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	1.8	8.4	....	
Butyl acetate	1.4	15.0	84	III
Butyl alcohol	1.7	....	....	
Butylene	2.0	9.7	....	
Carbon disulfide	1.2	50	−22	I
Carbon monoxide	12.5	74.2	....	
Crotonaldehyde	2.1	15.5	55	II
Cyclohexane	1.3	8.4	1	I
Cyclopropane	2.4	10.5	....	
Decane	0.67	2.6	115	III
Dichloroethylene (1, 2)	9.7	12.8	57	II
Diethyl selenide	3.5	....	....	
Dioxane	2.0	22.2	54	II
Ethane	3.1	12.5	....	
Ether (diethyl)	1.8	36.5	−49	I
Ethyl acetate	2.2	11.5	28	II
Ethyl alcohol	3.3	19.0	54	II
Ethyl bromide	6.7	11.3	....	
Ethyl cellosolve	2.6	15.7	104	III
Ethyl chloride	4.0	14.8	−58	I
Ethylene	2.7	28.6	....	
Ethylene dichloride	6.2	15.9	56	II
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	II
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	33.0	....	
Isobutyl alcohol	1.7	....	82	III
Isopentane	1.3	....	....	
Isopropyl acetate	1.8	7.8	43	II
Isopropyl alcohol	2.0	....	53	II
Methane	5.0	15.0	....	
Methyl acetate	3.1	15.5	14	I
Methyl alcohol	6.7	36.5	52	II
Methyl bromide	13.5	14.5	....	
Methyl butyl ketone	1.2	8.0	....	
Methyl chloride	8.2	18.7	....	
Methyl cyclohexane	1.1	....	25	II
Methyl ethyl ether	2.0	10.1	−35	I
Methyl ethyl ketone	1.8	9.5	30	II
Methyl formate	5.0	22.7	−2	I
Methyl propyl ketone	1.5	8.2	....	
Natural gas (variable)	4.3	13.5	....	
Naphtha (benzene)	1.1	6.0	20–110	III

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	....	176	III
Nonane	0.83	2.9	88	III
Octane	0.95	3.2	56	II
Paraldehyde	1.3	....	....	
Pentane	1.4	7.8	....	
Propane	2.1	10.1	....	
Propyl acetate	1.8	8.0	58	II
Propyl alcohol	2.1	13.5	59	II
Propylene	2.0	11.1	....	
Propylene dichloride	3.4	14.5	60	II
Propylene oxide	2.0	22.0	....	
Pyridine	1.8	12.4	74	III
Toluene (toluol)	1.3	7.0	40	II
Turpentine	0.8	....	95	III
Vinyl ether	1.7	27.0	....	
Vinyl chloride	4.0	21.7	....	
Water gas (variable)	6.0	70	....	
Xylene (xylol)	1.0	6.0	63	II

[a] Adapted from: *Fire and Explosion Hazards of Combustible Gases and Vapors*, by G. W. Jones; Chapter 13, *Industrial Hygiene and Toxicology*, edited by F. A. Patty (Interscience Publishers, 1948); *Properties of Flammable Liquids, Gases and Solids* (Associated) Factory Mutual Fire Ins. Cos., January (1940); and *National Fire Codes for Flammable Liquids, Gases, Chemicals and Explosives*—1945 (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 1934).

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 3 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 52.)

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.[14]

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 0.5 oz per cubic foot.[15–21]

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 8, 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.[22, 23, 24] Geographical distribution of plants known to produce hay fever is also recorded.[25, 26]

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,[25, 27, 28] 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, or 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.[25, 28, 29]

AIRBORNE BACTERIA

Study of the occurrence and significance of micro-organisms in the atmospheres 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.[30] 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 8), 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[32]

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 absorptions 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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