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

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
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	100	0.420
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) Tetrahydrofuran		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 (chloroethylene)		500	1.30
Xylene (xylol)		200	0.870

tion which may be associated with severe and irreversible injury.

5. 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 ⅓ 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 6.

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.[12, 13]

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.

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[a]	Threshold Limit Values, ACGIH 1958 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
(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
Pyrethum		0.002
(x) Rotenone		0.005

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

Substance	ASA Standards MAC, g/cu m[a]	Threshold Limit Values, ACGIH 1958 g/cu m[a]
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)		0.0005
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 appeared on the ACGIH tentative list, for 1956.

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.

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Table 5 .... Limits for Mineral Dusts

Substance	Threshold Limit Values ACGIH 1958 mppcf[a]
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

[a] mppcf—million particles per cubic foot of air, standard light field count.

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