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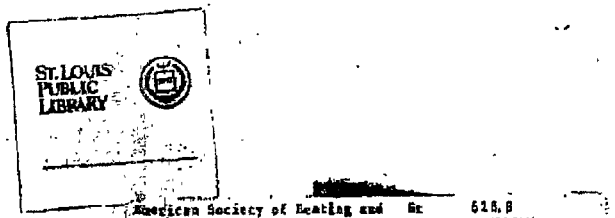

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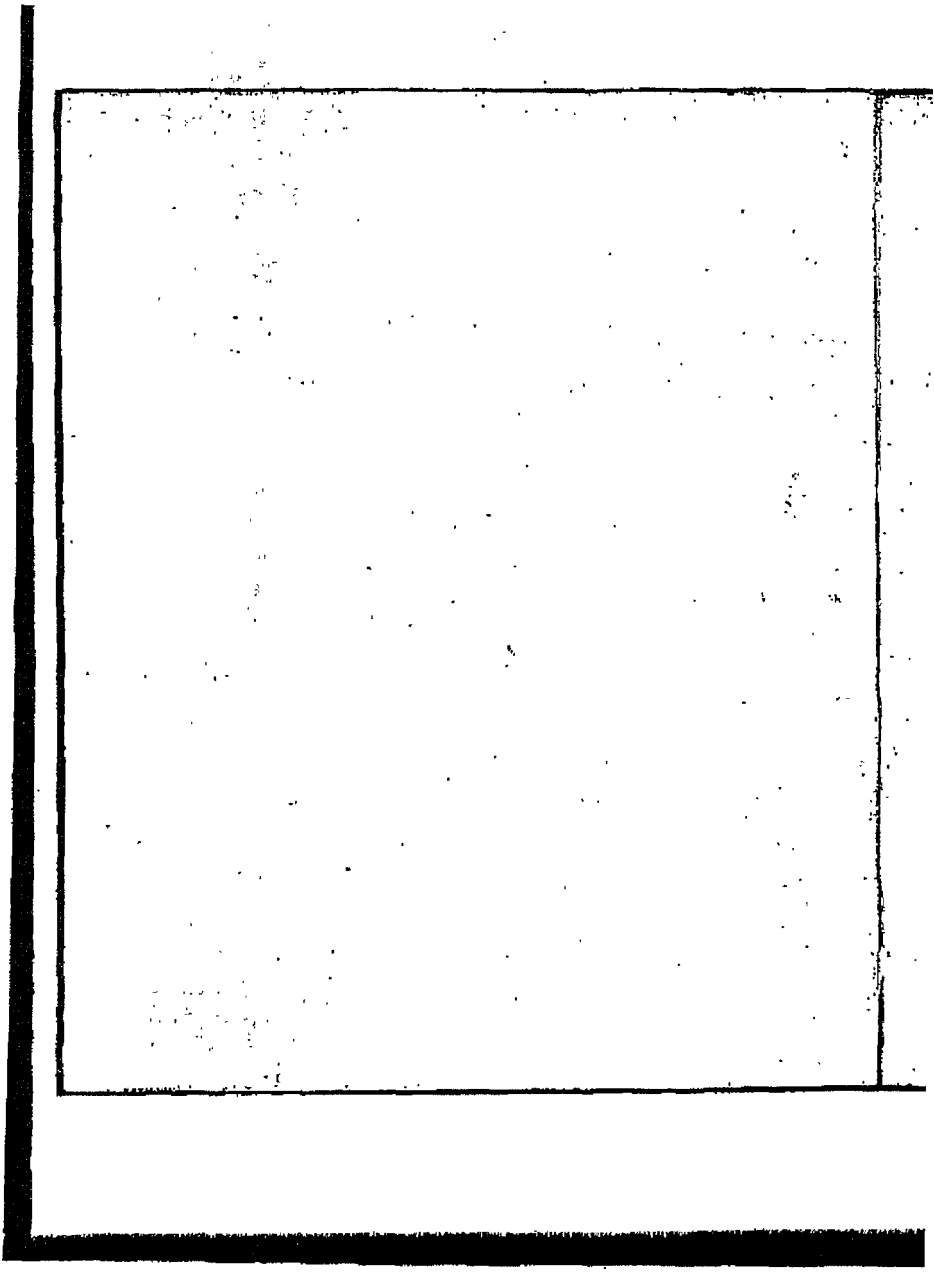

HEATING VENTILATING AIR CONDITIONING GUIDE 1959

An Instrument of Service
Prepared for the Profession
containing

A TECHNICAL DATA SECTION OF REFERENCE MATERIAL OF THE DESIGN AND SPECIFICATION OF HEATING, VENTILATING, AND AIR-CONDITIONING SYSTEMS BASED ON—THE TRANSACTIONS—THE INVESTIGATIONS OF THE RESEARCH LABORATORY AND COOPERATING INSTITUTIONS—AND THE PRACTICE OF THE MEMBERS AND FRIENDS OF THE SOCIETY; A MANUFACTURERS' CATALOG DATA SECTION CONTAINING ESSENTIAL AND RELIABLE INFORMATION CONCERNING MODERN EQUIPMENT; COMPLETE INDEXES TO TECHNICAL AND CATALOG DATA SECTIONS

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by acclimatized men working in hot environments (The Journal of Industrial Hygiene and Toxicology, Vol. 27, March 1945, p. 3[illegible]).

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CHAPTER 7

AIR CONTAMINANTS

Classification of Air Contaminants, Sizes of Airborne Particles, Air Pollution by Smoke, Ash, and Cinders, Smoke Abatement and Air Pollution Control, Odor Nuisances, Industrial Air Contaminants, Flammable Gases and Vapors, Combustible Dusts, Atmospheric Pollens, Airborne Bacteria, Radioactive Air Contaminants

THE normal constituents of the earth's atmosphere are oxygen, nitrogen, carbon dioxide, water vapor, argon, small or negligible amounts of other inert gases, hydrogen, variable traces of ozone, and small quantities of microscopic and submicroscopic solid matter, sometimes called *permanent atmospheric impurities*. From the viewpoint of the air-conditioning engineer, all other airborne substances may be termed contaminants. This term is applied preferably, however, to undesirable or chance impurities, since the occasion may arise for adding to the air controlled amounts of solid or gaseous diluents for the prevention of explosions; germicidal vapors or mists (aerosols) for bacteria control; masking substances for odor control; or a substitute for one of the normal gases, as, for example, when helium is used to replace nitrogen in atmospheres for compressed air-workers or divers.

Since control of the chemical quality of air is one of the functions of complete air conditioning, some knowledge of the *composition, concentration, and properties* of air contaminants under various circumstances is essential to the air-conditioning engineer.

Air contaminants arise from the normal processes of wind, storms, windstorms, sea-spray evaporation, thermal disintegration, earthquakes, volcanic eruption, combustion, manufacturing, transportation, agriculture, and the biochemical or biological processes of life. They are classified at various times as organic and inorganic, visible or invisible, microscopic or macroscopic, particulate or gaseous, toxic or harmless, beneficial or destructive. The following classification is based chiefly upon the origin or method of formation of air contaminants.

CLASSIFICATION OF AIR CONTAMINANTS

Air contaminants may be classified in the following groups: (1) dust, fumes, and smokes which are solid particulate contaminants, (2) mists and fogs which are liquid particulate contaminants, and (3) vapors and gases which are nonparticulate contaminants.

Dust, Fumes, and Smokes

Dusts are solid particles projected into the air by natural forces, such as wind, volcanic eruption, or earthquakes, and by mechanical processes, such as crushing, grinding, milling, drilling, demolition, shoveling, conveying, screening, bagging, and sweeping. Some of these types produce dust from larger masses, while others simply disperse materials that are already pulverized. Generally, particles are not called *dust* unless they are smaller than about 100 microns. Dusts may be of mineral type, such as rock, ore, metal, sand; *vegetable*, such as grain, flour, wood, cotton, pollen; or *animal*, such as wool, hair, silk, feathers, leather.

Fumes are solid particles commonly formed by the condensation of vapors from normally solid materials such as molten metals. Metallic fumes generally occur as the oxides in air because of the highly reactive nature of finely divided matter. Fumes may also be formed by sublimation, distillation, calcination, or chemical reaction, wherever such processes create airborne particles predominantly below the 1 micron size. Fumes permitted to age tend to flocculate into clumps or aggregates of larger size, thereby facilitating removal from air.

Smokes are the extremely small solid particles produced by incomplete combustion of organic substances such as tobacco, wood, coal, oil, tar, and other carbonaceous materials. The term smoke is commonly applied to the mixture of solid, liquid, and gaseous products of combustion, although the technical literature refuses to distinguish between such components as soot or carbon particles, fly-ash, cinders, tarry matter, unburned gases, and gaseous combustion products. The finest particulate constituents are much less than 1 micron in size, often in the range of 0.1 to 0.3 micron.

Mists and Fogs

Mists are very small airborne droplets of materials that are ordinarily liquid at normal temperatures and pressures. They may be formed by atomizing, spraying, splashing, mixing, violent chemical reaction, electrolytic evolution of gas from a liquid, or escape of a dissolved gas upon release of pressure. Very small droplets expelled or atomized into the air by sneezing constitute mists containing micro-organisms that become air contaminants.

Fogs are limited by some classifications to airborne droplets formed by condensation from the vapor state. This arbitrary distinction between *mist* and *fog* is of minor importance, as both terms are used to indicate the particulate state of airborne liquids (occasionally termed *aerosols*). *Fog nozzles* are so named because of their ability to produce extra fine droplets as compared to the mist from ordinary spray devices. The highly volatile nature of some liquids quickly reduces their airborne droplets from the mist to the fog range, and eventually to the vapor phase, until the air becomes saturated with that liquid. Many droplets in fogs or clouds are microscopic and submicroscopic in size, and may be considered as the transition state between the larger mists and the vapors.

Vapors and Gases

Vapors and Gases are nonparticulate air contaminants.

Vapors are the gaseous phase of substances that are either liquid or solid in their commonly known state, examples being gasoline, kerosine, benzene, carbon tetrachloride, mercury, iodine, camphor. Vapors may be changed to the solid or

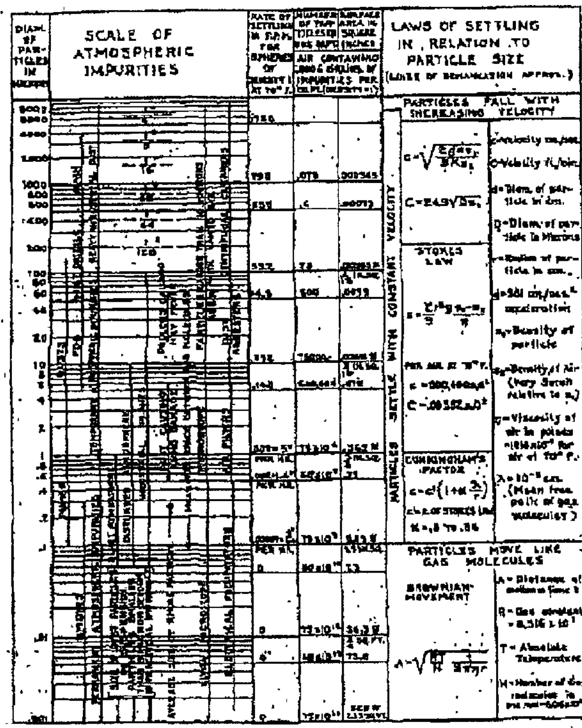

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Fig. 7 .... Sizes and Characteristics of Airborne Particulate Matter.

liquid form by increasing the pressure, decreasing the temperature, or applying both processes simultaneously. They are removed from the air by condensation with less difficulty than are the gases.

Gases are normally formless fluids which tend to occupy a space or enclosure completely and uniformly at ordinary temperatures and pressures. The following substances qualify as gases: oxygen, nitrogen, carbon dioxide, carbon monoxide, hydrogen, ammonia, sulfur dioxide. Gases, likewise, may be solidified or liquefied by the proper control of temperature and pressure.

The preceding classification is not suitable for the airborne living organisms, which range in size from the submicroscopic viruses to the largest pollen grains, and considering the smallest lower life. Bacteria range from about 0.2 to 5 microns in size, fungus spores from 1 to 10 microns, and pollen from 5 to 150 microns.

SIZES OF AIRBORNE PARTICLES

Fig. 7 is a graphic tabulation of the properties of airborne solids and liquids arranged according to size on the micron scale. There are 25,400 microns in 1 inch.

Particles larger than 10 microns are unlikely to remain suspended in air currents of moderate strength, but settle out by gravity at speeds dependent upon the shape, size and specific gravity of the particle, wind velocity, orientation of the collecting surface, and topography. These larger particles are of major interest to the engineer in the solution of nuisance problems, but it is usually the smaller particles, or those below 10 microns, that remain in the air long enough to be of hygienic as well as economic significance.

Industrial dust particles are predominantly of the order of 1 micron in size. Tremendous numbers are also present in the submicroscopic range below 0.5 micron, but those below 0.1 micron are not believed at present to be of practical importance, possibly due to their exceedingly small mass in comparison with the balance of airborne matter. In fact, particles this small may become the permanent atmospheric impurities that have little, if any, opportunity of settling because of the continual motion imparted to them by air currents and the molecular activity of gases (Brownian Movement).

The survey of atmospheric pollution in 14 American cities conducted from 1931 to 1933 indicated the average size of outdoor dust particles to be 0.5 micron, as collected by the Owens jet dust counter and measured under the microscope. Inability of the *light field* microscope to reveal particles in the 0.1 micron vicinity may have influenced the determination of average particle size.

The lower limit of particle size visible to the naked eye cannot be stated definitely. It depends not only upon the individual eye, but also upon the shape and color of the particle, intensity and quality of the light, and nature of the background or opportunity for contrast. Under ideal conditions a particle of 10-micron size might be recognized, while under less favorable conditions it may be impossible to distinguish a particle smaller than 50 microns. The lower limit of visibility probably ranges from 10 to 40 microns.

Dusts, powders, and granular materials are frequently classified by reference to the size of screens used for separation. Particles above 40 microns are said to be the screen sizes and those below, the subscreen or microscopic sizes. Approximate or theoretical sizes of particles corresponding to the mesh scale of the U. S. Standard Sieve Series are given in Table 1.

Table 1 .... Relation of Screen Mesh to Particle Size

U. S. Standard sieve mesh	400	325	200	150	100	60	35	18
Nominal sieve opening in microns	37	44	74	105	149	250	500	1000

Microscopic examination of screened dust indicates that the average diameter of a sample of irregular particles may be substantially larger than the openings of the screen through which it has passed, if the particle shapes deviate considerably from the spherical form.[4] The smallest dimension of many such particles will correspond to the maximum permissible distance between the wires of commercial screens made to ASTM Standard Specifications. Screening does not give sharp separation into size groups, and accordingly, such a classification is statistical rather than absolute.

AIR POLLUTION BY SMOKE, ASH, AND CINDERS

Total airborne solids settling in urban areas are usually reported as dust fall in tons per (square mile) (month). Such

Table 2 .... Dust Concentration Ranges

Location	Grains per 1000 Cu Ft[a]	Milligrams per Cubic Meter
Rural and suburban districts	0.02–0.2	0.05–0.5
Metropolitan districts	0.04–0.4	0.1–1.0
Industrial districts	0.1–2.0	0.2–5.0
Ordinary factories or workrooms	0.2–4.0	0.5–10
Excessively dusty factories or mines	4–400	10–1000
Minimum explosive concentrations	4000–200,000	10,000–500,000

[a] 1 grain per 1000 cu ft = [illegible] milligrams per cubic meter.
1 [illegible] per cubic foot = [illegible] per cubic meter.

data published for the cities in this country range from 20 to 200 tons per (square mile) (month). To the air-conditioning engineer this information may indicate the effectiveness of smoke abatement or fuel combustion control methods in his locality, but it does not provide a suitable index of the suspended dust that air cleaners in a ventilating system are expected to capture.[5,6] Gravimetric or weight data of the type given in Table 2 are preferable. In some cases airborne particle counts may be necessary, as for pollen, bacteria, spores, and insoluble dusts causing illness or lung disease.

Dust concentrations by weight cannot be converted readily to concentrations by particle count because of the variability of particle size, shape, and specific gravity, and the inherent characteristics of dust counting and weighing procedures. One milligram of dust per cubic meter of air may represent dust counts from 1 million to 100 million particles per cubic foot of air (light field microscope technic) according to the size distribution of the airborne dust sample. Information of this type for a specified application is best obtained by simultaneous sampling for both counting and weighing and noting carefully at the time all factors that might affect the reproducibility of the count-weight ratio.

Smoke Abatement and Air Pollution Control

Successful abatement of atmospheric pollution caused by smoke requires the combined efforts of the combustion engi

ness, industrial executive, public health officer, city planning commission, and the community at large. Electrification of industry and railroads, increase in the use of domestic oil and gas furnaces, and segregation of industrial districts are gradually providing effective aid in the solution of this problem. In the large cities where nuisances from smoke, fly-ash, and cinders is more serious, limited areas obtain some relief by the use of district heating. (See Chapters 33, 34, and 35 for further discussion on fuel-burning technics.)

Many present ordinances limit the number of minutes in any one hour that smoke of a specified density (determined by comparison with a Ringelmann Chart which is described in Chapter 44) may be discharged.

There is now considerable interest and activity in the control of air pollution factors in addition to smoke. Difficulty in the establishment of acceptable criteria for certain corrosive and irritant gases, such as fluorides and the oxides of sulfur and nitrogen discharged with the gases of combustion, and the frequently complicated technical and economic problems encountered in control, have delayed the drafting and enforcement of legislative measures. Recent reports of an increased incidence of diseases, such as pneumonia and lung cancer, in areas high in certain air contaminants, require further critical investigation before acceptance. The values finally adopted will undoubtedly be lower than the MAC (Maximum Allowable Concentration) limits for use in industry, because the exposure is continuous compared with the 8-hour day, 5- or 6-day week upon which MAC values are based, and because the exposed population contains individuals with greater variation in age and health status.

In foggy weather, or during an inversion of atmospheric conditions, accumulation of gaseous contaminants may cause irritation of eyes, nose, and respiratory passages, and possibly cause even more serious physiological effects. The Meuse Valley fog disaster (Belgium 1930) and the Donora smog (Pennsylvania 1948) are classic examples in the history of gaseous air pollution. In both instances it is believed that irritant gases, principally from industrial plants, accumulating during periods of exceptionally prolonged meteorological inversion and fog, contributed to the illness of many persons, and to the death of some who were especially susceptible.

Absorption of Solar Radiation

Absorption of solar ultra-violet light by smoke and soot is recognized as a health problem in many industrial cities. Measurements of solar radiation in Baltimore by actinic methods demonstrated that ultra-violet light intensity in the country was 50 percent greater than in the city. In New York City a loss as great as 50 percent in visible light was found by photoelectric measurements.

ODOR NUISANCE

A problem companionate with smoke abatement is the control of odor nuisance in the neighborhood of industrial plants discharging noxious or offensive air contaminants. Community planning and zoning will avoid much of the difficulty in the future, but meanwhile many industrial cities must resort to corrective measures by requiring installation of air cleaning devices, alteration of manufacturing processes, or termination of the offensive operation in residential or commercial districts.

Control of outdoor odor nuisance is especially troublesome because of the extremely minute quantities of contaminant that are capable of offending through a wide area. New industrial chemicals with strange or unfamiliar odors tend to receive more attention from the neighborhood than the customary odors generated by well-known processes and raw materials. Methods of odor control currently in use include charcoal adsorption, scrubbing towers and air washers, chlorination, condensation, masking, passage of the odorous air through combustion chambers, dispersion through a tall stack, and best of all, substitution of less offensive materials whenever possible.

Control of air quality within buildings ventilated for human occupancy is discussed in Chapter 6. Tobacco smoke odors, cooking odors, and body odors are air contaminants of the nuisance type which now command a decisive position in the standards of air quality for indoor comfort. However, the engineer will find, at times, that odors originating outside buildings in industrial or business districts may determine the kind and capacity of equipment he must provide for a high quality air-supply installation.

INDUSTRIAL AIR CONTAMINANTS

Many industrial processes are sources of contaminants. Their control is an important function of the ventilating or air-conditioning engineer, because the atmosphere within buildings is the medium whereby such finely divided matter is dispersed and transported from the source to remote locations where it may cause property damage, nuisance, fire, explosion, disease, and even death.

Tables 3, 4, and 5 give maximum allowable concentration values for many industrial air contaminants. Some of these values have been prepared by ASA Sectional Committee Z37 on Allowable Concentrations of Toxic Dusts and Gases, and others by the Committee on Threshold Limits of the American Conference of Governmental Industrial Hygienists. The values have been adopted by the American Conference of Governmental Industrial Hygienists and by many of the official industrial hygiene agencies.

It must be emphasized that these limits in the great majority of instances are only suggested maximum working levels since they are estimates, based in many cases upon incomplete environmental and medical studies. Where there is agreement between the *ASA Standard Z37* and ACGIH values, reliability of the ASA Standard is increased. The values are not fixed, but are subject to revision, upward or downward, with the development of new information. There is by no means complete agreement regarding these values among responsible industrial hygienists.

In applying these guide limits, the following factors must be considered:

1. The duration of exposure is 8 hr a day for 5 or 6 days a week.

2. The measurements are indicative of the concentration in the breathing zone of the exposed person.

3. The MAC is usually accepted as the average exposure value when the upper limits do not greatly exceed the MAC value. For example, it cannot be assumed that if 100 ppm is considered safe for 8-hour exposure, that 800 ppm for one hour will be permissible.

4. Two substances with similar MAC values may be quite different as to physiological effects at other concentrations. In one instance the selection of a limit may be predicated upon a discomfort factor, with a wide margin of safety before systemic effects would be encountered, while in another case the value represents an appreciable fraction of the concentra-

Table 3 . . . . Maximum Allowable Concentration of Gases and Vapors

Substance	ASA Standards MAC ppm[b] by volume	Threshold Limit Values ACGIH[a] 1958: ppm[b]	Threshold Limit Values ACGIH[a] 1958: g/cu m or oz/1000 cu ft
Acetaldehyde		200	0.360
Acetic acid		10	0.025
Acetic anhydride		5	0.020
Acetone		1000	2.400
Acrolein		0.5	0.0012
Acrylonitrile		20	0.045
Allyl alcohol		5	0.012
(x) Allyl chloride		5	0.015
Allyl propyl disulfide		2	0.012
Ammonia		100	0.070
Amyl acetate		200	1.050
Amyl alcohol (iso)		100	0.360
Aniline		5	0.019
Arsine		0.05	0.0002
Benzene (benzol)	100	25	0.080
Benzyl chloride		1	0.005
Bromine		1	0.007
Butadiene (1,3-butadiene)		1000	2.200
Butanone (methyl ethyl ketone)		250	0.740
Butyl acetate (n-butyl acetate)		200	0.950
Butyl alcohol (n-butanol)		100	0.300
Butylamine		5	0.015
* Butyl cellosolve (2-butoxyethanol)		50	0.240
Carbon dioxide		5000	9.000
Carbon disulfide	20	20	0.060
Carbon monoxide	100	100	0.110
Carbon tetrachloride		25	0.160
Cellosolve (2-ethoxyethanol)		200	0.740
Cellosolve acetate (2-ethoxyethyl acetate)		100	0.540
Chlorine		1	0.003
Chlorine trifluoride		0.1	0.0004
Chlorobenzene (monochlorobenzene)		75	0.350
Chloroform (trichloromethane)		100	0.490
1-Chloro-1-nitropropane		20	0.100
(x) Chloropicrin		1	0.007
Chloroprene (2-chloro-1,3-butadiene)		25	0.090
Cresol (all isomers)		5	0.022
Cyclohexane		400	1.400
Cyclohexanol		100	0.410
Cyclohexanone		100	0.400
Cyclohexene		400	1.350
Cyclopropane		400	0.690
(x) Decaborane		0.05	0.0003
Diacetone alcohol (4-hydroxy-4-methyl-2-pentanone)		50	0.240
Diborane		0.1*	0.0001
o-Dichlorobenzene		50	0.300
Dichlorodifluoromethane		1000	4.950
1,1-Dichloroethane		100	0.400
1,2-Dichloroethane (ethylene dichloride)		100	0.400
1,2-Dichloroethylene		200	0.790
Dichloroethyl ether		15	0.090
Dichloromonofluoromethane		1000	4.200
1,1-Dichloro-1-nitroethane		10	0.060
Dichlorotetrafluoroethane		1000	7.000
* Diethylamine		25	0.075
Difluorodibromomethane		100	0.860
Diisobutyl ketone		50	0.290
Dimethylaniline (N-dimethylaniline)		5	0.025
Dimethylsulfate		1	0.005
Dioxane (diethylene dioxide)		100	0.360
Ethyl acetate		400	1.400
(x) Ethyl acrylate		25	0.100
Ethyl alcohol (ethanol)		1000	1.900
Ethylamine		25	0.045
Ethyl benzene		200	0.870
Ethyl bromide		200	0.890
Ethyl chloride		1000	2.600
Ethyl ether		400	1.200
Ethyl formate		100	0.300
Ethyl silicate		100	0.850
Ethylene chlorohydrin		5	0.016
Ethylenediamine		10	0.025
Ethylene dibromide (1,2-dibromoethane)		25	0.190
Ethylene imine		5	0.009
Ethylene oxide		50	0.090
Fluorine		0.1	0.0002
Fluorotrichloromethane		1000	5.600
Formaldehyde	10	5	0.006
(x) Furfural		5	0.020
Gasoline		500	2.000
Heptane (n-heptane)		500	2.000
Hexane (n-hexane)		500	1.800
Hexanone (methyl butyl ketone)		100	0.410
Hexone (methyl isobutyl ketone)		100	0.410
Hydrazine		1	0.0013
Hydrogen bromide		5	0.017
Hydrogen chloride		5	0.007
Hydrogen cyanide		10	0.011
Hydrogen fluoride		3	0.002
Hydrogen peroxide, 90%		1	0.0014
Hydrogen selenide		0.05	0.0002
Hydrogen sulfide	20	20	0.030
* Iodine		0.1	0.001
Isophorone		25	0.140
Isopropylamine		5	0.012
* Mesityl oxide		25	0.100
Methyl acetate		200	0.610
Methyl acetylene		1000	1.650
(x) Methyl acrylate		10	0.035
Methyl alcohol (methanol)	200	200	0.260
Methyl bromide		20	0.080
Methyl cellosolve (2-methoxyethanol)		25	0.080
Methyl cellosolve acetate (ethylene glycol monomethyl ether acetate)		25	0.120
Methyl chloride	100	100	0.210
Methylal (dimethoxymethane)		1000	3.100

[a] ACGIH = American Conference of Governmental Industrial Hygienists. Reprinted by permission from A.M.A. Archives of Industrial Health, September 1957, Vol. 16, pp. 261-265.

[b] Parts of vapor or gas per million parts of air by volume.

(x) These values appeared in ACGIH tentative list for 1958.

* These items indicate changes made by ACGIH Committee on Threshold Limits in 1958.

Table 3 . . . . Maximum Allowable Concentration of Gases and Vapors (Concluded)

Substance	ASA Standards MAC ppm by volume	Threshold Limit Values ACGIH 1958: ppm*	g/cu m or oz/1000 cu ft
Methyl chloroform (1,1,1-trichloroethane)		500	2.700
Methylcyclohexane		500	2.000
Methylcyclohexanol		100	0.470
Methylcyclohexanone		100	0.460
Methyl formate		100	0.250
Methyl isobutyl carbinol (methylamyl alcohol)		25	0.100
Methylene chloride (dichloromethane)		500	1.750
Naphtha (coal tar)		200	0.800
Naphtha (petroleum)		500	2.000
Nickel carbonyl		0.001	0.000007
*(x) Nitric acid		10	0.025
p-Nitroaniline		1	0.006
Nitrobenzene		1	0.005
Nitroethane		100	0.310
Nitrogen dioxide		5	0.009
Nitroglycerine		0.5	0.005
Nitromethane		100	0.250
2-Nitropropane		50	0.180
Nitrotoluene		5	0.030
Octane		500	2.350
Ozone		0.1	0.0002
Pentane		1000	2.950
Pentanone (methyl propyl ketone)		200	0.700
Perchlorethylene (tetrachloroethylene)		200	1.350
Phenol		5	0.019
Phenylhydrazine		5	0.022
Phosgene (carbonyl chloride)		1	0.004
Phosphine		0.05	0.00007
Phosphorus trichloride		0.5	0.003
Propyl acetate		200	0.840
Propyl alcohol (isopropyl alcohol)		400	0.980
Propyl ether (isopropyl ether)		500	2.100
Propylene dichloride (1,2-dichloropropane)		75	0.350
Propylene imine		25	0.060
Pyridine		10	0.030
Quinone		0.1	0.0004
Stibine		0.1	0.0005
Stoddard solvent		500	2.90
Styrene monomer (phenylethylene)	400	200	0.850
Sulfur dioxide		5	0.013
Sulfur hexafluoride		1000	6.000
Sulfur monochloride		1	0.006
Sulfur pentafluoride		0.025	0.00025
p-Tertiarybutyltoluene		10	0.060
1,1,2,2-Tetrachloroethane		5	0.035
(x) Tetrahydrofurane		200	0.590
Tetranitromethane		1	0.008
Toluene (toluol)	200	200	0.750
o-Toluidine		5	0.022
Trichloroethylene	200	200	1.050
Trifluoromonobromomethane		1000	6.100
Turpentine		100	0.560
Vinyl chloride (chlorethylene)		500	1.30
Xylene (xylol)		200	0.870

tion which may be associated with severe and irreversible injury.

3. These values are upper limits; it is desirable to operate well below the levels if the engineering and economic factors permit. The prudent engineer will incorporate a reasonable margin of safety in his estimates of ventilation capacity.

In Table 3, Column 1 lists the ASA Sectional Committee Z37 MAC values; Column 2, those of the ACGIH Committee on Threshold Limits. Column 3 gives the value in grams per cubic meter or ounces per 1000 cu ft for the corresponding ACGIH limits.

In Table 4, Columns 2 and 3 are respectively the MAC values from the ASA and ACGIH Committees.

In Table 5, the MAC values for industrial dusts as given were obtained from data of the ACGIH Committee on Threshold Limits.

ACGIH limits for either gamma or Roentgen radiations are 0.3 roentgens per week.

Information on the properties and effects, with respect to health, of specific industrial air contaminants is available in publications listed at the end of this chapter.

FLAMMABLE GASES AND VAPORS

Adequate ventilation is a primary requirement for minimizing the hazard of fire or explosion due to gases and vapors. The need for good ventilation is not removed by the use of other precautions, such as the elimination of known ignition sources, segregation of hazardous operations, adoption of safe building construction, and installation of automatic alarms. Some safety engineers regard overventilation of an operation employing flammable liquids as a legitimate operating charge for the privilege or necessity of using a dangerous process. However, it is not possible to apply a reasonable safety factor to the ventilation estimate without consideration of the concentrations of gases or vapors that approach the danger point. Safety engineers prefer to limit the concentration to ¼ or ⅕ of the lower explosive limit, and this fact should be given full weight in determining the capacity and design of ventilating equipment. Rarely should consideration be given to operation above the upper explosive limit in the open areas of buildings or rooms—even though unoccupied—because the danger of temporary drop of gas concentration to a point within the explosive range is too great.

Ability of a flammable liquid to form explosive mixtures is determined largely by its vapor pressure, volatility, or rate of evaporation. *Flash point* is a convenient method of expressing this property in terms of the temperature scale. It may be defined as the temperature to which a combustible liquid must be heated to produce a flash when a small flame is passed across the surface of the liquid. The higher the flash point, the more safely can the liquid be handled. Liquids with flash points under 70 F should be regarded as highly flammable.

Upper and lower limits of flammability of gases and vapors, and the flash points of the corresponding liquids are given in Table 8.

Methods for estimating the flammable limits of mixtures of gases or vapors must be applied with caution; the reader is referred to other publications for this information.

Design of equipment for the control of combustible accumulation is outlined in Chapter 8. Construction of equipment for handling air containing flammable substances, or operating in atmospheres so contaminated, is discussed in Chapter 42.

It is customary to report the concentrations of flammable

Table 4 . . . . Limits for Toxic Dusts, Fumes, and Mists

Substance	ASA Standards MAC, g/cu m*	Threshold Limit Values, ACGIH 1958 g/cu m*
Aldrin (1,2,3,4,10,10-hexachloro-1,4,4a,5,8,8a-hexahydro-1,4,5,8-dimethanonaphthalene)		0.00025
Ammate (ammonium sulfamate)		0.015
Antimony		0.0005
(x) ANTU (alpha naphthyl thiourea)		0.0003
Arsenic		0.0005
Barium (soluble compounds)		0.0005
Cadmium oxide fume		0.0001
(x) Calcium arsenate		0.0001
Chlordane (1,2,4,5,6,7,8,8-octachloro-3a,4,7,7a-tetrahydro-4,7-methanoindane)		0.002
(x) Chlorinated camphene (60%)		0.0005
Chlorinated diphenyl oxide		0.0005
Chlorodiphenyl (42% chlorine)		0.001
(x) Chlorodiphenyl (54% chlorine)		0.0005
Chromic acid and chromates (as CrO_3)	0.0001	0.0001
Crag herbicide (sodium 2-(2,4-dichlorophenoxy) ethanol hydrogen sulfate)		0.015
Cyanide (as CN)		0.005
2,4-D (2,4-dichlorophenoxyacetic acid)		0.010
(x) DDT (2,2-bis(p-chlorophenyl)-1,1,1-trichloroethane)		0.001
Dieldrin (1,2,3,4,10,10-hexachloro-6,7-epoxy-1,4,4a,5,6,7,8,8a-octahydro-1,4,5,8-dimethanonaphthalene)		0.00025
(x) Dinitrobenzene		0.001
Dinitrotoluene		0.0015
Dinitro-o-cresol		0.0002
EPN (O-ethyl O-p-nitrophenyl thionobenzenephosphonate)		0.0005
(x) Ferbam (ferric dimethyl dithiocarbamate)		0.015
Ferrovanadium dust		0.001
Fluoride		0.0025
Hydroquinone		0.002
Iron oxide fume		0.015
Lead	0.00015	0.0002
(x) Lead arsenate		0.00015
Lindane (hexachlorocyclohexane, gamma isomer)		0.0005
Magnesium oxide fume		0.015
Malathion (O,O-dimethyl dithiophosphate of diethyl mercaptosuccinate)		0.015
Manganese	0.006	0.006
Mercury	0.0001	0.0001
Mercury (organic compounds)		0.00001
Methoxychlor (2,2-di-p-methoxyphenyl-1,1,1-trichloroethane)		0.015
Molybdenum (soluble compounds)		0.005
(insoluble compounds)		0.015
(x) Nicotine		0.0005
Parathion (O,O-diethyl O-p-nitrophenyl thiophosphate)		0.0001
Pentachloronaphthalene		0.0005
Pentachlorophenol		0.0005
Phosphorus (yellow)		0.0001
Phosphorus pentachloride		0.001
Phosphorus pentasulfide		0.001
Picric acid		0.0001
Pyrethrum		0.005
(x) Rotenone		0.005

Table 4 . . . . Limits for Toxic Dusts, Fumes, and Mists (Concluded)

Substance	ASA Standards MAC, g/cu m*	Threshold Limit Values, ACGIH 1958 g/cu m*
Selenium compounds (as Se)		0.0001
(x) Sodium fluoroacetate (1080)		0.0001
Sodium hydroxide		0.002
(x) Strychnine		0.00015
Sulfuric acid		0.001
TEDP (tetraethyl dithionopyrophosphate)		0.0002
TEPP (tetraethyl pyrophosphate)		0.00005
Tellurium		0.0001
Tetryl (2,4,6-trinitrophenylmethylnitramine)		0.0015
(x) Thiram (tetramethyl thiuram disulfide)		0.005
(x) Thallium (soluble compounds)		0.0001
Titanium dioxide		0.015
Trichloronaphthalene		0.005
Trinitrotoluene		0.0015
Uranium (soluble compounds)		0.00005
(insoluble compounds)		0.00025
Vanadium (V_2O_5 dust)		0.0005
(V_2O_5 fume)		0.0001
(x) Warfarin (3-(α-acetonylbenzyl)-4-hydroxycoumarin)		0.0001
Zinc oxide fumes		0.015
Zirconium compounds (as Zr)		0.005

* Grams of dust, fume, or mist per cubic meter of air.

(x) These values appeared on the ACGIH tentative list, for 1958.

Radioisotopes: For permissible concentrations of radioisotopes in air, see Maximum Permissible Amounts of Radioisotopes in the Human Body and Maximum Permissible Concentrations in Air and Water, Handbook 52, U. S. Department of Commerce, National Bureau of Standards, [illegible]. In addition, see Permissible Dose from External Sources of Ionizing Radiation, Handbook 59, U. S. Department of Commerce, National Bureau of Standards, [illegible].

Table 4 values reprinted by permission from AMA Archives of Industrial Health, September 1957, Vol. 16, pp. 261-265. No changes were made by ACGIH Committee on Threshold Limits at 1958 meeting.

Table 5 . . . . Limits for Mineral Dusts

Substance	Threshold Limit Values, ACGIH 1958 mppcf*
Aluminum oxide	50
Asbestos	5
Cement, Portland	50
Dust (nuisance, no free silica)	50
Mica (below 5% free silica)	20
Silica—high (above 50% free SiO_2)	5
Silica—medium (5 to 50% free SiO_2)	20
Silica—low (below 5% free SiO_2)	50
Silicon carbide	50
Soapstone (below 5% free SiO_2)	20
Talc	20

* mppcf—million particles per cubic foot of air, standard light field counts.

Table 5 values reprinted by permission from AMA Archives of Industrial Health, September 1957, Vol. 16, pp. 261-265. No changes were made by ACGIH Committee on Threshold Limits in 1958.

Table 6.... Approximate Limits of Flammability of Single Gases and Vapors in Air at Ordinary Temperatures and Pressures[a]

Gas or Vapor	Lower Limit Percent by Volume	Upper Limit Percent by Volume	Closed Cup[b] Flash Point Fahrenheit	NBFU Classification[c]
Acetaldehyde	4.0	57	−17	I
Acetone	2.5	12.8	0	I
Acetylene	2.5	80	....	
Allyl alcohol	2.5	....	70	II
Ammonia	15.5	26.6	....	
Amyl alcohol	1.2	....	100	III
Amyl chloride	1.6	....	....	
Amylene	1.6	7.7	....	
Benzene (benzol)	1.3	6.8	12	I
Benzyl chloride	1.1	....	140	II
Butane	1.9	8.4	....	
Butyl acetate	1.4	15.0	84	II
Butyl alcohol	1.7	....	....	
Butylene	2.0	9.7	....	
Carbon disulfide	1.3	44	−22	I
Carbon monoxide	12.5	74.2	....	
Crotonaldehyde	2.1	15.5	55	II
Cyclohexane	1.3	8.4	−4	I
Cyclopropane	2.4	10.4	....	
Decane	0.67	2.6	115	III
Dichloroethylene (1, 2)	9.7	12.8	57	II
Diethyl selenide	2.5	....	....	
Dioxane	2.0	22.2	54	II
Ethane	3.1	12.5	....	
Ether (diethyl)	1.9	36.5	−49	I
Ethyl acetate	2.2	11.5	28	I
Ethyl alcohol	3.3	19.0	55	I
Ethyl bromide	6.7	11.3	....	
Ethyl cellosolve	2.6	15.7	104	II
Ethyl chloride	4.0	14.8	−58	I
Ethylene	2.7	28.6	....	
Ethylene dichloride	6.2	15.9	56	I
Ethyl formate	2.7	16.5	−4	I
Ethyl nitrite	3.0	50	−31	I
Ethylene oxide	3.0	80	....	
Furfural (125 C)	2.1	....	140	III
Gasoline (variable)	1.4–1.5	7.4–7.6	−50	I
Heptane	1.0	6.0	25	I
Hexane	1.2	6.9	−15	I
Hydrogen cyanide	5.6	40.0	....	
Hydrogen	4.0	74.2	....	
Hydrogen sulfide	4.3	45.5	....	
Illuminating gas (coal gas)	5.3	32.0	....	
Isobutyl alcohol	1.7	....	82	II
Isopentane	1.3	....	....	
Isopropyl acetate	1.8	7.8	55	I
Isopropyl alcohol	2.0	....	53	I
Methane	5.0	15.0	....	
Methyl acetate	3.1	15.5	14	I
Methyl alcohol	6.7	36.5	52	I
Methyl bromide	13.5	14.5	....	
Methyl butyl ketone	1.2	8.0	....	
Methyl chloride	8.2	18.7	....	
Methyl cyclohexane	1.1	....	25	I
Methyl ethyl ether	2.0	10.1	−35	I
Methyl ethyl ketone	1.8	9.5	30	I
Methyl formate	5.0	22.7	−2	I
Methyl propyl ketone	1.5	8.2	....	
Natural gas (variable)	4.8	13.5	....	
Naphtha (benzene)	1.1	6.0	20–110	I

Table 6.... Approximate Limits of Flammability of Single Gases and Vapors in Air at Ordinary Temperatures and Pressures[a] (Concluded)

Gas or Vapor	Lower Limit Percent by Volume	Upper Limit Percent by Volume	Closed Cup[b] Flash Point Fahrenheit	NBFU Classification[c]
Naphthalene	0.9	5.9	176	III
Nonane	0.83	2.9	88	II
Octane	0.95	3.2	56	I
Paraldehyde	1.3	....	....	
Pentane	1.4	7.8	....	
Propane	2.1	10.1	....	
Propyl acetate	1.8	8.0	58	I
Propyl alcohol	2.1	13.5	59	I
Propylene	2.0	11.1	....	
Propylene dichloride	3.4	14.5	60	II
Propylene oxide	2.0	22.0	....	
Pyridine	1.8	12.4	68	III
Toluene (toluol)	1.3	7.0	40	I
Turpentine	0.8	....	95	II
Vinyl ether	1.7	27.0	....	
Vinyl chloride	4.0	21.7	....	
Water gas (variable)	6.5	70	....	
Xylene (xylol)	1.0	6.0	63	II

[a] Adapted from: Fire and Explosion Hazards of Combustible Gases and Vapors, by [illegible] (Chapter [illegible] in Industrial Hygiene and Toxicology, edited by F. A. Patty, Interscience Publishers, [illegible]); Prevention of Flammable Liquids, Gases and Solids [illegible] Factory Mutual [illegible]; [illegible] and National Fire Code for Flammable Liquids, Gases, Chemicals and Explosives—[illegible] (National Fire Protection Association).

[b] Closed cup refers to the equipment used in flash point determinations.

[c] From Standards for Storage, Handling and Use of Flammable Liquids (National Board of Fire Underwriters, No. 30, July [illegible]).

gases or vapors in percent by volume, or volume percent. Comparison with concentrations on the part per million scale used in chemical, medical, or industrial hygiene literature is readily made by the conversion: 1 percent = 10,000 ppm (parts of contaminant per million parts of air, by volume, or in other words, cubic feet of contaminant per million cubic feet of air). It will be noted in Table 6 that nearly all of the substances listed have lower explosive limits above 1.0 percent, while the maximum allowable concentrations for gases and vapors in Table 5 are below 1000 ppm or 0.1 percent in most cases. Therefore, control of toxic or injurious vapors to levels below their maximum allowable concentrations for health usually requires much more effective ventilation than for the prevention of a fire hazard.

COMBUSTIBLE DUSTS

A dust explosion is essentially a sudden pressure rise caused by the very rapid burning of airborne dust. The primary explosion often originates from a small amount of dust in suspension exposed to a source of ignition and the pressure and vibration it creates may be sufficient to dislodge large accumulations of dust on horizontal ledges or surfaces of the building and equipment, thereby creating a secondary explosion of great force. Thus the air-conditioning engineer is involved for two reasons: (1) to obtain a movement of dust-laden air into exhaust hoods or openings, and through ventilating or pneumatic conveying ducts, in a manner that will prevent accumulation of highly flammable dust at points

where it could ignite inside the equipment; and (2) to so design process ventilation as to prevent the escape of dust which might settle on horizontal surfaces and become a potential source of disaster at some distance from the dusty operation. (See Chapter 32.)

Intensity of a dust explosion depends upon: chemical and thermal properties of the dust; particle size and shape; concentration in air; proportion of inert dust in the air; moisture content and composition of the air; size and temperature of the ignition source; and degree of dispersion of the dust cloud. Investigations on the explosibility of dusts require determination of the maximum pressure developed during explosion of a known air concentration, as well as determination of the rate of pressure rise. Investigators frequently experience difficulty in obtaining dust suspensions of uniform dispersion, and this should be kept in mind when comparing results from several sources.

Minimum explosive concentrations of airborne dusts already tested range from 0.01 to 0.5 oz per cubic foot, or 10 to 500 grams per cubic meter of air. Maximum pressures generated have been reported as high as 500 psig, although they are more likely to be of the order of 50 psig. Investigations on the flammable characteristics of dusts are currently made at 0.1 and 0.2 oz per cubic foot.

ATMOSPHERIC POLLEN

Properties of pollen grains discharged by weeds, grasses, and trees and responsible for hay fever, are of special interest to designers of air cleaning equipment (see Allergic Disorders in Chapter 4, and Air Cleaning, Chapter 24). Whole grains and fragments transported by the air range chiefly between 10 and 50 microns in size, but some have been measured as small as 5 microns, and others over 100 microns in diameter. Ragweed pollen grains are fairly uniform in size within the range of 15 to 25 microns. Pollen grains can be removed from the air more readily than the particles of dust prevalent in outdoor air or produced by dusty processes, since the latter predominate in the range of 0.1 to 10 microns in size.

Most grains are quite hygroscopic and therefore vary in weight with the humidity. Illustrations and data on individual pollen grains are available in the botanical literature. Geographical distribution of plants known to produce hay fever is also recorded.

The quantity of pollen grains in the air is generally estimated by exposing an adhesive-coated glass plate outdoors for 24 hr, and then counting calibrated areas under the microscope. Methods are available for determining the number of grains in a measured volume of air, but their greater accuracy has not caused them to replace the more simple gravity slide method used for most pollen counts. Counting technics vary somewhat, but the daily pollen counts reported in local newspapers during the hay fever season usually represent the number of grains found on 1.8 sq cm of a 24-hr gravity slide.

Hay fever sufferers may notice the first symptoms when the pollen count is 10 to 25, and in some localities the maximum figures for the seasonal peak may approach 1000 for a 24-hr period, depending upon the sampling and reporting methods of the laboratory. Translation of gravity counts by special formulas to a volumetric basis, as the number of grains per cubic yard or per cubic foot of air, is unreliable because of the complexity of the modifying factors. When such information is important, it is best obtained directly by a volumetric instrument. The number of pollen grains per cubic yard of air evidently varies from 2 to 20 times the number found on 1 sq cm of a 24-hr gravity slide, depending on grain diameter, shape, specific gravity, wind velocity, humidity, and physical placement of the collecting plate.

AIRBORNE BACTERIA

Study of the occurrence and significance of micro-organisms in the atmosphere of the indoor world is absorbing the energies of a substantial number of physicians, bacteriologists, aerobiologists, physicists, public health workers, engineers, and hospital personnel. Some data are available on the types and quantities of bacteria found in a variety of spaces, but it is not possible at present to use this information as a conclusive index of the potential health hazard of a given environment. The reported number of airborne organisms may vary from 1 to 1000 per cubic foot of air, influenced somewhat by the method of testing. Many are attached to the dust particles present in the air.

Where it seems advisable or desirable to control the bacterial content of rooms, public conveyances, or buildings, highly effective methods are available (see Chapter 4), and their extended use may do much to assist the workers in this field in accumulating the necessary mass of evidence that will decide the practical value of air sterilization for the control of communicable disease. It is now well established that ultra-violet radiation is feasible for the protection or preservation of pharmaceuticals, cosmetics, and food products.

RADIOACTIVE AIR CONTAMINANTS

Radioactive air contaminants are physically similar to ordinary industrial and chemical plant contaminants. They differ from ordinary contaminants, however, in that they may be highly toxic when ingested and may present a direct radiation hazard when accumulated in appreciable quantities. Another factor which must be considered in the filtration of these materials is the possibility of their being concentrated in plant and animal life in the area of contamination. Concentrations resulting from absorption by plants and subsequent feeding of animals in the magnitude of several thousand times, is not unusual. Tolerances for radioactive contaminants have been established and are under continuing study and review. Guidance in regard to tolerance levels for discharge of contaminated air in different types of localities can best be had from the classified literature which is available through proper clearance procedures.

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CHAPTER 8

AIR CONDITIONING IN THE PREVENTION AND TREATMENT OF DISEASE

Sanitary Ventilation, Control of Airborne Infection, Value of Air Cooling Under Tropical Conditions, Treatment of Disease, Operating Rooms, Nurseries for Premature Infants, Fever Therapy, Cold Therapy, Allergic Disorders, Oxygen Therapy, General Hospital Air Conditioning

THE Second World War created an increase of interest in the preventive aspects of air conditioning. It re-emphasized the importance of the control of airborne infection and demonstrated the value of air cooling under tropical conditions for the preservation of food stuffs, for protection proper rest and sleep, and in the convalescence of patients.

The problem of air conditioning or air purification in shelters, hospitals and other occupied buildings, to reduce the hazard from radioactive particles following an atomic explosion, merits the most careful consideration. Shelters should be without windows, underground, strong enough to resist blast and have sufficient cover to protect against initial radiation. They should be closed to outdoor air in the period immediately following a blast but may eventually have to be provided with ventilation from outdoors to limit the increase of temperature, moisture or odor, resulting from the occupancy, or in extreme cases to avoid serious oxygen deficiency and increase of carbon dioxide. When air must be drawn from outdoors and power is available, a mechanical ventilation system can be used. This will make it possible to pressurize the shelter, to utilize special filtration apparatus and to control the entry of outdoor air at will.

A surface or subsurface burst of an atomic bomb will result in a wide dispersion of airborne radioactive particles.[1] Windows of buildings within a three-mile radius from the point of detonation of a 20 KT bomb will be broken, and consequently, no appreciable protection will be afforded by the use of conventional air-conditioning systems under these conditions. Beyond the three-mile radius many structures may be found with windows undamaged and otherwise capable of providing some degree of protection from airborne radioactive particles by the utilization of an air-conditioning system. However, conventional air-conditioning systems should not be relied upon for protection in urban structures which may be utilized in the accomplishment of specific missions following an atomic detonation. There are special techniques and devices available which will provide this protection.

The many incidents in Denver, Pa., in 1942 focused the attention of health authorities and engineers on the problem of air contamination by the gaseous wastes discharged into the air above cities. The U. S. Public Health Service investigating the incident[2] found that in this city several previous instances of lesser severity had occurred during the preceding 30 years as indicated by an increase of mortality rates during certain periods. A high percentage of the population suffered to some extent during the 1948 smog. Older individuals particularly were seriously affected with cardio-respiratory symptoms.

The exact way in which the contaminants due to gaseous wastes affect the human being is unknown.[3] It is believed that the combination of contaminants rather, than any single substance produces the toxic effects. The medical profession has much to learn about the effects of contaminants on human beings as a basis for determining when precise controls are needed."

SANITARY VENTILATION

During the last 20 years great popular interest has been aroused in the spread of respiratory infection indoors, and in its control by ventilation or its sanitary equivalents, air disinfection. In Europe three important documents have appeared in English, Swedish, and French literature.[4, 5, 6] In the United States where the study began, the vast literature has been consolidated, and definitions, formulations, and features of sanitary ventilation codified in a volume now being edited for publication.

The Council of Physical Medicine of the American Medical Association approved the radiant disinfection of air in 1942, and two sub-committees of the Committee on Research and Standards of the American Public Health Association have reported favorably upon the control of airborne infection by sanitary ventilation and on air sanitation respectively.[7, 8, 9, 10] The ASHAE Technical Advisory Committee on Air Sterilization from 1944 to 1948 reported progress in The ASHAE Journal, and recommended a set of definitions, formulations and factors for joint adoption by the American Public Health Association and the Society. The following sections on Control of Airborne Infection gives somewhat of the gists of the subject.

CONTROL OF AIRBORNE INFECTION

The majority of airborne diseases are spread indoors where people gather. Any program of air sanitation is influenced by a number of factors. In the winter months, the closing of doors, windows, and other means of access to the outdoor air to conserve warmth, as well as the crowding of persons indoors, provides conditions conducive to a high incidence of contagion. This seasonal phenomenon, illustrated in Fig. 1 which represents a study made by the U. S. Public Health Service, will capture the ventilating engineer insofar as air quality (determined by temperature, humidity, air replacement, type of air movement, and freedom from contamination) is a major intrinsic factor. Apart from the

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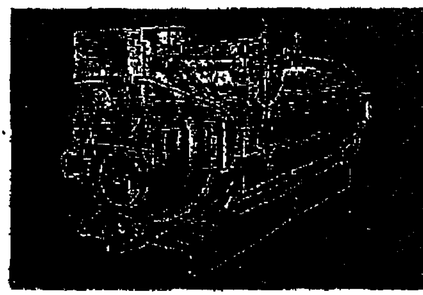

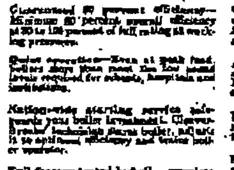

15 sizes; 150 models—oil, gas or combination oil-gas firing. Model CB boiler (shown) incorporates control panel and other controls on front for convenience; available in sizes 15-500 hp, 15-250 psi. Model LE (not shown) is available in sizes 100-600 hp, 15-250 psi.

Cleaver-Brooks BOILERS—Steam or hot water, for heating and processing. 15 to 600 hp. 15 to 250 psi. Oil, gas and combination oil & gas fired models

COMPLETE SELF-CONTAINED STANDARD SIZES									
HP	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Steam Capacity—lb. [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
HP	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Rated Capacity—[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

CLEAVER-BROOKS BOILER ADVANTAGES

Guaranteed 80 percent efficiency—Minimum 80 percent overall efficiency at 20 to 100 percent of full rating at working pressures.

Quiet operation—Even at peak load, boilers stay [illegible] meet the low sound levels required for schools, hospitals and institutions.

Nation-wide starting service safeguards your boiler investment. Cleaver-Brooks technician starts boiler, adjusts it to optimum efficiency and trains boiler operator.

Full factory tested including complete check of control system on every boiler. Your boiler is priced ready for efficient performance on arrival at your plant.

No costly chimney—Combustion gases are carried off through a small vent, eliminating high-cost chimneys.

One complete package—A complete unit from a single source—one responsibility. Ready for operation and service connections on arrival.

Compact—Maximum steam generating capacity in limited space. Requires little floor space . . . fits easily into low head room.

Automatic, safe operation—Controls centralized and conveniently located. Modern electronic combustion controls are standard equipment.

Fast, easy maintenance—Front and rear doors are hinged or davited for fast inspection, cleaning and servicing.

Fuel flexibility—Burns heavy or light oil, gas or combination oil/gas—simple, quick changeover.

Clean—Oil or gas firing keeps boiler room and plant clean, eliminates the problem of ash removal.

Totally enclosed control panel—Control panel conveniently located, contains burner switch, relays, blower motor starter and control switches. Wiring is in conformity with the National Electric Code.

Fast installation—No special foundation needed; existing concrete floors will suffice.

Complete unit approval—Labeled by Underwriters' Laboratories and Canadian Standard Association. Conforms to ASME code; factory tested before shipment.

Write for free descriptive literature and specifications. Or consult the Cleaver-Brooks representative listed in your classified telephone book under "BOILERS—MANUFACTURERS & DISTRIBUTORS"

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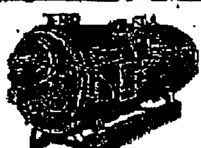


Cleaver-Brooks
Progress
Packaged Heating Boiler

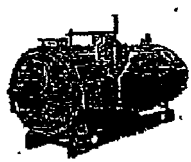
For commercial heating applications: apartment buildings, hotels, hospitals, stores, commercial and public buildings. Seven sizes up to [illegible] Btu output. Steam or hot water, gas or oil fired or combination oil/gas fired.

MONITOR BOILER				
MODEL	BOILER H.P.	CAPACITY Lb. Steam/hr	GROSS Btu	HEATING SURFACE sq ft
M-15	15	520	500	75
M-20	20	690	670	100
M-25	25	860	835	125
M-30	30	1035	1000	150
M-40	40	1380	1340	200
M-50	50	1725	1670	250
M-60	60	2070	2010	300

PROGRESS BOILER			
MODEL	GROSS Btu	EDR Steam (Sq Ft)	EDR Water (Sq Ft)
P-15	605,000	[illegible]	[illegible]
P-20	670,000	2790	4480
P-25	835,000	3480	5570
P-30	1,000,000	4170	6700
P-40	1,340,000	[illegible]	8930
P-50	1,670,000	[illegible]	11,150
P-60	2,010,000	8370	13,400

Cleaver-Brooks
Monitor
Packaged Boiler

Low-cost dry steam for dairies, laundries, dry cleaners, creameries, food processing and industrial applications. Seven sizes . . . 15-60 hp . . . 150 psi. Available in oil, gas or combination oil/gas models with quick fuel changeover.



Cleaver-Brooks Progress and Monitor Boiler Advantages:

- A complete package—From one company, one source. Factory-assembled, tested and shipped as a fully self-contained unit—ready for installation, and requiring only service connections.
- Four-pass, forced-draft design is an efficient combination to transmit a greater percentage of heat to boiler water.
- Field starting service—final check and adjustment by authorized service representative after installation, plus operator training—at no extra cost.
- Quiet-running blower supplies combustion air—eliminates need for expensive chimney.
- Electronic combustion-safety controls assure safe shut-down. Electric ignition assures smooth, noiseless light-off of main flame.

For complete details write direct or contact your Cleaver-Brooks representative listed under "BOILERS—MANUFACTURERS & DISTRIBUTORS" in your classified phone book.