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Ideal Heating Practice

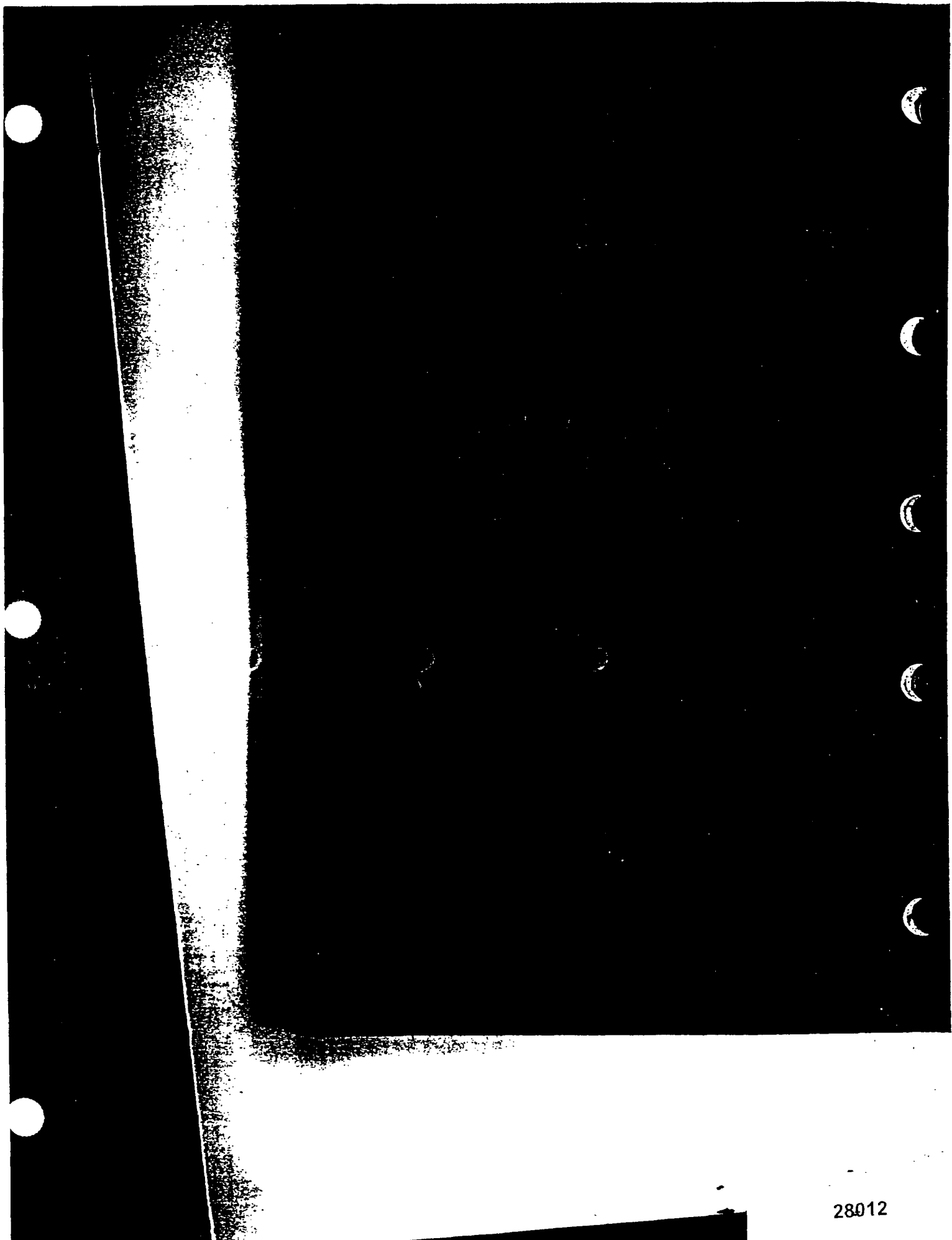


IDEAL

Heating Practice

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INTRODUCTORY

In this new hand-book "Ideal Heating Practice" we place at your disposal much information that should prove useful in your work. Among other things, it includes certain fundamentals for determining the necessary amount of Steam and Hot Water Radiation and the proper size of Boiler to heat a given space, under varying degrees of temperature and for various types of building construction, especially in replacement and modernization work.

In this book we cover the heating systems most commonly used, and confine our text to the smaller installations, avoiding those which would properly require the services of a heating engineer.

The statistics and formulas used are based on tests conducted by recognized authorities.

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DEFINITION OF HEATING TERMS

British Thermal Unit (B.t.u.)

The unit of heat measurement in the United States, Canada, and Great Britain is called the "British thermal unit." (B.t.u.)

One B.t.u. is the quantity of heat necessary to raise the temperature of one pound of water through one degree Fahrenheit. Broadly speaking, it is $\frac{1}{180}$ of the quantity of heat required to raise one pound of water from 32° F. to 212°F.

Sensible Heat

When heat is applied to water at any temperature below the boiling point, the temperature of water will rise until the boiling point is reached. Heat which raises the temperature of water, and which affects the thermometer, is called "sensible heat."

At this point (212 degrees at sea-level), and under atmospheric pressure, any further heat applied to the water will be absorbed without any rise in temperature until the water has been evaporated or converted into steam.

Latent Heat

It is evident that a large quantity of heat or energy has been expended in evaporating the water into steam, but this quantity of heat necessary to evaporate one pound of water from 212 degrees to steam at 212 degrees is approximately 970 B.t.u. This is called the "latent heat" of vaporization.

When water is evaporated under pressure, the latent heat decreases as the pressure increases. For example: Under a gauge pressure of two pounds the latent heat is approximately 966 B.t.u., and under a gauge pressure of five pounds the latent heat is approximately 961 B.t.u. (For latent heat under varying pressures see Table 14, page 91.)

Latent Heat Available

Latent heat becomes available when the steam is condensed into water. For example: When a pound of steam under two pounds pressure enters the radiator, and condenses therein, it gives off to the surrounding air 966 B.t.u.; and since one square foot of radiation will emit, or give off, 240 B.t.u. per hour under

standard conditions, it will require about four square feet of radiation to condense one pound of steam. To put it in another way, one square foot of radiation under standard conditions will condense about 0.25 pounds of steam per hour.

Co-efficient of Heat Emission

This term is usually applied to the heat emitted, or given off, by one square foot of actual radiator surface per hour for one degree temperature difference between the steam or water in the radiator and the air in the room.

When it is said that the co-efficient of a radiator is 1.66 it is meant that one square foot of surface will emit or give off 1.66 B.t.u. per hour for one degree temperature difference between the mean temperature of the steam in the radiator, and the mean temperature of the surrounding air. If the temperature of the steam in the radiator is 215 degrees and the mean temperature of the surrounding air is 70 degrees, the temperature difference will be 145 degrees, and 145 multiplied by 1.66 is about 240, showing that the radiator will give off 240 B.t.u. per square foot surface per hour under the conditions stated.

Usually the test made on radiation to determine the co-efficient is made as nearly as possible under standard conditions, that is, with one pound steam pressure at the boiler. This means that the steam will enter the radiator at about 215 degrees.

If the surrounding air is 70 degrees, the temperature difference will be 145 degrees. If the test shows that the radiator has emitted 240.7 B.t.u. per square foot surface per hour, the co-efficient is determined by dividing the heat emitted by the temperature difference. Thus $\frac{240.7}{145}$ gives 1.66. The temperature difference may be greater or less than 145 degrees, depending on the temperature of the steam and the temperature of the air in the room.

Co-efficients have a variation of 2% for each 10 degrees variation of temperature difference from standard (145). Therefore, if we have a temperature difference of 155 degrees, the co-efficient would be $1.66 \times 1.02 = 1.693$; by multiplying 155 by 1.693 we find under this condition a square foot of radiation will give off 262 B.t.u. per hour. If the temperature difference is 135 degrees, the co-efficient would be $1.66 \times .98 = 1.627$. Then by multiply-

ing 135 by 1.627 we find that a square foot of radiation will give off 219.6 B.t.u. per hour.

Heat

Heat is a form of energy and is believed to be a vibratory motion of the smallest particles (molecules) of which each body is composed.

The modes of propagation of heat are: Conduction, Convection and Radiation.

How Heat is Given Off by a Radiator

Heat is transmitted from the steam or water side of a radiator to the air side by conduction. After heat is conducted to the outer surface of the radiator, approximately 80% of the total heat given off is transmitted by convection, and the balance by radiation, so that complete transmission requires conduction, convection and radiation.

Conduction

By conduction, heat is transmitted from particle to particle of a body (internal conduction) or from one body to another, with which it is in contact (external conduction).

Convection

By convection, heat is carried away by the circulation of a fluid or gas, such as air, natural or forced.

Radiation

By radiation, heat passes through space by wave motion from one body to another without the aid of any material agency.

Heat Transmission

The passage of heat through any substance to a medium of lower temperature on the other side. For example: from the steam in a radiator to the air in the room through the walls of the radiator.

Co-efficient of Heat Transmittance

The co-efficient of heat transmittance is the amount of heat (B.t.u.) transmitted per hour per sq. ft. of surface per degree difference in temperature between the gases or liquid on the two sides of the surface.

NOTE: This includes radiation, conduction and convection.

Temperature

Temperature is a measure of the intensity of heat.

Density

Density is the weight per unit volume. (Generally used pounds per cu. ft.)

Combustion

Combustion is the chemical union of the combustible of a fuel with the oxygen of the air resulting in heat or light or both.

Rate of Combustion

Rate of Combustion is the number of pounds of coal burned per sq. ft. of grate per hour.

Gauge Pressure

Pressure measured from atmospheric pressure as a base.

Absolute Pressure

The gauge pressure plus the atmospheric pressure is equal to the absolute pressure.

Steam

Steam is water vapor.

Saturated Steam

Saturated Steam is water vapor in the condition in which it is generated from the water with which it is in contact.

Wet Saturated Steam

Wet Saturated Steam is steam containing entrained moisture.

Dry Saturated Steam

Dry Saturated Steam is steam containing no entrained moisture.

Superheated Steam

Superheated Steam is steam heated higher than the temperature corresponding to its pressure.

Heat of the Liquid

The sensible heat of a quantity of liquid above an arbitrary zero.

NOTE: Heat of the liquid increases with increase of pressure.

Latent Heat of Fusion

Latent Heat of Fusion is the quantity of heat to be added or extracted to change a solid into a liquid and vice versa without change of its temperature.

Latent Heat of Evaporation

Latent Heat of Evaporation is the heat required to change a liquid into a vapor without changing its temperature.

Specific Heat

Specific Heat is the quantity of heat (B.t.u.) required to raise one pound of a substance one degree F.

Actual Evaporation

Actual Evaporation is the number of pounds of water actually evaporated under the conditions of the test.

Evaporation

Evaporation is the process of transforming a substance from the liquid state into a gaseous state.

Equivalent Evaporation

Equivalent Evaporation is the number of pounds of water which a boiler would have evaporated if it received feedwater of 212° F. and vaporized it at the same temperature and atmospheric pressure. $34\frac{1}{2}$ pounds equivalent evaporation per hour equals 1 Boiler HP approximately 139 sq. ft. standard radiation (240 B.t.u. sq. ft.).

Evaporative Power

Evaporative Power is the number of pounds of water, (equivalent evaporation) evaporated per pound of coal burned.

Overall Efficiency

Overall Efficiency, also known as Boiler and Grate Efficiency, is the ratio of the heat absorbed by a boiler to the heat value of

the fuel fired. A general definition of efficiency is Output over Input.

Boiler Efficiency

Boiler Efficiency is the ratio expressed in per cent of heat absorbed by the boiler to the heat released in the fire box.

Calorific Value

Calorific Value is the number of heat units available from the complete combustion of one pound of moisture-free coal (B.t.u. per pound).

Specific Gravity

Specific Gravity is the ratio of the weight of a given body of any substance to the weight of an equal volume of a substance used as a standard. (The standard for solids and liquids is generally water—the standard for gases is generally air.)

CO

CO is the Symbol for carbon monoxide which denotes incomplete combustion of the carbon in the fuel.

CO₂

CO₂ is the Symbol for Carbon Dioxide, which is the result of complete combustion of the carbon in the fuel.

Condensation

Condensation—The change from a vapor into a liquid state due to cooling.

Calorie

One calorie is equal to 3.97 B.t.u.

Atmospheric Pressure

Atmospheric Pressure at sea level is 14.7 lbs. per sq. in.

Design Load

Design Load is the sum of the radiation, piping, domestic water and any other material or conditions and expressed in terms of Equivalent Direct Radiation 240 B.t.u. Steam 150 B.t.u. Water.

HEATING BOILERS

Outputs or Ratings

Ideal Boilers are constructed according to the low pressure heating boiler code of the American Society of Mechanical Engineers, (A.S.M.E.).

Output Standards

In order to be able to examine and compare the performance and output of ALL makes and sizes of ALL solid fuel burning heating boilers—the manufacturers established—especially for test comparison purpose—a standard heat value of 13,000 B.t.u. per pound HARD coal, moisture free.

Also a uniform pressure when testing boilers: For steam, two pounds gauge pressure 219 degrees F. temperature; for water, 180 degrees F. temperature.

It was decided to express all heating boiler ratings in square feet of installed radiation—selecting as a standard heat emission 240 B.t.u. for steam and 150 B.t.u. for water radiation per square foot of surface per hour.

Kind of Fuel Used in Ideal Boilers

Ideal coal burning boilers will operate in an entirely satisfactory manner when burning Anthracite, Bituminous, Coke, Lignite, Oil or Gas.

Oil Burning boilers are primarily intended for the use of Oil. Gas Burning boilers can only be used for Gas.

Selecting the Boiler

For all ordinary heating installations when direct cast iron or convactor type radiation is installed to maintain 70 degrees F. room temperature and with covered piping select the proper size boiler according to recommendations in American Radiator & Standard Sanitary Corporation Trade Price Sheet.

Selecting the Boiler for Special Conditions

On installations involving special boiler loads not regularly encountered on ordinary heating jobs and not provided for in the

Trade Price Sheet, such as Unit heaters, Pipe Coil radiation, Water Storage Tanks, Indirect or Direct Indirect radiation, high temperature water radiation or radiation in air other than 70 degrees F. or where the piping is not covered, it becomes necessary to select larger or smaller boilers than would be selected for the ordinary heating installation.

When special conditions exist involving one or more of the previously mentioned or other special conditions, they should be converted to the equivalent of 240 B.t.u. steam or 150 B.t.u. water, on which basis Ideal Boilers are rated.

If we were called upon to size a boiler where 1800 square feet of Peerless Wall radiation is installed in air at 50° F. and with piping uncovered, we should recommend a 3-S-10 Redflash rated at 2700 square feet; whereas, if we sized the boiler from Trade Price Sheet on the basis of 1800 square feet without giving consideration to the extra boiler tax due to the higher condensing effect of both the radiation and piping, we would recommend a 3-S-7 Boiler, which boiler would not perform satisfactorily.

When it is required to find the boiler tax imposed by special conditions, it is necessary to first convert all load to equal 240 B.t.u. steam and 150 B.t.u. water and for this purpose Tables 1 and 4 are provided.

TABLE 1
Multipliers for Converting Special Boiler Loads
to Equivalent Radiation Loads
of 240 B.t.u. Steam—150 B.t.u. Water.
For B.t.u. outputs of Hot Water Radiation, see Page 85.

Temperature of Air Surrounding Radiator Deg. F.	Average Water Temperature in Direct Radiator. Forced or Gravity Circulation					Steam Average Temp.
	170°F. Std.	180°F.	190°F.	200°F.	210°F.	
50	1.25	1.38	1.51	1.65	1.79	1.20
55	1.19	1.31	1.45	1.58	1.72	1.15
60	1.12	1.25	1.38	1.51	1.65	1.10
65	1.06	1.19	1.31	1.45	1.58	1.05
70	1.00	1.12	1.25	1.38	1.51	1.00
75	.94	1.06	1.19	1.31	1.45	.95
80	.88	1.00	1.12	1.25	1.38	.90

For converting multipliers on Indirect and Direct-Indirect Radiation, also outputs of Unit Heaters, Vento Heaters, etc., see next page.

Gravity Indirect Radiation multiply by 1.7

Direct Indirect Radiation multiply by 1.2

Unit Heaters See Manufacturers Catalog for B.t.u. output or rate of condensation.

Vento Heaters See Engineers Data Book for B.t.u. output or rate of condensation.

When the B.t.u. output or the rate of condensation on Unit Heaters, Vento Heaters, etc. is known, convert to equivalent radiation to establish boiler load (see Page 6).

Piping Loads must be considered

See Table 5 P. 86—Table 8 P. 88.

For Example:

If we have 100 sq. feet of Standard Column Steam Radiation standing in air at 50° F., we would have a greater boiler tax than this 100 square feet would impose standing in air at 70° F. So to find boiler tax, we multiply 100 by 1.20 (the converting multiplier) which equals 120 square feet of boiler tax. But if we had this same amount of radiation standing in air at 80° F., we would have less tax than if radiator was standing in air at 70° F. Therefore, our multiplier would be .90, or 100 multiplied by .90 which equals 90 square feet of boiler tax.

These differences are brought about by the fact that in 50° temperature, each sq. ft. of radiator surface will condense more steam than when the radiator is standing in air at 70° F. and will therefore impose a greater load on the boiler, whereas with the 80° F. temperature, each sq. ft. will condense a lesser amount of steam and therefore will not impose as much boiler load.

Since we have but one rating on Ideal Boilers, which rating represents the amount of installed radiation in air at 70 Deg. F. plus the normal amount of covered piping and pick-up, it becomes necessary to provide a means of selecting a boiler for other conditions. For this purpose we have provided Tables 1 and 4 and Charts 1 and 1A which greatly simplify this problem.

The following examples will serve as a guide for determining actual load, as expressed in terms of 240 B.t.u. Steam, and show how conversion multipliers are used.

EXAMPLE 1

Type of Equipment Installed Steam System	Radiation Piping, etc. Sq. Ft.	Conversion Factor for Converting to Equivalent Direct Rad.	Equivalent Direct Radiation Sq. Ft.
Standard Col. Radiation Air at 70° F.	1000	1.0	1000
Gravity Indirect Pin Radiation	200	*1.7	340
Peerless Wall Radiation Air at 50° F.	400	*1.2	480
Uncovered Piping Air at 60° F. Average		**46% of 1600 sq. ft. actual in- stalled radiation	
Total Sq. Ft. of Radiation	1600		736
Estimated Design Load (240 B.t.u.)			2556

*See Table 1

**See Table 5

By this it will be seen that although there is a total of 1600 square feet of installed radiation exposed to air at varying degrees of temperature, because of the increased condensing effect to which portions of the surface are subjected and the higher condensing effect of bare pipe as compared to covered pipe, the demand for steam is so increased that for the example cited the actual demand on the boiler would be equal to 2556 square feet of radiation at 240 B.t.u. output per square foot per hour.

To make selection of the proper size boiler, refer to Chart 1A, Page 17. Follow along bottom line (estimated design load) to 2556 sq. ft., follow intersecting line up to diagonal line, and follow intersecting horizontal line to left column and select boiler with installed radiator rating of 2200 sq. ft.

It seems advisable to shed a little light on this boiler selection, since we selected a boiler of lesser capacity than the load would seem to require.

The figures in left column of Charts 1 and 1A represent installed radiator rating as shown in trade-price sheet, and include covered piping and pick-up and, on hand-fired boilers, there is a reserve capacity for heating a normal amount of domestic hot water (10% of installed radiation expressed in gallons).

NOTE: When establishing design loads for use of Charts 1 and 1A, we must in all cases include piping loads whether covered or uncovered because the normal boiler capacity allowed for covered piping in installed radiator ratings is automatically deducted and, therefore, must be re-established.

On installations involving special conditions it becomes necessary to establish the total boiler load (design load) including piping (which in some cases may not be covered). Charts 1 and 1A (pages 16 and 17) are for the purpose of converting design load to catalog rating, and are for use on steam and hot water, hand-fired or automatically fired coal, oil or gas boilers.

Chart 1 for selecting boilers with ratings up to 1000 sq. ft. and Chart 1A for boilers of more than 1000 sq. ft. ratings.

EXAMPLE 2

Suppose we have a building with the following amounts of steam radiation installed under varying degrees of temperature, what size steam boiler will be required?

300	Sq. Ft. Column Radiation	— in air at 70 deg. F.
300	" " " "	" " " 60 " "
300	" " " "	" " " 50 " "
500	" " Peerless Wall Rad.	" " " 50 " "
200	" " Gravity Indirect Radiation	

1600 Sq. Ft. Installed Radiation.

Referring to Conversion Table 1 P. 12, we find opposite 70° under Standard Col. Steam Rad. the multiplier 1.00, opposite 60° the multiplier 1.10, opposite 50° the multiplier 1.20, and for Gravity Indirect the multiplier 1.70. So to arrive at boiler load expressed in terms of 240 B.t.u. per square foot, proceed as follows:

300 sq. ft. Std. Col. Rad.	× 1.00 =	300
300 " " " "	× 1.10 =	330
300 " " " "	× 1.20 =	360
500 " " Peerless Wall	× 1.20 =	600
200 " " Gravity Indirect Rad.	× 1.70 =	340
**Covered piping 19% of 1600 ft.	=	304

Estimated Design Load (240 B.t.u.) = 2234 sq. ft.

**See Table 5, P. 86.

By following Chart 1A as previously explained, we would select a boiler from trade price sheet having a 1925 sq. ft. Installed Radiator rating.

EXAMPLE 3

High Temperature Water

Since all hot water boilers are rated on the basis of 180° water at the boiler with 170° average temperature in the radiator and

NOTE: WHEN USING BOILER SELECTING CHARTS 1 AND 1A, PIPE TAX, WHETHER COVERED OR UNCOVERED, MUST ALWAYS BE INCLUDED.

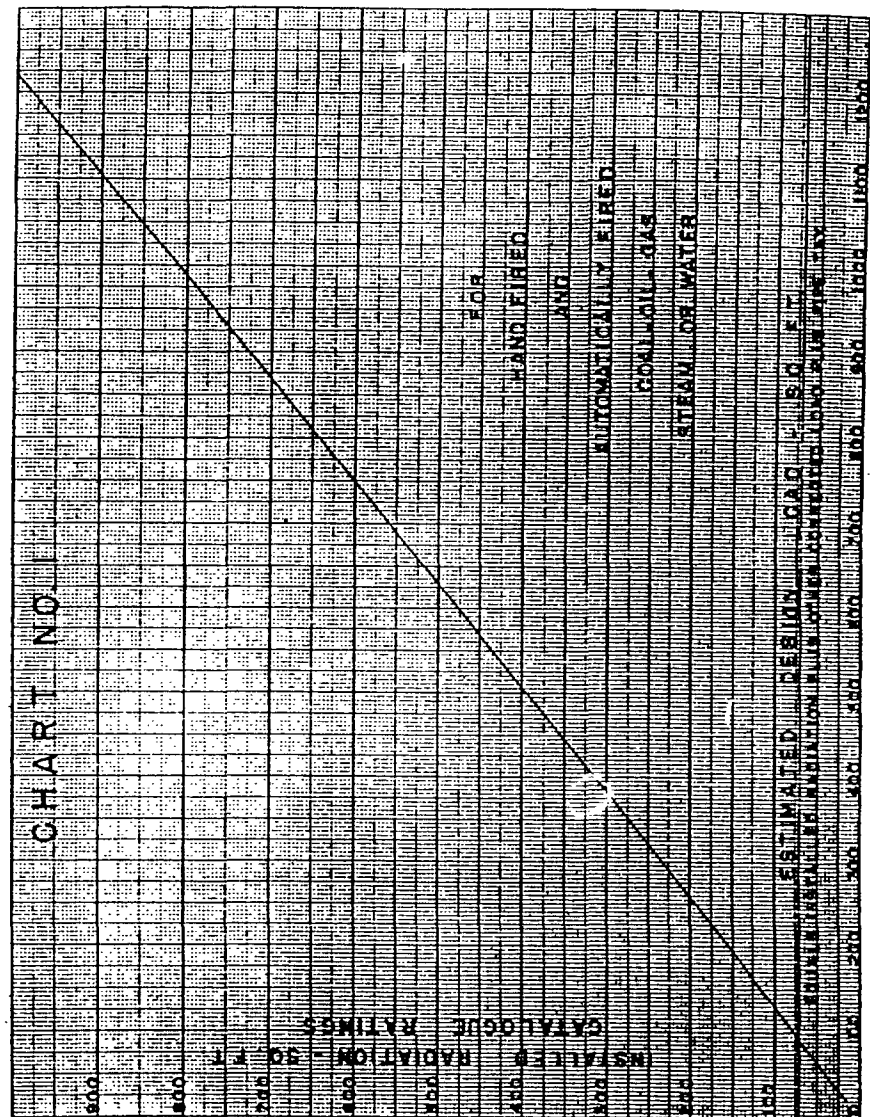


Chart No. 1

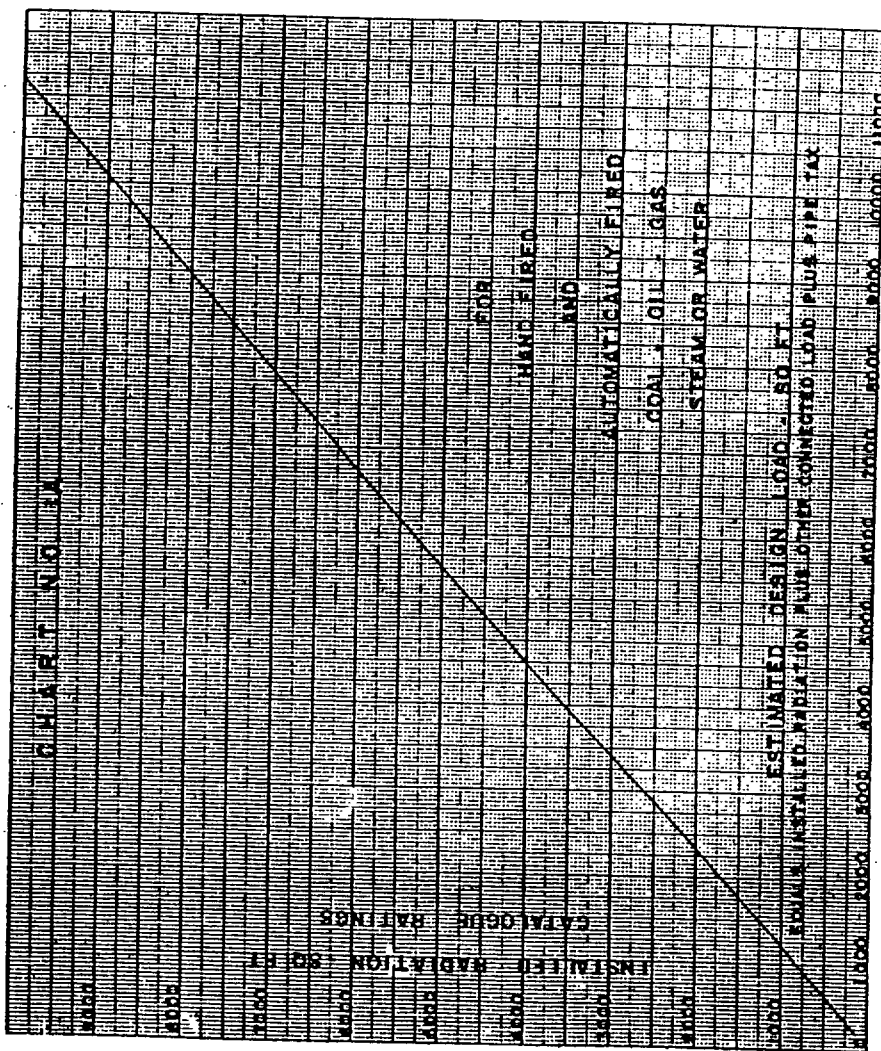


Chart No. 1A

150 B.t.u. output per sq. ft. of radiation, we are presented with a problem of selecting the proper size boiler when high temperature water is used, especially on forced circulated systems.

On gravity circulating systems, the average drop in water temperature through the system is about 25 deg., but due to the more rapid circulation on forced systems, the drop in temperature will average about 10 deg. This, together with the higher water temperature used on this type of system, causes each sq. ft. of radiation to impose an extra load on the boiler. See Page 85.

Suppose we have the following amounts of radiation and temperatures, what is our boiler load as expressed in standard conditions of 150 B.t.u. emission per sq. ft. per hour?

Average water temperature in radiators 190 deg. F.	
500 sq. ft. Std. Col. Rad. in air at 70 deg. F.	
300 " " " " " " " 60 " "	
200 " " " " " " " 50 " "	
1000	

Referring to Table 1, P. 12, opposite 70 deg. and under 190°, we find the multiplier 1.25, opposite 60 deg. the multiplier 1.38 and opposite 50 deg. the multiplier 1.51. To find boiler load we proceed as follows:

500 sq. ft. multiplied by 1.25 =	625
300 " " " " 1.38 =	414
200 " " " " 1.51 =	302
**Covered piping 22% of 1000 ft. =	
220	

Estimated Design Load (150 B.t.u.) = 1561 sq. ft.

**See Table 5, P. 86.

Make selection of boiler on Chart 1A as previously described. In this instance we would require a boiler with an Installed Radiator rating of 1300 sq. ft.

Boiler Loads

Boiler loads can be quite accurately estimated on any system regardless of the kind of material or conditions. There are, however, certain types of equipment such as Vento Heaters, Unit Heaters, large quantities of domestic water, swimming pools, etc. where the load imposed by the piping is comparatively small.

In instances where material or conditions, such as that above mentioned, are encountered, the load due to piping is in some

cases almost negligible: therefore, it would be unwise, for example, to add 22% for covered piping on 1000 sq. ft. of Vento because this type of radiation is usually located near the boiler and requires but a small amount of pipe per sq. ft.

In such cases it will be necessary to rely on your own best judgment in establishing pipe tax.

Replacing Old Boiler

If boiler is for replacement, the quantity of radiation required plus any other heating demands should guide in selecting the proper size boiler for the job. Do not select a boiler with the same grate area as the one to be replaced, because some boilers are replaced because they are too small for the job and in other cases because there is not sufficient radiation installed to heat the building, or simply because the boiler is damaged beyond repair. In all such cases select the size boiler according to actual requirements.

Bituminous Coal

Soft coal boiler ratings are based on a heat content of 13000 B.t.u. per pound of coal. If coal of lower heat value is used, the boiler size must be increased according to the following table.

B.t.u. Content of Coal	Percentage to be Added
13000	0
12000	14
11000	29
10000	46
9000	67

EXAMPLE: Suppose in our regular practice as outlined, we find that for a certain installation we require a boiler having a rating of 2000 sq. ft., but for this installation it is proposed to use coal with a heat value of only 9000 B.t.u. per pound.

In this case it will be necessary to select a boiler 67% larger than when 13000 B.t.u. coal is used, or a boiler having a rating of 3340 sq. ft.

Location of Boiler

The location of the boiler with respect to the location of the chimney is of importance. Best results will be obtained if the boiler can be located near the chimney, permitting the use of a short smoke pipe and no elbows. If the location of the boiler is such as to require the use of elbows in the smoke pipe, greater draft tension will be necessary. Each 90° elbow is equal to 15 lineal feet of smoke pipe and each 45° elbow is equal to 8 lineal feet in resistance. If, on the above basis, we have a smoke pipe with two 90° elbows, which is equal in length to 30 feet of straight smoke pipe so far as resistance is concerned, still it would be preferable to use the short smoke pipe, with the two 90° elbows. Having less cooling surface, the short smoke pipe maintains higher stack gas temperatures, which are necessary to create good draft.

Stoking Space

Stoking space should be considered. As a rule the space allowed in front of the boiler should be somewhat greater than the length of the boiler, and in the case of round boilers this space should be considerably more than the depth of the boiler.

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CAST IRON & STEEL BOILERS & FURNACES FOR COAL, OIL, GAS
• RADIATORS • CAST IRON ENAMELED & VITREOUS CHINA PLUMBING
FIXTURES & PLUMBERS' BRASS GOODS • WINTER AIR CONDITIONING UNITS
COAL & GAS WATER HEATERS • OIL BURNERS • HEATING ACCESSORIES

AUTOMATICALLY FIRED SYSTEMS

OIL - GAS - STOKER

Nearly one-third of all urban dwellings using central heating plants are now equipped with some type of automatic firing. The widespread use of automatic firing has brought with it many new problems not met with in hand fired systems. These problems involve chiefly, control of the fire and even distribution of heat. The primary function of the controls is to regulate the amount of fuel burned to meet load condition and control room temperature.

In addition to this type of control there are others that might be classed as safety controls, and while each performs a certain function, they are all more or less inter-related.

Controls may be classified as manual, continuous or automatic, depending on system requirements, but since we are interested primarily in heating we will treat only with fully automatic systems due to the fact that nearly all automatic heating systems are so equipped.

Complete Automatic Control

Automatically fired systems usually operate intermittently on the demand of the thermostat. The firing device starts when the thermostat calls for heat and stops when the thermostat is satisfied. Oil burners and stokers operate only on one firing rate: they are either fully on or fully off. Gas boiler controls permit a throttling of the gas supply and thereby the firing rate can be varied to meet the demand. The throttling action is accomplished on steam jobs by steam pressure and by water temperature on hot water jobs.

Intermittent Heating

Many attempts have been made to vary the firing rate on oil and stoker fired systems to meet the heating demand without success. Therefore, we must, for the present, accept intermittent heating operation, and as a matter of fact there can be little improvement since fast venting for steam and balancing fittings for water have been introduced.

With the introduction of new controls that shorten the on and off cycles, together with fast venting air valves and balancing fit-

tings, makes it possible to have a balanced distribution of heat to each radiator and brings intermittent oil and stoker systems to the point of perfection.

It eliminates "cold 70" which in the early days of automatic heating caused complaints particularly with oil and stoker firing.

On hot water systems the gas supply can be throttled to maintain any desired water temperature, and on steam systems the gas can be throttled so as to supply just enough heat for a few of the radiators that may be turned on, thus eliminating to a great extent intermittent heating.

There are two essentials necessary in automatically fired systems; First: the proper distribution of radiation, and Second: an even distribution of heat (Steam or Water) to each radiator.

The proper distribution of radiation is a simple mathematical problem, whereas, the even distribution of heat is functional and until recently a difficult problem. Even with the latest design and most up to date boiler and room temperature controls it remained a difficult problem until the introduction of fast venting adjustable air valves for steam radiators and balancing ells and fittings for forced hot water radiation. These latter devices added just that which was necessary to make automatic radiator heating outstanding for carefree comfort.

The Functions of Boiler and Room Temperature Controls

While each type of automatically fired system requires approximately the same kind of boiler and temperature control devices, it seems advisable to describe the functions of each of the devices which are more or less inter-related.

Therefore, in the following pages we describe in detail the various control devices used on each type of system, with accompanying diagrams showing the application of the controls.

CONTROLS FOR GAS FIRED SYSTEM

(See Figure 1)

Room Thermostat (No. 1)—The Thermostat controls the Gas Boiler. Illustration shows a 3-wire clock type. When the room temperature drops below the predetermined setting, the thermostat closes an electric circuit. The wire coil in the Thermotor Element (No. 11) is thereby energized (heated), causing the liquid to expand which exerts a pressure against a lever in the gas valve (No. 12). This action opens the valve and permits gas to flow to the main burner heads (No. 15) where it is ignited by the permanently burning pilots (No. 16) and (No. 17).

When the Room Thermostat has been satisfied, the electric circuit is broken, wire coil cools, liquid contracts and pressure against lever in gas valve is released, permitting gas valve to close.

Transformer (No. 2)—This is used for the purpose of reducing the voltage to the Room Thermostat (No. 1) Clock Motor.

Transformer (No. 3)—Another Transformer is used to reduce the voltage to the Thermotor Element (No. 11) from 110 to about 20 volts.

Relay (No. 4)—Here is illustrated the Relay and its wiring to the Room Thermostat (No. 1); to the Thermotor Element Transformer (No. 3); and to the Thermotor Element itself (No. 11). This Relay is necessary when using a 3-wire type of Room Thermostat, but is not necessary when the Detroit Lubricator Company's 2-wire Room Thermostat is used. The purpose of the Relay is simply to transpose a 3-wire circuit (of thermostat) to a 2-wire circuit (of Thermotor Valve).

Low Water Cut-Off (No. 5)—The purpose of this control is to extinguish the main burners in the event the water in a steam boiler drops below a safe level. This is accomplished by running the gas for the Thermostatic Pilot Element (No. 18) through the Low Water Cut-Off. When the water level drops, Float (No. 6) also drops, thereby stopping the flow of pilot element gas at No. 7. The Thermostatic Pilot Element flame is thus extinguished. This permits element coil (No. 18) to cool, the vapor contained in it cools and contracts, thereby eliminating the pressure against the lever in the gas valve (No. 12) and so permitting the gas valve to close.

When the water level in the boiler is brought back to normal, Float (No. 6) rises. Valve (No. 7) is opened. Pilot gas flows to pilot (No. 18) which gas is ignited by runner pilot (No. 17) and (No. 16). (17 is relit by constant burning pilot 16.) Liquid then becomes vapor and expands inside coil and opens gas valve (No. 12). Gas flows again to main burners where it is ignited by permanent burning pilot (No. 16). There is no Low Water Cut-Off on a water boiler.

Pressure and Vacuum Gauge (No. 8)—This instrument shows the steam pressure in the boiler or its vacuum.

In the case of a Water Boiler a combination Altitude Gauge and Thermometer would be used.

Thermotor Gas Valve (No. 12)—This valve controls the flow of gas to the burner heads (No. 15) inside the boiler. As explained under No. 1, when the Room Thermostat calls for heat the wire coil in Thermotor Element (No. 11) is energized, thus opening this valve.

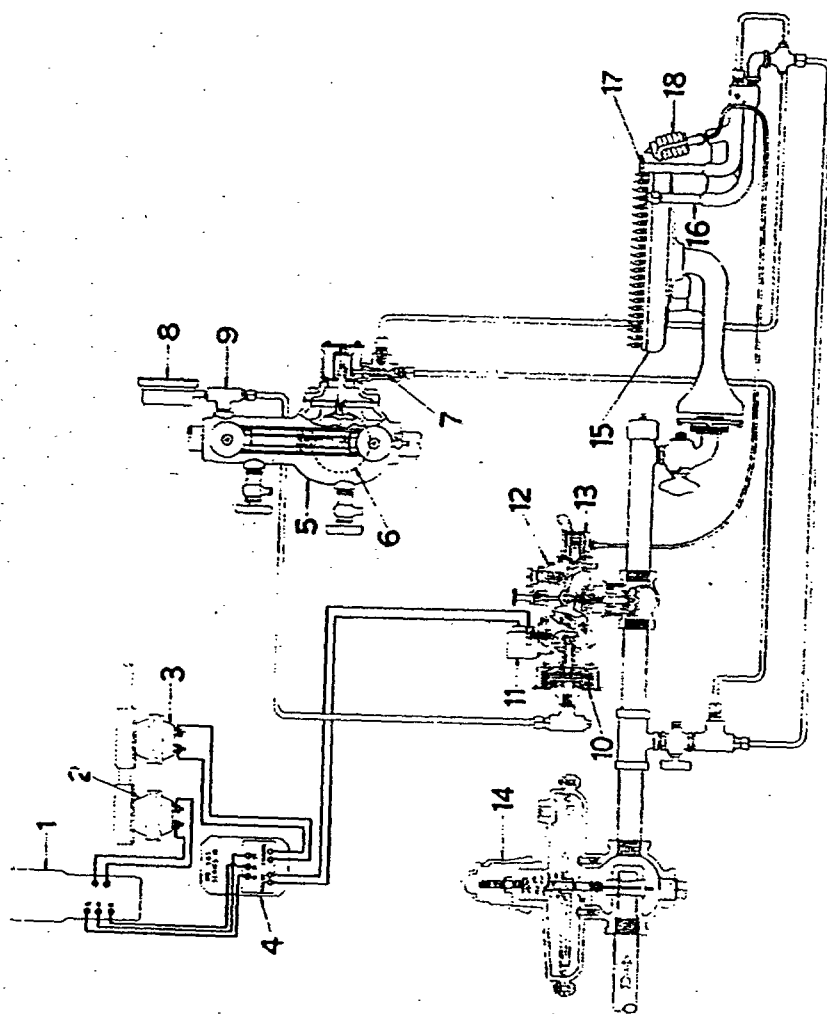
Part No. 10 is an integral part of the Gas Valve and is called a Steam Throttling Element. The steam pressure in the boiler is conveyed through a copper tube from Fitting (No. 9) to this Steam Throttling Element (No. 10).

When the steam pressure in the boiler exceeds that for which the valve was set, it overcomes the resistance of the spring in the Steam Throttling Element and throttles the flow of gas so as to maintain the desired pressure. Should the pressure continue to build up, the valve will close completely.

On a water boiler the same principle is used, but a thermal element is immersed in the water flow or is clamped in contact with the flow pipe.

This Gas Valve is also used on our Gas Convertors. When a Convertor is installed in a Furnace, a temperature type power element is used. The bulb is placed in the bonnet of the furnace. When prescribed limits of temperatures are reached, the gas flow is throttled or closed off completely, as the case may be.

Part No. 11 is also an integral part of the Gas Valve. This is the Thermotor Element referred to under No. 1. As explained there, a wire coil heats up causing a thrust against a lever inside the Gas Valve. The Valve is held open until the Room Thermo-



Controls for Gas Fired System
Figure 1

stat has been satisfied, whereupon the electric circuit breaks, and the Thermotor Element cools, permitting valve to close.

Part No. 13 is another integral part of the Gas Valve and is called the Thermostatic Pilot Element. It extends from the valve proper to a point near a main burner head. See No. 18, which is the pilot or coil end. A flame burns inside this coil. The flame heats the liquid inside the tube, causing liquid to vaporize with a resulting thrust against a lever inside the Gas Valve at No. 13.

If the pilot flame is accidentally extinguished, the vapor condenses and contracts, thus relieving the pressure against the lever inside the Gas Valve and thereby permitting the valve to resume its normal position WHICH IS "CLOSED". It will readily be perceived that the owner enjoys complete protection with our control.

Note particularly that this protection is not dependent on electricity. An Ideal Gas Boiler can be operated with total safety before electric current is available in the house and also in the event of current failure or interruption.

Gas Pressure Regulator (No. 14)—This control reduces and holds constant the pressure of the gas as it comes in from the street, through the meter and up to the gas boiler. The Regulator is placed in the gas line adjacent to the boiler and just ahead of the Gas Valve. When the gas comes out of the Regulator and enters the Gas Valve, it has been reduced to an unvarying pressure of only $2\frac{1}{2}$ " or 3" of water which is roughly, $1\frac{1}{2}$ to $1\frac{3}{4}$ ounces pressure per square inch.

OIL BURNER CONTROLS FOR STEAM

Year-Around Domestic Hot Water

(See Figure 2)

Room Thermostat (No. 1)—The thermostat controls burner. When the room temperature drops below the predetermined setting, the thermostat closes an electric circuit energizing a relay (an electric switch), in the stack control (No. 2); this relay starts the burner motor (No. 7); coupled to this is a pump which forces oil under pressure through the burner nozzle emitting a fine oil spray. The ignition transformer (No. 6) at the same time produces a hot spark across the electrodes, which ignites the oil mist and the flame is started. A fan within the blower housing and on the motor shaft provides the air necessary for combustion. The flame continues until the pressure in the boiler or the thermostat is satisfied, at which time, the electric circuit is opened and the burner stops.

Stack Control (No. 2)—Sometimes called a safety switch, this device is the key control in the system. It consists of a relay, a heat switch, a helix of thermostatic metals (actuated by the heat of the stack gas) and a transformer to reduce the voltage from 110 to about 24 volts for the auxiliary controls, which operate at low voltage.

If the flame is maintained, the heat switch is cut out of the circuit by the movement of the helix. On the other hand, if oil fails to ignite or flame failure occurs during regular operation, this control automatically shuts down the burner which cannot be restarted until the button on the control is shifted manually.

Pressure Limit Control (No. 3)—This control stops the burner motor when the steam pressure reaches the predetermined setting on the control. After the pressure reduces to a certain point, the control will again make contact and start the motor. This cycle will continue until the room thermostat is satisfied.

Immersion Operating Control (No. 4)—This control operates the burner whenever the water temperature falls below a predetermined setting, which is usually 160° to 180°.

Low Water Cutout (No. 5)—As the name implies, this control stops the burner if the water level in the boiler falls below a safe level. When the proper water level is reestablished, the system will again operate.

OIL BURNER CONTROLS FOR WATER

Year-Around Domestic Hot Water

(See Figure 3)

Room Thermostat (No. 1)—The thermostat controls burner. When the room temperature drops below the predetermined setting, the thermostat closes an electric circuit energizing a relay (an electric switch) in the stack control (No. 3); this relay starts the burner motor (No. 7); coupled to this is a pump which forces oil under pressure through the burner nozzle emitting a fine oil spray. The ignition transformer (No. 6) at the same time produces a hot spark across the electrodes, which ignites the oil mist and the flame is started. A fan within the blower housing and on the motor shaft provides the air necessary for combustion. The flame continues until the pressure in the boiler or the thermostat is satisfied, at which time, the electric circuit is opened and the burner stops.

Immersion Operating Control (No. 2)—This control operates the burner whenever the water temperature falls below a predetermined setting, which is usually 160° to 180°.

Stack Control (No. 3)—Sometimes called a safety switch, this device is the key control in the system. It consists of a relay, a heat switch, a helix of thermostatic metals (actuated by the heat of the stack gas), and a transformer to reduce the voltage from 110 to about 24 volts for the auxiliary controls, which operate at low voltage.

If the flame is maintained, the heat switch is cut out of the circuit by the movement of the helix. On the other hand, if oil fails to ignite or flame failure occurs during regular operation, this control automatically shuts down the burner which cannot be restarted until the button on the control is shifted manually.

Limit Control (No. 4)—This control stops the burner motor when the water temperature reaches the predetermined setting on the control. After the water temperature reduces to a certain point, the control will again make contact and start the motor. This cycle will continue until the room thermostat is satisfied.

Relay Transformer (No. 5)—The relay transformer serves two purposes—One: to supply low voltage current to the thermo-

stat; Two: to serve as a switch to turn on or off both the circulator motor and the burner motor in response to the room thermostat.

Reverse-Acting Immersion Control (No. 6)—This control is used if the boiler is equipped with a ~~reverse-acting~~ heater. Its purpose is to shut off the circulator if the water temperature falls below a predetermined setting. It prevents, thereby, cold return water from reaching the water heater coils.

Oil Burner Control Circuit—For Steam Boilers With Year-around Domestic Hot Water

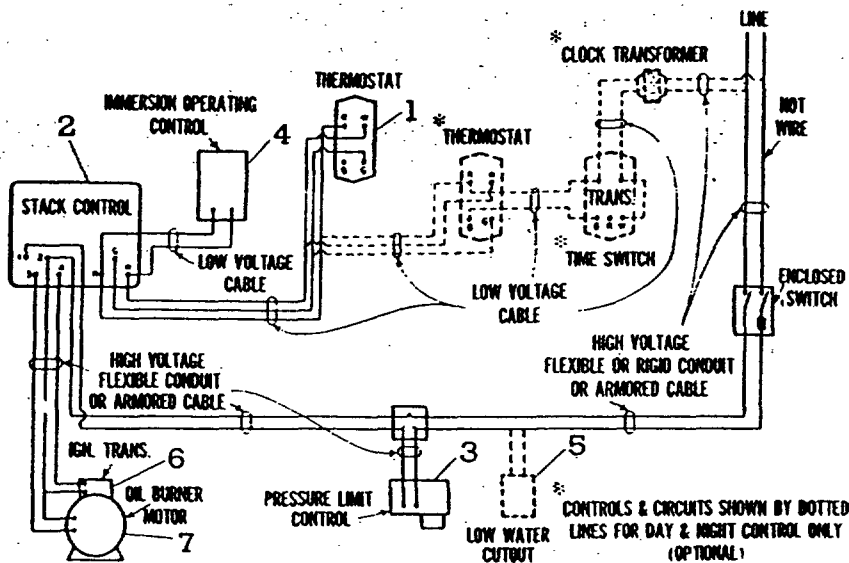


Figure 2

Oil Burner Control Circuit—For Water Boilers With Year-around Domestic Hot Water

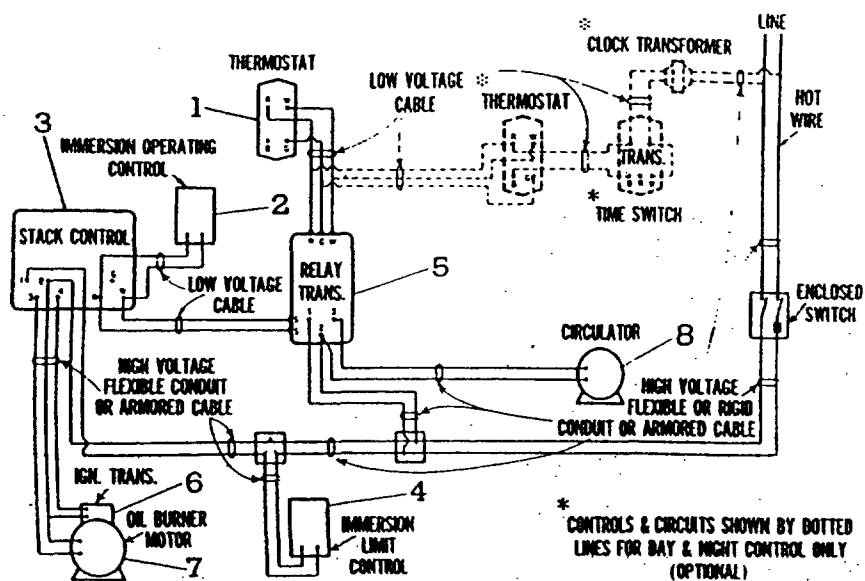


Figure 3

CONTROLS FOR STOKER FIRING

For Steam Boilers—no domestic hot water

(See Figure 4)

- 1—Room thermostat (low voltage)
- 2—Pressure limit control
- 3—Low water cutout
- 4—Timer relay

For Steam Boilers—with domestic hot water

(See Figure 4)

- 1—Room thermostat (low voltage)
- 2—Pressure limit control
- 3—Low water cutout
- 4—Timer relay
- 5—Immersion operating control

For Water Boilers—no domestic hot water

(See Figure 6)

- 1—Room thermostat (low voltage)
- 4—Timer relay
- 6—Immersion limit control

For Water Boilers—with year-around domestic hot water

(See Figure 5)

- 1—Room thermostat (low voltage)
- 5—Immersion operating control
- 6—Immersion limit control
- 7—Timer
- 8—Reverse acting immersion control
- 10—Relay transformer

Thermostat (No. 1)—The thermostat controls the stoker motor (No. 9). When the room temperature drops below a predetermined setting, the thermostat closes an electric circuit and starts the stoker motor. When the thermostat is satisfied, it opens its circuit and stops the stoker motor.

Pressure Limit Control (No. 2)—This control stops the stoker motor (No. 9) when the steam pressure reaches the predetermined setting on the control. After the pressure reduces to a certain point, the control will again make contact and start the motor. This cycle will continue until the room thermostat is satisfied.

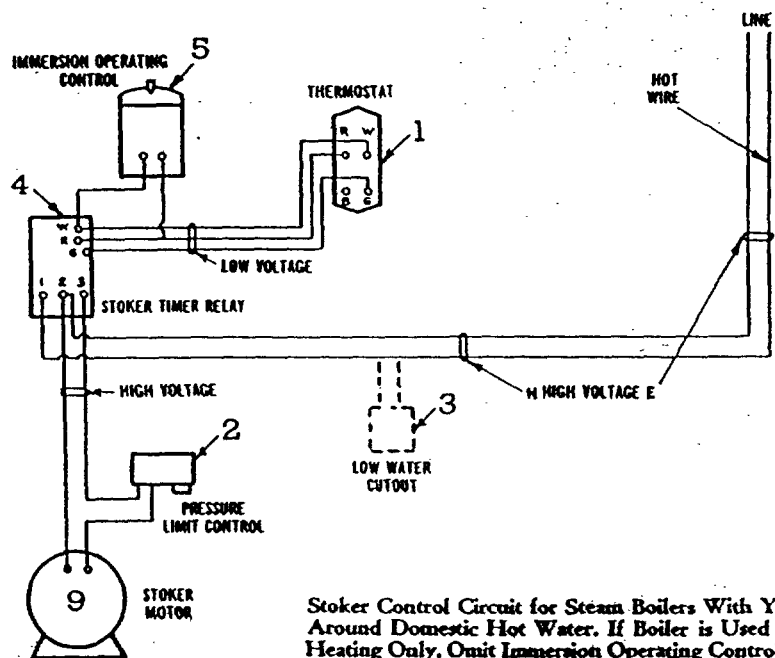
Low Water Cutout (No. 3)—As the name implies, this control stops the stoker motor (No. 9) if the water level in the boiler falls below a safe level. When the proper water level is reestablished, the system will again operate.

Timer Relay (No. 4)—In mild weather there occurs long intervals when no heat is required, during which periods the fire may go out, therefore the heating plant could not respond when the thermostat calls for heat. The Timer Relay (No. 4) serves the purpose of starting and stopping the stoker motor (No. 9) at intervals to keep the fire alive.

Immersion Operating Control (No. 5)—This control operates the burner whenever the water temperature falls below a predetermined setting, which is usually 160° to 180°.

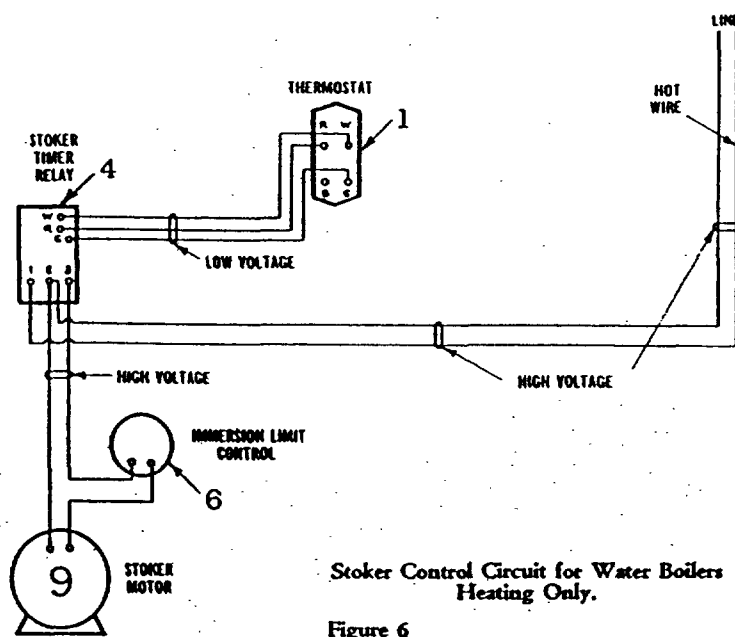
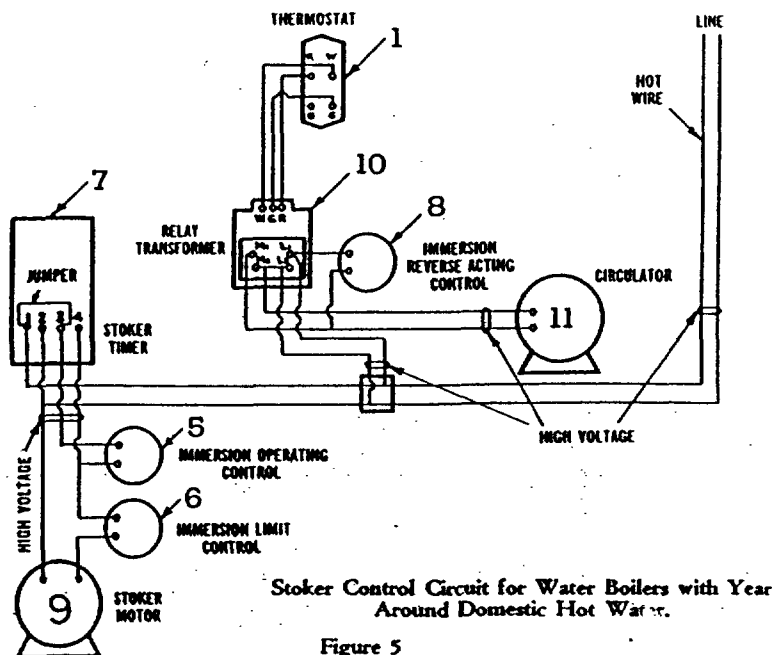
Reverse-Acting Immersion Control (No. 8)—This control will make contact and start the circulator (No. 11) when the water temperature approaches the boiling point regardless of the demands of the thermostat (No. 1). Its sole function is to prevent boiling in the event the fire cannot be checked fast enough after the stoker is stopped.

Relay Transformer (No. 10)—The relay transformer serves two purposes—One: to supply low voltage current to the thermostat; Two: to serve as a switch to turn on or off the circulator motor (No. 11) in response to the room thermostat.



Stoker Control Circuit for Steam Boilers With Year Around Domestic Hot Water. If Boiler is Used for Heating Only, Omit Immersion Operating Control 5.

Figure 4



HOW TO FIGURE RADIATION

A Method For Estimating Heating Requirements

Because of the widely varying conditions surrounding heating installations, it is impossible to lay down any one rule that can, without modifications, meet all conditions of temperature and building construction. There is wide variation in heat loss through different kinds of building material and different types of construction. There are many methods for figuring radiation, some with sufficient merit to recommend them, others that leave too much to the individual judgment, and still others that are not as nearly correct as a good guess.

The amount of radiation necessary to heat any given space can be accurately determined by computing the heat loss per hour in British thermal units (B.t.u.) and dividing the results by the number of B.t.u. given off by one square foot of radiation. The result will be the square feet of radiation required.

The B.t.u. method for estimating radiator requirements involves a considerable amount of mathematical calculations and is explained to show how to use this system and to prove the accuracy of the simplified method.

Demand and Supply

The problem of determining the amount of radiation for a room or building is very simple. It is merely a question of demand and supply. If we figure the heat loss using the B.t.u. system, we know exactly what the loss (demand) is. Knowing the demand, it is merely a question of selecting a radiator that will supply this demand (B.t.u. loss).

The B.t.u. Method of Figuring Radiation

The British thermal unit (B.t.u.) is the measure of heat. In other words, by using the B.t.u. method of heat transmission, we measure the amount of heat lost through the walls, windows, doors, ceiling, etc., for each degree of difference in temperature between the two sides.

Table 3, Pages 47 to 55, shows co-efficients of heat transmission per degree temperature difference between the inside and outside temperature for different kinds of building material and

construction, and the factors for air changes per cubic foot per degree temperature difference. Table 4, page 85 gives the number of B.t.u. transmitted per hour per square foot of radiation for both Steam and Hot Water.

Table 3 includes many types of construction and factors that are seldom used, of these only about ten are used in everyday practice.

When computing the amount of radiation for any given space, we must compute the heat loss through the walls, floor, ceiling, windows, and doors, and also the heat loss caused by air changes.

For Example:

Suppose we have a room 20' x 23' x 10' high, one end wall and one side wall exposed (12" brick furred and plastered), five windows single glass 3' x 5', with lath and plastered ceiling, single floor above exposed to unheated attic, room figured for $1\frac{1}{2}$ air changes, no floor loss considered, how many square feet of radiation would be required to heat this room to 70°F. inside, 0°F. outside?

First, find the temperature difference between inside and outside for which you are making calculations, which in this case is 70°, except for the ceiling which is 35°, (See Note—Page 52). Next multiply the co-efficient corresponding to the type of construction used, as shown in Table 3, Pages 47 to 55 by the temperature difference to determine the rate of transmission per square foot per hour for 70°.

Rates of Transmission

Rate of transmission for wall. The co-efficient for a 12" brick wall furred and plastered is .25, which multiplied by 70, the temperature difference equals 17.5 B.t.u. loss per square foot.

Rate of transmission for single glass is 1.13, which multiplied by 70, the temperature difference equals 79 B.t.u. loss per square foot.

Rate of transmission for ceiling. The co-efficient for ceiling, lath and plastered single floor above, is .28, which multiplied by 35, the temperature difference equals 9.8 B.t.u. loss per square foot.

The factor for $1\frac{1}{2}$ air changes is .0271, which multiplied by 70, the temperature increase per cu. ft. equals 1.897 B.t.u. required to heat the air from 0° to 70°.

The next step is to apply these rates of transmission to the amount of exposed wall, glass surface, ceiling and cubic contents as follows:

43' x 10' equals 430 square feet of exposed wall, less 75 square feet of glass, equals 355, which multiplied by 17.5 (the rate of transmission per square foot) equals..... 6212 B.t.u.

5 windows 3' x 5' equals 75 square feet of glass, which multiplied by 79 (the rate of transmission per square foot) equals 5925 B.t.u.

Ceiling 23' x 20' equals 460 square feet, which multiplied by 9.8 (the rate of transmission for one square foot) equals 4508 B.t.u.

For air change multiply length of room by width and height, which would be 20' x 23' x 10' equaling 4600 cubic feet, which multiplied by 1.897 (the factor for 1½ air changes) equals..... 8726 B.t.u.

Total heat loss..... 25371 B.t.u.

Next divide this total heat loss by 240, the number of B.t.u. given off by one square foot of Standard Column Steam Radiation. 25371 divided by 240 (See P. 6) equals 106 square feet of Steam Radiation, or 150 (See P. 85), the number of B.t.u. given off by one square foot of Hot Water Radiation or 169 square feet of Hot Water Radiation required to heat this room.

A SIMPLIFIED METHOD FOR FIGURING RADIATION

To eliminate the vast calculations which the B.t.u. method necessitates, we have compiled divisors (Table 3, Pages 47 to 55 for Steam and Hot Water) for determining the amount of Standard Column Steam or Hot Water Radiation for different types of construction for 70° inside, zero outside, and tables of multipliers (Tables 2, 2A, 2B, 2C, and 2D) for other inside and outside temperature, which divisors and multipliers will give the same results as the B.t.u. method of heat transmission.

Examples for Use of Divisor Tables:

EXAMPLE 1

To figure the same room as given on Page 35, refer to Table 3. Opposite 12" brick wall (P. 48), furred and plastered, we find the divisor 14. Opposite single glass (P. 55) the divisor 3, opposite ceiling (P. 52), lath and plastered $\frac{3}{4}$ " floor above, the divisor 24, and opposite $1\frac{1}{2}$ air change (P. 55) the divisor 125.

By dividing the square feet of exposed wall, the square feet of glass, the square feet of ceiling, and the cubic feet of space by these divisors, we arrive at the following:

355 square feet net exposed wall divided by 14 equals.....	25
75 square feet single glass divided by 3 equals.....	25
460 square feet of ceiling divided by 24 equals.....	19
4600 cubic feet of space divided by 125 equals.....	37
Square feet Steam Radiation.....	106

By using Hot Water divisors we would arrive at the following:

Square feet Hot Water Radiation.....	169
--------------------------------------	-----

The divisors shown in Table 3 for Steam and Hot Water were computed in the following manner:

By referring to Table 3, it will be noted that a 12" brick wall furred and plastered loses .25 B.t.u. per square foot per hour per degree temperature difference between outside and inside of buildings. Hence, .25 multiplied by 70 (the degree temp. difference) equals 17.5 B.t.u.; this divided into 240 (the number of B.t.u. given off by one square foot of Standard Column Steam Radiation) equals 14, which is the divisor, and shows that one sq. ft. of radiation will supply as much heat as is lost through 14 sq. ft. of wall as described.

In the same manner the divisor for single glass is computed and all other divisors shown except the divisors for cubic contents, which are computed in the following manner:

One B.t.u. will raise the temperature of 55 cubic feet of air one degree. Therefore, .0181 B.t.u. will heat one cubic foot of air one degree, so to heat one cubic foot of air 70° multiply .0181 by 70 which equals 1.267 B.t.u. If we now divide 1.267 B.t.u. into 240, the number of B.t.u. given off by one square foot of Steam Radiation, we find that one square foot of Steam Radiation will heat 190 cubic feet of air from zero to 70°F.

EXAMPLE 2

Suppose we have a room of the following dimensions and construction to be heated from zero outside to 70°F. inside:

- 2400 cubic feet of space (one air change);
- 260 square feet net exposed wall (12" brick furred and plastered);
- 60 square feet glass surface (single glass).

To figure the radiation for this room for steam, by referring to Table 3, we find:

- Opposite one air change the divisor 190.
- Opposite 12" brick wall furred and plastered the divisor 14.
- Opposite single window the divisor 3.

By dividing each of these into the amounts given in the example, we have the square feet of radiation necessary for each item, the sum of which is the total amount of radiation required.

For example:

2400 cubic feet of space (one air change) divided by 190 equals	12.6 sq. ft.
260 square feet net exposed wall (12" brick furred and plastered) divided by 14 equals	18.5 sq. ft.
60 square feet of glass surface (single glass) divided by 3 equals	20 sq. ft.
Total Steam Radiation required	51.1 sq. ft.

If this same room is to be heated to 60°, but with an 8" Plain Brick Wall, we find by using divisors in Table 3, the following:

2400 cubic feet of space divided by 190 equals	12.6 sq. ft.
260 square feet net exposed wall (8" Plain Brick) divided by 7 equals	37 sq. ft.
60 square feet single glass divided by 3 equals	20 sq. ft.
Total Steam Radiation	69.6 sq. ft.

The quantity of radiation required for 70°.

Table 2 gives correction factors for figuring the amount of steam radiation for temperatures other than zero deg. outside, 70 deg. inside.

Therefore, 69.6 square feet multiplied by .78 (the correction factor for 60° inside temperature) equals 54.3 sq. ft. Steam Rad.

The quantity required for 60°.

From this it will be seen that nearly every type of construction and range of temperature can be figured by use of divisors and correction factors as given.

To figure the amount of Gravity Hot Water Radiation use divisors in Column Hot Water Divisors, Pages 47 to 55. See Page 85—Heat Output of high temperature Hot Water Radiators.

TABLE 2

The following correction factors are for computing the amount of radiation for temperature other than zero degree outside 70 degrees F. inside, see examples P. 38 and below.

Steam Correction Factors For Temperatures Other Than 0 F.—70 F. (240 Btu/sq.ft.) Steam Temperature 215°							
	Indoor Temperature						
	50	55	60	65	70	75	80
Outdoor Temperature							
60			0	.07	.14	.23	.31
55		0	.07	.14	.21	.30	.39
50	0	.06	.13	.20	.29	.37	.47
45	.06	.13	.20	.27	.36	.45	.55
40	.12	.19	.26	.34	.43	.52	.63
35	.18	.25	.33	.41	.50	.60	.71
30	.24	.31	.39	.48	.57	.67	.79
25	.30	.38	.46	.55	.64	.75	.86
20	.36	.44	.52	.61	.71	.82	.94
15	.42	.50	.59	.68	.79	.90	1.02
10	.48	.57	.65	.75	.86	.97	1.10
5	.54	.63	.72	.82	.93	1.05	1.18
0	.61	.69	.78	.89	1.00	1.12	1.26
- 5	.67	.76	.85	.96	1.07	1.20	1.34
-10	.73	.82	.92	1.02	1.14	1.27	1.42
-15	.79	.88	.98	1.09	1.21	1.35	1.49
-20	.85	.94	1.05	1.16	1.29	1.42	1.57
-25	.91	1.01	1.11	1.23	1.36	1.50	1.65
-30	.97	1.07	1.18	1.30	1.43	1.57	1.73

TABLE 2A

Hot Water
Correction Factors For Temperatures Other Than 0° F.-70° F.
170° Average Water Temperature
(150 Btu/sq.ft.)

	Indoor Temperature						
	50	55	60	65	70	75	80
Outdoor Temperature							
60			0	.07	.14	.23	.33
55		0	.06	.13	.21	.31	.41
50	0	.06	.13	.20	.29	.38	.49
45	.06	.12	.19	.27	.36	.46	.57
40	.11	.18	.25	.34	.43	.54	.66
35	.17	.24	.32	.40	.50	.61	.74
30	.23	.30	.38	.47	.57	.69	.82
25	.28	.36	.44	.54	.64	.76	.90
20	.34	.42	.50	.60	.71	.84	.99
15	.40	.48	.57	.67	.79	.92	1.07
10	.45	.54	.63	.74	.86	.99	1.15
5	.51	.60	.69	.81	.93	1.07	1.23
0	.57	.66	.76	.87	1.00	1.15	1.32
- 5	.62	.72	.82	.94	1.07	1.22	1.40
-10	.68	.78	.88	1.01	1.14	1.30	1.48
-15	.74	.84	.95	1.07	1.22	1.38	1.56
-20	.79	.90	1.01	1.14	1.29	1.45	1.65
-25	.85	.96	1.07	1.21	1.36	1.53	1.72
-30	.91	1.02	1.14	1.28	1.43	1.61	1.81

If 40 sq. ft. of steam or hot water radiation are required for Standard conditions of 0° F. 70° F. and specification require that the space is to be heated from -10° F. to 70° F., refer to Table 2 or 2A under 70° indoor temperature and opposite -10° outdoor temperature find correction factor 1.14, multiply $40 \times 1.14 = 45.6$ sq. ft. the amount of radiation required for -10° -70° F.

Correction Factors for High Temperature Hot Water Radiation

Tables 2B, 2C, and 2D of correction factors are for use in connection with hot water radiation when the average water temperature is above 170°. These correction factors are used in the following manner. See also Table 4, Page 85.

If 40 sq. ft. of hot water radiation are required for standard conditions of 0° F. 70° F. and 170° average water temperature

and specifications call for 190° average water temperature, refer to Table 2C under 70° indoor temperature and opposite 0° outdoor temperature find correction factor .79. Multiply $40 \times .79 = 31.6$ sq. ft., the amount of radiation required for 0° F. outdoor and 70° F. indoor for the higher water temperature as compared to standard.

Tables 2B, 2C, and 2D are also used for correcting for temperatures other than 0° F. outdoors and 70° F. indoors as follows:

If 40 sq. ft. of hot water radiation are required for standard conditions of 0° F. outdoors and 70° F. indoors with 170° average water temperature and specifications call for -10° F. outdoor and 70° indoor with 190° F. average water temperature, refer to Table 2C under 70° indoor and opposite -10° F. outdoor temperature find correction factor .91. Multiply $40 \times .91 = 36.4$ sq. ft. the amount required for these conditions.

TABLE 2B

Hot Water
Correction Factors For Temperatures Other Than 0 F.—70 F.
180° Average Water Temperature
(170 Btu/sq. ft.)

	Indoor Temperature						
	50	55	60	65	70	75	80
Outdoor Temperature							
60			0	.06	.13	.26	.29
55		0	.06	.12	.19	.27	.36
50	0	.05	.11	.18	.25	.34	.43
45	.05	.11	.17	.24	.32	.40	.50
40	.10	.16	.23	.30	.38	.47	.57
35	.15	.21	.28	.36	.45	.54	.64
30	.20	.27	.34	.42	.51	.60	.71
25	.25	.32	.40	.48	.57	.67	.79
20	.30	.37	.45	.54	.63	.74	.86
15	.36	.43	.51	.60	.69	.80	.93
10	.41	.48	.57	.66	.76	.87	1.00
5	.46	.53	.62	.72	.82	.94	1.07
0	.51	.59	.68	.78	.88	1.01	1.14
- 5	.56	.64	.74	.84	.95	1.07	1.22
-10	.61	.69	.79	.90	1.01	1.14	1.29
-15	.66	.75	.85	.96	1.08	1.21	1.36
-20	.71	.80	.91	1.02	1.14	1.27	1.43
-25	.76	.85	.96	1.08	1.20	1.34	1.50
-30	.81	.91	1.02	1.14	1.26	1.41	1.57

TABLE 2C

Hot Water
Correction Factors For Temperatures Other Than 0 F.—70 F.
190° Average Water Temperature
(190 Btu/sq. ft.)

	Indoor Temperature						
	50	55	60	65	70	75	80
Outdoor Temperature							
60			0	.05	.11	.18	.25
55		0	.05	.11	.17	.24	.32
50	0	.05	.10	.16	.23	.30	.38
45	.05	.10	.15	.21	.28	.36	.44
40	.09	.15	.20	.27	.34	.42	.50
35	.14	.19	.25	.32	.40	.48	.57
30	.18	.24	.30	.37	.45	.54	.63
25	.23	.29	.36	.43	.51	.60	.69
20	.28	.34	.41	.48	.57	.66	.76
15	.32	.39	.46	.53	.62	.72	.82
10	.37	.44	.51	.59	.68	.78	.88
5	.42	.48	.56	.64	.74	.84	.95
0	.46	.53	.61	.69	.79	.89	1.01
— 5	.51	.58	.66	.75	.85	.95	1.07
—10	.55	.63	.71	.80	.91	1.01	1.14
—15	.60	.68	.76	.85	.96	1.07	1.20
—20	.65	.72	.81	.91	1.02	1.13	1.26
—25	.69	.77	.86	.96	1.08	1.19	1.33
—30	.74	.82	.91	1.02	1.13	1.25	1.39

TABLE 2D

Hot Water
Correction Factors For Temperatures Other Than 0 F.—70 F.
200° Average Water Temperature
(210 Btu/sq. ft.)

	Indoor Temperature						
	50	55	60	65	70	75	80
Outdoor Temperature							
60			0	.05	.10	.16	.23
55		0	.05	.10	.15	.21	.28
50	0	.05	.09	.14	.20	.27	.34
45	.04	.09	.14	.19	.25	.32	.39
40	.08	.13	.18	.24	.31	.37	.45
35	.13	.18	.23	.29	.36	.43	.51
30	.17	.22	.28	.34	.41	.48	.56
25	.21	.26	.32	.38	.46	.54	.62
20	.25	.31	.37	.43	.51	.59	.68
15	.30	.35	.42	.48	.56	.64	.73
10	.34	.40	.46	.53	.61	.69	.79
5	.38	.44	.51	.58	.66	.75	.84
0	.42	.48	.55	.63	.71	.80	.90
-5	.46	.53	.60	.68	.76	.86	.96
-10	.51	.57	.65	.72	.81	.91	1.01
-15	.55	.62	.69	.77	.87	.96	1.07
-20	.59	.66	.74	.82	.92	1.02	1.13
-25	.63	.71	.79	.87	.97	1.07	1.18
-30	.67	.75	.83	.92	1.02	1.12	1.24

CARE IN ESTIMATING ESSENTIAL

When estimating heat loss, care should be exercised to acquire a thorough knowledge of all conditions in connection with the room or building to be heated.

The first step necessary is to determine the temperature to be maintained which is termed the temperature difference between inside and outside of walls, floor, windows, ceiling, etc.

In estimating the various losses it is necessary to know the kind of construction, because the rate of heat transmission per degree temperature difference varies with the type of construction and consequently requires more or less radiation per square foot of surface.

Be Sure of Wall Construction

If the wall is of brick construction, make sure of the thickness—whether plain brick, or furred and plastered. To illustrate; with a 12" plain brick or plastered on brick wall the rate of transmission per square foot per degree temperature difference is .36 B.t.u. (Table 3). With a temperature difference of 70 degrees the loss per square foot per hour is 25 B.t.u. (.36 multiplied by 70). Dividing 25 into 240, (the B.t.u. given off by one square foot of steam radiation), gives 9.6 square feet of wall, or in other words, one square foot of steam radiation will supply as much heat as is lost through 9.6 square feet of wall under the above conditions.

If, however, a 12" brick wall furred and plastered is figured, the rate of transmission is .25 B.t.u., in which case one square foot of steam radiation would supply the heat loss through 14 square feet. Hence, it would require 46 per cent more radiation for the plain brick than would be required for a 12" brick wall furred and plastered.

If the wall construction is of frame and is made up of Lath and Plaster, Studding and Siding, the rate of transmission is .30 B.t.u. per square foot per hour per degree temperature difference, and therefore, one square foot of steam radiation will only supply as much heat as is lost through eleven square feet of exposed wall. If the wall is of good frame construction (Lath and Plaster Studding, Sheathing and Siding) one square foot of steam radiation will supply as much heat as is lost through 14 square feet of wall under the same temperature conditions. In this case there would be required 27% more radiation for the poorly constructed wall than would be required for the wall of good construction.

AIR CHANGES

In almost all formulas for figuring radiation there exists one particularly troublesome factor. This factor is the number of air changes per hour for which allowance should be made.

When mechanical ventilation is provided it can be figured quite accurately. But when direct radiation is used the amount of air leakage is problematical and in most cases individual judgment must be used. It varies according to exposures and to loosely fitted windows and doors. The number of changes may be from one to five per hour, depending entirely upon conditions.

As a guide in determining the number of air changes per hour, the following table can be used, subject to the conditions in each case.

DESCRIPTION	Air changes Per hour
Rooms with windows 1 side	1
Rooms with windows 2 sides	1½
Rooms with windows 3 sides	2
Rooms with windows 4 sides	2
Entrance Halls	2 to 3
Reception Halls	2
Bathrooms	2
Churches, Factories, Lofts, etc.	* ½ to 3
Public garages ground floor	* 2 to 5
Public garages upper floor	* ½ to 1
Private garages	2
Drug Stores	2 to 3
Clothing Stores	1

*Use Crack loss method, Page 46.

The above table of air changes is based on a wind velocity of 15 M.p.h. See page 55 or the A.S.H. & V.E. Guide for heat loss for higher wind velocities.

Metal Weather Strips

Where metal weather strips are provided, the number of air changes can be reduced 40% for double hung wood sash, 55% for double hung metal sash.

Storm Sash

When storm sash is used on well-fitted windows, very little, if any, reduction in air change will result; on poorly fitted windows a reduction of about 50% in air leakage will result.

Factory or Large Building

When estimating air changes in industrial or other buildings where the space to be heated is large, the practice of assuming one or more air changes per hour should be disregarded because if in a room 15 feet wide with three or four sides exposed, we have but two air changes, as is the accepted practice, we could not have two changes where similar exposures exist in a room 60 or 100 ft. wide.

For large spaces over 15 ft. wide, the amount of infiltration should be estimated on the crack loss method.

Crack Loss Method

CUBIC FOOT AIR LEAKAGE PER LINEAL FOOT CRACK PER HOUR

Wind Velocity M.p.h.	10	15	20	25	30
Ordinary double hung wood ash..... 1/16" crack 3/64" clearance.....					
Non-weatherstripped*.....	20	40	60	80	100
Ditto weatherstripped*.....	15	25	35	50	65
Double hung metal windows*.....	45	75	105	140	175

*Includes fram crack loss.

Assume the infiltration loss for doors double that shown for wood sash.

In rooms with one side exposed take all of the crack; with two exposed walls, figure leakage for wall having most crack; and with 3 or 4 walls exposed figure not less than half the total crack. In buildings having no partitions figure one half the total crack, this is assumed to be good practice since any infiltration through cracks on one side must pass out of the cracks on the opposite side.

Example for estimating length of crack: Suppose we have a double hung wood sash 3' X 5', how many feet of crack would we have?

Window crack $3 + 3 + 5 + 5 = 16$ plus 3 feet of meeting strip, total crack 19 lineal feet.

Based on a wind velocity of 15 M.p.h. our total infiltration would be, $19 \times 40 = 760$ cu. ft.

The above figures are for tight fitting windows. If windows are poorly fitted the leakage may be two or three times this amount.

TABLE OF COEFFICIENTS AND DIVISORS FOR VARIOUS TYPES OF BUILDING CONSTRUCTION

TABLE 3

Coefficients are expressed in B.t.u. per square foot per degree F. difference between air at the two sides and are based on wind velocities of 15 M.p.h. If higher wind velocities are to be considered, see Page 55 or A.S.H. & V.E. Guide for additional amount of radiation required.

Divisors are for Standard Steam and Hot Water Radiation under Standard Conditions of zero outside, 70 degrees F. inside, except ceilings. (See note, page 52.)

NOTE: Where possible, we have added to or deducted fractional divisors in Table 3. This, in most cases, makes little difference, but where a difference would be noticeable, we have used decimals. These occur when the divisor is small, as for example, 2.2 or 3.4 which by omitting the last figure would show too great a difference in results obtained.

WALLS

FRAME AND MISCELLANEOUS CONSTRUCTION

Uninsulated	Coefficients	Steam Divisors	Hot Water Divisors
Lath and Plaster, Studding and Siding	.30	11	7
Lath and Plaster, Studding, Sheathing and Siding or Shingles	.25	14*	8.5*
Lath and Plaster, Studding, Sheathing with 4" Brick Veneer	.27	13*	8*
Studding with Lath and Plaster, Two Sides	.34	10	6
Studding with Lath and Plaster, One Side	.62	5.5	3.5
Studding, Sheathing and Siding	.33	10	5
Studding and Sheathing or Siding	.70	5	3
Studding, Sheathing, Corrugated or Flat Iron	.36	9	6
Studding, Corrugated or Flat Iron	1.5	2.5	1.5

(Continued on next page)

WALLS (Continued)

Insulated	Coefficients	Steam Divisors	Hot Water Divisors
Lath and Plaster, Studding, Sheathing and Siding or Shingles with $3\frac{3}{8}$ " Rock Wool Fill	.072	45	30
Lath and Plaster, Studding, Sheathing and Siding or Shingles with 2" Rock Wool Fill	.10	34	22
Lath and Plaster, Studding, Sheathing and Siding or Shingles with $\frac{1}{2}$ " Flexible Insulation	.17	20	13
Lath and Plaster, Studding, Sheathing and 4" Brick Veneer with $3\frac{3}{8}$ " Rock Wool Fill	.074	45	30
Plaster on $\frac{1}{2}$ " Rigid Insulation Studding, Sheathing and Siding or Shingles	.19	18	11
Plaster on 1" Rigid Insulation, Studding, Sheathing and Siding or Shingles	.15	23	14
Plaster on $\frac{1}{2}$ " Rigid Insulation, Studding, Sheathing and 4" Brick Veneer	.20	17	11

GLASS WALLS

	Coefficients	Steam Divisors	Hot Water Divisors
Hollow glass tile walls 6" x 6" Wide 2" thick, wind velocity 15 M.p.h. outside still air inside	.60	5.7	3.5
With still air both sides	.48	7	4.5

BRICK, TILE, STONE, CEMENT, ETC.

BRICK	Coefficients	Steam Divisors	Hot Water Divisors
Plain 8"	.50	7	4
12"	.36	9	6
16"	.28	12	8
$\frac{1}{2}$ " Plaster 8"	.46	7.5	4.7
12"	.34	10	6
16"	.27	13	8
Furred and Plastered 8"	.30	11	7
12"	.25	14*	8.5*
16"	.20	17	11
Plaster on $\frac{1}{2}$ " Rigid Insulation, Furred 8"	.22	15	9
12"	.19	18	11
16"	.16	20	12

HOLLOW TILE—STUCCO EXTERIOR

		Coefficients	Steam Divisors	Hot Water Divisors
Plain	8"	.40	8.5	5
	10"	.39	9	6
	12"	.30	11	7
	16"	.25	14	8.5
Plastered	8"	.38	9	6
	10"	.37	9	6
	12"	.29	12	7
	16"	.24	14	9
Furred and Plastered	8"	.26	13	8
	10"	.26	13	8
	12"	.22	15	9
	16"	.19	18	11
Plaster on 1/2" Rigid Insulation, Furred	8"	.20	17	11
	10"	.19	18	11
	12"	.17	20	12
	16"	.15	23	14

BRICK, TILE, STONE, CEMENT, ETC.

LIMESTONE OR SANDSTONE		Coefficients	Steam Divisors	Hot Water Divisors
Plain Inside	8"	.71	4.8	3
	12"	.58	6	3.7
	16"	.49	7	4.8
	24"	.37	9	6
Plastered	8"	.64	5.3	3.3
	12"	.53	6.5	4
	16"	.45	7.5	5
	24"	.35	10	6
Furred and Plastered	8"	.37	9	6
	12"	.33	10	5
	16"	.30	11	7
	24"	.25	14	8.5
Plaster on 1/2" Rigid Insulation, Furred	8"	.25	14	8.5
	12"	.23	15	9
	16"	.22	15	9
	24"	.19	18	11

CONCRETE, STUCCO OR PLAIN EXTERIOR

		Coefficients	Steam Divisors	Hot Water Divisors
Plain Inside	6"	.79	4	2.5
	10"	.62	5.5	3.4
	16"	.48	7	4.3
	20"	.41	8	5
Plastered	6"	.70	5	3
	10"	.57	6	3.7
	16"	.44	8	5
	20"	.39	9	6
Furred and Plastered	6"	.39	9	6
	10"	.34	10	6
	16"	.29	12	7.5
	20"	.27	13	8
Plaster on 1/2" Rigid Insulation, Furred	6"	.27	13	8
	10"	.25	14	8.5
	16"	.22	15	9
	20"	.21	17	10

HOLLOW CINDER BLOCK, PLAIN EXTERIOR

		Coefficients	Steam Divisors	Hot Water Divisors
Plain Inside	8"	.42	8	5
	12"	.37	9	6
Plastered	8"	.39	9	6
	12"	.35	10	6
Furred and Plastered	8"	.27	12	7
	12"	.25	14	8.5
Plaster on 1/2" Rigid Insulation, Furred	8"	.21	17	10
	12"	.19	18	11

HOLLOW CONCRETE BLOCK, PLAIN EXTERIOR

		Coefficients	Steam Divisors	Hot Water Divisors
Plain Inside	8"	.56	6	3.7
	12"	.49	7	4.8
Plastered	8"	.52	6.5	4
	12"	.46	7.5	4.7
Furred and Plastered	8"	.32	10	6
	12"	.30	11	7
Plastered on 1/2" Rigid Insulation, Furred	8"	.24	14	9
	12"	.23	15	9

BRICK VENEER ON HOLLOW TILE, CONCRETE, ETC.

Outside Facing			Coefficients	Steam Divisors	Hot Water Divisors
4" Brick or Stone Veneer on	{ Hollow Tile Plain Inside	6"	.36	9	6
		8"	.34	9	6
		10"	.34	9	6
		12"	.27	13	8
4" Brick or Stone Veneer on	{ Hollow Tile Plastered	6"	.34	9	6
		8"	.33	10	5
		10"	.32	11	7
		12"	.26	13	8
4" Brick or Stone Veneer on	{ Hollow Tile Furred Lath and Plastered	6"	.24	14	9
		8"	.24	14	9
		10"	.23	15	9
		12"	.20	17	11
4" Brick or Stone Veneer on	{ Hollow Tile Plastered on 1/2" Rigid Insulation, Furred	6"	.19	18	11
		8"	.18	18	11
		10"	.18	18	11
		12"	.16	20	12
4" Brick or Stone Veneer on	{ Concrete Plain Inside	6"	.57	6	3.7
		10"	.48	7	4.3
		16"	.39	9	6
4" Brick or Stone Veneer on	{ Concrete Plastered	6"	.53	6.5	4
		10"	.45	7.6	4.3
		16"	.37	9	6
4" Brick or Stone Veneer on	{ Concrete Furred and Plastered	6"	.33	10	5
		10"	.30	11	7
		16"	.26	13	8
4" Brick or Stone Veneer on	{ Concrete Plastered on 1/2" Rigid Insulation, Furred	6"	.24	14	9
		10"	.22	15	9
		16"	.20	17	11
4" Brick Veneer on	{ Cinder Blocks Plain Inside	8"	.35	10	6
		12"	.31	11	7
4" Brick Veneer on	{ Cinder Blocks Plastered	8"	.33	10	5
		12"	.30	11	7
4" Brick Veneer on	{ Cinder Blocks Furred and Plastered	8"	.24	14	9
		12"	.22	15	9

(Continued on next page)

Outside Facing		Coefficients	Steam Divisors	Hot Water Divisors
4" Brick Veneer on	Cinder Blocks 8"	.19	18	11
	Plaster on 12"	.18	19	12
	1/2" Rigid Insulation			
	Furred			
4" Brick Veneer on	Concrete 8"	.44	8	5
	Blocks Plain 12"	.40	8.5	5
4" Brick Veneer on	Concrete 8"	.42	8	5
	Blocks 12"	.38	9	6
4" Brick Veneer on	Concrete 8"	.28	12	8
	Blocks Furred 12"	.26	13	8
4" Brick Veneer on	Concrete 8"	.21	17	10
	Blocks Plastered on 1/2"	.20	17	11
4" Brick Veneer on	Rigid Insulation			
	Furred			

FLOORS AND CEILINGS—EXPOSED

NOTE: It is assumed that the temperature of unheated attics will be 35° F. when the rooms below are heated. If ceilings are insulated, this temperature will be lowered, depending upon the heat transmission through the ceiling. These divisors for ceilings are based on 35° temperature difference.

	Coefficients	Steam Divisors	Hot Water Divisors
Wood Lath and Plaster	.62	x11*	x7*
Wood Lath and Plaster, 3/4" Flooring	.28	x24*	x14*
Metal Lath and Plaster	.69	x10*	x6*
Metal Lath and Plaster, 3/4" Flooring	.30	x24*	x14*
Plaster on 1/2" Rigid Insulation, No Flooring			
Plaster on 1/2" Rigid Insulation, 3/4" Flooring	.35	x20	x12
Metal Lath and Plaster 3 5/8" Rock Wool Fill, No Flooring	.21	x34	x20
Metal Lath and Plaster 3 5/8" Rock Wool Fill, 3/4" Flooring	.079	x80	x50
Metal Ceiling on Joists 3/4" Boards Above	.068	x100	x60
Metal Ceiling on Joists	.40	x16	x10
	1.5	x4.5	x3

CONCRETE FLOORS—STILL AIR

		Coefficients	Steam Divisors	Hot Water Divisors
3/4" Flooring on embedded sleepers	4"	.40	8.5	5
	6"	.37	9	6
3/4" Flooring on embedded sleepers Furred and Plastered	4"	.26	13	8
	6"	.25	14	8.5
3/4" Flooring on embedded sleepers Furred with 1/2" Rigid Insulation Plastered	4"	.20	17	11
	6"	.19	18	11
Plain Concrete on dirt	4"	1.07	3.2	2
	6"	.90	3.8	2.3
	8"	.79	4.3	2.7
Concrete with 1" Flooring on Sleepers Resting on Concrete	4"	.35	10	6
	6"	.33	10	5
	8"	.32	11	7
Concrete with Tile or Terrazzo Surface	4"	.98	3.4	2.2
	6"	.84	4	2.5
	8"	.74	4.6	3

ROOFS

COVERED WITH BUILT UP ROOFING PAPER, TAR AND GRAVEL

		Coefficients	Steam Divisors	Hot Water Divisors
Precast Cement Tile 1 5/8" thick, No Ceiling		.84	4	2.5
Precast Cement Tile 1 5/8" thick, 1/2" Rigid Insulation		.37	9	6
Precast Cement Tile 1 5/8" thick, Metal, Lath and Plaster		.43	8	5
Precast Cement Tile 1 5/8" thick, Metal Lath, Plaster 1/2" Rigid Insulation		.26	13	8
Concrete Plain	2"	.82	4	2.5
	4"	.72	4.8	3
	6"	.64	5.3	3.3
Concrete with 1/2" Rigid Insulation	2"	.37	9	6
	4"	.34	10	6
	6"	.33	10	5
Concrete with Metal Lath and Plaster	2"	.42	8	5
	4"	.40	8.5	5
	6"	.37	9	6

(Continued on next page)

		Coefficients	Steam Divisors	Hot Water Divisors
Concrete with Metal Lath and Plaster 1/2" Rigid Insulation.....	2"	.26	13	8
	4"	.25	14	8.5
	6"	.24	14	9
Wood	1"	.49	7	4.8
	1 1/2"	.37	9	6
	2"	.32	11	7
Wood with 1/2" Rigid Insulation	1"	.28	12	8
	1 1/2"	.24	14	9
	2"	.22	15	9
Wood with Metal Lath and Plaster	1"	.32	11	7
	1 1/2"	.26	13	8
	2"	.24	14	9
Wood, Metal Lath and Plaster, 1/2" Rigid Insulation.....	1"	.21	17	10
	1 1/2"	.19	18	11
	2"	.17	20	12
Sheet Metal		.95	3.6	2.2
Sheet Metal with 1/2" Rigid Insulation		.39	9	6
Sheet Metal with Metal Lath and Plaster		.46	7.5	4.7
Sheet Metal with Metal Lath and Plaster 1/2" Rigid Insulation.....		.27	13	8
Wood Shingles on Wood Strips, No Ceiling		.46	7.5	4.7
Wood Shingles as above with Lath and Plaster		.30	11	7
Wood Shingles on Wood Strips with 1/2" Rigid Insulation Plastered.....		.21	17	10
Wood Shingles on Wood Strips, Lath and Plaster with 3 5/8" Rock Wool Fill		.063	60	35
Asphalt or Asbestos Shingles, Composition Roofing, Slate or Tile Roofing on 3/4" Sheathing.....		.56	6	3.7
Roof as above with Lath and Plaster		.34	10	6
Roof as above with 1/2" Rigid Insulation Plastered		.23	15	9
Roof as above Lath and Plaster with 3 5/8" Rock Wool Fill.....		.059	60	35

DOORS, GLASS AND AIR CHANGES

	Coefficients	Steam Divisors	Hot Water Divisors
Solid Doors $\frac{3}{4}$ " thick	.69	5*	3*
Solid Doors $1\frac{1}{16}$ " thick	.59	6*	3.7*
Solid Doors $1\frac{5}{16}$ " thick	.52	6.5*	4*
Solid Doors $1\frac{5}{8}$ " thick	.46	7.5	4.7
Doors with Thin Panels	1.	3.4*	2*
Single Glass Window or Skylight	1.13	3*	2*
Double Glass Window or Skylight	.45	7.5	4.7
1 Air Change per cu. ft. per deg.	.0181	190*	120*
$1\frac{1}{2}$ Air Change per cu. ft. per deg.	.0271	125*	80*
2 Air Change per cu. ft. per deg.	.0362	95	60

*Asterisk indicates coefficients and divisors most commonly used.

NOTE: For one air change use 200 as divisor instead of 190 for simplicity.

x Indicates divisors for ceilings at 35 deg. temp. difference.

For coefficients of transmission for other types of building construction, see A.S.H. & V.E. Guide.

SUBMITTING ESTIMATES

When submitting estimate of the amount of radiation for a room or building, this estimate should clearly state, inside and outside temperatures, type of construction, wind velocity and number of air changes on which the estimate is based.

Divisors are based on 240 B.t.u. output for steam and 150 B.t.u. output for hot water. For other outputs of steam and hot water radiation see Table 4, and page 6.

INFILTRATION LOSSES

The air changes shown on page 45 and all heat loss calculations are based on a wind velocity of 15 M.p.h.

Should you be called upon to estimate radiator requirements for wind velocities greater than 15 M.p.h. allowance must be made for additional air changes. Additional air changes should be figured as shown below.

Windows and Doors With or Without Weatherstrips			
Wind Velocity M.p.h.	20	25	30
Amount to be added	50%	100%	160%

The infiltration loss for wind velocities other than those shown above can be arrived at by interpolation of these percentages.

EFFECT OF INCREASED WIND VELOCITIES ON HEAT LOSS THROUGH BUILDING MATERIALS

The heat loss factors "coefficients" for walls, etc., are practically constant regardless of wind velocities since the surface loss only represents a small part of the total construction loss except for glass, sheet iron or other highly conductive material.

Velocities above 15 M.p.h. cause a greater increase in the heat loss from a building, particularly that heat lost by air change, and through highly conductive material.

The higher heat loss due to increased wind velocities through the low conductive materials, such as built up walls, etc., is not of sufficient importance to be considered.

For the high conductive materials, the loss should be increased according to the following table.

Wind Velocity M.p.h.	15	20	25	30
Percentage Increase	0	5	7.5	10

For other wind velocities these figures can be interpolated.

Important Note: In the past it has been the practice to add an arbitrary percentage to the estimated amount of radiation required in rooms facing North or on the windward side of the building.

Since all heat loss calculations are based on an established outside temperature and a 15 M.p.h. wind velocity and since this wind velocity is exceeded in only two localities in the United States and then only by a small percentage, no additional allowance need be made unless it is definitely known that higher velocities exist for an appreciable length of time, in which case additional air change allowance may be made in rooms on windward side.

BASE TEMPERATURES COMPILED FROM WEATHER BUREAU RECORDS

State	City	* Design or Base Temp. Degree F.	State	City	* Design or Base Temp. Degree F.
Ala.	Mobile	15	Nev.	Tonopah	5
	Birmingham	5		Winnemucca	-15
Ariz.	Phoenix	25	N.H.	Concord	-20
	Flagstaff	-10	N.J.	Atlantic City	5
Ark.	Fort Smith	0	N.Y.	New York	0
	Little Rock	0		Albany	-10
Calif.	San Francisco	40		Buffalo	-5
	Los Angeles	40	N.M.	Santa Fe	0
Colo.	Denver	-15	N.C.	Raleigh	5
	Grand Junction	-5		Wilmington	10
Conn.	New Haven	0	N.Dak.	Bismarck	-30
D.C.	Washington	0		Devil's Lake	-30
Fla.	Jacksonville	25	Ohio	Cleveland	0
Ga.	Atlanta	5		Columbus	-5
	Savannah	25	Okla.	Oklahoma City	0
Idaho	Lewiston	-10	Oreg.	Baker	-10
	Pocatello	-15		Portland	0
Ill.	Chicago	-10	Pa.	Philadelphia	10
	Springfield	-10		Pittsburgh	-5
Ind.	Indianapolis	-10	R.I.	Providence	0
	Evansville	0	S.C.	Charleston	10
Iowa	Dubuque	-15		Columbia	0
	Sioux City	-20	S.Dak.	Huron	-30
Kans.	Concordia	-10		Rapid City	-20
	Dodge City	-10	Tenn.	Knoxville	0
Ky.	Louisville	-5		Memphis	5
La.	New Orleans	20	Texas	El Paso	10
	Shreveport	10		Fort Worth	5
Me.	Eastport	-10		San Antonio	20
	Portland	-10	Utah	Modena	-10
Md.	Baltimore	10		Salt Lake City	-5
Mass.	Boston	-5	Vt.	Burlington	-10
Mich.	Alpena	-15	Va.	Norfolk	15
	Detroit	-10		Lynchburg	10
	Marquette	-10		Richmond	10
Minn.	Duluth	-25	Wash.	Seattle	20
	Minneapolis	-20		Spokane	-15
Miss.	Vicksburg	0	W. Va.	Elkins	-10
Mo.	St. Joseph	-10		Parkersburg	-10
	St. Louis	-5	Wis.	Green Bay	-20
	Springfield	-10		La Crosse	-30
Mont.	Billings	-25		Milwaukee	-10
	Havre	-35	Wyo.	Sheridan	-25
Nebr.	Lincoln	-15		Lander	-25
	North Platte	-20			

*The outside or base temperature to be assumed for estimating heating requirements. These temperatures are approximately 15 deg. higher than the lowest temperature recorded.

The outside and inside temperatures and wind velocity used when estimating heating requirements should be stated in heating specifications.

TYPICAL TWO PIPE FLOW CONTROL SYSTEM OF HOT WATER HEATING

With Electrical Controls for Oil Firing

(See Figure 7)

Oil Burning Hot Water Heating Boiler (No. 1).

Radiant Heat Control (Room Thermostat) (No. 2)—Two wire low voltage Radiant Heat Control operates Circulator (4) through Relay Transformer (3). Note feeler bulb attached to return branch of radiator and connected to Radiant Heat Control by capillary tubing. Expansion and contraction of liquid in feeler bulb and tubing actuates switch of (2) bringing Circulator (4) on frequently to maintain a constant room temperature. Radiator temperature is allowed to vary only 10° by this method of control, which results in fractional degree control of room temperature.

Relay Transformer (No. 3)—Relay Transformer is needed to provide low voltage (about 20 volts) to Radiant Heat Control (2) and line voltage to circulator motor (4).

Circulator (No. 4)—Motor operated circulator (4) force circulates hot water from boiler (1) through piping and radiators (16), (17), (18), and back to boiler with very little loss in temperature. Circulator (4) is controlled by Radiant Heat Control (2) and runs frequently for short periods, but only as heat is required.

Water Temperature Control (No. 5)—Modulating Water Temperature Control (5) with one bulb immersed in flow riser operates oil burner (8) through Stack Control (7) to maintain boiler water temperature. Control (5) has a second bulb which clamps to return main to register water temperature in system. Dial of control (5) is set for minimum temperature, (usually

about 150° when domestic water is heated from boiler), and the boiler water is maintained at this temperature (150° to 160°) as long as this temperature is sufficient to satisfy Radiant Heat Control (2). As the weather grows colder, Circulator (4) will be running more often, raising the return main temperature. When the return temperature is nearly equal to the setting of the control (5) boiler temperature is automatically raised and kept approximately 15° higher than return main. Boiler temperature is, therefore, only raised upon demand for more heat, which makes it unnecessary to carry a maximum boiler temperature when not required.

Water Temperature Control (High Limit) (No. 6)—Clamp-on Limit Control (6) set for 210° wired in circuit to operating Water Temperature Control (5) to stop oil burner (8) in case of failure of control (5). Optional safety control.

Stack Control (No. 7)—A safety control consisting of Relay Transformer and an element inserted inside smoke pipe to operate from stack temperature. Water Temperature Control (5) is wired to low voltage terminals of Stack Control (7). High voltage wiring is from Stack Control (7) to Oil Burner Motor (8). When Water Temperature Control Switch (5) closes, Stack Control Relay (7) is closed providing line voltage to Burner Motor (8) and to the electrodes or burner ignition. If oil does not ignite, stack temperature is not raised and element in stack trips Stack Control Relay (7) shutting off burner and ignition. Stack Control is, therefore, a safety control to prevent burner from running in case of oil supply failure or ignition failure.

Oil Burner (No. 8).

Flow Control Valve (No. 9)—A specially constructed check valve with weighted disc heavy enough to prevent gravity circulation to radiators. Flow Control Valve disc is raised by pressure created by Water Circulator (4). Disc of Flow Control Valve (9) reseats cutting off circulation to radiators instantly when Radiant Heat Control (2) is satisfied and Circulator (4) stops. Air from Boiler (1) is vented into Pressure Tank (12) through vent pipe taken from side of Valve (9) below seat making Valve (9) water-tight.

Pressure Relief Valve (No. 10)—This being a closed pressure system a Pressure Relief Valve (10) is required to relieve any excess pressure that might be created due to overrun in boiler water temperature for any reason. Value (10) is set to relieve within the safe working pressure of the Boiler (1).

Pressure Reducing Valve (No. 11)—Valve (11) automatically fills the system to the correct pressure and admits fresh water whenever needed. It is placed in cold water supply line to reduce city pressure down to 12 pounds which is the average pressure required to fill a 2 or 3 story building. Can be adjusted on job for higher or lower delivery pressure.

Pressure Tank (No. 12)—Air Tight Pressure Tank (12) is used, making a Closed System. Higher temperature can be carried without steaming or any noise as the boiling point is raised with the system under pressure. Tank (12) is connected to Flow Control Valve (9) allowing for the expansion and contraction of heated water, as well as venting air from Boiler (1). Pressure Tank (12) is an essential part of all Closed Hot Water Systems.

~~Water Heater (No. 13)—Flow connection to Water Heater (13) is taken out of flow riser below Flow Control Valve (9) so boiler water circulates through shell of Heater (13) at all times. Domestic water enters through copper tubes inside Heater (13) absorbing heat and transmitting heated water to Storage Tank (14). Burner (8) is operative the year around to maintain Boiler Temperature (1) and supply ample domestic water.~~

Storage Tank (No. 14)—A Storage Tank (14) sized in accordance with the demand for hot water is installed and piped to Heater (13) as shown.

High Pressure Relief Valve (No. 15)—Valve (15) is installed in cold water supply line to Storage Tank (14) to protect Tank and plumbing fixtures from excess pressure. Can be furnished for pressure relief only or for pressure and temperature relief.

Tube Type Radiator (No. 16)—A modern cast-iron free standing tube radiator.

Slim-tube Type Radiator (No. 17)—A small tube radiator, cast iron, free standing, requiring less space than Radiator (16).

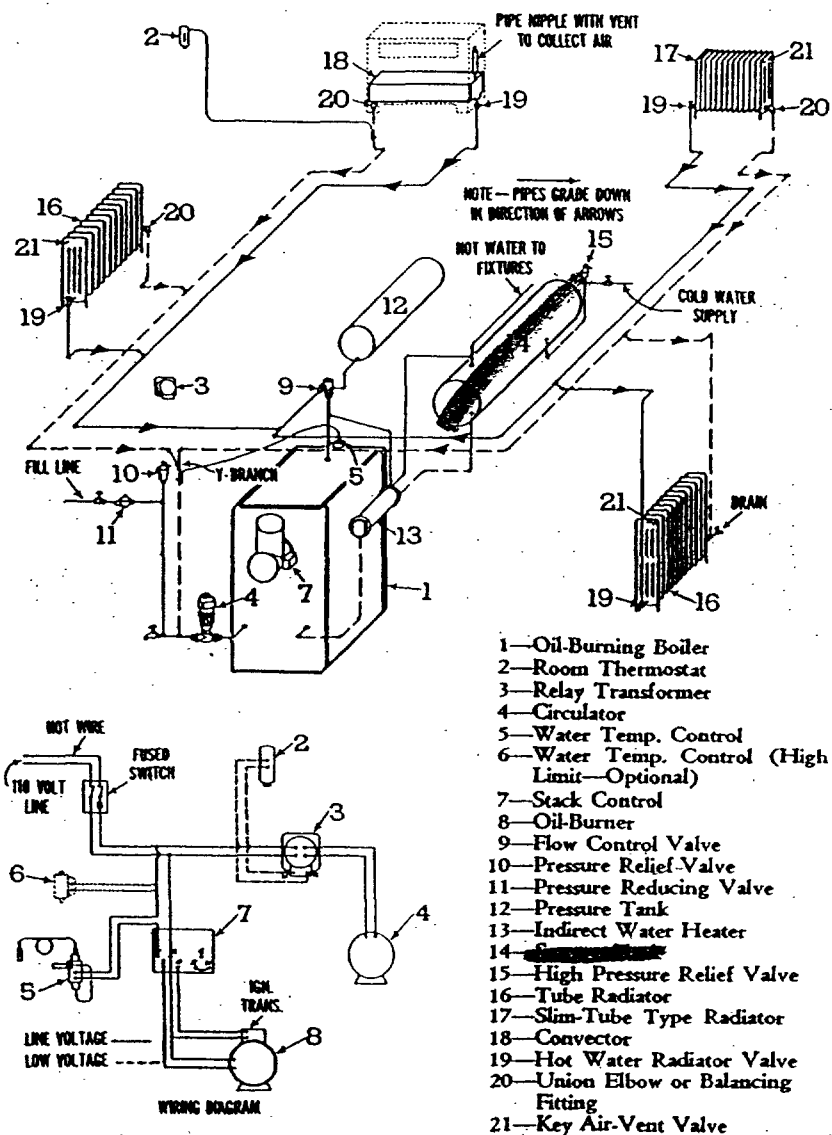
Convactor (No. 18)—A concealed radiator entirely recessed in the wall or can be installed free standing and encased with metal cabinet.

Radiator Valve (No. 19)—Each Radiator of a Hot Water Heating System is equipped with a Valve (19) for closing off circulation through any radiator. Generally Valve (19) only closed on bedroom radiators.

Union Elbow or Balancing Fitting (No. 20)—Balancing Fitting (20) is used in the return connection to each radiator providing a means of balancing circulation through each radiator.

Key Air-Vent Valve (No. 21)—Air-Vent Valve (21) is installed on each radiator to allow air in system to escape as system is being filled with water. Also to vent air that accumulates after system is fired.

Reverse-Acting Water Temperature Control (No. 22)—Required only on soft coal stoker-fired Flow Control System.



Typical Two-Pipe Flow Control System
 of Hot Water Heating

With Electrical Controls for Oil Firing

Figure 7

TYPICAL TWO PIPE FLOW CONTROL SYSTEM OF HOT WATER HEATING

With Electrical Controls for Stoker Firing

(See Figure 8)

Stoker Fired Hot Water Heating Boiler (No. 1).

Radiant Heat Control (Room Thermostat) (No. 2)—Two wire low voltage Radiant Heat Control operates Circulator (4) through Relay Transformer (3). Note feeler bulb attached to return branch of radiator and connected to Radiant Heat Control by capillary tubing. Expansion and contraction of liquid in feeler bulb and tubing actuates switch of (2) bringing Circulator (4) on frequently to maintain a constant room temperature. Radiator temperature is allowed to vary only 10° by this method of control which results in fractional degree control of room temperature.

Relay Transformer (No. 3)—Relay Transformer is needed to provide low voltage (about 20 volts) to Radiant Heat Control (2) and line voltage to Circulator Motor (4).

Circulator (No. 4)—Motor operated Circulator (4) force circulates hot water from boiler (1) through piping and radiators (16), (17), (18), and back to boiler with very little loss in temperature. Circulator (4) is controlled by Radiant Heat Control (2) and runs frequently for short periods, as heat is required.

Water Temperature Control (No. 5)—Immersion Water Temperature Control (5) is installed in flow riser leaving boiler and wired through Timer Relay (7) to operate Stoker Motor (8). Control (5) is set for approximately 150° and this boiler temperature overrides somewhat on a soft coal stoker job and usually ~~without raising Control (5) setting to a higher degree.~~

Water Temperature Control (High Limit) (No. 6)—Clamp-on Limit Control (6) set for 210° wired in circuit to operating Water Temperature Control (5) to stop Stoker Motor (8) in case of failure of Control (5). Optional safety control.

Timer Relay (No. 7)—Timer Relay (7) is a relay transformer with built-in timer. Water Temperature Control (5) is wired to low voltage terminals of Timer Relay (7) and line voltage terminals wired to Stoker Motor (8). Timer is set to operate Stoker

Motor (8) for short period every half hour or hour to maintain fire in Boiler (1). Timer can operate independently of Water Temperature Control (5).

Soft Coal Stoker (No. 8).

Flow Control Valve (No. 9)—A specially constructed check valve with weighted disc heavy enough to prevent gravity circulation to radiators. Flow Control Valve disc is raised by pressure created by Water Circulator (4). Disc of Flow Control Valve (9) reseats cutting off circulation to radiators instantly when Radiant Heat Control (2) is satisfied and Circulator (4) stops. Air from Boiler (1) is vented into Pressure Tank (12) through vent pipe taken from side of valve (9) below seat making Valve (9) water-tight.

Pressure Relief Valve (No. 10)—This being a closed pressure system, a Pressure Relief Valve (10) is required to relieve any excess pressure that might be created due to overrun in boiler water temperature for any reason. Valve (10) is set to relieve within the safe working pressure of the Boiler (1).

Pressure Reducing Valve (No. 11)—Valve (11) automatically fills the system to the correct pressure and admits fresh water whenever needed. It is placed in cold water supply line to reduce city pressure down to 12 pounds which is the average pressure required to fill a 2 or 3 story building. Can be adjusted on job for higher or lower delivery pressure.

Pressure Tank (No. 12)—Air tight Pressure Tank (12) is used in making a Closed System. Higher temperature can be carried without steaming or any noise as the boiling point is raised with the system under pressure. Tank (12) is connected to Flow Control Valve (9) allowing for the expansion and contraction of heated water, as well as venting air from Boiler (1). Tank (12) is an essential part of all Closed Hot Water Systems.

Indirect Water Heater (No. 13)—Flow connection to Water Heater (13) is taken out of flow riser below Flow Control Valve (9) so boiler water circulates through shell of Heater (13) at all times. Domestic water circulates through copper tubes inside Heater (13) absorbing heat and transmitting heated water to Storage Tank (14). Stoker (8) is operative the year around to maintain Boiler Temperature (1) and supply ample domestic water.

Storage Tank (No. 14)—A Storage Tank (14) sized in accordance with the demand for hot water is installed and piped to Heater (13) as shown.

High Pressure Relief Valve (No. 15)—Valve (15) is installed in cold water supply line to Storage Tank (14) to protect Tank and plumbing fixtures from excess pressure. Can be furnished for pressure relief only or for pressure and temperature relief.

Tube Type Radiator (No. 16)—A modern cast-iron free standing tube radiator.

Slim-Tube Type Radiator (No. 17)—A small tube radiator, cast iron, free standing, requiring less space than Radiator (16).

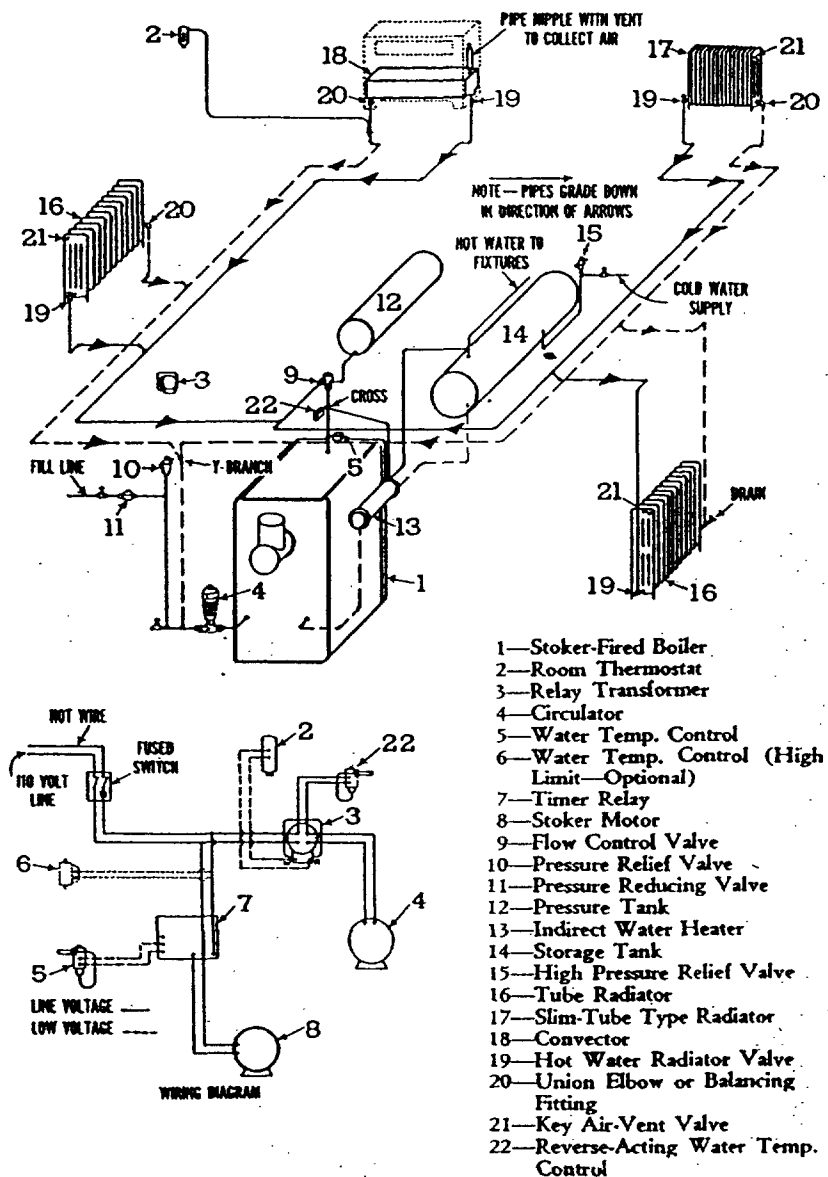
Convactor (No. 18)—A concealed radiator entirely recessed in the wall or can be installed free standing and encased with metal cabinet.

Radiator Valve (No. 19)—Each Radiator of a Hot Water Heating System is equipped with a Valve (19) for closing off circulation through any radiator. Generally, Valve (19) only closed on bedroom radiators.

Union Elbow or Balancing Fitting (No. 20)—Balancing Fitting (20) is used in the return connection to each radiator providing a means of balancing circulation through each radiator.

Key Air-Vent Valve (No. 21)—Is installed on each radiator to allow air in system to escape as system is being filled with water. Also to vent air that accumulates after system is fired.

Reverse-Acting Water Temperature Control (No. 22)—Control (22) is also installed in flow riser leaving Boiler (1). This control (22) makes contact on temperature increase and is to be set for 220°. Control (22) is wired across the line of Relay Transformer (3) in circuit to Circulator Motor (4). Purpose of Control (22) is to make contact if Boiler (1) temperature overrides to 220° after Radiant Heat Control (2) has been satisfied and Circulator (4) is not operating. Circulator (4) is brought on by Control (22) and operated for a very short cycle to lower Boiler (1) temperature. In addition to Control (22), it is advisable to install a close fitting swing damper in air chamber between stoker fan and retort, if stoker does not come equipped with a damper to retard natural draft through retort. This helps to prevent override of Boiler temperature on this type of Flow Control Hot Water Heating System.



Typical Two-Pipe Flow Control System of Hot Water Heating

With Electrical Controls for Stoker Firing

Figure 8

TYPICAL TWO PIPE FLOW CONTROL SYSTEM OF HOT WATER HEATING

With Electrical Controls for Gas Firing
(See Figure 9)

Gas-Fired Hot Water Heating Boiler (No. 1).

Radiant Heat Control (Room Thermostat) (No. 2)—Two wire low voltage Radiant Heat Control operates Circulator (4) through Relay Transformer (3). Note feeler bulb attached to return branch of radiator and connected to Radiant Heat Control by capillary tubing. Expansion and contraction of liquid in feeler bulb and tubing actuates switch of (2) bringing Circulator (4) on frequently to maintain a constant room temperature. Radiator temperature is allowed to vary only 10° by this method of control which results in fractional degree control of room temperature.

Relay Transformer (No. 3)—Relay Transformer is needed to provide low voltage (about 20 volts) to Radiant Heat Control (2) and line voltage to Circulator Motor (4).

Circulator (No. 4)—Motor operated Circulator (4) force circulates hot water from Boiler (1) through piping and radiators (16), (17), (18), and back to boiler with very little loss in temperature. Circulator (4) is controlled by Radiant Heat Control (2) and runs frequently for short periods, but only as heat is required.

Water Temperature Control (No. 5)—Modulating Water Temperature Control (5) with one bulb immersed in flow riser operates Gas Valve (8) to maintain boiler water temperature. Control (5) has a second bulb which clamps to return main to register water temperature in system. Dial of Control (5) is set for minimum temperature (usually about 150° when domestic water is heated from boiler), and the boiler water is maintained at this temperature (150° to 160°) as long as this temperature is sufficient to satisfy Radiant Heat Control (2). As the weather grows colder, Circulator (4) will be running more often raising the return main temperature. When the return temperature is nearly equal to the setting of the Control (5), boiler temperature is automatically raised and kept approximately 15° higher than

return main. Boiler temperature is, therefore, only raised upon demand for more heat which makes it unnecessary to carry a maximum boiler temperature when not required. ~~When domestic hot water is not heated from the boiler,~~ Control (5) may be left at all times at its lowest setting—110°.

Transformer (No. 6)—Supplies low voltage current (about 20 volts) for opening Gas Valve (8).

Water Temperature Control (High Limit) (No. 7)—Bulb (7) is installed in boiler water and Gas Valve (8) is set to shut off at about 220°, in case of failure of Water Temperature Control (5).

Gas Valve (No. 8)—Controlled by Water Temperature Control (5) to supply gas to burners. In addition to High Limit Water Temperature Control Bulb (7), Gas Valve also has a mechanically operated Safety Pilot Light (see Page 18) to ignite burners when Valve opens. If Safety Pilot should be extinguished, Gas Valve cannot open.

Flow Control Valve (No. 9)—A specially constructed check valve with weighted disc heavy enough to prevent gravity circulation to radiators. Flow Control Valve disc is raised by pressure created by Water Circulator (4). Disc of Flow Control Valve (9) reseats cutting off circulation to radiators instantly when Radiant Heat Control (2) is satisfied and Circulator (4) stops. Air from Boiler (1) is vented into Pressure Tank (12) through vent pipe taken from side of Valve (9) below seat making Valve (9) water-tight.

Pressure Relief Valve (No. 10)—This being a closed pressure system, a Pressure Relief Valve (10) is required to relieve any excess pressure that might be created due to overrun in boiler water temperature for any reason. Valve (10) is set to relieve within the safe working pressure of the Boiler (1).

Pressure Reducing Valve (No. 11)—Valve (11) automatically fills the system to the correct pressure and admits fresh water whenever needed. It is placed in cold water supply line to reduce city pressure down to 12 pounds which is the average pressure required to fill a 2 or 3 story building. Can be adjusted on job for higher or lower delivery pressure.

Pressure Tank (No. 12)—Air tight Pressure Tank (12) is used, making a Closed System. Higher temperature can be carried

without steaming or any noise as the boiling point is raised with the system under pressure. Tank (12) is connected to Flow Control Valve (9) allowing for the expansion and contraction of heated water, as well as venting air from Boiler (1). Pressure Tank (12) is an essential part of all Closed Hot Water Systems.

Indirect Water Heater (No. 13)—Flow connection to Water Heater (13) is taken out of flow riser below Flow Control Valve (9) so boiler water circulates through shell of Heater (13) at all times. Domestic water circulates through copper tubes inside Heater (13) absorbing heat and transmitting heated water to Storage Tank (14). Burner (8) is operative the year around to maintain Boiler Temperature (1) and supply ample domestic water.

Storage Tank (No. 14)—A Storage Tank (14) sized in accordance with the demand for hot water is installed and piped to Heater (13) as shown.

High Pressure Relief Valve (No. 15)—Valve (15) is installed in cold water supply line to Storage Tank (14) to protect Tank and plumbing fixtures from excess pressure. Can be furnished for pressure relief only or for pressure and temperature relief.

Tube Type Radiator (No. 16)—A modern cast iron, free standing, tube radiator.

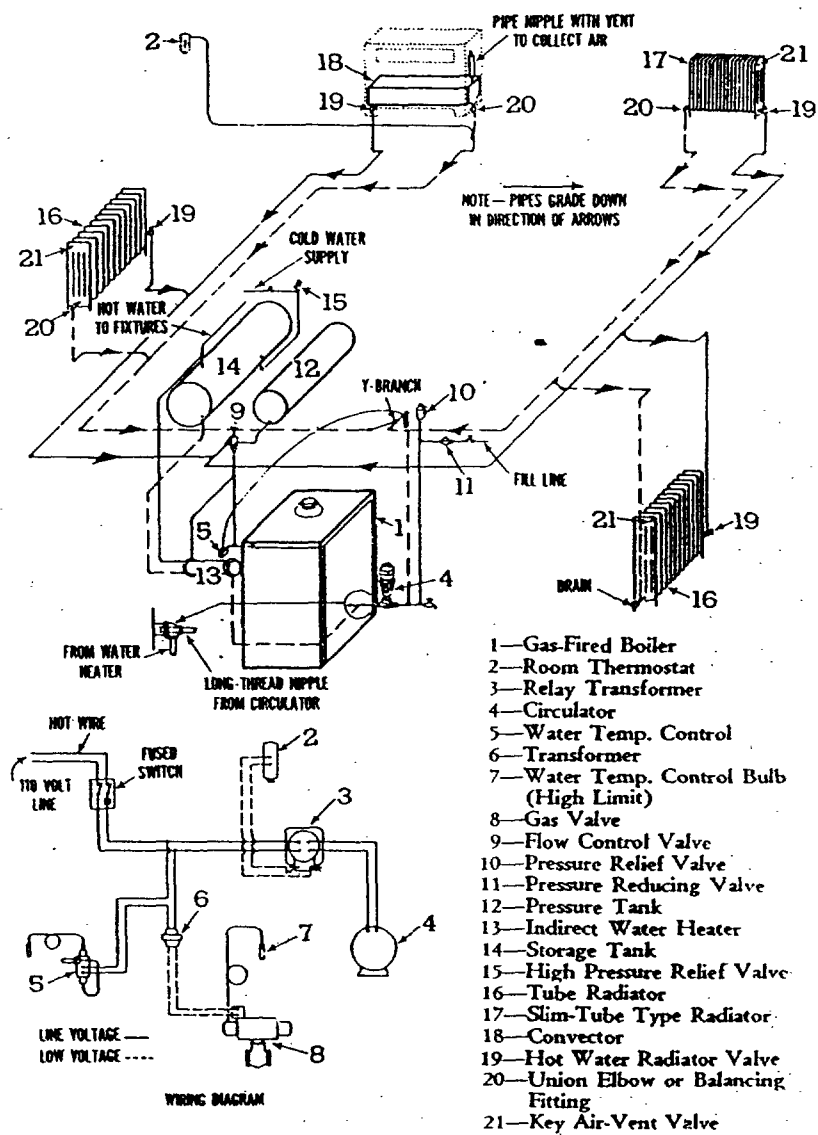
Slim-Tube Type Radiator (No. 17)—A small tube radiator, cast iron, free standing, requiring less space than Radiator (16).

Convactor (No. 18)—A concealed radiator entirely recessed in the wall or can be installed free standing and encased with metal cabinet.

Radiator Valve (No. 19)—Each Radiator of a Hot Water Heating System is equipped with a Valve (19) for closing off circulation through any radiator. Generally, Valve (19) only closed on bedroom radiators.

Union Elbow or Balancing Fitting (No. 20)—Balancing Fitting (20) is used in the return connection to each radiator providing a means of balancing circulation through each radiator.

Key Air-Vent Valve (No. 21)—Air-Vent Valve (21) is installed on each radiator to allow air in system to escape as system is being filled with water. Also to vent air that accumulates after system is fired.



Typical Two-Pipe Flow Control System
 of Hot Water Heating
 With Electrical Controls for Gas Firing

Figure 9

TYPICAL ONE PIPE FLOW CONTROL SYSTEM OF HOT WATER HEATING

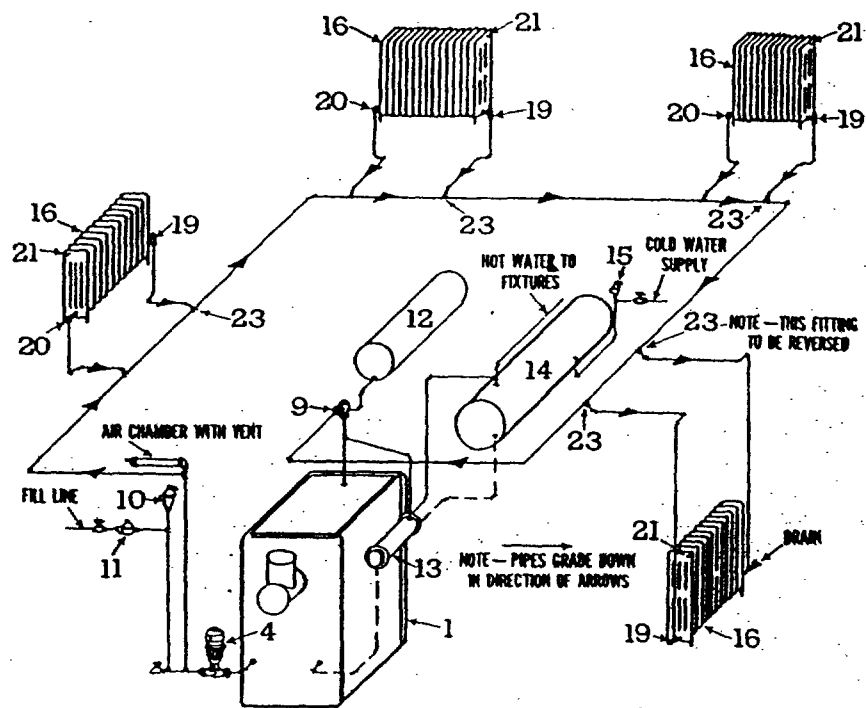
Automatically Fired

(See Figure 10)

[For Electrical Controls, See Drawings and Description for Oil, (Figure 7)
Gas, (Figure 9) and Stoker-Fired, (Figure 8) Systems]

1. Boiler. (With automatic firing device.)
4. Circulator. (Same as for Oil-Fired, page 58)
9. Flow Control Valve. (Same as for Oil-Fired, page 59)
10. Pressure Relief Valve. (Same as for Oil-Fired, page 60)
11. Pressure Reducing Valve. (Same as for Oil-Fired, page 60)
12. Pressure Tank. (Same as for Oil-Fired, page 60)
13. Indirect Water Heater. (Same as for Oil-Fired, page 60)
14. Storage Tank. (Same as for Oil-Fired, page 60)
15. High Pressure Relief Valve. (Same as for Oil-Fired, page 60)
16. Tube Type Radiator. (Same as for Oil-Fired, page 61)
19. Radiator Valve. (Same as for Oil-Fired, page 61)
20. Union Elbow or Balancing Fitting. (Same as for Oil-Fired, page 61)
21. Key Air-Vent Valve. (Same as for Oil-Fired, page 61)
23. One-Pipe Fitting. A special tee (23) from which the supply branch to the radiator (16) is taken. The One-Pipe Fitting is designed to divert through the Radiator (16) a part of the hot water being forced through the main by the Circulator (4). After being diverted through the Radiator and giving up a part of its heat, the water then returns to the single main through a common tee. In the case of a down-feed radiator, a second One-Pipe Fitting (23) must be used in a reversed position on the return branch to help pull the water up through the return after being forced down through the supply drop by the first One-Pipe Fitting.

*Note grade of main and air chamber required at high point for proper venting.



- 1—Boiler
- 4—Circulator
- 9—Flow Control Valve
- 10—Pressure Relief Valve
- 11—Pressure Reducing Valve
- 12—Pressure Tank
- 13—Water Heater

- 14—Storage Tank
- 15—High Pressure Relief Valve
- 16—Radiator
- 19—Hot Water Radiator Valve
- 20—Union Elbow or Balancing Fitting
- 21—Key Air-Vent Valve
- 23—One-Pipe Fitting

Typical One-Pipe Flow Control System of Hot Water Heating

Automatically Fired

(For Electrical Controls. See Drawings Illustrating Oil, Gas
and Stoker-Fired Systems)

Figure 10

TABLE OF MAINS AND BRANCHES

Forced Circulation Hot Water Heating Systems

COPPER PIPE

Sq. Ft. Radiation	Size and Number of Mains
0 to 300	One $\frac{3}{4}$ " up to 50' long over 50' long 1"
301 to 500	One 1" or two $\frac{3}{4}$ "
501 to 800	One $1\frac{1}{4}$ " or two 1"
801 to 1250	One $1\frac{1}{2}$ " or two $1\frac{1}{4}$ "
1251 to 2000	One 2" or two $1\frac{1}{2}$ "

STEEL OR WROUGHT IRON

Sq. Ft. Radiation	Size and Number of Mains
0 to 300	One 1"
301 to 500	One $1\frac{1}{4}$ " or two 1"
501 to 1000	One $1\frac{1}{2}$ " or two $1\frac{1}{4}$ "
1001 to 1500	One 2" or two $1\frac{1}{2}$ "
1501 to 2500	One $2\frac{1}{2}$ " or two 2"

Copper mains 2" and larger, Steel mains $2\frac{1}{2}$ " and larger may be reduced as they approach the end. Always be careful to see that the area when reduced equals or exceeds the combined area of the remaining branches.

SIZE BRANCHES AND RISERS

Two Pipe Forced Circulation Hot Water Branches, Risers and Valve Sizes, All Floors

Copper Pipe	Steel Pipe
0 to 60 sq. ft. Radiation $\frac{3}{8}$ "	0 to 100 sq. ft. Radiation $\frac{1}{2}$ "
61 to 125 sq. ft. Radiation $\frac{1}{2}$ "	Over 100 sq. ft. Radiation $\frac{3}{4}$ "
Over 125 sq. ft. Radiation $\frac{3}{4}$ "	

*When runouts are over 6' in length, use $\frac{1}{2}$ " runout.

Downfeed branches and valves to radiators on basement floor should be increased one size.

For size of mains and branches for one pipe systems, see Manufacturers Catalog.

NOTE: Above sizes recommended by leading manufacturers.

NOTE: The area of mains and branches for forced circulation systems should be as carefully balanced as for gravity system as above described. This applies when either copper, iron or steel pipe is used.

ONE PIPE GRAVITY STEAM HEATING SYSTEMS

This system is the most commonly used of all steam heating systems. Its popularity is largely due to low cost, simplicity of installation and satisfactory heating results.

The most common type installation is shown in Fig. 11, page 76. Other types of one pipe gravity piping systems may be desirable depending on conditions.

In this system the condensation returns to the boiler by gravity. The high point of the main is directly over the boiler and the system may comprise one or two circuits.

There is no set rule regarding the distance from the boiler water line to the low point of the main. This distance is governed almost entirely by the drop in pressure at a point where the last radiator connection is taken off the main. This does not apply to two pipe gravity systems.

Systems of Piping One Pipe Gravity Steam

In designing a one pipe gravity system of steam piping the following considerations are of importance.

First—The outlet from boiler should run as high as convenient before branching out and the main should pitch down $\frac{1}{4}$ " in each ten feet in length so that all water will drain to the boiler by gravity in the direction of the arrows as shown in Fig. 11.

Second—That it shall be free to expand, that is, so arranged that the joints will not be strained when the system is heated.

Third—That all points in the piping where air might accumulate shall be provided with a Quick Vent valve for removing air.

TABLE OF MAINS ONE PIPE GRAVITY STEAM SYSTEM
AND ONE PIPE GRAVITY VACUUM

Square feet Standard Column Radiation, Standard Conditions	Diameter Main Inches
up to 190	1½
" " 390	2
" " 650	2½
" " 1200	3
" " 1700	3½
" " 2400	4
" " 4500	5

Branches and Risers One Pipe Steam

The branches are the horizontal run of pipe connecting the risers to the main. Wherever possible these should be taken off the main at a 45° from the top and should pitch up from the main. Horizontal branches should be one size larger than risers, especially when the riser is supplying its full amount of radiation, see table below.

In no case should a horizontal branch on a one pipe job be over eight (8) feet in length, because branches over eight feet may not permit water of condensation to return to the main and may cause the radiator to fill with water. If, however, conditions are such that a branch over eight feet in length must be used, it should be pitched down from the main and be provided with a drip into return main, or this drip line may be connected back into bottom of steam main. This drip should be provided with a drain plug.

SIZE OF BRANCHES, RISERS, RUNOUTS AND VALVES UP FEED

Pipe & Valve Size Inches	Square Feet Standard Radiation		
	Horizontal Branches & Runouts	Vertical Risers	Radiator Valve
1	20	45	24
1¼	55	100	60
1½	80	150	80

Size of One Pipe Steam Main for Other Than Standard Conditions

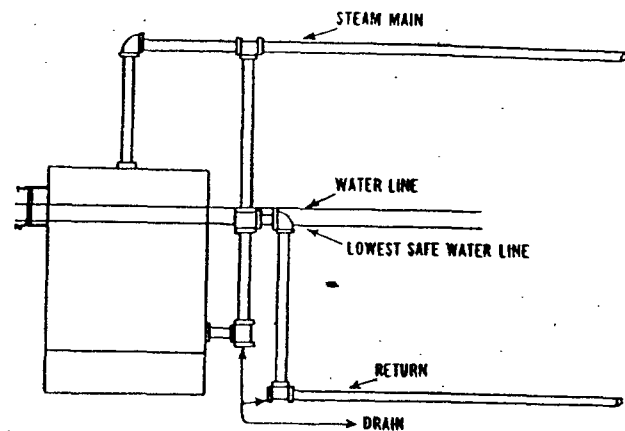
Above sizes for use when mains do not exceed 150 feet in length; over 150 feet use one size larger pipe.

Run main full size to a point six feet beyond the last branch taken off before making reduction of return main to boiler.

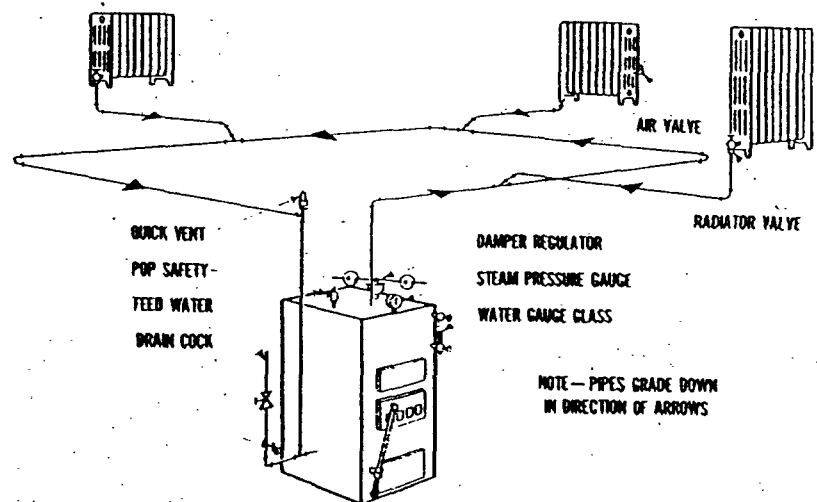
Mains may be run from 4 to 6 feet away from basement walls.

Hartford Safety Loop

The Hartford safety loop is for use where wet returns are used, but is of little or no value where the piping is run overhead constituting what is termed a dry return system.



HARTFORD SAFETY LOOP



TYPICAL LAYOUT
ONE PIPE GRAVITY STEAM HEATING SYSTEM

Fig. 11

TYPICAL TWO PIPE GRAVITY HOT WATER SYSTEM

(See Figure 13)
System of Piping

In this system is employed a flow main and a flow riser, a return main and a return riser. The flow mains and flow risers are those pipes which carry the water to the radiators and the return mains and return risers are the pipes which carry the water back to the boiler. The circulation is caused by the temperature difference between the up-flow and down-flow. This system is most commonly used for ordinary hot water heating installations.

The mains and horizontal branches should be designed so that the lowest point in the piping system will be directly over the boiler, and pitch up at least $\frac{1}{4}$ " in each ten feet of length to the far end of main. The return main is run parallel to the flow main of the same size, and is pitched in the same direction.

TABLE OF MAINS TWO PIPE GRAVITY HOT WATER SYSTEM

Square feet Standard Radiation Standard Conditions	Size Flow Main Inches	Size Return Main Inches
175	1½	1½
350	2	2
550	2½	2½
850	3	3
1000	3½	3½
1400	4	4
2000	5	5

Above sizes are for use when mains do not exceed 70 feet in length; for mains over 70 feet use one size larger pipe.

It is not considered good practice to reduce the size of small mains. They should be run full size to the end. 2½" or larger mains may be reduced one size, but if a main is reduced, there

should be a branch taken off the reducing fitting on a 45° from the top, for the purpose of relieving the air.

The actual internal area of the main should be equal to or greater than the combined area of the branches connected to it.

For example:

Suppose we have a job in which we are to install eleven radiators of sizes requiring the following size valves: 5-3/4", 3-1" and 3-1 1/4". The area of the main should equal or exceed the combined area of all of these values. By referring to Table 10, we arrive at the following:

Actual Internal Area of 5-3/4" pipes equals.....	2.65 sq. in.
Actual Internal Area of 3-1" pipes equals.....	2.58 sq. in.
Actual Internal Area of 3-1 1/4" pipes equals.....	4.5 sq. in.
Total	9.73 sq. in.

By referring again to Table 10, we find it will be necessary to use a 3 1/2" main having an actual internal area of 9.89 square inches, the nearest size which can be selected based on standard pipe sizes. This size gives us a surplus main capacity of .16 square inches, whereas, if we selected a 3" main with an internal area of 7.39 square inches, we would have a deficiency of 2.34 square inches and as a result two or more of the radiators would not be supplied with the proper amount of water. This would result in a short circuit and an uneven heating condition.

Branches and Risers

The horizontal branches connecting risers to mains should be of such size and taken off the main in such a way as to make each radiator circulate evenly. It is considered good practice to take all connections for second floor radiators, and also those radiators on the first floor that are close to the boiler, off the side of the main. Radiators on the first floor farther from the boiler should be taken off the main at a 45° from the top of main, using sizes as shown in the following table. The last connection taken off the main should be run to a first floor radiator.

SIZE OF RISERS—TWO PIPE GRAVITY HOT WATER

Square Feet Standard Radiation Standard Conditions	Pipe Sizes in Inches
FIRST FLOOR	
Up to 20 square feet.....	$\frac{1}{2}$
Above 21, up to 50 square feet.....	$\frac{3}{4}$
Above 51, up to 100 square feet.....	1
Above 101, up to 175 square feet.....	$1\frac{1}{4}$
Above 175, up to 250 square feet.....	$1\frac{1}{2}$
SECOND FLOOR	
Up to 30 square feet.....	$\frac{1}{2}$
Above 31, up to 70 square feet.....	$\frac{3}{4}$
Above 71, up to 120 square feet.....	1
Above 121, up to 250 square feet.....	$1\frac{1}{4}$
THIRD FLOOR	
Up to 40 square feet.....	$\frac{1}{2}$
Above 41, up to 100 square feet.....	$\frac{3}{4}$
Above 101, up to 175 square feet.....	1
Above 175, up to 300 square feet.....	$1\frac{1}{4}$

All of above sizes based on steel pipe.

Expansion Tank

Many Hot Water heating installations cause needless expense and trouble through the use of an expansion tank of inadequate size. It is important that the expansion tank be placed at least 3 feet above the top of highest radiator, and that it be connected with an expansion pipe, an overflow pipe, and a vent.

The expansion line should be connected to the return piping. The overflow line should be run to a suitable drain and should be vented, to prevent syphonic action. The overflow line should in no case be run to the outside of building as hoar frost is liable to accumulate and close end of overflow line, thus making a closed system, and will not permit of waste of expanded volume.

Freezing of expansion tank or expansion line must be avoided. If either the expansion tank or expansion line is allowed to freeze, the system may be solid full of water, allowing no place for expansion of the water when heat is applied, thereby generating excessive pressure, causing boiler, radiator or pipe to burst with sufficient force to cause damage.

The expansion tank should be protected against freezing. If the tank is located in a cold place, it is advisable to circulate water up to the tank as shown in Figure 12.

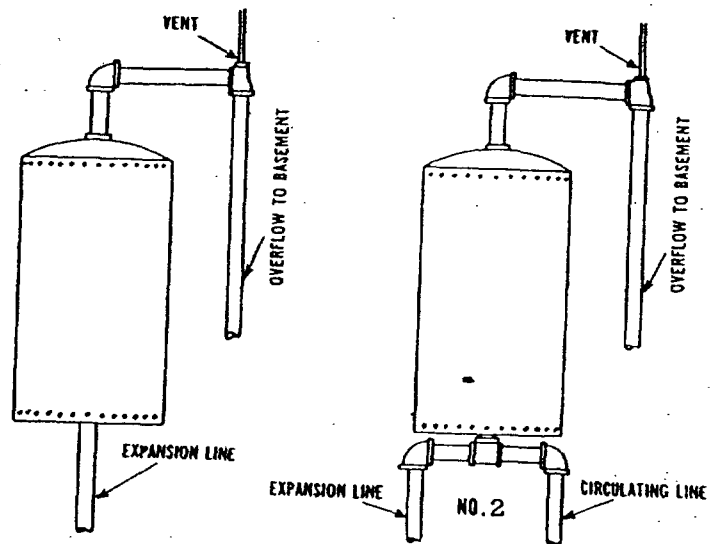


Figure 12

NOTE: When tank is circulated as in No. 2, Figure. 12, it should be placed directly over and as close to piping as possible.

TYPICAL LAYOUT TWO PIPE GRAVITY HOT WATER HEATING SYSTEM

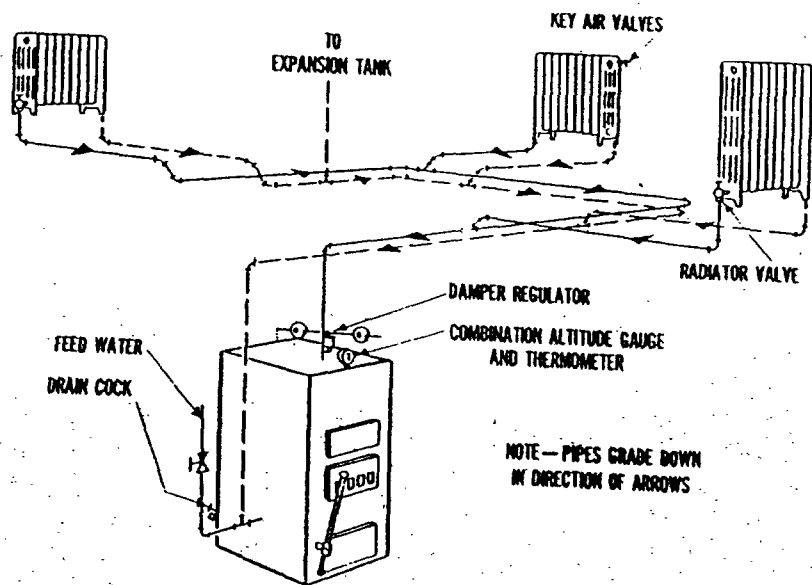


Figure 13

HOW TO ESTIMATE WATER HEATING REQUIREMENTS AND BOILER LOAD

Where water condition and pressure are favorable, the direct heating method of passing the water through the heater is advantageous. In localities where high water pressures are encountered or where large quantities of lime or magnesia is contained in the water, we recommend the use of storage tanks with steam coils and a steam boiler. This method imposes the water pressure on the storage tank instead of the boiler; and in the case of hard water, containing lime and magnesia, removable coils should be used which can be cleaned and replaced.

All storage tanks equipped with steam coils should have manhole for cleaning.

How to Estimate

When estimating water heating requirements, first convert gallons of water into pounds; each gallon of water weighs 8.3 lbs.

In selecting size of boiler required, base calculations on an output of 240 B.t.u. ($\frac{1}{4}$ pound) Steam or 150 B.t.u. Hot Water radiation per sq. ft. per hour.

NOTE: One B.t.u. will increase the temperature of one pound of water one degree.

Example 1:

Water to be heated 300 gal., to be heated 40 deg. per gal. per hour. What size steam or water boiler will be required?

300 gal. multiplied by 8.3 lbs. per gal. equals 2500 lbs., multiplied by 40 deg. rise in temperature equals 100,000 B.t.u. required.

To find size boiler required divide B.t.u. required by 240 steam or 150 water to convert B.t.u. requirement to radiator load.

100,000 divided by 240 = 416 E.D.R. steam

100,000 divided by 150 = 666 E.D.R. water

When selecting the boiler for heating domestic water, it should be borne in mind that practically all boiler load is represented by the B.t.u. required to heat the water, since there is only a small amount of pipe as compared to a radiator installation.

Let us assume in this case that the piping amounts to five per cent of the equivalent radiator load, in which case, we would size the boiler in the following manner.

Steam Boiler load 416 plus 5% = 437 sq. ft. Refer to Chart 1, Page 16, starting at bottom line (design load) follow line at 440 up to diagonal line and follow to left column and select the size boiler (343 sq. ft.) from trade price sheet.

Example 2:

Water to be heated 500 gal., to be heated 100 deg. in 3 hours, what size boiler will be required?

500 gal. multiplied by 8.3 lbs. equals 4150 lbs., multiplied by 100 deg. rise in temperature equals 415,000 B.t.u. required. Since we have 3 hours in which to heat the water divide 415,000 by 3 to get hourly requirement. 415,000 divided by 3 equals 138,300 B.t.u. per hour.

138,300 divided by 240 = 576 Steam E.D.R.

138,300 divided by 150 = 922 Water E.D.R.

If in this case, we again add 5% for piping, we would select a steam boiler with an installed radiator rating of 480 sq. ft. or a water boiler with an installed rating of 785 sq. ft. as shown on Chart 1.

RECOMMENDED FINAL TEMPERATURES

Private Dwellings	150 degree
Apartments	150 "
Office Buildings	140 "
Hotels	160 "
Restaurants	180 "

It is assumed that the average temperature of incoming water supplied for domestic use is 40° F.

MISCELLANEOUS NOTES AND DATA

Measuring Windows

When measuring window surfaces the full opening in the brick work should be considered as glass surface.

Figuring Indirect Radiation

When Indirect radiation (other than Vento) is used, there should be 45% more installed than would be required if direct radiation were used. Due to the increased rate of condensation as compared to direct, each square foot of Indirect radiation is equivalent to 1.7 square feet compared to Standard Column radiation as boiler load.

Figuring Direct-Indirect Radiation

When Direct-Indirect radiation is used 30% more will be required than if direct were used. Each square foot of Direct-Indirect will be equivalent to 1.2 square feet of Standard Column Radiation as boiler load.

Reaming Pipes

It is important that all pipe ends be thoroughly reamed to prevent the lodging of sediment and slowing up of circulation. A burr left in the end of a small size pipe has the effect of reducing the pipe area approximately one size.

Figuring Radiation in Rooms with High Ceilings

All heating calculations are based on ceilings 12 feet or less in height and for measuring room temperatures five feet above the floor. Therefore, provisions should be made for estimating the amount of direct radiation required in buildings with high ceilings such as churches, auditoriums, etc. A simple rule for estimating the extra amount of radiation in rooms with ceilings over 12 feet high is to add $1\frac{1}{2}\%$ to the amount of radiation figured for normal conditions for each foot in height over 12 feet. This applies particularly to direct radiation.

Locating Radiators

In most instances the problem of locating radiators solves itself, especially where only one radiator is required in a room.

For best results direct cast iron, Sunrad and convector radiators should be placed under windows on the cold side of the room. Radiators thus located will heat up the cold air entering the room through leakage around the window, and eliminate to a great degree possible cold cross drafts on the floor.

Gravity indirect radiators should not be located in front of windows because the down current of the heavy cold air retards air circulation in this type of installation.

In rooms with more than one exposed wall or with a large amount of glass surface causing high heat loss, two or more radiators may be required; these should be located as above to counteract these high heat losses due to infiltration and glass surface loss.

The correct location of the radiator should not be sacrificed for the accommodation of furniture; personal comfort is of first consideration.

Heating Basement Rooms

When estimating radiator requirements for basement rooms and the placing of the radiators, especially radiators hung on walls, which is made necessary due to boiler water line, the following will be of assistance.

Heat losses above grade level should be figured the same as for upstairs rooms. The wall loss below grade level should be figured the same as for walls exposed to air and be based on the mean temperature of the ground between grade level and floor level, the floor loss should be included.

In basement rooms where the radiator is placed on the wall or ceiling the temperature near the floor is usually cold, this can best be overcome by use of mechanical circulation such as a unit heater by use of which one or more ducts can be run to the floor to pick up the cold air and keep it in motion.

Add to Radiation for Intermittent Heating

Ten per cent if heated for short periods in daytime only.

Twenty per cent when the building is heated intermittently with long intervals of non-heating. Where this condition exists, the boiler size should be liberal.

ASSUMED TEMPERATURES

Living Rooms, Offices, Court Houses, etc.....	70
Lecture Halls, Auditoriums and Stores.....	65 to 68
Dormitories used only for sleeping.....	55 to 60
Bath Rooms.....	75
Factories, Light Work.....	65 to 68
Factories, Heavy Work.....	55 to 60
Gymnasiums.....	50 to 60
Churches.....	60 to 65
Hot Houses.....	77
Unheated Attic.....	35
Garages—Public.....	50 to 55
Garages—Private.....	40 to 50

These temperatures should be measured at a distance of about five feet or "head high" above the floor, and at least three feet from exposed wall.

TABLE 4
TRANSMISSION OF HEAT FROM HOT WATER RADIATORS

The number of B.t.u. given off per sq. ft. per hour for different types of radiators and for various water temperatures and with 70° F. surrounding air—gravity or forced flow:

Average Water Temperature in Radiators	Standard Direct Radiation	Sunrad Radiation	Arco Cast Iron Convectors	Arco Multifin Convectors	
				Gravity	Forced Flow
210	230	210	219	183	201
200	210	195	200	167	184
190	190	180	182	151	166
180	170	160	164	135	149
170	150	145	145	120	132
160	130	128	126	106	117
150	110	112	109	90	99

When sizing hot water heating boilers, convert radiation to "Standard 150 B.t.u. Output." Refer to pages 11 to 17, inclusive, also see example below.

EXAMPLE: Hot water boiler ratings are based on 150 B.t.u. emission per sq. ft. of radiation per hour. Therefore, if a radiator emits 230 B.t.u. per sq. ft. per hour, it imposes a 60% greater

load on the boiler; and if a radiator emits 110 B.t.u. per sq. ft., this radiator will impose a 27% lesser tax and the size boiler should be selected accordingly.

If it is desired to find the heat output of radiation for surrounding air temperatures other than 70° F., refer to Page 6, "Coefficients of Heat Emission," also Table 1, Page 12.

Piping Load

This problem involves so many variables as to make it difficult to establish a load factor that is not subject to debate.

The variables involve the questions of: How much of the total is in the mains? How much is in the branches? How much in the risers? What percentages of the risers are in outside walls? What percentages in inside walls? What are the surrounding air temperatures, etc.

These and many other problems are involved, still we believe a fairly close approximation is possible for the average installation by assuming that 50% of the load is chargeable to branches and risers and 50% to mains and assume them to be in air at 50° F., so on this basis, the following is offered as a guide for establishing piping loads.

TABLE 5

Square Feet of Installed Radiation	Per cent of Load Pipe Covered "A"	Per cent of Load Pipe Uncovered	
200	30	60	
400	27	58	
600	25	56	
800	24	54	
1000	22	52	
1200	21	50	
1400	20	48	
1600	19	46	
1800	18	44	
2000	17	42	
2200	16	40	
2500	15	36	
3000	14	32	
3500	13	26	
4000	12	22	

These percentages apply to both steam and hot water systems using steel pipe.

Owing to the fact that we have but one rating on all Ideal Boilers and since these ratings are based on installed radiation under standard conditions (240 B.t.u. steam 150 B.t.u. water) and include covered piping, it becomes necessary to provide for the selection of a boiler for jobs with uncovered piping, and also to show the percentage used for establishing our present installed boiler ratings with covered piping.

This information is necessary for arriving at design loads when using Charts 1 and 1A, which charts are used for converting total design load back to trade price sheet ratings.

The percentages under "A" are based on built-up asbestos 4-ply 1" covering for steam, and 3-ply $\frac{3}{4}$ " for water.

On large installations using bare steel pipe with air surrounding the pipe at a temperature higher than 50° F., slightly lower factors may be used than those shown in table.

NOTE: Regardless of any conditions or circumstances all risers in outside walls should be covered.

Bare Copper Pipe

For forced hot water systems, particularly one pipe systems, the load of bare piping can be assumed to be the same as shown in Table 5 under column "A". If the pipe is covered, take half of these figures.

TABLE 6
Square Feet of Surface per Linear Foot of Pipe

Size	$\frac{3}{8}$ "	$\frac{1}{2}$ "	$\frac{3}{4}$ "	1"	1 $\frac{1}{4}$ "	1 $\frac{1}{2}$ "
Steel	.176	.226	.275	.346	.434	.494
Standard Copper	.09	.1636	.23	.294	.361	.425
Size	2"	2 $\frac{1}{2}$ "	3"	3 $\frac{1}{2}$ "	4"	5"
Steel	.622	.753	.916	1.05	1.175	1.455
Standard Copper	.555	.708	.816	.921	1.08	

TABLE 7

Linear Feet of Pipe per Sq. Ft. of Surface

Size	$\frac{3}{8}$ "	$\frac{1}{2}$ "	$\frac{3}{4}$ "	1"	$1\frac{1}{4}$ "	$1\frac{1}{2}$ "
Steel	5.66	4.55	3.64	2.9	2.3	2.0
Standard Copper	7.64	6.11	4.36	3.4	2.74	2.35

Size	2"	$2\frac{1}{2}$ "	3"	$3\frac{1}{2}$ "	4"	5"
Steel	1.62	1.33	1.09	.95	.85	.687
Standard Copper	1.8	1.41	1.22	1.08	.925	

TABLE 8

Heat Loss from Horizontal Pipe Expressed in B.t.u. per square foot per Degree Fahrenheit Difference Between Pipe at 227° Temp. and Surrounding Still Air at 70° F.

Size	$\frac{1}{2}$ "	$\frac{3}{4}$ "	1"	$1\frac{1}{4}$ "	$1\frac{1}{2}$ "	
Bare Steel Pipe	2.98	2.84	2.78	2.71	2.68	
Covered Steel Pipe 1" Four-Ply Asbestos	.995	.898	.818	.751	.71	
Bare Copper Pipe	2.572	2.16	1.94	1.795	1.699	

Size	2"	$2\frac{1}{2}$ "	3"	$3\frac{1}{2}$ "	4"	5"
Bare Steel Pipe	2.62	2.57	2.50	2.47	2.43	2.40
Covered Steel Pipe 1" Four-Ply Asbestos	.667	.635	.60	.588	.575	.55
Bare Copper Pipe	1.573	1.45	1.434	1.44	1.367	

TABLE 9

Capacities of Steel Storage Tanks

Size Inches	Capacity Gallons	Size Inches	Capacity Gallons	Size Inches	Capacity Gallons	Size Inches	Capacity Gallons
18 X 36	40	24 X 48	94	30 X 72	221	36 X 96	424
18 X 48	53	24 X 60	117	30 X 84	258	36 X 108	477
18 X 60	66	24 X 72	141	30 X 96	294	36 X 120	530
18 X 72	79	24 X 84	164	30 X 108	335	42 X 60	360
18 X 84	92	24 X 96	188	30 X 120	372	42 X 72	432
20 X 48	65	24 X 108	212	36 X 36	159	42 X 84	504
20 X 60	82	24 X 120	235	36 X 48	212	42 X 96	572
20 X 72	98	30 X 36	110	36 X 60	265	42 X 108	644
24 X 36	71	30 X 48	147	36 X 72	318	42 X 120	716
24 X 42	82	30 X 60	184	36 X 84	371	42 X 144	860

TABLE 10

Actual Internal Area Standard Wrought Iron,
Steel and Copper Pipe

ACTUAL INTERNAL AREA

Diameter, Inches	Steel or Iron	Copper Types		
		K	L	M
$\frac{3}{8}$	.19	.127	.146	.159
$\frac{1}{2}$	.3	.218	.233	.254
$\frac{5}{8}$		.333	.348	.374
$\frac{3}{4}$	.53	.436	.484	.516
1	.86	.778	.825	.874
$1\frac{1}{4}$	1.5	1.217	1.256	1.309
$1\frac{1}{2}$	2.04	1.722	1.78	1.831
2	3.36	3.014	3.09	3.17
$2\frac{1}{2}$	4.78	4.656	4.77	4.89
3	7.39	6.637	6.81	6.98
$3\frac{1}{2}$	9.89	8.999	9.21	9.40
4	12.73	11.68	11.97	12.16
5	19.99	18.13	18.67	18.91

TABLE 11
Heat Units and Weight of Water

Temp. Deg. F.	Heat Units	Weight per Cu. Ft.	Temp. Deg. F.	Heat Units	Weight per Cu. Ft.
32	0	62.42	130	98.19	61.56
40	8	62.42	140	108.25	61.37
50	18	62.41	150	118.31	61.18
60	28.01	62.37	160	128.37	60.98
70	38.02	62.31	170	138.45	60.77
80	48.04	62.23	180	148.54	60.55
90	58.06	62.13	190	158.64	60.32
100	68.08	62.02	200	168.75	60.07
110	78.11	61.89	210	178.87	59.82
120	88.15	61.74	220	180.90	59.76

WATER

One Gallon of water weighs 8.33 lbs.
One Gallon of water equals 231 Cu. in.
At 39.1°F. water is at greatest density.

TABLE 12
Coefficients of Linear Expansion of
Pipe per 1°F Difference

Length = 1 Ft.	
Steel _____	0.00000636
Wrought Iron _____	0.00000648
Copper _____	0.00000887
Cast Iron _____	0.00000556

TABLE 13
Areas of Circles

Diam. Inches	Area	Diam. Inches	Area
1/2	0.1963	10	78.54
3/4	0.4417	11	95.03
1	0.7854	12	113.09
1 1/4	1.227	13	132.73
1 1/2	1.767	14	153.93
2	3.141	15	176.71
2 1/2	4.908	16	201.06
3	7.068	17	226.98
3 1/2	9.621	18	254.46
4	12.566	19	283.52
5	19.635	20	314.16
6	28.274	21	346.36
7	38.484	22	380.13
8	50.265	23	415.47
9	63.617	24	452.39

For Pipe Areas see Table 10.

TABLE 14
Properties of Saturated Steam

Boiling Point	Absolute Pressure Sq. In.	Inches Vacuum	Gauge Pres. Lbs.	Latent Heat	Heat of Liquid	Vol. 1 lb. Steam Cu. Ft.
192	9.74	10.09	.....	982.7	159.91	39.31
197	10.83	7.87	.....	979.7	164.93	35.62
201	11.76	5.97	.....	977.2	168.94	32.96
205	12.77	3.92	.....	974.7	172.96	30.53
210	14.13	1.16	.....	971.6	177.99	27.80
212	14.70	.....	.....	970.4	180.0	26.79
215	15.60	.....	0.90	968.4	183.0	25.35
217	16.22	.....	1.72	967.2	185.0	24.44
219	16.86	.....	2.16	965.9	187.1	23.57
222	17.87	.....	3.17	963.9	190.1	22.34
225	18.91	.....	4.21	962.0	193.1	21.17
227	19.64	.....	4.94	960.7	195.2	20.44
230	20.77	.....	6.07	958.7	198.2	19.39
232	21.56	.....	6.86	957.4	200.2	18.72
235	22.79	.....	8.09	955.4	203.2	17.78
237	23.64	.....	8.94	954.1	205.3	17.17
240	24.97	.....	10.27	952.1	208.3	16.32
242	25.88	.....	11.18	950.7	210.3	15.78
244	26.83	.....	12.13	949.4	212.4	15.26
246	27.80	.....	13.10	948.0	214.4	14.76
248	28.80	.....	14.10	946.7	216.4	14.28
250	29.82	.....	15.12	945.3	218.5	13.82

TABLE 15

Approximate Gravities, Heat Content and Weight of
Commercial Standard Grades of Fuel Oil

Number	Degrees Baume at 60° F.	Weight Per Gallon	Average B.t.u. Per Pound	Average B.t.u. per Gallon
1	40	6.86	19650	135000
2	35	7.07	19500	138000
3	30	7.28	19350	141000
4	25	7.52	19210	144500
5	20	7.79	19030	148000
6	15	8.04	18850	151650

TABLE 16

Average Heat Units Per Cubic Foot of Gas

Natural	1000 to 1200 B.t.u.
Manufactured	530 to 550 B.t.u.

TABLE 17

Average Weight, Coal and Coke

Anthracite Coal, Stove Size.....	52.5 lbs. per cu. ft.
Bituminous Coal, Mine Run.....	42 lbs. per cu. ft.
Coke, Stove Size.....	28 lbs. per cu. ft.

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