chairman, S. E. Dibble

Wm. H. Driscoll, *Vice-Chm.* — W. T. Jones
Homer Addams — Thornton Lewis
F. Paul Anderson — J. H. Walker
W. H. Carrier — Perry West
J. A. Cutler — A. C. Willard
W. E. Gillham — F. C. Houghten, *Secy.*

1926

President ..... W. H. Driscoll
1st Vice-President ..... F. Paul Anderson
2nd Vice-President ..... A. C. Willard
Treasurer ..... W. E. Gillham
Secretary ..... A. V. Hutchinson

Council

Chairman, W. H. Driscoll

F. Paul Anderson, *Vice-Chm.* — C. V. Haynes
W. H. Carrier — W. T. Jones
J. A. Cutler — E. B. Langenberg
S. E. Dibble — Thornton Lewis
W. E. Gillham — J. F. McIntire

A. C. Willard

1927

President ..... F. Paul Anderson
1st Vice-President ..... A. C. Willard
2nd Vice-President ..... Thornton Lewis
Treasurer ..... W. E. Gillham
Secretary ..... A. V. Hutchinson

Council

Chairman, F. Paul Anderson

A. C. Willard, *Vice-Chm.* — John Howatt
H. H. Angus — W. T. Jones
W. H. Carrier — J. J. Kissick
W. H. Driscoll — E. B. Langenberg
Roswell Farnham — Thornton Lewis
H. H. Fielding — J. F. McIntire
W. E. Gillham — H. Lee Moore
C. V. Haynes — F. B. Rowley

1928

President.....A. C. Willard
1st Vice-President.....Thornton Lewis
2nd Vice-President.....L. A. Harding
Treasurer.....W. E. Gillham
Secretary.....A. V. Hutchinson

Council

Chairman, A. C. Willard

Thornton Lewis, *Vice-Chm.*
F. Paul Anderson
H. H. Angus
W. H. Carrier
N. W. Downes
Roswell Farnham
W. E. Gillham
C. V. Haynes
John Howatt
W. T. Jones
J. J. Kissick
E. B. Langenberg
J. F. McIntire
H. Lee Moore
F. B. Rowley

1929

President.....Thornton Lewis
1st Vice-President.....L. A. Harding
2nd Vice-President.....W. H. Carrier
Treasurer.....W. E. Gillham
Secretary.....A. V. Hutchinson
Technical Secretary.....P. D. Close

Council

Chairman, Thornton Lewis

L. A. Harding, *Vice-Chm.*
H. H. Angus
W. H. Carrier
N. W. Downes
Roswell Farnham
W. E. Gillham
C. V. Haynes
John Howatt
W. T. Jones
E. B. Langenberg
G. L. Larson
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A. C. Willard

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1930

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Technical Secretary.....P. D. Close

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D. S. Boyden
R. H. Carpenter
J. D. Cassell
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Roswell Farnham
C. W. Farrar
John Howatt
W. T. Jones
E. B. Langenberg
G. L. Larson
Thornton Lewis
F. C. McIntosh
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F. B. Rowley

1931

President.....W. H. Carrier
1st Vice-President.....F. B. Rowley
2nd Vice-President.....W. T. Jones
Treasurer.....F. D. Mensing
Secretary.....A. V. Hutchinson
Technical Secretary.....P. D. Close

Council

Chairman, W. H. Carrier

F. B. Rowley, *Vice-Chm.*
D. S. Boyden
E. K. Campbell
R. H. Carpenter
J. D. Cassell
E. A. Eastwood
Roswell Farnham
E. H. Gurney
L. A. Harding
John Howatt
W. T. Jones
E. B. Langenberg
G. L. Larson
F. C. McIntosh
F. D. Mensing
W. A. Rowe