TLVs®
Threshold Limit Values for Chemical Substances in Workroom Air Adopted by ACGIH for 1973

PREFACE
CHEMICAL CONTAMINANTS

Threshold limit values refer to airborne concentrations of substances and represent conditions under which it is believed that nearly all workers may be repeatedly exposed day after day without adverse effect. Because of wide variation in individual susceptibility, however, a small percentage of workers may experience discomfort from some substances at concentrations at or below the threshold limit, a smaller percentage may be affected more seriously by aggravation of a pre-existing condition or by development of an occupational illness.

Simple tests are now available (J. Occup. Med. *9*: 537, 1967; Ann. N.Y. Acad. Sci., *151, Art. 2:* 968, 1968) that may be used to detect those individuals hypersusceptible to a variety of industrial chemicals (respiratory irritants, hemolytic chemicals, organic isocyanates, carbon disulfide). These tests *may be used to screen out by appropriate job* placement the hyperreactive worker and thus in effect improve the "[illegible]" the TLVs.

Threshold limit values refer to time-weighted concentrations for a 7 or 8-hour workday and 40-hour workweek. They should be used as guides in the control of health hazards and should not be used as fine lines between safe and dangerous concentrations. (Exceptions are the substances listed in Appendices E and F and those substances designated with a "C" or Ceiling value, Appendix D)

Time-weighted averages permit excursions above the limit provided they are compensated by equivalent excursions below the limit during the workday. In some instances it may be permissible to calculate the average concentration for a workweek rather than for a workday. The degree of permissible excursion is related to the magnitude of the threshold limit value of a particular substance as given in Appendix D. The relationship between threshold limit and permissible excursion is a rule of thumb and in certain cases may not apply. The amount by which threshold limits 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 factors must be taken into consideration in arriving at decision as to whether a hazardous condition exists.

Threshold limits are based on the best available information from industrial experience, from experimental human and animal studies, and, when possible, from a combination of the three. The basis on which the values are established may differ from substance to substance; *protection* against impairment of health may be a guiding factor for some, whereas reasonable freedom from irritation, narcosis, nuisance or other forms of stress may form the basis for others.

The amount and nature of the information available for establishing a TLV varies from substance to substance; consequently, the

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precision of the estimated TLV is also subject to variation and the latest *Documentation* should be consulted in order to assess the extent of the data available for a given substance.

The committee holds to the opinion that limits based on physical irritation should be considered no less binding than those based on physical impairment. There is increasing evidence that physical irritation may initiate, promote or accelerate physical impairment through interaction with other chemical or biologic agents.

In spite of the fact that serious injury is not believed likely as a result of exposure to the threshold limit concentrations, the best practice is to maintain concentrations of all atmospheric contaminants as low as is practical.

These limits are intended for use in the practice of industrial hygiene and should be interpreted and applied only by a person trained in this discipline. They are not intended for use, or for modification for use, (1) as a relative index of hazard or toxicity, (2) in the evaluation or air pollution nuisances, (3) in estimating the toxic potential of continuous, uninterrupted exposures, (4) as proof or disproof of an existing disease or physical condition, or (5) for adoption by countries whose working conditions differ from those in the United States of America and where substances and processes differ.

Ceiling vs Time-Weighted Average Limits. Although the time-weighted average concentration provides the most satisfactory, practical way of monitoring airborne agents for compliance with the limits, there are certain substances for which it is inappropriate. In the latter group are substances which are predominantly fast acting and whose threshold limit is more appropriately based on this particular response. Substances with this type of response are best controlled by a ceiling "C" limit that should not be exceeded. It is implicit in these definitions that the manner of sampling to determine compliance with the limits for each group must differ; a single brief sample, that is applicable to a "C" limit, is not appropriate to the time-weighted limit; here, a sufficient number of samples are needed to permit a time-weighted average concentration throughout a complete cycle of operations or throughout the work shift.

Whereas the ceiling limit places a definite boundary which concentrations should not be permitted to exceed, the time-weighted average limit requires an explicit limit to the excursions that are permissible above the listed values. The magnitude of these excursions may be pegged to the magnitude of the threshold limit by an appropriate factor shown in Appendix D. It should be noted that the same factors are used by the Committee in making a judgment whether to include or exclude a substance for a "C" listing.

"Skin" Notation. Listed substances followed by the designation "Skin" refer to the potential contribution to the overall exposure by the cutaneous route including mucuous membranes and eye, either by airborne, or more particularly, by direct contact with the substance. Vehicles can alter skin absorption. This attention-calling designation is intended to suggest appropriate measures for the prevention of cutaneous absorption so that the threshold limit is not invalidated.

Mixtures. Special consideration should be given also to the application of the TLVs in assessing the health hazards which may be associated with exposure to mixtures 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 C.

Nuisance Particulates. In contrast to fibrogenic dusts which cause scar tissue to be formed in lungs when inhaled in excessive amounts, so-called "nuisance" dusts have a long history of little adverse effect on lungs and do not produce significant organic disease or toxic effect when exposures are kept under reasonable control. The nuisance dusts have also been called (biologically) "inert" dusts, but the latter term is inappropriate to the extent that there is no dust which does not evoke some cellular response in the lung when inhaled in sufficient amount. However, the lung-tissue reaction caused by inhalation of nuisance dusts has the following characteristics: 1) The architecture of the air spaces remains intact. 2) Collagen (scar tissue) is not formed to a significant extent. 3) The tissue reaction is potentially reversible.

Excessive concentrations of nuisance dusts in the workroom air may seriously reduce visibility (iron oxide), may cause unpleasant deposits in [illegible] passages

(Portland Cement dust), or cause injury to the skin or mucous membranes by chemical or mechanical action per se or by the rigorous skin cleansing procedures necessary for their removal.

A threshold limit of 10mg/m³, or 30 mppcf, of total dust < 1% quartz is recommended for substances in these categories and for which no specific threshold limits have been assigned. This limit, for a normal workday, does not apply to brief exposures at higher concentrations. Neither does it apply to those substances which may cause physiologic impairment at lower concentrations but for which a threshold limit has not yet been adopted. Some nuisance particulates are given in Appendix E.

Simple Asphyxiants — "Inert" Gases or Vapors. A number of gases and vapors, when present in high concentrations in air, *act primarily as simple asphyxiants* without other significant physiologic effects. A TLV may not be recommended for each simple asphyxiant because the limiting factor is the available oxygen. The minimal oxygen content should be 18 percent by volume under normal atmospheric pressure (equivalent to a partial pressure, pO_2 of 135 mm Hg). Atmospheres deficient in O_2 do not provide adequate warning and most simple asphyxiants are odorless. Several simple asphyxiants present an explosion hazard. Account should be taken of this factor in limiting the concentration of the asphyxiant. Specific examples are listed in Appendix F.

Short-Term Limits (STLs). Because many industrial exposures are not continuous, 8-hour daily exposures, but are short-term, or intermittent, to which the TLVs do not necessarily apply, STLs for 5, 15, or 30 minutes for 142 substances have been put into the regulations of the Pennsylvania *Department of Health* (Chapter I, Art. 432, Revised Jan. 25, 1968). These STLs represent the maximal average atmospheric concentration of a contaminant to which a worker may be exposed for the stipulated time. The concentration represents an upper limit of exposure and assumes that there is sufficient recovery between exposures before another is initiated. The daily average exposure including that provided by the STL shall be such that the TLV shall not be exceeded.

Similar STLs for a more restricted number of substances have been recommended by the American National Standards Institute. This standard-setting body refers to these short-term limits as "peaks."

Physical Factors. It is recognized that such physical factors as heat, ultraviolet and ionising radiation, humidity, abnormal pressure (altitude) and the like may place added stress on the body so that the effects *from exposure* at a threshold limit [illegible] alter [illegible] to increase the toxic response of a substance. Although most threshold limits have built-in safety factors to guard against adverse effects to moderate deviations from normal environments, the safety factors of most substances are not of such a magnitude as to take care of gross deviations. For example, continuous work at temperatures above 90°F or overtime extending the workweek more than 25%, might be considered gross deviations. In such instances judgment must be exercised in the proper adjustments of the threshold limit values.

Biologic Limit Values (BLVs). Other means exist and may be necessary for monitoring worker exposure other than reliance on the Threshold Limit Values for industrial air, namely, the Biologic Limit Values. These values represent limiting amounts of substances (or their effects) to which the worker may be exposed without hazard to health or well-being as determined in his tissues and fluids or in his exhaled breath. The biologic measurements on which the BLVs are based can furnish two kinds of information useful in the control of worker exposure: (1) measure of the individual worker's over-all exposure; (2) measure of the worker's individual and characteristic response. Measurements of response furnish a superior estimate of the physiologic status of the worker, and may be made of (a) changes in amount of some critical biochemical constituent, (b) changes in activity of a critical enzyme, (c) changes in some physiologic function. Measurement of exposure may be made by (1) determining in blood, urine, hair, nails, in body tissues and fluids, the amount of substance to which the worker was exposed; (2) determination of the amount of the metabolite(s) of the substance in tissues and fluids; (3) determination of the amount of the substance in the exhaled breath. The biologic limits may be used as an adjunct to the TLVs for air, or in place of them. The U.S. National Institute for Occupational Safety and Health is proposing a series of these BLVs which will be issued from time to time as part of the

Criteria Documents for recommended industrial air standards.

Unlisted substances. There are a number of reasons why a substance does not appear in the Threshold Limit list; either insufficient information is available or it has not been brought to the attention of the Threshold Limits Committee from which a limit can be developed, or it is a substance that could be included in the Appendices E and F pertaining to Nuisance Particulates and Simple Asphyxiants. Substances appearing in these appendices serve as examples only; the appendices are not intended to be inclusive.

"Notice of Intent." At the beginning of each year, proposed actions of the Committee for the forthcoming year are issued in the form of a "Notice of Intended Changes." This Notice provides not only an opportunity for comment, but solicits suggestions of substances to be added to the list. The suggestions should be accompanied by substantiating evidence. The list of Intended Changes follows the Adopted Values in the TLV booklet.

Legal Status. By publication in the Federal Register (Vol. 36, No. 105, May 29, 1971) the Threshold Limit Values are now official federal standards for industrial air.

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ADOPTED VALUES
See Documentation for basis of TLVs

Substance	ppm[a]	mg/M[3][b]
Abate	—	10
*Acetaldehyde	100	180
Acetic acid	10	25
C Acetic anhydride	5	20
Acetone	1,000	2,400
Acetonitrile	40	70
2-Acetylaminofluorene — Skin	—	A[1]
Acetylene	F	—
Acetylene dichloride, see 1, 2-Dichloroethylene	—	—
Acetylene tetrabromide	1	14
Acrolein	0.1	0.25
Acrylamide — Skin	—	0.3
Acrylonitrile — Skin	20	45
Aldrin — Skin	—	0.25
Allyl alcohol — Skin	2	3
Allyl chloride	1	5
*Allyl glycidyl ether (AGE)	5	22
Allyl propyl disulfide	2	12
Alundum (Al_2O_3)	—	E
4-Aminodiphenyl — Skin	—	A[16]
2-Aminoethanol, see Ethanolamine	—	—
2-Aminopyridine	0.5	2
*Ammonia	25	18
Ammonium chloride, fume	—	10
Ammonium sulfamate (Ammate)	—	10

Capital letters refer to Appendices.
Footnotes (a thru h) see Page 31.
*1973 Addition.

Substance	ppm[a]	mg/M[3][b]
n-Amyl acetate	100	525
sec-Amyl acetate	125	650
Aniline — Skin	5	19
Anisidine (o, p-isomers) — Skin	0.1	0.5
Antimony & compounds (as Sb)	—	0.5
ANTU (alpha naphthyl thiourea)	—	0.3
Argon	F	—
Arsenic & compounds (as As)	—	0.5
Arsine	0.05	0.2
Asphalt (petroleum) fumes	—	5
Azinphos methyl — Skin	—	0.2
Barium (soluble compounds)	—	0.5
C Benzene (benzol) — Skin	25	80
Benzidine — Skin	—	A[16]
p-Benzoquinone, see Quinone	—	—
Benzoyl peroxide	—	5
Benzyl chloride	1	5
Beryllium	—	0.002
Biphenyl, see Diphenyl	—	—
*Bismuth telluride	—	10
*Bismuth telluride (Se-doped)	—	5
Boron oxide	—	10
Boron tribromide	1	10
C Boron trifluoride	1	3
Bromine	0.1	0.7
Bromine pentafluoride	0.1	0.7

Capital letters refer to Appendices.
Footnotes (a thru h) see Page 31.
*1973 Addition.

Substance	ppm[a]	mg/M[3][b]
Bromoform — Skin	0.5	5
Butadiene (1, 3-butadiene)	1,000	2,200
* Butane	500	1,200
Butanethiol, see Butyl mercaptan	—	—
2-Butanone	200	590
2-Butoxy ethanol (Butyl Cellosolve) — Skin	50	240
Butyl acetate (n-butyl acetate)	150	710
sec-Butyl acetate	200	950
tert-Butyl acetate	200	950
Butyl alcohol	100	300
sec-Butyl alcohol	150	450
tert-Butyl alcohol	100	300
C Butylamine — Skin	5	15
C tert-Butyl chromate (as CrO_3) — Skin	—	0.1
n-Butyl glycidyl ether (BGE)	50	270
Butyl mercaptan	0.5	1.5
p-tert-Butyltoluene	10	60
Cadmium (Metal dust and soluble salts)	—	0.2
**C Cadmium oxide fume (as Cd)	—	0.1
Calcium carbonate	—	E
Calcium arsenate	—	1
Calcium oxide	—	5
Camphor (Synthetic)	2	12
Carbaryl (Sevin®)	—	5
Carbon black	—	3.5

Capital letters refer to Appendices.
*1973 Addition.
**See Notice of Intended Changes.

Substance	ppm[a]	mg/M[3][b]
Carbon dioxide	5,000[f]	9,000
Carbon disulfide — Skin	20	60
Carbon monoxide	50	55
Carbon tetrachloride — Skin	10	65
Cellulose (paper fiber)	—	E
Chlordane — Skin	—	0.5
Chlorinated camphene — Skin	—	0.5
Chlorinated diphenyl oxide	—	0.5
Chlorine	1	3
Chlorine dioxide	0.1	0.3
C Chlorine trifluoride	0.1	0.4
C Chloroacetaldehyde	1	3
α-Chloroacetophenone (phenacylchloride)	0.05	0.3
Chlorobenzene (monochlorobenzene)	75	350
o-Chlorobenzylidene malononitrile (OCBM) — Skin	0.05	0.4
Chlorobromomethane	200	1,050
2-Chloro-1, 3-butadiene see Chloroprene	—	—
Chlorodiphenyl (42% Chlorine)		
Chlorodiphenyl (54% Chlorine) — Skin	—	0.5
1-Chloro, 2, 3- epoxy-propane, see Epichlorhydrin	—	—
2-Chloroethanol, see Ethylene chlorohydrin	—	—

Capital letters refer to Appendices.
[f]See 1973 Revised Documentation.

Substance	ppm[a]	mg/M[3][b]
Chloroethylene, see Vinyl chloride	—	—
** Chloroform (Trichloromethane)	(50)	(240)
1-Chloro-1-nitropropane	20	100
Chloropicrin	0.1	0.7
Chloroprene (2-chloro-1, 3-butadiene) — Skin	25	90
Chromic acid and chromates (as CrO_3)	—	0.1
Chromium, sol. chromic, chromous salts as Cr	—	0.5
** Metal & insol. salts	A[10]	(1.0)
Coal tar pitch volatiles (benzene soluble fraction) anthracene, BaP, phenanthrene, acridine, chrysene, pyrene)	A[10]	0.2
Cobalt, metal fume & dust	—	0.1
** Copper fume	—	(1)
Dusts and Mists	—	1
Corundum (Al_2O_3)	—	E
** Cotton Dust (raw)	—	(1)
Crag® herbicide	—	10
Cresol (all isomers) — Skin	5	22
Crotonaldehyde	2	6
Cumene — Skin	50	245
Cyanide (as CN) — Skin	—	5
Cyanogen	10	—
Cyclohexane	300	1,050
Cyclohexanol	50	200
Cyclohexanone	50	200
Cyclohexene	300	1,015

Capital letters refer to Appendices.
**See Notice of Intended Changes.

Substance	ppm[a]	mg/M[3][b]
Cyclopentadiene	75	200
2, 4-D	—	10
DDT	—	1
DDVP, see Dichlorvos	—	—
Decaborane — Skin	0.05	0.3
Dexon® — Skin	0.01	0.1
Diacetone alcohol (4-hydroxy-4-methyl-2-pentanone)	50	240
1, 2-Diaminoethane, see Ethylenediamine	—	—
Diazinon — Skin	—	0.1
Diazomethane	0.2	0.4
Diborane	0.1	0.1
* 1, 2-Dibromoethane (ethylene dibromide) — Skin	20	145
Dibrom®:	—	3
2-N Dibutylaminoethanol — Skin	2	14
Dibutyl phosphate	1	5
Dibutylphthalate	—	5
C Dichloroacetylene	0.1	0.4
C o-Dichlorobenzene	50	300
p-Dichlorobenzene	75	450
Dichlorobenzidine — Skin	—	A[10]
Dichlorodifluoromethane	1,000	4,950
1, 3-Dichloro-5, 5-dimethyl hydantoin	—	0.2
* 1, 1-Dichloroethane	200	320
1, 2-Dichloroethane	50	200
1, 2-Dichloroethylene	200	790
* Dichloroethyl ether — Skin	5	30
Dichloromethane, see Methylene chloride	—	—
Dichloromonofluoromethane	1,000	4,200
C 1, 1-Dichloro-1-nitroethane	10	60
1, 2-Dichloropropane, see Propylenedichloride	—	—
Dichlorotetrafluoroethane	1,000	7,000
Dichlorvos (DDVP) — Skin	0.1	1
Dieldrin — Skin	—	0.25
Diethylamine	25	75
Diethylamino ethanol — Skin	10	50
Diethylene triamine — Skin	1	4
Diethylether, see Ethyl ether	—	—
Difluorodibromomethane	100	860
C Diglycidyl ether (DGE)	0.5	2.8
Dihydroxybenzene, see Hydroquinone	—	—
* Diisobutyl ketone	25	150
Diisopropylamine — Skin	5	20
Dimethoxymethane, see Methylal	—	—
Dimethyl acetamide — Skin	10	35
Dimethylamine	10	18
4-Dimethylaminoazobenzene	—	A[9]
Dimethylaminobenzene, see Xylidene	—	—
Dimethylaniline (N-dimethylaniline) — Skin	5	25
Dimethylbenzene, see Xylene	—	—
Dimethyl 1, 2-dibromo-2-dichloroethyl phosphate, see DiBrom	—	—
Dimethylformamide — Skin	10	30
2, 6-Dimethylheptanone, see Diisobutyl ketone	—	—
1, 1-Dimethylhydrazine — Skin	0.5	1
Dimethylphthalate	—	5
** Dimethylsulfate — Skin	(1)	(5)
Dinitrobenzene (all isomers) — Skin	0.15	1
Dinitro-o-cresol — Skin	—	0.2
Dinitrotoluene — Skin	—	1.5
** Dioxane (Diethylene dioxide) — Skin	(100)	(360)
Diphenyl	0.2	1
Diphenyl amine	—	10
Diphenylmethane diisocyanate (see Methylene bisphenyl isocyanate (MDI)	—	—
Dipropylene glycol methyl ether — Skin	100	600
Diquat	—	0.5

Capital letters refer to Appendices.
*1973 Addition.
Footnotes (a thru b) are Page 31.

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Substance	ppm[a]	mg/M[3][b]
Di-sec. octyl phthalate (Di-2-ethylhexyl-phthalate)	—	5
Emery	—	E
Endosulfan (Thiodan®) — Skin	—	0.1
Endrin — Skin	—	0.1
Epichlorhydrin — Skin	5	19
EPN — Skin	—	0.5
1, 2-Epoxypropane, see Propyleneoxide	—	—
2, 3-Epoxy-1-propanol, see Glycidol	—	—
Ethane	F	—
Ethanethiol, see Ethylmercaptan	—	—
Ethanolamine	3	6
* 2-Ethoxyethanol — Skin	100	370
2-Ethoxyethylacetate (Cellosolve acetate) — Skin	100	540
Ethyl acetate	400	1,400
Ethyl acrylate — Skin	25	100
Ethyl alcohol (ethanol)	1,000	1,900
Ethylamine	10	18
Ethyl sec-amyl ketone (5-methyl-3-heptanone)	25	130
Ethyl benzene	100	435
Ethyl bromide	200	890
Ethyl butyl ketone (3-Heptanone)	50	230
Ethyl chloride	1,000	2,600
Ethyl ether	400	1,200
Ethyl formate	100	300
Ethyl mercaptan	0.5	1

Capital letters refer to Appendices.
*1973 Addition.

Substance	ppm[a]	mg/M[3][b]
Ethyl silicate	100	850
Ethylene	F	—
Ethylene chlorohydrin — Skin	5	16
Ethylenediamine	10	25
Ethylene dibromide, see 1, 2-Dibromoethane	—	—
Ethylene dichloride, see 1, 2-Dichloroethane	—	—
* Ethylene glycol, particulate	—	10
* Ethylene glycol, vapor	100	260
C Ethylene glycol dinitrate and/or Nitroglycerin — Skin	0.2[d]	—
Ethylene glycol monomethyl ether acetate (Methyl cellosolve acetate) — Skin	25	120
Ethylene imine — Skin	0.5	1
Ethylene oxide	50	90
Ethylidine chloride, see 1, 1-Dichloroethane	—	—
N-Ethylmorpholine — Skin		
Ferbam		
Ferrovanadium dust	—	1
Fluoride (as F)	—	2.5
* Fluorine	1	2
Fluorotrichloromethane	1,000	5,600
C Formaldehyde	2	3
Formic acid	5	9
Furfural — Skin	5	20
** Furfuryl alcohol	(5)	(20)

Capital letters refer to Appendices.
*1973 Addition.
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Substance	ppm[a]	mg/M[3][b]
Gasoline	—	[illegible]
* Germanium tetrahydride	0.2	0.6
Glass, fibrous[c] or dust	—	E
Glycerin mist	—	E
Glycidol (2, 3-Epoxy-1-propanol)	50	150
Glycol monoethyl ether, see 2-Ethoxyethanol	—	—
Graphite, (Synthetic)	—	E
Guthion,® see Azinphosmethyl	—	—
Gypsum	—	E
Hafnium	—	0.5
Helium	F	—
Heptachlor — Skin	—	0.5
Heptane (n-heptane)	500	2,000
Hexachloroethane — Skin	1	10
Hexachloronaphthalene — Skin	—	0.2
* Hexafluoroacetone	0.1	0.7
Hexane (n-hexane)	500	1,800
2-Hexanone	100	410
Hexone (Methyl isobutyl ketone)	100	410
sec-Hexyl acetate	50	300
Hydrazine — Skin	1	1.3
Hydrogen	F	—
Hydrogen bromide	3	10
C Hydrogen chloride	5	7
Hydrogen cyanide — Skin	10	11
Hydrogen fluoride	3	2
Hydrogen peroxide	1	1.4

Capital letters refer to Appendices.
Footnotes (a thru h) see Page 31.
*1973 Addition.

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Substance	ppm[a]	mg/M³[b]
Hydrogen selenide	0.05	0.2
Hydrogen sulfide	10	15
Hydroquinone	—	2
Indene	10	45
Indium and compounds, as In	—	0.1
C Iodine	0.1	1
** Iron oxide fume	—	(10)
Iron pentacarbonyl	0.01	0.08
Iron salts, soluble, as Fe	—	1
Isoamyl acetate	100	525
Isoamyl alcohol	100	360
Isobutyl acetate	150	700
Isobutyl alcohol	100	300
** Isophorone	(25)	(140)
Isopropyl acetate	250	950
Isopropyl alcohol	400	980
Isopropylamine	5	12
* Isopropylether	250	1,050
Isopropyl glycidyl ether (IGE)	50	240
Kaolin	—	E
Ketene	0.5	0.9
* Lead, inorg., fumes and dusts	—	0.15
Lead arsenate	—	0.15
Limestone	—	E
Lindane	—	0.5
Lithium hydride	—	0.025
L.P.G. (Liquified petroleum gas)	1,000	1,800
Magnesite	—	E
Magnesium oxide fume	—	10
Malathion — Skin	—	10

Capital letters refer to Appendices.
*1973 Addition.
**See Notice of Intended Changes.

Substance	ppm[a]	mg/M³[b]
Maleic anhydride	0.25	1
C Manganese and compounds, as Mn	—	5
Marble	—	E
Mercury (Alkyl compounds) — Skin	0.001	0.01
Mercury (All forms except alkyl)	—	0.05
Mesityl oxide	25	100
Methane	F	—
Methanethiol, see Methyl mercaptan	—	—
Methoxychlor	—	10
2-Methoxyethanol—Skin (Methyl cellosolve)	25	80
Methyl acetate	200	610
Methyl acetylene (propyne)	1,000	1,650
Methyl acetylene-propadiene mixture (MAPP)	1,000	1,800
Methyl acrylate — Skin	10	35
* Methyl acrylonitrile — Skin	1	3
Methylal (dimethoxymethane)	1,000	3,100
Methyl alcohol (methanol)	200	200
Methylamine	10	12
Methyl amyl alcohol, see Methyl isobutyl carbinol	—	—
Methyl 2-cyanoacrylate	2	8
Methyl isoamyl ketone	100	475

Capital letters refer to Appendices.
*1973 Addition.

Substance	ppm[a]	mg/M³[b]
Methyl (n-amyl) ketone (2-Heptanone)	100	465
* Methyl bromide — Skin	15	60
Methyl butyl ketone, see 2-Hexanone	—	—
Methyl cellosolve — Skin see 2-Methoxyethanol	—	—
Methyl cellosolve acetate — Skin, see Ethylene glycol monomethyl ether acetate	—	—
Methyl chloride	100	210
Methyl chloroform	350	1,900
Methylcyclohexane	500	2,000
* Methylcyclohexanol	50	235
* o-Methylcyclohexanone — Skin	50	230
Methylcyclopentadienyl manganese tricarbonyl (as Mn) — Skin	0.1	0.2
Methyl demeton — Skin	—	0.5
Methyl ethyl ketone (MEK), see 2-Butanone	—	—
Methyl formate	100	250
Methyl iodide — Skin	5	28
Methyl isobutyl carbinol — Skin	25	100
Methyl isobutyl ketone, see Hexone	—	—
Methyl isocyanate — Skin	0.02	0.05
Methyl mercaptan	0.5	1
Methyl methacrylate	100	410
Methyl parathion—Skin	—	0.2

*1973 Addition.

Substance	ppm[a]	mg/M[3][b]
Methyl propyl ketone, see 2-Pentanone	—	—
C Methyl silicate	5	30
C α Methyl styrene	100	480
C Methylene bisphenyl isocyanate (MDI)	0.02	0.2
** Methylene chloride (dichloromethane)	(500)	(1,740)
Molybdenum (soluble compounds)	—	5
(insoluble compounds)	—	10
Monomethyl aniline — Skin	2	9
C Monomethyl hydrazine — Skin	0.2	0.35
Morpholine — Skin	20	70
Naphtha (coal tar)	100	400
Naphthalene	10	50
β-Naphthylamine	—	A[15]
Neon	F	—
Nickel carbonyl	0.001	A[16] 0.007
Nickel, metal and soluble compounds (as Ni)	—	1
Nicotine — Skin	0.075	0.5
Nitric acid	2	5
Nitric oxide	25	30
p-Nitroaniline — Skin	1	6
Nitrobenzene — Skin	1	5
p-Nitrochlorobenzene — Skin	—	1
4-Nitrodiphenyl	—	A[16]
Nitroethane	100	310
Nitrogen	F	—
C Nitrogen dioxide	5	9

Capital letters refer to Appendices.
Footnotes (a thru h) see Page 31.
**See Notice of Intended Changes.

Substance	ppm[a]	mg/M[3][b]
Nitrogen trifluoride	10	29
Nitroglycerin — Skin	0.2	2
Nitromethane	100	250
1-Nitropropane	25	90
2-Nitropropane	25	90
N-Nitrosodimethylamine (dimethylnitrosoamine) — Skin	—	A[8]
Nitrotoluene — Skin	5	30
Nitrotrichloromethane, see Chloropicrin	—	—
Nitrous oxide	F	—
Octachloronaphthalene — Skin	—	0.1
Octane	400	1,900
Oil mist, particulate	—	5[f]
Oil mist, vapor	[a][B][2]	—
Osmium tetroxide	0.0002	0.002
Oxalic acid	—	1
Oxygen difluoride	0.05	0.1
Ozone	0.1	0.2
Paraquat — Skin	—	0.5
Parathion — Skin	—	0.1
Pentaborane	0.005	0.01
Pentachloronaphthalene — Skin		
Pentachlorophenol — Skin	—	0.5
Pentaerythritol	—	E
Pentane	500	1,500
2-Pentanone	200	700
Perchloroethylene	100	670
Perchloromethyl mercaptan	0.1	0.8
Perchloryl fluoride	3	14

Capital letters refer to Appendices.
Footnotes (a thru h) see Page 31.

Substance	ppm[a]	mg/M[3][b]
Petroleum Distillates (naphtha)	[a][B][2]	—
Phenol — Skin	5	19
Phenothiazine — Skin	—	5
p-Phenylene diamine — Skin	—	0.1
Phenyl ether (vapor)	1	7
Phenyl ether-Diphenyl mixture (vapor)	1	7
Phenylethylene, see Styrene	—	—
Phenyl glycidyl ether (PGE)	10	60
Phenylhydrazine — Skin	5	22
°C Phenylphosphine	0.05	0.25
Phosdrin (Mevinphos)® — Skin	0.01	0.1
Phosgene (carbonyl chloride)	0.1	0.4
Phosphine	0.3	0.4
Phosphoric acid	—	1
Phosphorus (yellow)	—	0.1
Phosphorus pentachloride	—	1
Phosphorus pentasulfide	—	1
Phosphorus trichloride	0.5	3
Phthalic anhydride	2	12
Picric acid — Skin	—	0.1
Pival® (2-Pivalyl-1, 3-indandione)	—	0.1
Plaster of Paris	—	E
Platinum (Soluble Salts) as Pt	—	0.002

Capital letters refer to Appendices.
Footnotes (a through h) see page 31.
°1973 Addition.

Substance	ppm[a]	mg/M[3][b]
Polychlorobiphenyls, see Chlorodiphenyls	—	—
Polytetrafluoroethylene decomposition products	—	B[i]
Propane	F	—
β Propiolactone	—	A[j]
Propargyl alcohol—Skin	1	2
n-Propyl acetate	200	840
Propyl alcohol	200	500
n-Propyl nitrate	25	110
Propylene dichloride (1, 2-Dichloropropane)	75	350
Propylene glycol monomethyl ether	100	360
Propylene imine — Skin	2	5
Propylene oxide	100	240
Propyne, see Methylacetylene	—	—
Pyrethrum	—	5
Pyridine	5	15
Quinone	0.1	0.4
RDX — Skin	—	1.5
Rhodium, Metal fume and dusts (as Rh)	—	0.1
Soluble salts	—	0.001
Rosanel	—	10
Rosin Core Solder, pyrolysis products (as formaldehyde)	—	0.1
Rotenone (commercial)	—	5
Rouge	—	E
Selenium compounds (as Se)	—	0.2
Selenium hexafluoride	0.05	0.4
*Silicon	—	10

Capital letters refer to Appendices.
*1973 Addition.

Substance	ppm[a]	mg/M[3][b]
Silicon carbide	—	E
Silver, metal and soluble compounds	—	0.01
Sodium fluoroacetate (1080) — Skin	—	0.05
**C Sodium hydroxide	—	(2)
Starch	—	E
Stibine	0.1	0.5
Stoddard solvent	200	1,150
Strychnine	—	0.15
Styrene (Monomer) (Phenyl ethylene)	100	420
Sucrose	—	E
Sulfur dioxide	5	13
Sulfur hexafluoride	1,000	6,000
Sulfuric acid	—	1
Sulfur monochloride	1	6
Sulfur pentafluoride	0.025	0.25
Sulfur tetrafluoride	0.1	0.4
Sulfuryl fluoride	5	20
Systox, see Demeton®	—	—
2, 4, 5 T	—	10
Tantalum	—	5
TEDP — Skin	—	0.2
Teflon® decomposition products	—	B[i]
Tellurium	—	0.1
Tellurium hexafluoride	0.02	0.2
TEPP — Skin	0.004	0.05
C Terphenyls	1	9
1, 1, 1, 2-Tetrachloro-2, 2-difluoroethane	500	4,170
1, 1, 2, 2-Tetrachloro-1, 2-difluoroethane	500	4,170

Capital letters refer to Appendices.
**See Notice of Intended Changes.

Substance	ppm[a]	mg/M[3][b]
1, 1, 2, 2-Tetrachloroethane — Skin	5	35
Tetrachloroethylene, see Perchloroethylene	—	—
Tetrachloromethane, see Carbon tetrachloride	—	—
Tetrachloronaphthalene — Skin	—	2
Tetraethyl lead (as Pb) — Skin	—	0.100[ah]
Tetrahydrofuran	200	590
Tetramethyl lead (as Pb) — Skin	—	0.150[ah]
Tetramethyl succinonitrile — Skin	0.5	3
Tetranitromethane	1	8
Tetryl (2, 4, 6-trinitrophenylmethylnitramine) — Skin	—	1.5
Thallium (soluble compounds)—Skin (as Tl)	—	0.1
Thiram®	—	5
Tin (inorganic compounds, except SnH_4 and SnO_2) as Sn	—	2
Tin (organic compounds) — Skin (as Sn)	—	0.1
Tin oxide	—	E
Titanium dioxide	—	E
*Toluene (toluol)	100	375
C Toluene-2, 4-diisocyanate	0.02	0.14
o-Toluidine	5	22

Capital letters refer to Appendices.
Footnotes [a thru h] see Page 31.
*1973 Addition.

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Substance	ppm[a]	mg/M[3][b]
Toxaphene, see Chlorinated camphene	—	—
Tributyl phosphate	—	5
1, 1, 1-Trichloroethane, see Methyl chloroform.	—	—
1, 1, 2-Trichloroethane — Skin	10	45
Trichloroethylene	100	535
Trichloromethane, see Chloroform	—	—
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
Trimethyl benzene	25	120
2, 4, 6-Trinitrophenol, see Pierie acid	—	—
2, 4, 6 — Trinitrophenylmethylnitramine, see Tetryl	—	—
Trinitrotoluene — Skin	0.2	1.5
Triorthocresyl phosphate	—	0.1
Triphenyl phosphate	—	3
Tungsten & compounds, as W		
Soluble	—	1
Insoluble	—	5
Turpentine	100	560
Uranium (natural) soluble & insoluble compounds, as U	—	0.2

Substance	ppm[a]	mg/M[3][b]
Vanadium (V_2O_5), as V		
Dust	—	0.5
Fume	—	0.05
Vinyl acetate	10	30
Vinyl benzene, see Styrene	—	—
Vinyl bromide	250	1,100
Vinyl chloride	200	510
Vinylcyanide, see Acrylonitrile	—	—
Vinyl toluene	100	480
Warfarin	—	0.1
Wood dust (nonallergenic)	—	5
Xylene (xylol)	100	435
Xylidine — Skin	5	25
Yttrium	—	1
Zinc chloride fume	—	1
Zinc oxide fume	—	5
Zirconium compounds (as Zr)	—	5

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

b) Approxi[illegible] per cubic [illegible]

d) An atmospheric concentration of not more than 0.02 ppm, or personal protection may be necessary to avoid headache.

e) <5-7 μm in diameter.

f) As sampled by method that does not collect vapor.

g) According to analytically determined composition.

h) For control of general room air, biologic monitoring is essential for personnel control.

Radioactivity: For permissible concentrations of radioisotopes 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, 1969. 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. A report, Basic Radiation Protection Criteria, published by the National Committee on Radiation Protection, revises and modernizes the concept of the NCRP standards of 1954, 1957 and 1958; obtainable as NCRP Rept. No. 39, P.O. Box 4867, Washington, D.C. 20008.

MINERAL DUSTS

Substance	m.p.p.c.f.[a]
, SiO_2	
Crystalline	
Quartz	TLV in mppcf: $\frac{300^{b}}{\%\ \text{quartz} + 10}$
	TLV for respirable dust in mg/m³: $\frac{10\ \text{mg/m}^{3\,(c)}}{\%\ \text{Respirable quartz} + 2}$

	TLV for "total dust," respirable and nonrespirable:
	$\frac{30 \text{ mg/m}^3}{\% \text{ quarts} + 3}$
Cristobalite.....	Use one-half the value calculated from the count or mass formulae for quarts.
Tridymite	Use one-half the value calculated from formulae for quarts.
Silica, fused	Use quarts formulae.
Amorphous, including natural diatomaceous earth.....	20

SILICATES (< 1% quarts)

**Asbestos, all forms.	—
Mica.....	20
*Perlite.....	30
Portland Cement..	30
Soapstone.....	20
Talc (non-asbestiform).....	20
Talc (fibrous) use asbestos limit....	—
Tremolite (see Asbestos).....	—
Graphite (natural).	15

*1973 Addition.
**See Notice of Intended Changes for Mineral Dusts.

*COAL DUST
(bituminous). 2 mg/m³ (respirable dust" fraction < 5% quarts).
If > 5% quarts use respirable mass formula.

NUISANCE PARTICULATES
(see Appendix E)

30 m.p.p.c.f. or 10 mg/m³
of total dust < 1% quarts

Conversion factors
mppcf × 35.3 = particles per cubic meter
= particles per c.c.

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

j) The percentage of quarts in the formula is the amount determined from airborne samples, except in those instances in which other methods have been shown to be applicable.

k) Both concentration and percent quarts for the application of this limit are to be determined from the fraction passing a size-selector with the following characteristics:

Aerodynamic Diameter (μm) (unit density sphere)	% passing selector
≯ 2	90
2.5	75
3.5	50
5.0	25
10	0

l) containing <1% quarts; if quarts content > 1%, use formulae for quarts.

p) see Page 39.

*1973 Addition.

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NOTICE OF INTENDED CHANGES
(for 1973)

These substances, with their corresponding values, comprise those for which either a limit has been proposed for the first time, or for which a change in the "Adopted" listing has been proposed. In both cases, the proposed limits should be considered trial limits that will remain in the listing for a period of at least two years. If, after two years no evidence comes to light that questions the appropriateness of the values herein, the values will be reconsidered for the "Adopted" list. In the interim, the 1972 Adopted limit will prevail. Documentation is available for each of these substances.

Substance	ppm[a]	mg/M[3][b]
Baygon	—	0.5
Butyl lactate	1	5
+C Cadmium oxide fume	—	0.05
Caprolactam —		
Dust	—	1
Vapor	5	25
Carbofuran — Skin	—	0.05
+ Carbon tetrabromide	0.1	1.4
+ Catechol	1	4.5
+ Cesium hydroxide	—	2
+ Chlorodifluoromethane	1000	3500
Chloroform	25	120
bis-Chloromethylether	—	A[10]
+ Chlorpyrifos (Dursban®) — Skin	—	0.2
+ o-Chlorostyrene	50	285
o-Chlorotoluene	50	250
+ 2-Chloro-6-(trichloromethyl) pyridine (N-Serve®)	—	10
+ Clopidol (Coyden®)	—	10
+ Copper fume	—	0.2
Cotton dust, raw	—	0.2[m]
+ Crufomate (Ruelene®)	—	5
Cyclohexylamine	10	40
+ Dicyclopentadienyliron	—	10
+ Diethylphthalate	—	5
Dimethyl sulfate—Skin	—	A[1]
+ 3,5-Dinitro-o-toluamide (Zoalene®)	—	5
Dioxane — Skin	50	180
Disyston — Skin	—	0.1
C Ethylidene norbornene	5	25
+ Formamide	20	30
Furfuryl alcohol	5	20
Hexachlorocyclopentadiene	0.01	0.1
+ Iron oxide fume	—	5
Isophorone	10	55
Manganese cyclopentadienyl tricarbonyl (as Mn)		
4, 4-Methylene bis (2-chloroaniline)—Skin	0.02	A[1]
C Methylene bis (4-cyclohexylene isocyanate)	0.01	0.11
Methylene chloride (Dichloromethane)	250	890
C Methylethyl ketone peroxide	0.2	1.5
Mineral wool fiber	—	10
Paraffin wax fume	—	2
Phorate (Thimet®) — Skin	—	0.05
+ Picloram (Tordon®)	—	10
C Potassium hydroxide	—	2
Silicon tetrahydride (Silane)	0.5	0.7
+C Sodium hydroxide	—	2
+C Subtilisins (Proteolytic enzymes as 100% pure crystalline enzyme)	—	0.0000[6][c]
+ Tricyclohexyltin hydroxide (Plictran®)	—	5
+ Vinylidene chloride	10	4
Zinc stearate	—	B

Capital letters refer to Appendices.
+ 1973 Revision or Addition.

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

b) Approximate milligrams of particulate per cubic meter of air.

m) Lint free dust as measured by the vertical-[illegible]riator, cotton-dust sampler described in the Transactions of the National Conference on Cotton Dust, J. R. Lynch, pg. 33, May 2, 1970.

c) Based on "high volume" sampling.

Capital letters refer to Appendices.
+ 1973 Revision or Addition.

NOTICE OF INTENDED CHANGES (Cont'd)
MINERAL DUSTS

Substance	TLV
Asbestos, all forms†	5 fibers/cc > 5μ in length[n] A[to]
Silica flour	Use respirable[p] mass formula for quartz.
Tripoli	Use respirable mass formula for quartz.

n) As determined by the membrane filter method at 400–450 X magnification (4 mm objective) phase contrast illumination.

p) "Respirable" dust as defined by the British Medical Research Council Criteria (1) and as sampled by a device producing equivalent results (2).

(1) Hatch, T. E. and Gross, P., Pulmonary Deposition and Retention of Inhaled Aerosols, p. 149. Academic Press, New York, New York, 1964.

(2) Interim Guide for Respirable Mass Sampling, AIHA Aerosol Technology Committee, AHIA J. *31*: 2, 1970, p. 133.

†A more stringent TLV for crocidolite may be required.

NOTICE OF INTENDED CHANGES (Cont'd)

APPENDIX A

Carcinogens

The Committee lists below those substances in industrial use that have proven carcinogenic in man, or have induced cancer in animals under appropriate experimental conditions. Present listing of those substances carcinogenic for man takes two forms, those for which a TLV has been assigned (1a), and those for which environmental conditions have not been sufficiently defined to assign a TLV (1b).

1a. *Human Carcinogens* — Substances recognized as occupational carcinogens with an assigned TLV:
Asbestos, all forms, 5 fibers/cc > 5μm in length.
bis (Chloromethyl) ether, 1ppb.
Chromates, certain insoluble forms, 100μg/m³
Coal tar pitch volatiles 200μg/m³
Nickel carbonyl, 1ppb

1b. *Human Carcinogens* — Substances known to be potent occupational carcinogens without an assigned TLV:
4-Aminodiphenyl (p-Xenylamine)
Benzidine & its salts
beta-Naphthylamine
4-Nitrodiphenyl

For the substances in 1b, no exposure or contact by any route, respiratory, skin or oral, as detected by the most sensitive methods, shall be permitted. "No exposure or contact" means permitting the process or operation by the best practicable engineering methods, and protecting the worker by proper equipment that will insure virtually no contact or entry of the carcinogen by any route.

2. *Experimental Carcinogens* — Industrial substances found to be of high potency in inducing tumors under experimental conditions in animals:
Beryllium
Chloromethyl methyl ether
3, 3'-Dichlorobenzidine
Dimethyl sulfate
Ethylenimine
4, 4'-Methylene bis (2-chloroaniline)
N-Nitrosodimethylamine
beta-Propiolactone

For the above, worker exposure by all routes should be reduced to a minimum in light of the warning of the potency of these substances to induce tumors in animals. "Reduced to a minimum" means extraordinary care shall be taken both in manufacture and in handling so that worker exposure by all routes is kept below the limit of sensitivity of the analytic method of determining the exposure concentration.

APPENDIX B

B¹ *Polytetrafluoroethylene® decomposition products.* Thermal decomposition of the fluorocarbon chain in air leads to the formation of oxidized products containing carbon, fluorine and oxygen. Because these products decompose in part by hydrolysis in alkaline solution, they can be quantitatively determined in air as fluoride to provide an index of exposure.

No TLV is recommended pending determination of the toxicity of the products, but air concentrations should be kept below the limit of sensitivity of the analytic method.

B[3] *Gasoline and/or Petroleum Distillates.* The composition of these materials varies greatly and thus a single TLV for all types of these materials is no longer applicable. In general, the aromatic hydrocarbon content will determine what TLV applies. Consequently the content of benzene, other aromatics and additives should be determined to arrive at the appropriate TLV (Elkins, et al. A.I.H.A.J. 24: 99, 1963).

[3]Trade Names: Algoflon, Fluon, Halon, Teflon, Tetran

APPENDIX C

B.1 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 fractions,

$$\frac{C_1}{T_1} + \frac{C_2}{T_2} + \cdots \frac{C_n}{T_n}$$

exceeds unity, then the threshold limit of the mixture should be considered as being exceeded. C_1 indicates the observed atmospheric concentration, and T_1 the corresponding threshold limit (See Example 1A.a. and 1A.c.).

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 *independent* as when purely local effects on different 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 $\left(\frac{C_1}{T_1} + \text{or} + \frac{C_2}{T_2} \text{ etc.}\right)$ itself has a value exceeding unity (See Example 1A. c.).

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 narcotic (trichloroethylene). Potentiation is characteristically exhibited at high concentrations, less probably at low.

When
teria
fumes, vapors or gases, 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 operations, diesel exhausts, etc. (Example 2 in 1A.a.).

THRESHOLD LIMIT VALUES FOR MIXTURES

EXAMPLES

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

a. *Additive effects.* (*Note: It is essential that the atmosphere be analyzed both qualitatively and quantitatively for each component present, in order to evaluate compliance or noncompliance with this calculated TLV.*)

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

Example No. 1: Air contains 5 ppm of carbon tetrachloride (TLV = 10 ppm) 20 ppm of ethylene dichloride (TLV = 50 ppm) and 10 ppm of ethylene dibromide (TLV = 20 ppm)

Atmospheric concentration of mixture = 5 + 20 + 10 = 35 ppm of mixture

$$\frac{5}{10} + \frac{20}{50} + \frac{10}{20} = \frac{25 + 20 + 25}{50} = 1.4$$

Threshold Limit is exceeded. Furthermore, the TLV of this mixture may be calculated by reducing the total fraction to 1.0; *i.e.*

$$\text{TLV of mixture} = \frac{35}{1.4} = 25 \text{ ppm}$$

Example No. 2: Air contains 200 ppm of hexane (TLV = 500 ppm) 100 ppm of methylene chloride (TLV = 500 ppm) and 20 ppm of perchloroethylene (TLV = 100 ppm)

Atmospheric concentration of mixture = 200 + 100 + 20 = 320 ppm of mixture

$$\frac{200}{500}+\frac{100}{500}+\frac{20}{100}=\frac{200+100+100}{500}=\frac{400}{500}=0.8$$

Threshold Limit is not exceeded. The TLV of this mixture = $\frac{320}{0.8}$ = 400ppm

1A.b. Special case when the source of contaminant is a liquid mixture and the atmospheric composition is *assumed* to be similar to that of the original material; e.g. on a time weighted average exposure basis, all of the liquid (solvent) mixture eventually evaporates.

Additive effects (approximate solution)

1. The percent composition (by weight) of the liquid mixture is known, the TLVs of the constituents must be listed in mg/m³.

(*Note: In order to evaluate compliance with this TLV, field sampling instruments should be calibrated, in the laboratory, for response to this specific quantitative and qualitative air-vapor mixture, and also to fractional concentrations of this mixture; e.g., 1/2 the TLV; 1/10 the TLV; 2 × the TLV; 10 × the TLV; etc.*)

TLV of mixture =

$$\frac{1}{\frac{f_a}{TLV_a}+\frac{f_b}{TLV_b}+\frac{f_c}{TLV_c}+\cdots\frac{f_n}{TLV_n}}$$

Example No. 1: Liquid solvent contains (by weight) 50% heptane (TLV = 2000 mg/m³) 30% methylene chloride (TLV = 1740 mg/m³) 20% perchlorethylene (TLV = 670 mg/m³)

TLV of mixture =

$$\frac{1}{\frac{0.5}{2000}+\frac{0.3}{1740}+\frac{0.2}{670}}=$$

$$\frac{1}{.00025+.00017+.0003}=\frac{1}{.00072}=$$

1390 mg/m³

Of this mixture: 50% or 695 mg/m³ is heptane, 30% or 417 mg/m³ is methylene chloride and 20% or 278 mg/m³ is perchlorethylene

These values can be converted to ppm as follows:

heptane —

2000 mg/m³ = 500 ppm
1 mg/m³ = 0.25 ppm
695 mg/m³ = 174 ppm

methylene chloride —

1740 mg/m³ = 500 ppm
1 mg/m³ = 0.287 ppm
417 mg/m³ = 119 ppm

perchlorethylene —

670 mg/m³ = 100 ppm
1 mg/m³ = 0.15 ppm
278 mg/m³ = 42 ppm

The TLV of this mixture =
174 + 119 + 42 = 335 ppm.

1A.c. *Independent effects.*
Air contains 0.15 mg/m³ of lead (TLV, 0.15) and 0.7 mg/m³ of sulfuric acid (TLV, 1).

$$\frac{0.15}{0.15}=1;\qquad \frac{0.7}{1}=0.7$$

Threshold limit is not exceeded.

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

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

(2) $C_1+C_2+\cdots+C_n=T,$

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

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) $C_i = aF_i p_i^\circ$.

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

(6) $$\frac{F_1 p_1^\circ}{T} + \frac{F_2 p_2^\circ}{T} + \cdots + \frac{F_n p_n^\circ}{T} = \frac{F_1 p_1^\circ}{T_1} + \frac{F_2 p_2^\circ}{T_2} + \cdots + \frac{F_n p_n^\circ}{T_n}$$

and solving for T,

(6.1) $$T = \frac{F_1 p_1^\circ + F_2 p_2^\circ + \cdots + F_n p_n^\circ}{\frac{F_1 p_1^\circ}{T_1} + \frac{F_2 p_2^\circ}{T_2} + \cdots + \frac{F_n p_n^\circ}{T_n}}$$

or $$\sum^{i} = a F_i p_i^\circ$$

(6.2) $$T = \frac{i = 1}{\sum^{i = n}}$$

$$i = \frac{F_i p_i^\circ}{T_i}$$

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.

1B.b. 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

Solvent	Mol. wt.	Density	TLV	p° at 25°C	Mol fraction in half-and-half solution by volume
Trichloroethylene (1)	131.4	1.46 g/ml	100	73mm Hg	0.527
Methylchloroform					

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

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

$$TLV = \frac{38.2 + 59.2}{\frac{38.2}{100} + \frac{59.2}{350}} = \frac{(97.4)\ (350)}{133.8 + 59.2} =$$

$$\frac{(97.4)\ (350)}{193.0} = 177$$

TLV = 177 ppm (Note difference in TLV when account is taken of vapor pressure and mol fraction in comparison with the above sample 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).

$$\frac{C_1}{0.1} + \frac{C_2}{0.5} = \frac{C_m}{C_m} \qquad C_2 = 2C_1$$

$$C_m = 3C_1$$

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

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

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

1C. TLV for Mixtures of Mineral Dusts.

mixtures of biologically active mineral dusts the general formula for mixtures may be used.

For a mixture containing 80% talc and 20% quartz, the TLV for 100% of the mixture is given by:

$$TLV = \frac{1}{\frac{0.8}{20} + \frac{0.2}{2.5}} = 8.4\ mppcf$$

Essentially the same result will be obtained if the limit of the more (most) toxic component is used provided the effects are additive. In the above example the limit for 20% quartz is 10 mppcf.

For another mixture of 25% quartz, 25% amorphous silica and 50% talc:

$$TLV = \frac{1}{\frac{0.25}{2.5} + \frac{0.25}{20} + \frac{0.5}{20}} = 7.3 \text{ mppcf}$$

The limit for 25% quartz approximates 8 mppcf.

APPENDIX D

PERMISSIBLE EXCURSIONS FOR TIME-WEIGHTED AVERAGE (TWA) LIMITS

The Excursion TLV Factor in the Table automatically defines the magnitude of the permissible excursion above the limit for those substances not given a "C" designation; i.e., the TWA limits. Examples in the Table show that nitrobenzene, the TLV for which is 1 ppm, should never be allowed to exceed 3 ppm. Similarly, carbon tetrachloride, TLV 10 ppm, should never be allowed to exceed 20 ppm. By contrast, those substances with a "C" designation are not subject to the excursion factor and must be kept at or below the TLV ceiling.

These limiting excursions are to be considered to provide a "rule-of-thumb" guidance for listed substances generally, and may not provide the most appropriate excursion for a particular substance e.g., the permissible excursion for CO is 400 ppm for 15 minutes.

For appropriate excursions for 142 substances consult Pa. Rules & Regs., Chap. 4, Art. 432, and "Acceptable Concentrations," ANSI.

Substance	TLV	Excursion Factor	Max. Conc. Permitted for short time
	ppm		ppm
Nitrobenzene	1	3	3
Carbon tetrachloride	10	2	20
o-Dichlorobenzene	50	1.5	75
Acetone	1000	1.25	1250
Boron trifluoride	C 1	—	1
Butylamine	C 5	—	5

EXCURSION FACTORS

For all substances not bearing C notation

	Excursion
TLV >0-1 (ppm or mg/m³),	Factor = 3
TLV >1-10 "	" = 2
TLV >10-100 "	" = 1.5
TLV >100-1000 "	" = 1.25

The number of times the excursion above the TLV is permitted is governed by conformity with the Time-Weighted Average TLV.

BASIS FOR ASSIGNING LIMITING "C" VALUES

By definition in the Preface, a listed value bearing a "C" designation refers to a "ceiling" value that should not be exceeded; all values

should fluctuate below the listed value. This, in effect, makes the "C" designation a maximal allowable concentration (MAC). In general, the bases for assigning or not assigning a "C" value rest on whether excursions of concentration above a proposed limit *for periods up to 15 minutes* may result in a) intolerable irritation, b) chronic, or irreversible tissue change, or c) narcosis of sufficient degree to increase accident proneness, impair self-rescue or materially reduce work efficiency.

APPENDIX E

Some Nuisance Particulates[q]

TLV, 30 mppcf or 10mg/m³

Alundum (Al_2O_3)	Kaolin
Calcium carbonate	Limestone
Cellulose (paper fiber)	Magnesite
Portland Cement	Marble
Corundum (Al_2O_3)	Pentaerythritol
Emery	Plaster of Paris
Glass, fibrous[r] or dust	
Glycerin Mist	Rouge
Graphite (synthetic)	Silicon Carbide
Gypsum	Starch
Vegetable oil mists (except castor, cashew nut, or similar irritant oils)	Sucrose
	Tin Oxide
	Titanium Dioxide

q) When toxic impurities are not present, e.g. quartz < 1%

r) <5-7μm in diameter

APPENDIX F

Some Simple Asphyxiants — "Inert" Gases and Vapors[s]

TLV, 1,000ppm

Acetylene	Hydrogen
Argon	Methane
Butane	Neon
Ethane	Nitrogen
Ethylene	Nitrous oxide[t]
Helium	Propane

s) As defined on pg. 6.

t) Nontoxic at or below TLV.

TLVs®

Threshold Limit Values

for

Physical Agents

Adopted by

ACGIH

for 1973

PREFACE

PHYSICAL AGENTS

These threshold limit values refer to levels of physical agents and represent conditions under which it is believed that nearly all workers may be repeatedly exposed day after day without adverse effect. Because of wide variations in individual susceptibility, exposure of an occasional individual, at, or even below, the threshold limit may not prevent annoyance, aggravation of a pre-existing condition, or physiological damage.

These threshold limits are based on the best available information from industrial experience, from experimental human and animal studies, and when possible, from a combination of the three.

These limits are intended for use in the practice of industrial hygiene and should be interpreted and applied only by a person trained in this discipline. They are not intended for use, or for modification for use, (1) in the evaluation or control of the levels of physical agents in the community, (2) as proof or disproof of an existing physical disability, or (3) for adoption by countries whose working conditions differ from those in the United States of America.

These values are reviewed annually by the Committee on Threshold Limits for Physical Agents for revisions or additions, as further information becomes available.

Notice of Intent — At the beginning of each year, proposed actions of the Committee for the forthcoming year are issued in the form of a "Notice of Intent." This notice provides not only an opportunity for comment, but solicits suggestions of physical agents to be added to the list. The suggestions should be accompanied by substantiating evidence.

As Legislative Code — The Conference recognizes that the Threshold Limit Values may be adopted in legislative codes and regulations. If so used, the intent of the concepts contained in the Preface should be maintained and provisions should be made to keep the list current.

Reprint Permission — This publication may be reprinted provided that written permission is obtained from the Secretary-Treasurer of the Conference and that this Preface be published in its entirety along with the Threshold Limit Values.

NOTICE OF INTENT TO ESTABLISH

THRESHOLD LIMIT VALUES

HEAT STRESS

These Threshold Limit Values refer to heat stress conditions under which it is believed that nearly all workers may be repeatedly exposed without adverse health effects. The TLVs shown in Table I are based on the assumption that nearly all acclimatized, fully clothed workers with adequate water and salt intake should be able to function effectively under the given working conditions without exceeding a deep body temperature of 38°C (WHO technical report series #412, 1969 *Health Factors Involved in Working Under Conditions of Heat Stress*).

Since measurement of deep body temperature is impractical for monitoring the workers' heat load, the measurement of environmental factors is required which most nearly correlate with deep body temperature and other physiological responses to heat. At the present time Wet Bulb-Globe Temperature Index (WBGT) is the simplest and most suitable technique to measure the environmental factors. WBGT values are calculated by the following equations:

1. Outdoors with solar load:
   WBGT = 0.7WB + 0.2GT + 0.1DB

2. Indoors or Outdoors with no solar load:
   WBGT = 0.7WB + 0.3GT

where:

WBGT = Wet Bulb-Globe Temperature Index
WB = Natural Wet-Bulb Temperature
DB = Dry-Bulb Temperature
GT = Globe Thermometer Temperature

The determination of WBGT requires the use of a black globe thermometer, a natural (static) wet-bulb thermometer, and a dry-bulb thermometer.

TABLE I

Permissible Heat Exposure Threshold Limit Values
(Values are given in °C. WBGT)

Work — Rest Regimen	Work Load		
	Light	Moderate	Heavy
Continuous work	30.0	26.7	25.0
75% Work — 25% Rest, Each hour	30.6	28.0	25.9
50% Work — 50% Rest, Each hour	31.4	29.4	27.9
25% Work — 75% Rest, Each hour	32.2	31.1	30.0

Higher heat exposures than shown in Table I are permissible if the workers have been undergoing medical surveillance and it has been established that they are more tolerant to work in heat than the average worker. Workers should not be permitted to continue their work when their deep body temperature exceeds 38.0°C.

APPENDIX G

1. *Measurement of the Environment*

The instruments required are a dry-bulb, a natural wet-bulb, a globe thermometer, and a stand. The measurement of the environmental factors shall be performed as follows:

A. The range of the dry and the natural wet bulb thermometer shall be −50°C to 50°C with an accuracy of ±0.5°C. The dry bulb thermometer must be shielded from the sun and the other radiant surfaces of the environment without restricting the airflow around the bulb. The wick of the natural wet-bulb thermometer shall be kept wet with distilled water for at least 1/2 hour before the temperature reading is made. It is not enough to immerse the other end of the wick into a reservoir of distilled water and wait until the whole wick becomes wet by capillarity. The wick shall be wetted by direct application of water from a syringe 1/2 hour before each reading. The wick shall extend over the bulb of the thermometer, covering the stem about one additional bulb length. The wick should always be clean and new wicks should be washed before using.

B. One globe thermometer, consisting of a 15 cm. (6-inch) diameter hollow copper sphere, painted on the outside with a matte black finish or equivalent shall be used. The bulb or sensor of a thermometer (range −5°C to 100°C with an accuracy of ±0.5°C) must be fixed in the center of the sphere. The globe thermometer shall be exposed at least 25 minutes before it is read.

[illegible] stand shall be used to suspend the three thermometers so that they do not restrict free air flow around the bulbs, and the wet-bulb and globe thermometer are not shaded.

D. It is permissible to use any other type of temperature sensor that gives identical reading to a mercury thermometer under the same conditions.

E. The thermometers must be so placed that the readings are representative of the condition where the men work or rest, respectively.

The methodology outlined above is more fully explained in the following publications:

1. "Prevention of Heat Casualties in Marine Corps Recruits, 1955-1960, with Comparative Incidence Rates and Climatic Heat Stresses in other Training Categories," by Captain David Minard, MC, USN, Research Report No. 4, Contract No. MR005.01-0001.01, Naval Medical Research Institute, Bethesda, Maryland, 21 February 1961.

2. "Heat Casualties in the Navy and Marine Corps, 1959-1962, with Appendices on the Field Use of the Wet Bulb-Globe Temperature Index," by Captain David Minard, MC, USN, and R. L. O'Brien, HMC, USN. Research Report No. 7, Contract No. MR 005.01-0001.01, Naval Medical Research Institute, Bethesda, Maryland, 12 March 1961.

3. *Minard, D.:* Prevention of Heat Casualties in Marine Corps Recruits. Military Medicine *126*(4): 261-272, 1961.

II. *Work Load Categories*

The heat produced by the body and the environmental heat together determine the total heat load. Therefore, if work is to be performed under hot environmental conditions, the workload category of each job shall be established and the heat exposure limit pertinent to the work load evaluated against the applicable standard in order to protect the worker from exposure beyond the permissible limit.

A. The work load category may be established by ranking each job into light, medium, and heavy categories on the basis of type of operation, where the work load is ranked into one of said three categories, i.e.

(1) light work: e.g., sitting or standing to control machines, performing light hand or arm work,

(2) moderate work: e.g., walking about with moderate lifting and pushing,

(3) heavy work: e.g., pick and shovel work,

the permissible heat exposure limit for that work load shall be determined from Table 1.

B. The ranking of the job may be performed either by measuring the worker's metabolic rate while performing his job or by estimating his metabolic rate by the use of the scheme shown in Table 2. Tables available in the literature listed below and in other publications as well may also be utilized.

1. Per-Olaf Astrand and Kaare Rodahl: "Textbook of Work Physiology" McGraw-Hill Book Company, New York, San Francisco, 1970.

2. Ergonomics Guide to Assessment of Metabolic and Cardiac Costs of Physical Work. Amer. Ind. Hyg. Assoc. J. *32:* 560, 1971.

3. Energy Requirements for Physical Work. Purdue Farm Cardiac Project. Agricultural Experiment Station. Research Progress Report No. 30, 1961.

4. J. V. G. A. Durnin and R. Passmore: "Energy, Work and Leisure." Heinemann Educational Books, Ltd., London, 1967.

TABLE 2

Assessment of Work Load

Average values of metabolic rate during different activities.

A. Body position and movement	Kcal./min.
Sitting	0.3
Standing	0.6
Walking	2.0-3.0
Walking up hill	add 0.8 per meter (yard) rise

B. Type of Work	Average Kcal./min.	Range Kcal./min.
Hand work		
light	0.4	0.2-1.2
heavy	0.9	
Work with one arm		
light	1.0	0.7-2.5
heavy	1.8	
Work with both arms		
light	1.5	1.0-3.5
heavy	2.5	
Work with body		
light	3.5	2.5-15.0
moderate	5.0	
heavy	7.0	
very heavy	9.0	

Light hand work: writing, hand knitting

Heavy hand work: typewriting

Heavy work with one arm: hammering in nails (shoemaker, upholsterer)

Light work with two arms: filing metal, planing wood, raking of a garden

Moderate work with the body: cleaning a floor, beating a carpet

Heavy work with the body: railroad track laying, digging, barking trees

Sample Calculation: Using a heavy hand tool on an assembly line

A. Walking along	2.0 Kcal./min.
B. Intermediate value between heavy work with two arms and light work with the body	3.0 Kcal./min.
	5.0 Kcal./min.
C. Add for basal metabolism	1.0 Kcal./min.
Total	6.0 Kcal./min.

Adapted from Lehmann, G.E., A. Muller and H. Spitzer: Der Kalorienbedarf bei gewerblicher Arbeit. Arbeitsphysiol. *14:* 166, 1950.

III. *Work-Rest Regimen*

The permissible exposure limits specified in Table I and Diagram A are based on the assumption that the WBGT value of the resting place is the same or very close to that of the work place. If the resting place is air conditioned and its climate is kept at or below 24°C (75°F.) WBGT, the allowable resting time may be reduced by 25%. The permissible exposure limits for continuous work are applicable where there is a work-rest regimen of a 5-day work week and an 8-hour work day with a short morning and afternoon break (approximately 15 minutes) and a longer lunch break (approximately 30 minutes). Higher exposure limits are permitted if additional resting time is allowed. All breaks, including unscheduled pauses and administrative or operational waiting periods during work may be counted as rest time when additional rest allowance must be given because of high environmental temperatures.

It is a common experience that when the work on a job is self-paced, the workers will spontaneously limit their hourly work load to 30–50% of their maximum physical performance capacity. They do this either by setting an appropriate work speed or by interspersing unscheduled breaks. Thus the daily average of the workers' metabolic rate seldom exceeds 330 kcal/hr. However, within an 8-hour work shift there may be periods where the workers' hourly average metabolic rate will be higher.

IV. *Water and Salt Supplementation*

During the hot season or when the worker is exposed to artificially generated heat, drinking water shall be made available to the workers in such a way that they are stimulated to frequently drink small amounts, i.e., one cup every 15–20 minutes (about 150 ml or 1/4 pint).

The water
(10°–15°C or 50.0 [illegible]) and shall be placed close to the workplace so that the worker can reach it without abandoning the work area.

The workers should be encouraged to salt their food abundantly during the hot season and particularly during hot spells. If the workers are unacclimatized, salted drinking water shall be made available in a concentration of 0.1% (1g NaCl to 1.0 liter or 1 level tablespoon of salt to 15 quarts of water). The added salt shall be completely dissolved before the water is distributed, and the water shall be kept reasonably cool.

V. *Other Considerations*

A. Clothing: The permissible heat exposure TLVs are valid for light summer clothing as customarily worn by workers when working under hot environmental conditions. If special clothing is required for performing a particular job and this clothing is heavier or it impedes sweat evaporation or has higher insulation value, the worker's heat tolerance is reduced, and the permissible heat exposure limits indicated in Table I and Figure 1 are not applicable. For each job category where special clothing is required, the permissible heat exposure limit shall be established by an expert.

B. Acclimatization and Fitness: The recommended heat stress TLVs are valid for acclimated workers who are physically fit.

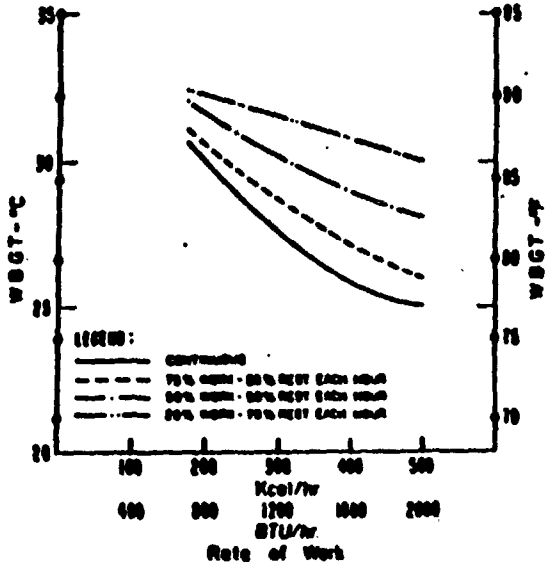

Figure 1 — Permissible Heat Exposure Threshold Limit Value

IONIZING RADIATION

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. A report, Basic Radiation Protection Criteria, published by the National Committee on Radiation Protection, revises and modernizes the concept of the NCRP standards of 1954, 1957 and 1958; obtainable as NCRP Rept. No. 39, P.O. Box 4867, Washington, D.C. 20008.

LASERS

The threshold limit values are for exposure to laser radiation under conditions to which nearly all workers may be exposed without adverse effects. The values should be used as guides in the control of exposures and should not be regarded as fine lines between safe and dangerous levels. They are based on the best available information from experimental studies.

Limiting Apertures

The TLVs expressed as radiant exposure or irradiance in this section may be averaged over an aperture of 1 mm except for TLVs for the eye in the spectral range of 400-1400 nm, which should be averaged over a 7 mm limiting aperture (pupil). No modification of the TLVs is permitted for pupil sizes less than 7 mm.

The TLVs for "extended sources" apply to sources which subtend an angle greater than α (Table 5) which varies with exposure time. This angle is not the beam divergence of the source.

Correction Factor A (CFA) for Eye Exposure

All TLVs in Tables 3 and 4 are to be used as given for wavelengths 400 nm to 700 nm. At all wavelengths greater than 1.00 μm and less than 1.4 μm the TLVs are to be increased by a factor of 5. TLV at wavelengths between 700 nm and 1.00 μm are to be increased by a uniformly extrapolated factor as shown in Figure 2.

Repetitively Pulsed Lasers

Since there are few experimental data for multiple pulses, caution must be used in the evaluation of such exposures. The protection standards for irradiance or radiant exposure in multiple pulse trains have the following limitations:

(1) The exposure from any single pulse in the train is limited to the protection standard for a single comparable pulse.

(2) The average irradiance for a group of pulses is limited to the protection standard as given in Tables 3, 4, or 6 of a single pulse of the same duration as the entire pulse group.

(3) When the Instantaneous Pulse Repetition Frequency (PRF) of any pulses within a train exceeds one, the protection standard applicable to each pulse is reduced as shown in Figure 6 for pulse durations less than 10^{-4} second. For pulses of greater duration, the following formula should be followed:

$$\text{Standard}\left(\begin{matrix}\text{single pulse}\\ \text{in train}\end{matrix}\right) = \frac{\text{Standard (pulse rate)}}{n}$$

where:

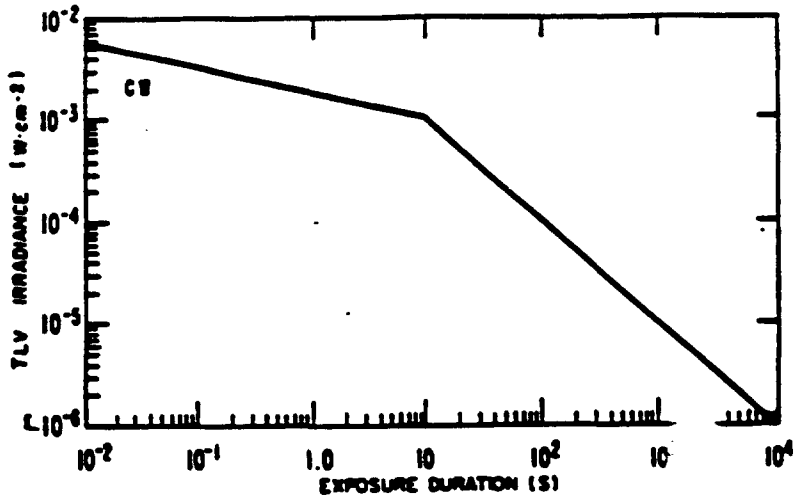

Figure 3b. TLV for intrabeam (direct) viewing of CW laser beam (400–700 nm).

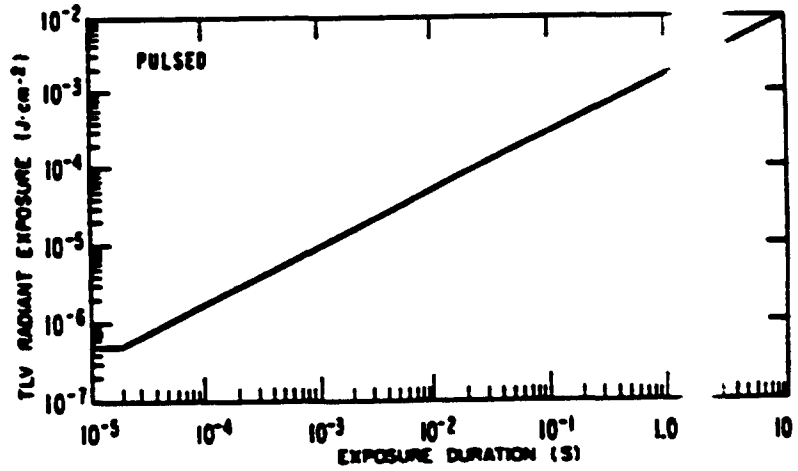

Figure 3a. TLV for intrabeam (direct) viewing of laser beam (400–700 nm).

n = number of pulses in train
t = duration of a single pulse in the train
Standard (nt) = protection standard of one pulse having a duration equal to nt seconds

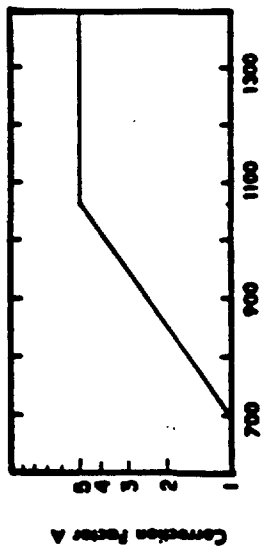

Figure 2. TLV correction factors for laser wavelengths (eye).

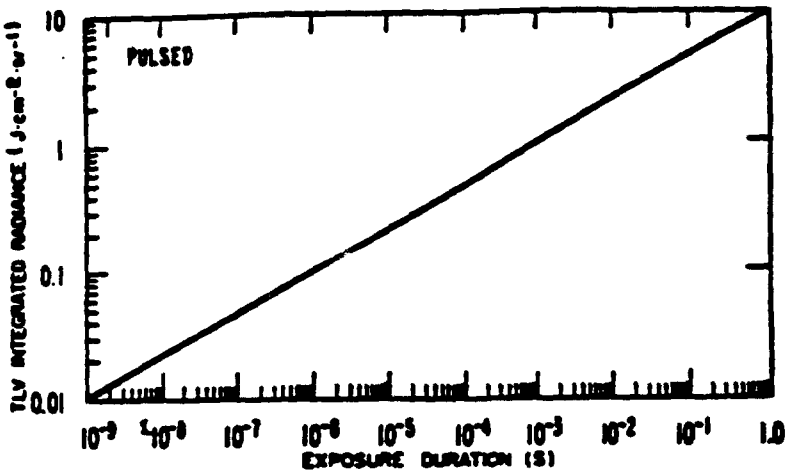

Figure 5a. TLV for extended sources or diffuse reflections of laser radiation (400–700 nm).

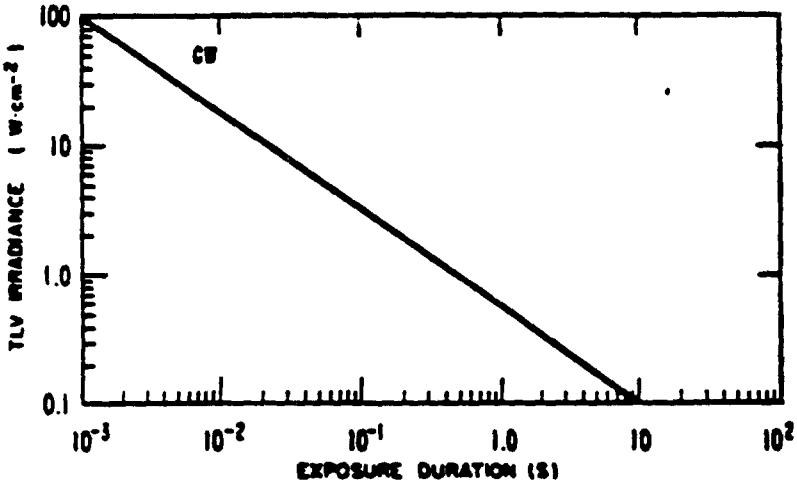

Figure 4b. TLV for CW laser exposure of skin and eyes for far-infrared radiation (wavelengths greater than 1.4 μm).

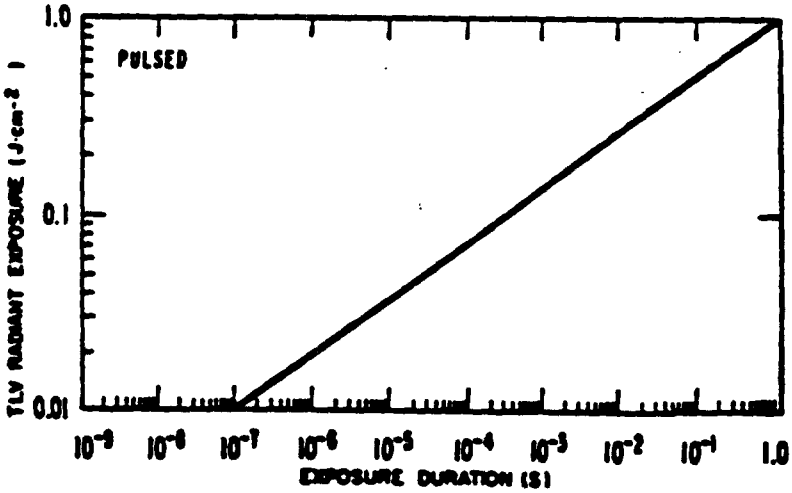

Figure 4a. TLV for laser exposure of skin and eyes for far-infrared

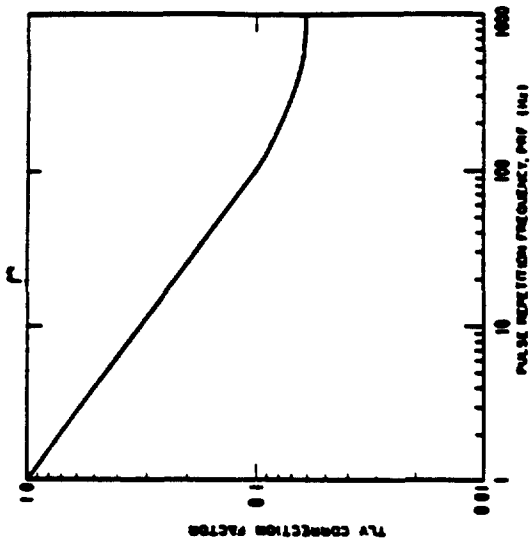

Figure 6. Multiplicative correction factor for repetitively pulsed lasers having ... less than 10^{-4} ... TLV for a single pulse of the pulse train is multiplied by the above correction factor. Correction factor for PRF greater than 1000 Hz is 0.06.

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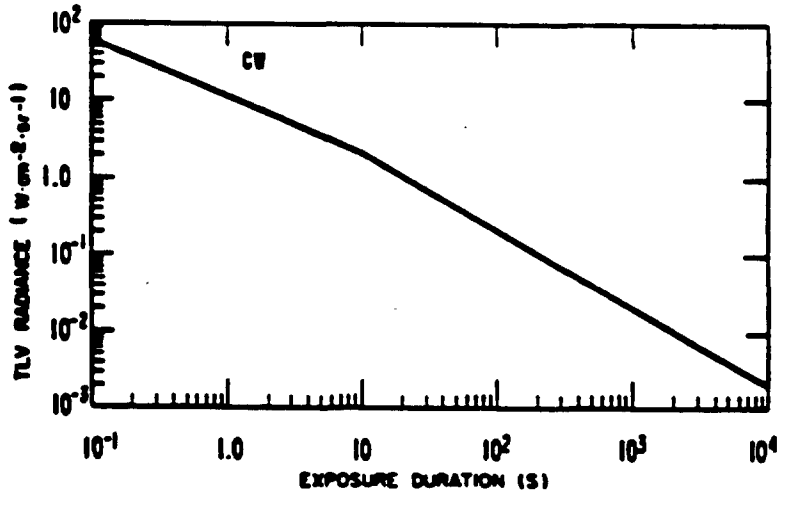

Figure 5b. TLV for extended sources or diffuse reflections of laser radiation (400–700 nm), CW.

TABLE 3

Threshold Limit Value for Direct Ocular Exposures (Intrabeam Viewing) from a Laser Beam

Spectral Region	Wave Length	Exposure Time, (t) Seconds	TLV
UVC	200 nm to 280 nm	10^{-9} to 3×10^{4}	3 mJ · cm^{-2}
UVB	280 nm to 302 nm	"	3 "
	303 nm	"	4 "
	304 nm	"	6 "
	305 nm	"	10 "
	306 nm	"	16 "
	307 nm	"	25 "
	308 nm	"	40 "
	309 nm	"	63 "
	310 nm	"	100 "
	311 nm	"	160 "
	312 nm	"	250 "
	313 nm	"	400 "
	314 nm	"	630 "
	315 nm	"	1.0 J · cm^{-2}
UVA	315 nm to 400 nm	10 to 10^{3}	1.0 J · cm^{-2}
"	"	10^{3} to 3×10^{4}	1.0 mW · cm^{-2}
Light	400 nm to 700 nm	10^{-9} to 1.8×10^{-5}	5×10^{-3} J · cm^{-2}
"	"	1.8×10^{-5} to 10	$\left[\frac{1.8t}{\sqrt{t}}\right]$ mJ · cm^{-2}
"	"	10 to 10^{4}	10 mJ · cm^{-2}
"	"	10^{4} to 3×10^{4}	10^{-2} W · cm^{-2}
Infrared A	700 nm to 1.06 μm	10^{-9} to 10^{3}	[light TLV's] × [CFA]
"	1.06 μm to 1.40 μm	10^{-9} to 10^{3}	(light TLV) × 5
"	700 nm to 1.06 μm	10^{3} to 3×10^{4}	10^{-2} [CFA] W · cm^{-2}
"	1.06 μm to 1.4 μm	" "	5×10^{-2} W · cm^{-2}
Infrared B & C	1.4 μm to 10^{3} μm	10^{-9} to 10^{-1}	10^{-3} J · cm^{-2}
"	" "	10^{-1} to 10	$0.56\sqrt{t}$ J · cm^{-2}
"	" "	10 to 3×10^{4}	0.1 W · cm^{-2}

NOTE: To aid in the determination of TLV's for exposure durations requiring calculations of fractional powers Figures 3, 4 and 6 may be used.

TABLE 4

Threshold Limit Values for Viewing a Diffuse Reflection of a Laser Beam or an Extended Source Laser

Spectral Region	Wave Length	Exposure Time, (t) Seconds	TLV
UV	200 nm to 400 nm	10^{-9} to 3×10^{4}	Same as Table 3
Light	400 nm to 700 nm	10^{-9} to 10	$10 \cdot \sqrt{t}$ J · cm^{-2} · sr^{-1}
"	"	10 to 10^{4}	20 J · cm^{-2} · sr^{-1}
"	"	10^{4} to 3×10^{4}	2×10^{-3} W · cm^{-2} · sr^{-1}
Infrared A	700 nm to 1.06 μm	10^{-9} to 10	CFA $\times$ 10 $\sqrt{t}$ J · cm^{-2} · sr^{-1}
"	"	10 to 10^{3}	CFA $\times$ 20 J · cm^{-2} · sr^{-1}
"	"	10^{3} to 3×10^{4}	CFA $\times$ 0.2 W · cm^{-2} · sr^{-1}
"	1.06 μm to 1.4 μm	10^{-9} to 10	50 $\times$ $\sqrt{t}$ J · cm^{-2} · sr^{-1}
"	"	10 to 10^{3}	100 J · cm^{-2} · sr^{-1}
"	"	10^{3} to 3×10^{4}	1.0 W · cm^{-2} · sr^{-1}
Infrared B & C	1.4 μm to 1 mm	10^{-9} to 3×10^{4}	Same as Table 3

NOTE: To aid in the determination of TLV's for exposure durations requiring calculations of fractional powers Figures 3 and 6 may be used.

TABLE 5

Limiting Angle of Extended Source TLVs Which May Be Used for Applying Extended Source TLVs

Exposure Duration(s)	Angle $\times$ (mrad)
10^{-9}	8.0
10^{-8}	5.6
10^{-7}	3.9
10^{-6}	2.8
10^{-5}	1.9
10^{-4}	2.2
10^{-3}	3.6
10^{-2}	5.9
10^{-1}	9.2
1.0	15
10	24
10^{2}	24
10^{3}	24
10^{4}	24

TABLE 6

Threshold Limit Value for Skin Exposure from a Laser Beam

Spectral Region	Wave Length	Exposure Time, (t) Seconds	TLV
UV	200 nm to 400 nm	10^{-9} to 3×10^{4}	Same as Table 3
Light & Infrared A	400 nm to 1400 nm	10^{-9} to 10^{-7}	2×10^{-2} J · cm^{-2}
"	"	10^{-7} to 10	1.1 $\sqrt{t}$ J · cm^{2}
"	"	10 to 3×10^{4}	0.2 W · cm^{-2}
Infrared B & C	1.4 μm to 1 mm	10^{-9} to 3×10^{4}	Same as Table 3

NOTE: To aid in the determination of TLV's for exposure durations requiring calculations of fractional powers Figures 3, 4 and 6 may be used.

MICROWAVES

These Threshold Limit Values refer to microwave energy in the frequency range of 100 Mlls to 100 Gllz and represent conditions under which it is believed that nearly all workers may be repeatedly exposed without adverse effect.

These values should be used as guides in the control of exposure of microwaves and should not be regarded as a fine line between safe and dangerous levels.

Recommended Values

The Threshold Limit Value for occupational microwave energy exposure where power densities are known and exposure time controlled is as follows:

1. For average power density levels up to but not exceeding 10 milliwatts per square centimeter, total exposure time shall be limited to the 8-hour workday (continuous exposure).
2. For average power density levels from 10 milliwatts per square centimeter up to but not exceeding 25 milliwatts per square centimeter, total exposure time shall be limited to no more than 10 minutes for any 60 minute period during an 8-hour workday (intermittent exposure).
3. For average power density levels in excess of 25 milliwatts per square centimeter, exposure is not permissible.

NOTE: For repetitively pulsed sources the average power density may be calculated by multiplying the peak power density by the duty cycle. The duty cycle is equal to the pulse duration in seconds times the pulse repetition rate in hertz.

NOISE*

These threshold limit values refer to sound pressure levels that represent conditions under which it is believed that nearly all workers may be repeatedly exposed without adverse effect on their ability to hear and understand normal speech. The medical profession (1, 2) has defined hearing impairment as an average hearing threshold level in excess of 25 decibels (ANSI S3.6 – 1969) at 500, 1000, and 2000 Hz, and the limits which are given have been established to prevent a hearing loss in excess of this value. These values should be used as guides in the control of noise exposure and, due to individual susceptibility, should not be regarded as fine lines between safe and dangerous levels.

Continuous or Intermittent

The sound level shall be determined by a sound level meter, meeting the standards of the American National Standards Institute and operating on the A-weighting network with slow meter response. Duration of exposure shall not *exceed that shown in Table 7.*

1. Guides for the Evaluation of Hearing Impairment. Transactions of the American Academy of Ophthalmology and Otolaryngology. (March-April, 1961).
2. Guides to the Evaluation of the Permanent Impairment; Ear, Nose, Throat and Related Structures. Journal of the American Medical Association 197:489 (August 1961).

*See Notice of Intended Changes, Page 92.

TABLE 7

Permissible Noise Exposures

Duration per day Hours	Sound Level dBA[a]
8	90
6	92
4	95
3	97
2	100
1-1/2	102
1	105
3/4	107
1/2	110
1/4	115*

* No exposure in excess of 115 dBA.

a) Sound level in decibels as measured on a standard level meter operating on the A-weighting network with slow meter response.

These values apply to total time of exposure per working day regardless of whether this is one continuous exposure or a number of short-term exposures but does not apply to impact or impulsive type of noises.

When the daily noise exposure is composed of two or more periods of noise exposure of different levels, their combined effect should be considered, rather than the individual effect of each. If the sum of the following fractions,

$$\frac{C_1}{T_1} + \frac{C_2}{T_2} + \cdots \frac{C_n}{T_n}$$

exceeds unity, then, the mixed exposure should be considered to exceed the threshold limit value, C_1 indicates the total time of exposure at a specified noise level, and T_1 indicates the total time of exposure permitted at that level. Noise exposures of less than 90 dBA do not enter into the above calculations.

Impulse or Impact Noise

It is recommended that exposure to impulsive or impact noise should not exceed 140 decibels peak sound pressure level.

ULTRAVIOLET RADIATION*

These threshold limit values refer to ultraviolet radiation in the spectral region between 200 and 400 nm and represent conditions under which it is believed that nearly all workers may be repeatedly exposed without adverse effect. These values for exposure of the eye or the skin apply to ultraviolet radiation from arcs, gas, and vapor discharges, fluorescent, and incandescent sources, but do not apply to ultraviolet lasers** or solar radiation. These levels should not be used for determining exposure of photosensitive individuals to ultraviolet radiation. These values should be used as guides in the control of exposure to continuous sources where the exposure duration shall not be less than 0.1 sec.

These values should be used as guides in the control of exposure to ultraviolet sources and should not be regarded as a fine line between safe and dangerous levels.

Recommended Values:

The threshold limit value for occupational exposure to ultraviolet radiation incident upon skin or eye where irradiance values are known and exposure time is controlled are as follows:

1. For the near ultraviolet spectral region (320 to 400 mm) total irradiance incident upon the unprotected skin or eye should not exceed 1 mw/cm² for periods greater than 10^3 seconds (approximately 16 minutes) and for exposure times less than 10^3 seconds should not exceed one J/cm².
2. For the actinic ultraviolet spectral region (200 — 315 nm), radiant exposure incident upon the unprotected skin or eye should not exceed the values given in Table 8 within an 8-hour period.
3. To determine the effective irradiance of a broadband source weighted against the peak of the spectral effectiveness curve (270 nm), the

$$E_{eff} = \sum E_\lambda S_\lambda \Delta_\lambda$$

where:

E_{eff} = effective irradiance relative to a monochromatic source at 270 nm

E_λ = spectral irradiance in W/cm²/nm

S_λ = relative spectral effectiveness (*unitless*)

Δ_λ = band width in nanometers

4. Permissible exposure time in seconds for exposure to actinic ultraviolet radiation incident upon the unprotected skin or eye may be computed by dividing 0.003 J/cm² by E_{eff} in W/cm². The exposure time may also be determined using Table 9 which provides exposure times corresponding to effective irradiances in μW/cm².

TABLE 8

Relative Spectral Effectiveness by Wave Length

Wavelength (nm)	TLV (mJ/cm²)	Relative Spectral Effectiveness S_λ
200	100	0.03
210	40	0.075
220	25	0.12
230	16	0.19
240	10	0.30
250	7.0	0.43
	6.0	0.5
	4.0	0.65
270	3.0	1.0
280	3.4	0.88
290	4.7	0.64
300	10	0.30
305	50	0.06
310	200	0.015
315	1000	0.003

See Notice of Intended Changes, Page 92.
*See Laser TLVs.

TABLE 9

Permissible Ultraviolet Exposures

Duration of Exposure Per Day	Effective Irradiance, E_{eff} ($\mu W/cm^2$)
8 hrs.	0.1
4 hrs.	0.2
2 hrs.	0.4
1 hr.	0.8
1/2 hr.	1.7
15 min.	3.3
10 min.	5
5 min.	10
1 min.	50
30 sec.	100
10 sec.	300
1 sec.	3,000
0.5 sec.	6,000
0.1 sec.	30,000

All the preceding TLV's for ultraviolet energy apply to sources which subtend an angle less than 80°. Sources which subtend a greater angle need to be measured only over an angle of 80°.

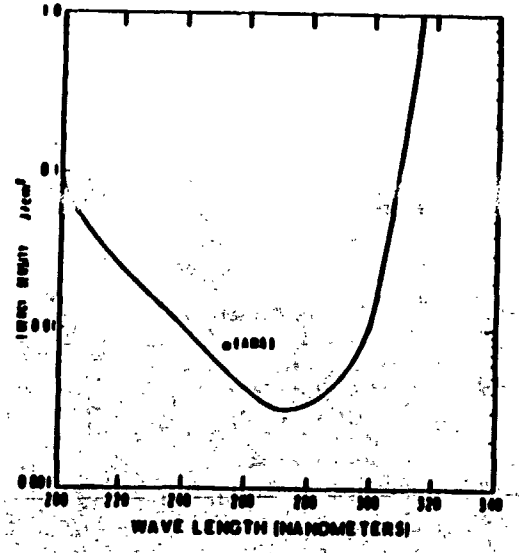

Figure 7. Threshold Limit Values for Ultraviolet Radiation

NOTICE OF INTENDED CHANGES (for 1973)

These physical agents, with their corresponding values, comprise those for which either a limit has been proposed for the first time, or for which a change in the "Adopted" listing has been proposed. In both cases, the proposed limits should be considered trial limits that will remain in the listing for a period of at least one year. If, after one year no evidence comes to light that questions the appropriateness of the values herein, the values will be reconsidered for the "Adopted" list.

NOISE

These threshold limit values refer to sound pressure levels and durations of exposure that represent conditions under which it is believed that nearly all workers may be repeatedly exposed without adverse effect on their ability to hear and understand normal speech. The medical profession has defined hearing impairment as an average hearing threshold level in excess of 25 decibels (ANSI-S3.6-1969) at 500, 1000, and 2000 Hz, and the limits which are given have been established to prevent a hearing loss in excess of this level. The values should be used as guides in the control of noise exposure and, due to individual susceptibility, should not be regarded as fine lines between safe and dangerous levels.

Continuous or Intermittent

The sound level shall be determined by a sound level meter, conforming as a minimum to the requirements of the American Na-

tional Standard Specification for Sound Level Meters, S1.4 (1971) Type S2A, and set to use the A-weighted network with slow meter response. Duration of exposure shall not exceed that shown in Table 10.

These values apply to total duration of exposure per working day regardless of whether this is one continuous exposure or a number of short-term exposures but does not apply to impact or impulsive type of noise.

When the daily noise exposure is composed of two or more periods of noise exposure of different levels, their combined effect should be considered, rather than the individual effect of each. If the sum of the following fractions:

$$\frac{C_1}{T_1} + \frac{C_2}{T_2} + \cdots \frac{C_n}{T_n}$$

exceeds unity, then, the mixed exposure should be considered to exceed the threshold limit value. C_1 indicates the total duration of exposure at a specific noise level, and T_1 indicates the total duration of exposure permitted at that level. All exposures of 80 dBA or greater shall be used in the above calculations.

Impulsive or Impact Noise

It is recommended that exposure to impulsive or impact noise should not exceed 140 decibles peak sound pressure level. Impulsive or impact noise is considered to be those variations in noise levels that involve maxima at intervals of greater than one per second. Where the intervals are less than one second, it should be considered continuous.

Table 10

Threshold Limit Values

Duration per day Hours	Sound Level dBA[a]
16	80
8	85
4	90
2	95
1	100
1/2	105
1/4	110
1/8	115*

* No exposure to continuous or intermittent in excess of 115 dBA

a) Sound level in decibels as measured on a sound level meter, conforming as a minimum to the requirements of the American National Standard Specification for Sound Level Meters, S1.4 (1971) Type S2A, and set to use the A-weighted network with slow meter response.

The threshold limit value shall apply also to solar radiation.