Table 8 .... Limits for Toxic Dusts, Fumes, and Mists

Substance	ASA Standards MAC, g/cu m[a]	Threshold Limit Values, ACGIH 1959 g/cu m[a]
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
ANTU (alpha naphthyl thiourea)		0.0003
Arsenic		0.0005
Barium (soluble compounds)		0.0005
(x) Beryllium		0.000002
Cadmium oxide fume		0.0001
Calcium arsenate		0.0001
Chlordane (1,2,4,5,6,7,8,8-octachloro-3a,4,7,7a-tetrahydro-4,7-methanoindane)		0.002
Chlorinated camphene (60%)		0.0005
Chlorinated diphenyl oxide		0.0005
Chlorodiphenyl (42% chlorine)		0.001
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
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
Dinitrobenzene		0.001
Dinitrotoluene		0.0015
Dinitro-o-cresol		0.0002
EPN (O-ethyl O-p-nitrophenyl thionobenzenephosphonate)		0.0005
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
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
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
Pyrethum		0.002
Rotenone		0.005
Selenium compounds (as Se)		0.0001
Sodium fluoroacetate (1080)		0.0001
Sodium hydroxide		0.002
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
Thiram (tetramethyl thiuram disulfide)		0.005
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
Warfarin (3-[α acetonylbenzyl]-4-hydroxycoumarin)		0.0005
Zinc oxide fumes		0.015
Zirconium compounds (as Zr)		0.005

[a] Grams of dust, fume, or mist per cubic meter of air.

(x) These values added to the list in 1959.

Radioactivity: 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, March, 1953. In addition, see *Permissible Dose from External Sources of Ionizing Radiation*, Handbook 59, U. S. Department of Commerce, National Bureau of Standards, September 24, 1954.

Table 8 values reprinted by permission of the ACGIH Committee on Threshold Limits.

and the flash points of the corresponding liquids are given in Table 9.

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.[44, 45]

Design of equipment for the control of combustible anesthetics is outlined in Chapter 8. Construction of equipment for handling air containing flammable substances, or operating in atmospheres so contaminated, is discussed in Chapter 52, Industrial Exhaust Systems.

It is customary to report the concentrations of flammable 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,

Table 9 .... 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	2.5	....	....	
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
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 1954).

or in other words, cubic feet of contaminant per million cubic feet of air). It will be noted in Table 9 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 6 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 po-