OCCUPATIONAL HEALTH BULLETIN

NORTH CAROLINA STATE BOARD OF HEALTH*

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Raleigh

THRESHOLD LIMIT VALUES FOR 1963

CONSULT LOCAL HEALTH DEPARTMENTS AND PHYSICIANS

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CONTROL HEALTH HAZARDS TO EMPLOYEES AT WORK

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PREVENT INDUSTRIAL DISEASES

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The Occupational Health Section
(SEE INSIDE COVER)

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THRESHOLD LIMIT VALUES FOR 1963

Adopted at the 25th Annual Meeting of the American Conference of Governmental Industrial Hygienists

Cincinnati, Ohio May 6,7, 1963

Threshold limits should be used as guides in the control of health hazards and should not be regarded as fine lines between safe and dangerous concentrations. They represent conditions under which it is believed that nearly all workers may be repeatedly exposed, day after day, without adverse effect. The values listed refer to time-weighted average concentrations for a normal workday. The amount by which these figures may be exceeded for short periods without injury to health depends upon a number of factors such as the nature of the contaminant, whether very high concentrations even for short periods produce acute poisoning, whether the effects are cumulative, the frequency with which high concentrations occur, and the duration of such periods. All must be taken into consideration in arriving at a decision as to whether a hazardous situation exists. Because it has been recognized that the threshold limits of certain acutely-acting substances may not provide a safety factor comparable to that of chronically-acting substances for which a time-weighted average applies, a "C" designation or "ceiling" has been affixed to such values indicating that the Threshold Limit Value should not be exceeded. The bases for the "C" listing is given in appendix C.

Special consideration should be given to the application of these values in assessing the health hazards which may be associated with exposure to combinations of two or more substances. A brief discussion of basic considerations involved in developing threshold limit values for mixtures, and methods for their development, amplified by specific examples are given in appendix B.

Threshold limits are based on the best available information from industrial experience, from experimental studies, and when possible, from a combination of the two.* These values are based on various criteria of toxic effects or on marked discomfort; thus, they should not be used as a common denominator of toxicity, nor should they be considered as the sole criterion in proving or disproving diagnosis of suspected occupational disease.

These limits are intended for use in the field of industrial hygiene and should be interpreted and employed only by persons trained in this field. They are not intended for use, or for modification for use, (1) as a relative index of toxicity, by making a ratio of two limits, or (2) in the evaluation or control of community air pollution or air pollution nuisances, or (3) in estimating the toxic potential of continuous uninterrupted exposures.

These values are reviewed annually by the Committee on Threshold Limits for revisions, or additions, as further information becomes available. The Committee welcomes the suggestion of substances to be added to the list and also comments, references, or reports of experience with these materials.

*"Documentation of Threshold Limit Values" is a compilation by the Committee on Threshold Limit Values of the best available technical evidence substantiating these VALUES. It can be purchased from the Secretary-Treasurer, American Conference of Governmental Industrial Hygienists, 1014 Broadway, Cincinnati 2, Ohio, price $4.

RECOMMENDED VALUES

(In Alphabetical Order)

Substance	ppm*	Mg/M³**
Acetaldehyde	200	360
Acetic acid	10	25
Acetic anhydride	5	20
Acetone	1,000	2,400
Acetonitrile	40	70
Acetylene tetrabromide	1	14
†Acrolein	0.1	0.25
Acrylonitrile - Skin	20	45
Aldrin (1,2,3,4,10,10-hexachloro-1,4,4a,5,8,8a-hexahydro-1,4,5,8-dimethano-naphthalene) - Skin	—	0.25
†Allyl alcohol - Skin	2	5
Allyl chloride	1	3
Allyl glycidyl ether (AGE)	10	45
Allyl propyl disulfide	2	12
†Ammonia	50	35
Ammonium sulfamate (Ammate)	—	15
†Amyl acetate	100	525
Amyl alcohol (isoamyl alcohol)	100	360
Aniline - Skin	5	19
Antimony	—	0.5
ANTU (alpha naphthyl thiourea)	—	0.3
Arsenic	—	0.5
Arsine	0.05	0.2
Barium (soluble compounds)	—	0.5
Benzene (benzol) - Skin	25	80
Benzidine	—	A[1]
Benzyl chloride	1	5
Beryllium	—	0.002
Boron oxide	—	15
Boron trifluoride	1	3
Bromine	0.1	0.7
Butadiene (1,3-butadiene)	1,000	2,200
2-Butanone (methyl ethyl ketone)	200	590
2-Butoxy ethanol (Butyl Cellosolve)	50	240
Butyl acetate (n-butyl acetate)	200	950
Butyl alcohol	100	300
tert. Butyl Alcohol	100	300
Butylamine	5	15
n-Butyl glycidyl ether (BGE)	50	270
Butyl mercaptan	10	35
p-tert. Butyltoluene	10	60
Cadmium oxide fume	—	0.1
Calcium arsenate	—	1

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†1963 Revision

Note: The word "skin" following a substance indicates that the substance can penetrate the skin to contribute to the exposure and threshold limit value should be reduced accordingly.

A Numbers, See Appendix A

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Substance	ppm*	Mg/M³**
Carbon dioxide	5,000	9,000
Carbon disulfide - Skin	20	60
Carbon monoxide	100	110
Carbon tetracholride - Skin	10	65
Chlordane (1,2,4,5,6,7,8,8-octachloro-3a,4,7,7a-tetrahydro-4,7-methanoindene)	—	0.5
Chlorinated camphene, 60%	—	0.5
Chlorinated diphenyl oxide	—	0.5
Chlorine	1	3
Chlorine dioxide	0.1	0.3
Chlorine trifluoride	0.1	0.4
Chloroacetaldehyde	1	3
Chlorobenzene (monochlorobenzene)	75	350
Chlorobromomethane	200	1,050
Chlorodiphenyl (42% Chlorine) - Skin	—	1
Chlorodiphenyl (54% Chlorine) - Skin	—	0.5
Chloroform (trichloromethane)	50	240
1-Chloro-1-nitropropane	20	100
Chloropicrin	0.1	0.7
Chloroprene (2-chloro-1,3-butadiene)	25	90
Chromic acid and chromates (as CrO_3)	—	0.1
Cobalt	—	0.5
Crag (R) herbicide (sodium 2-(2,4-dichlorophenoxy) ethanol hydrogen sulfate)	—	15
Cresol (all isomers) - Skin	5	22
Cyanide (as CN) - Skin	—	5
Cyclohexane	400	1,400
Cyclohexanol	50	200
Cyclohexanone	50	200
Cyclohexene	400	1,350
2,4-D (2.4-dichlorophenoxy-acetic acid)	—	10
DDT (2,2-bis (p-chlorophenyl)-1,1,1-trichloroethane) - Skin	—	1
Decaborane - Skin	0.05	0.3
Diacetone alcohol (4-hydroxy-4-methyl-2-pentanone)	50	240.
Didorane	0.1	0.1
1,2-Dibromoethane (Ethylene dibromide)	25	190
o-Dichlorobenzene	50	300
p-Dichlorobenzene	75	450
Dichlorodifluoromethane	1,000	4,950
1,1-Dichloroethane	100	400
1,2-Dichloroethane (ethylene dichloride)	50	200
1,2-Dichloroethylene	200	790
Dichloroethyl ether	15	90
Dichloromonofluoromethane	1,000	4,200
1,1-Dichloro-1-nitroethane	10	60
Dichlorotetrafluoroethane	1,000	7,000
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) - Skin	—	0.25
Diethylamine	25	75
Difluorodibromomethane	100	860
†Diglycidyl ether (DGE)	0.5	2.8 - Corrected for 1C
Diisobutyl ketone	50	290
Dimethyl acetamide - Skin	10	35

OLI 3742

Substance	ppm*	Mg/M³**
Dimethylaniline (N-dimethylaniline) - Skin	5	25
Dimethylformamide	20	60
1,1-Dimethylhydrazine - Skin	0.5	1
Dimethylsulfate - Skin	1	5
Dinitrobenzene - Skin	—	1
Dinitrotoluene - Skin	—	1.5
Dinitro-o-cresol - Skin	—	0.2
Dioxane (diethylene dioxide)	100	360
Dipropylene glycol methyl ether	100	600
EPN (O-ethyl O-p-nitrophenyl thionobenzene-phosphonate) -Skin	—	0.5
Ethyl acetate	400	1,400
Ethyl acrylate - Skin	25	100
Ethyl alcohol (ethanol)	1,000	1,900
Ethylamine	25	45
Ethylbenzene	200	870
Ethyl bromide	200	890
Ethyl chloride	1,000	2,600
Ethyl ether	400	1,200
Ethyl formate	100	300
†Ethyl mercaptan	20	52
Ethyl silicate	100	850
Ethylene chlorohydrin - Skin	5	16
Ethylenediamine	10	30
Ethylene glycol dinitrate (Combined EGDN + NG) - Skin	0.2	1.2
Ethylene imine - Skin	5	9
Ethylene oxide	50	90
2-Ethoxyethancl (Cellosolve)	200	740
2-Ethoxyethylacetate (Cellosolve Acetate)	100	540
Ferbam (ferric dimethyl dithiocarbamate)	—	15
Ferrovanadium dust	—	1
Fluoride (as F)	—	2.5
Fluorine	0.1	0.2
Fluorotrichloromethane	1,000	5,600
Formaldehyde	5	6
Furfural	5	20
Furfuryl alcohol	50	200
Gasoline	500	2,000
Glycidol (2,3-Epoxy-1-propanol)	50	150
Heptane (n-heptane)	500	2,000
Hexane (n-hexane)	500	1,800
Hexanone (methyl butyl ketone)	100	410
†sec-Hexyl acetate	50	295
Hexone (methyl isobutyl ketone)	100	410
Hydrazine - Skin	1	1.3
Hydrogen bromide	3	10
Hydrogen chloride	5	7
Hydrogen cyanide - Skin	10	11
Hydrogen fluoride	3	2
Hydrogen peroxide, 90%	1	1.4
Hydrogen selenide	0.05	0.2
Hydrogen sulfide	20	30
Hydroquinone	—	2

†1963 Revision

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Substance	ppm*	Mg/M^{3}**
Iodine	0.1	1
Iron oxide fume	—	15
Isophorone	25	140
Isopropylamine	5	12
Isopropyl glycidyl ether (IGE)	50	240
Ketene	0.5	0.9
Lead	—	0.2
Lead arsenate	—	0.15
Lindane (hexachlorocyclohexane, gamma isomer)	—	0.5
Lithium hydride	—	0.025
Magnesium oxide fume	—	15
Malathion (o,o-dimethyl dithiophosphate of diethyl mercaptosuccinate) - Skin	—	15
Manganese	—	5
Mercury - Skin	—	0.1
Mercury (organic compounds) - Skin	—	0.01
Mesityl oxide	25	100
Methoxychlor (2,2-di-p-methoxyphenyl-1,1,1-trichloroethane)	—	15
Methyl acetate	200	610
Methyl acetylene	1,000	1,650
Methyl acrylate - Skin	10	35
Methylal (dimethoxymethane)	1,000	3,100
Methyl alcohol (methanol)	200	260
Methyl bromide - Skin	20	80
Methyl cellosolve (2-methoxyethanol) - Skin	25	80
Methyl cellosolve acetate (ethylene glycol monomethyl ether acetate)	25	120
Methyl chloride	100	210
†Methyl chloroform (1,1,1-trichloroethane)	350	1,900
Methylcyclohexane	500	2,000
Methylcyclohexanol	100	470
Methylcyclohexanone	100	460
Methyl formate	100	250
Methyl isobutyl carbinol (methyl amyl alcohol)	25	100
†Methyl mercaptan	20	40
a Methyl styrene	100	480
Methylene chloride (dichloromethane)	500	1,750
Monomethyl aniline - Skin	2	9
Molybdenum (soluble compounds)	—	5
(insoluble compounds)	—	15
Naphtha (coal tar)	200	800
Naphtha (petroleum)	500	2,000
B-Naphthylamine	—	A[2]
Nickel carbonyl	0.001	0.007
Nicotine - Skin	—	0.5
Nitric acid	10	25
p-Nitroaniline - Skin	1	6
Nitrobenzene - Skin	1	5
Nitroethane	100	310
Nitrogen dioxide	5	9
Nitroglycerin (combined EGDN + NG) - Skin	0.2	2
Nitromethane	100	250

†1963 Revision

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Substance	ppm*	Mg/M³**
1-Nitropropane	25	90
2-Nitropropane	25	90
N-Nitrosodimethylamine (Dimethylnitrosamine) - Skin	A[3]	—
Nitrotoluene - Skin	5	30
Octane	500	2,350
Osmium tetroxide	—	0.002
Ozone	0.1	0.2
Parathion (O,O,diethyl-O-p-nitrophenyl thiophosphate) - Skin	—	0.1
Pentaborane	0.005	0.01
Pentachloronaphthalene - Skin	—	0.5
Pentachlorophenol - Skin	—	0.5
Pentanone (methyl propyl ketone)	200	700
Pentane	1,000	2,950
Perchloroethylene (tetrachloroethylene)	100	670
Perchloromethyl mercaptan	0.1	0.8
Perchloryl fluoride	3	13.5
Phenol - Skin	5	19
Phenyl glycidyl ether (PGE)	50	310
Phenylhydrazine - Skin	5	22
Phosdrin (2-carbomethoxy-1-methyl vinyl dimethyl phosphate)	—	0.1
Phosgene (carbonyl chloride)	1	4
† Phosphine	0.3	0.4
Phosphoric acid	—	1
Phosphorus (yellow)	—	0.1
Phosphorus pentachloride	—	1
Phosphorus pentasulfide	—	1
Phosphorus trichloride	0.5	3
Picric acid - Skin	—	0.1
Platinum (Soluble Salts)	—	0.002
Propyl acetate	200	840
Propyl alcohol (isopropyl alcohol)	400	980
Propyl ether (isopropyl ether)	500	2,100
n-Propyl nitrate	25	110
Propylene dichloride (1,2-dichloropropane)	75	350
Propylene imine - Skin	25	60
Propylene oxide	100	240
Pyrethrum	—	5
Pyridine	5	15
Quinone	0.1	0.4
Rotenone (commercial)	—	5
Selenium compounds (as Se)	—	0.1
Sodium fluoroacetate (1080) - Skin	—	0.05
Sodium hydroxide	—	2
Stibine	0.1	0.5
Stoddard solvent	500	2,900
Strychnine	—	0.15
Styrene monomer (phenylethylene)	100	420
Sulfur dioxide	5	13
Sulfur hexafluoride	1,000	6,000
Sulfuric acid	—	1
Sulfur monochloride	1	6
Sulfur pentafluoride	0.025	0.25

† 1963 Revision

OLI 3745

Substance	ppm*	Mg/M^3**
Sulfuryl fluoride	5	20
2,4,5T (2,4,5-Trichlorophenoxyacetic acid)	—	10
TEDP (tetraethyl dethionopyrophosphate) - Skin	—	0.2
Teflon (R) decomposition products	—	A4
TEPP (tetraethyl pyrophosphate) - Skin	—	0.05
Tellurium	—	0.1
1,1,2,2-Tetrachloroethane - Skin	5	35
Tetrahydrofuran	200	590
Tetranitromethane	1	8
Tetryl (2,4,6-trinitrophenylmethylnitramine) - Skin	—	1.5
Thallium (soluble compounds) - Skin	—	0.1
Thiram (tetramethyl thiuram disulfide)	—	5
Titanium dioxide	—	15
Toluene (toluol)	200	750
o-Toluidine - Skin	5	22
Tolylene-2,4-diisocyanate	0.02	0.14
Trichloroethylene	100	520
Trichloronaphthalene - Skin	—	5
1,2,3-Trichloropropane	50	300
1,1,2-Trichloro 1,2,2-trifluoroethane	1,000	7,600
Triethylamine	25	100
Trifluoromonobromomethane	1,000	6,100
Trinitrotoluene - Skin	—	1.5
Triorthocresyl phosphate	—	0.1
Triphenyl phosphate	—	3
Turpentine	100	560
Uranium (soluble compounds)	—	0.05
(insoluble compounds)	—	0.25
Vanadium C(V_2O_5 dust)	—	0.5
(V_2O_5 fume)	—	0.1
Vinyl chloride (chloroethylene)	500	1,300
Vinyl toulene	100	480
Warfarin(3 (a acetonylbenzyl) -4-hydroxycoumarin)	—	0.1
Yttrium	—	5
Xylene (xylol)	200	870
Xylidene - Skin	5	25
Zinc oxide fume	—	5
Zirconium compounds (as Zr)	—	5

Radioactivity: For permissible concentrations of radio-isotopes in air, see U.S. Department of Commerce, National Bureau of Standards, Handbook 69, "Maximum Permissible Body Burdens and Maximum Permissible Concentrations of Radionuclides in Air and in Water for Occupational Exposure," June 5, 1959. Also, see U. S. Department of Commerce, National Bureau of Standards, Handbook 59, "Permissible Dose from External Sources of Ionizing Radiation," September 24, 1954, and addendum of April 15, 1958.

Note: The word "Skin" following a substance indicates that the substance can penetrate the skin to contribute to the exposure and threshold limit value should be reduced accordingly.

Parts of vapor or gas per million parts of air by volume at 25°C and 760 mm. Hg pressure.

**Approximate milligrams of particulate per cubic meter of air.

A Numbers, See Appendix A

OLI 3746

MINERAL DUSTS

Substance	m.p.p.c.f.§
SILICA	
Crystalline	$\frac{250}{\%SiO_2 + 5}$
Quartz, Threshold Limit calculated from the formula=	
Cristobalite " " "	
Amorphous, including natural diatomaceous earth	20
SILICATES (less than 1% crystalline silica)	
Asbestos	5
Mica	20
Soapstone	20
Talc	20
Portland Cement	50
Miscellaneous (less than 1% crystalling silica)	50

Conversion factors:

mppcf x 35.3 = million particles per cubic meter
= particles per c.c.

§ Millions of particles per cubic foot of air, based on impinger samples counted by light-field technics.

= The percentage of crystalline silica in the formula is the amount determined from air-borne samples, except in those instances in which other methods have been shown to be applicable.

**SEE TENTATIVE VALUES ON FOLLOWING PAGE.

TENTATIVE VALUES

Substance	ppm+	Mg/M^{3}++
tert. butyl chromate (as CrO_3) - Skin	—	0.1
*Calcium oxide	—	5
Camphor	—	2
*Copper Fume	—	0.1
Dusts & Mists	—	1.0
DDVP (0,0-Dimethyl-2,2-dichlorovinyl phosphate)	—	1
*Demeton (R) (Systox)	—	0.1
Endrin (1,2,3,4,10,10-hexachloro-6,7-epoxy-1,4,4a, 5,6,7,8,8a-octa hydro 1,4-endo-5,8-dimethano-naphthalene) - Skin	—	0.1
Epichlorhydrin	5	19
Ethanolamine	3	6
*Graphite	—	15 mppcf
*Hafnium	—	0.5
Heptachlor (1,4,5,6,7,8,8a-heptachloro-3a,4,7,7a-tetrahydro-4,7-methanoindene)	—	0.5
*Methylamine	25	31
*Methyl Methacrylate	100	410
*Methylene bis phenylisocyanate	0.02	0.2
*Mineral Wool (Fiberglas)	—	2
*Naphthalene	10	50
Oil (mineral)	—	5
*B-Propiolactone	—	A5
*Silver	—	0.05
*Tantalum	—	5
*1,1,1,2,-Tetrachloro-2,2-difluoroethane	1000	8340
*1,1,2,2-Tetrachloro-1,2-difluoroethane	500	4170
*Tetraethyl lead - Skin	—	0.075
*Tin (inorganic compounds)	—	2
(organic compounds as Sn) - Skin	—	0.1

1963 Additions

+Parts of vapor or gas per million parts of air by volume and 25°C and 760 mm. Hg pressure

++Approximate milligrams of particulate per cubic meter of air.

A numbers, See Appendix A

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OLI 3748

APPENDIX A

A^1 Benzidine. Because of high incidence of bladder tumors in man, any exposure, including skin, is extremely hazardous.

A^2 B-Naphthylamine. Because of the extremely high incidence of bladder tumors in workers handling this compound, and the inability to control exposures, B-naphthylamine has been prohibited from manufacture, use and other activities that involve human contact by the State of Pennsylvania.

A^3 N-Nitrosodimethylamine. Because of extremely high toxicity and presumed carcinogenic potential of this compound, contact by any route should not be permitted.

A^4 Teflon (R) decomposition products. At least one identified component of Teflon decomposition products is extremely toxic, but in the absence of more complete toxicity information and suitable analytic methods, a definite threshold limit value is not recommended at this time; but air concentrations should be minimal.

A^5 B-Propiolactone. Because of high acute toxicity and demonstrated skin tumor production in animals, contact by any route should be avoided.

APPENDIX B

THRESHOLD LIMIT VALUES FOR MIXTURES

When two or more hazardous substances are present, their combined effect, rather than that of either individually, should be given primary consideration. In the absence of information to the contrary, the effects of the different hazards should be considered as additive. That is if the sum of the following fraction,

$$\frac{C^1}{T_1} + \frac{C^2}{T_2} + \cdots \frac{Cn}{Tn}$$

exceeds unity, than the threshold limit of the mixture should be considered as being exceeded. C indicates the observed atmospheric concentration, and T_1 the corresponding threshold limit, (See Example 1A.a).

Exceptions to the above rule may be made when there is good reason to believe that the chief effects of the different harmful substances are not in fact additive, but indipendent as when purely local effects on differenct organs of the body are produced by the various components of the mixture. In such cases the threshold limit ordinarily is exceeded only when at least one member of the series ($\frac{C_1}{T_1}$ or $\frac{C_2}{T_2}$ etc.) itself has a value exceeding unity, (See Example 1A.b.).

Antagonistic action or potentiation may occur with some combinations of atmospheric contaminants. Such cases at present must be determined individually. Potentiating or antagonistic agents are not necessarily harmful by themselves. Potentiating effects of exposure to such agents by routes other than that of inhalation is also possible, e.g. imbibed alcohol and inhaled narcotoc (trichlorethylene). Potentiation is characteristically exhibited at high concentrations, less probably at low.

When a given operation or process characteristically emits a number of harmful dusts, fumes, vapors or gasses, it will frequently be only feasible to attempt to evaluate the hazard by measurement of a single substance. In such cases, the threshold limit used for this substance should be reduced by a suitable factor, the magnitude of which will depend on the number, toxicity and relative quantity of the other contaminants ordinarily present.

Examples of processes which are typically associated with two or more harmful atmospheric contaminants are welding, automobile repair, blasting, painting, lacquering, certain foundry operation, diesel exhausts. etc. (Example 2.)

OLI 3750

THRESHOLD LIMIT VALUES FOR
MIXTURES

EXAMPLES

1A. General case, where air is analyzed for each component.

a. Additive Effects

$$\frac{C_1}{T_1} + \frac{C_2}{T_2} + \frac{C_3}{T_3} + \cdots \frac{C_n}{T_n} = 1$$

Air contains 5 ppm of carbon tetrachloride (TLV, 10), 20 ppm of ethylene dichloride (TLV,50) and 10ppm of ethylene dibromide, (TLV,25).

$$\frac{5}{10} + \frac{20}{50} + \frac{10}{25} = \frac{65}{50} = 1.3$$

Threshold limit is exceeded.

b. Independent Effects

Air contains 0.15 mg/m^3 of lead (TLV,0.2) and 0.7 mg/m^3 of sulfuric acid (TLV,1).

$$\frac{0.15}{0.20} = 0.75; \quad \frac{0.7}{1} = 0.7$$

Threshold limit is not exceeded.

1B. Special case when source of contaminant is a mixture and atmospheric composition is assumed similar to that of original material, i.e. vapor pressure of each component is the same at the observed temperature.

a. Additive Effects, approximate solution.
1. A mixture of equal parts (1) trichloroethylene (TLV, 100), and (2) methyl chloroform (TLV, 350).

$$\frac{C_1}{100} + \frac{C_2}{350} = \frac{C_m}{T_m}$$

Solution applicable to "spot" solvent mixture usage, where all or nearly all, solvent evaporates.

$$C_1 = C_2 = \frac{1}{2} C_m$$

$$\frac{C_1}{100} + \frac{C_1}{350} = \frac{2C_1}{T_m}$$

$$\frac{7C_1}{700} + \frac{2C_1}{700} = \frac{2C_1}{T_m}$$

$$T_m = 700 \times \frac{2}{9} = 155 \text{ ppm.}$$

1B.b. General Exact Solution for Mixtures of N Components With Additive Effects and Different Vapor Pressures.

OLI 3751

(1) $\frac{C_1}{T_1} + \frac{C_2}{T_2} + \ldots + \frac{C_n}{T_n} = 1;$

(2) $C_1 + C_2 + \ldots + C_n = T;$

(2.1) $\frac{C_1}{T} + \frac{C_2}{T} + \ldots + \frac{C_n}{T} = 1.$

By the Law of Partial Pressures,

(3) $C_i = ap_i,$

And by Raoult's Law,

(4) $p_i = F_i\, p_i^{\circ}.$

Combine (3) and (4) to obtain

(5) $C_i = aF_ip_i^{\circ}.$

Combining (1), (2,1), and (5), we obtain

(6) $\frac{F_1p_1^{\circ}}{T} + \frac{F_2p_2^{\circ}}{T} + \ldots + \frac{F_np_n^{\circ}}{T} = \frac{F_1p_1^{\circ}}{T_1} + \frac{F_2p_2^{\circ}}{T_2} + \ldots + \frac{F_np_n^{\circ}}{T_n}$ and solving for T,

(6.1) $$T = \frac{F_1p_1^{\circ} + F_2p_2^{\circ} + \ldots + F_np_n^{\circ}}{\frac{F_1p_1^{\circ}}{T_1} + \frac{F_2p_2^{\circ}}{T_2} + \ldots + \frac{F_np_n^{\circ}}{T_n}}$$

$i = n$

or $\Sigma \quad F_ip_i^{\circ}$

(6.2) $$T = \frac{i = 1}{\sum_{i=1}^{i=n} \frac{F_ip_i^{\circ}}{T_i}}$$

T = Threshold limit value in ppm.
C = Vapor concentration in ppm.
p = Vapor pressure of component in solution.
p° = Vapor pressure of pure component.
F = Mol fraction of component in solution.
a = A constant of proportionality.

Subscripts 1,2 ...n relate the above quantities to components 1,2 ...n, respectively.
Subscript i refers to an arbitrary component from 1 to n.
Absence of subscript relates the quantity to the mixture.

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Solution to be applied when there is a reservoir of the solvent mixture whose composition does not change appreciably by evaporation.

Exact Arithmetic Solution of Specific Mixture

	Mol. wt.	Density	T	p^o at 25°C	Mol fraction in half-and half solution by volume
Trichloro-ethylene (1)	131.4	1.46 g/ml	100	73mm Hg	0.527
Methylchlo-roform (2)	133.42	1.33 g/ml	350	125mm Hg	0.473

$$F_1 p_1^o = (0.527)\ (73) = 38.2$$

$$F_2 p_2^o = (0.473)\ (125) = 59.2$$

$$T = \frac{38.2 + 59.2}{\frac{38.2}{100} + \frac{59.2}{350}} = \frac{(97.4)\quad(350)}{133.8 + 59.2} = \frac{(97.4)\ (350)}{193.0} = 177$$

T = 177 ppm (Note difference in T.L.V. when account is taken of vapor pressure and mol fraction in comparison with above example where such account is not taken.)

2. A mixture of one part of (1) parathion (TLV, 0.1) and two parts of (2) EPN (TLV, 0.5).

$$\frac{C_1}{0.1} + \frac{C_2}{0.5} = \frac{C_m}{T_m}; \quad C_2 = 2C_1$$

$$C_m = 3C_1$$

$$\frac{C_1}{0.1} + \frac{2C_1}{0.5} = \frac{3C_1}{T_m}$$

$$\frac{7C_1}{0.5} = \frac{3C_1}{T_m}$$

$$T_m = \frac{1.5}{7} = 0.21\ mg/m^3$$

1C. Independent Effects

1. From naphtha (TLV, 500) containing 10 mole per cent benzene (TLV, 25) the narcotic effects can be considered as approximately the same as that of benzene-free naphtha.

   The blood effects can be considered as due to the benzene alone.

For intermittent exposure, a TLV of 500 ppm may be used as long as the average concentration does not exceed $25 \times \frac{100}{10} = 250$ ppm, the TLV based on the benzene content.

2. Diesel engine exhaust contains several irritants, one of which is nitrogen dioxide. A limit of 2 ppm NO_2 has been found to correlate fairly well with the beginning of subjective (irritation) effects from such gases, although no subjective effects are experienced from NO_2 alone at 5 ppm.

APPENDIX C

BASES FOR ASSIGNING LIMITING "C" VALUES*

T.L.V. RANGE ppm* or mg/m^3	Permitted Fluctuation Factor of T.L.V. for 5, 10 or 30 min.	Examples
0 to 1	3	Boron triflucride (1 ppm) at 3 ppm if repeatedly encountered for periods of 5, 10, or 30 minutes, may lead to pneumonitis; a "C" listing recommended
1+ to 10	2	
10+ to 100	1.5	Ethyl benzene (200 ppm) at 250 ppm if repeatedly encountered for periods of 5 or 10 minutes may prove intolerably irritating to the eyes; a "C" listing recommended.
100+ to 1000	1.25	

* According to this limitation, the presently listed TLVs will or will not be candidates for a "C" (ceiling) listing. 1963 TLVs not coming within this limitation will bear a "C" before the substance name. Judgment is based on whether the excursions in concentration under the time limits stated may result in a) intolerable irritation, b) chronic or irreversible tissue change, or c) narcosis of sufficient degree to increase accident proneness or materially reduce work efficiency.