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TLVs®
Threshold Limit Values
for
Chemical Substances
and
Physical Agents
in the
Workroom Environment
with
Intended Changes
for
1976

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Documentation of the Threshold Limit Values for Substances in Workroom Air.© A separate companion piece to the Chemical TLVs is issued by ACGIH under this title. This publication gives the pertinent scientific information and data with reference to literature sources that were used to base each limit. Each documentation also contains a statement defining the type of response against which the limit is safeguarding the worker. For a better understanding of the TLVs it is essential that the Documentation be consulted when the TLVs are being used.

Information concerning the availability of copies of the Documentation of the Threshold Limit Values for Substances in Workroom Air should be directed to the Secretary-Treasurer, ACGIH.

TLVs®
Threshold Limit Values for Chemical Substances in Workroom Air Adopted by ACGIH for 1976



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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. 15: 564, 1973; 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 "coverage" of the TLVs.

Three categories of Threshold Limit Values (TLVs) are specified herein, as follows:

a) Threshold Limit Value-Time Weighted Average (TLV-TWA) — the time-weighted average concentration for a normal 8-hour workday or 40-hour workweek, to which nearly all workers may be repeatedly exposed, day after day, without adverse effect.

b) Threshold Limit Value-Short Term Exposure Limit (TLV-STEL) — the maximal concentration to which workers can be exposed for a period up to 15 minutes continuously without suffering from 1) intolerable irritation, 2) chronic or irreversible tissue change, or 3) narcosis of sufficient degree to increase accident proneness, impair self-rescue, or materially reduce work efficiency, provided that no more than four excursions per day are permitted, with at least 60 minutes between exposure periods, and provided that the daily TLV-TWA also is not exceeded. The STEL should be considered a maximal allowable concentration, or absolute ceiling, not to be exceeded at any time during the 15-minute excursion period. STELs are based on one or more of the following criteria: (1) Adopted TLVs including those with a "C" or "ceiling" limit. (2) TWA-TLV Excursion Factors listed in Appendix D. (3) Pennsylvania Short-Term Limits for Exposure to Airborne Contaminants (Penna. Dept. of Hlth., Chapter 4, Art. 432, Rev. Jan. 25, 1968). (4) OSHA Occupational Safety and Health Standards, Fed. Reg. Vol. 36, No. 105, May 29, 1971. The TWA-STEL should not be used as engineering design criterion or considered as an emergency exposure level (EEL).

c) Threshold Limit Value-Ceiling (TLV-C) — the concentration that should not be exceeded even instantaneously.

For some substances, e.g., irritant gases, only one category, the TLV-Ceiling, may be relevant. For other substances, either two or three categories may be relevant, depending upon their physiologic action. It is important to observe that if any one of these three TLVs is exceeded, a potential hazard from that substance is presumed to exist.

The TLV-TWA 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 those substances in Category c), which have been designated "C" or Ceiling limit.]

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-fac-

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tors must be taken into consideration in arriving at a 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 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 control of community air pollution nuisances, (3) in estimating the toxic potential of continuous, uninterrupted exposures or other extended work periods, (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 noncompliance 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 determining the magnitude of the value of the STELs, or 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 mucous 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

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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, may cause unpleasant deposits in the eyes, ears and nasal 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 10 mg/m^3, 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.

Physical Factors. It is recognized that such physical factors as heat, ultraviolet and ionizing 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 may be altered. Most of these stresses act adversely 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. Brief & Scala (AIHAJ. 26, 467, 1975) have proposed formulae for calculating the TLV Reduction Factor for Novel Work Schedules, i.e. 10-hr workday.

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;

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(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 BLVs, and their associated procedures for determining compliance with them, should thus be regarded as an effective means of providing health surveillance of the worker

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 for 1968 are now official federal standards for industrial air.

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	ADOPTED VALUES		TENTATIVE VALUES	
	TWA		STEL	
Substance	ppm[a]	mg/m³[b]	ppm[a]	mg/m³[b]
Abate	—	10	—	20
Acetaldehyde	100	180	150	270
Acetic acid	10	25	15	37
C Acetic anhydride	5	20	5	20
Acetone	1,000	2,400	1,250	3,000
Acetonitrile	40	70	60	105
Acetylene	F	—	—	—
Acetylene dichloride, see 1, 2-Dichloroethylene	200	790	250	1,000
Acetylene tetrabromide	1	14	1.25	17.5
Acrolein	0.1	0.25	0.3	0.75
Acrylamide — Skin	—	0.3	—	0.6
Acrylonitrile — Skin	20	45	30	68
Aldrin — Skin	—	0.25	—	0 75
Allyl alcohol — Skin	2	5	4	10
Allyl chloride	1	3	2	6
Allyl glycidyl ether (AGE) — Skin	5	22	10	44
Allyl propyl disulfide	2	12	3	18
Alundum (Al_2O_3)	—	E	—	20
4-Aminodiphenyl — Skin	—	A1b	—	A1b
2-Aminoethanol, see Ethanolamine	3	6	6	12
2-Aminopyridine	0.5	2	1.5	6
Ammonia	25	18	35	27
Ammonium chloride-fume	—	10	—	20
Ammonium sulfamate (Ammate)	—	10	—	20
n-Amyl acetate	100	525	150	790
sec-Amyl acetate	125	650	150	810
Aniline — Skin	5	19	5	19
Anisidine (o-, p-isomers) — Skin	0.1	0.5	0.1	0.5
** Antimony & Compounds (as Sb)	—	(0.5)	—	(0.75)
ANTU (α-Naphthyl thiourea)	—	0.3	—	0 9

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

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Substance	ADOPTED VALUES TWA ppm[a]	TWA mg/m³[b]	TENTATIVE VALUES STEL ppm[a]	STEL mg/m³[b]
Argon	F	—	F	F
** Arsenic & compounds (as As)	—	(0.5)	—	(0.5)
Arsine	0.05	0.2	0.05	0.2
Asbestos (all forms)	—	A1a	A1a	A1a
Asphalt (petroleum) fumes	—	5	—	10
Azinphos methyl — Skin	—	0.2	—	0.6
Baygon (propoxur)	—	0.5	—	1.5
Barium (soluble compounds)	—	0.5	—	0.5
**C Benzene — Skin	(25)	(80)	(10)	(32)
Benzidine production — Skin	—	A1b	—	A1b
p-Benzoquinone, see Quinone	0.1	0.4	0.3	1.2
Benzoyl peroxide	—	5	—	5
Benzyl chloride	1	5	1	5
Beryllium	—	0.002	—	0.025
Biphenyl	0.2	1	0.2	1
Bismuth telluride	—	10	—	20
Bismuth telluride, Se-doped	—	5	—	10
Boron oxide	—	10	—	20
Boron tribromide	1	10	3	30
C Boron trifluoride	1	3	1	3
Bromine	0.1	0.7	0.3	2
Bromine pentafluoride	0.1	0.7	0.3	2
Bromochloromethane	200	1,050	250	1,300
Bromoform — Skin	0.5	5	0.5	5
Butadiene (1, 3-butadiene)	1,000	2,200	1,250	2,750
* Butane	600	1,400	750	1,610
Butanethiol, see Butyl mercaptan	0.5	1.5	0.5	1.5
2-Butanone	200	590	300	885
2-Butoxy ethanol (Butyl Cellosolve) — Skin	50	240	150	720

Capital letters refer to Appendices
Footnotes (a thru h) see Page 31
**See Notice of Intended Changes
*1976 Addition.

Substance	ADOPTED VALUES TWA ppm[a]	TWA mg/m³[b]	TENTATIVE VALUES STEL ppm[a]	STEL mg/m³[b]
n-Butyl acetate	150	710	200	950
sec-Butyl acetate	200	950	250	1,190
tert-Butyl acetate	200	950	250	1,190
*C n-Butyl alcohol — Skin	50	150	50	150
sec-Butyl alcohol	150	450	150	450
tert-Butyl alcohol	100	300	150	450
C Butylamine — Skin	5	15	5	15
C tert-Butyl chromate (as CrO_3) — Skin	—	0.1	—	0.1
n-Butyl glycidyl ether (BGE)	50	270	50	270
* n-Butyl lactate	5	25	5	25
Butyl mercaptan	0.5	1.5	0.5	1.5
p-tert-Butyltoluene	10	60	20	120
* Cadmium, dust & salts, as Cd	—	0.05	—	0.15
C Cadmium oxide fume, as Cd	—	0.05	—	0.05
Calcium carbonate	—	E	—	20
Calcium arsenate, as As	—	1	—	1
Calcium cyanamide	—	0.5	—	1
** Calcium oxide	—	(5)	—	(5)
Camphor, synthetic	2	12	3	18
Caprolactam Dust	—	1	—	3
Vapor	5	20	10	40
* Captan	—	5	—	15
Carbaryl (Sevin®)	—	5	—	10
* Carbofuran (Furadan®)	—	0.1	—	0.1
Carbon black	—	3.5	—	7
Carbon dioxide	5,000†	9,000	15,000	18,000
Carbon disulfide — Skin	20	60	30	90
Carbon monoxide	50	55	400	440
Carbon tetrabromide	0.1	1.4	0.3	4.2
Carbon tetrachloride — Skin	10	65	25	160
Cellulose (paper fiber)	—	E	—	20
Cesium hydroxide	—	2	—	2

Capital letters refer to Appendices.
†See 1974 Revised Documentation.
*1976 Addition.

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Substance	ADOPTED VALUES TWA ppm[a]	ADOPTED VALUES TWA mg/m³[b]	TENTATIVE VALUES STEL ppm[a]	TENTATIVE VALUES STEL mg/m³[b]
Chlordane — Skin	—	0.5	—	2
Chlorinated camphene — Skin	—	0.5	—	1
Chlorinated diphenyl oxide	—	0.5	—	1.5
Chlorine	1	3	3	9
Chlorine dioxide	0.1	0.3	0.3	0.9
C Chlorine trifluoride	0.1	0.4	0.1	0 4
C Chloroacetaldehyde	1	3	1	3
α-Chloroacetophenone (Phenacyl chloride)	0.05	0.3	0.05	0.3
Chlorobenzene (Monochlorobenzene)	75	350	75	350
o-Chlorobenzylidene malonoitrile — Skin	0.05	0.4	0.05	0.4
Chlorobromomethane	200	1,050	250	1,300
2-Chloro-1, 3-butadiene, see β Chloroprene	25	90	35	135
Chlorodifluoromethane	1,000	3,500	1,250	4,375
Chlorodiphenyl (42% Chlorine) — Skin	—	1	—	1
Chlorodiphenyl (54% Chlorine) — Skin	—	0.5	—	.1
1-Chloro, 2, 3-epoxy-propane (Epichlor-hydrin)	5	19	10	38
2-Chloroethanol (Ethylene chlorohydrin)	1	3	1	3
Chloroethylene (Vinyl chloride)	A1c	—	A1c	—
** Chloroform (Trichloromethane)	(25)	(120)	25A3	—
bis-Chloromethyl ether	0.001	A1a	0.001	A1a
1-Chloro-1-nitro-propane	20	100	20	100
Chloropicrin	0.1	0.7	0 1	0.7
β-Chloroprene — Skin	25	90	35	135

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

Substance	ADOPTED VALUES TWA ppm[a]	ADOPTED VALUES TWA mg/m³[b]	TENTATIVE VALUES STEL ppm[a]	TENTATIVE VALUES STEL mg/m³[b]
Chlorpyrifos (Dursban®) — Skin	—	0.2	—	0.6
o-Chlorostyrene	50	285	75	430
o-Chlorotoluene — Skin	50	250	75	375
2-Chloro-6-(trichloromethyl pyridine (N-Serve®)	—	10	—	20
Chromates, certain insoluble forms	—	A1a	—	A1a
Chromic acid and Chromates, as CrO_3	—	0.1	—	0.1
Chromium, Sol. chromic, chromous salts, as Cr.	—	0.5	—	0.5
Clopidol (Coyden®)	—	10	—	20
Coal tar pitch volatiles (See Particulate polycyclic aromatic hydrocarbons)	—	A1a	—	A1a
** Cobalt metal, dust and fume	—	(0.1)	—	(0.1)
Copper fume	—	0.2	—	0.2
Dusts & Mists	—	1	—	2
Corundum (Al_2O_3)	—	E	—	E
Cotton dust, raw	—	0.2[m]	—	0.6
Crag® herbicide	—	10	—	20
Cresol, all isomers — Skin	5	22	5	22
Crotonaldehyde	2	6	6	18
Crufomate®	—	5	—	20
Cumene — Skin	50	245	75	365
Cyanide, as CN — Skin	—	5	—	5
Cyanogen	10	20	10	20
Cyclohexane	300	1,050	375	1,300
Cyclohexanol	50	200	50	200
Cyclohexanone	50	200	50	200
Cyclohexene	300	1,015	300	1,015

Capital letters refer to Appendices.
**See Notice of Intended Changes.
m) See p. 33.

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Substance	ADOPTED VALUES TWA ppm[a]	ADOPTED VALUES TWA mg/m³[b]	TENTATIVE VALUES STEL ppm[a]	TENTATIVE VALUES STEL mg/m³[b]
Cyclohexylamine — Skin	10	40	10	40
Cyclopentadiene	75	200	150	400
2, 4-D (2, 4-Diphenoxy-acetic acid)	—	10	—	20
DDT (Dichlorodiphenyl-trichloroethane)	—	1	—	3
DDVP, See Dichlorvos	0.1	1	0.3	3
Decaborane — Skin	0.05	0.3	0.15	0.9
Demeton® — Skin	0.01	0.1	0.03	0.3
Diacetone alcohol (4-hydroxy-4-methyl-2-pentanone)	50	240	75	360
1, 2-Diaminoethane, See Ethylenediamine	10	25	10	25
Diazinon — Skin	—	0.1	—	0.3
Diazomethane	0.2	0.4	0.2	0.4
Diborane	0.1	0.1	0.1	0.1
1, 2-Dibromoethane (Ethylene dibromide) — Skin	20	145	30	220
Dibrom®	—	3	—	6
2-N-Dibutylaminoethanol — Skin	2	14	4	28
Dibutyl phosphate	1	5	2	10
Dibutyl phthalate	—	5	—	10
C Dichloracetylene	0.1	0.4	0.1	0.4
C o-Dichlorobenzene	50	300	50	300
p-Dichlorobenzene	75	450	110	675
Dichlorobenzidine — Skin	—	A2	—	A2
Dichlorodifluoromethane	1,000	4,950	1,250	6,200
1, 3-Dichloro-5, 5-dimethyl hydantoin	—	0.2	—	0.4
1, 1-Dichloroethane	200	820	250	1,025
1, 2-Dichloroethane	50	200	75	300
1, 2-Dichloroethylene	200	790	250	1,000
Dichloroethyl ether — Skin	5	30	10	60

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

Substance	ADOPTED VALUES TWA ppm[a]	ADOPTED VALUES TWA mg/m³[b]	TENTATIVE VALUES STEL ppm[a]	TENTATIVE VALUES STEL mg/m³[b]
* Dichloromethane, see Methylene chloride	200	720	200	720
** Dichloromonofluoro-methane	(1,000)	(4,200)	(1,250)	(5,250)
C 1, 1-Dichloro-1-nitroethane	10	60	10	60
1, 2-Dichloropropane, see Propylene dichloride	75	350	110	525
Dichlorotetrafluoro-ethane	1,000	7,000	1,250	8,750
Dichlorvos (DDVP) — Skin	0.1	1	0.3	3
* Dicyclopentadiene	5	30	5	30
Dicyclopentadienyl iron	—	10	—	20
Dieldrin — Skin	—	0.25	—	0.75
Diethylamine	25	75	25	75
Diethylaminoethanol — Skin	10	50	10	50
Diethylene triamine — Skin	1	4	1	4
Diethyl ether, see Ethyl ether	400	1,200	500	1,500
Diethyl phthalate	—	5	—	10
Difluorodibromomethane	100	860	150	1,290
C Diglycidyl ether (DGE)	0.5	2.8	0.5	2.8
Dihydroxybenzene, see Hydroquinone	—	2	—	3
Diisobutyl ketone	25	150	25	150
Diisopropylamine — Skin	5	20	5	20
Dimethoxymethane, see Methylal	1,000	3,100	1,250	3,875
Dimethyl acetamide — Skin	10	35	15	50
Dimethylamine	10	18	10	18

Capital letters refer to Appendices.
Footnotes (a thru h) see Page 31.
*1976 Addition.
**See Notice of Intended Changes.

MAP 000010

Substance	ADOPTED VALUES TWA ppm[a]	TWA mg/m³[b]	TENTATIVE VALUES STEL ppm[a]	STEL mg/m³[b]
Dimethylaminobenzene, see Xylidene	5	25	10	50
Dimethylaniline (N-Dimethylaniline) — Skin	5	25	10	50
Dimethylbenzene, see Xylene	100	435	150	650
Dimethyl-1, 2-dibromo-2-dichloroethyl phosphate, see Dibrom	—	3	—	6
Dimethylformamide — Skin	10	30	20	60
2, 6-Dimethylheptanone, see Diisobutyl ketone	25	150	25	150
1, 1-Dimethylhydrazine — Skin	0.5	1	1	2
Dimethylphthalate	—	5	—	10
** Dimethyl sulphate — Skin	(0.01)	(A2)	A2	—
Dinitrobenzene (all isomers) — Skin	0.15	1	0.5	3
Dinitro-o-cresol — Skin	—	0.2	—	0.6
3, 5-Dinitro-o-toluamide (Zoalene®)	—	5	—	10
Dinitrotoluene — Skin	—	1.5	—	5
Dioxane, tech. grade — Skin	50	180	50	180
Diphenyl, see Biphenyl	0.2	1	0.6	3
Diphenylamine	—	10	—	20
Diphenylmethane diisocyanate, see Methylene bisphenyl isocyanate (MDI)	0.02	0.2	0.02	0.2
Dipropylene glycol methyl ether — Skin	100	600	150	900

Capital letters refer to Appendices.
*1976 Addition.
**See Notice of Intended Changes.

Substance	ADOPTED VALUES TWA ppm[a]	TWA mg/m³[b]	TENTATIVE VALUES STEL ppm[a]	STEL mg/m³[b]
Diquat	—	0.5	—	1
Di-sec. octyl phthalate (Di-2-ethylhexyl-phthalate)	—	5	—	10
* Disulfuram	—	2	—	5
Disyston — Skin	—	0.1	—	0.3
2, 6-Ditert. butyl-p-cresol	—	10	—	20
* Dyfonate	—	0.1	—	0.1
Emery	—	E	—	20
Endosulfan (Thiodan®) — Skin	—	0.1	—	0.3
Endrin — Skin	—	0.1	—	0.3
Epichlorhydrin — Skin	5	20	10	40
EPN — Skin	—	0.5	—	1.5
1, 2-Epoxypropane, see Propylene oxide	100	240	150	360
2, 3-Epoxy-l-propanol, see Glycidol	50	150	65	190
Ethane	F	—	F	—
Ethanethiol, see Ethyl mercaptan	0.5	1	1.5	3
Ethanolamine	3	6	6	12
* Ethion (Nialate®) — Skin	—	0.4	—	0.4
2-Ethoxyethanol — Skin	100	370	150	560
2-Ethoxyethyl acetate (Cellosolve acetate) — Skin	100	540	150	810
Ethyl acetate	400	1,400	400	1,400
Ethyl acrylate — Skin	25	100	25	100
Ethyl alcohol (Ethanol)	1,000	1,900	1,000	1,900
Ethylamine	10	18	10	18
Ethyl sec-amyl ketone (4-Methyl-3-heptanone)	25	130	25	130
Ethyl benzene	100	435	125	545
Ethyl bromide	200	890	250	1,110

Capital letters refer to Appendices.
*1976 Addition.

MAP 000011

Substance	ADOPTED VALUES TWA ppm[a]	ADOPTED VALUES TWA mg/m³[b]	TENTATIVE VALUES STEL ppm[a]	TENTATIVE VALUES STEL mg/m³[b]
Ethylbutyl ketone (3-Heptanone)	50	230	75	345
Ethyl chloride	1,000	2,600	1,250	3,250
Ethyl ether	400	1,200	500	1,500
Ethyl formate	100	300	150	450
Ethyl mercaptan	0.5	1	0.5	1
Ethyl silicate	100	850	150	1,275
Ethylene	F	—	F	—
°C Ethylene chlorohydrin — Skin	1	3	1	3
Ethylene diamine	10	25	10	25
Ethylene dibromide, see 1, 2-Dibromoethane	20	145	30	220
Ethylene dichloride, see 1, 2-Dichloroethane	50	200	75	300
Ethylene glycol, Particulate	—	10	—	20
Vapor	100	260	125	325
C Ethylene glycol dinitrate and/or Nitroglycerin — Skin	0.2[d]	—	0.2	—
Ethylene glycol monomethyl ether acetate (Methyl cellosolve acetate) — Skin	25	120	40	180
Ethylene oxide	50	90	75	135
Ethylenimine — Skin	0.5	1	0.5	1
Ethylidene chloride, see 1, 1-Dichloroethane	200	320	250	400
C Ethylidene norbornene	5	25	5	25
N-Ethylmorpholine — Skin	20	94	20	94
* Fensulfothion (Dasanit)	—	0.1	—	0.1
Ferbam	—	10	—	20
Ferrovanadium dust	—	1	—	0.3
Fluoride (as F)	—	2.5	—	2.5
Fluorine	1	2	2	4

Capital letters refer to Appendices.
Footnotes (a thru h) see Page 31.
*1976 Addition.

Substance	ADOPTED VALUES TWA ppm[a]	ADOPTED VALUES TWA mg/m³[b]	TENTATIVE VALUES STEL ppm[a]	TENTATIVE VALUES STEL mg/m³[b]
Fluorotrichloromethane	1,000	5,600	1,250	7,000
C Formaldehyde	2	3	2	3
Formamide	20	30	30	45
Formic acid	5	9	5	9
Furfural — Skin	5	20	15	60
Furfuryl alcohol — Skin	5	20	10	40
Gasoline	—	B2	—	B2
Germanium tetrahydride	0.2	0.6	0.6	1.8
Glass, fibrous[e] or dust	—	E	—	E
**C Glutaraldehyde, activated or unactivated	—	(0.25)	—	(0.25)
Glycerin mist	—	E	—	E
Glycidol (2, 3-Epoxy-1-propanol)	50	150	75	225
Glycol monoethyl ether, see 2-Ethoxyethanol	100	370	150	560
Graphite (Synthetic)	—	E	—	—
Guthion®, see Azinphos-methyl	—	0.2	—	0.6
Gypsum	—	E	—	20
Hafnium	—	0.5	—	1.5
Helium	F	—	F	—
Heptachlor — Skin	—	0.5	—	1.5
* Heptane (n-Heptane)	400	1,600	500	2,000
Hexachlorocyclopentadiene	0.01	0.11	0.03	0.33
Hexachloroethane — Skin	1	10	3	30
Hexachloronaphthalene — Skin	—	0.2	—	0.6
Hexafluoroacetone	0.1	0.7	0.3	2.1
* Hexane (n-hexane)	100	360	125	450
* 2-Hexanone, see Methyl butyl ketone — Skin	25	100	40	150
Hexone (Methyl isobutyl ketone) — Skin	100	410	125	510
sec-Hexyl acetate	50	300	50	300

Capital letters refer to Appendices.
*1976 Addition.
**See Notice of Intended Changes.

MAP 000012

Substance	ADOPTED VALUES TWA ppm[a]	ADOPTED VALUES TWA mg/m³[b]	TENTATIVE VALUES STEL ppm[a]	TENTATIVE VALUES STEL mg/m³[b]
** Hydrazine — Skin	(1)	(1.3)	0.3	0.4
Hydrogen	F	—	F	—
* Hydrogenated terphenyls	0.5	5	0.5	5
Hydrogen bromide	3	10	3	10
C Hydrogen chloride	5	7	5	7
Hydrogen cyanide — Skin	10	11	15	16
Hydrogen fluoride	3	2	3	2
Hydrogen peroxide	1	1.4	2	2.8
Hydrogen selenide	0.05	0.2	0.05	0.2
Hydrogen sulfide	10	15	15	27
Hydroquinone	—	2	—	4
Indene	10	45	15	27
Indium & Compounds, as In	—	0.1	—	0.3
C Iodine	0.1	1	0.1	1
* Iodoform	0.2	3	0.4	0.6
Iron oxide fume	B4	5	—	10
Iron pentacarbonyl	0.01	0.08	0.01	0.08
Iron salts, soluble, as Fe	—	1	—	2
Isoamyl acetate	100	525	125	655
Isoamyl alcohol	100	360	125	450
Isobutyl acetate	150	700	187	875
* Isobutyl alcohol	50	150	75	225
*C Isophorone	5	25	5	25
Isopropyl acetate	250	950	310	1,185
Isopropyl alcohol — Skin	400	980	500	1,225
Isopropylamine	5	12	10	24
Isopropyl ether	250	1,050	310	1,320
Isopropyl glycidyl ether (IGE)	50	240	75	360
Kaolin	—	E	—	20
Ketene	0.5	0.9	1.5	2.7
Lead, inorg., fumes & dusts, as Pb	—	0.15	—	0.45
Lead arsenate, as Pb	—	0.15	—	0.45
Limestone	—	E	—	20
Lindane — Skin	—	0.5	—	1.5

Capital letters refer to Appendices
*1976 Addition.
**See Notice of Intented Changes.

Substance	ADOPTED VALUES TWA ppm[a]	ADOPTED VALUES TWA mg/m³[b]	TENTATIVE VALUES STEL ppm[a]	TENTATIVE VALUES STEL mg/m³[b]
Lithium hydride	—	0.025	—	0.025
L.P.G. (Liquified petroleum gas)	1,000	1,800	1,250	2,250
Magnesite	—	E	—	20
Magnesium oxide fume	—	10	—	10
Malathion — Skin	—	10	—	10
Maleic anhydride	0.25	1	0.25	1
C Manganese & Compounds, as Mn	—	5	—	5
Manganese cyclopentadienyl tricarbonyl (as Mn) — Skin	—	0.1	—	0.3
Marble	—	E	—	20
Mercury (Alkyl compounds) — Skin, As Hg	0.001	0.01	0.003	0.03
Mercury (All forms except alkyl) as Hg	—	0.05	—	0.15
Mesityl oxide	25	100	25	100
Methane	F	—	F	—
Methanethiol, see Methyl mercaptan	0.5	1	0.5	1
Methoxychlor	—	10	—	10
2-Methoxyethanol — Skin (Methyl cellosolve)	25	80	35	120
Methyl acetate	200	610	250	760
Methyl acetylene (propyne)	1,000	1,650	1,250	2,060
Methyl acetylene-propadiene mixture (MAPP)	1,000	1,800	1,250	2,250
Methyl acrylate — Skin	10	35	10	35
Methyl acrylonitrile — Skin	1	3	2	6
Methylal (dimethoxymethane)	1,000	3,100	1,250	3,875
Methyl alcohol (methanol) — Skin	200	260	250	310

Capital letters refers to Appendices.

MAP 000013

Substance	ADOPTED VALUES TWA ppm[a]	ADOPTED VALUES TWA mg/m³[b]	TENTATIVE VALUES STEL ppm[a]	TENTATIVE VALUES STEL mg/m³[b]
Methylamine	10	12	10	12
Methyl amyl alcohol, see Methyl isobutyl carbinol	25	100	40	150
Methyl 2-cyanoacrylate	2	8	4	16
Methyl isoamyl ketone	100	475	150	710
Methyl n-amyl ketone (2-Heptanone)	100	465	150	710
Methyl bromide — Skin	15	60	15	60
Methyl butyl ketone, see 2-Hexanone	25	100	40	150
Methyl cellosolve — Skin see 2-Methoxyethanol	25	80	35	120
Methyl cellosolve acetate — Skin, see Ethylene glycol monomethyl ether acetate	25	120	35	150
Methyl chloride	100	210	125	260
Methyl chloroform	350	1,900	450	2,375
* Methylcyclohexene	400	1,600	500	2,000
Methylcyclohexanol	50	235	75	350
o-Methycyclohexanone — Skin	50	230	75	345
Methylcyclopentadienyl manganese tricarbonyl (as Mn) — Skin	0.1	0.2	0.3	0.6
Methyl demeton — Skin	—	0.5	—	1.5
C Methylene bisphenyl isocyanate (MDI)	0.02	0.2	0.02	0.2
* Methylene chloride (dichloromethane)	200	720	250	900
4, 4'-Methylene bis (2-chloraniline) — Skin	0.02A2	—	0.02A2	—
C Methylene bis (4-cyclohexylisocyanate)	0.01	0.11	0.01	0.11
Methyl ethyl ketone (MEK), see 2-Butanone	200	590	250	740

*1976 Addition
Capital letters refer to Appendices.

Substance	ADOPTED VALUES TWA ppm[a]	ADOPTED VALUES TWA mg/m³[b]	TENTATIVE VALUES STEL ppm[a]	TENTATIVE VALUES STEL mg/m³[b]
C Methyl ethyl ketone peroxide	0.2	1.5	0.2	1.5
Methyl formate	100	250	150	375
Methyl iodide — Skin	5	28	10	56
Methyl isobutyl carbinol — Skin	25	100	40	150
Methyl isobutyl ketone, see Hexone	100	410	125	510
Methyl isocyanate — Skin	0.02	0.05	0.02	0.05
Methyl mercaptan	0.5	1	0.5	1
Methyl methacrylate	100	410	125	510
Methyl parathion — Skin	—	0.2	—	0.6
Methyl propyl ketone, see 2-Pentanone	200	700	250	875
C Methyl silicate	5	30	5	30
C α-Methyl styrene	100	480	100	480
Molybdenum, as Mo Soluble compounds	—	5	—	10
Insoluble compounds	—	10	—	20
Monomethyl aniline — Skin	2	9	4	18
C Monomethyl hydrazine — Skin	0.2	0.35	0.2	0.35
Morpholine — Skin	20	70	30	105
Naphthalene	10	50	15	75
β-Naphthylamine	—	A1b	—	A1b
Neon	F	—	F	—
* Nickel carbonyl	0.05	0.35	0.05	0.35
* Nickel, soluble compounds (as Ni)	—	0.1	—	0.3
Nicotine — Skin	—	0.5	—	1.5
Nitric acid	2	5	4	10
Nitric oxide	25	30	35	45
p-Nitroaniline — Skin	1	6	2	12
Nitrobenzene — Skin	1	5	2	10
p-Nitrochlorobenzene — Skin	—	1	—	2

Capital letters refer to Appendices.
Footnotes (a thru h) see Page 31.
*1976 Addition.

MAP 000014

Substance	ADOPTED VALUES TWA ppm[a]	ADOPTED VALUES TWA mg/m³[b]	TENTATIVE VALUES STEL ppm[a]	TENTATIVE VALUES STEL mg/m³[b]
4-Nitrodiphenyl	—	A1b	—	A1b
Nitroethane	100	310	150	465
C Nitrogen dioxide	5	9	5	9
Nitrogen trifluoride	10	29	15	45
Nitroglycerin[d] — Skin	0.2	2	0.2	2
Nitromethane	100	250	150	375
1-Nitropropane	25	90	35	135
2-Nitropropane	25	90	25	90
N-Nitrosodimethylamine (dimethylnitrosoamine) — Skin	—	A2	—	A2
Nitrotoluene — Skin	5	30	10	60
Nitrotrichloromethane, see Chloropicrin	0.1	0.7	0.3	2
Nitrous oxide	F	—	F	—
* Nonane	200	1,050	250	1,300
Octachloronaphthalene — Skin	—	0.1	—	0.3
* Octane	300	1,450	375	1,800
Oil mist, particulate	—	5[h]	—	10
Oil mist, vapor	[g]B2	—	B2	—
Osmium tetroxide, as Os	0.0002	0.002	0.0006	0.006
Oxalic acid	—	1	—	2
Oxygen difluoride	0.05	0.1	0.15	0.3
Ozone	0.1	0.2	0.3	0.6
Paraffin wax fume	—	2	—	6
** Paraquat — Skin	—	(0.5)	—	0.5
Parathion — Skin	—	0.1	—	0.3
Particulate polycyclic aromatic hydrocarbons (PPAH) as benzene solubles	—	0.2A1a	—	0.2A1a
Pentaborane	0.005	0.01	0.015	0.03
Pentachloronaphthalene — Skin	—	0.05	—	1.5
Pentachlorophenol — Skin	—	0.5	—	1.5

Capital letters refer to Appendices.
Footnotes (a thru h) see Page 31
*1976 Addition.
**See Notice of Intended Changes.

Substance	ADOPTED VALUES TWA ppm[a]	ADOPTED VALUES TWA mg/m³[b]	TENTATIVE VALUES STEL ppm[a]	TENTATIVE VALUES STEL mg/m³[b]
Pentaerythritol	—	E	—	20
* Pentane	600	1,800	750	2,250
2-Pentanone	200	700	250	875
Perchloroethylene — Skin	100	670	150	1,000
Perchloromethyl mercaptan	0.1	0.8	0.1	0.8
Perchloryl fluoride	3	14	6	28
Petroleum distillates (naphtha)	[g]B3	—	B3	—
Phenol — Skin	5	19	10	38
Phenothiazine — Skin	—	5	—	10
p-Phenylene diamine — Skin	—	0.1	—	0.1
Phenyl ether (vapor)	1	7	2	14
Phenyl ether-Diphenyl mixture (vapor)	1	7	2	14
Phenylethylene, see Styrene	100	420	125	525
Phenyl glycidyl ether (PGE)	10	60	15	90
Phenylhydrazine — Skin	5	22	10	44
C Phenylphosphine	0.05	0.25	0.05	0.25
Phorate (Thimet®) — Skin	—	0.05	—	0.15
Phosdrin (Mevinphos®) — Skin	0.01	0.1	0.03	0.3
* Phosgene (carbonyl chloride)	0.10	0.4	0.05	0.2
Phosphine	0.3	0.4	1	1
Phosphoric acid	—	1	—	3
Phosphorus (yellow)	—	0.1	—	0.3
Phosphorus pentachloride	—	1	—	3
Phosphorus pentasulfide	—	1	—	3
Phosphorus trichloride	0.5	3	0.5	3
* Phthalic anhydride	1	6	4	24
Picloram (Tordon®)	—	10	—	20
Picric acid — Skin	—	0.1	—	0.3

Capital letters refer to Appendices.
*1976 Addition.

MAP 000015

Substance	ADOPTED VALUES TWA ppm[a]	ADOPTED VALUES TWA mg/m³[b]	TENTATIVE VALUES STEL ppm[a]	TENTATIVE VALUES STEL mg/m³[b]
Pival* (2-Pivalyl-1, 3-indandione)	—	0.1	—	0.3
Plaster of Paris	—	E	—	20
Platinum (Soluble salts) as Pt	—	0.002	—	0.002
Polychlorobiphenyls, see Chlorodiphenyls	—	—	—	3
Polytetrafluoroethylene decomposition products	—	B1	—	B1
C Potassium hydroxide	—	2	—	2
Propane	F	—	F	—
β-Propiolactone	—	A2	—	A2
Propargyl alcohol — Skin	1	2	3	6
n-Propyl acetate	200	840	250	1,050
Propyl alcohol — Skin	200	500	250	625
n-Propyl nitrate	25	110	40	140
Propylene	F	—	F	—
Propylene dichloride (1, 2-Dichloropropane)	75	350	115	525
Propylene glycol monomethyl ether	100	360	150	450
Propylene imine — Skin	2	5	2	5
Propylene oxide	100	240	150	360
Propyne, see Methyl-acetylene	1,000	1,650	1,250	2,050
Pyrethrum	—	5	—	10
Pyridine	5	15	10	30
Quinone	0.1	0.4	0.3	1
RDX — Skin	—	1.5	—	3
* Resorcinol	10	45	20	90
Rhodium, Metal fume and dusts (as Rh)	—	0.1	—	0.3
Soluble salts	—	0.001	—	0.003
Ronnel	—	10	—	10
Rosin core solder pyrolysis products (as formaldehyde)	—	0.1	—	0.3

Capital letters refer to Appendices.
*1976 Addition.

Substance	ADOPTED VALUES TWA ppm[a]	ADOPTED VALUES TWA mg/m³[b]	TENTATIVE VALUES STEL ppm[a]	TENTATIVE VALUES STEL mg/m³[b]
Rotenone (commercial)	—	5	—	10
Rouge	—	E	—	20
Selenium compounds (as Se)	—	0.2	—	0.2
Selenium hexafluoride, as Se	0.05	0.4	0.05	0.4
Sevin* (see Carbaryl)	—	5	—	10
Silane (see Silicon tetrahydride)	0.05	0.7	1	1.5
Silicon	—	E	—	20
Silicon carbide	—	E	—	20
Silicon tetrahydride (Silane)	0.5	0.7	1	1.5
Silver, metal and soluble compounds, as Ag	—	0.01	—	0.03
*C Sodium azide	0.1	0.3	0.1	0.3
Sodium fluoroacetate (1080) — Skin	—	0.05	—	0.15
C Sodium hydroxide	—	2	—	2
Starch	—	E	—	20
Stibine	0.1	0.5	0.3	1.5
* Stoddard solvent	100	575	150	720
Strychnine	—	0.15	—	0.45
Styrene, monomer (Phenylethylene)	100	420	125	525
** Succinaldehyde (see Glutaraldehyde)	—	(0.25)	—	—
C Subtilisins (Proteolytic enzymes as 100% pure crystalline enzyme)	—	0.00006[c]	—	0.00006
Sucrose	—	E	—	20
Sulfur dioxide	5	13	5	13
Sulfur hexafluoride	1,000	6,000	1,250	7,500
Sulfuric acid	—	1	—	1
Sulfur monochloride	1	6	3	18
Sulfur pentafluoride	0.025	0.25	0.075	0.75
Sulfur tetrafluoride	0.1	0.4	0.3	1
Sulfuryl fluoride	5	20	10	40

**See notice of intended changes
o) See Page 33.

MAP 000016

Substance	ADOPTED VALUES TWA ppm[a]	ADOPTED VALUES TWA mg/m³[b]	TENTATIVE VALUES STEL ppm[a]	TENTATIVE VALUES STEL mg/m³[b]
Systox, see Demeton®	0.01	0.1	0.03	0.3
2, 4, 5-T	—	10	—	20
Tantalum	—	5	—	10
TEDP — Skin	—	0.2	—	0.6
Teflon® decomposition products	—	B1	—	B1
Tellurium	—	0.1	—	0.1
Tellurium hexafluoride, as Te	0.02	0.2	0.02	0.2
TEPP — Skin	0.004	0.05	0.012	0.15
C Terphenyls	1	9	1	9
1, 1, 1, 2-Tetrachloro-2, 2-difluoroethane	500	4,170	625	5,210
1, 1, 2, 2-Tetrachloro-1, 2-difluoroethane	500	4,170	625	5,210
1, 1, 2, 2-Tetrachloroethane — Skin	5	35	10	70
Tetrachloroethylene, see Perchloroethylene	100	670	150	1,000
Tetrachloromethane, see Carbon tetrachloride	10	65	20	130
Tetrachloronaphthalene — Skin	—	2	—	4
Tetraethyl lead (as Pb) — Skin	—	0.100[h]	—	0.3
Tetrahydrofuran	200	590	250	700
Tetramethyl lead (as Pb) — Skin	—	0.150[h]	—	0.45
Tetramethyl succinonitrile — Skin	0.5	3	1.5	9
Tetranitromethane	1	8	1	8
Tetryl (2, 4, 6-trinitrophenyl-methylnitramine) — Skin	—	1.5	—	3.0
Thallium (soluble compounds) — Skin (as Tl)	—	0.1	—	0.1

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

Substance	ADOPTED VALUES TWA ppm[a]	ADOPTED VALUES TWA mg/m³[b]	TENTATIVE VALUES STEL ppm[a]	TENTATIVE VALUES STEL mg/m³[b]
* 4, 4'-Thiobis (6-tert. butyl-m-cresol)	—	10	—	20
Thiram®	—	5	—	10
Tin (inorganic compounds, except SnH_4 and SnO_2) as Sn	—	2	—	4
Tin (organic compounds) — Skin (as Sn)	—	0.1	—	0.2
Tin oxide	—	E	—	20
Titanium dioxide	—	E	—	20
Toluene (toluol) — Skin	100	375	150	560
C Toluene-2, 4-diisocyanate (TDI)	0.02	0.14	0.02	0.14
o-Toluidine	5	22	10	44
Toxaphene, see Chlorinated camphene	—	0.5	—	1.5
Tributyl phosphate	—	5	—	5
1, 1, 1-Trichloroethane, see Methyl chloroform	350	1,900	440	2,380
1, 1, 2-Trichloroethane — Skin	10	45	20	90
Trichloroethylene	100	535	150	800
** Trichloromethane, see Chloroform	(25)	(120)	25A3	—
Trichloronaphthalene — Skin	—	5	—	10
1, 2, 3-Trichloropropane	50	300	150	450
1, 1, 2-Trichloro 1, 2, 2-trifluoroethane	1,000	7,600	1,250	9,500
Triethylamine	25	100	40	150
Tricyclohexyltin hydroxide (Plictran®)	—	5	—	10
Trifluoromonobromo-methane	1,000	6,100	1,200	7,625
Trimethyl benzene	25	120	35	180
2, 4, 6-Trinitrophenol, see Picric acid	—	0.1	—	0.3

Capital letters refer to Appendices.
*1976 Addition.
**See Notice of Intended Changes.

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Substance	ADOPTED VALUES TWA ppm[a]	ADOPTED VALUES TWA mg/m³[b]	TENTATIVE VALUES STEL ppm[a]	TENTATIVE VALUES STEL mg/m³[b]
2, 4, 6-Trinitrophenylmethylnitramine, see Tetryl				
** Trinitrotoluene (TNT) — Skin	—	1.5	—	3.0
Triorthocresyl phosphate	—	(1.5)	—	4.5
Triphenyl phosphate	—	0.1	—	0.3
Tungsten & compounds, as W		3	—	6
Soluble	—	1	—	3
Insoluble	—	5	—	10
Turpentine	100	560	150	840
Uranium (natural) soluble & insoluble compounds, as U	—	0.2	—	0.6
Vanadium (V_2O_5) as V				
Dust	—	0.5	—	1.5
C Fume	—	0.05	—	0.05
Vinyl acetate	10	30	20	60
Vinyl benzene, see Styrene	100	420	150	630
Vinyl bromide	250	1,100	250	1,100
** Vinyl chloride	(200)	(510)	A1c	A1c
Vinyl cyanide, see Acrylonitrile	20	45	30	70
Vinylidene chloride	10	40	20	80
Vinyl toluene	100	480	150	720
Warfarin	—	0.1	—	0.3
* Welding fumes (Total particulate)	—	5, B4	—	5, B4
Wood dust (nonallergenic)	—	5	—	10
Xylene (o-, m-, p-isomers) — Skin	100	435	150	655
*C m-Xylene α, α'-diamine	—	0.1	—	0.1
Xylidene — Skin	5	25	10	50
Yttrium	—	1	—	3
Zinc chloride fume	—	1	—	2
Zinc oxide fume	—	5	—	10
Zinc stearate	—	E	—	20
Zirconium compounds (as Zr)	—	5	—	10

*1976 Addition
**See Notice of Intended Changes

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 substance per cubic meter of air.
d) An atmospheric concentration of not more than 0.02 ppm, or personal protection may be necessary to avoid headache.
e) < 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.

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MINERAL DUSTS

Substance	
SILICA, SiO_2	
Crystalline	
Quartz	TLV in mppcf[i]: $\frac{300^{j}}{\%\ \text{quartz} + 10}$ TLV for respirable dust in mg/m³: $\frac{10\ \text{mg/m}^{3k}}{\%\ \text{Respirable quartz} + 2}$ TLV for "total dust," respirable and nonrespirable: $\frac{30\ \text{mg/m}^3}{\%\ \text{quartz} + 3}$
Cristobalite	Use one-half the value calculated from the count or mass formulae for quartz.
Tridymite	Use one-half the value calculated from formulae for quartz.
Silica, fused	Use quartz formulae.
Tripoli	Use respirable[p] mass quartz formula
***Amorphous*	20 mppcf[i]
SILICATES (< *1%* quartz)	
Asbestos, all forms[†]	5 fibers/cc > 5 μm in length[n]; A1a
Graphite (natural)	15 mppcf
Mica	20 mppcf
Mineral wool fiber	10 mg/m³
Perlite	30 mppcf
Portland Cement	30 mppcf
Soapstone	20 mppcf
Talc (nonasbestiform)	20 mppcf
Talc (fibrous) use Asbestos limit.	
Tremolite, see Asbestos.	

†A more stringent TLV for crocidolite may be required.
i), n) See p. 33
**See Notice of Intended Changes

COAL DUST

2 mg/m³ (respirable dust fraction < 5% quartz).
If > 5% quartz, use respirable mass formula.

NUISANCE PARTICULATES

(see Appendix E)

30 mppcf or 10 mg/m³[o]
of total dust < 1% quartz, or, 5 mg/m³ respirable dust.

Conversion factors:

mppcf × 35.3 = Million particles per cubic meter
= particles per c.c.

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

j) The percentage of quartz 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 quartz 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% quartz; if quartz content > 1%, use formulae for quartz.

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

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

o) Based on "high volume" sampling.

p) "Respirable" dust as defined by the British Medical

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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.

NOTICE OF INTENDED CHANGES (for 1976)

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. Documentation is available for each of these substances.

Substance	ppm[a]	mg/m³[b]
‡ Aliphatic solvent "140 Flash"	25	150
Antimony trioxide, handling & use, as Sb	—	0.5
Antimony trioxide production	—	A2, 0.05
Arsenic trioxide production	—	A1a, 0.05
‡ Atrazine	—	10
Benzene — Skin	A2, 10	A2, 30
Borates, tetra, sodium salts, Anhydrous	—	1
Decahydrate	—	5
Pentahydrate	—	1
‡ Butyl acrylate	10	55
C Cadmium oxide production	—	A2, 0.05
‡ Calcium hydroxide	—	5
‡ Calcium Oxide	—	2
Captafol (Difolatan®) — Skin	—	0.1
‡ Carbonyl fluoride	5	15
Catechol (Pyrocatechol)	5	20

Capital letters refer to Appendices.
‡1976 Revision or Addition.

Substance	ppm[a]	mg/m³[b]
‡ Chloroform	A2, 10	50
Chromite ore processing (as CrO_3)	—	A1a, 0.1
‡ Cobalt metal, fume and dust	—	0.05
Cyanamide	—	2
‡ Dichloromonofluoromethane	500	2,100
Dicrotophos (Bidrin®) — Skin	—	0.25
‡ Dimethyl carbamyl chloride	A2	A2
C Dimethyl sulfate	A2, 1	A2, 5
Dioxathion (Delnav®)	—	0.2
Diuron	—	10
‡C Glutaraldehyde (Activated and unactivated)	0.3	1.2
‡ Hexamethyl phosphoramide	A2	A2
Hydrazine	0.1	0.1
Isophorone diisocyanate — Skin	0.01	0.06
‡ Manganese tetroxide	—	1
Methomyl (Lannate®) — Skin	—	2.5
‡ 4, 4'-Methylene dianiline	—	A2
‡ N, Methyl-2-pyrrolidone	100	400
Monocrotophos (Azodrin®)	—	0.25
Nickel carbonyl	0.05	0.35
‡ Nickel sulfide roasting, as Ni	—	A1a, 1
‡ Paraquat, respirable sizes	—	0.1
‡ Phenyl mercaptan	0.5	2
‡ Phosgene	0.1	0.4
Phthalic anhydride	1	6
m-Phthalodinitrile	—	5
‡C Propylene glycol dinitrate — Skin	0.2	2
Rubber solvent	400	1,600
‡ "60 Solvent"	100	450
‡ "70 Solvent"	50	300
‡ Thioglycolic acid	1	5
C 1, 2, 4-Trichlorobenzene	5	40
‡ Trimethyl phosphite	0.5	2.6
‡C 2, 4, 6-Trinitrotoluene (TNT)	—	0.5

Capital letters refer to Appendices.
‡1976 Addition.

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Substance	ppm[a]	mg/m³[b]
† Valeraldehyde	50	175
Vinyl chloride	Pending, A1c	—
Vinyl cyclohexene dioxide	10	60
† VM & P Naphtha	400	1,800
Zinc chromate, as CrO_3	—	0.1

NOTICE OF INTENDED CHANGES
MINERAL DUSTS

Substance	TLV
† Silica, amorphous	5 mg/m³ Total dust (all sampled sizes) 2 mg/m³ Respirable dust (< 5 μm)
† Diatomaceous earth, natural	1.5 mg/m³, Respirable dust

NOTICE OF INTENDED CHANGES
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 three forms: Those for which a TLV has been assigned (1a), those for which environmental conditions have not been sufficiently defined to assign a TLV (1b), and (1c), those whose reassignment of a TLV is awaiting more definitive data, and hence should be treated as a 1-b carcinogen.

A1a. *Human Carcinogens*. Substances, or substances associated with industrial processes, recognized to have carcinogenic or cocarcinogenic potential, with an assigned TLV:

	TLV
Arsenic trioxide production	As_2O_3, 0.05 mg m³ as As SO_2, C 5.0 ppm Sb_2O_3, 0.05 mg/m³ as Sb
Asbestos, all forms*	5 fibers/cc, > 5 μm in length
bis (Chloromethyl) ether	0.001 ppm
Chromite ore processing	0.1 mg/m³ as Cr
Nickel sulfide roasting, fume & dust	1.0 mg/m³ as Ni
Particulate Polycyclic Aromatic Hydrocarbons (PPAH)	0.2 mg/m³, as benzene solubles

1b. *Human Carcinogens*. Substances, or substances associated with industrial processes, recognized to have carcinogenic potential without an assigned TLV:

4-Aminodiphenyl (p-Xenylamine)
Benzidine production
beta-Naphthylamine
4-Nitrodiphenyl

1c. *Human Carcinogens*. Substances with recognized carcinogenic potential awaiting reassignment of TLV pending further data acquisition:

Vinyl chloride

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 hermitizing the process or operation by the best practicable engi-

Capital letters refer to Appendices.
†1976 Addition.

*Cigarette smoking can enhance the incidence of bronchogenic carcinoma from this and others of these substances or processes.

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neering methods. The worker should be properly equipped to insure virtually no contact with the carcinogen.

A2. *Industrial Substances Suspect of Carcinogenic Potential for MAN.* Chemical substances or substances associated with industrial processes, which are suspect of inducing cancer, based on either (1) limited epidemiologic evidence, exclusive of clinical reports of single cases, or (2) demonstration of carcinogenesis in one or more animal species by appropriate methods.

Antimony trioxide production *	0.05 mg/m³
Benzene	10 ppm
Benz(a)pyrene	—
Beryllium	2.0 μg/m³
Cadmium oxide production	0.05 mg/m³
Chloroform	10 ppm
Chromates of lead and zinc	0.1 mg/m²
3, 3'-Dichlorobenzidine	—
Dimethylcarbamyl chloride	—
1, 1-Dimethyl hydrazine	0.5 ppm
Dimethyl sulfate	1 ppm
Epichlorhydrin	5 ppm
Hexamethyl phosphoramide	—
Hydrazine	0.1 ppm
4, 4'-Methylene bis (2-chloroaniline)	0.02 ppm
4, 4'-Methylene dianiline	—
Monomethyl hydrazine	0.2 ppm
Nitrosamines	—
Propane sultone	—
beta-Propiolactone	—
Thallium	0.1 mg/m³
Vinyl cyclohexene dioxide	10 ppm

For the above, worker exposure by all routes should be carefully controlled to levels consistent with the animal and human experience data (see Documentation), except for those substances with a listed TLV.

*Cigarette smoking can enhance the incidence of respiratory cancers from this or others of those substances or processes.

A3. *Guidelines for the Classification of Experimental ANIMAL Carcinogens.* The following guidelines are offered in the present state or knowledge as an aid in classifying substances in the occupational environment found to be carcinogenic in experimental animals. A need was felt by the Threshold Limits Committee for such a classification in order to take the first step in developing an appropriate TLV for occupational exposure.

Determination of Approximate Threshold of Response Requirement. In order to determine in which category to classify an experimental carcinogen for the purpose of assigning an industrial air limit (TLV), an approximate threshold of neoplastic response must be determined. Because of practical experimental difficulties, a precisely defined threshold cannot be attained. For the purposes of standard-setting, this is of little moment, as an appropriate risk, or safety, factor can be applied to the approximate threshold, the magnitude of which is dependent on the degree of potency of the carcinogenic response.

To obtain the best 'practical' threshold of neoplastic response, dosage decrements should be less than logarithmic. This becomes particularly important at levels greater than 10 ppm (or corresponding mg/m³). Accordingly, after a range-finding determination has been made by logarithmic decreases, two additional dosage levels are required within the levels of "effect" and "no effect" to approximate the true threshold of neoplastic response.

The second step should attempt to establish a metabolic relationship between animal and man for the particular substance found carcinogenic in animals. If the metabolic pathways are found comparable, the substance should be classed highly suspect as a carcinogen for man. If no such relation is found, the substance should remain listed as an experimental animal carcinogen until evidence to the contrary is found.

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Proposed Classification of Experimental Animal Carcinogens. Substances occurring in the occupational environment found carcinogenic for animals may be grouped into three classes, those of high, intermediate and low potency. In evaluating the incidence of animal cancers, significant incidence of cancer is defined as a neoplastic response which represents, in the judgment of the Committee, a significant excess of cancers above that occurring in negative controls.

EXCEPTIONS: No substance is to be considered an occupational carcinogen of any practical significance which reacts by the respiratory route at or above 1000 mg/m³ for the mouse, 2000 mg/m³ for the rat; by the dermal route, at or above 1500 mg/kg for the mouse, 3000 mg/kg for the rat; by the gastrointestinal route at or above 500 mg/kg/d for a lifetime, equivalent to about 100 g T.D. for the rate 10g T.D. for the mouse.

These dosage limitations exclude such substances as dioxane and trichlorethylene from consideration as carcinogens.

Examples: Dioxane — mice, hepatocellular and nasal tumors from 1015 mg/kg/d
Trichloroethylene — female mice, tumors (30/98 @ 900 mg/kg/d)

A3a. *INDUSTRIAL SUBSTANCES OF HIGH CARCINOGENIC POTENCY IN EXPERIMENTAL ANIMALS*

1. A substance to qualify as a carcinogen of high potency must fulfill one of the three following conditions in two animal species:

   1a. *Respiratory*. Elicit cancer from (1) dosages below 1 mg/m³ (or equivalent ppm) via the respiratory tract in 6- 7-hour daily repeated inhalation exposures throughout lifetime; or (2) from a single intratracheally administered dose not exceeding 1 mg of particulate, or liquid, per 100 ml or less of animal minute respiratory volume;

Examples: bis-Chloromethyl ether, malignant tumors, rats, @ 0.47 mg/m³ (0.1 ppm) in 2 years;

Hexamethyl phosphoramide, nasal squamous cell carcinoma, rats, @ 0.05 ppm, in 13 months

OR

1b. *Dermal*. Elicit cancer within 20 weeks by skin-painting, twice weekly at 2 mg/kg body weight or less per application for a total dose equal to or less than 1.5 mg, in a biologically inert vehicle;

Examples: 7, 12-Dimethylbenz(a)anthracene — skin tumors @ 0.12-0.8 mg T.D. in four weeks

Benz(a)pyrene, mice 12 μg, 3X/wk for 18 mos. T.D. 2.6 mg, 90.9% skin tumors

OR

1c. *Gastrointestinal*. Elicit cancer by daily intake via the gastrointestinal tract, within six months, with a six-month holding period, at a dosage below 1 mg/kg body weight per day; total dose, rat, ≤ 50 mg; mouse, ≤ 3.5 mg;

Examples: 7, 12-Dimethylbenz(a)anthracene — mammary tumors from 10 mg 1X

3-Methylcholanthrene — Tumors @ 3 sites from 8 mg in 89 weeks

Benz(a)pyrene, mice, 3.9% leukemias, from 30 mg T.D. 198 days

2. Elicit cancer by all three routes in at least two animal species according to conditions given in 1a, 1b, 1c.

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A3b. *INDUSTRIAL SUBSTANCES OF INTERMEDIATE CARCINOGENIC POTENCY IN EXPERIMENTAL ANIMALS*

To qualify as a carcinogen of intermediate potency, a substance should elicit cancer in two animal species at dosages intermediate between those described in A3a and A3c by two routes of administration.

Example: Diethyl carbamic acid
Dermal, mammary tumors, mice, 100%, 63 weeks, 500–1400 mg T.D.
Gastrointestinal, various type tumors, mice 42 weeks, 320 mg T.D.

Gastrointestinal, various type tumors, rats, 60 weeks, 110–930 mg T.D.

A3c. *INDUSTRIAL SUBSTANCES OF LOW CARCINOGENIC POTENCY IN EXPERIMENTAL ANIMALS*

To qualify as a carcinogen of low potency, a substance should elicit cancer in one animal species by any *one* of three routes of administration at the following prescribed dosages and conditions:

1a. *Respiratory.* Elicit cancer from (1) dosages greater than 10 mg/m³ (or equivalent ppm) via the respiratory tract in 6- 7-hour, daily repeated inhalation exposures, for 12 months' exposure and 12 months' observation period; or (2) from intratracheally administered dosages totaling more than 10 mg of particulate or liquid per 100 ml or more of animal minute respiratory volume;

Examples: Beryl (beryllium aluminum silicate) malig. lung tumors, rats, @ 15 mg/m³ @ 17 months

Benzidine, var. tumors, rats, 10–20 mg/m³ @ > 13 mos.

OR

1b. *Dermal.* Elicit cancer by skin-painting of mice in twice weekly dosages of > 10 mg/kg body

weight in a biologically inert vehicle for at least 75 weeks, i.e., ≥ 1.5g T.D.

Examples: Shale tar, mouse, 0.1 ml × 50 – g T.D. 59/60 skin tumors

Arsenic trioxide, man, dose unknown, but estimated to be high

1c. *Gastrointestinal.* Elicit cancer from daily oral dosages of 50 mg/kg/day or greater during the lifetime of the animal.

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 minimal.

B2 *Gasoline.* The composition of gasoline 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); Runion, ibid. *36*, 338, 1975).
Notice of intended changes

B3 *Petroleum Distillates.* For petroleum distillates for which no specific TLV's are listed, approximate values can be obtained by use of the following equation:

$$TLV = \frac{100}{\frac{\%\,A1}{3.6(200 - B.P.{}^{\circ}C.) + 20} - \frac{\%\,Ar}{1.3(200 - B.P.{}^{\circ}C.) + 10}} \text{ ppm}$$

*Trade Names: Algoflon, Fluon, Halon, Teflon, Tetran.

MAP 000024

where Al = aliphatic component
Ar = aromatic component
B.P. = mean boiling point in degrees centigrade (normally the 50% distillation temperature).

The equation cannot be used if the benzene content of the fraction exceeds 1%, nor if the mean boiling point is above 200°C.

It may also lead to error if there are large amounts of hexane or cyclohexane in the distillate.

If the molecular weight (average) is not known for the mixture, it can be approximated by the following equation:

M.W. = %Al + 0.88%Ar + 0.5(B.P.°C. − 100)

B4 *Welding Fumes — Total Particulate (NOC)**
TLV, 5 *mg/m³*

Welding fumes cannot be classified simply. The composition and quantity of both are dependent on the alloy being welded and the process and electrodes used. Reliable analysis of fumes cannot be made without considering the nature of the welding process and system being examined; reactive metals and alloys such as aluminum and titanium are arc-welded in a protective, inert atmosphere such as argon. These arcs create relatively little fume, but an intense radiation which can produce ozone. Similar processes are used to arc-weld steels, also creating a relatively low level of fumes. Ferrous alloys also are arc-welded in oxidizing environments which generate considerable fume, and can produce carbon monoxide instead of ozone. Such fumes generally are composed of discreet particles of amorphous slags containing iron, manganese, silicon and other metallic constituents depending on the alloy system involved. Chromium and nickel compounds are found in fumes when stainless steels are arc-welded. Some coated and flux-cored electrodes are formulated with fluorides and the fumes associated with them can contain significantly

*Not otherwise classified.

more fluorides than oxides. Because of the above factors, arc-welding fumes frequently must be tested for individual constituents which are likely to be present to determine whether specific TLV's are exceeded. Conclusions based on total fume concentration are generally adequate if no toxic elements are present in welding rod, metal, or metal coating and conditions are not conducive to the formation of toxic gases.

Most welding, even with primitive ventilation, does not produce exposures inside the welding helmet above 5 mg/m³. That which does, should be controlled.

APPENDIX C

C.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,

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

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 a 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

MAP 000025

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 a given operation or process characteristically emits a number of harmful dusts, 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 exhauts, etc.

C.1A Examples of THRESHOLD LIMIT VALUES FOR MIXTURES

The following formulae apply only when the components in a mixture have similar toxicologic effects; they should not be used for mixtures with widely differing reactivities, e.g. hydrogen cyanide & sulfur dioxide. In such case the formula for Independent Effects (1A.c.) should be used.

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.)*

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

Example No. 1A.a.: Air contains 5 ppm of carbontetrachloride (TLV = 10 ppm) 20 ppm of 1, 2-dichloroethane (TLV = 50 ppm) and 10 ppm of 1, 2-dibromoethane (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. Furthurmore, the TLV of this mixture may be calculated by reducing the total fraction to 1.0; i.e.

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

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.)

$$\text{TLV of mixture} = \frac{1}{\frac{f_a}{TLV_a} + \frac{f_b}{TLV_b} + \frac{f_c}{TLV_c} + \ldots \frac{f_n}{TLV_n}}$$

Example No. 1: Liquid contains (by weight)
50% heptane: TLV = 400 ppm or 1600 mg/m³
1 mg/m³ = 0.25 ppm

MAP 000026

30% methylene chloride: TLV = 200 ppm or 720 mg/m³
1 mg/m³ ≡ 0.28 ppm

20% perchloroethylene: TLV = 100 ppm or 670 mg/m³
1 mg/m³ ≡ 0.15 ppm

$$\text{TLV of Mixture} = \frac{1}{\frac{0.5}{1600} + \frac{0.3}{720} + \frac{0.2}{670}}$$

$$= \frac{1}{0.00031 + 0.00042 + 0.00030}$$

$$= \frac{1}{0.00103} = 970 \text{ mg/m}^3$$

of this mixture
50% or (970) (0.5) = 485 mg/m³ is heptane
30% or (970) (0.3) = 291 mg/m³ is methylene chloride
20% or (970) (0.2) = 194 mg/m³ is perchloroethylene
These values can be converted to ppm as follows:

heptane: 485 mg/m³ × 0.25 ppm (≡ 1 mg/m³) = 121 ppm
methylene chloride: 291 mg/m³ × 0.28 ppm (≡ 1 mg/m³) = 81 ppm
perchloroethylene: 194 mg/m³ × 0.15 ppm (≡ 1 mg/m³) = 29 ppm

TLV of mixture = 121 + 81 + 29 = 231 ppm, or 970 mg/m³

Example No. 2. Liquid solvent contains (by weight)

50% isopropyl alcohol: TLV = 400 ppm or 980 mg/m³
1 mg/m³ ≡ 0.41 ppm

30% dichloroethane: TLV = 50 ppm or 200 mg/m³
1 mg/m³ ≡ 0.25 ppm

20% perchloroethylene: TLV = 100 ppm or 670 mg/m³
1 mg/m³ ≡ 0.15 ppm

$$\text{TLV of Mixture} = \frac{1}{\frac{0.5}{980} + \frac{0.3}{200} + \frac{0.2}{670}}$$

$$= \frac{1}{0.00051 + 0.0015 + 0.000298}$$

$$= \frac{1}{0.002308} = 433 \text{ mg/m}^3$$

of this mixture
50% or (433) (0.5) = 2.6 mg/m³ is isopropyl alcohol
30% or (433) (0.3) = 130 mg/m³ is dichloroethane
20% or (433) (0.2) = 87 mg/m³ is perchloroethylene

These values can be converted to ppm as follows:

isopropyl alcohol: $216 \frac{\text{mg}}{\text{m}^3} \times 0.41$ ppm (≡ mg/m³)
= 89 ppm

dichloroethane: $130 \frac{\text{mg}}{\text{m}^3} \times 0.25$ ppm (≡ mg/m³)
= 33 ppm

perchloroethylene: $87 \frac{\text{mg}}{\text{m}^3} \times 0.15$ ppm (≡ mg/m³)
= 13 ppm

TLV of mixture = 89 + 33 + 13 = 135 ppm or 433 mg/m³

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. TLV for Mixtures of Mineral Dusts.

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

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

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$$TLV = \frac{1}{\frac{0.8}{20} + \frac{0.2}{2.7}} = 9 \text{ mppcf}$$

TLV of asbestiform talc (pure) = 20 mppcf
TLV of quartz (pure) =

$$\frac{300}{100 + 10} = \frac{300}{110} = 2.7 \text{ mppcf}$$

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:

25% quartz — TLV (pure) = 2.7 mppcf
25% amorphous silica — TLV (pure) = mppcf
50% talc TLV (pure) = 20 mppcf

$$TLV = \frac{1}{\frac{0.25}{2.7} + \frac{0.25}{20} + \frac{0.5}{20}} = 8 \text{ mppcf}$$

The limit for 25% quartz approximates 9 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
Nitrobenzene	1	3	3
Carbon tetrachloride	10	2	20
Trimethyl benzene	25	1.5	40
Acetone	1000	1.25	1250
Boron trifluoride	C 1	—	1
Butylamine	C 5	—	5

EXCURSION FACTORS

For all substances not bearing C notation

TLV>0–1	(ppm or mg/m³),	Excursion 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.

INTERPRETATION OF MEASURED PEAK CONCENTRATIONS

With increasing use of rapid, direct-reading analytical instruments for airborne contaminants in the work area, the question of interpretation of essentially "instantaneous" peaks arises. Although no general statement can be made covering all occupational substances, the following guidelines should prove helpful, assuming peak excursions conform to time-weighted average TLV as stated above.

The toxicologic importance of momentary peak concentrations depends on whether the substance is fast or slow acting. If slow acting, as for quartz, lead, or car-

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bon monoxide, momentary peaks are of no toxicologic concern provided, of course, they are not astronomic. On the other hand, fast-acting substances that rapidly produce disabling narcosis, e.g., H_2S, or intolerable irritation or asphyxiation, NH_3, SO_2, CO_2, or initiate sensitization — the organic isocyanates, even "instantaneous" peaks appreciably above the permissible excursion, should not be permitted, unless information exists to the contrary. Other more specific excursions will be developed in the future.

APPENDIX E
Some Nuisance Particulates[q]
TLV, 30 mppcf or 10mg/m³

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

q) When toxic impurities are not present, e.g. quartz < 1%, and when determined by appropriate methods (cf p. 38).

r) <7 μm in diameter

APPENDIX F
Some Simple Asphyxiants[s]

Acetylene	Hydrogen
Argon	Methane
Butane	Neon
Ethane	Nitrous oxide
Ethylene	Propane
Helium	Propylene

s) As defined on pg. 6.

APPENDIX G

Calculations for Conversion of Particle Count Concentration (by Standard Light Field — Midget Impinger Techniques), in mppcf, to Respirable Mass Concentration (by Respirable Sampler) in mg/m³.[†]

1. In 1967, Jacobsen and Tomb,[†] derived an empirical relationship of 5.6 mppcf to 1 milligram of respirable dust per cubic meter of air, based on 23 sets of samples, mostly coal dust. The following calculation results in an equivalence of 6.37 mppcf to 1 mg/m³ of respirable dust. Thus, an approximate ratio of 6 mppcf to 1 mg/m³ of respirable dust is suggested for conversion of TLVs from a count to a mass basis when the density and mass median diameter have not been determined.
2. Basic assumptions:
   a) Average density for silica containing dusts $\approx$ 2.5 gms/cm³ (2500 mg/cm³). Pulmonary significant dust densities may vary from 1.2 gm/cm³ for coal dust to 3.1 gms/cm³ for Portland Cement. Silica densities vary from 2.2 (amorphous) to 2.3 (cristobalite and tridymite) to 2.5 (alpha-quartz.) gms per cm³.
   b) The mass median diameter (mmd) of particles collected in midget impinger samplers and counted by the standard light field technique, *and* collected in a respirable sampler is approximately 1.5 μm or 1.5×10^{-4} cm. This assumption is, of course, quite arbitrary since the mmd of all dust clouds is quite variable, depending on many independent parameters, such as source of dust, age of dust cloud, meteorological conditions, etc.
3. Calculation:
   a) vol. per particle: $4/3\ \pi\ r^3$; $r = 0.75 \times 10^{-4}$ cm
   $= 4/3 \cdot \pi \cdot (0.75 \times 10^{-4})^3$
   $= 1.77 \times 10^{-12}$ cm³

[†] "Relationship Between Gravimetric Respirable Dust Concentration and Midget Impinger Number Concentration," by Murray Jacobson and T. F. Tomb, AIHAJ, 28: Nov.–Dec. 1967.

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b) wt. per particle = vol. × density
$= 1.77 \times 10^{-12}$ cm³ × 2.5×10^{3} mg/cm³
$= 4.425 \times 10^{-9}$ mg/particle

c) 1 particle/ft.³ = 35.5 part./m³
(since 35.5 cu ft = 1 cu m.)
10^{6} part./ft³ = mppcf = 35.5×10^{6} part./m³

wt. of 1 mppcf ≡ 35.5×10^{6} part./m³ × 4.425×10^{-9} mg/part.

1 mppcf ≡ 0.157 mg/m³
or
6.37 mppcf ≡ 1 mg/m³
or approximately 6 mpccf ≡ 1 mg/m³.

4. Equivalent TLVs in mppcf and mg/m³ (respirable mass) for Mineral Dusts.

Substance	Threshold Limit Value		
	Count mppcf	Resp. Mass mg/m³	Total Mass* mg/m³
Silica (SiO_2)			
Amorphous	20	(3)**	(6)
Cristobalite	1.5	0.05	0.15
Fused silica	3	0.1	0.3
Quartz	3	0.1	0.3
Tridymite	1.5	0.05	0.15
Coal Dust	(12)	2	(4)
Diatomaceous earth, natural	—	1.5	—
Graphite	15	(2.5)	(5)
Mica	20	(3)	(6)
Mineral wool fiber	—	(5)	10
Nuisance particulates	30	(5)	10
Perlite	30	(5)	(10)
Portland Cement	30	(5)	(10)
Soapstone	20	(3)	(6)
Talc (nonasbestiform)	20	(3)	(6)
Tripoli	(3)	0.1	(0.3)

*Unless otherwise specified, respirable mass is presumed to equal approximately 50% of total mass
**All values in parentheses ( ) represent newly calculated values based on equivalence of 6 mppcf ≡ 1 mg/m³ respirable mass and respirable mass ≡ 50% total mass

TLVs®
Threshold Limit Values for Physical Agents Adopted by ACGIH for 1976



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1976 TLV PHYSICAL AGENTS COMMITTEE

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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.

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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 1 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*; F. N. Dukes-Dobos and A. Henschel: *"Development of Permissible Heat Exposure Limits for Occupational Work."* ASHRAE Journal, Vol. 15: No. 9, September 1973, pp. 57–62.)

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:
   $WBGT = 0.7WB + 0.2GT + 0.1\ DB$
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 1

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

	Work Load		
Work — Rest Regimen	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 1 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

HEAT STRESS

I. *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 −5°C to 50°C with an accuracy of ±0.5°C. The dry bulb thermometer must be shielded

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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.

C. One 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 1964.

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 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 (up to 200 Kcal/hr or 800 Btu/hr): e.g., sitting or standing to control machines, performing light hand or arm work,

(2) moderate work (200–350 Kcal/hr or 800–1400 Btu/hr): e.g., walking about with moderate lifting and pushing,

(3) heavy work (350–500 Kcal/hr or 1400–2000 Btu/hr): 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. When this method is used the permissible heat exposure limit can be determined by Figure 1.

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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 1 and Figure 1 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. Where the WBGT of the work area is different from that of the rest area a time-weighted average value should be used for both environmental and metabolic heat. When time-weighted average values are used the appropriate curve on Figure 1 is the solid line labeled "continuous."

The time-weighted average metabolic rate (M) shall be determined by the equation:

$$\text{Av. } M = \frac{(M_1) \times (t_1) + (M_2) \times (t_2) + \ldots + (M_n) \times (t_n)}{(t_1) + (t_2) + \ldots + (t_n)}$$

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Where M_1 M_2, M_n are estimated or measured metabolic rates for the various activities of the worker during the total time period. t_1, t_2, t_n are the elapsed times in minutes spent at the corresponding metabolic rate as determined by a time study.

The time-weighted average WBGT shall be determined by the equation:

$$\text{Av. WBGT} = \frac{(\text{WBGT}_1) \times (t_1) + (\text{WBGT}_2) \times t_2 + \ldots + (\text{WBGT}_n) \times (t_n)}{(t_1) + (t_2) + \ldots + (t_n)}$$

where WBGT_1, WBGT_2, WBGT_n are calculated values of WBGT for the various work and rest areas occupied during total time periods. t_1, t_2, t_n are the elapsed times in minutes spent in the corresponding areas which are determined by a time study. Where exposure to hot environmental conditions is continuous for several hours or the entire work day, the time-weighted averages shall be calculated as hourly time-weighted average i.e., $t_1 + t_2 + \ldots t_n = 60$ minutes. Where the exposure is intermittent, the time-weighted averages shall be calculated as two-hour time-weighted averages, i.e., $t_1 + t_2 + \ldots t_n = 120$ minutes.

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 shall be kept reasonably cool (10°–15°C or 50.0°–60.0°F) 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 cothing 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 1 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.

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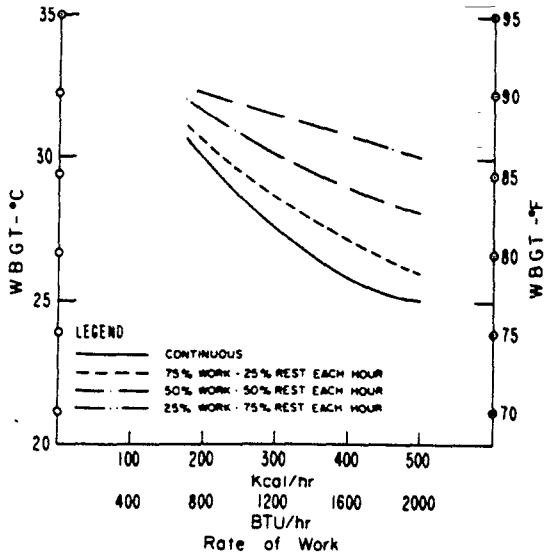


Figure 1 — Permissible Heat Exposure Threshold Limit Value

IONIZING RADIATION

See U.S. Department of Commerce National Bureau of Standards, Handbook 59, "Permissible Dose from External Sources of Ionizing Radition," 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); and except for all TLVs for wavelengths between 0.1–1 mm where the limiting aperture is 10 mm. 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 Factors A and B (C_A and C_B) 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 1.06 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 1.06 μm are to be increased by a uniformly extrapolated factor as shown in Figure 2. For certain exposure durations at wavelengths between 700–800 nm, correction factor C_B is applied.

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.

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(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^{-5} second. For pulses of greater duration, the following formula should be followed:

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

where:

n = number of pulses in train
τ = duration of a single pulse in the train
Standard ($n\tau$) = protection standard of one pulse having a duration equal to $n\tau$ seconds.

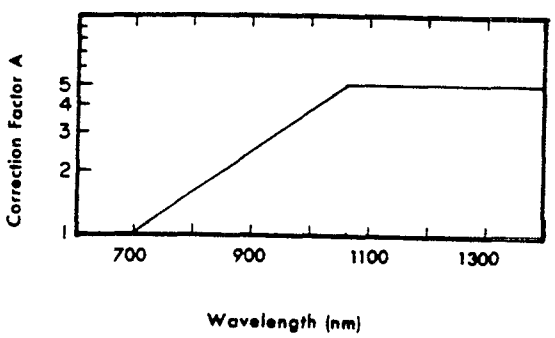


Figure 2 — TLV correction factors for laser wavelengths (eye).

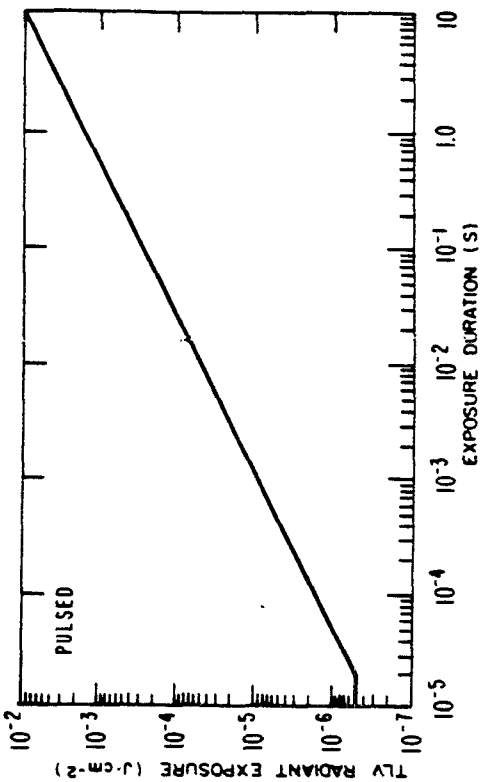


Figure 3a — TLV for intrabeam (direct) viewing of laser beam (400–700 nm).

MAP 000037

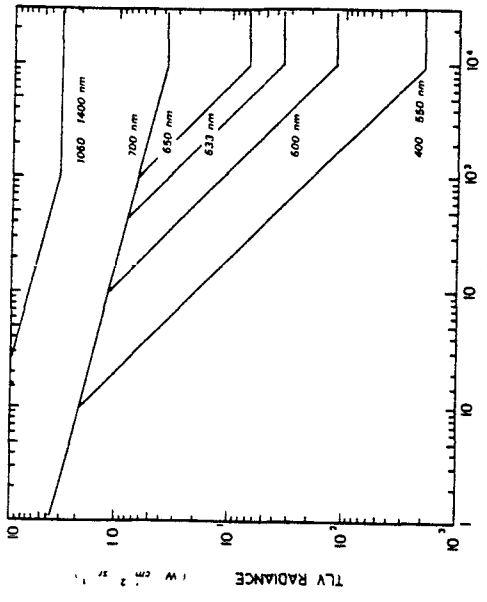


Figure 3b — TLV for intrabeam (direct) viewing of CW laser beam (400–1400 nm).

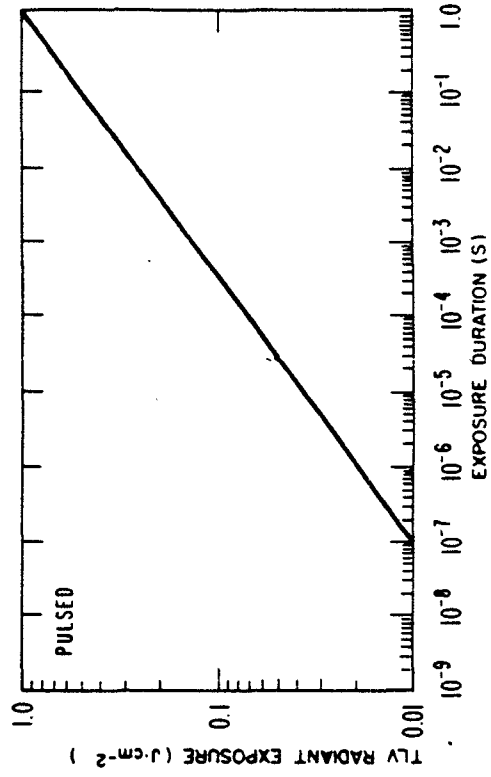


Figure 4a — TLV for laser exposure of skin and eyes for far-infrared radiation (wavelengths greater than ~1.4 μm).

MAP 000038

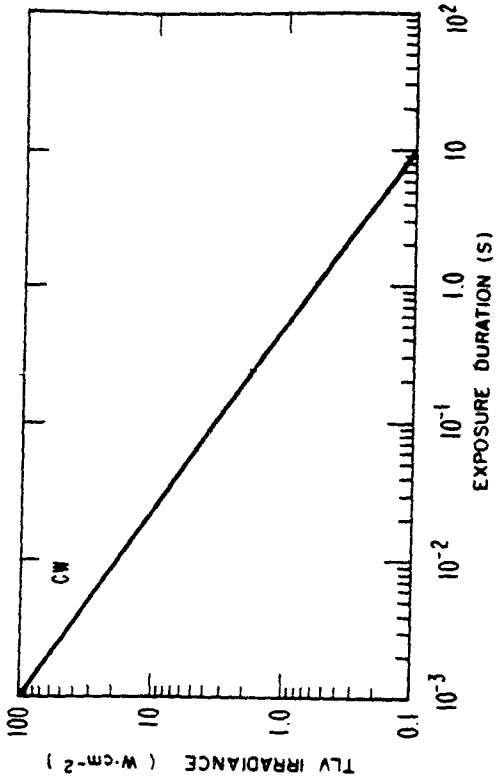


Figure 4b — TLV for CW laser exposure of skin and eyes for far-infrared radiation (wavelengths greater than 1.4 μm).

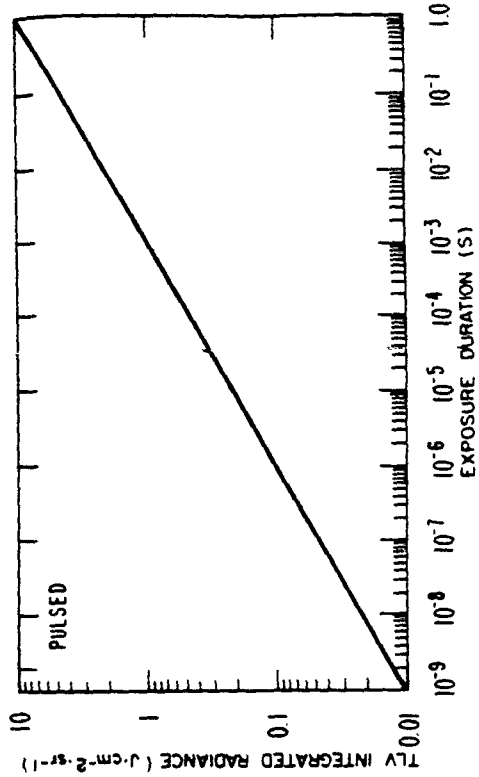


Figure 5a — TLV for extended sources or diffuse reflections of laser radiation (400–700 nm).

MAP 000039

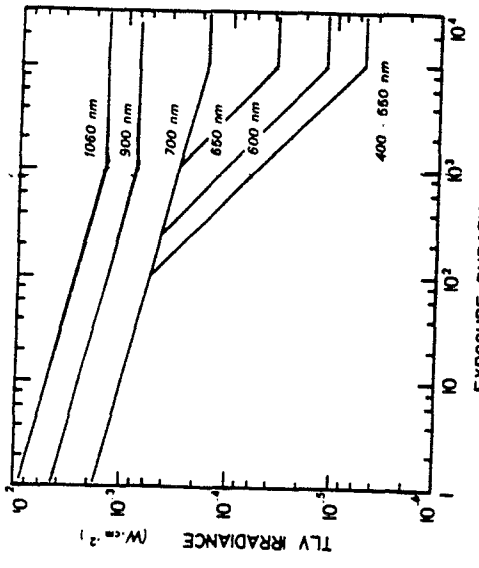


Figure 5b — TLV for extended sources or diffuse reflections of laser radiation (400–1400 nm), CW

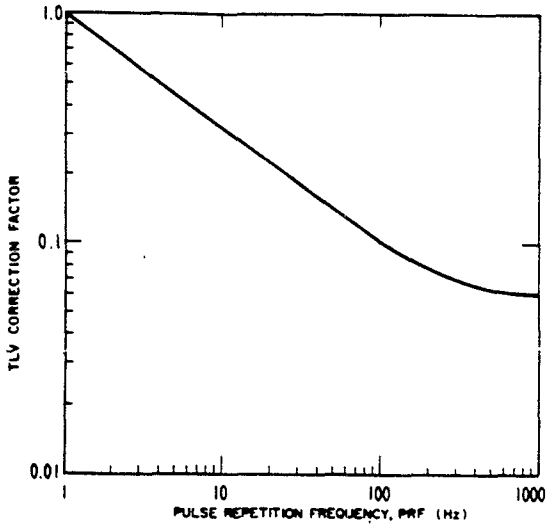


Figure 6 — Multiplicative correction factor for repetitively pulsed lasers having pulse durations less than 10^{-5} second. TLV for a single pulse of the pulse train is multiplied by the above correction factor. Correction factor for PRF greater than 1000 H_z is 0.06.

MAP 000040

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^{-3} 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 $^{-2}$

TABLE 3 (Cont.)

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^{-7} J • cm $^{-2}$
	400 nm to 700 nm	1.8×10^{-5} to 10	1.8 ($t/\sqrt[4]{t}$) mJ • cm $^{-2}$
	400 nm to 549 nm	10 to 10^{4}	10 mJ • cm $^{-2}$
	550 nm to 700 nm	10 to T_1	1.8 ($t/\sqrt[4]{t}$) mJ • cm $^{-2}$
	550 nm to 700 nm	T_1 to 10^{4}	10 C_B mJ • cm $^{-2}$
	400 nm to 700 nm	10^{4} to 3×10^{4}	C_B μW • cm $^{-2}$
IR-A	700 nm to 1059 nm	10^{-9} to 1.8×10^{-5}	5 $C_A \times 10^{-7}$ J • cm $^{-2}$
	700 nm to 1059 nm	1.8×10^{-5} to 10^{3}	1.8 C_A ($t/\sqrt[4]{t}$) mJ • cm $^{-2}$
	1060 nm to 1400 nm	10^{-9} to 10^{-4}	5×10^{-6} J • cm $^{-2}$
	1060 nm to 1400 nm	10^{-4} to 10^{3}	9($t/\sqrt[4]{t}$) mJ • cm $^{-2}$
	700 nm to 1400 nm	10^{3} to 3×10^{4}	320 C_A μW • cm $^{-2}$
IR-B & C	1.4 μm to 10^{-3} μm	10^{-9} to 10^{-7}	10^{-2} J • cm ^{2}
	" "	10^{-7} to 10	0.56 $\sqrt[4]{t}$ J • cm $^{-2}$
	" "	10 to 3×10^{4}	0.1 W • cm $^{-2}$

C_A - See Fig. 2, Laser TLV listing.
C_B = 1 for λ = 400 to 550 nm, $C_B = 10^{[0.015(\lambda - 550)]}$ for λ = 550 to 700 nm
T_1 = 10 s for λ = 400 to 550 nm, $T_1 = 10 \times 10^{[0.02(\lambda - 550)]}$ for λ = 550 to 700 n

MAP 000041

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^{-3} to 3×10^{4}	Same as Table 3
Light	400 nm to 700 nm	10^{-9} to 10	$10\ \sqrt[4]{t}$ J • cm^{-2} • sr^{-1}
	400 nm to 549 nm	10 to 10^{4}	21 J • cm^{-2} • sr^{-1}
	550 nm to 700 nm	10 to T_1	$3.83\ (t/\sqrt[4]{t})$ J • cm^{-2} • sr^{-1}
	550 nm to 700 nm	T_1 to 10^{4}	$21/C_B$ J cm^{-2} • sr^{-1}
	400 nm to 700 nm	10^{4} to 3×10^{4}	$2.1/C_B \times 10^{-3}$ W • cm^{-2} • sr^{-1}
IR-A	700 nm to 1400 nm	10^{-9} to 10	$10\ C_A\ \sqrt[4]{t}$ J • cm^{-2} • sr^{-1}
	700 nm to 1400 nm	10 to 10^{3}	$3.83\ C_A\ (t/\sqrt[4]{t})$ J • cm^{-2} • sr^{-1}
	700 nm to 1400 nm	10^{3} to 3×10^{4}	$0.64\ C_A$ W • cm^{-2} • sr^{-1}
IR-B & C	1.4 μm to 1 mm	10^{-9} to 3×10^{4}	Same as Table 3

C_A, C_B, and T_1 are the same as in footnote to Table 3.

TABLE 5

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

Exposure Duration(s)	Angle α (mrad)
10^{-9}	8.0
10^{-8}	5.4
10^{-7}	3.7
10^{-6}	2.5
10^{-5}	1.7
10^{-4}	2.2
10^{-3}	3.6
10^{-2}	5.7
10^{-1}	9.2
1.0	15
10	24
10^{2}	24
10^{3}	24
10^{4}	24

MAP 000042

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 & IR-A	400 nm to 1400 nm	10^{-9} to 10^{-1}	$2\ C_A \times 10^{-2}$ J • cm^{-2}
	" "	10^{-7} to 10	$1.1\ C_A \sqrt{t}$ J • cm^{-2}
IR-B & C	1.4 μm to 1 mm	10^{-9} to 3×10^{4}	Same as Table 3

$C_A = 1.0$ for λ = 400–700 nm; see Figure 2 Laser TLV list for greater wavelength values.

NOTE: To aid in the determination of TLV's for exposure durations requiring calculations of fractional powers Figures 3, 4, 5 and 6 may be used.

MICROWAVES*

These Threshold Limit Values refer to microwave energy in the frequency range of 100 MHz to 100 GHz 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.

*See Notice of Intended Changes, Page 00; Notice of Intent to Study, page 00.

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

MAP 000043

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 National 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 7.

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 on-the-job noise exposures of 80 dBA or greater shall be used in the above calculations.

Table 7
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.

IMPULSIVE OR IMPACT NOISE

It is recommended that exposure to impulsive or impact noise shall not exceed the limits listed in Table 8 or taken from Figure 7. No exposures in excess of 140 decibels peak sound pressure level are permitted. 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 8
Threshold Limit Values
Impulsive or Impact Noise

Sound Level dB*	Permitted Number of Impulses or Impacts per day
140	100
130	1000
120	10,000

*It should be recognized that the application of the TLV for noise will not protect all workers from the adverse effects of noise exposure. A hearing conservation program with audiometric testing is necessary when workers are exposed to noise at or above the TLV levels.
**Decibels peak sound pressure level.

MAP 000044

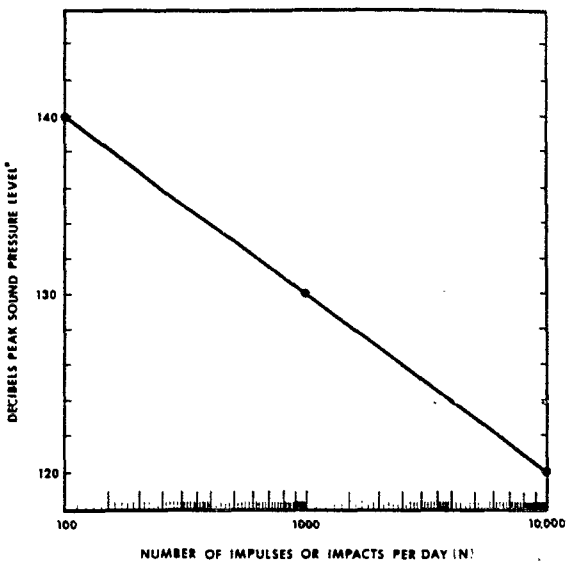


Figure 7 —

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, and solar radiation, but do not apply to ultraviolet lasers.* 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 nm) total irradiance incident upon the unprotected skin or eye should not exceed 1 mw/cm^2 for periods greater than 10^3 seconds (approximately 16 minutes) and for exposure times less than 10^3 seconds should not exceed one J/cm^2.
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 9 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 following weighting formula should be used:

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

*See Laser TLVs.

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where:

E_{eff} = effective irradiance relative to a monochromatic source at 270 nm in W/cm² (J/s/cm²)

E_λ = spectral irradiance in W/cm²/nm

S_λ = relative spectral effectiveness (unitless)

$\Delta\lambda$ = 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 10 which provides exposure times corresponding to effective irradiances in μW/cm².

TABLE 9

Relative Spectral Effectiveness by Wavelength

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
254	6.0	0.5
260	4.6	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

**1 m J/cm² = 10^{-3} J/cm²

TABLE 10

Permissible Ultraviolet Exposures

Duration of Exposure Per Day	Effective Irradiance, E_{eff} (μW/cm²)***
8 hrs.	0.1
4 hrs.	0.2
2 hrs.	0.4
1 hr.	0.8
30 min.	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 TLVs 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°.

***1μW/cm² = 10^{-6} W/cm²

MAP 000046

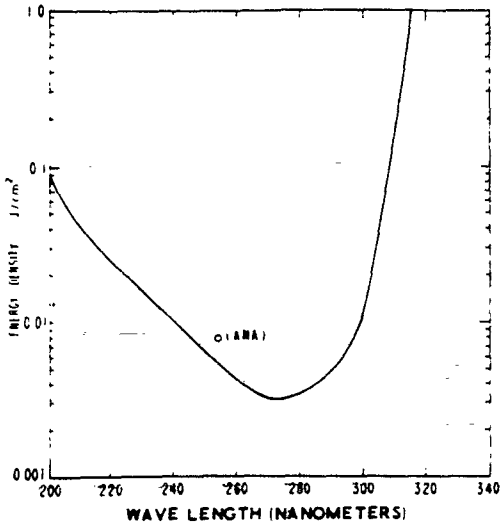


Figure 8 — Threshold Limit Values for Ultraviolet Radiation

Conditioned (tanned) individuals can tolerate skin exposure in excess of the TLV without erythemal effects. However, such conditioning may not protect persons against skin cancer.

NOTICE OF INTENDED CHANGES (for 1976)

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.

MICROWAVES

These Threshold Limit Values refer to microwave energy in the frequency range of 300 MHz to 300 GHz and represent conditions under which it is believed that nearly all workers may be repeatedly exposed without adverse effect.

Under conditions of moderate to severe heat stress, the recommended values may need to be reduced.* Therefore, these values should be used as guides in the control of exposure to microwave energy and should not be regarded as a fine line between safe and dangerous levels.

Recommended Values:

The Threshold Limit Value for occupational exposure to microwave energy, where power density or field intensity is known and exposure time is controlled, is as follows:

1. For exposure to continuous wave (CW) sources, the power density level shall not exceed 10 milliwatts per square centimeter (mW/cm^2) for continuous exposure, and the total exposure time shall be limited to an 8-hour workday. This power density is approximately equivalent to a free-space electric field strength of 200 volts-per-meter rms (V/m) and a free-space magnetic field strength of 0.5 ampere-per-meter rms (A/m).
2. Exposures to CW power density levels greater than 10 mW/cm^2 are permissible up to a maximum of 25 mW/cm^2 based upon an average energy density of 1 milliwatt-hour per square centimeter (mWh/cm^2) averaged over any 0.1 hour period. For example, at 25 mW/cm^2, the permissible exposure duration is approximately 2.4 minutes in any 0.1 hour period.
3. For repetitively pulsed microwave sources, the average field strength or power density is calculated by multiplying the peak-pulse value by the duty cycle. The duty cycle is equal to the pulse duration in sec-

*Mumford, W.W., "Heat Stress Due to R. F. Radiation," Proceedings of IEEE, Vol. 57, No. 2, Feb. 1969, pp. 171–178.

MAP 000047

onds times the pulse repetition rate in Hertz. Exposure during an 8-hour workday shall not exceed the following values which are averaged over any 0.1 hour period:

Power Density	10 mW/cm²
Energy Density	1 mWh/cm²
Mean Squared Electric Field Strength	40,000 V²/m²
Mean Squared Magnetic Field Strength	0.25 A²/m²

4. Exposure is not permissible in CW or repetitively pulsed fields with an average power density in excess of 25 mW/cm² or approximate equivalent free-space field strengths of 300 V/m or 0.75 A/m.

NOTICE OF INTENT TO ESTABLISH THRESHOLD LIMIT VALUES

LIGHT AND NEAR-INFRARED RADIATION

These Threshold Limit Values refer to visible and near-infrared radiation in the wavelength range of 400 nm to 1400 nm and represent conditions under which it is believed that nearly all workers may be exposed without adverse effect. These values should be used as guides in the control of exposure to light and should not be regarded as a fine line between safe and dangerous levels.

Recommended Values:

The Threshold Limit Value for occupational exposure to broad-band light and near-infrared radiation for the eye apply to exposure in any eight-hour workday and require knowledge of the spectral radiance (L_λ) and total irradiance (E) of the source as measured at the position(s) of the eye of the worker. Such detailed spectral data of a white light source is generally only required if the luminance of the source exceeds 1 cd cm^{-2}. At luminances less than this value the TLV would not be exceeded.

The TLV's are:

1. To protect against retinal thermal injury, the spectral radiance of the lamp weighted against the function R

(Table 14) should not exceed:

$$\sum_{400}^{1400} L_\lambda R_\lambda \Delta\lambda \leq \sqrt{t}/\alpha t \qquad (1)$$

where L_λ is in W cm^{-2} sr^{-1} and t is the viewing duration (or pulse duration if the lamp is pulsed) limited to 1 μs to 10 s, and α is the angular subtense of the source in radians. If the lamp is oblong, α refers to the longest dimension that can be viewed. For instance, at a viewing distance r = 100 cm from a tubular lamp of length l = 50 cm, the viewing angle is:

$$\alpha = l/r = 50/100 = 0.5 \text{ rad} \qquad (2)$$

2. To protect against retinal injury from chronic blue-light exposure the integrated spectral radiance of the lamp weighted against the blue-light hazard function B_λ (Table 14) should not exceed:

$$\sum_{400}^{1400} L_\lambda t\, B_\lambda \Delta\lambda \leq 100 \text{ Jcm}^{-2}\text{sr}^{-1} \quad (t \leq 10^4 \text{s}) \qquad (3a)$$

$$\sum_{400}^{1400} L_\lambda B_\lambda \Delta\lambda \leq 10^{-2} \text{ Wcm}^{-2}\text{sr}^{-1} \quad (t > 10^4 \text{s}) \qquad (3b)$$

For a source radiance L which exceeds 2 mW cm^{-2} sr^{-1} in the blue spectral region, the permissible exposure duration t_{max} in seconds is simply:

$$t_{max} = 100 \text{ J cm}^{-2}\text{ sr}^{-1}/\text{L (blue)} \qquad (4)$$

The latter limits are greater than the maximum permissible exposure limits for 440 nm laser radiation (see Laser TLV) because a 2–3 mm pupil is assumed rather than a 7 mm pupil for the Laser TLV.

3. *Infrared Radiation:* To avoid possible delayed effects upon the lens of the eye (cataractogenesis), the infrared radiation ($\lambda > 770$ nm) should be limited to 10 mWcm^{-2}. For an infrared heat lamp or any near-infrared source where a strong visual stimulus is absent, the near infrared (770–1400 nm) radiance as viewed by the eye should be limited to:

$$\sum_{770}^{1400} E_\lambda \Delta_\lambda = 600/\alpha \qquad (5)$$

for extended duration viewing conditions. This limit is based upon a 7 mm pupil diameter.

MAP 000048

TABLE 11

SPECTRAL WEIGHTING FUNCTIONS FOR ASSESSING RETINAL HAZARDS FROM BROAD — BAND OPTICAL SOURCES

Wavelength (nm)	Blue-Light Hazard Function B_λ	Burn Hazard Function R_λ
400	0.10	1.0
405	0.20	2.0
410	0.40	4.0
415	0.80	8.0
420	0.90	9.0
425	0.95	9.5
430	0.98	9.8
435	1.0	10
440	1.0	10
445	0.97	9.7
450	0.94	9.4
455	0.90	9.0
460	0.80	8.0
465	0.70	7.0
470	0.62	6.2
475	0.55	5.5
480	0.45	4.5
485	0.40	4.0
490	0.22	2.2
495	0.16	1.6
500–600	$10^{[(450-\lambda)/50]}$	1.0
600–700	0.001	1.0
700–1060	0.001	$10^{[(\lambda-700)/515]}$
1060–1400	0.001	0.2

AIRBORNE UPPER SONIC AND ULTRASONIC ACOUSTIC RADIATION

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. The values listed in Table 15 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. The levels for the third octave bands centered below 20 kHz are below those which cause subjective effects. Those levels for 1/3 octaves above 20 kHz are for prevention of possible hearing losses from subharmonics of these frequencies.

TABLE 12

Permissible Ultrasound Exposure Levels

Mid-Frequency of Third-Octave Band kHz	One-Third Octave — Band Level in dB reference 0.0002 dynes/cm²
10	80
12.5	80
16	80
20	105
25	110
31.5	115
40	115
50	115

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NOTICE OF INTENT TO STUDY

These agents comprise those which the Physical Agents Committee of ACGIH proposes to study during this year to determine the feasibility of establishing proposed TLVs in 1976. Comments and suggestions, accompanied by substantitive evidence, are solicited.

1. *Radiofrequency Radiation*. Specifically, that portion of the spectrum from 10 MHz to 100 MHz.
2. *Microwave Radiation*. Specifically from 100 GHz to 300 GHz.
3. *Magnetic Fields*. Both pulsed and continuous.
4. *Laser Radiation*. Specifically ultraviolet radiation for pulsed exposures, and repetitively pulsed light and infrared-A laser exposures.
5. *Ultrasonic Energy*. Specifically, acoustic energy at frequencies above 10 kHz.
6. *Vibration*. Segmental and whole-body.

The American Conference of Governmental Industrial Hygienists was organized in 1938 by a group of governmental industrial hygienists who desired a medium for the free exchange of ideas, experiences and the promotion of standards and techniques in industrial health.

It is an organization devoted to the development of administrative and technical aspects of worker health protection. The association has contributed substantially to the development and improvement of official industrial health services to industry and labor. The committees on Industrial Ventilation and Threshold Limit Values are recognized throughout the world for their expertise and contributions to industrial hygiene.

Membership is limited to professional personnel in governmental agencies or educational institutions engaged in occupational safety and health programs. The more than 1600 members from across the United States and around the world give the organization an international scope.

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JOHN E. FOX

TLVs®
Threshold Limit Values
for
Chemical Substances
and
Physical Agents
in the
Workroom Environment
with
Intended Changes
for
1977



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Documentation of the Threshold Limit Values for Substances in Workroom Air. A separate companion piece to the Chemical TLVs is issued by ACGIH under this title. This publication gives the pertinent scientific information and data with reference to literature sources that were used to base each limit. Each documentation also contains a statement defining the type of response against which the limit is safeguarding the worker. For a better understanding of the TLVs it is essential that the Documentation be consulted when the TLVs are being used.

Information concerning the availability of copies of the Documentation of the Threshold Limit Values for Substances in Workroom Air should be directed to the Secretary-Treasurer, ACGIH.

TLVs®
Threshold Limit Values for Chemical Substances in Workroom Air Adopted by ACGIH for 1977



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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.

Tests are available (J. Occup. Med. 15: 564, 1973; 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).

Three categories of Threshold Limit Values (TLVs) are specified herein, as follows:

a) Threshold Limit Value-Time Weighted Average (TLV-TWA) — the time-weighted average concentration for a normal 8-hour workday or 40-hour workweek, to which nearly all workers may be repeatedly exposed, day after day, without adverse effect.

b) Threshold Limit Value-Short Term Exposure Limit (TLV-STEL) — the maximal concentration to which workers can be exposed for a period up to 15 minutes continuously without suffering from 1) irritation, 2) chronic or irreversible tissue change, or 3) narcosis of sufficient degree to increase accident proneness, impair self-rescue, or materially reduce work efficiency, provided that no more than four excursions per day are permitted, with at least 60 minutes between exposure periods, and provided that the daily TLV-TWA also is not exceeded. The STEL should be considered a maximal allowable concentration, or absolute ceiling, not to be exceeded at any time during the 15-minute excursion period. STELs are based on one or more of the following criteria: (1) Adopted TLVs including those with a "C" or "ceiling"

limit. (2) TWA-TLV Excursion Factors listed in Appendix D. (3) Pennsylvania Short-Term Limits for Exposure to Airborne Contaminants (Penna. Dept. of Hlth., Chapter 4, Art. 432, Rev. Jan. 25, 1968). (4) OSHA Occupational Safety and Health Standards, Fed. Reg. Vol. 36, No. 105, May 29, 1971. The TWA-STEL should not be used as engineering design criterion or considered as an emergency exposure level (EEL).

c) Threshold Limit Value-Ceiling (TLV-C) — the concentration that should not be exceeded even instantaneously.

For some substances, e.g., irritant gases, only one category, the TLV-Ceiling, may be relevant. For other substances, either two or three categories may be relevant, depending upon their physiologic action. It is important to observe that if any one of these three TLVs is exceeded, a potential hazard from that substance is presumed to exist.

The TLV-TWA should be used as guides in the control of health hazards and should not be used as fine lines between safe and dangerous concentrations.

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 a 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

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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 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 control of community air pollution nuisances, (3) in estimating the toxic potential of continuous, uninterrupted exposures or other extended work periods, (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 noncompliance 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 determining the magnitude of the value of the STELs, or 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 mucous 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

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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, may cause unpleasant deposits in the eyes, ears and nasal 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 10 mg/m^3, 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.

Physical Factors. It is recognized that such physical factors as heat, ultraviolet and ionizing 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 may be altered. Most of these stresses act adversely 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 BLVs, and their associated procedures for determining compliance with them, should thus be regarded as an effective means of providing health surveillance of the worker.

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Unlisted Substances. Many substances present or handled in industrial processes do not appear on the TLV list. In a number of instances the material is rarely present as a particulate, vapor or other airborne contaminant, and a TLV is not necessary. In other cases sufficient information to warrant development of a TLV, even on a tentative basis, is not available to the Committee. Other substances, of low toxicity, could be included in Appendix E pertaining to nuisance particulates. This list (as well as Appendix F) is not meant to be all inclusive; the substances serve only as examples.

In addition there are some substances of not inconsiderable toxicity, which have been omitted primarily because only a limited number of workers (e.g., employees of a single plant) are known to have potential exposure to possibly harmful concentrations.

"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 for 1968 are now official federal standards for industrial air.

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Substance	ADOPTED VALUES TWA ppm[a]	TWA mg/m³[b]	TENTATIVE VALUES STEL ppm[a]	STEL mg/m³[b]
Abate	—	10	—	20
Acetaldehyde	100	180	150	270
Acetic acid	10	25	15	37
C Acetic anhydride	5	20	—	—
Acetone	1,000	2,400	1,250	3,000
Acetonitrile	40	70	60	105
Acetylene	F	—	—	—
Acetylene dichloride, see 1, 2-Dichloroethylene	200	790	250	1,000
Acetylene tetrabromide	1	14	1.25	17.5
Acrolein	0.1	0.25	0.3	0.75
Acrylamide — Skin	—	0.3	—	0.6
Acrylonitrile — Skin	20	45	30	68
Aldrin — Skin	—	0.25	—	0.75
Allyl alcohol — Skin	2	5	4	10
Allyl chloride	1	3	2	6
Allyl glycidyl ether (AGE) — Skin	5	22	10	44
Allyl propyl disulfide	2	12	3	18
Alundum (Al_2O_3)	—	E	—	20
4-Aminodiphenyl — Skin	—	A1b	—	A1b
2-Aminoethanol, see Ethanolamine	3	6	6	12
2-Aminopyridine	0.5	2	1.5	6
Ammonia	25	18	35	27
Ammonium chloride-fume	—	10	—	20
Ammonium sulfamate (Ammate)	—	10	—	20
n-Amyl acetate	100	525	150	790
sec-Amyl acetate	125	650	150	810
Aniline — Skin	5	19	—	—
Anisidine (o-, p-isomers) — Skin	0.1	0.5	—	—
** Antimony & Compounds (as Sb)	—	(0.5)	—	—
ANTU (α-Naphthyl thiourea)	—	0.3	—	0.9

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

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Substance	ADOPTED VALUES TWA ppm[a]	ADOPTED VALUES TWA mg/m³[b]	TENTATIVE VALUES STEL ppm[a]	TENTATIVE VALUES STEL mg/m³[b]
Argon	F	—	F	F
** Arsenic & compounds (as As)	—	(0.5)	—	—
Arsine	0.05	0.2	—	—
Asbestos (all forms)	—	A1a	—	A1a
Asphalt (petroleum) fumes	—	5	—	10
Azinphos methyl — Skin	—	0.2	—	0.6
Baygon (propoxur)	—	0.5	—	1.5
Barium (soluble compounds)	—	0.5	—	—
Benzene — Skin	10, A2	30, A2	—	—
Benzidine production — Skin	—	A1b	—	A1b
p-Benzoquinone, see Quinone	0.1	0.4	0.3	1.2
Benzoyl peroxide	—	5	—	—
Benz(a)pyrene	—	A2	—	A2
Benzyl chloride	1	5	—	—
Beryllium	—	0.002	—	0.025
Biphenyl	0.2	1	—	—
Bismuth telluride	—	10	—	20
Bismuth telluride, Se-doped	—	5	—	10
* Borates, tetra, sodium salts, Anhydrous	—	1	—	—
Decahydrate	—	5	—	—
Pentahydrate	—	1	—	—
Boron oxide	—	10	—	20
Boron tribromide	1	10	3	30
C Boron trifluoride	1	3	—	—
Bromine	0.1	0.7	0.3	2
Bromine pentafluoride	0.1	0.7	0.3	2
Bromochloromethane	200	1,050	250	1,300
Bromoform — Skin	0.5	5	—	—
Butadiene (1, 3-butadiene)	1,000	2,200	1,250	2,750
Butane	600	1,400	750	1,610

Capital letters refer to Appendices
Footnotes (a thru h) see Page 31
**See Notice of Intended Changes.
*1977 Addition

Substance	ADOPTED VALUES TWA ppm[a]	ADOPTED VALUES TWA mg/m³[b]	TENTATIVE VALUES STEL ppm[a]	TENTATIVE VALUES STEL mg/m³[b]
Butanethiol, see Butyl mercaptan	0.5	1.5	—	—
2-Butanone	200	590	300	885
2-Butoxy ethanol (Butyl Cellosolve) — Skin	50	240	150	720
n-Butyl acetate	150	710	200	950
sec-Butyl acetate	200	950	250	1,190
tert-Butyl acetate	200	950	250	1,190
C n-Butyl alcohol — Skin	50	150	—	—
sec-Butyl alcohol	150	450	—	—
tert-Butyl alcohol	100	300	150	450
C Butylamine — Skin	5	15	—	—
C tert-Butyl chromate (as CrO_3) — Skin	—	0.1	—	—
n-Butyl glycidyl ether (BGE)	50	270	—	—
n-Butyl lactate	5	25	—	—
Butyl mercaptan	0.5	1.5	—	—
p-tert-Butyltoluene	10	60	20	120
Cadmium, dust & salts (as Cd)	—	0.05	—	0.15
C Cadmium oxide fume (as Cd)	—	0.05	—	—
Calcium carbonate	—	E	—	20
Calcium arsenate (as As)	—	1	—	—
Calcium cyanamide	—	0.5	—	1
** Calcium hydroxide	—	5	—	—
** Calcium oxide	—	(5)	—	—
Camphor, synthetic	2	12	3	18
Caprolactam Dust	—	1	—	3
Vapor	5	20	10	40
* Captafol (Difolatan®) — Skin	—	0.1	—	—
Captan	—	5	—	15
Carbaryl (Sevin®)	—	5	—	10
Carbofuran (Furadan®)	—	0.1	—	—
Carbon black	—	3.5	—	7
Carbon dioxide	5,000	9,000	15,000	18,000
Carbon disulfide — Skin	20	60	30	90

Capital letters refer to Appendices.
**See Notice of Intended Changes.
*1977 Addition.

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Substance	ADOPTED VALUES TWA ppm[a]	TWA mg/m³[b]	TENTATIVE VALUES STEL ppm[a]	STEL mg/m³[b]
Carbon monoxide	50	55	400	440
Carbon tetrabromide	0.1	1.4	0.3	4.2
Carbon tetrachloride — Skin	10	65	25	160
* Catechol (Pyrocatechol)	5	20	—	—
Cellulose (paper fiber)	—	E	—	20
Cesium hydroxide	—	2	—	—
Chlordane — Skin	—	0.5	—	2
Chlorinated camphene — Skin	—	0.5	—	1
Chlorinated diphenyl oxide	—	0.5	—	1.5
Chlorine	1	3	3	9
Chlorine dioxide	0.1	0.3	0.3	0.9
C Chlorine trifluoride	0.1	0.4	—	—
C Chloroacetaldehyde	1	3	—	—
α-Chloroacetophenone (Phenacyl chloride)	0.05	0.3	—	—
Chlorobenzene (Monochlorobenzene)	75	350	—	—
o-Chlorobenzylidene malononitrile — Skin	0.05	0.4	—	—
Chlorobromomethane	200	1,050	250	1,300
2-Chloro-1, 3-butadiene, see β Chloroprene	25	90	35	135
Chlorodifluoromethane	1,000	3,500	1,250	4,375
Chlorodiphenyl (42% Chlorine) — Skin	—	1	—	—
Chlorodiphenyl (54% Chlorine) — Skin	—	0.5	—	1
1-Chloro, 2, 3-epoxy-propane (Epichlorhydrin)	5	20	10	40
2-Chloroethanol (Ethylene chlorohydrin)	1	3	—	—
Chloroethylene (Vinyl chloride)	A1c	—	A1c	—

Capital letters refer to Appendices
*1977 Addition

Substance	ADOPTED VALUES TWA ppm[a]	TWA mg/m³[b]	TENTATIVE VALUES STEL ppm[a]	STEL mg/m³[b]
** Chloroform (Trichloromethane)	(25)	(120)	—	—
bis-Chloromethyl ether	0.001	A1a	—	A1a
1-Chloro-1-nitro-propane	20	100	—	—
Chloropicrin	0.1	0.7	—	—
β-Chloroprene — Skin	25	90	35	135
Chlorpyrifos (Dursban®) — Skin	—	0.2	—	0.6
o-Chlorostyrene	50	285	75	430
o-Chlorotoluene — Skin	50	250	75	375
2-Chloro-6-(trichloromethyl pyridine (N-Serve®)	—	10	—	20
Chromates, certain insoluble forms	—	0.05A1a	—	A1a
Chromic acid and Chromates, (as Cr.)	—	0.05	—	—
Chromium, Sol. chromic, chromous salts (as Cr.)	—	0.5	—	—
Clopidol (Coyden®)	—	10	—	20
Coal tar pitch volatiles (See Particulate polycyclic aromatic hydrocarbons)	—	A1a	—	A1a
** Cobalt metal, dust and fume	—	(0.1)	—	—
Copper fume	—	0.2	—	—
Dusts & Mists	—	1	—	2
Corundum (Al_2O_3)	—	E	—	E
Cotton dust, raw	—	0.2[m]	—	0.6
Crag® herbicide	—	10	—	20
Cresol, all isomers — Skin	5	22	—	—
Crotonaldehyde	2	6	6	18
Crufomate®	—	5	—	20
Cumene — Skin	50	245	75	365

m) See p 34.
Footnotes (a thru h) see Page 31.
**See Notice of Intended Changes.

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Substance	ADOPTED VALUES TWA ppm[a]	ADOPTED VALUES TWA mg/m³[b]	TENTATIVE VALUES STEL ppm[a]	TENTATIVE VALUES STEL mg/m³[b]
* Cyanamide	—	2	—	—
Cyanide, as CN — Skin	—	5	—	—
Cyanogen	10	20	—	—
Cyclohexane	300	1,050	375	1,300
Cyclohexanol	50	200	—	—
Cyclohexanone	50	200	—	—
Cyclohexene	300	1,015	—	—
Cyclohexylamine — Skin	10	40	—	—
Cyclopentadiene	75	200	150	400
2, 4-D (2, 4-Diphenoxy-acetic acid)	—	10	—	20
DDT (Dichlorodiphenyl-trichloroethane)	—	1	—	3
DDVP, See Dichlorvos	0.1	1	0.3	3
Decaborane — Skin	0.05	0.3	0.15	0.9
Demeton® — Skin	0.01	0.1	0.03	0.3
Diacetone alcohol (4-hydroxy-4-methyl-2-pentanone)	50	240	75	360
1, 2-Diaminoethane, See Ethylenediamine	10	25	—	—
Diazinon — Skin	—	0.1	—	0.3
Diazomethane	0.2	0.4	—	—
Diborane	0.1	0.1	—	—
1, 2-Dibromoethane (Ethylene dibromide) — Skin	20	145	30	220
Dibrom®	—	3	—	6
2-N-Dibutylaminoethanol — Skin	2	14	4	28
Dibutyl phosphate	1	5	2	10
Dibutyl phthalate	—	5	—	10
C Dichloracetylene	0.1	0.4	—	—
C o-Dichlorobenzene	50	300	—	—
p-Dichlorobenzene	75	450	110	675
Dichlorobenzidine — Skin	—	A2	—	A2
Dichlorodifluoromethane	1,000	4,950	1,250	6,200

Capital letters refer to Appendices
Footnotes (a thru h) see Page 31
*1977 Addition.

Substance	ADOPTED VALUES TWA ppm[a]	ADOPTED VALUES TWA mg/m³[b]	TENTATIVE VALUES STEL ppm[a]	TENTATIVE VALUES STEL mg/m³[b]
1, 3-Dichloro-5, 5-dimethyl hydantoin	—	0.2	—	0.4
1, 1-Dichloroethane	200	820	250	1,025
1, 2-Dichloroethane	50	200	75	300
1, 2-Dichloroethylene	200	790	250	1,000
Dichloroethyl ether — Skin	5	30	10	60
Dichloromethane, see Methylene chloride	200	720	250	900
** Dichloromonofluoro-methane	(1,000)	(4,200)	—	—
C 1, 1-Dichloro-1-nitroethane	10	60	—	—
1, 2-Dichloropropane, see Propylene dichloride	75	350	110	525
Dichlorotetrafluoro-ethane	1,000	7,000	1,250	8,750
Dichlorvos (DDVP) — Skin	0.1	1	0.3	3
* Dicrotophos (Bidrin®) — Skin	—	0.25	—	—
Dicyclopentadiene	5	30	—	—
Dicyclopentadienyl iron	—	10	—	20
Dieldrin — Skin	—	0.25	—	0.75
Diethylamine	25	75	—	—
Diethylaminoethanol — Skin	10	50	—	—
Diethylene triamine — Skin	1	4	—	—
Diethyl ether, see Ethyl ether	400	1,200	500	1,500
Diethyl phthalate	—	5	—	10
Difluorodibromomethane	100	860	150	1,290
C Diglycidyl ether (DGE)	0.5	2.8	—	—
Dihydroxybenzene, see Hydroquinone	—	2	—	3
Diisobutyl ketone	25	150	—	—

Capital letters refer to Appendices.
*1977 Addition
**See Notice of Intended Changes

MAP 000060

Substance	ADOPTED VALUES TWA ppm[a]	ADOPTED VALUES TWA mg/m³[b]	TENTATIVE VALUES STEL ppm[a]	TENTATIVE VALUES STEL mg/m³[b]
Diisopropylamine — Skin	5	20	—	—
Dimethoxymethane, see Methylal	1,000	3,100	1,250	3,875
Dimethyl acetamide — Skin	10	35	15	50
Dimethylamine	10	18	—	—
Dimethylaminobenzene, see Xylidene	5	25	10	50
Dimethylaniline (N-Dimethylaniline) — Skin	5	25	10	50
Dimethylbenzene, see Xylene	100	435	150	650
Dimethyl-1, 2-dibromo-2-dichloroethyl phosphate, see Dibrom	—	3	—	6
Dimethylformamide — Skin	10	30	20	60
2, 6-Dimethylheptanone, see Diisobutyl ketone	25	150	—	—
1, 1-Dimethylhydrazine — Skin	0.5	1	1	2
Dimethylphthalate	—	5	—	10
* C Dimethyl sulfate — Skin	0.1, A2	0.5, A2	—	—
Dinitrobenzene (all isomers) — Skin	0.15	1	0.5	3
Dinitro-o-cresol — Skin	—	0.2	—	0.6
3, 5-Dinitro-o-toluamide (Zoalene®)	—	5	—	10
Dinitrotoluene — Skin	—	1.5	—	5
Dioxane, tech. grade — Skin	50	180	—	—
* Dioxathion (Delnav®)	—	0.2	—	—
Diphenyl, see Biphenyl	0.2	1	0.6	3
Diphenylamine	—	10	—	20

Capital letters refer to Appendices
*1977 Addition
Footnotes (a thru h) see Page 31

Substance	ADOPTED VALUES TWA ppm[a]	ADOPTED VALUES TWA mg/m³[b]	TENTATIVE VALUES STEL ppm[a]	TENTATIVE VALUES STEL mg/m³[b]
Diphenylmethane diisocyanate, see Methylene bisphenyl isocyanate (MDI)	0.02	0.2	0.02	0.2
Dipropylene glycol methyl ether — Skin	100	600	150	900
Diquat	—	0.5	—	1
Di-sec, octyl phthalate (Di-2-ethylhexyl-phthalate)	—	5	—	10
Disulfuram	—	2	—	5
Disyston — Skin	—	0.1	—	0.3
2, 6-Ditert. butyl-p-cresol	—	10	—	20
* Diuron	—	10	—	—
Dyfonate	—	0.1	—	—
Emery	—	E	—	20
Endosulfan (Thiodan®) — Skin	—	0.1	—	0.3
Endrin — Skin	—	0.1	—	0.3
Epichlorhydrin — Skin	5	20	10	40
EPN — Skin	—	0.5	—	1.5
1, 2-Epoxypropane, see Propylene oxide	100	240	150	360
2, 3-Epoxy-1-propanol, see Glycidol	50	150	65	190
Ethane	F	—	F	—
Ethanethiol, see Ethyl mercaptan	0.5	1	1.5	3
Ethanolamine	3	6	6	12
Ethion (Nialate®) — Skin	—	0.4	—	—
2-Ethoxyethanol — Skin	100	370	150	560
2-Ethoxyethyl acetate (Cellosolve acetate) — Skin	100	540	150	810
Ethyl acetate	400	1,400	—	—
Ethyl acrylate — Skin	25	100	—	—
Ethyl alcohol (Ethanol)	1,000	1,900	—	—
Ethylamine	10	18	—	—

Footnotes (a thru h) see Page 31.
*1977 Addition.

MAP 000061

Substance	ADOPTED VALUES TWA ppm[a]	TWA mg/m³[b]	TENTATIVE VALUES STEL ppm[a]	STEL mg/m³[b]
Ethyl sec-amyl ketone (4-Methyl-3-heptanone)	25	130	—	—
Ethyl benzene	100	435	125	545
Ethyl bromide	200	890	250	1,110
Ethylbutyl ketone (3-Heptanone)	50	230	75	345
Ethyl chloride	1,000	2,600	1,250	3,250
Ethyl ether	400	1,200	500	1,500
Ethyl formate	100	300	150	450
Ethyl mercaptan	0.5	1	—	—
Ethyl silicate	(100)	(850)	—	—
Ethylene	F	—	F	—
C Ethylene chlorohydrin — Skin	1	3	—	—
Ethylene diamine	10	25	—	—
Ethylene dibromide, see 1, 2-Dibromoethane	20	145	30	220
Ethylene dichloride, see 1, 2-Dichloroethane	50	200	75	300
Ethylene glycol, Particulate	—	10	—	20
Vapor	100	260	125	325
C Ethylene glycol dinitrate and/or Nitroglycerin — Skin	0.2[d]	—	—	—
Ethylene glycol monomethyl ether acetate (Methyl cellosolve acetate) — Skin	25	120	40	180
Ethylene oxide	50	90	75	135
Ethylenimine — Skin	0.5	1	—	—
Ethylidene chloride, see 1, 1-Dichloroethane	200	320	250	400
C Ethylidene norbornene	5	25	—	—
N-Ethylmorpholine — Skin	20	94	20	94
Fensulfothion (Dasanit)	—	0.1	—	—
Ferbam	—	10	—	20

Capital letters refer to Appendices

Substance	ADOPTED VALUES TWA ppm[a]	TWA mg/m³[b]	TENTATIVE VALUES STEL ppm[a]	STEL mg/m³[b]
Ferrovanadium dust	—	1	—	0.3
Fluoride (as F)	—	2.5	—	—
Fluorine	1	2	2	4
Fluorotrichloromethane	1,000	5,600	1,250	7,000
C Formaldehyde	2	3	—	—
Formamide	20	30	30	45
Formic acid	5	9	5	9
Furfural — Skin	5	20	15	60
Furfuryl alcohol — Skin	5	20	10	40
Gasoline	—	B2	—	B2
Germanium tetrahydride	0.2	0.6	0.6	1 8
Glass, fibrous[c] or dust	—	E	—	E
**C Glutaraldehyde, activated or unactivated	—	(0.25)	—	—
Glycerin mist	—	E	—	E
Glycidol (2, 3-Epoxy-1-propanol)	50	150	75	225
Glycol monoethyl ether, see 2-Ethoxyethanol	100	370	150	560
Graphite (Synthetic)	—	E	—	—
Guthion®, see Azinphos-methyl	—	0.2	—	0.6
Gypsum	—	E	—	20
Hafnium	—	0.5	—	1.5
Helium	F	—	F	—
Heptachlor — Skin	—	0.5	—	1.5
Heptane (n-Heptane)	400	1,600	500	2,000
Hexachlorocyclopentadiene	0.01	0.11	0.03	0.33
Hexachloroethane — Skin	1	10	3	30
Hexachloronaphthalene — Skin	—	0.2	—	0.6
Hexafluoroacetone	0.1	0.7	0.3	2.1
Hexane (n-hexane)	100	360	125	450
2-Hexanone, see Methyl butyl ketone — Skin	25	100	40	150
Hexone (Methyl isobutyl ketone) — Skin	100	410	125	510

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

MAP 000062

Substance	ADOPTED VALUES TWA ppm[a]	TWA mg/m³[b]	TENTATIVE VALUES STEL ppm[a]	STEL mg/m³[b]
sec-Hexyl acetate	50	300	—	—
C Hexylene glycol	25	125	—	—
* Hydrazine — Skin	0.1	0.1	—	—
Hydrogen	F	—	F	—
Hydrogenated terphenyls	0.5	5	—	—
Hydrogen bromide	3	10	—	—
C Hydrogen chloride	5	7	—	—
Hydrogen cyanide — Skin	10	11	15	16
Hydrogen fluoride	3	2	—	—
Hydrogen peroxide	1	1.4	2	2.8
Hydrogen selenide	0.05	0.2	—	—
Hydrogen sulfide	10	15	15	27
Hydroquinone	—	2	—	4
Indene	10	45	15	27
Indium & Compounds (as In)	—	0.1	—	0.3
C Iodine	0.1	1	—	—
Iodoform	0.2	3	0.4	0.6
Iron oxide fume	B3	5	—	10
Iron pentacarbonyl	0.01	0.08	—	—
Iron salts, soluble (as Fe)	—	1	—	2
Isoamyl acetate	100	525	125	655
Isoamyl alcohol	100	360	125	450
Isobutyl acetate	150	700	187	875
Isobutyl alcohol	50	150	75	225
C Isophorone	5	25	—	—
* Isophorone diisocyanate — Skin	0.01	0.06	—	—
Isopropyl acetate	250	950	310	1,185
Isopropyl alcohol — Skin	400	980	500	1,225
Isopropylamine	5	12	10	24
Isopropyl ether	250	1,050	310	1,320
Isopropyl glycidyl ether (IGE)	50	240	75	360
Kaolin	—	E	—	20
Ketene	0.5	0.9	1.5	2.7

Capital letters refer to Appendices
*1977 Addition.

Substance	ADOPTED VALUES TWA ppm[a]	TWA mg/m³[b]	TENTATIVE VALUES STEL ppm[a]	STEL mg/m³[b]
Lead, inorg., fumes & dusts (as Pb)	—	0.15	—	0.45
Lead arsenate (as Pb)	—	0.15	—	0.45
Lead Chromate (as Cr)	—	0.05, A2	—	—
Limestone	—	E	—	20
Lindane — Skin	—	0.5	—	1.5
Lithium hydride	—	0.025	—	—
L.P.G. (Liquified petroleum gas)	1,000	1,800	1,250	2,250
Magnesite	—	E	—	20
Magnesium oxide fume	—	10	—	—
Malathion — Skin	—	10	—	—
Maleic anhydride	0.25	1	—	—
C Manganese & Compounds (as Mn)	—	5	—	—
Manganese cyclopentadienyl tricarbonyl (as Mn) — Skin	—	0.1	—	0.3
Marble	—	E	—	20
Mercury (Alkyl compounds) — Skin, As Hg	0.001	0.01	0.003	0.03
Mercury (All forms except alkyl) as Hg	—	0.05	—	0.15
Mesityl oxide	25	100	—	—
Methane	F	—	F	—
Methanethiol, see Methyl mercaptan	0.5	1	—	—
* Methomyl (Lannate®) — Skin	—	2.5	—	—
Methoxychlor	—	10	—	—
2-Methoxyethanol — Skin (Methyl cellosolve)	25	80	35	120
Methyl acetate	200	610	250	760
Methyl acetylene (propyne)	1,000	1,650	1,250	2,060

*1977 Addition.
Capital letters refer to Appendices.

MAP 000063

Substance	ADOPTED VALUES TWA ppm[a]	ADOPTED VALUES TWA mg/m³[b]	TENTATIVE VALUES STEL ppm[a]	TENTATIVE VALUES STEL mg/m³[b]
Methyl acetylene-propadiene mixture (MAPP)	1,000	1,800	1,250	2,250
Methyl acrylate — Skin	10	35	—	—
Methyl acrylonitrile — Skin	1	3	2	6
Methylal (dimethoxymethane)	1,000	3,100	1,250	3,875
Methyl alcohol (methanol) — Skin	200	260	250	325
Methylamine	10	12	—	—
Methyl amyl alcohol, see Methyl isobutyl carbinol	25	100	40	150
Methyl 2-cyanoacrylate	2	8	4	16
Methyl isoamyl ketone	100	475	150	710
Methyl n-amyl ketone (2-Heptanone)	100	465	150	710
Methyl bromide — Skin	15	60	—	—
Methyl butyl ketone, see 2-Hexanone	25	100	40	150
Methyl cellosolve — Skin see 2-Methoxyethanol	25	80	35	120
Methyl cellosolve acetate — Skin, see Ethylene glycol monomethyl ether acetate	25	120	35	150
Methyl chloride	100	210	125	260
Methyl chloroform	350	1,900	450	2,375
Methylcyclohexene	400	1,600	500	2,000
Methylcyclohexanol	50	235	75	350
o-Methycyclohexanone — Skin	50	230	75	345
Methylcyclopentadienyl manganese tricarbonyl (as Mn) — Skin	0.1	0.2	0.3	0.6
Methyl demeton — Skin	—	0.5	—	1.5
C Methylene bisphenyl isocyanate (MDI)	0.02	0.2	—	—

Capital letters refers to Appendices

Substance	ADOPTED VALUES TWA ppm[a]	ADOPTED VALUES TWA mg/m³[b]	TENTATIVE VALUES STEL ppm[a]	TENTATIVE VALUES STEL mg/m³[b]
* Methylene chloride (dichloromethane)	200	720	250	900
4, 4'-Methylene bis (2-chloraniline) — Skin	0.02, A2	—	A2	—
C Methylene bis (4-cyclohexylisocyanate)	0.01	0.11	—	—
Methyl ethyl ketone (MEK), see 2-Butanone	200	590	250	740
C Methyl ethyl ketone peroxide	0.2	1.5	—	—
Methyl formate	100	250	150	375
Methyl iodide — Skin	5	28	10	56
Methyl isobutyl carbinol — Skin	25	100	40	150
Methyl isobutyl ketone, see Hexone	100	410	125	510
Methyl isocyanate — Skin	0.02	0.05	—	—
Methyl mercaptan	0.5	1	—	—
Methyl methacrylate	100	410	125	510
Methyl parathion — Skin	—	0.2	—	0.6
Methyl propyl ketone, see 2-Pentanone	200	700	250	875
C Methyl silicate	5	30	—	—
C α-Methyl styrene	100	480	—	—
Molybdenum (as Mo) Soluble compounds	—	5	—	10
Insoluble compounds	—	10	—	20
* Monocrotophos (Azodrin®)	—	0.25	—	—
Monomethyl aniline — Skin	2	9	4	18
C Monomethyl hydrazine — Skin	0.2	0.35	—	—
Morpholine — Skin	20	70	30	105
Naphthalene	10	50	15	75

Capital letters refer to Appendices
Footnotes (a thru h) see Page 31.
*1977 Addition

MAP 000064

Substance	ADOPTED VALUES TWA ppm[a]	TWA mg/m³[b]	TENTATIVE VALUES STEL ppm[a]	STEL mg/m³[b]
β-Naphthylamine	—	A1b	—	A1b
Neon	F	—	F	—
* Nickel carbonyl	0.05	0.35	—	—
Nickel metal	—	1	—	—
Nickel, soluble compounds (as Ni)	—	0.1	—	0.3
Nicotine — Skin	—	0.5	—	1.5
Nitric acid	2	5	4	10
Nitric oxide	25	30	35	45
p-Nitroaniline — Skin	1	6	2	12
Nitrobenzene — Skin	1	5	2	10
p-Nitrochlorobenzene — Skin	—	1	—	2
4-Nitrodiphenyl	—	A1b	—	A1b
Nitroethane	100	310	150	465
C Nitrogen dioxide	5	9	—	—
Nitrogen trifluoride	10	29	15	45
Nitroglycerin[d] — Skin	0.2	2	—	—
Nitromethane	100	250	150	375
1-Nitropropane	25	90	35	135
2-Nitropropane	25	90	—	—
N-Nitrosodimethylamine (dimethylnitrosoamine) — Skin	—	A2	—	A2
Nitrotoluene — Skin	5	30	10	60
Nitrotrichloromethane, see Chloropicrin	0.1	0.7	0.3	2
Nonane	200	1,050	250	1,300
Octachloronaphthalene — Skin	—	0.1	—	0.3
Octane	300	1,450	375	1,800
Oil mist	—	5[h]	—	10
Osmium tetroxide (as Os)	0.0002	0.002	0.0006	0.006
Oxalic acid	—	1	—	2
Oxygen difluoride	0.05	0.1	0.15	0.3
Ozone	0.1	0.2	0.3	0.6
Paraffin wax fume	—	2	—	6

Capital letters refer to Appendices
Footnotes (a thru h) see Page 31
*1977 Addition

Substance	ADOPTED VALUES TWA ppm[a]	TWA mg/m³[b]	TENTATIVE VALUES STEL ppm[a]	STEL mg/m³[b]
** Paraquat — Skin	—	(0.5)	—	—
Parathion — Skin	—	0.1	—	0.3
Particulate polycyclic aromatic hydrocarbons (PPAH) as benzene solubles	—	0.2, A1a	—	A1a
Pentaborane	0.005	0.01	0.015	0.03
Pentachloronaphthalene	—	0.5	—	1.5
Pentachlorophenol — Skin	—	0.5	—	1.5
Pentaerythritol	—	E	—	20
Pentane	600	1,800	750	2,250
2-Pentanone	200	700	250	875
Perchloroethylene — Skin	100	670	150	1,000
Perchloromethyl mercaptan	0.1	0.8	—	—
Perchloryl fluoride	3	14	6	28
Petroleum distillates (naphtha)	*B3	—	B3	—
Phenol — Skin	5	19	10	38
Phenothiazine — Skin	—	5	—	10
p-Phenylene diamine — Skin	—	0.1	—	—
Phenyl ether (vapor)	1	7	2	14
Phenyl ether-Diphenyl mixture (vapor)	1	7	2	14
Phenylethylene, see Styrene	100	420	125	525
Phenyl glycidyl ether (PGE)	10	60	15	90
Phenylhydrazine — Skin	5	22	10	44
C Phenylphosphine	0.05	0.25	—	—
Phorate (Thimet®) — Skin	—	0.05	—	0.15
Phosdrin (Mevinphos®) — Skin	0.01	0.1	0.03	0.3
Phosgene (carbonyl chloride)	0.10	0.4	—	—

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

MAP 000065

Substance	ADOPTED VALUES TWA ppm[a]	ADOPTED VALUES TWA mg/m³[b]	TENTATIVE VALUES STEL ppm[a]	TENTATIVE VALUES STEL mg/m³[b]
Phosphine	0.3	0.4	1	1
Phosphonic acid	—	1	—	3
Phosphorus (yellow)	—	0.1	—	0.3
Phosphorus pentachloride	—	1	—	3
Phosphorus pentasulfide	—	1	—	3
Phosphorus trichloride	0.5	3	—	—
* Phthalic anhydride	1	6	4	24
* m-Phthalodinitrile	—	5	—	—
Picloram (Tordon®)	—	10	—	20
Picric acid — Skin	—	0.1	—	0.3
Pival® (2-Pivalyl-1, 3-indandione)	—	0.1	—	0.3
Plaster of Paris	—	E	—	20
Platinum (Soluble salts) as Pt	—	0.002	—	—
Polychlorobiphenyls, see Chlorodiphenyls	—	—	—	—
Polytetrafluoroethylene decomposition products	—	B1	—	B1
C Potassium hydroxide	—	2	—	—
Propane	F	—	F	—
β-Propiolactone	—	A2	—	A2
Propargyl alcohol — Skin	1	2	3	6
n-Propyl acetate	200	840	250	1,050
Propyl alcohol — Skin	200	500	250	625
n-Propyl nitrate	25	110	40	140
Propylene	F	—	F	—
Propylene dichloride (1, 2-Dichloropropane)	75	350	115	525
Propylene glycol monomethyl ether	100	360	150	450
Propylene imine — Skin	2	5	—	—
Propylene oxide	100	240	150	360
Propyne, see Methyl-acetylene	1,000	1,650	1,250	2,050
Pyrethrum	—	5	—	10

Capital letters refer to Appendices
*1977 Addition

Substance	ADOPTED VALUES TWA ppm[a]	ADOPTED VALUES TWA mg/m³[b]	TENTATIVE VALUES STEL ppm[a]	TENTATIVE VALUES STEL mg/m³[b]
Pyridine	5	15	10	30
Quinone	0.1	0.4	0.3	1
RDX — Skin	—	1.5	—	3
Resorcinol	10	45	20	90
Rhodium, Metal fume and dusts (as Rh)	—	0.1	—	0.3
Soluble salts	—	0.001	—	0.003
Ronnel	—	10	—	—
Rosin core solder pyrolysis products (as formaldehyde)	—	0.1	—	0.3
Rotenone (commercial)	—	5	—	10
Rouge	—	E	—	20
* Rubber solvent	400	1,600	—	—
* Selenium compounds (as Se)	—	0.2	—	—
Selenium hexafluoride, as Se	0.05	0.4	0.05	0.4
Sevin® (see Carbaryl)	—	5	—	10
Silane (see Silicon tetrahydride)	0.5	7	—	—
Silicon	—	E	—	20
Silicon carbide	—	E	—	20
Silicon tetrahydride (Silane)	0.5	0.7	1	1.5
Silver, metal and soluble compounds, as Ag	—	0.01	—	0.03
C Sodium azide	0.1	0.3	—	—
Sodium fluoroacetate (1080) — Skin	—	0.05	—	0.15
C Sodium hydroxide	—	2	—	—
Starch	—	E	—	20
Stibine	0.1	0.5	0.3	1.5
Stoddard solvent	100	575	150	720
Strychnine	—	0.15	—	0.45
Styrene, monomer (Phenylethylene)	100	420	125	525
** Succinaldehyde (see Glutaraldehyde)	—	(0.25)	—	—

Capital letters refer to Appendices
*1977 Addition.
**See Notice of Intended Changes.

MAP 000066

Substance	ADOPTED VALUES TWA ppm[a]	ADOPTED VALUES TWA mg/m³[b]	TENTATIVE VALUES STEL ppm[a]	TENTATIVE VALUES STEL mg/m³[b]
C Subtilisins (Proteolytic enzymes as 100% pure crystalline enzyme)	—	0.00006[o]	—	—
Sucrose	—	E	—	—
Sulfur dioxide	5	13	—	20
Sulfur hexafluoride	1,000	6,000	1,250	7,500
Sulfuric acid	—	1	—	—
Sulfur monochloride	1	6	3	18
Sulfur pentafluoride	0.025	0.25	0.075	0.75
Sulfur tetrafluoride	0.1	0.4	0.3	1
Sulfuryl fluoride	5	20	10	40
Systox, see Demeton®	0.01	0.1	0.03	0.3
2, 4, 5-T	—	10	—	20
Tantalum	—	5	—	10
TEDP — Skin	—	0.2	—	0.6
Teflon® decomposition products	—	B1	—	B1
Tellurium	—	0.1	—	—
Tellurium hexafluoride, as Te	0.02	0.2	—	—
TEPP — Skin	0.004	0.05	0.012	0.15
C Terphenyls	1	9	—	—
1, 1, 1, 2-Tetrachloro-2, 2-difluoroethane	500	4,170	625	5,210
1, 1, 2, 2-Tetrachloro-1, 2-difluoroethane	500	4,170	625	5,210
1, 1, 2, 2-Tetrachloroethane — Skin	5	35	10	70
Tetrachloroethylene, see Perchloroethylene	100	670	150	1,000
Tetrachloromethane, see Carbon tetrachloride	10	65	20	130
Tetrachloronaphthalene	—	2	—	4
Tetraethyl lead (as Pb) — Skin	—	0.100[h]	—	0.3

Capital letters refer to Appendices.
Footnotes (a thru h) see Page 31
o) See Page 34

Substance	ADOPTED VALUES TWA ppm[a]	ADOPTED VALUES TWA mg/m³[b]	TENTATIVE VALUES STEL ppm[a]	TENTATIVE VALUES STEL mg/m³[b]
Tetrahydrofuran	200	590	250	700
Tetramethyl lead (as Pb) — Skin	—	0.150[h]	—	0.45
Tetramethyl succinonitrile — Skin	0.5	3	1.5	9
Tetranitromethane	1	8	—	—
Tetryl (2, 4, 6-trinitrophenyl-methylnitramine) — Skin	—	1.5	—	3.0
Thallium, soluble compounds (as Tl) — Skin	—	0.1	—	—
4, 4'-Thiobis (6-tert. butyl-m-cresol)	—	10	—	20
Thiram®	—	5	—	10
Tin, inorganic compounds, except SnH_4 and SnO_2, (as Sn)	—	2	—	4
Tin, organic compounds (as Sn) — Skin	—	0.1	—	0.2
Tin oxide	—	E	—	20
Titanium dioxide	—	E	—	20
Toluene (toluol) — Skin	100	375	150	560
C Toluene-2, 4-diisocyanate (TDI)	0.02	0.14	—	—
o-Toluidine	5	22	10	44
Toxaphene, see Chlorinated camphene	—	0.5	—	1.5
Tributyl phosphate	—	5	—	5
1, 1, 1-Trichloroethane, see Methyl chloroform	350	1,900	440	2,380
1, 1, 2-Trichloroethane — Skin	10	45	20	90
Trichloroethylene	100	535	150	800
** Trichloromethane, see Chloroform	(25)	(120)	—	—
Trichloronaphthalene	—	5	—	10
1, 2, 3-Trichloropropane	50	300	150	450

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

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Substance	ADOPTED VALUES TWA ppm[a]	TWA mg/m³[b]	TENTATIVE VALUES STEL ppm[a]	STEL mg/m³[b]
1, 1, 2-Trichloro 1, 2, 2-trifluoroethane	1,000	7,600	1,250	9,500
Triethylamine	25	100	40	150
Tricyclohexyltin hydroxide (Plictran®)	—	5	—	10
Trifluoromonobromomethane	1,000	6,100	1,200	7,625
Trimethyl benzene	25	120	35	180
2, 4, 6-Trinitrophenol, see Picric acid	—	0.1	—	0.3
2, 4, 6-Trinitrophenylmethylnitramine, see Tetryl	—	1.5	—	3.0
** Trinitrotoluene (TNT) — Skin	—	(1.5)	—	—
Triorthocresyl phosphate	—	0.1	—	0.3
Triphenyl phosphate	—	3	—	6
Tungsten & compounds, as W				
Soluble	—	1	—	3
Insoluble	—	5	—	10
Turpentine	100	560	150	840
Uranium (natural) soluble & insoluble compounds, as U	—	0.2	—	0.6
Vanadium (V_2O_5), as V				
C Dust	—	0.5	—	1.5
Fume	—	0.05	—	—
Vinyl acetate	10	30	20	60
Vinyl benzene, see Styrene	100	420	150	630
Vinyl bromide	(250)	(1,100)	—	—
** Vinyl chloride	(200)	(510)	—	—
Vinyl cyanide, see Acrylonitrile	20	45	30	70
* Vinyl cyclohexene dioxide	10	60	—	—
Vinylidene chloride	10	40	20	80
Vinyl toluene	100	480	150	720

*1977 Addition
**See Notice of Intended Changes

Substance	ADOPTED VALUES TWA ppm[a]	TWA mg/m³[b]	TENTATIVE VALUES STEL ppm[a]	STEL mg/m³[b]
Warfarin	—	0.1	—	0.3
* Welding fumes (Total particulate)	—	5, B3	—	B3
Wood dust (nonallergenic)	—	5	—	10
Xylene (o-, m-, p-isomers) — Skin	100	435	150	655
*C m-Xylene α, α'-diamine	—	0.1	—	—
Xylidene — Skin	5	25	10	50
Yttrium	—	1	—	3
Zinc chloride fume	—	1	—	2
* Zinc chromate (as Cr)	—	0.05, A2	—	—
Zinc oxide fume	—	5	—	10
Zinc stearate	—	E	—	20
Zirconium compounds (as Zr)	—	5	—	10

*1976 Addition
Capital letters refer to Appendices

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 substance per cubic meter of air.
d) An atmospheric concentration of not more than 0.02 ppm, or personal protection may be necessary to avoid headache for intermittent exposure.
e) < 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

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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 30175, Washington, D.C. 20014.

MINERAL DUSTS

Substance	
SILICA, SiO_2	
Crystalline	
Quartz	TLV in mppcf[i]: $\frac{300^{j}}{\%\ \text{quartz} + 10}$ TLV for respirable dust in mg/m³: $\frac{10\ \text{mg/m}^3\ [k]}{\%\ \text{Respirable quartz} + 2}$ TLV for "total dust," respirable and nonrespirable: $\frac{30\ \text{mg/m}^3}{\%\ \text{quartz} + 3}$
Cristobalite	Use one-half the value calculated from the count or mass formulae for quartz.
Tridymite	Use one-half the value calculated from formulae for quartz.
Silica, fused	Use quartz formulae.
Tripoli	Use respirable[n] mass quartz formula
***Amorphous*	20 mppcf[i]

**See Notice of Intended Changes.

SILICATES (< 1% quartz)	
Asbestos, all forms+	5 fibers/cc > 5μm in length[m]; A1a
Graphite (natural)	15 mppcf
Mica	20 mppcf
Mineral wool fiber	10 mg/m³
Perlite	30 mppcf
Portland Cement	30 mppcf
Soapstone	20 mppcf
Talc (nonasbestiform)	20 mppcf
Talc (fibrous), use Asbestos limit.	
Tremolite, see Asbestos.	

COAL DUST

2 mg/m³ (respirable dust fraction < 5% quartz).
If > 5% quartz, use respirable mass formula.

NUISANCE PARTICULATES

(see Appendix E)

30 mppcf or 10 mg/m³[j]
of total dust < 1% quartz, or, 5 mg/m³ respirable dust.

Conversion factors:

mppcf × 35.3 = Million 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 quartz 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 quartz for the application of this limit are to be determined from the fraction passing a size-selector with the following characteristics:

+A more stringent TLV for crocidolite may be required.

l), n) See p. 34.

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

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

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

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

o) Based on "high volume" sampling.

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.

NOTICE OF INTENDED CHANGES (for 1977)

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. Documentation is available for each of these substances.

Substance	ppm[a]	mg/m³[b]
Aliphatic solvent "140 Flash"	25	150
÷ Aluminum metal and oxide	—	10
÷ Aluminum pyro powders	—	5
÷ Aluminum welding fumes	—	5
÷ Aluminum, soluble salts	—	2
÷ Aluminum alkyls (NOC)*	—	2
÷ 3-Amino 1, 2, 4-triazole	A2	—
÷ Antimony, soluble salts (as Sb)	—	2
Antimony trioxide, handling & use (as Sb)	—	0.5
Antimony trioxide production (as Sb)	—	0.05, A2
Arsenic trioxide production (as As)	—	0.05, A1a
Atrazine	—	10
÷ Benomyl	—	10
÷ Bromacil	—	10
Butyl acrylate	10	55
C Cadmium oxide production (as Cd)	—	0.05, A2
Calcium hydroxide	—	5
Calcium oxide	—	2
Carbonyl fluoride	5	15
Chloroform	10, A2	50
÷ Chloromethyl methyl ether	A1b	A1b
Chromite ore processing (chromate), as Cr	—	0.05, A1a
÷ Cobalt metal, dust & fume (as Co)	—	0.05
÷ Cyclopentane	300	850
Dichloromonofluoromethane	500	2,100
Dimethyl carbamyl chloride	A2	A2
÷ Ethyl silicate	10	85
÷C Glutaraldehyde	0.2	0.8
÷ Hexachlorobutadiene	A2	A2

Capital letters refer to Appendices
÷1977 Revision or Addition
*Not otherwise classified.

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Substance	ppm[a]	mg/m³[b]
Hexamethyl phosphoramide — Skin	A2	A2
+ Lead chromate (as Cr)	—	0.05, A2
+ Manganese fume (as Mn)	—	1
Manganese tetroxide	—	1
4, 4'-Methylene dianiline	—	A2
N, Methyl-2-pyrrolidone	100	400
Nickel sulfide roasting (as Ni)	—	1, A1a
Paraquat, respirable sizes	—	0.1
+ Phenyl-beta-naphthylamine	A2	A2
Phenyl mercaptan	0.5	2
Phosgene	0.1	0.4
m-Phthalodinitrile	—	5
C Propylene glycol dinitrate-Skin	0.2	2
Thioglycolic acid	1	5
C 1, 2, 4-Trichlorobenzene	5	40
Trimetnyl phosphite	0.5	2.6
C 2, 4, 6-Trinitrotoluene (TNT)	—	0.5
Valeraldehyde	50	175
+ Vinyl bromide	5	22
Vinyl chloride	Pending, A1c	—
+ VM & P Naphtha	300	1,350

NOTICE OF INTENDED CHANGES
MINERAL DUSTS

Substance	TLV
Silica, amorphous	5 mg/m³ Total dust (all sampled sizes) 2 mg/m³ Respirable dust (< 5 μm)
Diatomaceous earth, natural	1.5 mg/m³, Respirable dust

Capital letters refer to Appendices
+1977 Addition.

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 three forms: Those for which a TLV has been assigned (1a), those for which environmental conditions have not been sufficiently defined to assign a TLV (1b), and (1c), those whose reassignment of a TLV is awaiting more definitive data, and hence should be treated as a 1b carcinogen.

A1a. *Human Carcinogens*. Substances, or substances associated with industrial processes, recognized to have carcinogenic or cocarcinogenic potential, with an assigned TLV:

	TLV
Arsenic trioxide production	As_2O_3, 0.05 mg/m³ as As SO_2, C 5.0 ppm Sb_2O_3, 0.5 mg/m³ (as Sb)
Asbestos, all forms*	5 fibers/cc, > 5 μm in length
bis (Chloromethyl) ether	0.001 ppm
Chromite ore processing (chromate),	0.05 mg/m³ (as Cr)
Nickel sulfide roasting, fume & dust	1.0 mg/m³(as Ni)
Particulate Polycyclic Aromatic Hydrocarbons (PPAH)	0.2 mg/m³, as benzene solubles

1b. *Human Carcinogens*. Substances, or substances associated with industrial processes, recognized to

*Cigarette smoking can enhance the incidence of bronchogenic carcinoma from this and others of these substances or processes.

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have carcinogenic potential without an assigned TLV:

4-Aminodiphenyl (p-Xenylamine)
Benzidine production
beta-Naphthylamine
4-Nitrodiphenyl

1c. *Human Carcinogens*. Substances with recognized carcinogenic potential awaiting reassignment of TLV pending further data acquisition:

Vinyl chloride

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 hermitizing the process or operation by the best practicable engineering methods. The worker should be properly equipped to insure virtually no contact with the carcinogen.

A2. *Industrial Substances Suspect of Carcinogenic Potential for MAN*. Chemical substances or substances associated with industrial processes, which are suspect of inducing cancer, based on either (1) limited epidemiologic evidence, exclusive of clinical reports of single cases, or (2) demonstration of carcinogenesis in one or more animal species by appropriate methods.

Antimony trioxide production*	0.05 mg/m³
Benzene — Skin	10 ppm
Benz(a)pyrene	——
Beryllium	2.0 μg/m³
Cadmium oxide production	0.05 mg/m³
Chloroform	10 ppm
Chromates of lead and zinc (as Cr)	0.05 mg/m³
3, 3'-Dichlorobenzidine	——
Dimethylcarbamyl chloride	——

*Cigarette smoking can enhance the incidence of respiratory cancers from this or others of these substances or processes

1, 1-Dimethyl hydrazine	0.5 ppm
Dimethyl sulfate	1 ppm
Epichlorhydrin	5 ppm
Hexamethyl phosphoramide — Skin	——
Hydrazine	0.1 ppm
4, 4'-Methylene bis (2-chloroaniline) — Skin	0.02 ppm
4, 4'-Methylene dianiline	——
Monomethyl hydrazine	0.2 ppm
Nitrosamines	——
Propane sultone	——
beta-Propiolactone	——
Vinyl cyclohexene dioxide	10 ppm

For the above, worker exposure by all routes should be carefully controlled to levels consistent with the animal and human experience data (see Documentation), including those substances with a listed TLV.

A3. *Guidelines for the Classification of Experimental ANIMAL Carcinogens*. The following guidelines are offered in the present state of knowledge as an aid in classifying substances in the occupational environment found to be carcinogenic in experimental animals. A need was felt by the Threshold Limits Committee for such a classification in order to take the first step in developing an appropriate TLV for occupational exposure.

Determination of Approximate Threshold of Response Requirement. In order to determine in which category to classify an experimental carcinogen for the purpose of assigning an industrial air limit (TLV), an approximate threshold of neoplastic response must be determined. Because of practical experimental difficulties, a precisely defined threshold cannot be attained. For the purposes of standard-setting, this is of little moment, as an appropriate risk, or safety, factor can be applied to the approximate threshold, the magnitude of which

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is dependent on the degree of potency of the carcinogenic response.

To obtain the best 'practical' threshold of neoplastic response, dosage decrements should be less than logarithmic. This becomes particularly important at levels greater than 10 ppm (or corresponding mg/m³). Accordingly, after a range-finding determination has been made by logarithmic decreases, two additional dosage levels are required within the levels of "effect" and "no effect" to approximate the true threshold of neoplastic response.

The second step should attempt to establish a metabolic relationship between animal and man for the particular substance found carcinogenic in animals. If the metabolic pathways are found comparable, the substance should be classed highly suspect as a carcinogen for man. If no such relation is found, the substance should remain listed as an experimental animal carcinogen until evidence to the contrary is found.

Proposed Classification of Experimental Animal Carcinogens. Substances occurring in the occupational environment found carcinogenic for animals may be grouped into three classes, those of high, intermediate and low potency. In evaluating the incidence of animal cancers, significant incidence of cancer is defined as a neoplastic response which represents, in the judgment of the Committee, a significant excess of cancers above that occurring in negative controls.

EXCEPTIONS: No substance is to be considered an occupational carcinogen of any practical significance which reacts by the respiratory route at or above 1000 mg/m³ for the mouse, 2000 mg/m³ for the rat; by the dermal route, at or above 1500 mg/kg for the mouse, 3000 mg/kg for the rat; by the gastrointestinal route at or above 500 mg/kg/d for a lifetime, equivalent to about 100 g T.D. for the rat, 10g T.D. for the mouse.

These dosage limitations exclude such substances as dioxane and trichlorethylene from consideration as carcinogens.

Examples: Dioxane — rats, hepatocellular and nasal tumors from 1015 mg/kg/d, oral

Trichloroethylene — female mice, tumors (30/98 @ 900 mg/kg/d), oral

A3a. *INDUSTRIAL SUBSTANCES OF HIGH CARCINOGENIC POTENCY IN EXPERIMENTAL ANIMALS*

1. A substance to qualify as a carcinogen of high potency must fulfill one of the three following conditions in two animal species:

1a. *Respiratory*. Elicit cancer from (1) dosages below 1 mg/m³ (or equivalent ppm) via the respiratory tract in 6-7-hour daily repeated inhalation exposures throughout lifetime; or (2) from a single intratracheally administered dose not exceeding 1 mg of particulate, or liquid, per 100 ml or less of animal minute respiratory volume;

Examples: bis-Chloromethyl ether, malignant tumors, rats, @ 0.47 mg/m³ (0.1 ppm) in 2 years;

Hexamethyl phosphoramide, nasal squamous cell carcinoma, rats, @ 0.05 ppm, in 13 months

OR

1b. *Dermal*. Elicit cancer within 20 weeks by skin-painting, twice weekly at 2 mg/kg body weight or less per application for a total dose equal to or less than 1.5 mg, in a biologically inert vehicle;

Examples: 7, 12-Dimethylbenz(a)anthracene — skin tumors @ 0.12-0.8 mg T.D. in four weeks

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Benz(a)pyrene, mice 12 μg 3X/wk for 18 mos. T.D. 2.6 mg, 90.9% skin tumors

OR

1c. *Gastrointestinal*. Elicit cancer by daily intake via the gastrointestinal tract, within six months, with a six-month holding period, at a dosage below 1 mg/kg body weight per day; total dose, rat, ≤ 50 mg; mouse, ≤ 3.5 mg;

Examples: 7, 12-Dimethylbenz(a)anthracene — mammary tumors from 10 mg 1X

3-Methylcholanthrene — Tumors @ 3 sites from 8 mg in 89 weeks

Benz(a)pyrene, mice, 3.9% leukemias, from 30 mg T.D. 198 days

2. Elicit cancer by all three routes in at least two animal species at dose levels prescribed for high or intermediate potency.

A3b. *INDUSTRIAL SUBSTANCES OF INTERMEDIATE CARCINOGENIC POTENCY IN EXPERIMENTAL ANIMALS*

To qualify as a carcinogen of intermediate potency, a substance should elicit cancer in two animal species at dosages intermediate between those described in A3a and A3c by two routes of administration.

Example: Carbamic acid Ethyl Ester
Dermal, mammary tumors, mice, 100%, 63 weeks, 500–1400 mg T.D.
Gastrointestinal, various type tumors, mice 42 weeks, 320 mg T.D.

Gastrointestinal, various type tumors, rats, 60 weeks, 110–930 mg T.D.

A3c. *INDUSTRIAL SUBSTANCES OF LOW CARCINOGENIC POTENCY IN EXPERIMENTAL ANIMALS*

To qualify as a carcinogen of low potency, a substance should elicit cancer in one animal species by any *one* of three routes of administration at the following prescribed dosages and conditions:

1a. *Respiratory*. Elicit cancer from (1) dosages greater than 10 mg/m³ (or equivalent ppm) via the respiratory tract in 6- 7-hour, daily repeated inhalation exposures, for 12 months' exposure and 12 months' observation period; or (2) from intratracheally administered dosages totaling more than 10 mg of particulate or liquid per 100 ml or more of animal minute respiratory volume;

Examples: Beryl (beryllium aluminum silicate) malig. lung tumors, rats, @ 15 mg/m³ @ 17 months

Benzidine, var. tumors, rats, 10–20 mg/m³ @ > 13 mos.

OR

1b. *Dermal*. Elicit cancer by skin-painting of mice in twice weekly dosages of > 10 mg/kg body weight in a biologically inert vehicle for at least 75 weeks, i.e., ≥ 1.5g T.D.

Examples: Shale tar, mouse, 0.1 ml × 50 – g T.D. 59/60 skin tumors

Arsenic trioxide, man, dose unknown, but estimated to be high

1c. *Gastrointestinal*. Elicit cancer from daily oral dosages of 50 mg/kg/day or greater during the lifetime of the animal.

APPENDIX B
SUBSTANCES OF VARIABLE COMPOSITION

B1 *Polytetrafluoroethylene* decomposition products*. Thermal decomposition of the fluorocarbon chain in

*Trade Names Algoflon Fluon, Halon, Teflon, Tetran

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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 minimal.

B2 *Gasoline*. The composition of gasoline 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); Runion, ibid. *36*, 338, 1975).

B3 *Welding Fumes — Total Particulate (NOC)* TLV, 5 mg/m³*

Welding fumes cannot be classified simply. The composition and quantity of both are dependent on the alloy being welded and the process and electrodes used. Reliable analysis of fumes cannot be made without considering the nature of the welding process and system being examined; reactive metals and alloys such as aluminum and titanium are arc-welded in a protective, inert atmosphere such as argon. These arcs create relatively little fume, but an intense radiation which can produce ozone. Similar processes are used to arc-weld steels, also creating a relatively low level of fumes. Ferrous alloys also are arc-welded in oxidizing environments which generate considerable fume, and can produce carbon monoxide instead of ozone. Such fumes generally are composed of discreet particles of amorphous slags containing iron, manganese, silicon and other metallic constituents depending on the alloy system involved. Chromium and nickel compounds are found in fumes when stainless steels are arc-welded. Some coated and flux-cored electrodes are formulated with fluorides and the fumes associated with them can contain significantly more fluorides than oxides. Because of the above factors, arc-welding fumes frequently must be tested for individual constituents which are likely to be present to determine whether specific TLV's are exceeded. Conclusions based on total fume concentration are generally adequate if no toxic elements are present in welding rod, metal, or metal coating and conditions are not conducive to the formation of toxic gases.

Most welding, even with primitive ventilation, does not produce exposures inside the welding helmet above 5 mg/m³. That which does, should be controlled.

*Not otherwise classified

APPENDIX C
MIXTURES

C.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 a 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.).

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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 a given operation or process characteristically emits a number of harmful dusts, 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 exhauts, etc.

C.1A Examples of THRESHOLD LIMIT VALUES FOR MIXTURES

The following formulae apply only when the components in a mixture have similar toxicologic effects; they should not be used for mixtures with widely differing reactivities, e.g. hydrogen cyanide & sulfur dioxide. In such case the formula for Independent Effects (1A.c.) should be used.

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.)*

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

Example No. 1A.a.: Air contains 5 ppm of carbontetrachloride (TLV = 10 ppm) 20 ppm of 1, 2-dichloroethane (TLV = 50 ppm) and 10 ppm of 1, 2-dibromoethane (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. Furthurmore, the TLV of this mixture may be calculated by reducing the total fraction to 1.0; i.e.

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

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.)

$$\text{TLV of mixture} = \frac{1}{\frac{f_a}{TLV_a} + \frac{f_b}{TLV_b} + \frac{f_c}{TLV_c} + \ldots \frac{f_n}{TLV_n}}$$

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Example No. 1: Liquid contains (by weight)

50% heptane: TLV = 400 ppm or 1600 mg/m³
1 mg/m³ ≅ 0.25 ppm

30% methylene chloride: TLV = 200 ppm or 720 mg/m³
1 mg/m³ ≅ 0.28 ppm

20% perchloroethylene: TLV = 100 ppm or 670 mg/m³
1 mg/m³ ≅ 0.15 ppm

$$\text{TLV of Mixture} = \frac{1}{\frac{0.5}{1600} + \frac{0.3}{720} + \frac{0.2}{670}}$$

$$= \frac{1}{0.00031 + 0.00042 + 0.00030}$$

$$= \frac{1}{0.00103} = 970 \text{ mg/m}^3$$

of this mixture
50% or (970) (0.5) = 485 mg/m³ is heptane
30% or (970) (0.3) = 291 mg/m³ is methylene chloride
20% or (970) (0.2) = 194 mg/m³ is perchloroethylene

These values can be converted to ppm as follows:

heptane: 485 mg/m³ × 0.25 = 121 ppm
methylene chloride: 291 mg/m³ × 0.28 = 81 ppm
perchloroethylene: 194 mg/m³ × 0.15 = 29 ppm

TLV of mixture = 121 + 81 + 29 = 231 ppm, or 970 mg/m³

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. TLV for Mixtures of Mineral Dusts.

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

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

$$\text{TLV} = \frac{1}{\frac{0.8}{20} + \frac{0.2}{2.7}} = 9 \text{ mppcf}$$

TLV of nonasbestiform talc (pure) = 20 mppcf
TLV of quartz (pure) =

$$\frac{300}{100 + 10} = \frac{300}{110} = 2.7 \text{ mppcf}$$

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:

25% quartz — TLV (pure) = 2.7 mppcf
25% amorphous silica — TLV (pure) = mppcf
50% talc TLV (pure) = 20 mppcf

$$\text{TLV} = \frac{1}{\frac{0.25}{2.7} + \frac{0.25}{20} + \frac{0.5}{20}} = 8 \text{ mppcf}$$

The limit for 25% quartz approximates 9 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.

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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
Nitrobenzene	1	3	3
Carbon tetrachloride	10	2	20
Trimethyl benzene	25	1.5	40
Acetone	1000	1.25	1250
Boron trifluoride	C 1	—	1
Butylamine	C 5	—	5

EXCURSION FACTORS

For all substances not bearing C notation

		Excursion Factor
TLV>0–1	(ppm or mg/m³),	= 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.

INTERPRETATION OF MEASURED PEAK CONCENTRATIONS

With increasing use of rapid, direct-reading analytical instruments for airborne contaminants in the work area, the question of interpretation of essentially "instantaneous" peaks arises. Although no general statement can be made covering all occupational substances, the following guidelines should prove helpful, assuming peak excursions conform to time-weighted average TLV as stated above.

The toxicologic importance of momentary peak concentrations depends on whether the substance is fast or slow acting. If slow acting, as for quartz, lead, or carbon monoxide, momentary peaks are of no toxicologic concern provided, of course, they are not astronomic. On the other hand, fast-acting substances that rapidly produce disabling narcosis, e.g., H_2S, or intolerable irritation or asphyxiation, NH_3, SO_2, CO_2, or initiate sensitization — the organic isocyanates, even "instantaneous" peaks appreciably above the permissible excursion, should not be permitted, unless information exists to the contrary. Other more specific excursions will be developed in the future.

APPENDIX E

Some Nuisance Particulates[a]

TLV, 30 mppcf or 10mg/m³

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

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

r) <7μm in diameter

APPENDIX F
Some Simple Asphyxiants[s]

Acetylene	Hydrogen
Argon	Methane
Butane	Neon
Ethane	Propane
Ethylene	Propylene
Helium	

s) As defined on pg. 6.

APPENDIX G

Calculations for Conversion of Particle Count Concentration (by Standard Light Field — Midget Impinger Techniques), in mppcf, to Respirable Mass Concentration (by Respirable Sampler) in mg/m^3.†

1. In 1967, Jacobsen and Tomb,† derived an empirical relationship of 5.6 mppcf to 1 milligram of respirable dust per cubic meter of air, based on 23 sets of samples, mostly coal dust. The following calculation results in an equivalence of 6.37 mppcf to 1 mg/m^3 of respirable dust. Thus, an approximate ratio of 6 mppcf to 1 mg/m^3 of respirable dust is suggested for conversion of TLVs from a count to a mass basis when the density and mass median diameter have not been determined.

† "Relationship Between Gravimetric Respirable Dust Concentration and Midget Impinger Number Concentration," by Murray Jacobson and T. F Tomb. AIHAJ. 28. Nov.–Dec. 1967.

2. Basic assumptions:

   a) Average density for silica containing dusts ≈ 2.5 gms/cm^3 (2500 mg/cm^3). Pulmonary significant dust densities may vary from 1.2 gm/cm^3 for coal dust to 3.1 gms/cm^3 for Portland Cement. Silica densities vary from 2.2 (amorphous) to 2.3 (cristobalite and tridymite) to 2.5 (alpha-quartz.) gms per cm^3.

   b) The mass median diameter (mmd) of particles collected in midget impinger samplers and counted by the standard light field technique, *and* collected in a respirable sampler is approximately 1.5 μm or 1.5×10^{-4} cm. This assumption is, of course, quite arbitrary since the mmd of all dust clouds is quite variable, depending on many independent parameters, such as source of dust, age of dust cloud, meteorological conditions, etc.

3. Calculation:

   a) vol. per particle: $4/3\ \pi\ r^3$; $r = 0.75 \times 10^{-4}$ cm
   $= 4/3 \cdot \pi \cdot (0.75 \times 10^{-4})^3$
   $= 1.77 \times 10^{-12}$ cm^3

   b) wt. per particle = vol. × density
   $= 1.77 \times 10^{-12}$ cm^3 $\times$ 2.5×10^3 mg/cm^3
   $= 4.425 \times 10^{-9}$ mg/particle

   c) 1 particle/ft.^{3} = 35.5 part./m^3
   (since 35.5 cu ft = 1 cu m.)
   10^6 part./ft^3 = mppcf = 35.5×10^6 part./m^3

   wt. of 1 mppcf ≡ 35.5×10^6 part./m^3 × 4.425×10^{-9} mg/part.

   1 mppcf ≡ 0.157 mg/m^3
   or
   6.37 mppcf ≡ 1 mg/m^3
   or approximately 6 mpccf ≡ 1 mg/m^3.

4. Equivalent TLVs in mppcf and mg/m^3 (respirable mass) for Mineral Dusts.

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Substance	Threshold Limit Value		
	Count mppcf	Resp. Mass mg/m³	Total Mass* mg/m³
Silica (SiO_2)			
Amorphous	20	(3)**	(6)
Cristobalite	1.5	0.05	0.15
Fused silica	3	0.1	0.3
Quartz	3	0.1	0.3
Tridymite	1.5	0.05	0.15
Coal Dust	(12)	2	(4)
Diatomaceous earth, natural	—	1.5	—
Graphite	15	(2.5)	(5)
Mica	20	(3)	(6)
Mineral wool fiber	—	(5)	10
Nuisance particulates	30	(5)	10
Perlite	30	(5)	(10)
Portland Cement	30	(5)	(10)
Soapstone	20	(3)	(6)
Talc (nonasbestiform)	20	(3)	(6)
Tripoli	(3)	0.1	(0.3)

*Unless otherwise specified, respirable mass is presumed to equal approximately 50% of total mass

**All values in parentheses ( ) represent newly calculated values based on equivalence of 6 mppcf ≡ 1 mg m³ respirable mass and respirable mass ≡ 50% total mass

TLVs®
Threshold Limit Values for Physical Agents Adopted by ACGIH for 1977

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1977 TLV PHYSICAL AGENTS COMMITTEE

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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.

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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 1 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*; F. N. Dukes-Dobos and A. Henschel: *"Development of Permissible Heat Exposure Limits for Occupational Work."* ASHRAE Journal, Vol. 15: No. 9, September 1973, pp. 57–62.)

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 + 0.1 DB
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 1

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

	Work Load		
Work — Rest Regimen	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 1 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

HEAT STRESS

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 −5°C to 50°C with an accuracy of ±0.5°C. The dry bulb thermometer must be shielded

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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. A 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.

C. A 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 thermometers 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 1964.

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

II. *Work Load Categories*

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 (up to 200 Kcal/hr or 800 Btu/hr): e.g., sitting or standing to control machines, performing light hand or arm work,

(2) moderate work (200–350 Kcal/hr or 800–1400 Btu/hr): e.g., walking about with moderate lifting and pushing,

(3) heavy work (350–500 Kcal/hr or 1400–2000 Btu/hr): 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. When this method is used the permissible heat exposure limit can be determined by Figure 1.

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

2. "Ergonomies 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 1 and Figure 1 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. Where the WBGT of the work area is different from that of the rest area a time-weighted average value should be used for both environmental and metabolic heat. When time-weighted average values are used the appropriate curve on Figure 1 is the solid line labeled "continuous."

The time-weighted average metabolic rate (M) shall be determined by the equation:

$$\text{Av. } M = \frac{(M_1) \times (t_1) + (M_2) \times (t_2) + \ldots + (M_n) \times (t_n)}{(t_1) + (t_2) + \ldots + (t_n)}$$

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Where M_1 M_2, M_n are estimated or measured metabolic rates for the various activities of the worker during the total time period. t_1, t_2, t_n are the elapsed times in minutes spent at the corresponding metabolic rate as determined by a time study.

The time-weighted average WBGT shall be determined by the equation:

$$\text{Av. WBGT} = \frac{(\text{WBGT}_1) \times (t_1) + (\text{WBGT}_2) \times t_2 + \ldots + (\text{WBGT}_n) \times (t_n)}{(t_1) + (t_2) + \ldots + (t_n)}$$

where WBGT_1, WBGT_2, WBGT_n are calculated values of WBGT for the various work and rest areas occupied during total time periods. t_1, t_2, t_n are the elapsed times in minutes spent in the corresponding areas which are determined by a time study. Where exposure to hot environmental conditions is continuous for several hours or the entire work day, the time-weighted averages shall be calculated as hourly time-weighted average i.e., $t_1 + t_2 + \ldots t_n = 60$ minutes. Where the exposure is intermittent, the time-weighted averages shall be calculated as two-hour time-weighted averages, i.e., $t_1 + t_2 + \ldots t_n = 120$ minutes.

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 shall be kept reasonably cool (10°–15°C or 50.0°–60.0°F) 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 cothing 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 1 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.

MAP 000085

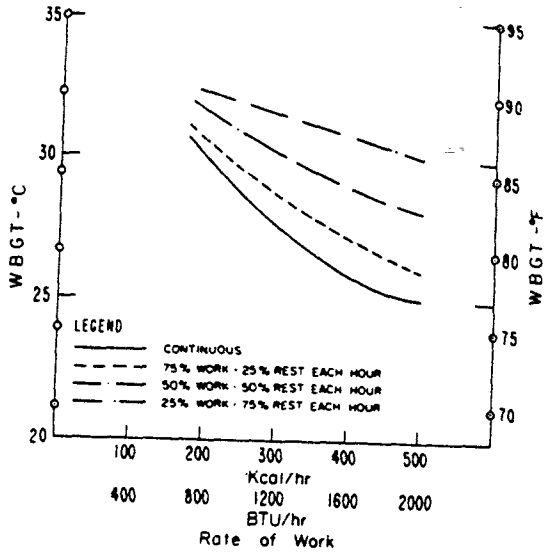


Figure 1 — Permissible Heat Exposure Threshold Limit Value

IONIZING RADIATION

See U.S. Department of Commerce National Bureau of Standards, Handbook 59, "Permissible Dose from External Sources of Ionizing Radition," 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); and except for all TLVs for wavelengths between 0.1–1 mm where the limiting aperture is 10 mm. 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 Factors A and B (C_A and C_B) 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 1.06 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 1.06 μm are to be increased by a uniformly extrapolated factor as shown in Figure 2. For certain exposure durations at wavelengths between 700–800 nm, correction factor C_B is applied.

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.

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(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^{-5} second. For pulses of greater duration, the following formula should be followed:

$$\text{Standard}\begin{pmatrix}\text{single pulse}\\ \text{in train}\end{pmatrix} = \frac{\text{Standard (pulse } n\tau)}{n}$$

where:

n = number of pulses in train
τ = duration of a single pulse in the train
Standard ($n\tau$) = protection standard of one pulse having a duration equal to $n\tau$ seconds.

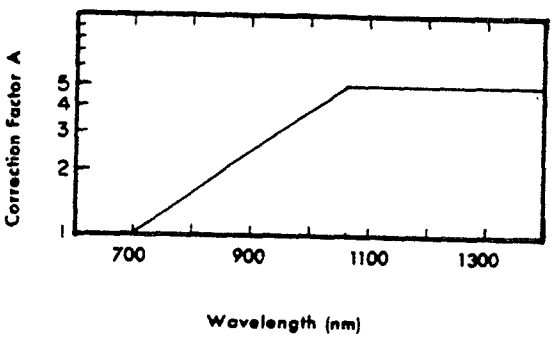


Figure 2 — TLV correction factors for laser wavelengths (eye).

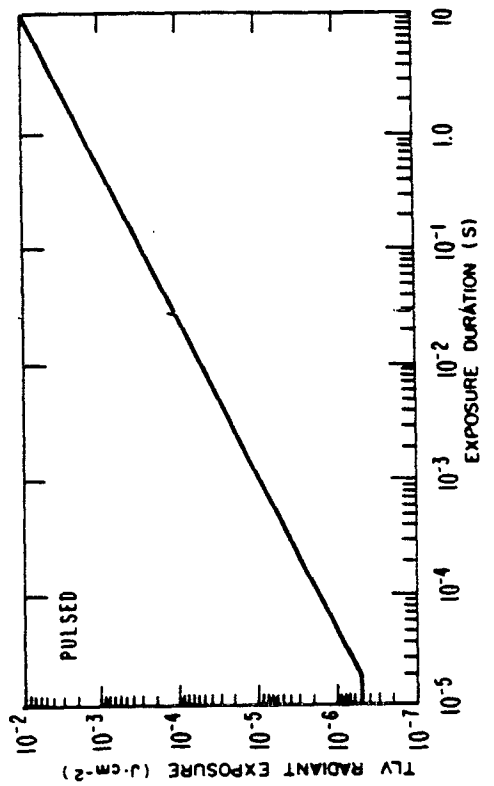


Figure 3a — TLV for intrabeam (direct) viewing of laser beam (400–700 nm).

MAP 000087

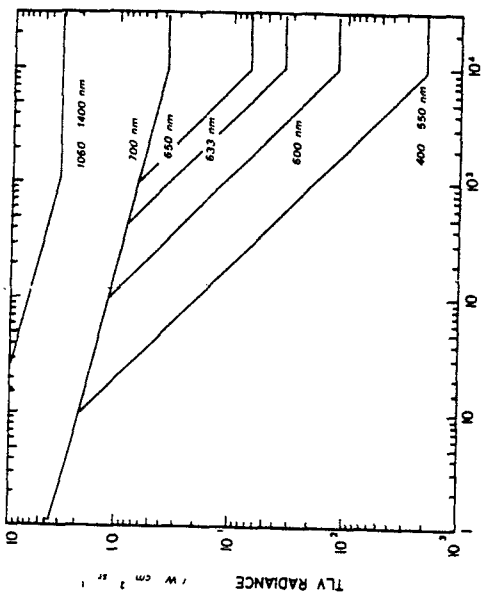


Figure 3b — TLV for intrabeam (direct) viewing of CW laser beam (400–1400 nm).

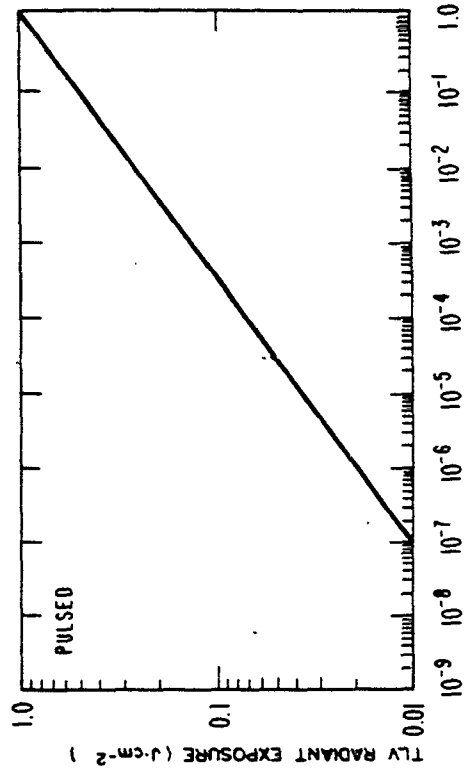


Figure 4a — TLV for laser exposure of skin and eyes for far-infrared radiation (wavelengths greater than 1.4 μm).

MAP 000088

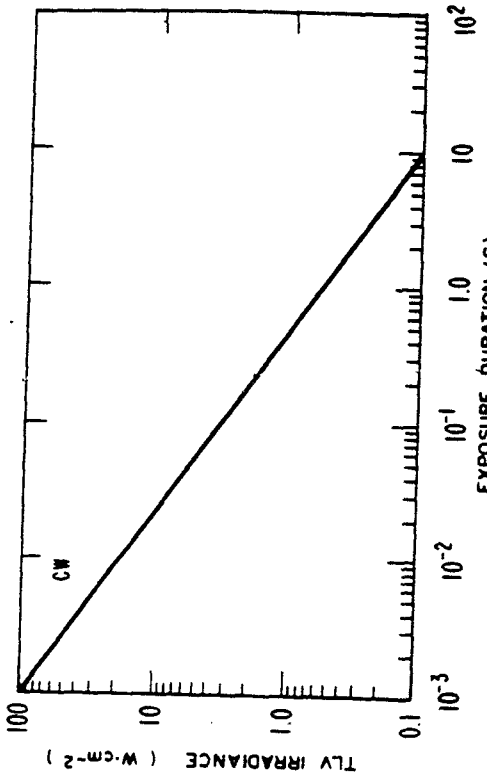


Figure 4b — TLV for CW laser exposure of skin and eyes for far-infrared radiation (wavelengths greater than 1.4 μm).

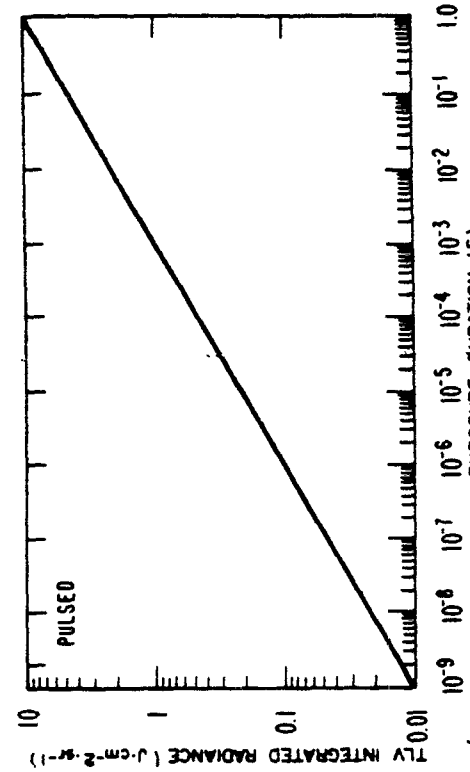


Figure 5a — TLV for extended sources or diffuse reflections of laser radiation (400–700 nm).

MAP 000089

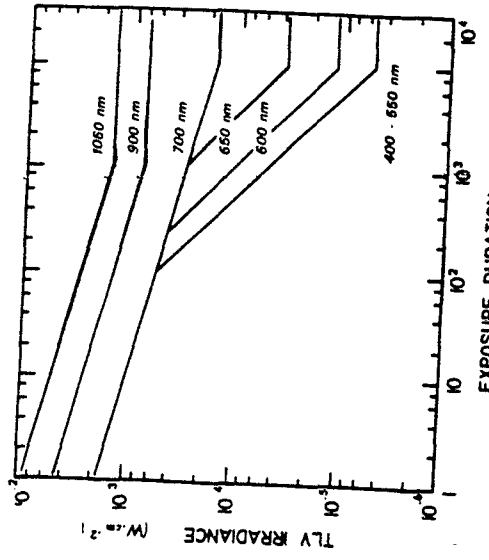


Figure 5b — TLV for extended sources or diffuse reflections of laser radiation (400–1400 nm), CW

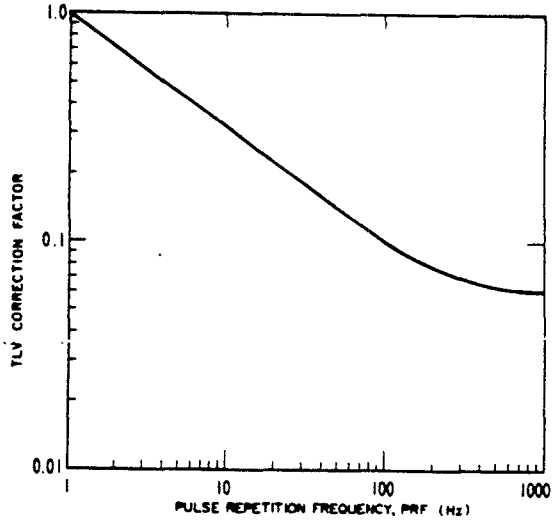


Figure 6 — Multiplicative correction factor for repetitively pulsed lasers having pulse durations less than 10^{-5} second. TLV for a single pulse of the pulse train is multiplied by the above correction factor. Correction factor for PRF greater than 1000 H_z is 0.06.

MAP 000090

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^{-3} 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}*

TABLE 3 (Cont.)

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^{-7} J • cm^{-2}
	400 nm to 700 nm	1.8×10^{-5} to 10	1.8 ($t/\sqrt{t}$) mJ • cm^{-2}
	400 nm to 549 nm	10 to 10^{4}	10 mJ • cm^{-2}
	550 nm to 700 nm	10 to T_1	1.8 ($t/\sqrt{t}$) mJ • cm^{-2}
	550 nm to 700 nm	T_1 to 10^{4}	10 C_B mJ • cm^{-2}
	400 nm to 700 nm	10^{4} to 3×10^{4}	C_B μW • cm^{-2}
IR-A	700 nm to 1059 nm	10^{-9} to 1.8×10^{-5}	5 $C_A \times 10^{-7}$ J • cm^{-2}
	700 nm to 1059 nm	1.8×10^{-5} to 10^{3}	1.8 C_A ($t/\sqrt{t}$) mJ • cm^{-2}
	1060 nm to 1400 nm	10^{-9} to 10^{-4}	5×10^{-6} J • cm^{-2}
	1060 nm to 1400 nm	10^{-4} to 10^{3}	9($t/\sqrt{t}$) mJ • cm^{-2}
	700 nm to 1400 nm	10^{3} to 3×10^{4}	320 C_A μW • cm^{-2}
IR-B & C	1.4 μm to 10^{3} μm	10^{-9} to 10^{-7}	10^{-2} J • cm^{2}
	"	10^{-7} to 10	0.56 $\sqrt{t}$ J • cm^{-2}
	"	10 to 3×10^{4}	0.1 W • cm^{-2}

C_A – See Fig. 2, Laser TLV listing.
C_B = 1 for λ = 400 to 550 nm; C_B = $10^{0.015(\lambda - 550)}$ for λ = 550 to 700 nm.
T_1 = 10 s for λ = 400 to 550 nm; T_1 = $10 \times 10^{0.015(\lambda - 550)}$ for λ = 550 to 700 n.

MAP 000091

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	$10\sqrt{t}$ J • cm^{-2} • sr^{-1}
	400 nm to 549 nm	10 to 10^{4}	21 J • cm^{-2} • sr^{-1}
	550 nm to 700 nm	10 to T_1	$3.83\ (t/\sqrt{t})$ J • cm^{-2} • sr^{-1}
	550 nm to 700 nm	T_1 to 10^{4}	$21/C_B$ J cm^{-2} • sr^{-1}
	400 nm to 700 nm	10^{4} to 3×10^{4}	$2.1/C_B \times 10^{-3}$ W • cm^{-2} • sr^{-1}
IR-A	700 nm to 1400 nm	10^{-9} to 10	$10\ C_A\sqrt{t}$ J • cm^{-2} • sr^{-1}
	700 nm to 1400 nm	10 to 10^{3}	$3.83\ C_A\ (t/\sqrt{t})$ J • cm^{-2} • sr^{-1}
	700 nm to 1400 nm	10^{3} to 3×10^{4}	$0.64\ C_A$ W • cm^{-2} • sr^{-1}
IR-B & C	1.4 μm to 1 mm	10^{-9} to 3×10^{4}	Same as Table 3

C_A, C_B, and T_1 are the same as in footnote to Table 3.

TABLE 5

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

Exposure Duration(s)	Angle α (mrad)
10^{-9}	8.0
10^{-8}	5.4
10^{-7}	3.7
10^{-6}	2.5
10^{-5}	1.7
10^{-4}	2.2
10^{-3}	3.6
10^{-2}	5.7
10^{-1}	9.2
1.0	15
10	24
10^{2}	24
10^{3}	24
10^{4}	24

MAP 000092

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 & IR-A	400 nm to 1400 nm	10^{-9} to 10^{-7}	$2\ C_A \times 10^{-2}$ J • cm^{-2}
	"	10^{-7} to 10	$1.1\ C_A\ t^{1/4}$ J • cm^{-2}
IR-B & C	1.4 μm to 1 mm	10^{-9} to 3×10^{4}	Same as Table 3

$C_A = 1.0$ for λ = 400–700 nm; see Figure 2 Laser TLV list for greater wavelength values.

NOTE: To aid in the determination of TLV's for exposure durations requiring calculations of fractional powers Figures 3, 4, 5 and 6 may be used.

MICROWAVES*

These Threshold Limit Values refer to microwave energy in the frequency range of 100 MHz to 100 GHz 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.

*See Notice of Intended Changes, Page 89. Notice of Intent to Study, page 94

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

MAP 000093

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 National 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 7.

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 on-the-job noise exposures of 80 dBA or greater shall be used in the above calculations.

Table 7
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.

IMPULSIVE OR IMPACT NOISE

It is recommended that exposure to impulsive or impact noise shall not exceed the limits listed in Table 8 or taken from Figure 7. No exposures in excess of 140 decibels peak sound pressure level are permitted. 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 8
Threshold Limit Values
Impulsive or Impact Noise

Sound Level dB*	Permitted Number of Impulses or Impacts per day
140	100
130	1000
120	10,000

*It should be recognized that the application of the TLV for noise will not protect all workers from the adverse effects of noise exposure. A hearing conservation program with audiometric testing is necessary when workers are exposed to noise at or above the TLV levels.
**Decibels peak sound pressure level.

MAP 000094

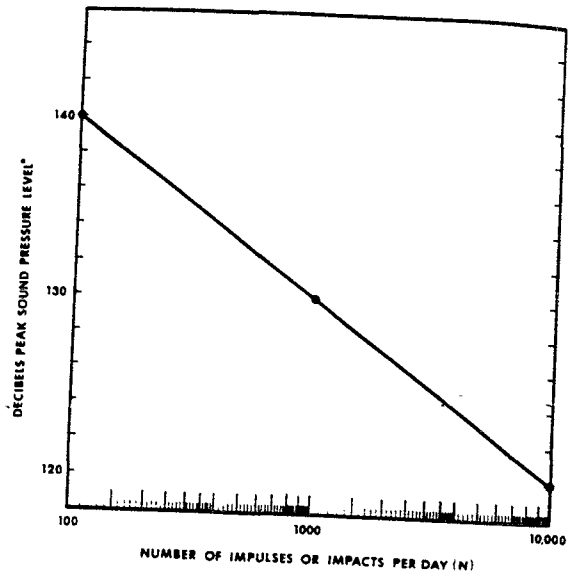


Figure 7 —

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, and solar radiation, but do not apply to ultraviolet lasers.* 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 nm) 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 9 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 following weighting formula should be used:

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

*See Laser TLVs.

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where:

E_{eff} = effective irradiance relative to a monochromatic source at 270 nm in W/cm² (J/s/cm²)

E_λ = spectral irradiance in W/cm²/nm

S_λ = relative spectral effectiveness (unitless)

$\Delta\lambda$ = 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 10 which provides exposure times corresponding to effective irradiances in μW/cm².

TABLE 9

Relative Spectral Effectiveness by Wavelength

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
254	6.0	0.5
260	4.6	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

**1 m J/cm² = 10^{-3} J/cm²

TABLE 10

Permissible Ultraviolet Exposures

Duration of Exposure Per Day	Effective Irradiance, E_{eff} (μW/cm²)***
8 hrs.	0.1
4 hrs.	0.2
2 hrs.	0.4
1 hr.	0.8
30 min.	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 TLVs 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°.

***1μW/cm² = 10^{-6} W/cm²

MAP 000096

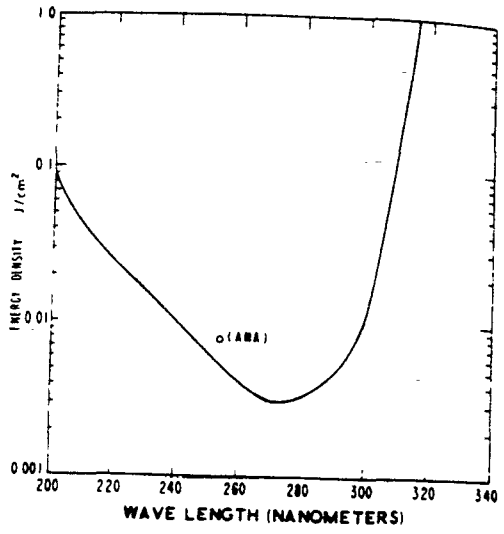


Figure 8 — Threshold Limit Values for Ultraviolet Radiation

Conditioned (tanned) individuals can tolerate skin exposure in excess of the TLV without erythemal effects. However, such conditioning may not protect persons against skin cancer.

NOTICE OF INTENDED CHANGES (for 1977)

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.

MICROWAVES

These Threshold Limit Values refer to microwave energy in the frequency range of 300 MHz to 300 GHz and represent conditions under which it is believed that nearly all workers may be repeatedly exposed without adverse effect.

Under conditions of moderate to severe heat stress, the recommended values may need to be reduced.* Therefore, these values should be used as guides in the control of exposure to microwave energy and should not be regarded as a fine line between safe and dangerous levels.

Recommended Values:

The Threshold Limit Value for occupational exposure to microwave energy, where power density or field intensity is known and exposure time is controlled, is as follows:

1. For exposure to continuous wave (CW) sources, the power density level shall not exceed 10 milliwatts per square centimeter (mW/cm^2) for continuous exposure, and the total exposure time shall be limited to an 8-hour workday. This power density is approximately equivalent to a free-space electric field strength of 200 volts-per-meter rms (V/m) and a free-space magnetic field strength of 0.5 ampere-per-meter rms (A/m).
2. Exposures to CW power density levels greater than 10 mW/cm^2 are permissible up to a maximum of 25 mW/cm^2 based upon an average energy density of 1 milliwatt-hour per square centimeter (mWh/cm^2) averaged over any 0.1 hour period. For example, at 25 mW/cm^2, the permissible exposure duration is approximately 2.4 minutes in any 0.1 hour period.
3. For repetitively pulsed microwave sources, the average field strength or power density is calculated by multiplying the peak-pulse value by the duty cycle. The duty cycle is equal to the pulse duration in sec-

*Mumford, W.W., "Heat Stress Due to R. F. Radiation," Proceedings of IEEE, Vol. 57, No. 2, Feb. 1969, pp. 171–178.

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onds times the pulse repetition rate in Hertz. Exposure during an 8-hour workday shall not exceed the following values which are averaged over any 0.1 hour period:

Power Density	10 mW/cm²
Energy Density	1 mWh/cm²
Mean Squared Electric Field Strength	40,000 V²/m²
Mean Squared Magnetic Field Strength	0.25 A²/m²

4. Exposure is not permissible in CW or repetitively pulsed fields with an average power density in excess of 25 mW/cm² or approximate equivalent free-space field strengths of 300 V/m or 0.75 A/m.

NOTICE OF INTENT TO ESTABLISH THRESHOLD LIMIT VALUES

LIGHT AND NEAR-INFRARED RADIATION

These Threshold Limit Values refer to visible and near-infrared radiation in the wavelength range of 400 nm to 1400 nm and represent conditions under which it is believed that nearly all workers may be exposed without adverse effect. These values should be used as guides in the control of exposure to light and should not be regarded as a fine line between safe and dangerous levels.

Recommended Values:

The Threshold Limit Value for occupational exposure to broad-band light and near-infrared radiation for the eye apply to exposure in any eight-hour workday and require knowledge of the spectral radiance (L_λ) and total irradiance (E) of the source as measured at the position(s) of the eye of the worker. Such detailed spectral data of a white light source is generally only required if the luminance of the source exceeds 1 cd cm^{-2}. At luminances less than this value the TLV would not be exceeded.

The TLV's are:

1. To protect against retinal thermal injury, the spectral radiance of the lamp weighted against the function R

(Table 11) should not exceed:

$$\sum_{400}^{1400} L_\lambda R_\lambda \Delta\lambda \leq \sqrt{t}/\alpha t \qquad (1)$$

where L_λ is in W cm^{-2} sr^{-1} and t is the viewing duration (or pulse duration if the lamp is pulsed) limited to 1 μs to 10 s, and α is the angular subtense of the source in radians. If the lamp is oblong, α refers to the longest dimension that can be viewed. For instance, at a viewing distance r = 100 cm from a tubular lamp of length l = 50 cm, the viewing angle is:

$$\alpha = l/r = 50/100 = 0.5 \text{ rad} \qquad (2)$$

2. To protect against retinal injury from chronic blue-light exposure the integrated spectral radiance of the lamp weighted against the blue-light hazard function B_λ (Table 11) should not exceed:

$$\sum_{400}^{1400} L_\lambda t B_\lambda \Delta\lambda \leq 100 \text{ Jcm}^{-2} \text{ sr}^{-1} \ (t \leq 10^4 \text{s}) \qquad (3a)$$

$$\sum_{400}^{1400} L_\lambda B_\lambda \Delta\lambda \leq 10^{-2} \text{ Wcm}^{-2} \text{ sr}^{-1} \ (t > 10^4 \text{s}) \qquad (3b)$$

For a source radiance L which exceeds 2 mW cm^{-2} sr^{-1} in the blue spectral region, the permissible exposure duration t_{max} in seconds is simply:

$$t_{max} = 100 \text{ J cm}^{-2} \text{ sr}^{-1}/\text{L (blue)} \qquad (4)$$

The latter limits are greater than the maximum permissible exposure limits for 440 nm laser radiation (see Laser TLV) because a 2–3 mm pupil is assumed rather than a 7 mm pupil for the Laser TLV.

3. *Infrared Radiation:* To avoid possible delayed effects upon the lens of the eye (cataractogenesis), the infrared radiation ($\lambda > 770$ nm) should be limited to 10 $mWcm^{-2}$. For an infrared heat lamp or any near-infrared source where a strong visual stimulus is absent, the near infrared (770–1400 nm) radiance as viewed by the eye should be limited to:

$$\sum_{770}^{1400} E_\lambda \Delta_\lambda = 600/\alpha \qquad (5)$$

for extended duration viewing conditions. This limit is based upon a 7 mm pupil diameter.

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TABLE 11

SPECTRAL WEIGHTING FUNCTIONS FOR ASSESSING RETINAL HAZARDS FROM BROAD — BAND OPTICAL SOURCES

Wavelength (nm)	Blue-Light Hazard Function B_λ	Burn Hazard Function R_λ
400	0.10	1.0
405	0.20	2.0
410	0.40	4.0
415	0.80	8.0
420	0.90	9.0
425	0.95	9.5
430	0.98	9.8
435	1.0	10
440	1.0	10
445	0.97	9.7
450	0.94	9.4
455	0.90	9.0
460	0.80	8.0
465	0.70	7.0
470	0.62	6.2
475	0.55	5.5
480	0.45	4.5
485	0.40	4.0
490	0.22	2.2
495	0.16	1.6
500–600	$10^{[(450-\lambda)/50]}$	1.0
600–700	0.001	1.0
700–1060	0.001	$10^{[(700-\lambda)/515]}$
1060–1400	0.001	0.2

AIRBORNE UPPER SONIC AND ULTRASONIC ACOUSTIC RADIATION

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. The values listed in Table 15 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. The levels for the third octave bands centered below 20 kHz are below those which cause subjective effects. Those levels for 1/3 octaves above 20 kHz are for prevention of possible hearing losses from subharmonics of these frequencies.

TABLE 12

Permissible Ultrasound Exposure Levels

Mid-Frequency of Third-Octave Band kHz	One-Third Octave — Band Level in dB reference 0.0002 dynes/cm²
10	80
12.5	80
16	80
20	105
25	110
31.5	115
40	115
50	115

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NOTICE OF INTENT TO STUDY

These agents comprise those which the Physical Agents Committee of ACGIH proposes to study during this year to determine the feasibility of establishing proposed TLVs in 1977 Comments and suggestions, accompanied by substantitive evidence, are solicited.

1. *Radiofrequency Radiation.* Specifically, that portion of the spectrum from 10 MHz to 100 MHz.
2. *Microwave Radiation.* Specifically from 100 GHz to 300 GHz.
3. *Magnetic Fields.* Both pulsed and continuous.
4. *Laser Radiation.* Specifically ultraviolet radiation for pulsed exposures, and repetitively pulsed light and infrared-A laser exposures.
5. *Ultrasonic Energy.* Specifically, acoustic energy at frequencies above 10 kHz.
6. *Vibration.* Segmental and whole-body.

The American Conference of Governmental Industrial Hygienists was organized in 1938 by a group of governmental industrial hygienists who desired a medium for the free exchange of ideas, experiences and the promotion of standards and techniques in industrial health. The Conference is not an official Government Agency.

It is an organization devoted to the development of administrative and technical aspects of worker health protection. The association has contributed substantially to the development and improvement of official industrial health services to industry and labor. The committees on Industrial Ventilation and Threshold Limit Values are recognized throughout the world for their expertise and contributions to industrial hygiene.

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John Fox

TLVs®
Threshold Limit Values
for
Chemical Substances
and
Physical Agents
in the
Workroom Environment
with
Intended Changes
for
1978



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Documentation of the Threshold Limit Values for Substances in Workroom Air.© A separate companion piece to the Chemical TLVs is issued by ACGIH under this title. This publication gives the pertinent scientific information and data with reference to literature sources that were used to base each limit. Each documentation also contains a statement defining the type of response against which the limit is safeguarding the worker. For a better understanding of the TLVs it is essential that the Documentation be consulted when the TLVs are being used.

Information concerning the availability of copies of the Documentation of the Threshold Limit Values for Substances in Workroom Air should be directed to the Executive Secretary, ACGIH (third edition, fourth printing, 1978, $20.00).

TLVs® Threshold Limit Values for Chemical Substances in Workroom Air Adopted by ACGIH for 1978



MAP 000103

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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.

Tests are available (J. Occup. Med. 15: 564, 1973; 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).

Three categories of Threshold Limit Values (TLVs) are specified herein, as follows:

a) Threshold Limit Value-Time Weighted Average (TLV-TWA) — the time-weighted average concentration for a normal 8-hour workday or 40-hour workweek, to which nearly all workers may be repeatedly exposed, day after day, without adverse effect.

b) Threshold Limit Value-Short Term Exposure Limit (TLV-STEL) — the maximal concentration to which workers can be exposed for a period up to 15 minutes continuously without suffering from 1) irritation, 2) chronic or irreversible tissue change, or 3) narcosis of sufficient degree to increase accident proneness, impair self-rescue, or materially reduce work efficiency, provided that no more than four excursions per day are permitted, with at least 60 minutes between exposure periods, and provided that the daily TLV-TWA also is not exceeded. The STEL should be considered a maximal allowable concentration, or ceiling, not to be exceeded at any time during the 15-minute excursion period. STELs are based on one or more of the following criteria: (1) Adopted TLVs including those with a "C" or "ceiling" limit. (2) TWA-TLV Excursion Factors listed in Appendix D. (3) Pennsylvania Short-Term Limits for Exposure to Airborne Contaminants (Penna. Dept. of Hlth., Chapter 4, Art. 432, Rev. Jan. 25, 1968). (4) OSHA Occupational Safety and Health Standards, 40 FR 23073, May 28, 1975. (5) NIOSH criteria for recommended standards for occupational exposure to specific substances. The TWA-STEL should not be used as engineering design criterion or considered as an emergency exposure level (EEL).

c) Threshold Limit Value-Ceiling (TLV-C) — the concentration that should not be exceeded even instantaneously.

For some substances, e.g., irritant gases, only one category, the TLV-Ceiling, may be relevant. For other substances, either two or three categories may be relevant, depending upon their physiologic action. It is important to observe that if any one of these three TLVs is exceeded, a potential hazard from that substance is presumed to exist.

The TLV-TWA should be used as guides in the control of health hazards and should not be used as fine lines between safe and dangerous concentrations.

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 a 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

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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 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 control of community air pollution nuisances, (3) in estimating the toxic potential of continuous, uninterrupted exposures or other extended work periods, (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 noncompliance 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 determining the magnitude of the value of the STELs, or 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 mucous 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

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significant extent. (3) The tissue reaction is potentially reversible.

Excessive concentrations of nuisance dusts in the workroom air may seriously reduce visibility, may cause unpleasant deposits in the eyes, ears and nasal 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 10 mg/m³, or 30 mppcf, of total dust < 1% quartz, or, 5 mg/m³ respirable dust 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.

Physical Factors. It is recognized that such physical factors as heat, ultraviolet and ionizing 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 may be altered. Most of these stresses act adversely 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 BLVs, and their associated procedures for determining compliance with them, should thus be regarded as an effective means of providing health surveillance of the worker.

Unlisted Substances. Many substances present or handled in industrial processes do not appear on the TLV list. In a number of instances the material is rarely present as a particulate, vapor or other airborne contaminant, and a TLV is not necessary. In other cases sufficient information to warrant development of a TLV, even on a tentative basis, is not available to the Committee. Other substances, of low toxicity, could be included in Appendix E pertaining to nuisance particulates. This list (as well as Appendix F) is not meant to be all inclusive; the substances serve only as examples.

In addition there are some substances of not inconsiderable toxicity, which have been omitted primarily because only a limited number of workers (e.g., employ-

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ees of a single plant) are known to have potential exposure to possibly harmful concentrations.

"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. Values listed in parenthesis in the "Adopted" list are to be used during the period in which a proposed change for that Value is listed in the Notice of Intended Changes.

Legal Status. By publication in the Federal Register (Vol. 36, No. 105, May 29, 1971) the Threshold Limit Values for 1968 were made official federal standards for industrial air. Since 1971, new standards for certain of these substances have been promulgated by OSHA.

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	ADOPTED VALUES		TENTATIVE VALUES	
	TWA		STEL	
Substance	ppm[a]	mg/m³[b]	ppm[a]	mg/m³[b]
Abate	—	10	—	20
Acetaldehyde	100	180	150	270
Acetic acid	10	25	15	37
C Acetic anhydride	5	20	—	—
Acetone	1,000	2,400	1,250	3,000
Acetonitrile	40	70	60	105
Acetylene	F	—	—	—
Acetylene dichloride, see 1, 2-Dichloroethylene	200	790	250	1,000
Acetylene tetrabromide	1	14	1.5	18
Acrolein	0.1	0.25	0.3	0.8
Acrylamide — Skin	—	0.3	—	0.6
** Acrylonitrile — Skin	(20)	(45)	(30)	(65)
Aldrin — Skin	—	0.25	—	0.75
Allyl alcohol — Skin	2	5	4	10
Allyl chloride	1	3	2	6
Allyl glycidyl ether (AGE) — Skin	5	22	10	44
Allyl propyl disulfide	2	12	3	18
Alundum (Al_2O_3)	—	E	—	20
4-Aminodiphenyl — Skin	—	A1b	—	A1b
2-Aminoethanol, see Ethanolamine	3	8	6	15
2-Aminopyridine	0.5	2	2	4
Ammonia	25	18	35	27
Ammonium chloride-fume	—	10	—	20
Ammonium sulfamate (Ammate)	—	10	—	20
n-Amyl acetate	100	530	150	800
sec-Amyl acetate	125	670	150	800
** Aniline — Skin	(5)	(19)	—	—
Anisidine (o-, p-isomers) — Skin	0.1	0.5	—	—
** Antimony & Compounds (as Sb)	—	(0.5)	—	—
* Antimony trioxide, handling and use (as Sb)	—	0.5	—	—
** Antimony trioxide production (as Sb)	—	(0.5, A2)	—	—

Capital letters refer to Appendices
Footnotes (a thru g) see Page 31
**See Notices of Intended Changes
*1978 Addition

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Substance	ADOPTED VALUES TWA ppm[a]	ADOPTED VALUES TWA mg/m³[b]	TENTATIVE VALUES STEL ppm[a]	TENTATIVE VALUES STEL mg/m³[b]
ANTU (α-Naphthyl thiourea)	—	0.3	—	0.9
Argon	F	—	F	F
** Arsenic & compounds (as As)	—	(0.5)	—	—
** Arsenic trioxide production (as As)	—	(A1a)	—	—
Arsine	0.05	0.2	—	—
** Asbestos (all forms)	—	(A1a)	—	(A1a)
Asphalt (petroleum) fumes	—	5	—	10
* Atrazine	—	10	—	—
Azinphos-methyl — Skin	—	0.2	—	0.6
Barium (soluble compounds), as Ba	—	0.5	—	—
Baygon (propoxur)	—	0.5	—	2
Benzene	10, A2	30, A2	—	—
Benzidine production — Skin	—	A1b	—	A1b
p-Benzoquinone, see Quinone	0.1	0.4	0.3	2
Benzoyl peroxide	—	5	—	—
Benz(a)pyrene	—	A2	—	A2
Benzyl chloride	1	5	—	—
Beryllium	—	0.002	—	0.025
Biphenyl	0.2	1.5	0.6	4
C Bisphenol A, see Diglycidal ether (DGE)	0.5	3.0	—	—
Bismuth telluride	—	10	—	20
Bismuth telluride, Se-doped	—	5	—	10
Borates, tetra, sodium salts, Anhydrous	—	1	—	—
Decahydrate	—	5	—	—
Pentahydrate	—	1	—	—
Boron oxide	—	10	—	20
Boron tribromide	1	10	3	30
C Boron trifluoride	1	3	—	—
Bromine	0.1	0.7	0.3	2
Bromine pentafluoride	0.1	0.7	0.3	2

Capital letters refer to Appendices
Footnotes (a thru g) see Page 31
**See Notice of Intended Changes.
*1978 Addition.

Substance	ADOPTED VALUES TWA ppm[a]	ADOPTED VALUES TWA mg/m³[b]	TENTATIVE VALUES STEL ppm[a]	TENTATIVE VALUES STEL mg/m³[b]
Bromochloromethane/ chlorobromomethane	200	1,050	250	1,300
Bromoform — Skin	0.5	5	—	—
Butadiene (1, 3-butadiene)	1,000	2,200	1,250	2,750
Butane	600	1,430	750	1,780
Butanethiol, see Butyl mercaptan	0.5	1.5	—	—
2-Butanone	200	590	300	885
2-Butoxyethanol (Butyl Cellosolve) — Skin	50	240	150	720
n-Butyl acetate	150	710	200	950
sec-Butyl acetate	200	950	250	1,190
tert-Butyl acetate	200	950	250	1,190
* Butyl acrylate	10	55	—	—
C n-Butyl alcohol — Skin	50	150	—	—
sec-Butyl alcohol	150	450	—	—
tert-Butyl alcohol	100	300	150	450
C Butylamine — Skin	5	15	—	—
C tert-Butyl chromate (as CrO_3) — Skin	—	0.1	—	—
n-Butyl glycidyl ether (BGE)	50	270	—	—
n-Butyl lactate	5	25	—	—
Butyl mercaptan	0.5	1.5	—	—
p-tert-Butyltoluene	10	60	20	120
Cadmium, dust & salts (as Cd)	—	0.05	—	0.2
C Cadmium oxide fume (as Cd)	—	0.05	—	—
** Cadmium oxide production (as Cd)	—	(A2)	—	—
Calcium carbonate/ marble	—	E	—	20
Calcium arsenate (as As)	—	1	—	—
Calcium cyanamide	—	0.5	—	1
* Calcium hydroxide	—	5	—	—
* Calcium oxide	—	2	—	—
Camphor, synthetic	2	12	3	18
Caprolactam Dust	—	1	—	3
Vapor	5	20	10	40

Capital letters refer to Appendices.
**See Notice of Intended Changes.
*1978 Addition.

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Substance	ADOPTED VALUES TWA ppm[a]	ADOPTED VALUES TWA mg/m³[b]	TENTATIVE VALUES STEL ppm[a]	TENTATIVE VALUES STEL mg/m³[b]
Captafol (Difolatan®) — Skin	—	0.1	—	—
Captan	—	5	—	15
Carbaryl (Sevin®)	—	5	—	10
Carbofuran (Furadan®)	—	0.1	—	—
Carbon black	—	3.5	—	7
Carbon dioxide	5,000	9,000	15,000	18,000
** Carbon disulfide — Skin	(20)	(60)	(30)	(90)
Carbon monoxide	50	55	400	440
Carbon tetrabromide	0.1	1.4	0.3	4
Carbon tetrachloride — Skin	10	65	20	130
* Carbonyl chloride (Phosgene)	0.1	0.4	—	—
* Carbonyl fluoride	5	15	—	—
Catechol (Pyrocatechol)	5	20	—	—
Cellulose (paper fiber)	—	E	—	20
Cesium hydroxide	—	2	—	—
Chlordane — Skin	—	0.5	—	2
Chlorinated camphene — Skin	—	0.5	—	1
Chlorinated diphenyl oxide	—	0.5	—	2
Chlorine	1	3	3	9
Chlorine dioxide	0.1	0.3	0.3	0.9
C Chlorine trifluoride	0.1	0.4	—	—
C Chloroacetaldehyde	1	3	—	—
α-Chloroacetophenone (Phenacyl chloride)	0.05	0.3	—	—
Chlorobenzene (Monochlorobenzene)	75	350	—	—
o-Chlorobenzylidene malononitrile — Skin	0.05	0.4	—	—
Chlorobromomethane/ Bromochloromethane	200	1,050	250	1,300
2-Chloro-1, 3-butadiene, see β Chloroprene — Skin	25	90	35	125
Chlorodifluoromethane	1,000	3,500	1,250	4,375
Chlorodiphenyl (42% Chlorine) — Skin	—	1	—	2

Capital letters refer to Appendices.
**See Notice of Intended Changes.
*1978 Addition.

Substance	ADOPTED VALUES TWA ppm[a]	ADOPTED VALUES TWA mg/m³[b]	TENTATIVE VALUES STEL ppm[a]	TENTATIVE VALUES STEL mg/m³[b]
Chlorodiphenyl (54% Chlorine) — Skin	—	0.5	—	1
1-Chloro, 2, 3-epoxy-propane (Epichlorhydrin) — Skin	5	20	10	40
C 2-Chloroethanol (Ethylene chlorohydrin) — Skin	1	3	—	—
** Chloroethylene (Vinyl chloride)	(A1c)	—	(A1c)	—
* Chloroform (Trichloromethane)	10, A2	50, A2	—	—
bis-Chloromethyl ether	0.001	A1a	—	A1a
1-Chloro-1-nitro-propane	20	100	—	—
Chloropicrin	0.1	0.7	0.3	2
** β-Chloroprene — Skin	(25)	(90)	(35)	(135)
Chlorpyrifos (Dursban®) — Skin	—	0.2	—	0.6
o-Chlorostyrene	50	285	75	430
o-Chlorotoluene — Skin	50	250	75	375
2-Chloro-6-(trichloromethyl pyridine (N-Serve®)	—	10	—	20
Chromates, certain insoluble forms	—	0.05, A1a	—	A1a
Chromic acid and Chromates, (as Cr)	—	0.05	—	—
* Chromite ore processing (chromate), as Cr	—	0.05, A1a	—	—
Chromium, Sol. chromic, chromous salts (as Cr)	—	0.5	—	—
Clopidol (Coyden®)	—	10	—	20
Coal tar pitch volatiles (See Particulate polycyclic aromatic hydrocarbons)	—	0.2, A1a	—	A1a
** Cobalt metal, dust and fume (as Co)	—	(0.1)	—	—

Capital letters refer to Appendices.
Footnotes (a thru g) see Page 31.
**See Notice of Intended Changes.
*1978 Addition.

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Substance	ADOPTED VALUES TWA ppm[a]	ADOPTED VALUES TWA mg/m³[b]	TENTATIVE VALUES STEL ppm[a]	TENTATIVE VALUES STEL mg/m³[b]
Copper fume	—	0.2	—	
Dusts & Mists (as Cu)	—	1	—	
Corundum (Al_2O_3)	—	E	—	2
Cotton dust, raw	—	0.2[b]	—	E
Crag® herbicide	—	10	—	0.6
Cresol, all isomers — Skin	5	22	—	20
Crotonaldehyde	2	6	6	
Crufomate®	—	5	—	18
Cumene — Skin	50	245	75	20
Cyanamide	—	2	—	365
Cyanide, as CN — Skin	—	5	—	
Cyanogen	10	20	—	
Cyclohexane	300	1,050	375	1,300
Cyclohexanol	50	200	—	
Cyclohexanone	50	200	—	
Cyclohexene	300	1,015	—	
Cyclohexylamine — Skin	10	40	—	
Cyclopentadiene	75	200	150	400
2, 4-D (2, 4-Diphenoxy-acetic acid)	—	10	—	20
DDT (Dichlorodiphenyl-trichloroethane)	—	1	—	3
DDVP, see Dichlorvos — Skin	0.1	1	0.3	3
Decaborane — Skin	0.05	0.3	0.15	0.9
Demeton® — Skin	0.01	0.1	0.03	0.3
Diacetone alcohol (4-hydroxy-4-methyl-2-pentanone)	50	240	75	360
1, 2-Diaminoethane, see Ethylenediamine	10	25	—	
Diazinon — Skin	—	0.1	—	0.3
Diazomethane	0.2	0.4	—	
Diborane	0.1	0.1	—	
** 1, 2-Dibromoethane (Ethylene dibromide) — Skin	(20)	(155)	(30)	(230)
Dibrom®	—	3	—	6
2-N-Dibutylaminoethanol — Skin	2	14	4	28
Dibutyl phosphate	1	5	2	10

I) See p. 33.

Footnotes (a thru g) see Page 31.

**See Notice of Intended Changes

Substance	ADOPTED VALUES TWA ppm[a]	ADOPTED VALUES TWA mg/m³[b]	TENTATIVE VALUES STEL ppm[a]	TENTATIVE VALUES STEL mg/m³[b]
Dibutyl phthalate	—	5	—	10
C Dichloracetylene	0.1	0.4	—	—
C o-Dichlorobenzene	50	300	—	—
p-Dichlorobenzene	75	450	110	675
Dichlorobenzidine — Skin	—	A2	—	A2
Dichlorodifluoromethane	1,000	4,950	1,250	6,200
1, 3-Dichloro-5, 5-dimethyl hydantoin	—	0.2	—	0.4
1, 1-Dichloroethane	200	810	250	1,010
** 1, 2-Dichloroethane	(50)	(200)	(75)	(300)
1, 2-Dichloroethylene	200	790	250	1,000
Dichloroethyl ether — Skin	5	30	10	60
** Dichloromethane, see Methylene chloride	(200)	(700)	(250)	(870)
*** Dichloromonofluoro-methane	(1,000)	(4,200)	—	—
C 1, 1-Dichloro-1-nitroethane	10	60	—	—
1, 2-Dichloropropane, see Propylene dichloride	75	350	110	510
Dichlorotetrafluoro-ethane	1,000	7,000	1,250	8,750
Dichlorvos (DDVP) — Skin	0.1	1	0.3	3
Dicrotophos (Bidrin®) — Skin	—	0.25	—	—
Dicyclopentadiene	5	30	—	—
Dicyclopentadienyl iron	—	10	—	20
Dieldrin — Skin	—	0.25	—	0.75
Diethylamine	25	75	—	—
Diethylaminoethanol — Skin	10	50	—	—
Diethylene triamine — Skin	1	4	—	—
Diethyl ether, see Ethyl ether	400	1,200	500	1,500
Diethyl phthalate	—	5	—	10
Difluorodibromomethane	100	860	150	1,290

Capital letters refer to Appendices

**See Notice of Intended Changes.

MAP 000111

Substance	ADOPTED VALUES TWA ppm[a]	ADOPTED VALUES TWA mg/m³[b]	TENTATIVE VALUES STEL ppm[a]	TENTATIVE VALUES STEL mg/m³[b]
C Diglycidyl ether (DGE)	0.5	3	—	—
Dihydroxybenzene, see Hydroquinone	—	2	—	4
Diisobutyl ketone	25	150	—	—
Diisopropylamine — Skin	5	20	—	—
Dimethoxymethane, see Methylal	1,000	3,100	1,250	3,875
Dimethyl acetamide — Skin	10	35	15	50
* Dimethyl carbamyl chloride	A2	A2	—	—
Dimethylamine	10	18	—	—
Dimethylaminobenzene, see Xylidene — Skin	5	25	10	50
Dimethylaniline (N, N-Dimethylaniline) — Skin	5	25	10	50
Dimethylbenzene, see Xylene — Skin	100	435	150	650
Dimethyl-1, 2-dibromo-2-dichloroethyl phosphate, see Dibrom	—	3	—	6
Dimethylformamide — Skin	10	30	20	60
2, 6-Dimethyl-4-heptanone, see Diisobutyl ketone	25	150	—	—
1, 1-Dimethylhydrazine — Skin	0.5	1	1	2
Dimethylphthalate	—	5	—	10
C Dimethyl sulfate — Skin	0.1, A2	0.5, A2	—	—
Dinitrobenzene (all isomers) — Skin	0.15	1	0.5	3
Dinitro-o-cresol — Skin	—	0.2	—	0.6
3, 5-Dinitro-o-toluamide (Zoalene®)	—	5	—	10
Dinitrotoluene — Skin	—	1.5	—	5
Dioxane, tech. grade — Skin	50	180	—	—
Dioxathion (Delnav®) — Skin	—	0.2	—	—

Capital letters refer to Appendices.
Footnotes (a thru g) see Page 31
*1978 Addition.

Substance	ADOPTED VALUES TWA ppm[a]	ADOPTED VALUES TWA mg/m³[b]	TENTATIVE VALUES STEL ppm[a]	TENTATIVE VALUES STEL mg/m³[b]
Diphenyl, see Biphenyl	0.2	1.5	0.6	4
Diphenylamine	—	10	—	20
C Diphenylmethane diisocyanate, see Methylene bisphenyl isocyanate (MDI)	0.02	0.2	—	—
Dipropylene glycol methyl ether — Skin	100	600	150	900
Diquat	—	0.5	—	1
Di-sec, octyl phthalate (Di-2-ethylhexyl-phthalate)	—	5	—	10
Disulfiram	—	2	—	5
Disyston — Skin	—	0.1	—	0.3
2, 6-Ditert. butyl-p-cresol	—	10	—	20
Diuron	—	10	—	—
Dyfonate	—	0.1	—	—
Emery	—	E	—	20
Endosulfan (Thiodan®) — Skin	—	0.1	—	0.3
Endrin — Skin	—	0.1	—	0.3
** Epichlorhydrin — Skin	(5)	(20)	(10)	(40)
EPN — Skin	—	0.5	—	2
1, 2-Epoxypropane, see Propylene oxide	100	240	150	360
2, 3-Epoxy-1-propanol, see Glycidol	50	150	75	225
Ethane	F	—	F	—
Ethanethiol, see Ethyl mercaptan	0.5	1	2	3
Ethanolamine	3	8	6	15
Ethion (Nialate®) — Skin	—	0.4	—	—
2-Ethoxyethanol — Skin	100	370	150	560
2-Ethoxyethyl acetate (Cellosolve acetate) — Skin	100	540	150	810
Ethyl acetate	400	1,400	—	—
Ethyl acrylate — Skin	25	100	—	—
Ethyl alcohol (Ethanol)	1,000	1,900	—	—
Ethylamine	10	18	—	—

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

MAP 000112

Substance	ADOPTED VALUES TWA ppm[a]	ADOPTED VALUES TWA mg/m³[b]	TENTATIVE VALUES STEL ppm[a]	TENTATIVE VALUES STEL mg/m³[b]
Ethyl sec-amyl ketone (4-Methyl-3-heptanone)	25	130	—	—
Ethyl benzene	100	435	125	545
Ethyl bromide	200	890	250	1,110
Ethylbutyl ketone (3-Heptanone)	50	230	75	345
Ethyl chloride	1,000	2,600	1,250	3,250
Ethyl ether	400	1,200	500	1,500
Ethyl formate	100	300	150	450
Ethyl mercaptan	0.5	1	2	3
** Ethyl silicate	(100)	(850)	—	—
Ethylene	F	—	F	—
C Ethylene chlorohydrin — Skin	1	3	—	—
Ethylenediamine	10	25	—	—
** Ethylene dibromide, see 1, 2-Dibromoethane	(20)	(155)	(30)	(230)
** Ethylene dichloride, see 1, 2-Dichloroethane	(50)	(200)	(75)	(300)
Ethylene glycol, Particulate	—	10	—	20
Vapor	100	250	125	325
C Ethylene glycol dinitrate and/or Nitroglycerin — Skin	0.2[n]	2	—	—
Ethylene glycol monomethyl ether acetate (Methyl cellosolve acetate) — Skin	25	120	35	170
Ethylene oxide	50	90	75	135
Ethylenimine — Skin	0.5	1	—	—
Ethylidene chloride, see 1, 1-Dichloroethane	200	810	250	1,010
C Ethylidene norbornene	5	25	—	—
N-Ethylmorpholine — Skin	20	94	—	—
Fensulfothion (Dasanit)	—	0.1	—	—
Ferbam	—	10	—	20
Ferrovanadium dust	—	1	—	0.3
Fluoride (as F)	—	2.5	—	—
Fluorine	1	2	2	4

Capital letters refer to Appendixes
**See Notice of Intended Changes

Substance	ADOPTED VALUES TWA ppm[a]	ADOPTED VALUES TWA mg/m³[b]	TENTATIVE VALUES STEL ppm[a]	TENTATIVE VALUES STEL mg/m³[b]
Fluorotrichloromethane	1,000	5,600	1,250	7,000
C Formaldehyde	2	3	—	—
Formamide	20	30	30	45
Formic acid	5	9	—	—
Furfural — Skin	5	20	15	60
Furfuryl alcohol — Skin	5	20	10	40
Gasoline	—	B2	—	B2
Germanium tetrahydride	0.2	0.6	0.6	1.8
Glass, fibrous[c] or dust	—	10	—	—
**C Glutaraldehyde, activated or unactivated	—	(0.25)	—	—
Glycerin mist	—	E	—	E
Glycidol (2, 3-Epoxy-1-propanol)	50	150	75	225
Glycol monoethyl ether, see 2-Ethoxyethanol — Skin	100	370	150	560
Graphite (Synthetic)	—	E	—	—
Guthion®, see Azinphos-methyl — Skin	—	0.2	—	0.6
Gypsum	—	E	—	20
Hafnium	—	0.5	—	1.5
Helium	F	—	F	—
Heptachlor — Skin	—	0.5	—	2
Heptane (n-Heptane)	400	1,600	500	2,000
Hexachlorocyclopentadiene	0.01	0.1	0.03	0.3
Hexachloroethane — Skin	1	10	3	30
Hexachloronaphthalene — Skin	—	0.2	—	0.6
Hexafluoroacetone	0.1	0.7	0.3	2
Hexane (n-hexane)	100	360	125	450
* Hexamethyl phosphoramide — Skin	A2	A2	—	—
2-Hexanone, see Methyl butyl ketone — Skin	25	100	40	165
Hexone (Methyl isobutyl ketone) — Skin	100	410	125	510

Capital letters refer to Appendices
Footnotes (a thru g) see Page 31.
*1978 Addition.
**See Notice of Intented Changes

MAP 000113

Substance	ADOPTED VALUES TWA ppm[a]	ADOPTED VALUES TWA mg/m³[b]	TENTATIVE VALUES STEL ppm[a]	TENTATIVE VALUES STEL mg/m³[b]
sec-Hexyl acetate	50	300	—	—
C Hexylene glycol	25	125	—	—
Hydrazine — Skin	0.1, A2	0.1, A2	—	—
Hydrogen	F	—	F	—
Hydrogenated terphenyls	0.5	5	—	—
Hydrogen bromide	3	10	—	—
C Hydrogen chloride	5	7	—	—
** Hydrogen cyanide — Skin	(10)	(11)	(15)	(16)
Hydrogen fluoride	3	2	—	—
Hydrogen peroxide	1	1.5	2	3
Hydrogen selenide	0.05	0.2	—	—
Hydrogen sulfide	10	15	15	27
Hydroquinone	—	2	—	4
Indene	10	45	15	70
Indium & Compounds (as In)	—	0.1	—	0.3
C Iodine	0.1	1	—	—
Iodoform	0.6	10	1	20
Iron oxide fume	B3	5	—	10
Iron pentacarbonyl	0.01	0.08	—	—
Iron salts, soluble (as Fe)	—	1	—	2
Isoamyl acetate	100	525	125	655
Isoamyl alcohol	100	360	125	450
Isobutyl acetate	150	700	187	875
Isobutyl alcohol	50	150	75	225
C Isophorone	5	25	—	—
Isophorone diisocyanate — Skin	0.01	0.09	—	—
Isopropyl acetate	250	950	310	1,185
Isopropyl alcohol — Skin	400	980	500	1,225
Isopropylamine	5	12	10	24
Isopropyl ether	250	1,050	310	1,320
Isopropyl glycidyl ether (IGE)	50	240	75	360
Kaolin	—	E	—	20
Ketene	0.5	0.9	1.5	3
Lead, inorg., fumes & dusts (as Pb)	—	0.15	—	0.45
Lead arsenate (as Pb)	—	0.15	—	0.45
Lead chromate (as Cr)	—	0.05, A2	—	—

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

Substance	ADOPTED VALUES TWA ppm[a]	ADOPTED VALUES TWA mg/m³[b]	TENTATIVE VALUES STEL ppm[a]	TENTATIVE VALUES STEL mg/m³[b]
Limestone	—	E	—	20
Lindane — Skin	—	0.5	—	1.5
Lithium hydride	—	0.025	—	—
L.P.G. (Liquified petroleum gas)	1,000	1,800	1,250	2,250
Magnesite	—	E	—	20
Magnesium oxide fume (as Mg)	—	10	—	—
Malathion — Skin	—	10	—	—
Maleic anhydride	0.25	1	—	—
C Manganese & Compounds (as Mn)	—	5	—	—
Manganese cyclopentadienyl tricarbonyl (as Mn) — Skin	—	0.1	—	0.3
* Manganese Tetroxide	—	1	—	—
Marble/calcium carbonate	—	E	—	20
Mercury (Alkyl compounds) — Skin, (as Hg)	0.001	0.01	0.003	0.03
Mercury (All forms except alkyl), as Hg	—	0.05	—	0.15
Mesityl oxide	25	100	—	—
Methane	F	—	F	—
Methanethiol, see Methyl mercaptan	0.5	1	—	—
Methomyl (Lannate®) — Skin	—	2.5	—	—
Methoxychlor	—	10	—	—
2-Methoxyethanol — Skin (Methyl cellosolve)	25	80	35	120
Methyl acetate	200	610	250	760
Methyl acetylene (propyne)	1,000	1,650	1,250	2,040
Methyl acetylene-propadiene mixture (MAPP)	1,000	1,800	1,250	2,250
Methyl acrylate — Skin	10	35	—	—

Capital letters refer to Appendices
* 1978 Addition.

MAP 000114

Substance	ADOPTED VALUES TWA ppm[a]	ADOPTED VALUES TWA mg/m³[b]	TENTATIVE VALUES STEL ppm[a]	TENTATIVE VALUES STEL mg/m³[b]
Methylacrylonitrile — Skin	1	3	2	6
Methylal (dimethoxymethane)	1,000	3,100	1,250	3,875
Methyl alcohol (methanol) — Skin	200	260	250	310
Methylamine	10	12	—	—
Methyl amyl alcohol, see Methyl isobutyl carbinol — Skin	25	100	40	160
Methyl 2-cyanoacrylate	2	8	4	16
Methyl n-amyl ketone (2-Heptanone)	100	465	150	710
Methyl bromide — Skin	15	60	—	—
Methyl butyl ketone, see 2-Hexanone — Skin	25	100	40	165
Methyl cellosolve — Skin see 2-Methoxyethanol	25	80	35	120
Methyl cellosolve acetate — Skin, see Ethylene glycol monomethyl ether acetate	25	120	35	170
Methyl chloride	100	210	125	260
Methyl chloroform (1, 1, 1-Trichloroethane)	350	1,900	450	2,380
Methylcyclohexane	400	1,600	500	2,000
Methylcyclohexanol	50	235	75	350
o-Methycyclohexanone — Skin	50	230	75	345
Methylcyclopentadienyl manganese tricarbonyl (as Mn) — Skin	0.1	0.2	0.3	0.6
Methyl demeton — Skin	—	0.5	—	1.5
C Methylene bisphenyl isocyanate (MDI)	0.02	0.2	—	—
** Methylene chloride (dichloromethane)	(200)	(700)	(250)	(870)
4, 4'-Methylene bis (2-chloraniline) — Skin	0.02, A2	—	A2	—
C Methylene bis (4-cyclohexylisocyanate)	0.01	0.11	—	—

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

Substance	ADOPTED VALUES TWA ppm[a]	ADOPTED VALUES TWA mg/m³[b]	TENTATIVE VALUES STEL ppm[a]	TENTATIVE VALUES STEL mg/m³[b]
Methyl ethyl ketone (MEK), see 2-Butanone	200	590	300	885
C Methyl ethyl ketone peroxide	0.2	1.5	—	—
Methyl formate	100	250	150	375
Methyl iodide — Skin	5	28	10	56
Methyl isoamyl ketone	100	475	150	710
Methyl isobutyl carbinol — Skin	25	100	40	165
Methyl isobutyl ketone, see Hexone — Skin	100	410	125	510
Methyl isocyanate — Skin	0.02	0.05	—	—
Methyl mercaptan	0.5	1	—	—
Methyl methacrylate	100	410	125	510
Methyl parathion — Skin	—	0.2	—	0.6
Methyl propyl ketone, see 2-Pentanone	200	700	250	875
C Methyl silicate	5	30	—	—
C α-Methyl styrene	100	480	—	—
Molybdenum (as Mo) Soluble compounds	—	5	—	10
Insoluble compounds	—	10	—	20
Monocrotophos (Azodrin®)	—	0.25	—	—
Monomethyl aniline — Skin	2	9	4	18
C Monomethyl hydrazine — Skin	0.2	0.35	—	—
Morpholine — Skin	20	70	30	105
Naphthalene	10	50	15	75
β-Naphthylamine	—	A1b	—	A1b
Neon	F	—	F	—
Nickel carbonyl	0.05	0.35	—	—
Nickel metal	—	1	—	—
Nickel, soluble compounds (as Ni)	—	0.1	—	0.3
Nickel sulfide roasting, fume & dust (as Ni)	—	1, A1a	—	—
Nicotine — Skin	—	0.5	—	1.5
Nitric acid	2	5	4	10

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

MAP 000115

Substance	ADOPTED VALUES TWA ppm[a]	ADOPTED VALUES TWA mg/m³[b]	TENTATIVE VALUES STEL ppm[a]	TENTATIVE VALUES STEL mg/m³[b]
Nitric oxide	25	30	35	45
p-Nitroaniline — Skin	1	6	2	12
Nitrobenzene — Skin	1	5	2	10
p-Nitrochlorobenzene — Skin	—	1	—	2
4-Nitrodiphenyl	—	A1b	—	A1b
Nitroethane	100	310	150	465
C Nitrogen dioxide	5	9	—	—
Nitrogen trifluoride	10	29	15	45
C Nitroglycerin — Skin	0.2[c]	2	—	—
Nitromethane	100	250	150	375
1-Nitropropane	25	90	35	135
** 2-Nitropropane	(25)	(90)	—	—
N-Nitrosodimethylamine (dimethylnitrosoamine) — Skin	—	A2	—	A2
Nitrotoluene — Skin	5	30	10	60
Nitrotrichloromethane, see Chloropicrin	0.1	0.7	0.3	2
Nonane	200	1,050	250	1,300
Octachloronaphthalene — Skin	—	0.1	—	0.3
Octane	300	1,450	375	1,800
Oil mist, mineral	—	5[d]	—	10
Osmium tetroxide (as Os)	0.0002	0.002	0.0006	0.006
Oxalic acid	—	1	—	2
Oxygen difluoride	0.05	0.1	0.15	0.3
Ozone	0.1	0.2	0.3	0.6
Paraffin wax fume	—	2	—	6
* Paraquat, respirable sizes	—	0.1	—	—
Parathion — Skin	—	0.1	—	0.3
Particulate polycyclic aromatic hydrocarbons (PPAH), as benzene solubles	—	0.2, A1a	—	A1a
Pentaborane	0.005	0.01	0.015	0.03
Pentachloronaphthalene	—	0.5	—	2
Pentachlorophenol — Skin	—	0.5	—	1.5

Capital letters refer to Appendices
Footnotes (a thru g) see Page 31
*1978 Addition
**See Notice of Intended Changes.

Substance	ADOPTED VALUES TWA ppm[a]	ADOPTED VALUES TWA mg/m³[b]	TENTATIVE VALUES STEL ppm[a]	TENTATIVE VALUES STEL mg/m³[b]
Pentaerythritol	—	E	—	20
Pentane	600	1,800	750	2,250
2-Pentanone	200	700	250	875
Perchloroethylene — Skin	100	670	150	1,000
Perchloromethyl mercaptan	0.1	0.8	—	—
Perchloryl fluoride	3	14	6	28
Phenol — Skin	5	19	10	38
Phenothiazine — Skin	—	5	—	10
p-Phenylene diamine — Skin	—	0.1	—	—
Phenyl ether (vapor)	1	7	2	14
Phenyl ether-Diphenyl mixture (vapor)	1	7	2	14
Phenylethylene, see Styrene, monomer	100	420	125	525
Phenyl glycidyl ether (PGE)	10	60	15	90
* Phenyl mercaptan	0.5	2	—	—
Phenylhydrazine — Skin	5	22	10	44
C Phenylphosphine	0.05	0.25	—	—
Phorate (Thimet®) — Skin	—	0.05	—	0.2
Phosdrin (Mevinphos®) — Skin	0.01	0.1	0.03	0.3
* Phosgene (carbonyl chloride)	0.1	0.4	—	—
Phosphine	0.3	0.4	1	1
Phosphoric acid	—	1	—	3
Phosphorus (yellow)	—	0.1	—	0.3
** Phosphorus pentachloride	—	(1)	—	(3)
Phosphorus pentasulfide	—	1	—	3
Phosphorus trichloride	0.5	3	—	—
Phthalic anhydride	1	6	4	24
m-Phthalodinitrile	—	5	—	—
Picloram (Tordon®)	—	10	—	20
Picric acid — Skin	—	0.1	—	0.3
Pival® (2-Pivalyl-1, 3-indandione)	—	0.1	—	0.3
Plaster of Paris	—	E	—	20

Capital letters refer to Appendices.
*1978 Addition.
**See Notices of Intended Changes.

0004077 PST

MAP 000116

Substance	ADOPTED VALUES TWA ppm[a]	ADOPTED VALUES TWA mg/m³[b]	TENTATIVE VALUES STEL ppm[a]	TENTATIVE VALUES STEL mg/m³[b]
Platinum (Soluble salts) as Pt	—	0.002	—	—
Polychlorobiphenyls, see Chlorodiphenyls — Skin	—	—	—	—
Polytetrafluoroethylene decomposition products	—	B1	—	B1
C Potassium hydroxide	—	2	—	—
Propane	F	—	F	—
β-Propiolactone	—	A2	—	A2
Propargyl alcohol — Skin	1	2	3	6
n-Propyl acetate	200	840	250	1,050
Propyl alcohol — Skin	200	500	250	625
n-Propyl nitrate	25	105	40	470
Propylene	F	—	F	—
Propylene dichloride (1, 2-Dichloropropane)	75	350	110	510
*C Propylene glycol dinitrate — Skin	0.2	2	—	—
Propylene glycol monomethyl ether	100	360	150	540
Propylene imine — Skin	2	5	—	—
Propylene oxide	100	240	150	360
Propyne, see Methyl acetylene	1,000	1,650	1,250	2,040
Pyrethrum	—	5	—	10
Pyridine	5	15	10	30
Quinone	0.1	0.4	0.3	2
RDX — Skin	—	1.5	—	3
Resorcinol	10	45	20	90
Rhodium, Metal fume and dusts (as Rh)	—	0.1	—	0.3
Soluble salts (as Rh)	—	0.001	—	0.003
Ronnel	—	10	—	—
Rosin core solder pyrolysis products (as formaldehyde)	—	0.1	—	0.3
Rotenone (commercial)	—	5	—	10
Rouge	—	E	—	20

Capital letters refer to Appendices
*1978 Addition.

Substance	ADOPTED VALUES TWA ppm[a]	ADOPTED VALUES TWA mg/m³[b]	TENTATIVE VALUES STEL ppm[a]	TENTATIVE VALUES STEL mg/m³[b]
Rubber solvent (Naphtha)	400	1,600	—	—
Selenium compounds (as Se)	—	0.2	—	—
Selenium hexafluoride, as Se	0.05	0.4	0.05	0.4
Sevin® (see Carbaryl)	—	5	—	10
Silane (see Silicon tetrahydride)	0.5	7	1	2
Silicon	—	E	—	20
Silicon carbide	—	E	—	20
Silicon tetrahydride (Silane)	0.5	0.7	1	2
** Silver, metal and soluble compounds, as Ag	—	(0.01)	—	(0.03)
C Sodium azide	0.1	0.3	—	—
Sodium fluoroacetate (1080) — Skin	—	0.05	—	0.15
C Sodium hydroxide	—	2	—	—
Starch	—	E	—	20
Stibine	0.1	0.5	0.3	1.5
Stoddard solvent	100	575	125	720
Strychnine	—	0.15	—	0.45
Styrene, monomer (Phenylethylene)	100	420	125	525
C Subtilisins (Proteolytic enzymes as 100% pure crystalline enzyme)	—	0.00006[a]	—	—
Sucrose	—	E	—	20
** Sulfur dioxide	(5)	(13)	—	—
Sulfur hexafluoride	1,000	6,000	1,250	7,500
Sulfuric acid	—	1	—	—
Sulfur monochloride	1	6	3	18
Sulfur pentafluoride	0.025	0.25	0.075	0.75
Sulfur tetrafluoride	0.1	0.4	0.3	1
Sulfuryl fluoride	5	20	10	40
Systox, see Demeton® — Skin	0.01	0.1	0.03	0.3
2, 4, 5-T	—	10	—	20
Tantalum	—	5	—	10

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

MAP 000117

Substance	ADOPTED VALUES TWA ppm[a]	TWA mg/m³[b]	TENTATIVE VALUES STEL ppm[a]	STEL mg/m³[b]
TEDP — Skin	—	0.2	—	0.6
Teflon® decomposition products	—	B1	—	B1
Tellurium & compounds (as Te)	—	0.1	—	—
Tellurium hexafluoride, as Te	0.02	0.2	—	—
TEPP — Skin	0.004	0.05	0.01	0.2
**C Terphenyls	(1)	(9)	—	—
1, 1, 1, 2-Tetrachloro-2, 2-difluoroethane	500	4,170	625	5,210
1, 1, 2, 2-Tetrachloro-1, 2-difluoroethane	500	4,170	625	5,210
1, 1, 2, 2-Tetrachloroethane — Skin	5	35	10	70
Tetrachloroethylene, see Perchloroethylene — Skin	100	670	150	1,000
Tetrachloromethane, see Carbon tetrachloride — Skin	10	65	20	130
Tetrachloronaphthalene	—	2	—	4
Tetraethyl lead (as Pb) — Skin	—	0.100[p]	—	0.3
Tetrahydrofuran	200	590	250	735
Tetramethyl lead (as Pb) — Skin	—	0.150[p]	—	0.5
Tetramethyl succinonitrile — Skin	0.5	3	2	9
Tetranitromethane	1	8	—	—
Tetryl (2, 4, 6-trinitrophenyl-methylnitramine) — Skin	—	1.5	—	3.0
Thallium, soluble compounds (as Tl) — Skin	—	0.1	—	—
4, 4'-Thiobis (6-tert. butyl-m-cresol)	—	10	—	20
* Thioglycolic acid	1	5	—	—

Capital letters refer to Appendices.
*1978 Addition.
**See Notice of Intended Changes

Substance	ADOPTED VALUES TWA ppm[a]	TWA mg/m³[b]	TENTATIVE VALUES STEL ppm[a]	STEL mg/m³[b]
Thiram®	—	5	—	10
Tin, inorganic compounds, except SnH_4 and SnO_2 (as Sn)	—	2	—	4
Tin, organic compounds (as Sn) — Skin	—	0.1	—	0.2
Tin oxide (as Sn)	—	E	—	20
Titanium dioxide (as Ti)	—	E	—	20
Toluene (toluol) — Skin	100	375	150	560
**C Toluene-2, 4-diisocyanate (TDI)	(0.02)	(0.14)	—	—
o-Toluidine	5	22	10	44
Toxaphene, see Chlorinated camphene — Skin	—	0.5	—	2.0
Tributyl phosphate	—	5	—	5
*C 1, 2, 4-Trichlorobenzene	5	40	—	—
1, 1, 1-Trichloroethane, see Methyl chloroform	350	1,900	440	2,380
1, 1, 2-Trichloroethane — Skin	10	45	20	90
Trichloroethylene	100	535	150	800
* Trichloromethane, see Chloroform	10, A2	50, A2	—	—
Trichloronaphthalene	—	5	—	10
1, 2, 3-Trichloropropane	50	300	75	450
1, 1, 2-Trichloro 1, 2, 2-trifluoroethane	1,000	7,600	1,250	9,500
Triethylamine	25	100	40	160
Tricyclohexyltin hydroxide (Plictran®)	—	5	—	10
Trifluoromonobromo-methane	1,000	6,100	1,200	7,300
Trimethyl benzene	25	125	35	170
2, 4, 6-Trinitrophenol, see Picric acid — Skin	—	0.1	—	0.3
2, 4, 6-Trinitrophenyl-methylnitramine, see Tetryl — Skin	—	1.5	—	3.0
*C 2, 4, 6-Trinitrotoluene (TNT)	—	0.5	—	—

Capital letters refer to Appendices.
*1978 Addition.
**See Notice of Intended Changes.

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Substance	ADOPTED VALUES TWA ppm[a]	TWA mg/m³[b]	TENTATIVE VALUES STEL ppm[a]	STEL mg/m³[b]
Trorthocresyl phosphate	—	0.1	—	0.3
Triphenyl phosphate	—	3	—	6
Tungsten & compounds, as W				
Soluble	—	1	—	3
Insoluble	—	5	—	10
Turpentine	100	560	150	840
Uranium (natural) soluble & insoluble compounds, as U	—	0.2	—	0.6
Vanadium (V_2O_5), as V				
Dust	—	0.5	—	1.5
C Fume	—	0.05	—	—
* Valeraldehyde	50	175	—	—
Vinyl acetate	10	30	20	60
Vinyl benzene, see Styrene	100	420	150	630
** Vinyl bromide	(250)	(1,100)	—	—
** Vinyl chloride	(A1c)	—	(A1c)	—
Vinyl cyanide, see Acrylonitrile — Skin	20	45	30	65
Vinyl cyclohexene dioxide	10	60	—	—
Vinylidene chloride	10	40	20	80
Vinyl toluene	100	480	150	720
Warfarin	—	0.1	—	0.3
Welding fumes (NOC)+	—	5, B3	—	B3
Wood dust (nonallergenic)	—	5	—	10
Xylene (o-, m-, p-isomers) — Skin	100	435	150	655
C m-Xylene α, α'-diamine	—	0.1	—	—
Xylidene — Skin	5	25	10	50
Yttrium	—	1	—	3
Zinc chloride fume	—	1	—	2
Zinc chromate (as Cr)	—	0.05, A2	—	—
Zinc oxide fume	—	5	—	10
Zinc stearate	—	E	—	20
Zirconium compounds (as Zr)	—	5	—	10

Capital letters refer to Appendices
-(NOC) not otherwise classified
*1978 Addition
**See Notice of Intended Changes

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 substance per cubic meter of air.
d) An atmospheric concentration of not more than 0.02 ppm, or personal protection may be necessary to avoid headache for intermittent exposure.
e) < 7 μm in diameter.
f) As sampled by method that does not collect vapor.
g) 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, 1959; Addendum 1, August 1963 (NCRP Report No. 22). Also, see U.S. Department of Commerce National Bureau of Standards, Handbook 59, "Permissible Dose from External Sources of Ionizing Radiation," September 24, 1954, an 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, 7910 Woodmont Ave., Washington, D.C. 20014.

MINERAL DUSTS

Substance	
SILICA, SiO_2	
Crystalline	
Quartz	TLV in mppcf[a]: $\frac{300^{f}}{\%\ \text{quartz} + 10}$ TLV for respirable dust in mg/m³: $\frac{10\ \text{mg/m}^3{}^{g}}{\%\ \text{Respirable quartz} + 2}$ TLV for "total dust," respirable and nonrespirable: $\frac{30\ \text{mg/m}^3}{\%\ \text{quartz} + 3}$

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Cristobalite	Use one-half the value calculated from the count or mass formulae for quartz.
Tridymite	Use one-half the value calculated from formulae for quartz.
Silica, fused	Use quartz formulae.
Tripoli	Use respirable[o] mass quartz formula

**Amorphous ..... (20 mppcf[h])

SILICATES (< 1% quartz)

**Asbestos, all forms	(5 fibers/cc> 5μm in length[m]; A1a)
Mica	20 mppcf
Mineral wool fiber	10 mg/m³
Perlite	30 mppcf
Portland Cement	30 mppcf
Soapstone	20 mppcf
Talc (nonasbestiform)	20 mppcf

**Talc (fibrous), use Asbestos limit.
**Tremolite, see Asbestos.

COAL DUST

2 mg/m³ (respirable dust fraction < 5% quartz).
If > 5% quartz, use respirable mass formula.

NUISANCE PARTICULATES
(see Appendix E)

30 mppcf or 10 mg/m³[k])
of total dust < 1% quartz, or, 5 mg/m³ respirable dust.

Conversion factors:
mppcf × 35.3 = Million particles per cubic meter
= particles per cc

h) Millions of particles per cubic foot of air, based on impinger samples counted by light-field technics.
i) The percentage of quartz in the formula is the amount determined from airborne samples, except in those instances in which other methods have been shown to be applicable.
j) Both concentration and percent quartz 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

k) containing <1% quartz; if quartz content > 1%, use formulae for quartz.
l) Lint-free dust as measured by the vertical-elutriator, cotton-dust sampler described in the Transactions of the National Conference on Cotton Dust, J. R. Lynch, pg. 33, May 2, 1970.
m) As determined by the membrane filter method at ~~400–450X~~ magnification (4 mm objective) phase contrast illumination.
n) Based on "high volume" sampling.
o) "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.

NOTICE OF INTENDED CHANGES (for 1978)

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. Documentation is available for each of these substances.

**See Notice of Intended Changes.

MAP 000120

Substance	TWA ppm[a]	TWA mg/m³[b]	STEL ppm[a]	STEL mg/m³[b]
÷ Acetylsalicylic acid (Aspirin)	—	5	—	—
÷ Acrylonitrile	A1c	A1c	—	—
Aluminum metal and oxide	—	10	—	20
Aluminum pyro powders	—	5	—	—
Aluminum welding fumes	—	5	—	—
Aluminum, soluble salts	—	2	—	—
Aluminum, alkyls (NOC)*	—	2	—	—
3-Amino 1, 2, 4-triazole	A2	A2	—	—
÷ Aniline and homologues — Skin	2	10	5	20
Antimony, soluble salts (as Sb)	—	2	—	—
Antimony trioxide production	—	—, A2	—	—
Arsenic (soluble), as As	—	0.2	—	—
Arsenic trioxide production	—	—, A1a	—	—
÷ Baytex	—	0.1	—	0.3
Benomyl	—	10	—	15
Bromacil	—	10	—	20
÷ o-sec Butylphenol — Skin	5	—	—	—
Cadmium oxide production	—	—, A2	—	—
÷ Carbon disulfide	10	30	—	—
÷ Chloroacetyl chloride	0.05	0.2	—	—
÷ Chloromethyl methyl ether	A1b	A1b	—	—
÷ β-Chloroprene — Skin	10	45	—	—
Cobalt metal, dust & fume (as Co)	—	0.05	—	0.1
÷C Cyanogen chloride	0.3	0.6	—	—
Cyclopentane	300	850	450	1,000
÷ Dalapon	1	—	—	—
÷ 1, 2-Dibromoethane — Skin	A1c	A1c	—	—
÷ Dichloromonofluoro-methane	10	40	—	—
÷ Dichloropropene	1	5	10	50
÷ Diethanolamine	3	15	—	—
÷ Divinyl benzene	10	50	—	—
÷ Epichlorhydrine — Skin	2	10	5	20

Capital letters refer to Appendices
÷1978 Revision or Addition
*Not otherwise classified (NOC).

Substance	TWA ppm[a]	TWA mg/m³[b]	STEL ppm[a]	STEL mg/m³[b]
Ethyl silicate	10	85	30	250
÷ Ethylene dibromide, see 1, 2-Dibromoethane	A1c	A1c	—	—
÷ Ethylene dichloride, see 1, 2-Dichloroethane	10	40	15	60
C Glutaraldehyde	0.2	0.8	—	—
Hexachlorobutadiene	A2	A2	—	—
÷C Hydrogen cyanide — Skin	10	10	—	—
÷ 2-Hydroxypropyl acrylate — Skin	0.5	3	—	—
÷ N-Isopropylaniline — Skin	2	10	5	20
Manganese fume (as Mn)	—	1	—	3
÷ Methylene chloride (dichloromethane)	100	360	500	1,700
÷ 4, 4-Methylene dianiline	0.1	0.8	0.5	4
÷C 2-Nitropropane	25, A2	90, A2	—	—
Phenyl-beta-naphthylamine	A2	A2	—	—
÷ Phosphorous pentachloride	0.1	1	—	—
÷ Propionic acid	10	30	15	45
÷ Silver, metal	—	0.1	—	—
÷ Sodium bisulfite	—	5	—	—
÷ Sodium metabisulfite	—	5	—	—
÷ Sulfur dioxide	2	5	5	15
÷C Terphenyls	0.5	5	—	—
÷ Tetrasodium pyrophosphate	—	5	—	—
÷ Toluene-2, 4-diisocyanate (TDI)	0.002	0.015	0.005	0.035
÷ Trichloroacetic acid	—	1	—	—
÷ Vinyl bromide	5, A2	20, A2	—	—
÷ Vinyl chloride	5, A1a	10, A1a	—	—
VM & P Naphtha	300	1,350	400	1,800

Capital letters refer to Appendices
÷1978 Addition

MAP 000121

NOTICE OF INTENDED CHANGES
MINERAL DUSTS

Substance	TLV
† Asbestos	
Amosite	0.5 fiber/cc, A1a
Chrysotile	2 fibers/cc, A1a
Crocidolite	0.2 fiber/cc, A1a
Tremolite	0.5 fiber/cc, A1a
Other forms	2 fibers/cc, A1a
Diatomaceous earth, natural	1.5 mg/m³, Respirable dust
Silica, amorphous	5 mg/m³, Total dust (all sampled sizes) 2 mg/m³, Respirable dust (< 5 μm)
† Talc (fibrous)	0.5 fiber/cc

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 three forms: Those for which a TLV has been assigned (1a), those for which environmental conditions have not been sufficiently defined to assign a TLV (1b), and (1c), those whose reassignment of a TLV is awaiting more definitive data, and hence should be treated as a 1b carcinogen.

A1a. *Human Carcinogens*. Substances, or substances associated with industrial processes, recognized to have carcinogenic or cocarcinogenic potential, with an assigned TLV:

	TLV
** Arsenic trioxide production	(As_2O_3, 0.05 mg/m³ as As) (SO_2, C 5.0 ppm)
	(Sb_2O_3, 0.5 mg/m³ (as Sb))
** Asbestos, all forms*	(5 fibers/cc, > 5 μm in length)
bis (Chloromethyl) ether	0.001 ppm
Chromite ore processing (chromate)	0.05 mg/m³ (as Cr)
Nickel sulfide roasting, fume & dust	1.0 mg/m³ (as Ni)
Particulate Polycyclic Aromatic Hydrocarbons (PPAH)	0.2 mg/m³, as benzene solubles
Vinyl Chloride	5 ppm

A1b. *Human Carcinogens*. Substances, or substances associated with industrial processes, recognized to have carcinogenic potential without an assigned TLV:

Chloromethyl methyl ether
4-Aminodiphenyl (p-Xenylamine)
Benzidine production
beta-Naphthylamine
4-Nitrodiphenyl

A1c. *Human Carcinogens*. Substances with recognized carcinogenic potential awaiting reassignment of TLV pending further data acquisition:

Acrylonitrile
1, 2-Dibromoethane (Ethylene dibromide)

For the substances in 1b or 1c, 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 hermitizing the process or operation by the best practicable engineering methods. The worker should be properly equipped to insure virtually no contact with the carcinogen.

**See Notice of Intended Changes
†1978 Addition.

*Cigarette smoking can enhance the incidence of respiratory cancers from this and others of these substances or processes.

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A2. *Industrial Substances Suspect of Carcinogenic Potential for MAN*. Chemical substances or substances associated with industrial processes, which are suspect of inducing cancer, based on either (1) limited epidemiologic evidence, exclusive of clinical reports of single cases, or (2) demonstration of carcinogenesis in one or more animal species by appropriate methods.

3-Amino 1, 2, 4-triazole	
** Antimony trioxide production*	(0.5 mg/m³)
Benzene	10 ppm
Benz(a)pyrene	——
Beryllium	2.0 μg/m³
** Cadmium oxide production	(0.05 mg/m³)
Chloroform	10 ppm
Chromates of lead and zinc (as Cr)	0.05 mg/m³
3, 3'-Dichlorobenzidine	——
Dimethylcarbamyl chloride	——
1, 1-Dimethyl hydrazine	0.5 ppm
Dimethyl sulfate — Skin	0.1 ppm
Epichlorhydrin	5 ppm
Hexachlorobutadiene	——
Hexamethyl phosphoramide — Skin	——
Hydrazine	0.1 ppm
Lead chromate	0.05 mg/m³
4, 4'-Methylene bis (2-chloroaniline) — Skin	0.02 ppm
Monomethyl hydrazine	0.2 ppm
C 2-Nitropropane	25 ppm
Nitrosamines	——
Phenyl-beta-naphthylamine	——
Propane sultone	——
beta-Propiolactone	——
Vinyl cyclohexene dioxide	10 ppm
Zinc chromate (as Cr)	0.05 mg/m³

For the above, worker exposure by all routes should be carefully controlled to levels consistent with the animal and human experience data (see Documentation), including those substances with a listed TLV.

*Cigarette smoking can enhance the incidence of respiratory cancers from this or others of these substances or processes

A3. *Guidelines for the Classification of Experimental ANIMAL Carcinogens*. The following guidelines are offered in the present state of knowledge as an aid in classifying substances in the occupational environment found to be carcinogenic in experimental animals. A need was felt by the Threshold Limits Committee for such a classification in order to take the first step in developing an appropriate TLV for occupational exposure.

Determination of Approximate Threshold of Response Requirement. In order to determine in which category to classify an experimental carcinogen for the purpose of assigning an industrial air limit (TLV), an approximate threshold of neoplastic response must be determined. Because of practical experimental difficulties, a precisely defined threshold cannot be attained. For the purposes of standard-setting, this is of little moment, as an appropriate risk, or safety, factor can be applied to the approximate threshold, the magnitude of which is dependent on the degree of potency of the carcinogenic response.

To obtain the best 'practical' threshold of neoplastic response, dosage decrements should be less than logarithmic. This becomes particularly important at levels greater than 10 ppm (or corresponding mg/m³). Accordingly, after a range-finding determination has been made by logarithmic decreases, two additional dosage levels are required within the levels of "effect" and "no effect" to approximate the true threshold of neoplastic response.

The second step should attempt to establish a metabolic relationship between animal and man for the particular substance found carcinogenic in animals. If the metabolic pathways are found comparable, the substance should be classed highly suspect as a carcinogen for man. If no such relation is found, the substance should remain listed as an experimental animal carcinogen until evidence to the contrary is found.

Proposed Classification of Experimental Animal Carcinogens. Substances occurring in the occupational environment found carcinogenic for animals

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may be grouped into three classes, those of high, intermediate and low potency. In evaluating the incidence of animal cancers, significant incidence of cancer is defined as a neoplastic response which represents, in the judgment of the Committee, a significant excess of cancers above that occurring in negative controls.

EXCEPTIONS: No substance is to be considered an occupational carcinogen of any practical significance which reacts by the respiratory route at or above 1000 mg/m³ for the mouse, 2000 mg/m³ for the rat; by the dermal route, at or above 1500 mg/kg for the mouse, 3000 mg/kg for the rat; by the gastrointestinal route at or above 500 mg/kg/d for a lifetime, equivalent to about 100 g T.D. for the rat, 10g T.D. for the mouse.

These dosage limitations exclude such substances as dioxane and trichlorethylene from consideration as carcinogens.

Examples: Dioxane — rats, hepatocellular and nasal tumors from 1015 mg/kg/d, oral

Trichloroethylene — female mice, tumors (30/98 @ 900 mg/kg/d), oral

A3a. *INDUSTRIAL SUBSTANCES OF HIGH CARCINOGENIC POTENCY IN EXPERIMENTAL ANIMALS*

1. A substance to qualify as a carcinogen of high potency must fulfill one of the three following conditions in two animal species:

   1a. *Respiratory*. Elicit cancer from (1) dosages below 1 mg/m³ (or equivalent ppm) via the respiratory tract in 6- 7-hour daily repeated inhalation exposures throughout lifetime; or (2) from a single intratracheally administered dose not exceeding 1 mg of particulate, or liquid, per 100 ml or less of animal minute respiratory volume;

   Examples: bis-Chloromethyl ether, malignant tumors, rats, @ 0.47 mg/m³ (0.1 ppm) in 2 years;

Hexamethyl phosphoramide, nasal squamous cell carcinoma, rats, @ 0.05 ppm, in 13 months

OR

1b. *Dermal*. Elicit cancer within 20 weeks by skin-painting, twice weekly at 2 mg/kg body weight or less per application for a total dose equal to or less than 1.5 mg, in a biologically inert vehicle;

Examples: 7, 12-Dimethylbenz(a)anthracene — skin tumors @ 0.12-0.8 mg T.D. in four weeks

Benz(a)pyrene, mice 12 μg, 3X/wk for 18 mos. T.D. 2.6 mg, 90.9% skin tumors

OR

1c. *Gastrointestinal*. Elicit cancer by daily intake via the gastrointestinal tract, within six months, with a six-month holding period, at a dosage below 1 mg/kg body weight per day; total dose, rat, ≤ 50 mg; mouse, ≤ 3.5 mg;

Examples: 7, 12-Dimethylbenz(a)anthracene — mammary tumors from 10 mg 1X

3-Methylcholanthrene — Tumors @ 3 sites from 8 mg in 89 weeks

Benz(a)pyrene, mice, 3.9% leukemias, from 30 mg T.D. 198 days

2. Elicit cancer by all three routes in at least two animal species at dose levels prescribed for high or intermediate potency.

A3b. *INDUSTRIAL SUBSTANCES OF INTERMEDIATE CARCINOGENIC POTENCY IN EXPERIMENTAL ANIMALS*

To qualify as a carcinogen of intermediate potency, a substance should elicit cancer in two animal spe-

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cies at dosages intermediate between those described in A3a and A3c by two routes of administration.

Example: Carbamic acid ethyl ester
Dermal, mammary tumors, mice, 100%, 63 weeks, 500–1400 mg T.D.
Gastrointestinal, various type tumors, mice 42 weeks, 320 mg T.D.

Gastrointestinal, various type tumors, rats, 60 weeks, 110–930 mg T.D.

A3c. *INDUSTRIAL SUBSTANCES OF LOW CARCINOGENIC POTENCY IN EXPERIMENTAL ANIMALS*

To qualify as a carcinogen of low potency, a substance should elicit cancer in one animal species by any *one* of three routes of administration at the following prescribed dosages and conditions:

1a. *Respiratory*. Elicit cancer from (1) dosages greater than 10 mg/m³ (or equivalent ppm) via the respiratory tract in 6- 7-hour, daily repeated inhalation exposures, for 12 months' exposure and 12 months' observation period; or (2) from intratracheally administered dosages totaling more than 10 mg of particulate or liquid per 100 ml or more of animal minute respiratory volume;

Examples: Beryl (beryllium aluminum silicate) malig. lung tumors, rats, @ 15 mg/m³ @ 17 months

Benzidine, var. tumors, rats, 10–20 mg/m³ @ > 13 mos.

OR

1b. *Dermal*. Elicit cancer by skin-painting of mice in twice weekly dosages of > 10 mg/kg body weight in a biologically inert vehicle for at least 75 weeks, i.e., ≥ 1.5g T.D.

Examples: Shale tar, mouse, 0.1 ml × 50 – g T.D. 59/60 skin tumors

Arsenic trioxide, man, dose unknown, but estimated to be high

1c. *Gastrointestinal*. Elicit cancer from daily oral

dosages of 50 mg/kg/day or greater during the lifetime of the animal.

APPENDIX B
SUBSTANCES OF VARIABLE COMPOSITION

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 minimal.

B2 *Gasoline*. The composition of gasoline 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); Runion, ibid. *36*, 338, 1975).

B3 *Welding Fumes — Total Particulate (NOC)***
TLV, 5 *mg/m³*

Welding fumes cannot be classified simply. The composition and quantity of both are dependent on the alloy being welded and the process and electrodes used. Reliable analysis of fumes cannot be made without considering the nature of the welding process and system being examined; reactive metals and alloys such as aluminum and titanium are arc-welded in a protective, inert atmosphere such as argon. These arcs create relatively little fume, but an intense radiation which can produce ozone. Similar processes are used to arc-weld steels, also creating a relatively low level of fumes. Ferrous alloys also are arc-welded in oxidizing environments which generate considerable fume, and can produce carbon monoxide instead of ozone. Such fumes generally are composed of discreet particles of amorphous slags con-

*Trade Names Algoflon, Fluon, Halon, Teflon, Tetran
**Not otherwise classified (NOC)

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taining iron, manganese, silicon and other metallic constituents depending on the alloy system involved. Chromium and nickel compounds are found in fumes when stainless steels are arc-welded. Some coated and flux-cored electrodes are formulated with fluorides and the fumes associated with them can contain significantly more fluorides than oxides. Because of the above factors, arc-welding fumes frequently must be tested for individual constituents which are likely to be present to determine whether specific TLV's are exceeded. Conclusions based on total fume concentration are generally adequate if no toxic elements are present in welding rod, metal, or metal coating and conditions are not conducive to the formation of toxic gases.

Most welding, even with primitive ventilation, does not produce exposures inside the welding helmet above 5 mg/m³. That which does, should be controlled.

APPENDIX C
MIXTURES

C.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,

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

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 a 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 a given operation or process characteristically emits a number of harmful dusts, 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.

C.1A Examples of THRESHOLD LIMIT VALUES FOR MIXTURES

The following formulae apply only when the components in a mixture have similar toxicologic effects; they should not be used for mixtures with widely differing reactivities, e.g. hydrogen cyanide & sulfur dioxide. In such case the formula for Independent Effects (1A.c.) should be used.

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.)*

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

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Example No. 1A.a.: Air contains 400 ppm of acetone (TLV = 1000 ppm) 150 ppm of secbutyl acetate (TLV = 200 ppm) and 100 ppm of 2-butanone (TLV = 200 ppm)

Atmospheric concentration of mixture = 400 + 150 + 100 = 650 ppm of mixture

$$\frac{400}{1000} + \frac{150}{200} + \frac{100}{200} = 0.4 + 0.75 + 0.5 = 1.65$$

Threshold Limit is exceeded.

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 contains (by weight)

50% heptane: TLV = 400 ppm or 1600 mg/m³
1 mg/m³ ≡ 0.25 ppm

30% methyl chloroform: TLV = 350 ppm or 1900 mg/m³
1 mg/m³ ≡ 0.28 ppm

20% perchloroethylene: TLV = 100 ppm or 670 mg/m³
1 mg/m³ ≡ 0.15 ppm

$$\text{TLV of Mixture} = \frac{1}{\frac{0.5}{1600} + \frac{0.3}{1900} + \frac{0.2}{670}}$$

$$= \frac{1}{0.00031 + 0.00016 + 0.00030}$$

$$= \frac{1}{0.00077} = 1300 \text{ mg/m}^3$$

of this mixture
50% or (1300) (0.5) = 650 mg/m³ is heptane
30% or (1300) (0.3) = 390 mg/m³ is methyl chloroform
20% or (1300) (0.2) = 260 mg/m³ is perchloroethylene

These values can be converted to ppm as follows:

heptane: 650 mg/m³ × 0.25 = 162 ppm
methyl chloroform: 390 mg/m³ × 0.18 = 70 ppm
perchloroethylene: 260 mg/m³ × 0.15 = 39 ppm

TLV of mixture = 162 + 70 + 39 = 271 ppm, or 1300 mg/m³

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).

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

Threshold limit is not exceeded.

1B. TLV for Mixtures of Mineral Dusts.

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

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

$$\text{TLV} = \frac{1}{\frac{0.8}{20} + \frac{0.2}{2.7}} = 9 \text{ mppcf}$$

TLV of nonasbestiform talc (pure) = 20 mppcf

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TLV of quartz (pure) =

$$\frac{300}{100 + 10} = \frac{300}{110} = 2.7 \text{ mppcf}$$

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:

25% quartz — TLV (pure) = 2.7 mppcf
25% amorphous silica — TLV (pure) = mppcf
50% talc TLV (pure) = 20 mppcf

$$TLV = \frac{1}{\frac{0.25}{2.7} + \frac{0.25}{20} + \frac{0.5}{20}} = 8 \text{ mppcf}$$

The limit for 25% quartz approximates 9 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
Nitrobenzene	1	3	2
Carbon tetrachloride	10	2	20
Trimethyl benzene	25	1.5	35
Acetone	1000	1.25	1250
Boron trifluoride	C 1	—	1
Butylamine	C 5	—	5

EXCURSION FACTORS

For all substances not bearing C notation

		Excursion Factor	
TLV > 0–1	(ppm or mg/m³),		= 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.

INTERPRETATION OF MEASURED PEAK CONCENTRATIONS

With increasing use of rapid, direct-reading analytical instruments for airborne contaminants in the work area, the question of interpretation of essentially "instantaneous" peaks arises. Although no general statement can be made covering all occupational substances, the following guidelines should prove helpful, assuming peak excursions conform to time-weighted average TLV as stated above.

The toxicologic importance of momentary peak concentrations depends on whether the substance is fast or slow acting. If slow acting, as for quartz, lead, or carbon monoxide, momentary peaks are of no toxicologic concern provided, of course, they are not astronomic. On the other hand, fast-acting substances that rapidly produce disabling narcosis, e.g., H_2S, or intolerable irritation or asphyxiation, NH_3, SO_2, CO_2, or initiate sensitization — the organic isocyanates, even "instantaneous" peaks appreciably above the permissible excursion, should not be permitted, unless information exists to the

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contrary. Other more specific excursions will be developed in the future.

APPENDIX E
Some Nuisance Particulates[p]

TLV. 30 mppcf or 10mg/m³ of total dust < 1% quartz, or, 5 mg/m³ respirable dust

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

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

APPENDIX F
Some Simple Asphyxiants[q]

Acetylene	Hydrogen
Argon	Methane
Butane	Neon
Ethane	Propane
Ethylene	Propylene
Helium	

q) As defined on pg. 6.

APPENDIX G

Calculations for Conversion of Particle Count Concentration (by Standard Light Field — Midget Impinger Techniques), in mppcf, to Respirable Mass Concentration (by Respirable Sampler) in mg/m³.†

†"Relationship Between Gravimetric Respirable Dust Concentration and Midget Impinger Number Concentration," by Murray Jacobson and T. F. Tomb AIHAJ, 28 Nov-Dec 1967.

1. In 1967, Jacobsen and Tomb.† derived an empirical relationship of 5.6 mppcf to 1 milligram of respirable dust per cubic meter of air, based on 23 sets of samples, mostly coal dust. The following calculation results in an equivalence of 6.37 mppcf to 1 mg/m³ of respirable dust. Thus, an approximate ratio of 6 mppcf to 1 mg/m³ of respirable dust is suggested for conversion of TLVs from a count to a mass basis when the density and mass median diameter have not been determined.

2. Basic assumptions:
   a) Average density for silica containing dusts ≈ 2.5 gms/cm³ (2500 mg/cm³). Pulmonary significant dust densities may vary from 1.2 gm/cm³ for coal dust to 3.1 gms/cm³ for Portland Cement. Silica densities vary from 2.2 (amorphous) to 2.3 (cristobalite and tridymite) to 2.5 (alpha-quartz.) gms per cm³.
   b) The mass median diameter (mmd) of particles collected in midget impinger samplers and counted by the standard light field technique, *and* collected in a respirable sampler is approximately 1.5 μm or 1.5×10^{-4} cm. This assumption is, of course, quite arbitrary since the mmd of all dust clouds is quite variable, depending on many independent parameters, such as source of dust, age of dust cloud, meteorological conditions, etc.

3. Calculation:
   a) vol. per particle: $4/3\ \pi\ r^3$; $r = 0.75 \times 10^{-4}$ cm
      $= 4/3 \cdot \pi \cdot (0.75 \times 10^{-4})^3$
      $= 1.77 \times 10^{-12}$ cm³
   b) wt. per particle = vol. × density
      $= 1.77 \times 10^{-12}$ cm³ $\times\ 2.5 \times 10^{3}$ mg/cm³
      $= 4.425 \times 10^{-9}$ mg/particle
   c) 1 particle/ft.³ = 35.5 part./m³
      (since 35.5 cu ft = 1 cu m.)
      10^6 part./ft³ = mppcf = 35.5×10^6 part./m³

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wt. of 1 mppcf = 35.5×10^6 part./m^3 × 4.425×10^{-9} mg/part.

1 mppcf = 0.157 mg/m^3

or

6.37 mppcf = 1 mg/m^3

or approximately 6 mpccf = 1 mg/m^3.

4. Equivalent TLVs in mppcf and mg/m^3 (respirable mass) for Mineral Dusts.

Substance	Threshold Limit Value		
	Count mppcf	Resp. Mass mg/m^3	Total Mass* mg/m^3
Silica (SiO_2)			
Amorphous	20	(3)**	(6)
Cristobalite	1.5	0.05	0.15
Fused silica	3	0.1	0.3
Quartz	3	0.1	0.3
Tridymite	1.5	0.05	0.15
Coal Dust	(12)	2	(4)
Diatomaceous earth, natural	—	1.5	—
Graphite (natural)	15	(2.5)	(5)
Mica	20	(3)	(6)
Mineral wool fiber	—	(5)	10
Nuisance particulates	30	(5)	10
Perlite	30	(5)	(10)
Portland Cement	30	(5)	(10)
Soapstone	20	(3)	(6)
Talc (nonasbestiform)	20	(3)	(6)
Tripoli	(3)	0.1	(0.3)

*Unless otherwise specified, respirable mass is presumed to equal approximately 50% of total mass.

**All values in parentheses ( ) represent newly calculated values based on equivalence of 6 mppcf = 1 mg/m^3 respirable mass and respirable mass = 50% total mass.

TLVs®
Threshold Limit Values for Physical Agents Adopted by ACGIH for 1978

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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.

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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 1 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*; F. N. Dukes-Dobos and A. Henschel: "*Development of Permissible Heat Exposure Limits for Occupational Work*," ASHRAE Journal, Vol. 15: No. 9, September 1973, pp. 57–62.)

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 + 0.1 DB
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 1

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

	Work Load		
Work — Rest Regimen	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 1 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.

EVALUATION AND CONTROL

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 −5°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

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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. A 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.

C. A 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 as that of 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 1964.

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

II. *Work Load Categories*

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 (up to 200 Kcal/hr or 800 Btu/hr): e.g., sitting or standing to control machines, performing light hand or arm work,

(2) moderate work (200–350 Kcal/hr or 800–1400 Btu/hr): e.g., walking about with moderate lifting and pushing,

(3) heavy work (350–500 Kcal/hr or 1400–2000 Btu/hr): 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. When this method is used the permissible heat exposure limit can be determined by Figure 1.

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

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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 1 and Figure 1 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. Where the WBGT of the work area is different from that of the rest area a time-weighted average value should be used for both environmental and metabolic heat. When time-weighted average values are used the appropriate curve on Figure 1 is the solid line labeled "continuous."

The time-weighted average metabolic rate (M) shall be determined by the equation:

$$\text{Av. } M = \frac{(M_1) \times (t_1) + (M_2) \times (t_2) + \ldots + (M_n) \times (t_n)}{(t_1) + (t_2) + \ldots + (t_n)}$$

Where M_1 M_2, M_n are estimated or measured metabolic rates for the various activities of the worker during the total time period. t_1, t_2, t_n are the elapsed times in minutes spent at the corresponding metabolic rate as determined by a time study.

The time-weighted average WBGT shall be determined by the equation:

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$$\text{Av. WBGT} = \frac{(WBGT_1) \times (t_1) + (WBGT_2) \times t_2 + \ldots + (WBGT_n) \times (t_n)}{(t_1) + (t_2) + \ldots + (t_n)}$$

where $WBGT_1$, $WBGT_2$, $WBGT_n$ are calculated values of WBGT for the various work and rest areas occupied during total time periods. t_1, t_2, t_n are the elapsed times in minutes spent in the corresponding areas which are determined by a time study. Where exposure to hot environmental conditions is continuous for several hours or the entire work day, the time-weighted averages shall be calculated as hourly time-weighted average i.e., $t_1 + t_2 + \ldots t_n = 60$ minutes. Where the exposure is intermittent, the time-weighted averages shall be calculated as two-hour time-weighted averages, i.e., $t_1 + t_2 + \ldots t_n = 120$ minutes.

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 shall be kept reasonably cool (10°–15°C or 50.0°–60.0°F) 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 cothing 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 1 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.

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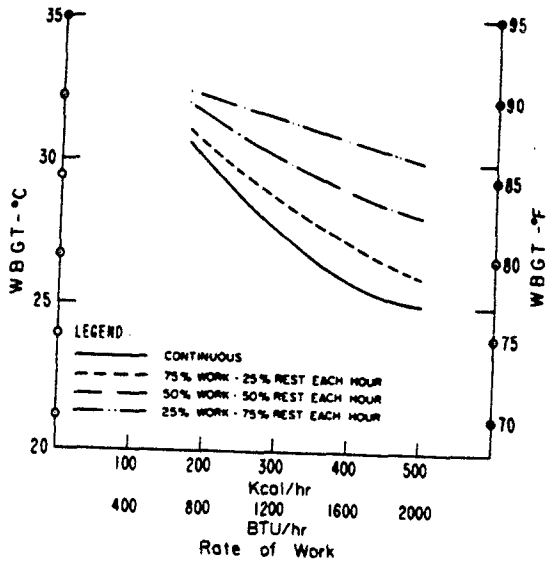


Figure 1 — Permissible Heat Exposure Threshold Limit Value

IONIZING RADIATION

The recommendations of the National Council on Radiation Protection and Measurements (NCRP) are suggested as threshold limit values to which nearly all workers may be exposed without adverse effects. The limits should be used as guides for the control of exposure and should not be regarded as fine lines between safe and dangerous levels. The underlying philosophy of radiation protection is to keep all exposures as low as reasonably achievable.

The two basic reference documents are as follows:

a. "Basic Radiation Protection Criteria," NCRP Report No. 39, issued January 15, 1971.

b. "Maximum Permissible Body Burdens and Maximum Permissible Concentrations of Radionuclides in Air and in Water for Occupational Exposure," US Department of Commerce, National Bureau of Standards Handbook 69, issued June 5, 1959, with Addendum 1 issued August 1963. Available as NCRP Report No. 22.

The above documents, as well as information on numerous other NCRP Reports addressing specific subjects in ionizing radiation protection are available from: NCRP Publications, 7910 Woodmont Ave., Washington, DC 20014.

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); and except for all TLVs for wavelengths between 0.1–1 mm where the limiting aperture is 10 mm. No modification of the TLVs is permitted for pupil sizes less than 7 mm.

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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 Factors A and B (C_A and C_B)

The TLVs for ocular exposure in Tables 3 and 4 are to be used as given for all wavelength ranges. The TLVs for wavelengths between 700 nm and 1049 nm are to be increased by a uniformly extrapolated factor (C_A) as shown in Figure 2. Between 1049 nm and 1400 nm, the TLV has been increased by a factor (C_A) of five. For certain exposure times at wavelengths between 550 nm and 700 nm, correction factor (C_B) must be applied.

The TLVs for skin exposure are given in Table 6. The TLVs are to be increased by a factor (C_A) as shown in Figure 2 for wavelengths between 700 nm and 1400 nm. To aid in the determination of TLVs for exposure durations requiring calculations of fractional powers Figures 3, 4, 5 and 6 may be used.

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^{-5} second. For pulses of greater duration, the following formula should be followed:

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

where:

n = number of pulses in train

τ = duration of a single pulse in the train

Standard ($n\tau$) = protection standard of one pulse having a duration equal to $n\tau$ seconds.

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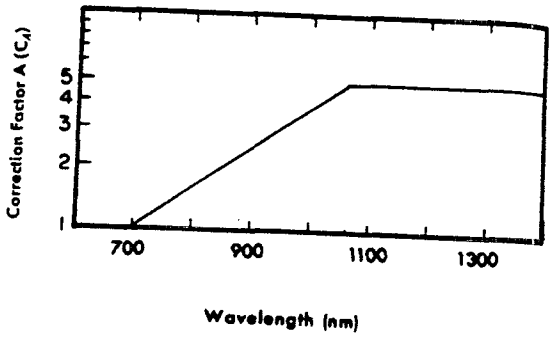


Figure 2 — TLV correction factor for $\lambda = 700 - 1400$ nm*

*For $\lambda = 700 - 1049$ nm, $C_A = 10^{[0.002(\lambda - 700)]}$
For $\lambda = 1050 - 1400$ nm, $C_A = 5$

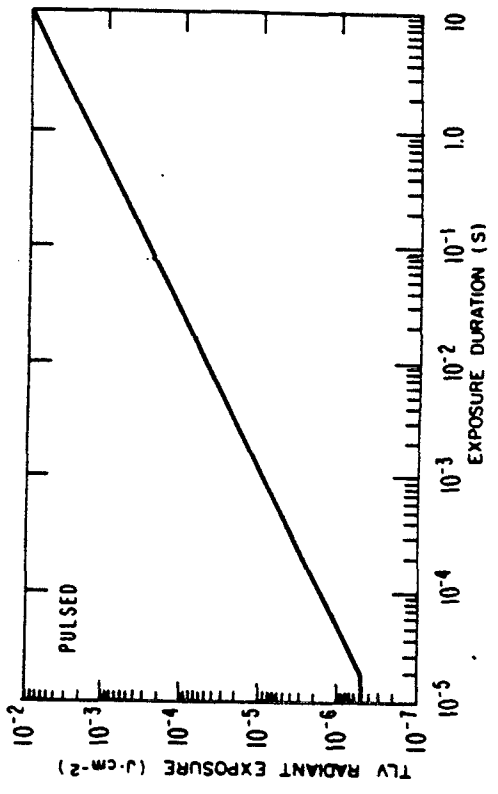


Figure 3a — TLV for intrabeam (direct) viewing of laser beam (400–700 nm).

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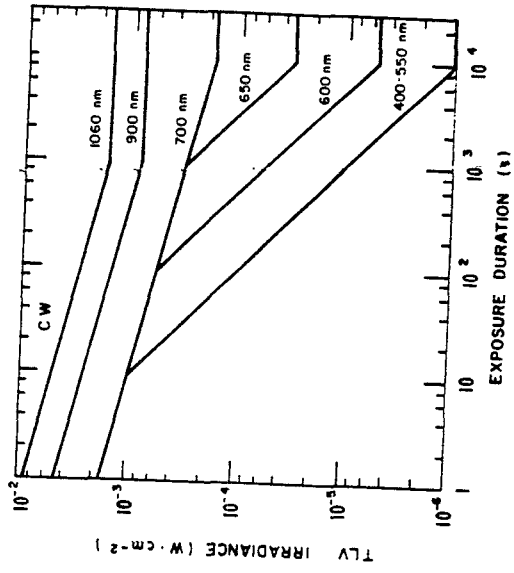


Figure 3b

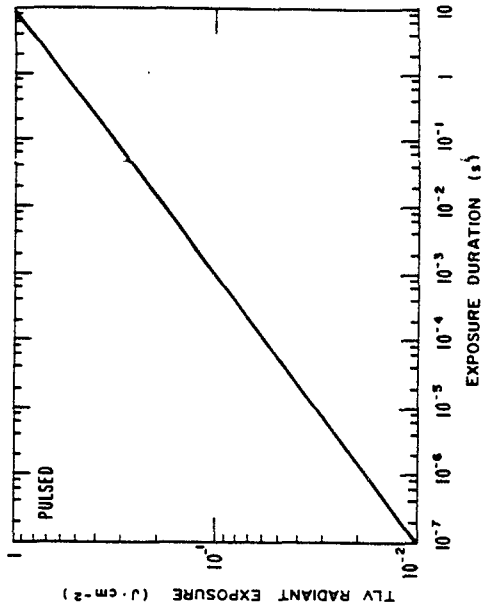


Figure 4a

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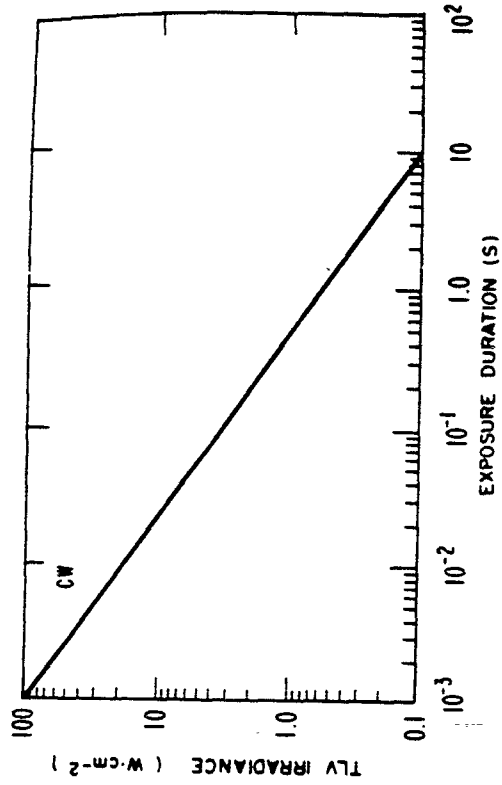


Figure 4b — TLV for CW laser exposure of skin and eyes for far-infrared radiation (wavelengths greater than 1.4 μm).

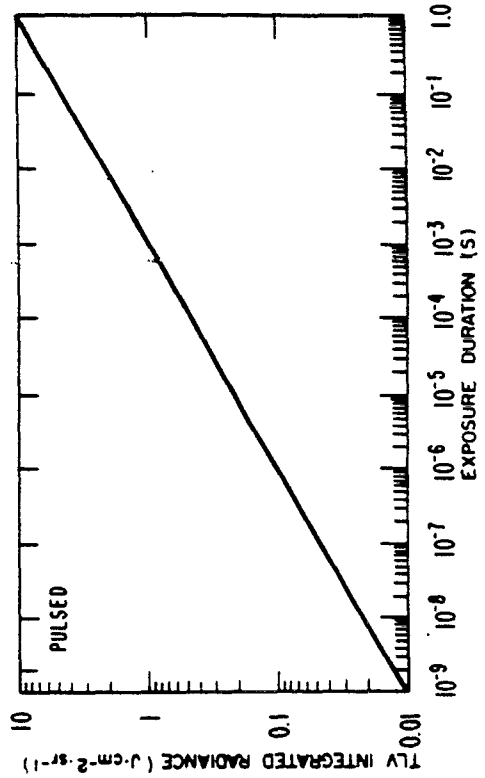


Figure 5a — TLV for extended sources or diffuse reflections of laser radiation (400–700 nm).

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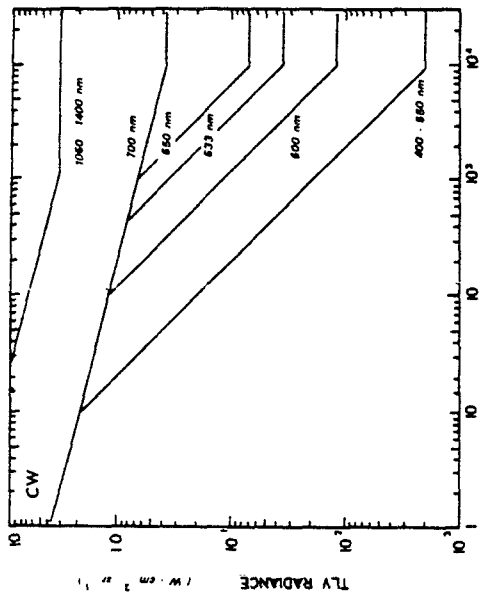


Figure 5b — TLV for intrabeam (direct) viewing of CW laser beam (400–1400 nm).

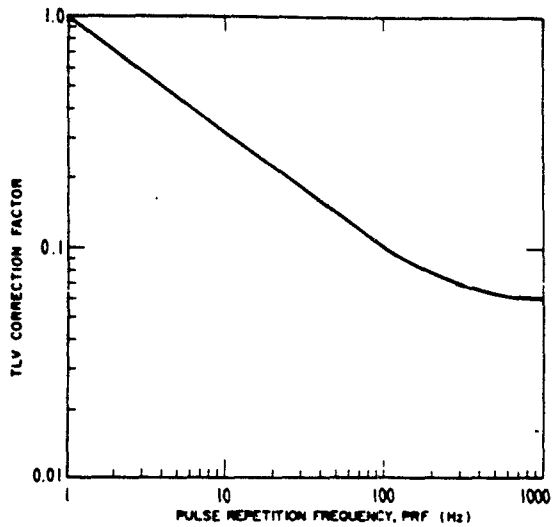


Figure 6 — Multiplicative correction factor for repetitively pulsed lasers having pulse durations less than 10^{-3} second. TLV for a single pulse of the pulse train is multiplied by the above correction factor. Correction factor for PRF greater than 1000 Hz is 0.06.

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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^{-3} 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 "

TABLE 3 (Cont.)

UVA	315 nm to 400 nm	10^{-9} to 10	$.56\ t^{1/4}$ J • cm^{-2}
	"	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^{-7} J • cm^{-2}
	400 nm to 700 nm	1.8×10^{-5} to 10	$1.8\ (t/\sqrt{t})$ mJ • cm^{-2}
	400 nm to 549 nm	10 to 10^{4}	10 mJ • cm^{-2}
	550 nm to 700 nm	10 to T_1	$1.8\ (t/\sqrt{t})$ mJ • cm^{-2}
	550 nm to 700 nm	T_1 to 10^{4}	10 C_B mJ • cm^{-2}
	400 nm to 700 nm	10^{4} to 3×10^{4}	C_B μW • cm^{2}
IR-A	700 nm to 1049 nm	10^{-9} to 1.8×10^{-5}	$5\ C_A \times 10^{-7}$ J • cm^{-2}
	700 nm to 1049 nm	1.8×10^{-5} to 10^{3}	$1.8\ C_A\ (t/\sqrt{t})$ mJ • cm^{-2}
	1050 nm to 1400 nm	10^{-9} to 10^{-4}	5×10^{-6} J • cm^{-2}
	1050 nm to 1400 nm	10^{-4} to 10^{3}	$9(t/\sqrt{t})$ mJ • cm^{-2}
	700 nm to 1400 nm	10^{3} to 3×10^{4}	320 C_A μW • cm^{-2}
IR-B & C	1.4 μm to 10^{3} μm	10^{-9} to 10^{-7}	10^{-2} J • cm^{2}
	"	10^{-7} to 10	$0.56\sqrt{t}$ J • cm^{-2}
	"	10 to 3×10^{4}	0.1 W • cm^{2}

C_A See Fig 2

C_B = 1 for λ = 400 to 549 nm; $C_B = 10^{(0.015\ (\lambda\ -\ 550))}$ for λ = 550 to 700 nm.

T_1 = 10 s for λ = 400 to 549 nm; $T_1 = 10 \times 10^{(0.02\ (\lambda\ -\ 550))}$ for λ = 550 to 700 n

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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^{-3} to 3×10^{4}	Same as Table 3
Light	400 nm to 700 nm	10^{-9} to 10	$10\sqrt[4]{t}$ J • cm^{-2} • sr^{-1}
	400 nm to 549 nm	10 to 10^{4}	21 J • cm^{-2} • sr^{-1}
	550 nm to 700 nm	10 to T_1	$3.83\,(t/\sqrt[4]{t})$ J • cm^{-2} • sr^{-1}
	550 nm to 700 nm	T_1 to 10^{4}	21 C_B J • cm^{-2} • sr^{-1}
	400 nm to 700 nm	10^{1} to 3×10^{4}	$2.1\,C_B t \times 10^{-3}$ W • cm^{-2} • sr^{-1}
IR-A	700 nm to 1400 nm	10^{-9} to 10	$10\,C_4\sqrt[4]{t}$ J • cm^{-2} • sr^{-1}
	700 nm to 1400 nm	10 to 10^{3}	$3.83\,C_4\,(t/\sqrt[4]{t})$ J • cm^{-2} • sr^{-1}
	700 nm to 1400 nm	10^{3} to 3×10^{4}	0.64 C_4 W • cm^{-2} • sr^{-1}
IR-B & C	1.4 μm to 1 mm	10^{-9} to 3×10^{4}	Same as Table 3

C_1, C_B, and T_1 are the same as in footnote to Table 3.

TABLE 5

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

Exposure Duration(s)	Angle α (mrad)
10^{-9}	8.0
10^{-8}	5.4
10^{-7}	3.7
10^{-6}	2.5
10^{-5}	1.7
10^{-4}	2.2
10^{-3}	3.6
10^{-2}	5.7
10^{-1}	9.2
1.0	15
10	24
10^{2}	24
10^{3}	24
10^{4}	24

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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^{-3} to 3×10^{4}	Same as Table 3
Light & IR-A	400 nm to 1400 nm	10^{-9} to 10^{-7}	$2\ C_A \times 10^{-2}$ J • cm^{-2}
	"	10^{-7} to 10	$1.1\ C_A \sqrt{t}$ J • cm^{-2}
IR-B & C	1.4 μm to 1 mm	10^{-9} to 3×10^{4}	Same as Table 3

C_A = 1.0 for λ = 400–700 nm; see Figure 2 for λ = 700 to 1400 nm.

MICROWAVES

These Threshold Limit Values refer to microwave energy in the frequency range of 300 MHz to 300 GHz and represent conditions under which it is believed that nearly all workers may be repeatedly exposed without adverse effect.

Under conditions of moderate to severe heat stress, the recommended values may need to be reduced.* Therefore, these values should be used as guides in the control of exposure to microwave energy and should not be regarded as a fine line between safe and dangerous levels.

Recommended Values:

The Threshold Limit Value for occupational exposure to microwave energy, where power density or field intensity is known and exposure time is controlled, is as follows:

1. For exposure to continuous wave (CW) sources, the power density level shall not exceed 10 milliwatts per square centimeter (mW/cm²) for continuous exposure, and the total exposure time shall be limited to an 8-hour workday. This power density is approximately equivalent to a free-space electric field strength of 200 volts-per-meter rms (V/m) and a free-space magnetic field strength of 0.5 ampere-per-meter rms (A/m).
2. Exposures to CW power density levels greater than 10 mW/cm² are permissible up to a maximum of 25 mW/cm² based upon an average energy density of 1 milliwatt-hour per square centimeter (mWh/cm²) averaged over any 0.1 hour period. For example, at 25 mW/cm², the permissible exposure duration is approximately 2.4 minutes in any 0.1 hour period.
3. For repetitively pulsed microwave sources, the average field strength or power density is calculated by multiplying the peak-pulse value by the duty cycle. The duty cycle is equal to the pulse duration in seconds times the pulse repetition rate in Hertz. Exposure during an 8-hour workday shall not exceed the

*Mumford, W.W., "Heat Stress Due to R. F. Radiation," Proceedings of IEEE, Vol. 57, No. 2, Feb. 1969, pp. 171–178.

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following values which are averaged over any 0.1 hour period:

Power Density	10 mW/cm^2
Energy Density	1 mWh/cm^2
Mean Squared Electric Field Strength	40,000 V^2/m^2
Mean Squared Magnetic Field Strength	0.25 A^2/m^2

4. Exposure is not permissible in CW or repetitively pulsed fields with an average power density in excess of 25 mW/cm^2 or approximate equivalent free-space field strengths of 300 V/m or 0.75 A/m.

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.

It should be recognized that the application of the TLV for noise will not protect all workers from the adverse effects of noise exposure. A hearing conservation program with audiometric testing is necessary when workers are exposed to noise at or above the TLV 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 National 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 7.

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:

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

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 on-the-job noise exposures of 80 dBA or greater shall be used in the above calculations.

Table 7
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.

IMPULSIVE OR IMPACT NOISE

It is recommended that exposure to impulsive or impact noise shall not exceed the limits listed in Table 8 or taken from Figure 7. No exposures in excess of 140 decibels peak sound pressure level are permitted. Impulsive or impact noise is considered to be those variations in noise levels that involve maxima at intervals of greater

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than one per second. Where the intervals are less than one second, it should be considered continuous.

Table 8
Threshold Limit Values
Impulsive or Impact Noise

Sound Level dB**	Permitted Number of Impulses or Impacts per day
140	100
130	1000
120	10,000

**Decibels peak sound pressure level.

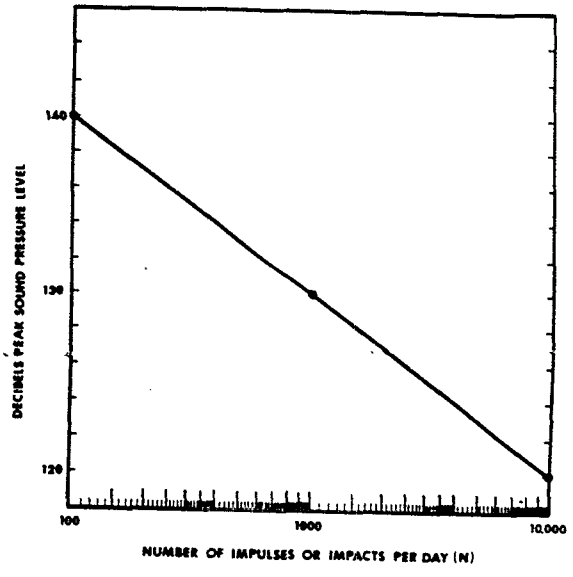


Figure 7 — Threshold Limit Values for Impulse/Impact Noise.

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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, and solar radiation, but do not apply to ultraviolet lasers.* These values do not apply to ultraviolet radiation exposure of photosensitive individuals or of individuals concomitantly exposed to photosensitizing agents (Fitzpatrick, et al., eds., Sunlight and Man, Univ. Tokyo Press, Tokyo, Japan, 1974). 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 nm) 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 9 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 following weighting formula should be used:

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

where:

E_{eff} = effective irradiance relative to a monochromatic source at 270 nm in W/cm² (J/s/cm²)

E_λ = spectral irradiance in W/cm²/nm

S_λ = relative spectral effectiveness (unitless)

$\Delta\lambda$ = 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 10 which provides exposure times corresponding to effective irradiances in μW/cm².

TABLE 9

Relative Spectral Effectiveness by Wavelength

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
254	6.0	0.5
260	4.6	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 Laser TLVs.

**1 m J/cm² = 10^{-3} J/cm²

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TABLE 10

Permissible Ultraviolet Exposures

Duration of Exposure Per Day	Effective Irradiance, E_{eff} (μW/cm^2)***
8 hrs.	0.1
4 hrs.	0.2
2 hrs.	0.4
1 hr.	0.8
30 min.	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°.

***1μW/cm^2 = 10^{-6} W/cm^2

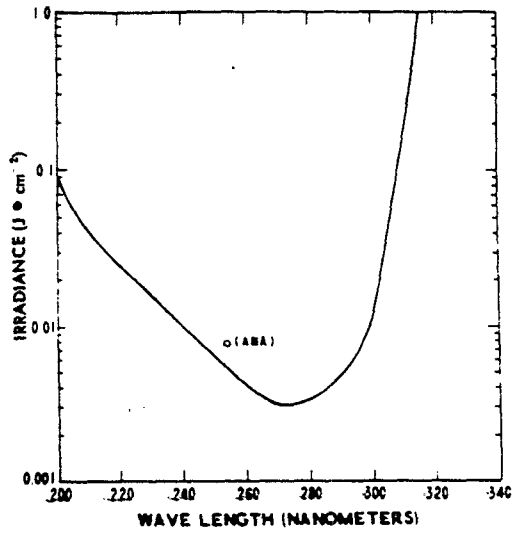


Figure 8 — Threshold Limit Values for Ultraviolet Radiation

Conditioned (tanned) individuals can tolerate skin exposure in excess of the TLV without erythemal effects. However, such conditioning may not protect persons against skin cancer.

NOTICE OF INTENDED CHANGES (for 1978)

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.

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NOTICE OF INTENT TO ESTABLISH THRESHOLD LIMIT VALUES

LIGHT AND NEAR-INFRARED RADIATION

These Threshold Limit Values refer to visible and near-infrared radiation in the wavelength range of 400 nm to 1400 nm and represent conditions under which it is believed that nearly all workers may be exposed without adverse effect. These values should be used as guides in the control of exposure to light and should not be regarded as a fine line between safe and dangerous levels.

Recommended Values:

The Threshold Limit Value for occupational exposure to broad-band light and near-infrared radiation for the eye apply to exposure in any eight-hour workday and require knowledge of the spectral radiance (L_λ) and total irradiance (E) of the source as measured at the position(s) of the eye of the worker. Such detailed spectral data of a white light source is generally only required if the luminance of the source exceeds 1 cd cm^{-2}. At luminances less than this value the TLV would not be exceeded.

The TLV's are:

1. To protect against retinal thermal injury, the spectral radiance of the lamp weighted against the function R (Table 11) should not exceed:

$$\sum_{400}^{1400} L_\lambda R_\lambda \Delta\lambda \leq 1/\alpha\, t^{1/2} \qquad (1)^*$$

where L_λ is in W cm^{-2} sr^{-1} and t is the viewing duration (or pulse duration if the lamp is pulsed) limited to 1 μs to 10 s, and α is the angular subtense of the source in radians. If the lamp is oblong, α refers to the longest dimension that can be viewed. For instance, at a viewing distance r = 100 cm from a tubular lamp of length l = 50 cm, the viewing angle is:

$$\alpha = l/r = 50/100 = 0.5 \text{ rad} \qquad (2)$$

2. To protect against retinal photochemical injury from chronic blue-light exposure the integrated spectral radiance of the lamp weighted against the blue-light hazard function B_λ (Table 11) should not exceed:

$$\sum_{400}^{1400} L_\lambda\, t\, B_\lambda \Delta\lambda \leq 100 \text{ Jcm}^{-2} \text{ sr}^{-1} \quad (t \leq 10^4 \text{s}) \qquad (3a)$$

$$\sum_{400}^{1400} L_\lambda B_\lambda \Delta\lambda \leq 10^{-2} \text{ Wcm}^{-2} \text{ sr}^{-1} \quad (t > 10^4 \text{s}) \qquad (3b)$$

For a source radiance L which exceeds 2 mW cm^{-2} sr^{-1} in the blue spectral region, the permissible exposure duration t_{max} in seconds is simply:

$$t_{max} = 100 \text{ J cm}^{-2} \text{ sr}^{-1}/\text{L (blue)} \qquad (4)$$

The latter limits are greater than the maximum permissible exposure limits for 440 nm laser radiation (see Laser TLV) because a 2–3 mm pupil is assumed rather than a 7 mm pupil for the Laser TLV.

3. *Infrared Radiation:* To avoid possible delayed effects upon the lens of the eye (cataractogenesis), the infrared radiation ($\lambda > 770$ nm) should be limited to 10 $mWcm^{-2}$. For an infrared heat lamp or any near-infrared source where a strong visual stimulus is absent, the near infrared (770–1400 nm) radiance as viewed by the eye should be limited to:

$$\sum_{770}^{1400} L_\lambda \Delta\lambda = 0.6/\alpha \qquad (5)^*$$

for extended duration viewing conditions. This limit is based upon a 7 mm pupil diameter.

*Formulae (1) and (2) are empirical and are not, strictly speaking, dimensionally correct. To make the formulae dimensionally correct, one would have to insert a dimensional correction factor k in the right hand numerator in each formula. For formula (1) this would be k_t = 1 W • rad • $s^{1/2}/(cm^2 \bullet sr)$, and for formula (5) k_α = 1 W • $rad/(cm^2 \bullet sr)$.

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TABLE 11

SPECTRAL WEIGHTING FUNCTIONS FOR ASSESSING RETINAL HAZARDS FROM BROAD — BAND OPTICAL SOURCES

Wavelength (nm)	Blue-Light Hazard Function B_λ	Burn Hazard Function R_λ
400	0.10	1.0
405	0.20	2.0
410	0.40	4.0
415	0.80	8.0
420	0.90	9.0
425	0.95	9.5
430	0.98	9.8
435	1.0	10
440	1.0	10
445	0.97	9.7
450	0.94	9.4
455	0.90	9.0
460	0.80	8.0
465	0.70	7.0
470	0.62	6.2
475	0.55	5.5
480	0.45	4.5
485	0.40	4.0
490	0.22	2.2
495	0.16	1.6
500–600	$10^{[(450-\lambda)/50]}$	1.0
600–700	0.001	1.0
700–1049	0.001	$10^{[(700-\lambda)/505]}$
1050–1400	0.001	0.2

AIRBORNE UPPER SONIC AND ULTRASONIC ACOUSTIC RADIATION

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. The values listed in Table 15 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. The levels for the third octave bands centered below 20 kHz are below those which cause subjective effects. Those levels for 1/3 octaves above 20 kHz are for prevention of possible hearing losses from subharmonics of these frequencies.

TABLE 12

Permissible Ultrasound Exposure Levels

Mid-Frequency of Third-Octave Band kHz	One-Third Octave — Band Level in dB reference 0.0002 dynes/cm²
10	80
12.5	80
16	80
20	105
25	110
31.5	115
40	115
50	115

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PHYSICAL AGENTS UNDER STUDY

These agents comprise those which the Physical Agents Committee of ACGIH proposes to study during this year to determine the feasibility of establishing proposed TLVs in 1979. Comments and suggestions, accompanied by substantitive evidence, are solicited.

1. *Radiofrequency Radiation*. Specifically, that portion of the spectrum from 10 MHz to 100 MHz.
2. *Extremely Low Frequency (ELF) Radiation*. Specifically, that portion of the spectrum from 0 to 300 Hz.
3. *Magnetic Fields*. Both pulsed and continuous.
4. *Laser Radiation*. Specifically ultraviolet radiation for pulsed exposures, and repetitively pulsed light and infrared-A laser exposures.
5. *Ultrasonic Energy*. Specifically, acoustic energy at frequencies above 10 kHz.
6. *Vibration*. Segmental and whole-body.
7. *Cold Stress*.
8. *Pressure Variations*.

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It is an organization devoted to the development of administrative and technical aspects of worker health protection. The association has contributed substantially to the development and improvement of official industrial health services to industry and labor. The committees on Industrial Ventilation and Threshold Limit Values are recognized throughout the world for their expertise and contributions to industrial hygiene.

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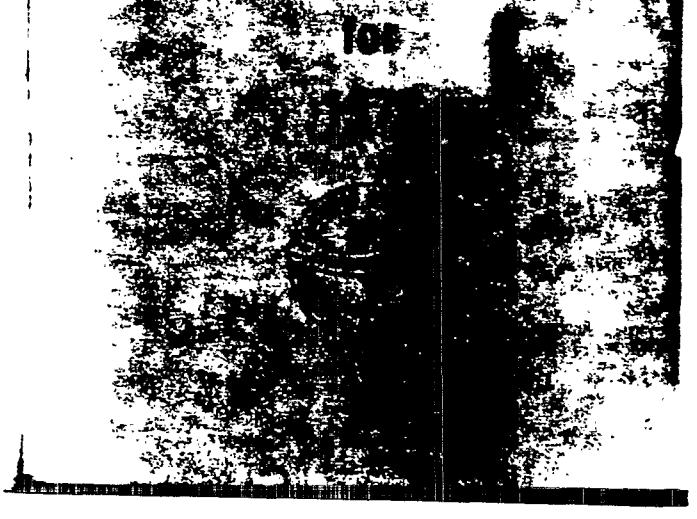
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TLVs®
Threshold Limit Values for Chemical Substances and Physical Agents in the Workroom Environment with Intended Changes for



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Documentation of the Threshold Limit Values for Substances in Workroom Air.© A separate companion piece to the Chemical TLVs is issued by ACGIH under this title. This publication gives the pertinent scientific information and data with reference to literature sources that were used to base each limit. Each documentation also contains a statement defining the type of response against which the limit is safeguarding the worker. For a better understanding of the TLVs it is essential that the Documentation be consulted when the TLVs are being used.

Information concerning the availability of copies of the Documentation of the Threshold Limit Values for Substances in Workroom Air should be directed to the Publications Office, ACGIH (third edition, fourth printing, 1978, $20.00).

TLVs®
Threshold Limit Values for Chemical Substances in Workroom Air Adopted by ACGIH for 1979



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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.

Tests are available (J. Occup. Med. 15: 564, 1973; 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).

Three categories of Threshold Limit Values (TLVs) are specified herein, as follows:

a) Threshold Limit Value-Time Weighted Average (TLV-TWA) — the time-weighted average concentration for a normal 8-hour workday or 40-hour workweek, to which nearly all workers may be repeatedly exposed, day after day, without adverse effect.

b) Threshold Limit Value-Short Term Exposure Limit (TLV-STEL) — the maximal concentration to which workers can be exposed for a period up to 15 minutes continuously without suffering from 1) irritation, 2) chronic or irreversible tissue change, or 3) narcosis of sufficient degree to increase accident proneness, impair self-rescue, or materially reduce work efficiency, provided that no more than four excursions per day are permitted, with at least 60 minutes between exposure periods, and provided that the daily TLV-TWA also is not exceeded. The STEL should be considered a maximal allowable concentration, or ceiling, not to be exceeded at any time during the 15-minute excursion period. STELs are based on one or more of the following criteria: (1) Adopted TLVs including those with a "C" or "ceiling" limit. (2) TWA-TLV Excursion Factors listed in Appendix D. (3) Pennsylvania Short-Term Limits for Exposure to Airborne Contaminants (Penna. Dept. of Hlth., Chapter 4, Art. 432, Rev. Jan. 25, 1968). (4) OSHA Occupational Safety and Health Standards, 40 FR 23073, May 28, 1975. (5) NIOSH criteria for recommended standards for occupational exposure to specific substances. The TWA-STEL should not be used as engineering design criterion or considered as an emergency exposure level (EEL).

c) Threshold Limit Value-Ceiling (TLV-C) — the concentration that should not be exceeded even instantaneously.

For some substances, e.g., irritant gases, only one category, the TLV-Ceiling, may be relevant. For other substances, either two or three categories may be relevant, depending upon their physiologic action. It is important to observe that if any one of these three TLVs is exceeded, a potential hazard from that substance is presumed to exist.

The TLV-TWA should be used as guides in the control of health hazards and should not be used as fine lines between safe and dangerous concentrations.

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 a 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.

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The amount and nature of the information available for establishing a TLV varies from substance to substance; consequently, the 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 control of community air pollution nuisances, (3) in estimating the toxic potential of continuous, uninterrupted exposures or other extended work periods, (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 noncompliance 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 determining the magnitude of the value of the STELs, or 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 mucous 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, may cause unpleasant deposits in the eyes, ears and nasal passages (Portland Cement dust), or cause injury to the skin or mucous membranes by chemical or me-

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chanical action per se or by the rigorous skin cleansing procedures necessary for their removal.

A threshold limit of 10 mg/m^3, or 30 mppcf, of total dust < 1% quartz, or, 5 mg/m^3 respirable dust 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.

Physical Factors. It is recognized that such physical factors as heat, ultraviolet and ionizing 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 may be altered. Most of these stresses act adversely 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 BLVs, and their associated procedures for determining compliance with them, should thus be regarded as an effective means of providing health surveillance of the worker.

Unlisted Substances. Many substances present or handled in industrial processes do not appear on the TLV list. In a number of instances the material is rarely present as a particulate, vapor or other airborne contaminant, and a TLV is not necessary. In other cases sufficient information to warrant development of a TLV, even on a tentative basis, is not available to the Committee. Other substances, of low toxicity, could be included in Appendix E pertaining to nuisance particulates. This list (as well as Appendix F) is not meant to be all inclusive; the substances serve only as examples.

In addition there are some substances of not inconsiderable toxicity, which have been omitted primarily because only a limited number of workers (e.g., employees of a single plant) are known to have potential exposure to possibly harmful concentrations.

"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.

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The list of Intended Changes follows the Adopted Values in the TLV booklet. Values listed in parenthesis in the "Adopted" list are to be used during the period in which a proposed change for that Value is listed in the Notice of Intended Changes.

Legal Status. The Threshold Limit Values, as issued by ACGIH, are recommendations and should be used as guidelines for good practices. Wherever these values (of whatever year) have been used or included by reference in Federal and/or State statutes and registers, the TLVs do have the force and effects of law.

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Substance	ADOPTED VALUES TWA ppm[a]	ADOPTED VALUES TWA mg/m³[b]	TENTATIVE VALUES STEL ppm[a]	TENTATIVE VALUES STEL mg/m³[b]
Abate	—	10	—	20
Acetaldehyde	100	180	150	270
Acetic acid	10	25	15	37
C Acetic anhydride	5	20	—	—
** Acetone	(1,000)	(2,400)	(1,250)	(3,000)
Acetonitrile	40	70	60	105
Acetylene	F	—	—	—
Acetylene dichloride, see 1, 2-Dichloroethylene	200	790	250	1,000
Acetylene tetrabromide	1	15	1.5	20
Acrolein	0.1	0.25	0.3	0.8
Acrylamide — Skin	—	0.3	—	0 6
** Acrylonitrile — Skin	(20)	(45)	(30)	(65)
Aldrin — Skin	—	0.25	—	0.75
Allyl alcohol — Skin	2	5	4	10
Allyl chloride	1	3	2	6
Allyl glycidyl ether (AGE) — Skin	5	22	10	44
Allyl propyl disulfide	2	12	3	18
* Aluminum metal and oxide	—	10	—	20
* Aluminum pyro powders	—	5	—	—
* Aluminum welding fumes	—	5	—	—
* Aluminum, soluble salts	—	2	—	—
* Aluminum, alkyls (NOC)*	—	2	—	—
Alundum®	—	E	—	20
4-Aminodiphenyl — Skin	—	A1b	—	A1b
2-Aminoethanol, see Ethanolamine	3	8	6	15
2-Aminopyridine	0.5	2	2	4
* 3-Amino 1, 2, 4-triazole	A2	A2	—	—
Ammonia	25	18	35	27
Ammonium chloride-fume	—	10	—	20
Ammonium sulfamate (Ammate)	—	10	—	20
n-Amyl acetate	100	530	150	800
sec-Amyl acetate	125	670	150	800
** Aniline — Skin	(5)	(19)	—	—
Anisidine (o-, p-isomers) — Skin	0.1	0.5	—	—

Capital letters refer to Appendices
Footnotes (a thru f) see Page 31
**See Notices of Intended Changes
*1979 Addition

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Substance	ADOPTED VALUES TWA ppm[a]	ADOPTED VALUES TWA mg/m³[b]	TENTATIVE VALUES STEL ppm[a]	TENTATIVE VALUES STEL mg/m³[b]
** Antimony & Compounds (as Sb)	—	(0.5)	—	—
Antimony trioxide, handling and use (as Sb)	—	0.5	—	—
** Antimony trioxide production (as Sb)	—	(0.5, A2)	—	—
ANTU (α-Naphthyl thiourea)	—	0.3	—	0.9
Argon	F	—	F	F
** Arsenic & compounds (as As)	—	(0.5)	—	—
** Arsenic trioxide production (as As)	—	(A1a)	—	—
Arsine	0.05	0.2	—	—
** Asbestos (all forms)	—	(A1a)	—	(A1a)
Asphalt (petroleum) fumes	—	5	—	10
Atrazine	—	10	—	—
Azinphos-methyl — Skin	—	0.2	—	0.6
Barium (soluble compounds), as Ba	—	0.5	—	—
Baygon (propoxur)	—	0.5	—	2
* Benomyl	0.8	10	1.3	15
Benzene	10, A2	30, A2	—	—
Benzidine production — Skin	—	A1b	—	A1b
p-Benzoquinone, see Quinone	0.1	0.4	0.3	2
Benzoyl peroxide	—	5	—	—
Benzo(a)pyrene	—	A2	—	A2
Benzyl chloride	1	5	—	—
Beryllium	—	0.002, A2	—	—
Biphenyl	0.2	1.5	0.6	4
Bismuth telluride	—	10	—	20
Bismuth telluride, Se-doped	—	5	—	10
Borates, tetra, sodium salts, Anhydrous	—	1	—	—
Decahydrate	—	5	—	—
Pentahydrate	—	1	—	—
Boron oxide	—	10	—	20
Boron tribromide	1	10	3	30
C Boron trifluoride	1	3	—	—
* Bromacil	1	10	2	20
Bromine	0.1	0.7	0.3	2
Bromine pentafluoride	0.1	0.7	0.3	2
Bromochloromethane/ chlorobromomethane	200	1,050	250	1,300
Bromoform — Skin	0.5	5	—	—
Butadiene (1, 3-butadiene)	1,000	2,200	1,250	2,750
** Butane	(600)	(1,430)	(750)	(1,780)
Butanethiol, see Butyl mercaptan	0.5	1.5	—	—
2-Butanone	200	590	300	885
** 2-Butoxyethanol (Butyl Cellosolve) — Skin	(50)	(240)	(150)	(720)
n-Butyl acetate	150	710	200	950
sec-Butyl acetate	200	950	250	1,190
tert-Butyl acetate	200	950	250	1,190
Butyl acrylate	10	55	—	—
C n-Butyl alcohol — Skin	50	150	—	—
** sec-Butyl alcohol	(150)	(450)	—	—
tert-Butyl alcohol	100	300	150	450
C Butylamine — Skin	5	15	—	—
C tert-Butyl chromate (as CrO_3) — Skin	—	0.1	—	—
** n-Butyl glycidyl ether (BGE)	(50)	(270)	—	—
n-Butyl lactate	5	25	—	—
Butyl mercaptan	0.5	1.5	—	—
p-tert-Butyltoluene	10	60	20	120
Cadmium, dust & salts (as Cd)	—	0.05	—	0.2
C Cadmium oxide fume (as Cd)	—	0.05	—	—
** Cadmium oxide production (as Cd)	—	(A2)	—	—
Calcium carbonate/ marble	—	E	—	20
Calcium arsenate (as As)	—	1	—	—

Capital letters refer to Appendices
Footnotes (a thru f) see Page 31
**See Notice of Intended Changes
*1979 Addition

Capital letters refer to Appendices
*1979 Addition
**See Notice of Intended Changes

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Substance	ADOPTED VALUES TWA ppm[a]	ADOPTED VALUES TWA mg/m³[b]	TENTATIVE VALUES STEL ppm[a]	TENTATIVE VALUES STEL mg/m³[b]
Calcium cyanamide	—	0.5	—	1
Calcium hydroxide	—	5	—	—
Calcium oxide	—	2	—	—
Camphor, synthetic	2	12	3	18
Caprolactam:				
Dust	—	1	—	3
Vapor	5	20	10	40
Captafol (Difolatan®) — Skin	—	0.1	—	—
Captan	—	5	—	15
Carbaryl (Sevin®)	—	5	—	10
Carbofuran (Furadan®)	—	0.1	—	—
Carbon black	—	3.5	—	7
Carbon dioxide	5,000	9,000	15,000	18,000
** Carbon disulfide — Skin	(20)	(60)	(30)	(90)
Carbon monoxide	50	55	400	440
Carbon tetrabromide	0.1	1.4	0.3	4
** Carbon tetrachloride — Skin	(10)	(65)	(20)	(130)
Carbonyl chloride (Phosgene)	0.1	0.4	—	—
** Carbonyl fluoride	(5)	(15)	—	—
Catechol (Pyrocatechol)	5	20	—	—
Cellulose (paper fiber)	—	E	—	20
Cesium hydroxide	—	2	—	—
Chlordane — Skin	—	0.5	—	2
Chlorinated camphene — Skin	—	0.5	—	1
Chlorinated diphenyl oxide	—	0.5	—	2
Chlorine	1	3	3	9
Chlorine dioxide	0.1	0.3	0.3	0.9
C Chlorine trifluoride	0.1	0.4	—	—
C Chloroacetaldehyde	1	3	—	—
α-Chloroacetophenone (Phenacyl chloride)	0.05	0.3	—	—
Chlorobenzene (Monochlorobenzene)	75	350	—	—
o-Chlorobenzylidene malononitrile — Skin	0.05	0.4	—	—
Chlorobromomethane/ Bromochloromethane	200	1,050	250	1,300

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

Substance	ADOPTED VALUES TWA ppm[a]	ADOPTED VALUES TWA mg/m³[b]	TENTATIVE VALUES STEL ppm[a]	TENTATIVE VALUES STEL mg/m³[b]
2-Chloro-1, 3-butadiene, see β Chloroprene — Skin	25	90	35	125
Chlorodifluoromethane	1,000	3,500	1,250	4,375
Chlorodiphenyl (42% Chlorine) — Skin	—	1	—	2
Chlorodiphenyl (54% Chlorine) — Skin	—	0.5	—	1
1-Chloro, 2, 3-epoxy-propane (Epichlorhydrin) — Skin	5	20	10	40
C 2-Chloroethanol (Ethylene chlorohydrin) — Skin	1	3	—	—
** Chloroethylene (Vinyl chloride)	(A1c)	—	(A1c)	—
Chloroform (Trichloromethane)	10, A2	50, A2	—	—
bis-Chloromethyl ether	0.001	A1a	—	A1a
** 1-Chloro-1-nitropropane	(20)	(100)	—	—
Chloropicrin	0.1	0.7	0.3	2
** β-Chloroprene — Skin	(25)	(90)	(35)	(135)
Chlorpyrifos (Dursban®) — Skin	—	0.2	—	0.6
o-Chlorostyrene	50	285	75	430
o-Chlorotoluene — Skin	50	250	75	375
2-Chloro-6-(trichloromethyl pyridine (N-Serve®)	—	10	—	20
** Chromates, certain insoluble forms	— (0.05,A1a)		—	(A1a)
** Chromic acid and Chromates, (as Cr)	—	(0.05)	—	—
Chromite ore processing (chromate), as Cr	— 0.05, A1a		—	—
Chromium, Sol. chromic, chromous salts (as Cr)	—	0.5	—	—
Clopidol (Coyden®)	—	10	—	20
Coal tar pitch volatiles				

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

MAP 000161

Substance	ADOPTED VALUES TWA ppm[a]	ADOPTED VALUES TWA mg/m³[b]	TENTATIVE VALUES STEL ppm[a]	TENTATIVE VALUES STEL mg/m³[b]
(See Particulate polycyclic aromatic hydrocarbons)	—	0.2, A1a	—	A1a
** Cobalt metal, dust and fume (as Co)	—	(0.1)	—	—
Copper fume	—	0.2	—	—
Dusts & Mists (as Cu)	—	1	—	2
Corundum (Al_2O_3)	—	E	—	E
Cotton dust, raw	—	0.2[k]	—	0.6
Crag® herbicide	—	10	—	20
Cresol, all isomers — Skin	5	22	—	—
Crotonaldehyde	2	6	6	18
Crufomate®	—	5	—	20
Cumene — Skin	50	245	75	365
Cyanamide	—	2	—	—
Cyanides, as CN — Skin	—	5	—	—
Cyanogen	10	20	—	—
Cyclohexane	300	1,050	375	1,300
Cyclohexanol	50	200	—	—
** Cyclohexanone	(50)	(200)	—	—
Cyclohexene	300	1,015	—	—
Cyclohexylamine — Skin	10	40	—	—
Cyclopentadiene	75	200	150	400
2, 4-D (2, 4-Diphenoxy-acetic acid)	—	10	—	20
DDT (Dichlorodiphenyl-trichloroethane)	—	1	—	3
DDVP, see Dichlorvos — Skin	0.1	1	0.3	3
Decaborane — Skin	0.05	0.3	0.15	0.9
Demeton® — Skin	0.01	0.1	0.03	0.3
Diacetone alcohol (4-hydroxy-4-methyl-2-pentanone)	50	240	75	360
1, 2-Diaminoethane, see Ethylenediamine	10	25	—	—
Diazinon — Skin	—	0.1	—	0.3
Diazomethane	0.2	0.4	—	—
Diborane	0.1	0.1	—	—

Capital letters refer to Appendices
**See Notice of Intended Changes
k) See p. 33.

Substance	ADOPTED VALUES TWA ppm[a]	ADOPTED VALUES TWA mg/m³[b]	TENTATIVE VALUES STEL ppm[a]	TENTATIVE VALUES STEL mg/m³[b]
** 1, 2-Dibromoethane (Ethylene dibromide) — Skin	(20)	(155)	(30)	(230)
Dibrom®	—	3	—	6
2-n-Dibutylaminoethanol — Skin	2	14	4	28
Dibutyl phosphate	1	5	2	10
Dibutyl phthalate	—	5	—	10
C Dichloracetylene	0.1	0.4	—	—
C o-Dichlorobenzene	50	300	—	—
p-Dichlorobenzene	75	450	110	675
Dichlorobenzidine — Skin	—	A2	—	A2
Dichlorodifluoromethane	1,000	4,950	1,250	6,200
1, 3-Dichloro-5, 5-dimethyl hydantoin	—	0.2	—	0.4
1, 1-Dichloroethane	200	810	250	1,010
** 1, 2-Dichloroethane	(50)	(200)	(75)	(300)
1, 2-Dichloroethylene	200	790	250	1,000
Dichloroethyl ether — Skin	5	30	10	60
** Dichloromethane, see Methylene chloride	(200)	(700)	(250)	(870)
** Dichloromonofluoro-methane	(1,000)	(4,200)	—	—
C 1, 1-Dichloro-1-nitroethane	10	60	—	—
1, 2-Dichloropropane, see Propylene dichloride	75	350	110	510
Dichlorotetrafluoro-ethane	1,000	7,000	1,250	8,750
Dichlorvos (DDVP) — Skin	0.1	1	0.3	3
Dicrotophos (Bidrin®) — Skin	—	0.25	—	—
Dicyclopentadiene	5	30	—	—
Dicyclopentadienyl iron	—	10	—	20
Dieldrin — Skin	—	0.25	—	0.75
** Diethylamine	(25)	(75)	—	—
Diethylaminoethanol — Skin	10	50	—	—

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

MAP 000162

Substance	ADOPTED VALUES TWA ppm[a]	ADOPTED VALUES TWA mg/m³[b]	TENTATIVE VALUES STEL ppm[a]	TENTATIVE VALUES STEL mg/m³[b]
Diethylene triamine — Skin	1	4	—	—
Diethyl ether, see Ethyl ether	400	1,200	500	1,500
Diethyl phthalate	—	5	—	10
Difluorodibromomethane	100	860	150	1,290
**C Diglycidyl ether (DGE)	(0.5)	(3)	—	—
Dihydroxybenzene, see Hydroquinone	—	2	—	4
Diisobutyl ketone	25	150	—	—
Diisopropylamine — Skin	5	20	—	—
Dimethoxymethane, see Methylal	1,000	3,100	1,250	3,875
Dimethyl acetamide — Skin	10	35	15	50
* Dimethyl carbamyl chloride	A2	A2	—	—
Dimethylamine	10	18	—	—
Dimethylaminobenzene, see Xylidene — Skin	5	25	10	50
Dimethylaniline (N, N-Dimethylaniline) — Skin	5	25	10	50
Dimethylbenzene, see Xylene — Skin	100	435	150	650
Dimethyl-1, 2-dibromo-2-dichloroethyl phosphate, see Dibrom	—	3	—	6
Dimethylformamide — Skin	10	30	20	60
2, 6-Dimethyl-4-heptanone, see Diisobutyl ketone	25	150	—	—
1, 1-Dimethylhydrazine — Skin	0.5	1	1	2
Dimethylphthalate	—	5	—	10
C Dimethyl sulfate — Skin	0.1, A2	0.5, A2	—	—
Dinitrobenzene (all isomers) — Skin	0.15	1	0.5	3
Dinitro-o-cresol — Skin	—	0.2	—	0.6

Capital letters refer to Appendices.
Footnotes (a thru f) see Page 31
*1979 Addition
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Substance	ADOPTED VALUES TWA ppm[a]	ADOPTED VALUES TWA mg/m³[b]	TENTATIVE VALUES STEL ppm[a]	TENTATIVE VALUES STEL mg/m³[b]
3, 5-Dinitro-o-toluamide (Zoalene®)	—	5	—	10
Dinitrotoluene — Skin	—	1.5	—	5
** Dioxane, tech. grade — Skin	(50)	(180)	—	—
Dioxathion (Delnav®) — Skin	—	0.2	—	—
Diphenyl, see Biphenyl	0.2	1.5	0.6	4
Diphenylamine	—	10	—	20
C Diphenylmethane diisocyanate, see Methylene bisphenyl isocyanate (MDI)	0.02	0.2	—	—
Dipropylene glycol methyl ether — Skin	100	600	150	900
Diquat	—	0.5	—	1
Di-sec, octyl phthalate (Di-2-ethylhexyl-phthalate)	—	5	—	10
Disulfiram	—	2	—	5
Disyston — Skin	—	0.1	—	0.3
2, 6-Ditert. butyl-p-cresol	—	10	—	20
Diuron	—	10	—	—
Dyfonate	—	0.1	—	—
Emery	—	E	—	20
Endosulfan (Thiodan®) — Skin	—	0.1	—	0.3
Endrin — Skin	—	0.1	—	0.3
** Epichlorhydrin — Skin	(5)	(20)	(10)	(40)
EPN — Skin	—	0.5	—	2
1, 2-Epoxypropane, see Propylene oxide	100	240	150	360
2, 3-Epoxy-1-propanol, see Glycidol	50	150	75	225
Ethane	F	—	F	—
Ethanethiol, see Ethyl mercaptan	0.5	1	2	3
Ethanolamine	3	8	6	15
Ethion (Nialate®) — Skin	—	0.4	—	—
** 2-Ethoxyethanol — Skin	(100)	(370)	(150)	(560)
** 2-Ethoxyethyl acetate (Cellosolve acetate) —				

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

MAP 000163

Substance	ADOPTED VALUES TWA ppm[a]	ADOPTED VALUES TWA mg/m³[b]	TENTATIVE VALUES STEL ppm[a]	TENTATIVE VALUES STEL mg/m³[b]
Skin	(100)	(540)	(150)	(810)
Ethyl acetate	400	1,400	—	—
** Ethyl acrylate — Skin	(25)	(100)	—	—
Ethyl alcohol (Ethanol)	1,000	1,900	—	—
Ethylamine	10	18	—	—
Ethyl amyl ketone (5-Methyl-3-heptanone)	25	130	—	—
Ethyl benzene	100	435	125	545
Ethyl bromide	200	890	250	1,110
Ethylbutyl ketone (3-Heptanone)	50	230	75	345
Ethyl chloride	1,000	2,600	1,250	3,250
Ethyl ether	400	1,200	500	1,500
Ethyl formate	100	300	150	450
Ethyl mercaptan	0.5	1	2	3
* Ethyl silicate	10	85	30	255
Ethylene	F	—	F	—
C Ethylene chlorohydrin — Skin	1	3	—	—
Ethylenediamine	10	25	—	—
** Ethylene dibromide, see 1, 2-Dibromoethane	(20)	(155)	(30)	(230)
** Ethylene dichloride, see 1, 2-Dichloroethane	(50)	(200)	(75)	(300)
Ethylene glycol, Particulate	—	10	—	20
** Vapor	(100)	(250)	(125)	(325)
**C Ethylene glycol dinitrate and/or Nitroglycerin — Skin	(0.2)	(2)	—	—
Ethylene glycol monomethyl ether acetate (Methyl cellosolve acetate) — Skin	25	120	35	170
** Ethylene oxide	(50)	(90)	(75)	(135)
Ethylenimine — Skin	0.5	1	—	—
Ethylidene chloride, see 1, 1-Dichloroethane	200	810	250	1,010
C Ethylidene norbornene	5	25	—	—

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

Substance	ADOPTED VALUES TWA ppm[a]	ADOPTED VALUES TWA mg/m³[b]	TENTATIVE VALUES STEL ppm[a]	TENTATIVE VALUES STEL mg/m³[b]
n-Ethylmorpholine — Skin	20	95	—	—
Fensulfothion (Dasanit)	—	0.1	—	—
Ferbam	—	10	—	20
Ferrovanadium dust	—	1	—	0.3
Fluoride (as F)	—	2.5	—	—
Fluorine	1	2	2	4
Fluorotrichloromethane	1,000	5,600	1,250	7,000
C Formaldehyde	2	3	—	—
Formamide	20	30	30	45
Formic acid	5	9	—	—
** Furfural — Skin	(5)	(20)	(15)	(60)
Furfuryl alcohol — Skin	5	20	10	40
Gasoline	—	B2	—	B2
Germanium tetrahydride	0.2	0.6	0.6	1.8
Glass, fibrous* or dust	—	10	—	—
*C Glutaraldehyde	0.2	0.7	—	—
Glycerin mist	—	E	—	E
** Glycidol (2, 3-Epoxy-1-propanol)	(50)	(150)	(75)	(225)
Glycol monoethyl ether, see 2-Ethoxyethanol — Skin	100	370	150	560
Graphite (Synthetic)	—	E	—	—
Guthion®, see Azinphos-methyl — Skin	—	0.2	—	0.6
Gypsum	—	E	—	20
Hafnium	—	0.5	—	1.5
Helium	F	—	F	—
Heptachlor — Skin	—	0.5	—	2
Heptane (n-Heptane)	400	1,600	500	2,000
Hexachlorocyclopentadiene	0.01	0.1	0.03	0.3
Hexachloroethane — Skin	1	10	3	30
Hexachloronaphthalene — Skin	—	0.2	—	0.6
Hexafluoroacetone	0.1	0.7	0.3	2
** Hexane (n-hexane)	(100)	(360)	(125)	(450)
Hexamethyl phosphoramide —				

Capital letters refer to Appendices.
*1979 Addition
**See Notice of Intended Changes

MAP 000164

Substance	ADOPTED VALUES TWA ppm[a]	TWA mg/m³[b]	TENTATIVE VALUES STEL ppm[a]	STEL mg/m³[b]
Skin	A2	A2	—	—
2-Hexanone, see Methyl butyl ketone — Skin	25	100	40	165
** Hexone (Methyl isobutyl ketone) — Skin	(100)	(410)	(125)	(510)
sec-Hexyl acetate	50	300	—	—
C Hexylene glycol	25	125	—	—
Hydrazine — Skin	0.1, A2	0.1, A2	—	—
Hydrogen	F	—	F	—
Hydrogenated terphenyls	0.5	5	—	—
Hydrogen bromide	3	10	—	—
C Hydrogen chloride	5	7	—	—
** Hydrogen cyanide — Skin	(10)	(11)	(15)	(16)
Hydrogen fluoride (as F)	3	2	—	—
Hydrogen peroxide	1	1.5	2	3
Hydrogen selenide (as Se)	0.05	0.2	—	—
Hydrogen sulfide	10	15	15	27
Hydroquinone	—	2	—	4
Indene	10	45	15	70
Indium & Compounds (as In)	—	0.1	—	0.3
C Iodine	0.1	1	—	—
Iodoform	0.6	10	1	20
Iron oxide fume (Fe_2O_3, as Fe)	B3	5	—	10
Iron pentacarbonyl (as Fe)	0.01	0.08	—	—
Iron salts, soluble (as Fe)	—	1	—	2
Isoamyl acetate	100	525	125	655
Isoamyl alcohol	100	360	125	450
Isobutyl acetate	150	700	187	875
Isobutyl alcohol	50	150	75	225
C Isophorone	5	25	—	—
Isophorone diisocyanate — Skin	0.01	0.09	—	—
Isopropyl acetate	250	950	310	1,185
Isopropyl alcohol — Skin	400	980	500	1,225
Isopropylamine	5	12	10	24
Isopropyl ether	250	1,050	310	1,320

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

Substance	ADOPTED VALUES TWA ppm[a]	TWA mg/m³[b]	TENTATIVE VALUES STEL ppm[a]	STEL mg/m³[b]
Isopropyl glycidyl ether (IGE)	50	240	75	360
Kaolin	—	E	—	20
Ketene	0.5	0.9	1.5	3
Lead, inorg., fumes & dusts (as Pb)	—	0.15	—	0.45
Lead arsenate (as Pb)	—	0.15	—	0.45
Lead chromate (as Cr)	—	0.05, A2	—	—
Limestone	—	E	—	20
Lindane — Skin	—	0.5	—	1.5
Lithium hydride	—	0.025	—	—
L.P.G. (Liquified petroleum gas)	1,000	1,800	1,250	2,250
Magnesite	—	E	—	20
Magnesium oxide fume (as Mg)	—	10	—	—
Malathion — Skin	—	10	—	—
Maleic anhydride	0.25	1	—	—
C Manganese & Compounds (as Mn)	—	5	—	—
* Manganese fume (as Mn)	—	1	—	3
Manganese cyclopentadienyl tricarbonyl (as Mn) — Skin	—	0.1	—	0.3
Manganese Tetroxide	—	1	—	—
Marble/calcium carbonate	—	E	—	20
Mercury (Alkyl compounds) — Skin, (as Hg)	0.001	0.01	0.003	0.03
Mercury (All forms except alkyl), as Hg	—	0.05	—	0.15
** Mesityl oxide	(25)	(100)	—	—
Methane	F	—	F	—
Methanethiol, see Methyl mercaptan	0.5	1	—	—
Methomyl (Lannate®) — Skin	—	2.5	—	—
Methoxychlor	—	10	—	—

Capital letters refer to Appendices.
*1979 Addition.
**See Notices of Intended Changes.

MAP 000165

Substance	ADOPTED VALUES TWA ppm[a]	ADOPTED VALUES TWA mg/m³[b]	TENTATIVE VALUES STEL ppm[a]	TENTATIVE VALUES STEL mg/m³[b]
2-Methoxyethanol — Skin (Methyl cellosolve)	25	80	35	120
Methyl acetate	200	610	250	760
Methyl acetylene (propyne)	1,000	1,650	1,250	2,040
Methyl acetylene-propadiene mixture (MAPP)	1,000	1,800	1,250	2,250
Methyl acrylate — Skin	10	35	—	—
Methylacrylonitrile — Skin	1	3	2	6
Methylal (dimethoxymethane)	1,000	3,100	1,250	3,875
Methyl alcohol (methanol) — Skin	200	260	250	310
Methylamine	10	12	—	—
Methyl amyl alcohol, see Methyl isobutyl carbinol — Skin	25	100	40	160
Methyl 2-cyanoacrylate	2	8	4	16
** Methyl n-amyl ketone (2-Heptanone)	(100)	(465)	(150)	(710)
** Methyl bromide — Skin	(15)	(60)	—	—
** Methyl butyl ketone, see 2-Hexanone — Skin	(25)	(100)	(40)	(165)
Methyl cellosolve — Skin see 2-Methoxyethanol	25	80	35	120
Methyl cellosolve acetate — Skin, see Ethylene glycol monomethyl ether acetate	25	120	35	170
** Methyl chloride	(100)	(210)	(125)	(260)
Methyl chloroform (1, 1, 1-Trichloroethane)	350	1,900	450	2,380
Methylcyclohexane	400	1,600	500	2,000
Methylcyclohexanol	50	235	75	350
o-Methycyclohexanone — Skin	50	230	75	345
Methylcyclopentadienyl manganese tricarbonyl (as Mn) — Skin	0.1	0.2	0.3	0.6

Capital letters refers to Appendices
**See Notice of Intended Changes

Substance	ADOPTED VALUES TWA ppm[a]	ADOPTED VALUES TWA mg/m³[b]	TENTATIVE VALUES STEL ppm[a]	TENTATIVE VALUES STEL mg/m³[b]
Methyl demeton — Skin	—	0.5	—	1.5
C Methylene bisphenyl isocyanate (MDI)	0.02	0.2	—	—
** Methylene chloride (dichloromethane)	(200)	(700)	(250)	(870)
4, 4'-Methylene bis (2-chloraniline) — Skin	0.02, A2	—	A2	—
C Methylene bis (4-cyclohexylisocyanate)	0.01	0.11	—	—
Methyl ethyl ketone (MEK), see 2-Butanone	200	590	300	885
C Methyl ethyl ketone peroxide	0.2	1.5	—	—
Methyl formate	100	250	150	375
** Methyl iodide — Skin	(5)	(28)	(10)	(56)
Methyl isoamyl ketone	100	475	150	710
Methyl isobutyl carbinol — Skin	25	100	40	165
Methyl isobutyl ketone, see Hexone — Skin	100	410	125	510
Methyl isocyanate — Skin	0.02	0.05	—	—
Methyl mercaptan	0.5	1	—	—
Methyl methacrylate	100	410	125	510
Methyl parathion — Skin	—	0.2	—	0.6
Methyl propyl ketone, see 2-Pentanone	200	700	250	875
**C Methyl silicate	(5)	(30)	—	—
**C α-Methyl styrene	(100)	(480)	—	—
Molybdenum (as Mo) Soluble compounds	—	5	—	10
Insoluble compounds	—	10	—	20
Monocrotophos (Azodrin®)	—	0.25	—	—
Monomethyl aniline — Skin	2	9	4	18
C Monomethyl hydrazine — Skin	0.2	0.35	—	—
Morpholine — Skin	20	70	30	105
Naphthalene	10	50	15	75

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

MAP 000166

Substance	ADOPTED VALUES TWA ppm[a]	ADOPTED VALUES TWA mg/m³[b]	TENTATIVE VALUES STEL ppm[a]	TENTATIVE VALUES STEL mg/m³[b]
β-Naphthylamine	—	A1b	—	A1b
Neon	F	—	F	—
Nickel carbonyl (as Ni)	0.05	0.35	—	—
Nickel metal	—	1	—	—
Nickel, soluble compounds (as Ni)	—	0.1	—	0.3
Nickel sulfide roasting, fume & dust (as Ni)	—	1, A1a	—	—
Nicotine — Skin	—	0.5	—	1.5
Nitric acid	2	5	4	10
Nitric oxide	25	30	35	45
p-Nitroaniline — Skin	1	6	2	12
Nitrobenzene — Skin	1	5	2	10
p-Nitrochlorobenzene — Skin	—	1	—	2
4-Nitrodiphenyl	—	A1b	—	A1b
Nitroethane	100	310	150	465
**C Nitrogen dioxide	(5)	(9)	—	—
Nitrogen trifluoride	10	30	15	45
**C Nitroglycerin — Skin	(0.2)	(2)	—	—
Nitromethane	100	250	150	375
** 1-Nitropropane	(25)	(90)	(35)	(135)
** 2-Nitropropane	(25)	(90)	—	—
n-Nitrosodimethylamine (dimethylnitrosoamine) — Skin	—	A2	—	A2
Nitrotoluene — Skin	5	30	10	60
Nitrotrichloromethane, see Chloropicrin	0.1	0.7	0.3	2
Nonane	200	1,050	250	1,300
Octachloronaphthalene — Skin	—	0.1	—	0.3
Octane	300	1,450	375	1,800
Oil mist, mineral	—	5[e]	—	10
Osmium tetroxide (as Os)	0.0002	0.002	0.0006	0.006
Oxalic acid	—	1	—	2
Oxygen difluoride	0.05	0.1	0.15	0.3
Ozone	0.1	0.2	0.3	0.6
Paraffin wax fume	—	2	—	6
Paraquat, respirable sizes	—	0.1	—	—

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

Substance	ADOPTED VALUES TWA ppm[a]	ADOPTED VALUES TWA mg/m³[b]	TENTATIVE VALUES STEL ppm[a]	TENTATIVE VALUES STEL mg/m³[b]
Parathion — Skin	—	0.1	—	0.3
Particulate polycyclic aromatic hydrocarbons (PPAH), as benzene solubles	—	0.2, A1a	—	A1a
Pentaborane	0.005	0.01	0.015	0.03
Pentachloronaphthalene	—	0.5	—	2
Pentachlorophenol — Skin	—	0.5	—	1.5
Pentaerythritol	—	E	—	20
Pentane	600	1,800	750	2,250
2-Pentanone	200	700	250	875
Perchloroethylene — Skin	100	670	150	1,000
Perchloromethyl mercaptan	0.1	0.8	—	—
Perchloryl fluoride	3	14	6	28
Phenol — Skin	5	19	10	38
Phenothiazine — Skin	—	5	—	10
* n-Phenyl-beta-naphthylamine	A2	A2	—	—
p-Phenylene diamine — Skin	—	0.1	—	—
Phenyl ether (vapor)	1	7	2	14
** Phenyl ether-Diphenyl mixture (vapor)	(1)	(7)	(2)	(14)
Phenylethylene, see Styrene, monomer	100	420	125	525
Phenyl glycidyl ether (PGE)	10	60	15	90
Phenyl mercaptan	0.5	2	—	—
Phenylhydrazine — Skin	5	20	10	45
C Phenylphosphine	0.05	0.25	—	—
Phorate (Thimet®) — Skin	—	0.05	—	0.2
Phosdrin (Mevinphos®) — Skin	0.01	0.1	0.03	0.3
Phosgene (carbonyl chloride)	0.1	0.4	—	—
Phosphine	0.3	0.4	1	1
Phosphoric acid	—	1	—	3

Capital letters refer to Appendices
Footnotes (a thru f) see Page 31.
*1979 Addition.
**See Notice of Intended Changes.

MAP 000167

Substance	ADOPTED VALUES TWA ppm[a]	ADOPTED VALUES TWA mg/m³[b]	TENTATIVE VALUES STEL ppm[a]	TENTATIVE VALUES STEL mg/m³[b]
Phosphorus (yellow)	—	0.1	—	0.3
** Phosphorus pentachloride	—	(1)	—	(3)
Phosphorus pentasulfide	—	1	—	3
Phosphorus trichloride	0.5	3	—	—
Phthalic anhydride	1	6	4	24
m-Phthalodinitrile	—	5	—	—
Picloram (Tordon®)	—	10	—	20
Picric acid — Skin	—	0.1	—	0.3
Pival® (2-Pivalyl-1, 3-indandione)	—	0.1	—	0.3
Plaster of Paris	—	E	—	20
Platinum (Soluble salts) as Pt	—	0.002	—	—
Polychlorobiphenyls, see Chlorodiphenyls — Skin	—	—	—	—
Polytetrafluoroethylene decomposition products	—	B1	—	B1
C Potassium hydroxide	—	2	—	—
Propane	F	—	F	—
** β-Propiolactone	—	(A2)	—	(A2)
Propargyl alcohol — Skin	1	2	3	6
n-Propyl acetate	200	840	250	1,050
Propyl alcohol — Skin	200	500	250	625
n-Propyl nitrate	25	105	40	470
Propylene	F	—	F	—
Propylene dichloride (1, 2-Dichloropropane)	75	350	110	510
**C Propylene glycol dinitrate — Skin	(0.2)	(2)	—	—
Propylene glycol monomethyl ether	100	360	150	540
Propylene imine — Skin	2	5	—	—
** Propylene oxide	(100)	(240)	(150)	(360)
Propyne, see Methyl acetylene	1,000	1,650	1,250	2,040
Pyrethrum	—	5	—	10
Pyridine	5	15	10	30
Quinone	0.1	0.4	0.3	2
RDX — Skin	—	1.5	—	3

Capital letters refer to Appendices
**See notice of intended changes

Substance	ADOPTED VALUES TWA ppm[a]	ADOPTED VALUES TWA mg/m³[b]	TENTATIVE VALUES STEL ppm[a]	TENTATIVE VALUES STEL mg/m³[b]
Resorcinol	10	45	20	90
Rhodium, Metal fume and dusts (as Rh)	—	0.1	—	0.3
Soluble salts (as Rh)	—	0.001	—	0.003
Ronnel	—	10	—	—
Rosin core solder pyrolysis products (as formaldehyde)	—	0.1	—	0.3
Rotenone (commercial)	—	5	—	10
Rouge	—	E	—	20
Rubber solvent (Naphtha)	400	1,600	—	—
Selenium compounds (as Se)	—	0.2	—	—
Selenium hexafluoride, (as Se)	0.05	0.2	—	—
Sevin® (see Carbaryl)	—	5	—	10
Silane (see Silicon tetrahydride)	0.5	0.7	1	1.5
Silicon	—	E	—	20
Silicon carbide	—	E	—	20
Silicon tetrahydride (Silane)	0.5	0.7	1	1.5
** Silver, metal and soluble compounds, as Ag	—	(0.01)	—	(0.03)
C Sodium azide	0.1	0.3	—	—
Sodium fluoroacetate (1080) — Skin	—	0.05	—	0.15
C Sodium hydroxide	—	2	—	—
Starch	—	E	—	20
Stibine	0.1	0.5	0.3	1.5
Stoddard solvent	100	575	125	720
Strychnine	—	0.15	—	0.45
** Styrene, monomer (Phenylethylene)	(100)	(420)	(125)	(525)
C Subtilisins (Proteolytic enzymes as 100% pure crystalline enzyme)	—	0.00006[m]	—	—
Sucrose	—	E	—	20
** Sulfur dioxide	(5)	(13)	—	—
Sulfur hexafluoride	1,000	6,000	1,250	7,500
Sulfuric acid	—	1	—	—

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

MAP 000168

Substance	ADOPTED VALUES TWA ppm[a]	ADOPTED VALUES TWA mg/m³[b]	TENTATIVE VALUES STEL ppm[a]	TENTATIVE VALUES STEL mg/m³[b]
Sulfur monochloride	1	6	3	18
Sulfur pentafluoride	0.025	0.25	0.075	0.75
Sulfur tetrafluoride	0.1	0.4	0.3	1
Sulfuryl fluoride	5	20	10	40
Systox, see Demeton® — Skin	0.01	0.1	0.03	0.3
2, 4, 5-T	—	10	—	20
Tantalum	—	5	—	10
TEDP — Skin	—	0.2	—	0.6
Teflon® decomposition products	—	B1	—	B1
Tellurium & compounds (as Te)	—	0.1	—	—
Tellurium hexafluoride, as Te	0.02	0.2	—	—
TEPP — Skin	0.004	0.05	0.01	0.2
**C Terphenyls	(1)	(9)	—	—
1, 1, 1, 2-Tetrachloro-2, 2-difluoroethane	500	4,170	625	5,210
1, 1, 2, 2-Tetrachloro-1, 2-difluoroethane	500	4,170	625	5,210
1, 1, 2, 2-Tetrachloroethane — Skin	5	35	10	70
Tetrachloroethylene, see Perchloroethylene — Skin	100	670	150	1,000
Tetrachloromethane, see Carbon tetrachloride — Skin	10	65	20	130
Tetrachloronaphthalene	—	2	—	4
Tetraethyl lead (as Pb) — Skin	—	0.100[c]	—	0.3
Tetrahydrofuran	200	590	250	735
Tetramethyl lead (as Pb) — Skin	—	0.150[c]	—	0.5
Tetramethyl succinonitrile — Skin	0.5	3	2	9
Tetranitromethane	1	8	—	—
Tetryl (2, 4, 6-trinitrophenyl-methylnitramine) — Skin	—	1.5	—	3.0

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

Substance	ADOPTED VALUES TWA ppm[a]	ADOPTED VALUES TWA mg/m³[b]	TENTATIVE VALUES STEL ppm[a]	TENTATIVE VALUES STEL mg/m³[b]
Thallium, soluble compounds (as Tl) — Skin	—	0.1	—	—
4, 4'-Thiobis (6-tert. butyl-m-cresol)	—	10	—	20
Thioglycolic acid	1	5	—	—
Thiram®	—	5	—	10
Tin, inorganic compounds, except SnH_4 and SnO_2 (as Sn)	—	2	—	4
Tin, organic compounds (as Sn) — Skin	—	0.1	—	0.2
Tin oxide (as Sn)	—	E	—	20
Titanium dioxide (as Ti)	—	E	—	20
Toluene (toluol) — Skin	100	375	150	560
**C Toluene-2, 4-diisocyanate (TDI)	(0.02)	(0.14)	—	—
o-Toluidine	5	22	10	44
Toxaphene, see Chlorinated camphene — Skin	—	0.5	—	2.0
** Tributyl phosphate	—	(5)	—	(5)
1, 2, 4-Trichlorobenzene	5	40	—	—
1, 1, 1-Trichloroethane, see Methyl chloroform	350	1,900	450	2,380
1, 1, 2-Trichloroethane — Skin	10	45	20	90
** Trichloroethylene	(100)	(535)	(150)	(800)
Trichloromethane, see Chloroform	10, A2	50, A2	—	—
Trichloronaphthalene	—	5	—	10
1, 2, 3-Trichloropropane	50	300	75	450
1, 1, 2-Trichloro 1, 2, 2-trifluoroethane	1,000	7,600	1,250	9,500
Triethylamine	25	100	40	160
Tricyclohexyltin hydroxide (Plictran®)	—	5	—	10
Trifluoromonobromo-methane	1,000	6,100	1,200	7,300
Trimethyl benzene	25	125	35	170
* Trimethyl phosphite	0.5	2.6	—	—

Capital letters refer to Appendices.
*1979 Addition.
**See Notice of Intended Changes.

MAP 000169

Substance	ADOPTED VALUES TWA ppm[a]	TWA mg/m³[b]	TENTATIVE VALUES STEL ppm[a]	STEL mg/m³[b]
2, 4, 6-Trinitrophenol, see Picric acid — Skin	—	0.1	—	0.3
2, 4, 6-Trinitrophenylmethylnitramine, see Tetryl — Skin	—	1.5	—	3.0
C 2, 4, 6-Trinitrotoluene (TNT)	—	0.5	—	—
Triorthocresyl phosphate	—	0.1	—	0.3
Triphenyl phosphate	—	3	—	6
Tungsten & compounds, as W				
Soluble	—	1	—	3
Insoluble	—	5	—	10
Turpentine	100	560	150	840
Uranium (natural) soluble & insoluble compounds, as U	—	0.2	—	0.6
** Vanadium (V_2O_5), as V				
Dust	—	(0.5)	—	(1.5)
C Fume	—	(0.05)	—	—
Valeraldehyde	50	175	—	—
Vinyl acetate	10	30	20	60
** Vinyl benzene, see Styrene	(100)	(420)	(125)	(525)
** Vinyl bromide	(250)	(1,100)	—	—
** Vinyl chloride	(A1c)	—	(A1c)	—
Vinyl cyanide, see Acrylonitrile — Skin	(20)	(45)	(30)	(65)
Vinyl cyclohexene dioxide	10	60	—	—
Vinylidene chloride	10	40	20	80
** Vinyl toluene	(100)	(480)	(150)	(720)
* VM & P Naphtha	300	1,350	400	1,800
Warfarin	—	0.1	—	0.3
Welding fumes (NOC)†	—	5, B3	—	B3
** Wood dust (nonallergenic)	—	(5)	—	(10)
Xylene (o-, m-, p-isomers) — Skin	100	435	150	655
C m-Xylene α, α'-diamine	—	0.1	—	—
Xylidene — Skin	5	25	10	50

Capital letters refer to Appendices
*1978 Addition
**See Notice of Intended Changes

Substance	ADOPTED VALUES TWA ppm[a]	TWA mg/m³[b]	TENTATIVE VALUES STEL ppm[a]	STEL mg/m³[b]
Yttrium	—	1	—	3
Zinc chloride fume	—	1	—	2
Zinc chromate (as Cr)	—	0.05, A2	—	—
Zinc oxide fume	—	5	—	10
Zinc stearate	—	E	—	20
Zirconium compounds (as Zr)	—	5	—	10

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 substance per cubic meter of air.
d) <7 μm in diameter.
e) As sampled by method that does not collect vapor.
f) For control of general room air, biologic monitoring is essential for personnel control.

Radioactivity: The Committee accepts the philosophy and recommendations of the National Council on Radiation Protection and Measurements (NCRP) for the ionizing radiation TLV. The NCRP is charted by Congress to, in part, collect, analyze, develop and disseminate information and recommendations about protection against radiation and about radiation measurements, quantities and units, including development of basic concepts in these areas. NCRP Report No. 39 (reference 1) provides basic philosophy and concepts leading to protection criteria established in the same report. Other NCRP reports address specific areas of radiation protection and, collectively, provide an excellent basis for establishing a sound program for radiation control. The Committee recommends the listed references as substantative documentation of a sound basis for ionizing radiation protection. The Committee also strongly recommends that all exposures to ionizing radiations be kept low as reasonably achievable within the stated guidance.

References:

1. "Basic Radiation Protection Criteria," NCRP Report No. 39, issued January 15, 1971.

MAP 000170

2. Maximum Permissible Body Burdens and Maximum Permissible Concentrations of Radionuclides in Air and in Water for Occupational Exposure," US Department of Commerce, National Bureau of Standards Handbook 69, issued June 5, 1959, with Addendum 1 issued August 1963. Available as NCRP Report No. 22.

The above documents, as well as information on numerous other NCRP Reports addressing specific subjects in ionizing radiation protection are available from: NCRP Publications, PO Box 30175, Washington, DC 20014.

MINERAL DUSTS

Substance	
SILICA, SiO_2	
Crystalline	
Quartz	TLV in mppcf[o]: $\frac{300^{h}}{\%\ \text{quartz} + 10}$ TLV for respirable dust in mg/m³: $\frac{10\ \text{mg/m}^3\ i}{\%\ \text{Respirable quartz} + 2}$ TLV for "total dust," respirable and nonrespirable: $\frac{30\ \text{mg/m}^3}{\%\ \text{quartz} + 3}$
Cristobalite	Use one-half the value calculated from the count or mass formulae for quartz.
Tridymite	Use one-half the value calculated from formulae for quartz.
Silica, fused	Use quartz formulae.
Tripoli	Use respirable[n] mass quartz formula
**Amorphous	(20 mppcf[o])
SILICATES (<1% quartz)	
**Asbestos, all forms	(5 fibers/cc > 5μm in length[j]; A1a)
Mica	20 mppcf
Mineral wool fiber	10 mg/m³
Perlite	30 mppcf
Portland Cement	30 mppcf
Soapstone	20 mppcf
Talc (nonasbestiform)	20 mppcf

**Talc (fibrous), use Asbestos limit.
**Tremolite, see Asbestos.

COAL DUST

2 mg/m³ (respirable dust fraction < 5% quartz).
If > 5% quartz, use respirable mass formula.

NUISANCE PARTICULATES
(see Appendix E)

30 mppcf or 10 mg/m³[j]
of total dust < 1% quartz, or, 5 mg/m³ respirable dust.

Conversion factors:
mppcf × 35.3 = Million particles per cubic meter
= particles per cc

---

g) Millions of particles per cubic foot of air, based on impinger samples counted by light-field technics.
h) The percentage of quartz in the formula is the amount determined from airborne samples, except in those instances in which other methods have been shown to be applicable.
i) Both concentration and percent quartz 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

j) containing <1% quartz; if quartz content > 1%, use formulae for quartz.
k) Lint-free dust as measured by the vertical-elutriator, cotton-dust sampler described in the Transactions of

**See Notice of Intended Changes

**See Notice of Intended Changes

MAP 000171

the National Conference on Cotton Dust, J. R. Lynch, pg. 33. May 2. 1970.

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

m) Based on "high volume" sampling.

n) "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.

NOTICE OF INTENDED CHANGES (for 1979)

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. Documentation is available for each of these substances.

Substance	TWA ppm[a]	TWA mg/m³[b]	STEL ppm[a]	STEL mg/m³[b]
+ Acetone	750	1780	1000	2375
Acetylsalicylic acid (Aspirin)	—	5	—	—
+ Acrylic Acid	10	30	—	—
Acrylonitrile	A1b	A1b	—	—
Aniline and homologues — Skin	2	10	5	20
Antimony, soluble salts (as Sb)	—	2	—	—
Antimony trioxide production	—	—, A2	—	—
Arsenic (soluble), as As	—	0.2	—	—
Arsenic trioxide production	—	—, A2	—	—
Baytex	—	0.1	—	0 3
+ Butane	800	1900	—	—
+ 2-Butoxyenthanol (Butyl Cellosolve)-Skin	25	120	75	360
+ sec-Butyl alcohol	100	305	150	455
+ n-Butyl glycidyl ether (BGE)	25	135	—	—
o-sec Butylphenol — Skin	5	—	—	—
Cadmium oxide production	—	—, A2	—	—
Carbon disulfide	10	30	—	—
+ Carbon tetrachloride — Skin	5, A2	30, A2	20	125
+ Carbonyl fluoride	2	5	5	15
Chloroacetyl chloride	0.05	0.2	—	—
Chloromethyl methyl ether	A1b	A1b	—	—
+ 1-Chloro-1-nitropropane	2	10	—	—
+ Chloropentafluoroethane	1000	6320	—	—
β-Chloroprene — Skin	10	45	—	—
+ Chromium metal	—	0.5	—	—
+ Chromium (II) compounds (as Cr)	—	0.5	—	—
+ Chromium (III) compounds (as Cr)	—	0.5	—	—
+ Chromium (VI) compounds (as Cr) Water soluble Cr VI compounds	—	0.05	—	—

Capital letters refer to Appendices
+1979 Revision or Addition

MAP 000172

Substance	TWA ppm[a]	TWA mg/m³[b]	STEL ppm[a]	STEL mg/m³[b]
Certain water insoluble Cr VI compounds	—	0.05, A1a	—	—
† Chrysene	A2	A2	—	—
Cobalt metal, dust & fume (as Co)	—	0.05	—	0.1
C Cyanogen chloride	0.3	0.6	—	—
† Cyclohexanone	25	100	100	400
† Cyclopentane	600	1,720	900	2,580
Dalapon	1	—	—	—
1, 2-Dibromoethane — Skin	A1b	A1b	—	—
1, 2-Dichloroethane	10	40	15	60
Dichloromonofluoro-methane	10	40	—	—
† 1, 1-Dichloro-1-nitroethane	2	10	10	60
Dichloropropene	1	5	10	50
Diethanolamine	3	15	—	—
† Diethylamine	10	30	25	75
† Diethyl ketone	200	705	—	—
† Diglycidyl ether (DGE)	0.1	0.5	—	—
† Dioxane, tech. grade — Skin	25	90	100	360
† Dipropyl ketone	50	235	—	—
Divinyl benzene	10	50	—	—
Epichlorhydrin — Skin	2	10	5	20
† 2-Ethoxyethanol — Skin	50	185	100	370
† 2-Ethoxyethyl acetate (Cellosolve acetate) — Skin	50	270	100	540
† Ethyl acrylate — Skin	5	20	25	100
Ethylene dibromide, see 1, 2-Dibromoethane	A1b	A1b	—	—
Ethylene dichloride, see 1, 2-Dichloroethane	10	40	15	60
†C Ethylene glycol, vapor	50	125	—	—
† Ethylene glycol dinitrate	0.02	0.2	0.04	0.4
† Ethylene oxide	10	20	—	—
† Furfural — Skin	2	8	—	—
† Glycidol (2, 3-Epoxy-1-propanol)	25	75	100	300
Hexachlorobutadiene	A2	A2	—	—
† Hexane (n-hexane)	25	90	100	350
(other Isomers)	500	1,800	—	—
† Hexone (Methyl isobutyl ketone) — Skin	50	205	75	300

Capital letters refer to Appendices.
†1979 Addition

Substance	TWA ppm[a]	TWA mg/m³[b]	STEL ppm[a]	STEL mg/m³[b]
C Hydrogen cyanide — Skin	10	10	—	—
2-Hydroxypropyl acrylate — Skin	0.5	3	—	—
† Isopropoxyethanol	25	105	75	320
n-Isopropylaniline — Skin	2	10	5	20
† Mesityl oxide	15	60	25	100
† Methacrylic acid	20	70	—	—
† Methyl n-amyl ketone (2-Heptanone)	50	235	100	465
† Methyl bromide — Skin	5	20	15	60
† Methyl n-butyl ketone	5	20	—	—
† Methyl chloride	50	105	100	205
Methylene chloride (dichloromethane)	100	360	500	1,700
4, 4-Methylene dianiline	0.1	0.8	0.5	4
† Methyl iodide — Skin	2, A2	10, A2	5	30
† Methyl isopropyl ketone	200	705	—	—
† Methyl silicate	1	6	5	30
† α-Methyl styrene	50	240	100	485
† Nitrogen dioxide	3	6	5	10
† Nitroglycerin	0.02	0.2	0.04	0.4
† 1-Nitropropane	15	55	25	90
C 2-Nitropropane	25, A2	90, A2	—	—
† Phenyl ether — Diphenyl mixture (vapor)	0.5	4	2	8
Phosphorous pentachloride	0.1	1	—	—
† Platinum metal	—	1	—	—
† β-Propiolactone	0.5, A2	1.5, A2	1	3
Propionic acid	10	30	15	45
† Propylene glycol dinitrate	0.02	0.2	0.04	0.4
† Propylene oxide	20	50	—	—
Silver, metal	—	0.1	—	—
† Silver, soluble compounds (as Ag)	—	0.01	—	—
Sodium bisulfite	—	5	—	—
Sodium metabisulfite	—	5	—	—
† Styrene, monomer (phenylethylene)	50	215	100	425
Sulfur dioxide	2	5	5	15
C Terphenyls	0.5	5	—	—
Tetrasodium pyrophosphate	—	5	—	—

Capital letters refer to Appendices.
†1979 Addition.

MAP 000173

Substance	TWA ppm[a]	TWA mg/m³[b]	STEL ppm[a]	STEL mg/m³[b]
† Toluene-2, 4-diisocyanate (TDI)	0.005	0.04	0.02	0.15
† Tributyl phospate	0.2	2.5	0.4	5
Trichloroacetic acid	—	1	—	—
† Trichloroethylene	50	270	150	805
† Trimellitic anhydride	0.005	0.04	—	—
† Vanadium (V_2O_5), as V, dust & fume	—	0.05	—	—
Vinyl bromide	5, A2	20, A2	—	—
Vinyl chloride	5, A1a	10, A1a	—	—
† Vinyl toluene	50	240	100	485
† Wood dust, hard wood (as in furniture making)	—	1	—	—

NOTICE OF INTENDED CHANGES
MINERAL DUSTS

Substance	TLV
Asbestos	
Amosite	0.5 fiber/cc, A1a
Chrysotile	2 fibers/cc, A1a
Crocidolite	0.2 fiber/cc, A1a
Tremolite	0.5 fiber/cc, A1a
Other forms	2 fibers/cc, A1a
Diatomaceous earth, natural	1.5 mg/m³, Respirable dust
Silica, amorphous	6 mg/m³, Total dust (all sampled sizes)
	3 mg/m³, Respirable dust (< 5 μm)
Talc (fibrous)	0.5 fiber/cc

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).

A1a. *Human Carcinogens*. Substances, or substances associated with industrial processes, recognized to have carcinogenic or cocarcinogenic potential, with an assigned TLV:

	TLV
** Arsenic trioxide production	(As_2O_3, 0.05 mg/m³ as As) (SO_2, C 5.0 ppm) (Sb_2O_3, 0.5 mg/m³ (as Sb))
** Asbestos, all forms*	(5 fibers/cc, > 5 μm in length)
bis (Chloromethyl) ether	0.001 ppm
Chromite ore processing (chromate)	0.05 mg/m³ (as Cr)
Nickel sulfide roasting, fume & dust	1.0 mg/m³ (as Ni)
Particulate Polycyclic Aromatic Hydrocarbons (PPAH)	0.2 mg/m³, as benzene solubles
Vinyl chloride	5 ppm

* * *

A1b. *Human Carcinogens*. Substances, or substances associated with industrial processes, recognized to have carcinogenic potential without an assigned TLV:

Acrylonitrile
4-Aminodiphenyl (p-Xenylamine)
Benzidine production
Chloromethyl methyl ether
1, 2-Dibromoethane (Ethylene dibromide)
β-Naphthylamine
4-Nitrodiphenyl

† 1979 Addition

*Cigarette smoking can enhance the incidence of respiratory cancers from this or others of these substances or processes
**See Notice of Intended Changes

MAP 000174

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. The worker should be properly equipped to insure virtually no contact with the carcinogen.

A2. *Industrial Substances Suspect of Carcinogenic Potential for MAN*. Chemical substances or substances associated with industrial processes, which are suspect of inducing cancer, based on either (1) limited epidemiologic evidence, exclusive of clinical reports of single cases, or (2) demonstration of carcinogenesis in one or more animal species by appropriate methods.

3-Amino 1, 2, 4-triazole	
**Antimony trioxide production*	(0.5 mg/m³)
Benzene	10 ppm
Benz(a)pyrene	——
Beryllium	2.0 μg/m³
**Cadmium oxide production	(0.05 mg/m³)
Chloroform	10 ppm
Chromates of lead and zinc (as Cr)	0.05 mg/m³
3, 3'-Dichlorobenzidine	——
Dimethylcarbamyl chloride	——
1, 1-Dimethyl hydrazine	0.5 ppm
Dimethyl sulfate — Skin	0.1 ppm
Epichlorhydrin	5 ppm
Hexachlorobutadiene	——
Hexamethyl phosphoramide — Skin	——
Hydrazine	0.1 ppm
Lead chromate	0.05 mg/m³
4, 4'-Methylene bis (2-chloroaniline) — Skin	0.02 ppm
Monomethyl hydrazine	0.2 ppm
C 2-Nitropropane	25 ppm
n-Nitrosodimethylamine	——
* n-Phenyl-beta-naphthylamine	——
Propane sultone	——
beta-Propiolactone	——
Vinyl cyclohexene dioxide	10 ppm
Zinc chromate (as Cr)	0.05 mg/m³

**Cigarette smoking can enhance the incidence of respiratory cancers from this or others of these substances or processes.

For the above, worker exposure by all routes should be carefully controlled to levels consistent with the animal and human experience data (see Documentation), including those substances with a listed TLV.

THE COMMITTEE GUIDELINES FOR CLASSIFICATION OF EXPERIMENTAL ANIMAL CARCINOGENS

The following guidelines are offered in the present state of knowledge as an aid in classifying substances in the occupational environment found to be carcinogenic in experimental animals. A need was felt by the Threshold Limits Committee for such a classification in order to take the first step in developing an appropriate TLV for occupational exposure.

Determination of Approximate Threshold of Response Requirement. In order to determine in which category to classify an experimental carcinogen for the purpose of assigning an industrial air limit (TLV), an approximate threshold of neoplastic response must be determined. Because of practical experimental difficulties, a precisely defined threshold cannot be attained. For the purposes of standard-setting, this is of little moment, as an appropriate risk, or safety, factor can be applied to the approximate threshold, the magnitude of which is dependent on the degree of potency of the carcinogenic response.

To obtain the best 'practical' threshold of neoplastic response, dosage decrements should be less than logarithmic. This becomes particularly important at levels greater than 10 ppm (or corresponding mg/m³). Accordingly, after a range-finding determination has been made by logarithmic decreases, two additional dosage levels are required within the levels of "effect" and "no effect" to approximate the true threshold of neoplastic response.

The second step should attempt to establish a metabolic relationship between animal and man for the particular substance found carcinogenic in animals. If the metabolic pathways are found compa-

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rable, the substance should be classed highly suspect as a carcinogen for man. If no such relation is found, the substance should remain listed as an experimental animal carcinogen until evidence to the contrary is found.

Proposed Classification of Experimental Animal Carcinogens. Substances occurring in the occupational environment found carcinogenic for animals may be grouped into three classes, those of high, intermediate and low potency. In evaluating the incidence of animal cancers, significant incidence of cancer is defined as a neoplastic response which represents, in the judgment of the Committee, a significant excess of cancers above that occurring in negative controls.

EXCEPTIONS: No substance is to be considered an occupational carcinogen of any practical significance which reacts by the respiratory route at or above 1000 mg/m³ for the mouse, 2000 mg/m³ for the rat; by the dermal route, at or above 1500 mg/kg for the mouse, 3000 mg/kg for the rat; by the gastrointestinal route at or above 500 mg/kg/d for a lifetime, equivalent to about 100 g T.D. for the rat, 10g T.D. for the mouse.

These dosage limitations exclude such substances as dioxane and trichlorethylene from consideration as carcinogens.

Examples: Dioxane — rats, hepatocellular and nasal tumors from 1015 mg/kg/d, oral

Trichloroethylene — female mice, tumors (30/98 @ 900 mg/kg/d), oral

Industrial Substances of High Carcinogenic Potency in Experimental Animals.

1. A substance to qualify as a carcinogen of high potency must fulfill one of the three following conditions in two animal species:

   1a. *Respiratory*. Elicit cancer from (1) dosages below 1 mg/m³ (or equivalent ppm) via the respiratory tract in 6- 7-hour daily repeated inhalation exposures throughout lifetime; or (2) from a single intratracheally administered dose not exceeding 1 mg of particulate, or liquid, per 100 ml or less of animal minute respiratory volume;

   Examples: bis-Chloromethyl ether, malignant tumors, rats, @ 0.47 mg/m³ (0.1 ppm) in 2 years;

   Hexamethyl phosphoramide, nasal squamous cell carcinoma, rats, @ 0.05 ppm, in 13 months

   OR

   1b. *Dermal*. Elicit cancer within 20 weeks by skin-painting, twice weekly at 2 mg/kg body weight or less per application for a total dose equal to or less than 1.5 mg, in a biologically inert vehicle;

   Examples: 7, 12-Dimethylbenz(a)anthracene — skin tumors @ 0.12-0.8 mg T.D. in four weeks

   Benzo(a)pyrene, mice 12 μg, 3X/wk for 18 mos. T.D. 2.6 mg, 90.9% skin tumors

   OR

   1c. *Gastrointestinal*. Elicit cancer by daily intake via the gastrointestinal tract, within six months, with a six-month holding period, at a dosage below 1 mg/kg body weight per day; total dose, rat, ≤ 50 mg; mouse, ≤ 3.5 mg;

   Examples: 7, 12-Dimethylbenz(a)anthracene — mammary tumors from 10 mg 1X

   3-Methylcholanthrene — Tumors @ 3 sites from 8 mg in 89 weeks

   Benzo(a)pyrene, mice, 3.9% leukemias, from 30 mg T.D. 198 days

2. Elicit cancer by all three routes in at least two animal species at dose levels prescribed for high or intermediate potency.

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Industrial Substances of Intermediate Carcinogenic Potency in Experimental Animals.

To qualify as a carcinogen of intermediate potency, a substance should elicit cancer in two animal species at dosages intermediate between those described in A3a and A3c by two routes of administration.

Example: Carbamic acid ethyl ester
Dermal, mammary tumors, mice, 100%, 63 weeks, 500–1400 mg T.D.
Gastrointestinal, various type tumors, mice 42 weeks, 320 mg T.D.

Gastrointestinal, various type tumors, rats, 60 weeks, 110–930 mg T.D.

Industrial Substances of Low Carcinogenic Potency in Experimental Animals.

To qualify as a carcinogen of low potency, a substance should elicit cancer in one animal species by any *one* of three routes of administration at the following prescribed dosages and conditions:

1a. *Respiratory*. Elicit cancer from (1) dosages greater than 10 mg/m³ (or equivalent ppm) via the respiratory tract in 6- 7-hour, daily repeated inhalation exposures, for 12 months' exposure and 12 months' observation period; or (2) from intratracheally administered dosages totaling more than 10 mg of particulate or liquid per 100 ml or more of animal minute respiratory volume;

Examples: Beryl (beryllium aluminum silicate) malig. lung tumors, rats, @ 15 mg/m³ @ 17 months

Benzidine, var. tumors, rats, 10–20 mg/m³ @ >13 mos.

OR

1b. *Dermal*. Elicit cancer by skin-painting of mice in twice weekly dosages of >10 mg/kg body weight in a biologically inert vehicle for at least 75 weeks, i.e., ≥ 1.5g T.D.

Examples: Shale tar, mouse, 0.1 ml × 50 = 5g T.D. 59/60 skin tumors

Arsenic trioxide, man, dose unknown, but estimated to be high

1c. *Gastrointestinal*. Elicit cancer from daily oral dosages of 50 mg/kg/day or greater during the lifetime of the animal.

APPENDIX B
SUBSTANCES OF VARIABLE COMPOSITION

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 minimal.

B2 *Gasoline*. The composition of gasoline 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); Runion, ibid. *36*, 338, 1975).

B3 *Welding Fumes — Total Particulate (NOC)***
TLV, 5 *mg/m³*

Welding fumes cannot be classified simply. The composition and quantity of both are dependent on the alloy being welded and the process and electrodes used. Reliable analysis of fumes cannot be made without considering the nature of the welding process and system being examined; reactive metals and alloys such as aluminum and titanium are arc-welded in a protective, inert atmosphere such as argon. These arcs create relatively little fume, but an intense radiation which can produce ozone. Similar processes are used to arc-weld steels, also creating a relatively low level of fumes. Ferrous alloys also are arc-welded in oxidizing environments which generate considerable fume, and can produce carbon

*Trade Names. Algoflon, Fluon, Halon, Teflon, Tetran
**Not otherwise classified (NOC).

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monoxide instead of ozone. Such fumes generally are composed of discreet particles of amorphous slags containing iron, manganese, silicon and other metallic constituents depending on the alloy system involved. Chromium and nickel compounds are found in fumes when stainless steels are arc-welded. Some coated and flux-cored electrodes are formulated with fluorides and the fumes associated with them can contain significantly more fluorides than oxides. Because of the above factors, arc-welding fumes frequently must be tested for individual constituents which are likely to be present to determine whether specific TLV's are exceeded. Conclusions based on total fume concentration are generally adequate if no toxic elements are present in welding rod, metal, or metal coating and conditions are not conducive to the formation of toxic gases.

Most welding, even with primitive ventilation, does not produce exposures inside the welding helmet above 5 mg/m³. That which does, should be controlled.

APPENDIX C
MIXTURES

C.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,

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

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 a 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.).

Synergistic action or potentiation may occur with some combinations of atmospheric contaminants. Such cases at present must be determined individually. Potentiating or synergistic 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 a given operation or process characteristically emits a number of harmful dusts, 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.

C.1A Examples of THRESHOLD LIMIT VALUES FOR MIXTURES

The following formulae apply only when the components in a mixture have similar toxicologic effects; they should not be used for mixtures with widely differing reactivities, e.g. hydrogen cyanide & sulfur dioxide. In such case the formula for Independent Effects (1A.c.) should be used.

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.)*

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

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Example No. 1A.a.: Air contains 400 ppm of acetone (TLV = 1000 ppm) 150 ppm of secbutyl acetate (TLV = 200 ppm) and 100 ppm of 2-butanone (TLV = 200 ppm)

Atmospheric concentration of mixture = 400 + 150 + 100 = 650 ppm of mixture

$$\frac{400}{1000} + \frac{150}{200} + \frac{100}{200} = 0.4 + 0.75 + 0.5 = 1.65$$

Threshold Limit is exceeded.

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 contains (by weight)
50% heptane: TLV = 400 ppm or 1600 mg/m³
1 mg/m³ ≡ 0.25 ppm
30% methyl chloroform: TLV = 350 ppm or 1900 mg/m³
1 mg/m³ ≡ 0.28 ppm

20% perchloroethylene: TLV = 100 ppm or 670 mg/m³
1 mg/m³ ≡ 0.15 ppm

$$\text{TLV of Mixture} = \frac{1}{\frac{0.5}{1600} + \frac{0.3}{1900} + \frac{0.2}{670}}$$

$$= \frac{1}{0.00031 + 0.00016 + 0.00030}$$

$$= \frac{1}{0.00077} = 1300 \text{ mg/m}^3$$

of this mixture
50% or (1300) (0.5) = 650 mg/m³ is heptane
30% or (1300) (0.3) = 390 mg/m³ is methyl chloroform
20% or (1300) (0.2) = 260 mg/m³ is perchloroethylene

These values can be converted to ppm as follows:

heptane: 650 mg/m³ × 0.25 = 162 ppm
methyl chloroform: 390 mg/m³ × 0.18 = 70 ppm
perchloroethylene: 260 mg/m³ × 0.15 = 39 ppm

TLV of mixture = 162 + 70 + 39 = 271 ppm, or 1300 mg/m³

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. TLV for Mixtures of Mineral Dusts.

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

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

$$\text{TLV} = \frac{1}{\frac{0.8}{20} + \frac{0.2}{2.7}} = 9 \text{ mppcf}$$

TLV of nonasbestiform talc (pure) = 20 mppcf

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TLV of quartz (pure) =

$$\frac{300}{100 + 10} = \frac{300}{110} = 2.7 \text{ mppcf}$$

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:

25% quartz — TLV (pure) = 2.7 mppcf
25% amorphous silica — TLV (pure) = mppcf
50% talc TLV (pure) = 20 mppcf

$$\text{TLV} = \frac{1}{\frac{0.25}{2.7} + \frac{0.25}{20} + \frac{0.5}{20}} = 8 \text{ mppcf}$$

The limit for 25% quartz approximates 9 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
Nitrobenzene	1	3	2
Carbon tetrachloride	10	2	20
Trimethyl benzene	25	1.5	35
Acetone	1000	1.25	1250
Boron trifluoride	C 1	—	1
Butylamine	C 5	—	5

EXCURSION FACTORS

For all substances not bearing C notation

		Excursion Factor	
TLV > 0–1	(ppm or mg/m³),	"	= 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.

INTERPRETATION OF MEASURED PEAK CONCENTRATIONS

With increasing use of rapid, direct-reading analytical instruments for airborne contaminants in the work area, the question of interpretation of essentially "instantaneous" peaks arises. Although no general statement can be made covering all occupational substances, the following guidelines should prove helpful, assuming peak excursions conform to time-weighted average TLV as stated above.

The toxicologic importance of momentary peak concentrations depends on whether the substance is fast or slow acting. If slow acting, as for quartz, lead, or carbon monoxide, momentary peaks are of no toxicologic concern provided, of course, they are not astronomic. On the other hand, fast-acting substances that rapidly produce disabling narcosis, e.g., H_2S, or intolerable irritation or asphyxiation, NH_3, SO_2, CO_2, or initiate sensitization — the organic isocyanates, even "instantaneous" peaks appreciably above the permissible excursion, should not be permitted, unless information exists to the

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contrary. Other more specific excursions will be developed in the future.

APPENDIX E
Some Nuisance Particulates[o]

TLV. 30 mppcf or 10mg/m³ of total dust < 1% quartz, or, 5 mg/m³ respirable dust

Alundum®	Kaolin
Calcium carbonate	Limestone
Calcium silicate	Magnesite
Cellulose (paper fiber)	Marble
Portland Cement	Mineral Wool Fiber
Corundum (Al_2O_3)	Pentaerythritol
Emery	Plaster of Paris
Glycerin Mist	Silicon
Graphite (synthetic)	Silicon Carbide
Gypsum	Starch
Vegetable oil mists (except castor, cashew nut, or similar irritant oils)	Sucrose
	Tin Oxide
	Titanium Dioxide
	Zinc Stearate
	Zinc oxide dust

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

APPENDIX F
Some Simple Asphyxiants[p]

Acetylene	Hydrogen
Argon	Methane
Butane	Neon
Ethane	Propane
Ethylene	Propylene
Helium	

p) As defined on pg. 6.

APPENDIX G
Conversion of mppcf to Mass Concentration

Calculations for Conversion of Particle Count Concentration (by Standard Light Field — Midget Impinger Techniques), in mppcf, to Respirable Mass Concentration (by Respirable Sampler) in mg/m³.+

+ Relationship Between Gravimetric Respirable Dust Concentration and Midget Impinger Number Concentration. by Murray Jacobson and T F Tomb AIHAJ. 28 Nov–Dec. 1967

1. In 1967, Jacobsen and Tomb,+ derived an empirical relationship of 5.6 mppcf to 1 milligram of respirable dust per cubic meter of air, based on 23 sets of samples, mostly coal dust. The following calculation results in an equivalence of 6.37 mppcf to 1 mg/m³ of respirable dust. Thus, an approximate ratio of 6 mppcf to 1 mg/m³ of respirable dust is suggested for conversion of TLVs from a count to a mass basis when the density and mass median diameter have not been determined.

2. Basic assumptions:
   a) Average density for silica containing dusts ≈ 2.5 gms/cm³ (2500 mg/cm³). Pulmonary significant dust densities may vary from 1.2 gm/cm³ for coal dust to 3.1 gms/cm³ for Portland Cement. Silica densities vary from 2.2 (amorphous) to 2.3 (cristobalite and tridymite) to 2.5 (alpha-quartz.) gms per cm³.
   b) The mass median diameter (mmd) of particles collected in midget impinger samplers and counted by the standard light field technique, *and* collected in a respirable sampler is approximately 1.5 μm or 1.5×10^{-4} cm. This assumption is, of course, quite arbitrary since the mmd of all dust clouds is quite variable, depending on many independent parameters, such as source of dust, age of dust cloud, meteorological conditions, etc.

3. Calculation:
   a) vol. per particle: $4/3\ \pi\ r^3$; $r = 0.75 \times 10^{-4}$ cm
      $= 4/3 \cdot \pi \cdot (0.75 \times 10^{-4})^3$
      $= 1.77 \times 10^{-12}$ cm³
   b) wt. per particle = vol. × density
      $= 1.77 \times 10^{-12}$ cm³ $\times\ 2.5 \times 10^{3}$ mg/cm³
      $= 4.425 \times 10^{-9}$ mg/particle
   c) 1 particle/ft.³ = 35.5 part./m³
      (since 35.5 cu ft = 1 cu m.)
      10^6 part./ft³ = mppcf = 35.5×10^6 part./m³

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wt. of 1 mppcf = 35.5×10^6 part./m³ × 4.425×10^{-9} mg/part.

1 mppcf = 0.157 mg/m³

or

6.37 mppcf = 1 mg/m³

or approximately 6 mpccf = 1 mg/m³.

4. Equivalent TLVs in mppcf and mg/m³ (respirable mass) for Mineral Dusts.

Substance	Threshold Limit Value		
	Count mppcf	Resp. Mass mg/m³	Total Mass* mg/m³
Silica (SiO_2)			
Amorphous	20	(3)**	(6)
Cristobalite	1.5	0.05	0.15
Fused silica	3	0.1	0.3
Quartz	3	0.1	0.3
Tridymite	1.5	0.05	0.15
Coal Dust	(12)	2	(4)
Diatomaceous earth, natural	—	1.5	—
Graphite (natural)	15	(2.5)	(5)
Mica	20	(3)	(6)
Mineral wool fiber	—	(5)	10
Nuisance particulates	30	(5)	10
Perlite	30	(5)	(10)
Portland Cement	30	(5)	(10)
Soapstone	20	(3)	(6)
Talc (nonasbestiform)	20	(3)	(6)
Tripoli	(3)	0.1	(0.3)

*Unless otherwise specified, respirable mass is presumed to equal approximately 50% of total mass.

**All values in parentheses ( ) represent newly calculated values based on equivalence of 6 mppcf = 1 mg/m³ respirable mass and respirable mass = 50% total mass.

TLVs®
Threshold Limit Values for Physical Agents Adopted by ACGIH for 1979

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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.

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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 1 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*; F. N. Dukes-Dobos and A. Henschel: *"Development of Permissible Heat Exposure Limits for Occupational Work."* ASHRAE Journal, Vol. 15: No. 9, September 1973, pp. 57–62.)

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:
   $WBGT = 0.7WB + 0.2GT + 0.1\ DB$
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 1

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

	Work Load		
Work — Rest Regimen	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 1 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.

EVALUATION AND CONTROL

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 −5°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

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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. A 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.

C. A 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 as that of 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 1964.

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

II. *Work Load Categories*

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 (up to 200 Kcal/hr or 800 Btu/hr): e.g., sitting or standing to control machines, performing light hand or arm work,

(2) moderate work (200–350 Kcal/hr or 800–1400 Btu/hr): e.g., walking about with moderate lifting and pushing,

(3) heavy work (350–500 Kcal/hr or 1400–2000 Btu/hr): 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. When this method is used the permissible heat exposure limit can be determined by Figure 1.

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

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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 1 and Figure 1 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. Where the WBGT of the work area is different from that of the rest area a time-weighted average value should be used for both environmental and metabolic heat. When time-weighted average values are used the appropriate curve on Figure 1 is the solid line labeled "continuous."

The time-weighted average metabolic rate (M) shall be determined by the equation:

$$\text{Av. } M = \frac{(M_1) \times (t_1) + (M_2) \times (t_2) + \ldots + (M_n) \times (t_n)}{(t_1) + (t_2) + \ldots + (t_n)}$$

Where M_1 M_2, M_n are estimated or measured metabolic rates for the various activities of the worker during the total time period. t_1, t_2, t_n are the elapsed times in minutes spent at the corresponding metabolic rate as determined by a time study.

The time-weighted average WBGT shall be determined by the equation:

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$$\text{Av. WBGT} = \frac{(\text{WBGT}_1) \times (t_1) + (\text{WBGT}_2) \times t_2 + \ldots + (\text{WBGT}_n) \times (t_n)}{(t_1) + (t_2) + \ldots + (t_n)}$$

where WBGT_1, WBGT_2, WBGT_n are calculated values of WBGT for the various work and rest areas occupied during total time periods. t_1, t_2, t_n are the elapsed times in minutes spent in the corresponding areas which are determined by a time study. Where exposure to hot environmental conditions is continuous for several hours or the entire work day, the time-weighted averages shall be calculated as hourly time-weighted average i.e., $t_1 + t_2 + \ldots t_n = 60$ minutes. Where the exposure is intermittent, the time-weighted averages shall be calculated as two-hour time-weighted averages, i.e., $t_1 + t_2 + \ldots t_n = 120$ minutes.

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 shall be kept reasonably cool (10°–15°C or 50.0°–60.0°F) 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 cothing 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 1 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.

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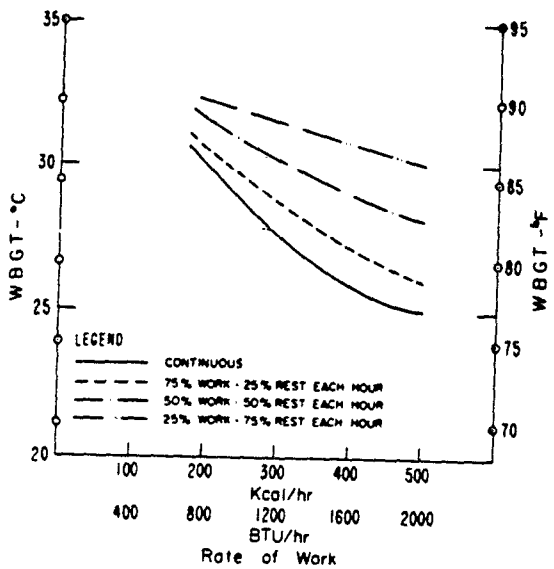


Figure 1 — Permissible Heat Exposure Threshold Limit Value

IONIZING RADIATION

The Committee accepts the philosophy and recommendations of the National Council on Radiation Protection and Measurements (NCRP) for the ionizing radiation TLV. The NCRP is charted by Congress to, in part, collect, analyze, develop and disseminate information and recommendations about protection against radiation and about radiation measurements, quantities and units, including development of basic concepts in these areas. NCRP Report No. 39 (reference 1) provides basic philosophy and concepts leading to protection criteria established in the same report. Other NCRP reports address specific areas of radiation protection and, collectively, provide an excellent basis for establishing a sound program for radiation control. The Committee recommends the listed references as substantative documentation of a sound basis for ionizing radiation protection. The committee also strongly recommends that all exposures to ionizing radiations be kept as low as reasonably achievable within the stated guidance.

References:

1. "Basic Radiation Protection Criteria," NCRP Report No. 39, issued January 15, 1971.
2. Maximum Permissible Body Burdens and Maximum Permissible Concentrations of Radionuclides in Air and in Water for Occupational Exposure," US Department of Commerce, National Bureau of Standards Handbook 69, issued June 5, 1959, with Addendum 1 issued August 1963. Available as NCRP Report No. 22. The above documents, as well as information on numerous other NCRP Reports addressing specific subjects in ionizing radiation protection are available from: NCRP Publications, PO Box 30175, Washington, DC 20014.

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.

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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); and except for all TLVs for wavelengths between 0.1–1 mm where the limiting aperture is 10 mm. 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 Factors A and B (C_A and C_B)

The TLVs for ocular exposure in Tables 3 and 4 are to be used as given for all wavelength ranges. The TLVs for wavelengths between 700 nm and 1049 nm are to be increased by a uniformly extrapolated factor (C_A) as shown in Figure 2. Between 1049 nm and 1400 nm, the TLV has been increased by a factor (C_A) of five. For certain exposure times at wavelengths between 550 nm and 700 nm, correction factor (C_B) must be applied.

The TLVs for skin exposure are given in Table 6. The TLVs are to be increased by a factor (C_A) as shown in Figure 2 for wavelengths between 700 nm and 1400 nm. To aid in the determination of TLVs for exposure durations requiring calculations of fractional powers Figures 3, 4, 5 and 6 may be used.

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^{-5} second. For pulses of greater duration, the following formula should be followed:

$$\text{Standard}\begin{pmatrix}\text{single pulse}\\ \text{in train}\end{pmatrix} = \frac{\text{Standard (pulse } n\tau)}{n}$$

where:

n = number of pulses in train
τ = duration of a single pulse in the train
Standard ($n\tau$) = protection standard of one pulse having a duration equal to $n\tau$ seconds.

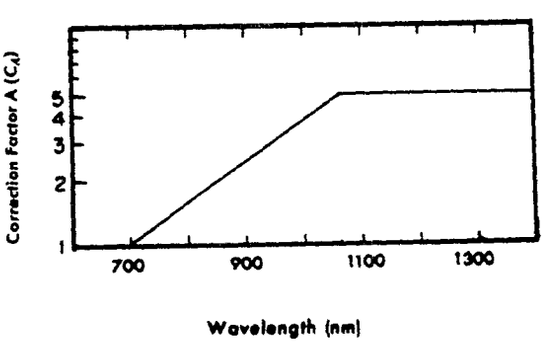


Figure 2 — TLV correction factor for λ = 700 – 1400 nm*

*For λ = 700 – 1049 nm, $C_A = 10^{[0.002(\lambda - 700)]}$
For λ = 1050 – 1400 nm, C_A = 5

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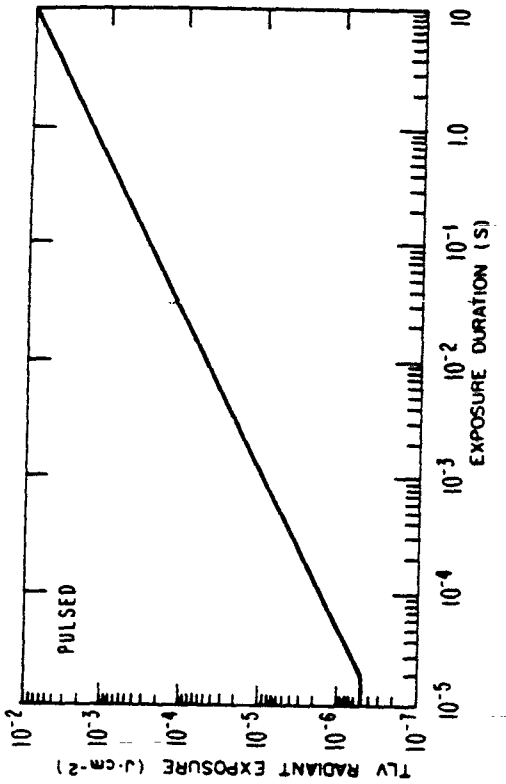


Figure 3a — TLV for intrabeam (direct) viewing of laser beam (400–700 nm).

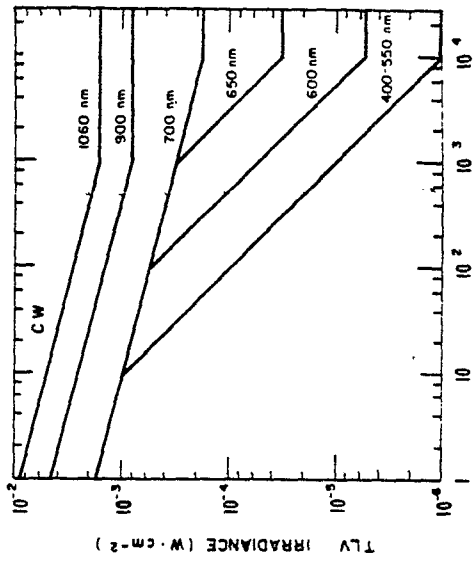


Figure 3b — TLV for intrabeam (direct) viewing of CW laser beam (400–1400 nm)

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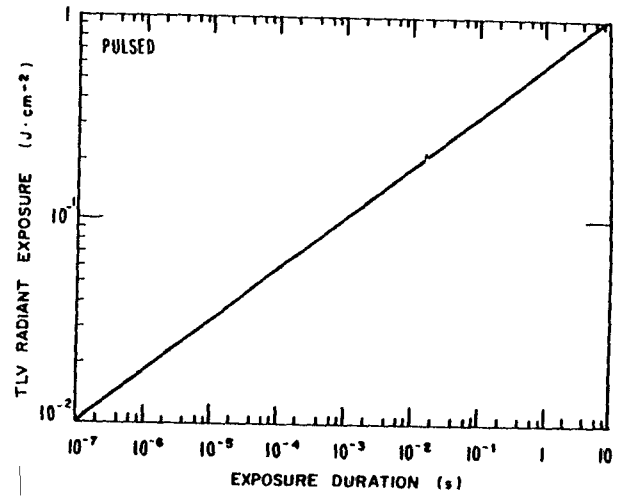


Figure 4a — TLV for laser exposure of skin and eyes for far-infrared radiation (wave-lengths greater than 1.4 μm).

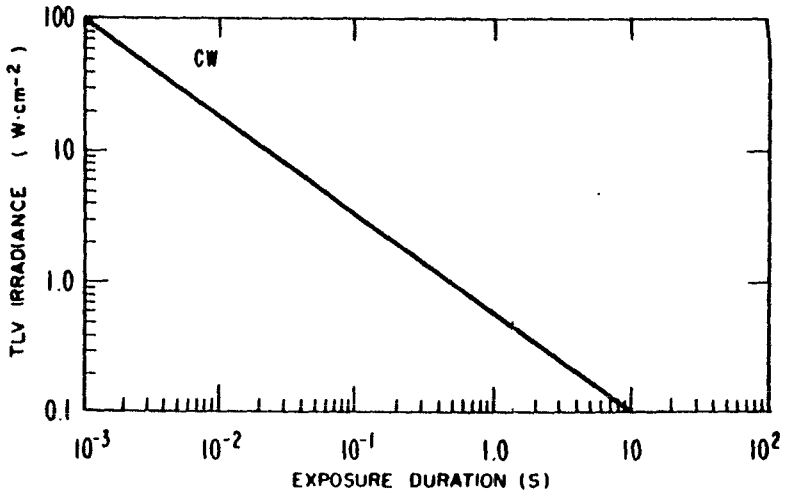


Figure 4b — TLV for CW laser exposure of skin and eyes for far-infrared radiation (wavelengths greater than 1.4 μm).

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

Figure 5b — TLV for intrabeam (direct) viewing of CW laser beam (400–1400 nm).

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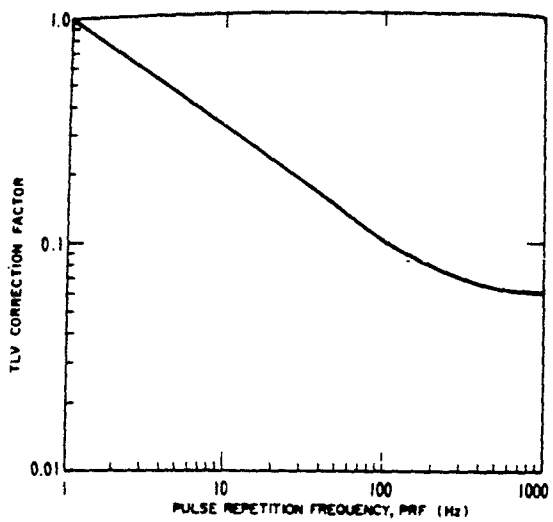


Figure 6 — Multiplicative correction factor for repetitively pulsed lasers having pulse durations less than 10^{-3} second. TLV for a single pulse of the pulse train is multiplied by the above correction factor. Correction factor for PRF greater than 1000 Hz is 0.06.

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^{-3} 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 " "

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TABLE 3 (Cont.)

UVA	315 nm to 400 nm	10^{-9} to 10	$.56\, t^{1/4}$ J • cm^{-2}
	" "	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^{-7} J • cm^{-2}
	400 nm to 700 nm	1.8×10^{-5} to 10	$1.8\,(t/\sqrt[4]{t})$ mJ • cm^{-2}
	400 nm to 549 nm	10 to 10^4	10 mJ • cm^{-2}
	550 nm to 700 nm	10 to T_1	$1.8\,(t/\sqrt[4]{t})$ mJ • cm^{-2}
	550 nm to 700 nm	T_1 to 10^4	$10\, C_B$ mJ • cm^{-2}
	400 nm to 700 nm	10^4 to 3×10^4	C_B μW • cm^{-2}
IR-A	700 nm to 1049 nm	10^{-9} to 1.8×10^{-5}	$5\, C_A \times 10^{-7}$ J • cm^{-2}
	700 nm to 1049 nm	1.8×10^{-5} to 10^3	$1.8\, C_A\,(t/\sqrt[4]{t})$ mJ • cm^{-2}
	1050 nm to 1400 nm	10^{-9} to 10^{-4}	5×10^{-6} J • cm^{-2}
	1050 nm to 1400 nm	10^{-4} to 10^3	$9(t/\sqrt[4]{t})$ mJ • cm^{-2}
	700 nm to 1400 nm	10^3 to 3×10^4	$320\, C_A$ μW • cm^{-2}
IR-B & C	1.4 μm to 10^3 μm	10^{-9} to 10^{-7}	10^{-2} J • cm^2
	" "	10^{-7} to 10	$0.56\sqrt[4]{t}$ J • cm^{-2}
	" "	10 to 3×10^4	0.1 W • cm^{-2}

C_A See Fig. 2

C_B 1 for λ = 400 to 549 nm; $C_B = 10^{[0.015\,(\lambda - 550)]}$ for λ = 550 to 700 nm

T_1 10 s for λ = 400 to 549 nm; $T_1 = 10 \times 10^{[0.02\,(\lambda - 550)]}$ for λ 550 to 700 n

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^{-3} to 3×10^4	Same as Table 3
Light	400 nm to 700 nm	10^{-9} to 10	$10\sqrt[4]{t}$ J • cm^{-2} • sr^{-1}
	400 nm to 549 nm	10 to 10^4	21 J • cm^{-2} • sr^{-1}
	550 nm to 700 nm	10 to T_1	$3.83\,(t/\sqrt[4]{t})$ J • cm^{-2} • sr^{-1}
	550 nm to 700 nm	T_1 to 10^4	$21\, C_B$ J • cm^{-2} • sr^{-1}
	400 nm to 700 nm	10^4 to 3×10^4	$2.1\, C_B t \times 10^{-3}$ W • cm^{-2} • sr^{-1}
IR-A	700 nm to 1400 nm	10^{-9} to 10	$10\, C_A\sqrt[4]{t}$ J • cm^{-2} • sr^{-1}
	700 nm to 1400 nm	10 to 10^3	$3.83\, C_A\,(t/\sqrt[4]{t})$ J • cm^{-2} • sr^{-1}
	700 nm to 1400 nm	10^3 to 3×10^4	$0.64\, C_A$ W • cm^{-2} • sr^{-1}
IR-B & C	1.4 μm to 1 mm	10^{-9} to 3×10^4	Same as Table 3

C_A, C_B, and T_1 are the same as in footnote to Table 3.

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TABLE 5

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

Exposure Duration(s)	Angle α (mrad)
10^{-9}	8.0
10^{-8}	5.4
10^{-7}	3.7
10^{-6}	2.5
10^{-5}	1.7
10^{-4}	2.2
10^{-3}	3.6
10^{-2}	5.7
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^{-3} to 3×10^{4}	Same as Table 3
Light & IR-A	400 nm to 1400 nm	10^{-9} to 10^{-7}	$2\,C_A \times 10^{-2}$ J • cm^{-2}
	" "	10^{-7} to 10	$1.1\,C_A \sqrt{t}$ J • cm^{-2}
IR-B & C	1.4 μm to 1 mm	10^{-9} to 3×10^{4}	Same as Table 3

$C_A = 1.0$ for λ = 400–700 nm, see Figure 2 for λ = 700 to 1400 nm

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MICROWAVES

These Threshold Limit Values refer to microwave energy in the frequency range of 300 MHz to 300 GHz and represent conditions under which it is believed that nearly all workers may be repeatedly exposed without adverse effect.

Under conditions of moderate to severe heat stress, the recommended values may need to be reduced.* Therefore, these values should be used as guides in the control of exposure to microwave energy and should not be regarded as a fine line between safe and dangerous levels.

Recommended Values:

The Threshold Limit Value for occupational exposure to microwave energy, where power density or field intensity is known and exposure time is controlled, is as follows:

1. For exposure to continuous wave (CW) sources, the power density level shall not exceed 10 milliwatts per square centimeter (mW/cm^2) for continuous exposure, and the total exposure time shall be limited to an 8-hour workday. This power density is approximately equivalent to a free-space electric field strength of 200 volts-per-meter rms (V/m) and a free-space magnetic field strength of 0.5 ampere-per-meter rms (A/m).
2. Exposures to CW power density levels greater than 10 mW/cm^2 are permissible up to a maximum of 25 mW/cm^2 based upon an average energy density of 1 milliwatt-hour per square centimeter (mWh/cm^2) averaged over any 0.1 hour period. For example, at 25 mW/cm^2, the permissible exposure duration is approximately 2.4 minutes in any 0.1 hour period.
3. For repetitively pulsed microwave sources, the average field strength or power density is calculated by multiplying the peak-pulse value by the duty cycle. The duty cycle is equal to the pulse duration in seconds times the pulse repetition rate in Hertz. Exposure during an 8-hour workday shall not exceed the following values which are averaged over any 0.1 hour period:

Power Density	10 mW/cm^2
Energy Density	1 mWh/cm^2
Mean Squared Electric Field Strength	40,000 V^2/m^2
Mean Squared Magnetic Field Strength	0.25 A^2/m^2

4. Exposure is not permissible in CW or repetitively pulsed fields with an average power density in excess of 25 mW/cm^2 or approximate equivalent free-space field strengths of 300 V/m or 0.75 A/m.

*Mumford, W. W., "Heat Stress Due to R. F. Radiation," Proceedings of IEEE, Vol. 57, No. 2, Feb. 1969, pp. 171–178.

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.

It should be recognized that the application of the TLV for noise will not protect all workers from the adverse effects of noise exposure. A hearing conservation program with audiometric testing is necessary when workers are exposed to noise at or above the TLV 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 National 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 7.

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,

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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 on-the-job noise exposures of 80 dBA or greater shall be used in the above calculations.

Table 7
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.

IMPULSIVE OR IMPACT NOISE

It is recommended that exposure to impulsive or impact noise shall not exceed the limits listed in Table 8 or taken from Figure 7. No exposures in excess of 140 decibels peak sound pressure level are permitted. 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 8
Threshold Limit Values
Impulsive or Impact Noise

Sound Level dB**	Permitted Number of Impulses or Impacts per day
140	100
130	1000
120	10,000

**Decibels peak sound pressure level.

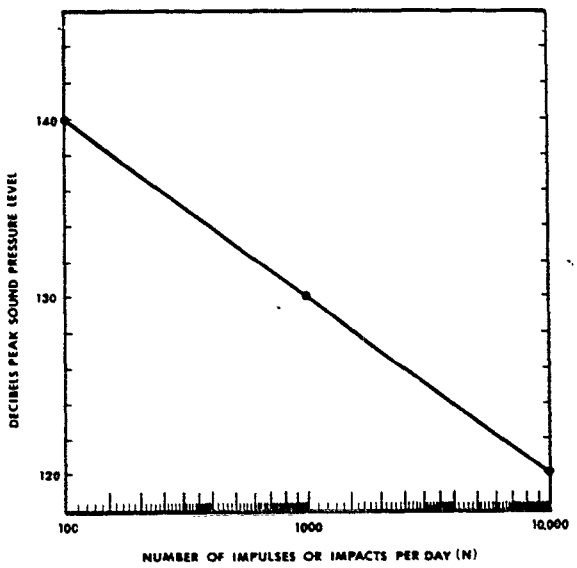


Figure 7 — Threshold Limit Values for Impulse/Impact Noise.

MAP 000197

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, and solar radiation, but do not apply to ultraviolet lasers.* These values do not apply to ultraviolet radiation exposure of photosensitive individuals or of individuals concomitantly exposed to photosensitizing agents (Fitzpatrick, et al., eds., Sunlight and Man, Univ. Tokyo Press, Tokyo, Japan, 1974). 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 nm) 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 9 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 following weighting formula should be used:

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

*See Laser TLVs

where:

E_{eff} = effective irradiance relative to a monochromatic source at 270 nm in W/cm² (J/s/cm²)

E_λ = spectral irradiance in W/cm²/nm

S_λ = relative spectral effectiveness (unitless)

$\Delta\lambda$ = 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 10 which provides exposure times corresponding to effective irradiances in μW/cm².

TABLE 9

Relative Spectral Effectiveness by Wavelength

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
254	6.0	0.5
260	4.6	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

**1 m J/cm² = 10^{-3} J/cm²

MAP 000198

TABLE 10

Permissible Ultraviolet Exposures

Duration of Exposure Per Day	Effective Irradiance, E_{eff} (μW/cm^2)***
8 hrs.	0.1
4 hrs.	0.2
2 hrs.	0.4
1 hr.	0.8
30 min.	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°.

***1 μW·cm^2 = 10^{-6} W cm^2

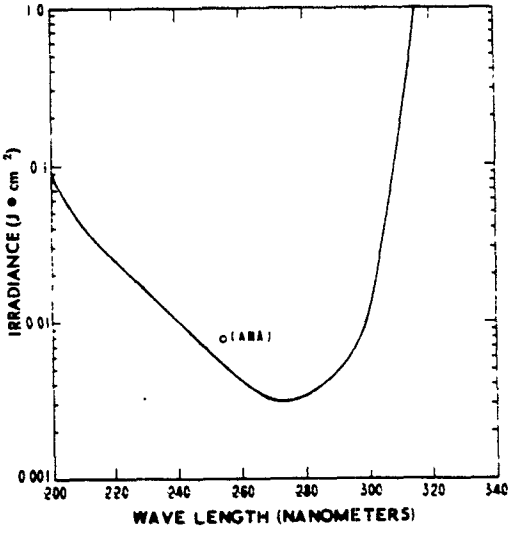


Figure 8 — Threshold Limit Values for Ultraviolet Radiation

Conditioned (tanned) individuals can tolerate skin exposure in excess of the TLV without erythemal effects. However, such conditioning may not protect persons against skin cancer.

NOTICE OF INTENDED CHANGES (for 1979)

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.

MAP 000199

NOTICE OF INTENT TO ESTABLISH THRESHOLD LIMIT VALUES

LIGHT AND NEAR-INFRARED RADIATION

These Threshold Limit Values refer to visible and near-infrared radiation in the wavelength range of 400 nm to 1400 nm and represent conditions under which it is believed that nearly all workers may be exposed without adverse effect. These values should be used as guides in the control of exposure to light and should not be regarded as a fine line between safe and dangerous levels.

Recommended Values:

The Threshold Limit Value for occupational exposure to broad-band light and near-infrared radiation for the eye apply to exposure in any eight-hour workday and require knowledge of the spectral radiance (L_λ) and total irradiance (E) of the source as measured at the position(s) of the eye of the worker. Such detailed spectral data of a white light source is generally only required if the luminance of the source exceeds 1 cd cm^{-2}. At luminances less than this value the TLV would not be exceeded.

The TLV's are:

1. To protect against retinal thermal injury, the spectral radiance of the lamp weighted against the function R (Table 11) should not exceed:

$$\sum_{400}^{1400} L_\lambda R_\lambda \Delta\lambda \leq 1/\alpha t^{1/2} \qquad (1)^*$$

where L_λ is in W cm^{-2} sr^{-1} and t is the viewing duration (or pulse duration if the lamp is pulsed) limited to 1 μs to 10 s, and α is the angular subtense of the source in radians. If the lamp is oblong, α refers to the longest dimension that can be viewed. For instance, at a viewing distance r = 100 cm from a tubular lamp of length l = 50 cm, the viewing angle is:

$$\alpha = l/r = 50/100 = 0.5 \text{ rad} \qquad (2)$$

2. To protect against retinal photochemical injury from chronic blue-light exposure the integrated spectral radiance of the lamp weighted against the blue-light hazard function B_λ (Table 11) should not exceed:

$$\sum_{400}^{1400} L_\lambda \, t \, B_\lambda \, \Delta\lambda \leq 100 \text{ Jcm}^{-2} \text{ sr}^{-1} \quad (t \leq 10^4 \text{ s}) \qquad (3a)$$

$$\sum_{400}^{1400} L_\lambda \, B_\lambda \, \Delta\lambda \leq 10^{-2} \text{ Wcm}^{-2} \text{ sr}^{-1} \quad (t > 10^4 \text{ s}) \qquad (3b)$$

For a source radiance L which exceeds 2 mW cm^{-2} sr^{-1} in the blue spectral region, the permissible exposure duration t_{max} in seconds is simply:

$$t_{max} = 100 \text{ J cm}^{-2} \text{ sr}^{-1}/L \text{ (blue)} \qquad (4)$$

The latter limits are greater than the maximum permissible exposure limits for 440 nm laser radiation (see Laser TLV) because a 2–3 mm pupil is assumed rather than a 7 mm pupil for the Laser TLV.

3. *Infrared Radiation:* To avoid possible delayed effects upon the lens of the eye (cataractogenesis), the infrared radiation ($\lambda > 770$ nm) should be limited to 10 $mWcm^{-2}$. For an infrared heat lamp or any near-infrared source where a strong visual stimulus is absent, the near infrared (770–1400 nm) radiance as viewed by the eye should be limited to:

$$\sum_{770}^{1400} L_\lambda \, \Delta\lambda = 0.6/\alpha \qquad (5)^*$$

for extended duration viewing conditions. This limit is based upon a 7 mm pupil diameter.

*Formulae (1) and (2) are empirical and are not, strictly speaking, dimensionally correct. To make the formulae dimensionally correct, one would have to insert a dimensional correction factor k in the right hand numerator in each formula. For formula (1) this would be k_1 = 1 W • rad • $s^{1/2}$ • (cm^2 • sr), and for formula (5) k_2 = 1 W • rad (cm^2 • sr)

MAP 000200

TABLE 11

SPECTRAL WEIGHTING FUNCTIONS FOR ASSESSING RETINAL HAZARDS FROM BROAD — BAND OPTICAL SOURCES

Wavelength (nm)	Blue-Light Hazard Function B_λ	Burn Hazard Function R_λ
400	0.10	1.0
405	0.20	2.0
410	0.40	4.0
415	0.80	8.0
420	0.90	9.0
425	0.95	9.5
430	0.98	9.8
435	1.0	10
440	1.0	10
445	0.97	9.7
450	0.94	9.4
455	0.90	9.0
460	0.80	8.0
465	0.70	7.0
470	0.62	6.2
475	0.55	5.5
480	0.45	4.5
485	0.40	4.0
490	0.22	2.2
495	0.16	1.6
500–600	$10^{[(450-\lambda)/50]}$	1.0
600–700	0.001	1.0
700–1049	0.001	$10^{[(700-\lambda)/505]}$
1050–1400	0.001	0.2

AIRBORNE UPPER SONIC AND ULTRASONIC ACOUSTIC RADIATION

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. The values listed in Table 15 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. The levels for the third octave bands centered below 20 kHz are below those which cause subjective effects. Those levels for 1/3 octaves above 20 kHz are for prevention of possible hearing losses from subharmonics of these frequencies.

TABLE 12

Permissible Ultrasound Exposure Levels

Mid-Frequency of Third-Octave Band kHz	One-Third Octave — Band Level in dB reference 0.0002 dynes/cm²
10	80
12.5	80
16	80
20	105
25	110
31.5	115
40	115
50	115

MAP 000201

PHYSICAL AGENTS UNDER STUDY

The Physical Agents Committee of ACGIH has examined the current literature and has not found sufficient information to propose a TLV. However, these agents will remain under study during the coming year to examine new evidence indicating the need and feasibility for establishing a proposed TLV. Comments and suggestions, accompanied by substantive documentation are solicited and should be forwarded to the Executive Secretary, ACGIH. Documentation summarizing the current status of the biological effects literature is available on those agents preceded by an asterisk.

1. *Radiofrequency Radiation*. Specifically, that portion of the spectrum from 10 MHz to 100 MHz.
2. *Extremely Low Frequency (ELF) Radiation*. Specifically, that portion of the spectrum from 0 to 300 Hz.
3. *Magnetic Fields*. Both pulsed and continuous.
4. *Laser Radiation*. Specifically ultraviolet radiation for pulsed exposures, and repetitively pulsed light and infrared-A laser exposures.
5. *Ultrasonic Energy*. Specifically, acoustic energy at frequencies above 10 kHz.
6. *Vibration*. Segmental and whole-body.
7. *Cold Stress*.
8. *Pressure Variations*.

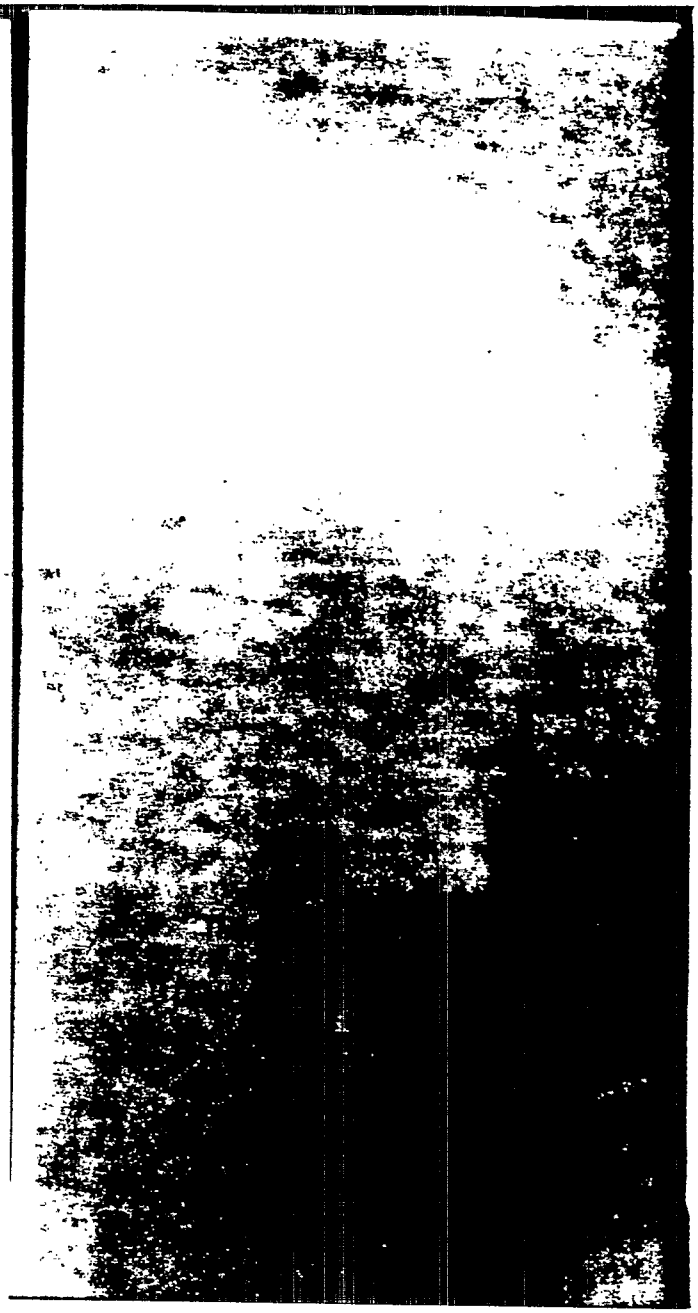
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It is an organization devoted to the development of administrative and technical aspects of worker health protection. The association has contributed substantially to the development and improvement of official industrial health services to industry and labor. The committees on Industrial Ventilation and Threshold Limit Values are recognized throughout the world for their expertise and contributions to industrial hygiene.

Membership is limited to professional personnel in governmental agencies or educational institutions engaged in occupational safety and health programs. The more than 2300 members from across the United States and around the world give the organization an international scope.



MAP 000202



JOHN E. FOX

TLVs®
Threshold Limit Values
for
Chemical Substances
and
Physical Agents
in the
Workroom Environment
with
Intended Changes
for
1980



MAP 000204

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Documentation of the Threshold Limit Values: A separate companion piece to the TLVs is issued by ACGIH under this title. This publication gives the pertinent scientific information and data with reference to literature sources that were used to base each limit. Each documentation also contains a statement defining the type of response against which the limit is safeguarding the worker. For a better understanding of the TLVs it is essential that the Documentation be consulted when the TLVs are being used.

Information concerning the availability of copies of the Documentation of the Threshold Limit Values should be directed to the Publications Office, ACGIH, P.O. Box 1937, Cincinnati, OH 45201.

TLVs®
Threshold Limit Values for Chemical Substances in Workroom Air Adopted by ACGIH for 1980



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1980 TLV AIRBORNE CONTAMINANTS COMMITTEE

The Conference appreciates the untiring guidance Dr. Elkins has given the TLV Airborne Contaminants Committee over these past years. We wish him well in his retirement.

1979—1980 INTERIM TLV AIRBORNE CONTAMINANTS COMMITTEE

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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.

Tests are available (J. Occup. Med. 15: 564, 1973; 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).

Three categories of Threshold Limit Values (TLVs) are specified herein, as follows:

a) Threshold Limit Value-Time Weighted Average (TLV-TWA) — the time-weighted average concentration for a normal 8-hour workday or 40-hour workweek, to which nearly all workers may be repeatedly exposed, day after day, without adverse effect.

b) Threshold Limit Value-Short Term Exposure Limit (TLV-STEL) — the maximal concentration to which workers can be exposed for a period up to 15 minutes continuously without suffering from 1) irritation, 2) chronic or irreversible tissue change, or 3) narcosis of sufficient degree to increase accident proneness, impair self-rescue, or materially reduce work efficiency, provided that no more than four excursions per day are permitted, with at least 60 minutes between exposure periods, and provided that the daily TLV-TWA also is not exceeded. The STEL should be considered a maximal allowable concentration, or ceiling, not to be exceeded at any time during the 15-minute excursion period. STELs are based on one or more of the following criteria: (1) Adopted TLVs including those with a "C" or "ceiling" limit. (2) Pennsylvania Short-Term Limits for Exposure to Airborne Contaminants (Penna. Dept. of Hlth., Chapter 4, Art. 432, Rev. Jan. 25, 1968). (3) OSHA Occupational Safety and Health Standards, 40 FR 23073, May 28, 1975. (4) NIOSH criteria for recommended standards for occupational exposure to specific substances. The TWA-STEL should not be used as engineering design criterion or considered as an emergency exposure level (EEL).

c) Threshold Limit Value-Ceiling (TLV-C) — the concentration that should not be exceeded even instantaneously.

For some substances, e.g., irritant gases, only one category, the TLV-Ceiling, may be relevant. For other substances, either two or three categories may be relevant, depending upon their physiologic action. It is important to observe that if any one of these three TLVs is exceeded, a potential hazard from that substance is presumed to exist.

The TLV-TWA should be used as guides in the control of health hazards and should not be used as fine lines between safe and dangerous concentrations.

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 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 a 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 precision of the estimated TLV is also subject to variation and the latest

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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 control of community air pollution nuisances, (3) in estimating the toxic potential of continuous, uninterrupted exposures or other extended work periods, (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 noncompliance 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. It should be noted that the

same factors are used by the Committee in determining the magnitude of the value of the STELs, or 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 mucous 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, may cause unpleasant deposits in the eyes, ears and nasal 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 10 mg/m^3, or 30 mppcf, of total dust < 1% quartz, or, 5 mg/m^3 respirable dust 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.

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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.

Physical Factors. It is recognized that such physical factors as heat, ultraviolet and ionizing 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 may be altered. Most of these stresses act adversely 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 BLVs, and their associated procedures for determining compliance with them, should thus be regarded as an effective means of providing health surveillance of the worker.

Unlisted Substances. Many substances present or handled in industrial processes do not appear on the TLV list. In a number of instances the material is rarely present as a particulate, vapor or other airborne contaminant, and a TLV is not necessary. In other cases sufficient information to warrant development of a TLV, even on a tentative basis, is not available to the Committee. Other substances, of low toxicity, could be included in Appendix E pertaining to nuisance particulates. This list (as well as Appendix F) is not meant to be all inclusive; the substances serve only as examples.

In addition there are some substances of not inconsiderable toxicity, which have been omitted primarily because only a limited number of workers (e.g., employees of a single plant) are known to have potential exposure to possibly harmful concentrations.

"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. Values listed in parenthesis in the "Adopted" list are to be used during the period in which a proposed change for that Value is listed in the Notice of Intended Changes.

Legal Status. The Threshold Limit Values, as issued by ACGIH, are recommendations and should be used as guidelines for good practices. Wherever these values (of whatever year) have been used or included by reference in Federal and/or State statutes

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and registers, the TLVs do have the force and effects of law.

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Substance	ADOPTED VALUES TWA ppm[a]	ADOPTED VALUES TWA mg/m³[b]	TENTATIVE VALUES STEL ppm[a]	TENTATIVE VALUES STEL mg/m³[b]
Abate	—	10	—	20
Acetaldehyde	100	180	150	270
Acetic acid	10	25	15	37
C Acetic anhydride	5	20	—	—
** Acetone	(1,000)	(2,400)	(1,250)	(3,000)
Acetonitrile	40	70	60	105
Acetylene	F	—	—	—
Acetylene dichloride, see 1, 2-Dichloroethylene	200	790	250	1,000
Acetylene tetrabromide	1	15	1.5	20
* Acetylsalicylic acid (Aspirin)	—	5	—	—
Acrolein	0.1	0.25	0.3	0.8
Acrylamide — Skin	—	0.3	—	0.6
** Acrylonitrile — Skin	(A1b)	(A1b)	—	—
Aldrin — Skin	—	0.25	—	0.75
Allyl alcohol — Skin	2	5	4	10
Allyl chloride	1	3	2	6
Allyl glycidyl ether (AGE) — Skin	5	22	10	44
Allyl propyl disulfide	2	12	3	18
Aluminum metal and oxide	—	10	—	20
Aluminum pyro powders	—	5	—	—
Aluminum welding fumes	—	5	—	—
Aluminum, soluble salts	—	2	—	—
Aluminum, alkyls (NOC)*	—	2	—	—
Aluminum oxide (Al_2O_3)	—	E	—	20
4-Aminodiphenyl — Skin	—	A1b	—	A1b
2-Aminoethanol, see Ethanolamine	3	8	6	15
2-Aminopyridine	0.5	2	2	4
3-Amino 1, 2, 4-triazole	A2	A2	—	—
Ammonia	25	18	35	27
Ammonium chloride-fume	—	10	—	20
Ammonium sulfamate (Ammate)	—	10	—	20
n-Amyl acetate	100	530	150	800
sec-Amyl acetate	125	670	150	800
* Aniline & homologues — Skin	2	10	5	20

Capital letters refer to Appendices.
Footnotes (a thru f) see Page 32.
*1980 Addition
**See Notices of Intended Changes.

MAP 000210

Substance	ADOPTED VALUES TWA ppm[a]	TWA mg/m³[b]	TENTATIVE VALUES STEL ppm[a]	STEL mg/m³[b]
Anisidine (o-, p-isomers) — Skin	0.1	0.5	—	—
** Antimony & Compounds (as Sb)	—	(0.5)	—	—
Antimony trioxide, handling and use (as Sb)	—	0.5	—	—
* Antimony trioxide production	—	A2	—	—
ANTU (α-Naphthyl thiourea)	—	0.3	—	0.9
Argon	F	—	F	F
* Arsenic & soluble compounds, as As	—	0.2	—	—
* Arsenic trioxide production	—	A2	—	—
Arsine	0.05	0.2	—	—
* Asbestos, see MINERAL DUSTS	—	A1a	—	A1a
Asphalt (petroleum) fumes	—	5	—	10
Atrazine	—	10	—	—
Azinphos-methyl — Skin	—	0.2	—	0.6
Barium (soluble compounds), as Ba	—	0.5	—	—
Baygon (propoxur)	—	0.5	—	2
* Baytex, see Fenthion	—	0.1	—	0.3
Benomyl	—	10	—	15
Benzene	10, A2	30, A2	25, A2	75, A2
** Benzidine production — Skin	—	(A1b)	—	(A1b)
p-Benzoquinone, see Quinone	0.1	0.4	0.3	2
Benzoyl peroxide	—	5	—	—
Benzo(a)pyrene	—	A2	—	A2
Benzyl chloride	1	5	—	—
Beryllium	—	0.002, A2	—	—
Biphenyl	0.2	1.5	0.6	4
Bismuth telluride	—	10	—	20
Bismuth telluride, Se-doped	—	5	—	10

Capital letters refer to Appendices.
Footnotes (a thru f) see Page 32
*1980 Addition.
**See Notice of Intended Changes

Substance	ADOPTED VALUES TWA ppm[a]	TWA mg/m³[b]	TENTATIVE VALUES STEL ppm[a]	STEL mg/m³[b]
Borates, tetra, sodium salts,				
Anhydrous	—	1	—	—
Decahydrate	—	5	—	—
Pentahydrate	—	1	—	—
Boron oxide	—	10	—	20
Boron tribromide	1	10	3	30
C Boron trifluoride	1	3	—	—
Bromacil	1	10	2	20
Bromine	0.1	0.7	0.3	2
Bromine pentafluoride	0.1	0.7	0.3	2
Bromochloromethane, see Chlorobromomethane	200	1,050	250	1,300
Bromoform — Skin	0.5	5	—	—
Butadiene (1, 3-butadiene)	1,000	2,200	1,250	2,750
** Butane	(600)	(1,430)	(750)	(1,780)
Butanethiol, see Butyl mercaptan	0.5	1.5	—	—
2-Butanone, see Methyl ethyl ketone (MEK)	200	590	300	885
** 2-Butoxyethanol (Butyl Cellosolve) — Skin	(50)	(240)	(150)	(720)
n-Butyl acetate	150	710	200	950
sec-Butyl acetate	200	950	250	1,190
tert-Butyl acetate	200	950	250	1,190
Butyl acrylate	10	55	—	—
C n-Butyl alcohol — Skin	50	150	—	—
** sec-Butyl alcohol	(150)	(450)	—	—
tert-Butyl alcohol	100	300	150	450
C Butylamine — Skin	5	15	—	—
C tert-Butyl chromate (as CrO_3) — Skin	—	0.1	—	—
** n-Butyl glycidyl ether (BGE)	(50)	(270)	—	—
n-Butyl lactate	5	25	—	—
Butyl mercaptan	0.5	1.5	—	—
* o-sec-Butylphenol — Skin	5	30	—	—
p-tert-Butyltoluene	10	60	20	120

Capital letters refer to Appendices.
*1980 Addition.
**See Notice of Intended Changes.

MAP 000211

Substance	ADOPTED VALUES TWA ppm[a]	ADOPTED VALUES TWA mg/m³[b]	TENTATIVE VALUES STEL ppm[a]	TENTATIVE VALUES STEL mg/m³[b]
Cadmium, dust & salts (as Cd)	—	0.05	—	0.2
C Cadmium oxide fume (as Cd)	—	0.05	—	—
** Cadmium oxide production (as Cd)	—	(A2)	—	—
Calcium carbonate/ marble	—	E	—	20
Calcium cyanamide	—	0.5	—	1
Calcium hydroxide	—	5	—	—
Calcium oxide	—	2	—	—
Camphor, synthetic	2	12	3	18
Caprolactam				
Dust	—	1	—	3
Vapor	5	20	10	40
Captafol (Difolatan®) — Skin	—	0.1	—	—
Captan	—	5	—	15
Carbaryl (Sevin®)	—	5	—	10
Carbofuran (Furadan®)	—	0.1	—	—
Carbon black	—	3.5	—	7
Carbon dioxide	5,000	9,000	15,000	18,000
* Carbon disulfide — Skin	10	30	—	—
Carbon monoxide	50	55	400	440
Carbon tetrabromide	0.1	1.4	0.3	4
** Carbon tetrachloride — Skin	(10)	(65)	(20)	(130)
Carbonyl chloride (Phosgene)	0.1	0.4	—	—
** Carbonyl fluoride	(5)	(15)	—	—
Catechol (Pyrocatechol)	5	20	—	—
Cellulose (paper fiber)	—	E	—	20
Cesium hydroxide	—	2	—	—
Chlordane — Skin	—	0.5	—	2
Chlorinated camphene — Skin	—	0.5	—	1
Chlorinated diphenyl oxide	—	0.5	—	2
Chlorine	1	3	3	9
Chlorine dioxide	0.1	0.3	0.3	0.9
C Chlorine trifluoride	0.1	0.4	—	—

Capital letters refer to Appendices
*1980 Addition
**See Notice of Intended Changes

Substance	ADOPTED VALUES TWA ppm[a]	ADOPTED VALUES TWA mg/m³[b]	TENTATIVE VALUES STEL ppm[a]	TENTATIVE VALUES STEL mg/m³[b]
C Chloroacetaldehyde	1	3	—	—
α-Chloroacetophenone (Phenacyl chloride)	0.05	0.3	—	—
* Chloroacetyl chloride	0.05	0.2	—	—
Chlorobenzene (Monochlorobenzene)	75	350	—	—
** o-Chlorobenzylidene malononitrile — Skin	(0.05)	(0.4)	—	—
Chlorobromomethane	200	1,050	250	1,300
* 2-Chloro-1, 3-butadiene, see β Chloroprene — Skin	10	45	—	—
Chlorodifluoromethane	1,000	3,500	1,250	4,375
Chlorodiphenyl (42% Chlorine) — Skin	—	1	—	2
Chlorodiphenyl (54% Chlorine) — Skin	—	0.5	—	1
* 1-Chloro, 2, 3-epoxy-propane (Epichlorohydrin) — Skin	2	8	5	19
C 2-Chloroethanol (Ethylene chlorohydrin) — Skin	1	3	—	—
* Chloroethylene, see Vinyl chloride	5, A1a	10, A1a	—	—
Chloroform (Trichloromethane)	10, A2	50, A2	50	225
bis-Chloromethyl ether	0.001	A1a	—	A1a
** 1-Chloro-1-nitropropane	(20)	(100)	—	—
Chloropicrin	0.1	0.7	0.3	2
* β-Chloroprene — Skin	10	45	—	—
o-Chlorostyrene	50	285	75	430
o-Chlorotoluene — Skin	50	250	75	375
2-Chloro-6-(trichloromethyl) pyridine (N-Serve®)	—	10	—	20
Chlorpyrifos (Dursban®) — Skin	—	0.2	—	0.6
** Chromates, certain insoluble forms	—	(0.05,A1a)	—	(A1a)

Capital letters refer to Appendices.
Footnotes (a thru f) see Page 32.
*1980 Addition.
**See Notice of Intended Changes.

MAP 000212

Substance	ADOPTED VALUES TWA ppm[a]	ADOPTED VALUES TWA mg/m³[b]	TENTATIVE VALUES STEL ppm[a]	TENTATIVE VALUES STEL mg/m³[b]
** Chromic acid and Chromates, (as Cr)	—	(0.05)	—	—
Chromite ore processing (chromate), as Cr	—	0.05, A1a	—	—
Chromium, Sol. chromic, chromous salts (as Cr)	—	0.5	—	—
Clopidol (Coyden®)	—	10	—	20
Coal tar pitch volatiles, as benzene solubles	—	0.2, A1a	—	A1a
** Cobalt metal, dust and fume (as Co)	—	(0.1)	—	—
Copper fume	—	0.2	—	—
Dusts & Mists (as Cu)	—	1	—	2
Corundum (Al_2O_3)	—	E	—	E
Cotton dust, raw	—	0.2[k]	—	0.6
Crag® herbicide, see Sodium 2, 4-dichlorophenoxyethyl sulfate	—	10	—	20
Cresol, all isomers — Skin	5	22	—	—
Crotonaldehyde	2	6	6	18
Crufomate®	—	5	—	20
Cumene — Skin	50	245	75	365
Cyanamide	—	2	—	—
Cyanides, as CN — Skin	—	5	—	—
Cyanogen	10	20	—	—
*C Cyanogen chloride	0.3	0.6	—	—
Cyclohexane	300	1,050	375	1,300
Cyclohexanol	50	200	—	—
** Cyclohexanone	(50)	(200)	—	—
Cyclohexene	300	1,015	—	—
Cyclohexylamine — Skin	10	40	—	—
Cyclonite — Skin	—	1.5	—	3
Cyclopentadiene	75	200	150	400
2, 4-D (2, 4-Dichlorophenoxy-acetic acid)	—	10	—	20
DDT (Dichlorodiphenyl-trichloroethane)	—	1	—	3

Capital letters refer to Appendices.
*1980 Addition.
**See Notice of Intended Changes.
k) See p. 35.

Substance	ADOPTED VALUES TWA ppm[a]	ADOPTED VALUES TWA mg/m³[b]	TENTATIVE VALUES STEL ppm[a]	TENTATIVE VALUES STEL mg/m³[b]
DDVP, see Dichlorvos — Skin	0.1	1	0.3	3
Decaborane — Skin	0.05	0.3	0.15	0.9
Demeton® — Skin	0.01	0.1	0.03	0.3
Diacetone alcohol (4-hydroxy-4-methyl-2-pentanone)	50	240	75	360
1, 2-Diaminoethane, see Ethylenediamine	10	25	—	—
Diazinon — Skin	—	0.1	—	0.3
Diazomethane	0.2	0.4	—	—
Diborane	0.1	0.1	—	—
** 1, 2-Dibromomethane, see Ethylene dibromide — Skin	(A1b)	(A1b)	—	—
Dibrom®	—	3	—	6
2-n-Dibutylaminoethanol — Skin	2	14	4	28
Dibutyl phosphate	1	5	2	10
Dibutyl phthalate	—	5	—	10
C Dichloracetylene	0.1	0.4	—	—
C o-Dichlorobenzene	50	300	—	—
p-Dichlorobenzene	75	450	110	675
3, 3'-Dichlorobenzidene — Skin	—	A2	—	A2
Dichlorodifluoromethane	1,000	4,950	1,250	6,200
1, 3-Dichloro-5, 5-dimethyl hydantoin	—	0.2	—	0.4
1, 1-Dichloroethane	200	810	250	1,010
* 1, 2-Dichloroethane, see Ethylene dichloride	10	40	15	60
1, 2-Dichloroethylene	200	790	250	1,000
Dichloroethyl ether — Skin	5	30	10	60
* Dichlorofluoromethane	10	40	—	—
** Dichloromethane, see Methylene chloride	(200)	(700)	(250)	(870)
C 1, 1-Dichloro-1-nitroethane	10	60	—	—
1, 2-Dichloropropane, see Propylene				

Capital letters refer to Appendices.
Footnotes (a thru f) see Page 32.
*1980 Addition.
**See Notice of Intented Changes.

MAP 000213

Substance	ADOPTED VALUES TWA ppm[a]	ADOPTED VALUES TWA mg/m³[b]	TENTATIVE VALUES STEL ppm[a]	TENTATIVE VALUES STEL mg/m³[b]
dichloride	75	350	110	510
* Dichloropropene — Skin	1	5	10	50
* 2, 2-Dichloropropionic acid	1	6	—	—
Dichlorotetrafluoro-ethane	1,000	7,000	1,250	8,750
Dichlorvos (DDVP) — Skin	0.1	1	0.3	3
Dicrotophos (Bidrin®) — Skin	—	0.25	—	—
Dicyclopentadiene	5	30	—	—
Dicyclopentadienyl iron	—	10	—	20
Dieldrin — Skin	—	0.25	—	0.75
* Diethylamine	3	15	—	—
Diethylaminoethanol — Skin	10	50	—	—
Diethylene triamine — Skin	1	4	—	—
Diethyl ether, see Ethyl ether	400	1,200	500	1,500
Diethyl phthalate	—	5	—	10
Difluorodibromomethane	100	860	150	1,290
**C Diglycidyl ether (DGE)	(0.5)	(3)	—	—
Dihydroxybenzene, see Hydroquinone	—	2	—	4
Diisobutyl ketone	25	150	—	—
Diisopropylamine — Skin	5	20	—	—
Dimethoxymethane, see Methylal	1,000	3,100	1,250	3,875
Dimethyl acetamide — Skin	10	35	15	50
Dimethylamine	10	18	—	—
Dimethylaminobenzene, see Xylidene — Skin	5	25	10	50
Dimethylaniline (N, N-Dimethylaniline) — Skin	5	25	10	50
Dimethylbenzene, see Xylene — Skin	100	435	150	650
Dimethyl carbamyl chloride	A2	A2	—	—

Capital letters refer to Appendices.
*1980 Addition.
**See Notice of Intended Changes.

Substance	ADOPTED VALUES TWA ppm[a]	ADOPTED VALUES TWA mg/m³[b]	TENTATIVE VALUES STEL ppm[a]	TENTATIVE VALUES STEL mg/m³[b]
Dimethyl-1, 2-dibromo-2-dichloroethyl phosphate, see Dibrom	—	3	—	6
Dimethylformamide — Skin	10	30	20	60
2, 6-Dimethyl-4-heptanone, see Diisobutyl ketone	25	150	—	—
1, 1-Dimethylhydrazine — Skin	0.5	1	1	2
Dimethylphthalate	—	5	—	10
Dimethyl sulfate — Skin	0.1, A2	0.5, A2	—	—
Dinitrobenzene (all isomers) — Skin	0.15	1	0.5	3
Dinitro-o-cresol — Skin	—	0.2	—	0.6
3, 5-Dinitro-o-toluamide (Zoalene®)	—	5	—	10
Dinitrotoluene — Skin	—	1.5	—	5
** Dioxane, tech. grade — Skin	(50)	(180)	—	—
Dioxathion (Delnav®) — Skin	—	0.2	—	—
Diphenyl, see Biphenyl	0.2	1.5	0.6	4
Diphenylamine	—	10	—	20
C Diphenylmethane diisocyanate, see Methylene bisphenyl isocyanate (MDI)	0.02	0.2	—	—
Dipropylene glycol methyl ether — Skin	100	600	150	900
Diquat	—	0.5	—	1
Di-sec, octyl phthalate (Di-2-ethylhexyl-phthalate)	—	5	—	10
Disulfiram	—	2	—	5
Disulfoton (Disyston®)	—	0.1	—	0.3
2, 6-Ditert. butyl-p-cresol	—	10	—	20
Diuron	—	10	—	—
* Divinyl benzene	10	50	—	—
Dyfonate — Skin	—	0.1	—	—
Emery	—	E	—	20

Capital letters refer to Appendices.
*1980 Addition.
**See Notice of Intended Changes.

MAP 000214

Substance	ADOPTED VALUES TWA ppm[a]	ADOPTED VALUES TWA mg/m³[b]	TENTATIVE VALUES STEL ppm[a]	TENTATIVE VALUES STEL mg/m³[b]
Endosulfan (Thiodan®) — Skin	—	0.1	—	0.3
Endrin — Skin	—	0.1	—	0.3
* Epichlorohydrin — Skin	2	10	5	20
EPN — Skin	—	0.5	—	2
1, 2-Epoxypropane, see Propylene oxide	100	240	150	360
2, 3-Epoxy-1-propanol, see Glycidol	50	150	75	225
Ethane	F	—	F	—
Ethanethiol, see Ethyl mercaptan	0.5	1	2	3
Ethanolamine	3	8	6	15
Ethion (Nialate®) — Skin	—	0.4	—	—
** 2-Ethoxyethanol — Skin	(100)	(370)	(150)	(560)
** 2-Ethoxyethyl acetate (Cellosolve acetate) — Skin	(100)	(540)	(150)	(810)
Ethyl acetate	400	1,400	—	—
** Ethyl acrylate — Skin	(25)	(100)	—	—
Ethyl alcohol (Ethanol)	1,000	1,900	—	—
Ethylamine	10	18	—	—
Ethyl amyl ketone (5-Methyl-3-heptanone)	25	130	—	—
Ethyl benzene	100	435	125	545
Ethyl bromide	200	890	250	1,110
Ethylbutyl ketone (3-Heptanone)	50	230	75	345
Ethyl chloride	1,000	2,600	1,250	3,250
Ethylene	F	—	F	—
C Ethylene chlorohydrin — Skin	1	3	—	—
Ethylenediamine	10	25	—	—
** Ethylene dibromide	(A1b)	(A1b)	—	—
* Ethylene dichloride	10	40	15	60
Ethylene glycol, Particulate	—	10	—	20
** Vapor	(100)	(250)	(125)	(325)
**C Ethylene glycol dinitrate and/or Nitroglycerin				

Capital letters refer to Appendices.
*1980 Addition.
**See Notices of Intended Changes
Footnotes (a thru f) see Page 32.

Substance	ADOPTED VALUES TWA ppm[a]	ADOPTED VALUES TWA mg/m³[b]	TENTATIVE VALUES STEL ppm[a]	TENTATIVE VALUES STEL mg/m³[b]
— Skin	(0.2)	(2)	—	—
Ethylene glycol methyl ether acetate (Methyl Cellosolve® acetate) — Skin	25	120	35	170
** Ethylene oxide	(50)	(90)	(75)	(135)
Ethylenimine — Skin	0.5	1	—	—
Ethyl ether	400	1,200	500	1,500
Ethyl formate	100	300	150	450
Ethylidene chloride, see 1, 1-Dichloroethane	200	810	250	1,010
C Ethylidene norbornene	5	25	—	—
Ethyl mercaptan	0.5	1	2	3
** N-Ethylmorpholine — Skin	20	95	—	—
Ethyl silicate	10	85	30	255
Fensulfothion (Dasanit)	—	0.1	—	—
Fenthion	—	0.1	—	0.3
Ferbam	—	10	—	20
Ferrovanadium dust	—	1	—	0.3
Fluoride (as F)	—	2.5	—	—
Fluorine	1	2	2	4
** Fluorotrichloromethane, see Trichlorofluoromethane	(1,000)	(5,600)	(1,250)	(7,000)
C Formaldehyde	2	3	—	—
Formamide	20	30	30	45
Formic acid	5	9	—	—
** Furfural — Skin	(5)	(20)	(15)	(60)
** Furfuryl alcohol — Skin	(5)	(20)	(10)	(40)
** Gasoline	—	(B2)	—	(B2)
Germanium tetrahydride	0.2	0.6	0.6	1.8
Glass, fibrous[c] or dust	—	10	—	—
*C Glutaraldehyde	0.2	0.7	—	—
Glycerin mist	—	E	—	E
** Glycidol (2, 3-Epoxy-1-propanol)	(50)	(150)	(75)	(225)
Glycol monoethyl ether, see 2-Ethoxyethanol — Skin	100	370	150	560
Graphite (Synthetic)	—	E	—	—
Guthion®, see				

Capital letters refer to Appendices.
*1980 Addition.
**See Notice of Intended Changes.

MAP 000215

Substance	ADOPTED VALUES TWA ppm[a]	TWA mg/m³[b]	TENTATIVE VALUES STEL ppm[a]	STEL mg/m³[b]
Azinphos-methyl — Skin	—	0.2	—	0.6
Gypsum	—	E	—	20
Hafnium	—	0.5	—	1.5
Helium	F	—	F	—
Heptachlor — Skin	—	0.5	—	2
Heptane (n-Heptane)	400	1,600	500	2,000
Hexachlorocyclopentadiene	0.01	0.1	0.03	0.3
** Hexachloroethane — Skin	(1)	(10)	(3)	(30)
Hexachloronaphthalene — Skin	—	0.2	—	0.6
Hexafluoroacetone	0.1	0.7	0.3	2
** Hexane (n-hexane)	(100)	(360)	(125)	(450)
Hexamethyl phosphoramide — Skin	A2	A2	—	—
2-Hexanone, see Methyl butyl ketone — Skin	25	100	40	165
** Hexone, see Methyl isobutyl ketone) — Skin	(100)	(410)	(125)	(510)
sec-Hexyl acetate	50	300	—	—
C Hexylene glycol	25	125	—	—
Hydrazine — Skin	0.1, A2	0.1, A2	—	—
Hydrogen	F	—	F	—
Hydrogenated terphenyls	0.5	5	—	—
Hydrogen bromide	3	10	—	—
C Hydrogen chloride	5	7	—	—
*C Hydrogen cyanide — Skin	10	10	—	—
Hydrogen fluoride (as F)	3	2.5	6	5
Hydrogen peroxide	1	1.5	2	3
Hydrogen selenide (as Se)	0.05	0.2	—	—
Hydrogen sulfide	10	14	15	21
Hydroquinone	—	2	—	4
* 2-Hydroxypropyl acrylate — Skin	0.5	3	—	—
Indene	10	45	15	70

Capital letters refer to Appendices
*1980 Addition.
**See Notice of Intended Changes.

Substance	ADOPTED VALUES TWA ppm[a]	TWA mg/m³[b]	TENTATIVE VALUES STEL ppm[a]	STEL mg/m³[b]
Indium & Compounds (as In)	—	0.1	—	0.3
C Iodine	0.1	1	—	—
Iodoform	0.6	10	1	20
Iron oxide fume (Fe_2O_3, as Fe)	B3	5	—	10
** Iron pentacarbonyl (as Fe)	(0.01)	(0.08)	—	—
Iron salts, soluble (as Fe)	—	1	—	2
Isoamyl acetate	100	525	125	655
Isoamyl alcohol	100	360	125	450
Isobutyl acetate	150	700	187	875
Isobutyl alcohol	50	150	75	225
C Isophorone	5	25	—	—
Isophorone diisocyanate — Skin	0.01	0.09	—	—
Isopropyl acetate	250	950	310	1,185
Isopropyl alcohol — Skin	400	980	500	1,225
Isopropylamine	5	12	10	24
* N-Isopropylaniline — Skin	2	10	5	20
Isopropyl ether	250	1,050	310	1,320
Isopropyl glycidyl ether (IGE)	50	240	75	360
Kaolin	—	E	—	20
Ketene	0.5	0.9	1.5	3
Lead, inorg., fumes & dusts (as Pb)	—	0.15	—	0.45
** Lead arsenate (as Pb)	—	(0.15)	—	(0.45)
Lead chromate (as Cr)	—	0.05, A2	—	—
Limestone	—	E	—	20
Lindane — Skin	—	0.5	—	1.5
Lithium hydride	—	0.025	—	—
L.P.G. (Liquified petroleum gas)	1,000	1,800	1,250	2,250
Magnesite	—	E	—	20
Magnesium oxide fume (as Mg)	—	10	—	—
Malathion — Skin	—	10	—	—
Maleic anhydride	0.25	1	—	—

Capital letters refer to Appendices.
*1980 Addition.
**See Notice of Intended Changes.

MAP 000216

Substance	ADOPTED VALUES TWA ppm[a]	ADOPTED VALUES TWA mg/m³[b]	TENTATIVE VALUES STEL ppm[a]	TENTATIVE VALUES STEL mg/m³[b]
C Manganese & Compounds (as Mn)	—	5	—	—
Manganese fume (as Mn)	—	1	—	3
Manganese cyclopentadienyl tricarbonyl (as Mn) — Skin	—	0.1	—	0.3
Manganese Tetroxide	—	1	—	—
Marble/calcium carbonate	—	E	—	20
Mercury (Alkyl compounds) — Skin, (as Hg)	—	0.01	—	0.03
** Mercury (All forms except alkyl), as Hg	—	(0.05)	—	(0.15)
** Mesityl oxide	(25)	(100)	—	—
Methane	F	—	F	—
Methanethiol, see Methyl mercaptan	0.5	1	—	—
Methomyl (Lannate®) — Skin	—	2.5	—	—
Methoxychlor	—	10	—	—
2-Methoxyethanol — Skin (Methyl Cellosolve®)	25	80	35	120
Methyl acetate	200	610	250	760
Methyl acetylene (propyne)	1,000	1,650	1,250	2,040
Methyl acetylene-propadiene mixture (MAPP)	1,000	1,800	1,250	2,250
Methyl acrylate — Skin	10	35	—	—
Methylacrylonitrile — Skin	1	3	2	6
Methylal (dimethoxymethane)	1,000	3,100	1,250	3,875
Methyl alcohol (methanol) — Skin	200	260	250	310
Methylamine	10	12	—	—
Methyl amyl alcohol, see Methyl isobutyl carbinol — Skin	25	100	40	160

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

Substance	ADOPTED VALUES TWA ppm[a]	ADOPTED VALUES TWA mg/m³[b]	TENTATIVE VALUES STEL ppm[a]	TENTATIVE VALUES STEL mg/m³[b]
** Methyl n-amyl ketone (2-Heptanone)	(100)	(465)	(150)	(710)
** Methyl bromide — Skin	(15)	(60)	—	—
** Methyl butyl ketone — Skin	(25)	(100)	(40)	(165)
Methyl Cellosolve® — Skin see 2-Methoxyethanol	25	80	35	120
Methyl Cellosolve® acetate — Skin, see Ethylene glycol monomethyl ether acetate	25	120	35	170
** Methyl chloride	(100)	(210)	(125)	(260)
Methyl chloroform (1, 1, 1-Trichloroethane)	350	1,900	450	2,450
Methyl 2-cyanoacrylate	2	8	4	16
Methylcyclohexane	400	1,600	500	2,000
Methylcyclohexanol	50	235	75	350
o-Methycyclohexanone — Skin	50	230	75	345
Methylcyclopentadienyl manganese tricarbonyl (as MN) — Skin	—	0.2	—	0.6
Methyl demeton — Skin	—	0.5	—	1.5
C Methylene bisphenyl isocyanate (MDI)	0.02	0.2	—	—
** Methylene chloride (dichloromethane)	(200)	(700)	(250)	(870)
4, 4'-Methylene bis (2-chloroaniline) — Skin	0.02, A2	0.22, A2	—	—
C Methylene bis (4-cyclohexylisocyanate)	0.01	0.11	—	—
* 4, 4-Methylene dianiline	0.1	0.8	0.5	4
Methyl ethyl ketone (MEK)	200	590	300	885
C Methyl ethyl ketone peroxide	0.2	1.5	—	—
Methyl formate	100	250	150	375
C Methyl hydrazine — Skin	0.2	0.35	—	—
** Methyl iodide — Skin	(5)	(28)	(10)	(56)

Capital letters refer to Appendices.
*1980 Addition.
**See Notice of Intended Changes.

MAP 000217

Substance	ADOPTED VALUES TWA ppm[a]	TWA mg/m³[b]	TENTATIVE VALUES STEL ppm[a]	STEL mg/m³[b]
** Methyl isoamyl ketone	(100)	(475)	(150)	(710)
Methyl isobutyl carbinol — Skin	25	100	40	165
Methyl isobutyl ketone	100	410	125	510
Methyl isocyanate — Skin	0.02	0.05	—	—
Methyl mercaptan	0.5	1	—	—
Methyl methacrylate	100	410	125	510
Methyl parathion — Skin	—	0.2	—	0.6
Methyl propyl ketone	200	700	250	875
**C Methyl silicate	(5)	(30)	—	—
**C α-Methyl styrene	(100)	(480)	—	—
Molybdenum (as Mo) Soluble compounds	—	5	—	10
Insoluble compounds	—	10	—	20
Monocrotophos (Azodrin®)	—	0.25	—	—
** Monomethyl aniline — Skin	(2)	(9)	(4)	(18)
Morpholine — Skin	20	70	30	105
Naphthalene	10	50	15	75
β-Naphthylamine	—	A1b	—	A1b
Neon	F	—	F	—
Nickel carbonyl (as Ni)	0.05	0.35	—	—
Nickel metal	—	1	—	—
Nickel, soluble compounds (as Ni)	—	0.1	—	0.3
Nickel sulfide roasting, fume & dust (as Ni)	—	1, A1a	—	—
Nicotine — Skin	—	0.5	—	1.5
Nitric acid	2	5	4	10
Nitric oxide	25	30	35	45
p-Nitroaniline — Skin	1	6	2	12
Nitrobenzene — Skin	1	5	2	10
p-Nitrochlorobenzene — Skin	—	1	—	2
4-Nitrodiphenyl	—	A1b	—	A1b
Nitroethane	100	310	150	465
**C Nitrogen dioxide	(5)	(9)	—	—
Nitrogen trifluoride	10	30	15	45
**C Nitroglycerin — Skin	(0.2)	(2)	—	—

Capital letters refer to Appendices.
Footnotes (a thru f) see Page 32.
*1980 Addition
**See Notice of Intended Changes.

Substance	ADOPTED VALUES TWA ppm[a]	TWA mg/m³[b]	TENTATIVE VALUES STEL ppm[a]	STEL mg/m³[b]
Nitromethane	100	250	150	375
** 1-Nitropropane	(25)	(90)	(35)	(135)
*C 2-Nitropropane	25, A2	90, A2	—	—
N-Nitrosodimethylamine (dimethylnitrosoamine) — Skin	—	A2	—	A2
** Nitrotoluene — Skin	(5)	(30)	(10)	(60)
Nitrotrichloromethane, see Chloropicrin	0.1	0.7	0.3	2
Nonane	200	1,050	250	1,300
Octachloronaphthalene — Skin	—	0.1	—	0.3
Octane	300	1,450	375	1,800
Oil mist, mineral	—	5[e]	—	10
Osmium tetroxide (as Os)	0.0002	0.002	0.0006	0.006
Oxalic acid	—	1	—	2
Oxygen difluoride	0.05	0.1	0.15	0.3
Ozone	0.1	0.2	0.3	0.6
Paraffin wax fume	—	2	—	6
Paraquat, respirable sizes	—	0.1	—	—
Parathion — Skin	—	0.1	—	0.3
Particulate polycyclic aromatic hydro-carbons (PPAH), see Coal tar pitch volatiles	—	0.2, A1a	—	A1a
Pentaborane	0.005	0.01	0.015	0.03
Pentachloronaphthalene	—	0.5	—	2
Pentachlorophenol — Skin	—	0.5	—	1.5
Pentaerythritol	—	E	—	20
Pentane	600	1,800	750	2,250
2-Pentanone, see Methyl propyl ketone	200	700	250	875
** Perchloroethylene — Skin	(100)	(670)	(150)	(1,000)
Perchloromethyl mercaptan	0.1	0.8	—	—

Capital letters refer to Appendices.
Footnotes (a thru f) see Page 32.
*1980 Addition.
**See Notice of Intended Changes.

MAP 000218

Substance	ADOPTED VALUES TWA ppm[a]	TWA mg/m³[b]	TENTATIVE VALUES STEL ppm[a]	STEL mg/m³[b]
Perchloryl fluoride	3	14	6	28
Phenol — Skin	5	19	10	38
Phenothiazine — Skin	—	5	—	10
* N-Phenyl-beta-naphthylamine	A2	A2	—	—
p-Phenylene diamine — Skin	—	0.1	—	—
Phenyl ether (vapor)	1	7	2	14
** Phenyl ether-Diphenyl mixture (vapor)	(1)	(7)	(2)	(14)
Phenylethylene, see Styrene, monomer	100	420	125	525
** Phenyl glycidyl ether (PGE)	(10)	(60)	(15)	(90)
Phenylhydrazine — Skin	5	20	10	45
Phenyl mercaptan	0.5	2	—	—
C Phenylphosphine	0.05	0.25	—	—
Phorate (Thimet®) — Skin	—	0.05	—	0.2
Phosdrin (Mevinphos®) — Skin	0.01	0.1	0.03	0.3
Phosgene (carbonyl chloride)	0.1	0.4	—	—
Phosphine	0.3	0.4	1	1
Phosphoric acid	—	1	—	3
Phosphorus (yellow)	—	0.1	—	0.3
* Phosphorus pentachloride	0.1	1	—	—
Phosphorus pentasulfide	—	1	—	3
** Phosphorus trichloride	(0.5)	(3)	—	—
Phthalic anhydride	1	6	4	24
m-Phthalodinitrile	—	5	—	—
Picloram (Tordon®)	—	10	—	20
Picric acid — Skin	—	0.1	—	0.3
Pival® (2-Pivalyl-1, 3-indandione)	—	0.1	—	0.3
Plaster of Paris	—	E	—	20
Platinum (Soluble salts) as Pt	—	0.002	—	—
Polychlorobiphenyls, see Chlorodiphenyls — Skin	—	—	—	—

Capital letters refer to Appendices.
*1980 Addition.
**See Notice of Intended Changes.

Substance	ADOPTED VALUES TWA ppm[a]	TWA mg/m³[b]	TENTATIVE VALUES STEL ppm[a]	STEL mg/m³[b]
Polytetrafluoroethylene decomposition products	—	B1	—	B1
C Potassium hydroxide	—	2	—	—
Propane	F	—	F	—
Propargyl alcohol — Skin	1	2	3	6
** β-Propiolactone	—	(A2)	—	(A2)
* Propionic acid	10	30	15	45
n-Propyl acetate	200	840	250	1,050
Propyl alcohol — Skin	200	500	250	625
n-Propyl nitrate	25	105	40	470
Propylene	F	—	F	—
Propylene dichloride (1, 2-Dichloropropane)	75	350	110	510
**C Propylene glycol dinitrate — Skin	(0.2)	(2)	—	—
Propylene glycol monomethyl ether	100	360	150	540
** Propylene imine — Skin	(2)	(5)	—	—
** Propylene oxide	(100)	(240)	(150)	(360)
Propyne, see Methyl acetylene	1,000	1,650	1,250	2,040
Pyrethrum	—	5	—	10
Pyridine	5	15	10	30
Quinone	0.1	0.4	0.3	2
RDX, see Cyclonite — Skin	—	1.5	—	3
Resorcinol	10	45	20	90
** Rhodium, Metal fume and dusts (as Rh)	—	(0.1)	—	(0.3)
Soluble salts (as Rh)	—	0.001	—	0.003
Ronnel	—	10	—	—
Rosin core solder pyrolysis products (as formaldehyde)	—	0.1	—	0.3
Rotenone (commercial)	—	5	—	10
Rouge	—	E	—	20
Rubber solvent (Naphtha)	400	1,600	—	—
Selenium compounds (as Se)	—	0.2	—	—

Capital letters refer to Appendices.
*1980 Addition.
**See Notice of Intended Changes.

MAP 000219

Substance	ADOPTED VALUES TWA ppm[a]	TWA mg/m³[b]	TENTATIVE VALUES STEL ppm[a]	STEL mg/m³[b]
Selenium hexafluoride, (as Se)	0.05	0.2	—	—
Sevin® (see Carbaryl)	—	5	—	10
** Silane (see Silicon tetrahydride)	(0.5)	(0.7)	(1)	(1.5)
Silicon	—	E	—	20
Silicon carbide	—	E	—	20
** Silicon tetrahydride (Silane)	(0.5)	(0.7)	(1)	(1.5)
* Silver, metal	—	0.1	—	—
** Silver, soluble compounds, as Ag	—	(0.01)	—	(0.03)
C Sodium azide	0.1	0.3	—	—
* Sodium bisulfite	—	5	—	—
Sodium 2, 3-dichloro-phenoxyethyl sulfate	—	10	—	20
Sodium fluoroacetate (1080) — Skin	—	0.05	—	0.15
C Sodium hydroxide	—	2	—	—
* Sodium metabisulfite	—	5	—	—
Starch	—	E	—	20
Stibine	0.1	0.5	0.3	1.5
** Stoddard solvent	100	(575)	(125)	(720)
Strychnine	—	0.15	—	0.45
** Styrene, monomer (Phenylethylene)	(100)	(420)	(125)	(525)
C Subtilisins (Proteolytic enzymes as 100% pure crystaline enzyme)	—	0.00006[m]	—	—
Sucrose	—	E	—	20
* Sulfur dioxide	2	5	5	10
Sulfur hexafluoride	1,000	6,000	1,250	7,500
Sulfuric acid	—	1	—	—
Sulfur monochloride	1	6	3	18
Sulfur pentafluoride	0.025	0.25	0.075	0.75
Sulfur tetrafluoride	0.1	0.4	0.3	1
Sulfuryl fluoride	5	20	10	40
Systox, see Demeton® — Skin	0.01	0.1	0.03	0.3
2, 4, 5-T	—	10	—	20

Capital letters refer to Appendices.
*1980 Addition.
**See Notice of Intended Changes.
m) See Page 35

Substance	ADOPTED VALUES TWA ppm[a]	TWA mg/m³[b]	TENTATIVE VALUES STEL ppm[a]	STEL mg/m³[b]
Tantalum	—	5	—	10
TEDP — Skin	—	0.2	—	0.6
Teflon® decomposition products	—	B1	—	B1
Tellurium & compounds (as Te)	—	0.1	—	—
Tellurium hexafluoride, as Te	0.02	0.2	—	—
TEPP — Skin	0.004	0.05	0.01	0.2
*C Terphenyls	0.5	5	—	—
1, 1, 1, 2-Tetrachloro-2, 2-difluoroethane	500	4,170	625	5,210
1, 1, 2, 2-Tetrachloro-1, 2-difluoroethane	500	4,170	625	5,210
** 1, 1, 2, 2-Tetrachloroethane — Skin	(5)	(35)	(10)	(70)
Tetrachloroethylene, see Perchloroethylene — Skin	100	670	150	1,000
Tetrachloromethane, see Carbon tetrachloride — Skin	10	65	20	130
Tetrachloronaphthalene	—	2	—	4
Tetraethyl lead (as Pb) — Skin	—	0.100^	—	0.3
Tetrahydrofuran	200	590	250	735
Tetramethyl lead (as Pb) — Skin	—	0.150^	—	0.5
Tetramethyl succinonitrile — Skin	0.5	3	2	9
* Tetrasodium pyrophosphate	—	1	—	—
Tetranitromethane	1	8	—	—
Tetryl (2, 4, 6-trinitrophenyl-methylnitramine) — Skin	—	1.5	—	3.0
Thallium, soluble compounds (as Tl) — Skin	—	0.1	—	—

Capital letters refer to Appendices.
Footnotes (a thru f) see Page 32.
*1980 Addition.
**See Notice of Intended Changes.

MAP 000220

Substance	ADOPTED VALUES TWA ppm[a]	ADOPTED VALUES TWA mg/m³[b]	TENTATIVE VALUES STEL ppm[a]	TENTATIVE VALUES STEL mg/m³[b]
4, 4'-Thiobis (6-tert. butyl-m-cresol)	—	10	—	20
Thioglycolic acid	1	5	—	—
Thiram®	—	5	—	10
** Tin, inorganic compounds, except SnH_4 and SnO_2 (as Sn)	—	(2)	—	(4)
Tin, organic compounds (as Sn) — Skin	—	0.1	—	0.2
** Tin oxide (as Sn)	—	(E)	—	(20)
Titanium dioxide (as Ti)	—	E	—	20
Toluene (toluol) — Skin	100	375	150	560
**C Toluene-2, 4-diisocyanate (TDI)	(0.02)	(0.14)	—	—
** o-Toluidine	(5)	(22)	(10)	(44)
Toxaphene, see Chlorinated camphene — Skin	—	0.5	—	2.0
** Tributyl phosphate	—	(5)	—	(5)
* Trichloroacetic acid	—	1	—	—
1, 2, 4-Trichlorobenzene	5	40	—	—
1, 1, 1-Trichloroethane, see Methyl chloroform	350	1,900	450	2,380
1, 1, 2-Trichloroethane — Skin	10	45	20	90
** Trichloroethylene	(100)	(535)	(150)	(800)
** Trichlorofluoromethane	(1,000)	(5,600)	(1,250)	(7,000)
Trichloromethane, see Chloroform	10, A2	50, A2	—	—
Trichloronaphthalene	—	5	—	10
1, 2, 3-Trichloropropane	50	300	75	450
1, 1, 2-Trichloro 1, 2, 2-trifluoroethane	1,000	7,600	1,250	9,500
Tricyclohexyltin hydroxide (Plictran®)	—	5	—	10
Triethylamine	25	100	40	160
Trifluorobromomethane	1,000	6,100	1,200	7,300
Trimethyl benzene	25	125	35	170
** Trimethyl phosphite	(0.5)	(2.6)	—	—
2, 4, 6-Trinitrophenol, see Picric acid — Skin	—	0.1	—	0.3

Capital letters refer to Appendices.
*1980 Addition.
**See Notice of Intended Changes.

Substance	ADOPTED VALUES TWA ppm[a]	ADOPTED VALUES TWA mg/m³[b]	TENTATIVE VALUES STEL ppm[a]	TENTATIVE VALUES STEL mg/m³[b]
2, 4, 6-Trinitrophenyl-methylnitramine, see Tetryl — Skin	—	1.5	—	3.0
**C 2, 4, 6-Trinitrotoluene (TNT)	—	(0.5)	—	—
Triorthocresyl phosphate	—	0.1	—	0.3
Triphenyl amine	—	5	—	—
Triphenyl phosphate	—	3	—	6
Tungsten & compounds, as W				
Soluble	—	1	—	3
Insoluble	—	5	—	10
Turpentine	100	560	150	840
Uranium (natural) soluble & insoluble compounds, as U	—	0.2	—	0.6
** Vanadium (V_2O_5), as V				
Dust	—	(0.5)	—	(1.5)
C Fume	—	(0.05)	—	—
Valeraldehyde	50	175	—	—
Vinyl acetate	10	30	20	60
** Vinyl benzene, see Styrene	(100)	(420)	(125)	(525)
* Vinyl bromide	5, A2	20, A2	—	—
* Vinyl chloride	5, A1a	10, A1a	—	—
** Vinyl cyanide, see Acrylonitrile	(A1b)	(A1b)	—	—
Vinyl cyclohexene dioxide	10	60	—	—
Vinylidene chloride	10	40	20	80
** Vinyl toluene	(100)	(480)	(150)	(720)
VM & P Naphtha	300	1,350	400	1,800
Warfarin	—	0.1	—	0.3
Welding fumes (NOC)†	—	5, B3	—	B3
** Wood dust (nonallergenic)	—	(5)	—	(10)
Xylene (o-, m-, p-isomers) — Skin	100	435	150	655
C m-Xylene α, α'-diamine	—	0.1	—	—

*1980 Addition
**See Notice of Intended Changes.
Capital letters refer to Appendices.
†(NOC) not otherwise classified

MAP 000221

Substance	ADOPTED VALUES TWA ppm[a]	TWA mg/m³[b]	TENTATIVE VALUES STEL ppm[a]	STEL mg/m³[b]
** Xylidene — Skin	(5)	(25)	(10)	(50)
Yttrium	—	1	—	3
Zinc chloride fume	—	1	—	2
Zinc chromate (as Cr)	—	0.05, A2	—	—
Zinc oxide fume	—	5	—	10
Zinc stearate	—	E	—	20
Zirconium compounds (as Zr)	—	5	—	10

**See notice of intended changes

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 substance per cubic meter of air.
d) < 7 μm in diameter.
e) As sampled by method that does not collect vapor.
f) For control of general room air, biologic monitoring is essential for personnel control.

Radioactivity: The Committee accepts the philosophy and recommendations of the National Council on Radiation Protection and Measurements (NCRP) for the ionizing radiation TLV. The NCRP is charted by Congress to, in part, collect, analyze, develop and disseminate information and recommendations about protection against radiation and about radiation measurements, quantities and units, including development of basic concepts in these areas. NCRP Report No. 39 (reference 1) provides basic philosophy and concepts leading to protection criteria established in the same report. Other NCRP reports address specific areas of radiation protection and, collectively, provide an excellent basis for establishing a sound program for radiation control. The Committee recommends the listed references as substantative documentation of a sound basis for ionizing radiation protection. The Committee also strongly recommends that all exposures to ionizing radiations be kept low as reasonably achievable within the stated guidance.

References:
1. "Basic Radiation Protection Criteria," NCRP Report No. 39, issued January 15, 1971.
2. Maximum Permissible Body Burdens and Maximum Permissible Concentrations of Radionuclides in Air and in Water for Occupational Exposure," US Department of Commerce, National Bureau of Standards Handbook 69, issued June 5, 1959, with Addendum 1 issued August 1963. Available as NCRP Report No. 22.
The above documents, as well as information on numerous other NCRP Reports addressing specific subjects in ionizing radiation protection are available from: NCRP Publications, PO Box 30175, Washington, DC 20014.

MINERAL DUSTS

Substance	
SILICA, SiO_2	
Crystalline	
Quartz	TLV in mppcf[a]: $\frac{300^{h}}{\%\ \text{quartz} + 10}$ TLV for respirable dust in mg/m³: $\frac{10\ \text{mg/m}^3}{\%\ \text{Respirable quartz} + 2}$ TLV for "total dust," respirable and nonrespirable: $\frac{30\ \text{mg/m}^3}{\%\ \text{quartz} + 3}$
Cristobalite	Use one-half the value calculated from the count or mass formulae for quartz.
Tridymite	Use one-half the value calculated from formulae for quartz.
Silica, fused	Use quartz formulae.
Tripoli	Use respirable[n] mass quartz formula
**Amorphous*	(20 mppcf[a])

**See Notice of Intended Changes.
g), n), i) See p. 34.
n) See p. 35.

MAP 000222

SILICATES (< 1% quartz)

*Asbestos	
Amosite	0.5 fiber > 5μm/cc, A1a
Chrysotile	2 fibers > 5μm/cc, A1a
Crocidolite	0.2 fiber > 5μm/cc, A1a
Other forms	2 fibers > 5μm/cc, A1a
Mica	20 mppcf
Mineral wool fiber	10 mg/m³
Perlite	30 mppcf
Portland Cement	30 mppcf
Soapstone	20 mppcf
**Talc (nonasbestiform)	(20 mppcf)
**Talc (fibrous), (use Asbestos limit.)	

COAL DUST

2 mg/m³ (respirable dust fraction < 5% quartz).
If > 5% quartz, use respirable mass formula.

NUISANCE PARTICULATES
(see Appendix E)

30 mppcf or 10 mg/m³[j]
of total dust < 1% quartz, or, 5 mg/m³ respirable dust.

Conversion factors:
mppcf × 35.3 = Million particles per cubic meter
= particles per cc

g) Millions of particles per cubic foot of air, based on impinger samples counted by light-field technics.
h) The percentage of quartz in the formula is the amount determined from airborne samples, except in those instances in which other methods have been shown to be applicable.
i) Both concentration and percent quartz 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

*1980 Addition.
**See Notice of Intended Changes.

j) containing < 1% quartz; if quartz content > 1%, use formulae for quartz.
k) Lint-free dust as measured by the vertical-elutriator, cotton-dust sampler described in the Transactions of the National Conference on Cotton Dust, J. R. Lynch, pg. 33, May 2, 1970.
l) As determined by the membrane filter method at 400–450X magnification (4 mm objective) phase contrast illumination.
m) Based on "high volume" sampling.
n) "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.

NOTICE OF INTENDED CHANGES (for 1980)

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. Documentation is available for each of these substances.

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Substance	TWA ppm[a]	TWA mg/m³[b]	STEL ppm[a]	STEL mg/m³[b]
Acetone	750	1780	1000	2375
Acrylic acid	10	30	—	—
† Acrylonitrile	2, A1a	4.5, A1a	—	—
† Benzidine — Skin	—	A1b	—	—
Butane	800	1900	—	—
2-Buoxyethanol (Butyl Cellosolve®) — Skin	25	120	75	360
sec-Butyl alcohol	100	305	150	455
n-Butyl glycidyl ether (BGE)	25	135	—	—
† Cadmium oxide production	—	0.05	—	—
Carbon tetrachloride — Skin	5, A2	30, A2	20, A2	125, A2
Carbonyl fluoride	2	5	5	15
†C o-Chlorobenzylidene malononitrile	0.05	0.4	—	—
† Chloromethyl methyl ether	A2	A2	—	—
1-Chloro-1-nitropropane	2	10	—	—
Chloropentafluoroethane	1000	6320	—	—
Chromium metal	—	0.5	—	—
Chromium (II) compounds, as Cr	—	0.5	—	—
Chromium (III) compounds, as Cr	—	0.5	—	—
Chromium (VI) compounds, as Cr Water soluble Cr VI compounds	—	0.05	—	—
Certain water insoluble Cr VI compounds	—	0.05, A1a	—	—
† Chromyl chloride	0.025	0.15	—	—
Chrysene	A2	A2	—	—
Cobalt metal, dust & fume, as Co	—	0.05	—	0.1
Cyclohexanone	25	100	100	400
Cyclopentane	600	1720	900	2580
1, 2-Dibromoethane, see Ethylene dibromide — Skin	A2	A2	—	—
1, 1-Dichloro-1-nitroethane	2	10	10	60
Diethylamine	10	30	25	75
Diethyl ketone	200	705	—	—
Diglycidyl ether (DGE)	0.1	0.5	—	—

Capital letters refer to Appendices
†1980 Revision or Addition.

Substance	TWA ppm[a]	TWA mg/m³[b]	STEL ppm[a]	STEL mg/m³[b]
Dioxane, tech. grade — Skin	25	90	100	360
Dipropyl ketone	50	235	—	—
† Enfluorane	75	575	—	—
2-Ethoxyethanol — Skin	50	185	100	370
2-Ethoxyethyl acetate (Cellosolve® acetate) — Skin	50	270	100	540
Ethyl acrylate — Skin	5	20	25	100
† Ethylene dibromide — Skin	A2	A2	—	—
C Ethylene glycol, vapor	50	125	—	—
Ethylene glycol dinitrate	0.02	0.2	0.04	0.4
Ethylene oxide	10	20	—	—
† N-Ethylmorpholine — Skin	5	23	20	95
Furfural — Skin	2	8	10	40
† Furfuryl alcohol — Skin	10	40	15	60
† Gasoline	300	900	500	1500
Glycidol (2, 3-Epoxy-1-propanol)	25	75	100	300
† Halothane	50	400	—	—
† Hexachlorobutadiene	0.02, A2	0.24, A2	—	—
† Hexachloroethane — Skin	10	100	—	—
† Hexane (n-Hexane)	50	180	—	—
(other Isomers)	500	1800	1,000	3,600
Hexone, see Methyl isobutyl ketone — Skin	50	205	75	300
† Iron pentacarbonyl, as Fe	0.1	0.8	0.2	0.16
† Isooctyl alcohol	50	270	—	—
Isopropoxyethanol	25	105	75	320
† Lead arsenate, as $Pb_3(AsO_4)_2$	—	0.15	—	0.45
† Mercury (All forms except alkyl) — Skin, as Hg Vapor	—	0.05	—	—
Aryl & inorganic compounds	—	0.1	—	—
Mesityl oxide	15	60	25	100
Methacrylic acid	20	70	—	—
† 4-Methoxyphenol	—	5	—	—
Methyl n-amyl ketone (2-Heptanone)	50	235	100	465
† N-Methyl aniline — Skin	0.5	2	1	5

Capital letters refer to Appendices.
†1980 Revision or Addition

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Substance	TWA ppm[a]	TWA mg/m³[b]	STEL ppm[a]	STEL mg/m³[b]
Methyl bromide — Skin	5	20	15	60
Methyl n-butyl ketone	5	20	—	—
Methyl chloride	50	105	100	205
Methylene chloride (dichloromethane)	100	360	500	1,700
Methyl iodide — Skin	2, A2	10, A2	5, A2	30, A2
† Methyl isoamyl ketone	50	240	—	—
Methyl isobutyl ketone — Skin	50	205	75	300
Methyl isopropyl ketone	200	705	—	—
Methyl silicate	1	6	5	30
α-Methyl styrene	50	240	100	485
† p-Nitroaniline — Skin	—	3	—	—
† p-Nitrochlorobenzene — Skin	0.5	3	—	—
Nitrogen dioxide	3	6	5	10
Nitroglycerin	0.02	0.2	0.04	0.4
1-Nitropropane	15	55	25	90
† Nitrotoluene — Skin	2	11	—	—
† Perchloroethylene — Skin	50	335	—	—
† Persulfates, alkali metal, as S_2O_8	—	2	—	—
Phenyl ether — Diphenyl mixture (vapor)	0.5	4	2	16
† Phenyl glycidyl ether (PGE)	1	6	—	—
† Phosphorus oxychloride	0.1	0.6	0.5	3
† Phosphorus trichloride	0.2	1.5	0.5	3
† Piperazine dihydrochloride	—	5	—	—
Platinum metal	—	1	—	—
β-Propiolactone	0.5, A2	1.5, A2	1, A2	3, A2
Propylene glycol dinitrate	0.02	0.2	0.04	0.4
† Propylene imine — Skin	2, A2	5, A2	—	—
Propylene oxide	20	50	—	—
† Rhodium, Metal	—	1	—	—
Insoluble compounds, as Rh	—	0.1	—	0.3
† Silicon tetrahydride (Silane)	5	7	—	—
Silver, soluble compounds, as Ag	—	0.01	—	—
† Stoddard solvent	100	525	200	1,050
Styrene, monomer (phenylethylene)	50	215	100	425

Capital letters refer to Appendices
†1980 Revision or Addition.

Substance	TWA ppm[a]	TWA mg/m³[b]	STEL ppm[a]	STEL mg/m³[b]
† 1, 1, 2, 2-Tetrachloroethane — Skin	1	7	5	35
† Tin, tin oxide & inorganic compounds, except SnH_4, as Sn	—	2	—	4
† o-Tolidine	A2	A2	—	—
Toluene-2, 4-diisocyanate (TDI)	0.005	0.04	0.02	0.15
† o-Toluidine	2	9	—	—
Tributyl phosphate	0.2	2.5	0.4	5
Trichloroethylene	50	270	150	805
†C Trichlorofluoromethane	1,000	5,600	—	—
Trimellitic anhydride	0.005	0.04	—	—
† Trimethyl phosphite	2	10	5	25
† 2, 4, 6-Trinitrotoluene (TNT) — Skin	—	0.5	—	3
† Vanadium, as V_2O_5, dust & fume	—	0.05	—	—
Vinyl toluene	50	240	100	485
Wood dust, hard wood (as in furniture making)	—	1	—	—
† Xylidine — Skin	2	10	—	—

NOTICE OF INTENDED CHANGES
MINERAL DUSTS

Substance	TLV
Diatomaceous earth, natural	1.5 mg/m³, Respirable dust
Silica, amorphous	6 mg/m³, Total dust (all sampled sizes)
	3 mg/m³, Respirable dust (< 5 μm)
† Talc (containing no fibers)	15 mppcf or 2 mg/m³, Respirable Dust
† Talc (fiber-containing)	2 fibers/cc, > 5 μm in length

Capital letters refer to Appendices.
†1980 Revision or Addition.

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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).

A1a. *Human Carcinogens*. Substances, or substances associated with industrial processes, recognized to have carcinogenic or cocarcinogenic potential, with an assigned TLV:

	TLV
† Acrylonitrile	2 ppm
††Asbestos	
Amosite	0.5 fiber > 5μm/cc
Chrysotile	2 fibers > 5μm/cc
Crocidolite	0.2 fiber > 5μm/cc
Other forms	2 fibers > 5μm/cc
bis (Chloromethyl) ether	0.001 ppm
Chromite ore processing (chromate)	0.05 mg/m³, as Cr
Nickel sulfide roasting, fume & dust	1.0 mg/m³, as Ni
Coal tar pitch volatiles	0.2 mg/m³, as benzene solubles
†† Vinyl chloride	5 ppm

* * *

A1b. *Human Carcinogens*. Substances, or substances associated with industrial processes, recognized to have carcinogenic potential without an assigned TLV:

** Acrylonitrile
4-Aminodiphenyl (p-Xenylamine)
† Benzidine — Skin
** Chloromethyl methyl ether
** Ethylene dibromide
β-Naphthylamine
4-Nitrodiphenyl

†1980 Addition
††1980 Adoption
**See Notice of Intended Changes

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. The worker should be properly equipped to insure virtually no contact with the carcinogen.

A2. *Industrial Substances Suspect of Carcinogenic Potential for MAN*. Chemical substances or substances associated with industrial processes, which are suspect of inducing cancer, based on either (1) limited epidemiologic evidence, exclusive of clinical reports of single cases, or (2) demonstration of carcinogenesis in one or more animal species by appropriate methods.

3-Amino 1, 2, 4-triazole	
†† Antimony trioxide production*	——
†† Arsenic trioxide production	——
Benzene	10 ppm
Benzo(a)pyrene	——
Beryllium	2.0 μg/m³
** Cadmium oxide production	——
Carbon tetrachloride	5 ppm
Chloroform	10 ppm
† Chloromethyl methyl ether	——
Chromates of lead and zinc, as Cr	0.05 mg/m³
3, 3'-Dichlorobenzidine	——
Dimethylcarbamyl chloride	——
1, 1-Dimethyl hydrazine	0.5 ppm
Dimethyl sulfate — Skin	0.1 ppm
† Ethylene dibromide — Skin	——
† Hexachlorobutadiene	0.02 ppm
Hexamethyl phosphoramide — Skin	——
Hydrazine	0.1 ppm
4, 4'-Methylene bis (2-chloroaniline) — Skin	0.02 ppm
Methyl hydrazine	0.2 ppm
Methyl iodide	2 ppm
††C 2-Nitropropane	25 ppm
n-Nitrosodimethylamine	——
n-Phenyl-beta-naphthylamine	——

*Cigarette smoking can enhance the incidence of respiratory cancers from this or others of these substances or processes.
†1980 Addition.
††1980 Adoption.
**See Notice of Intended Changes.

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Propane sultone	——
beta-Propiolactone	——
† Propylene imine — Skin	2 ppm
† o-Tolidine	——
†† Vinyl bromide	5 ppm
Vinyl cyclohexene dioxide	10 ppm

For the above, worker exposure by all routes should be carefully controlled to levels consistent with the animal and human experience data (see Documentation), including those substances with a listed TLV.

THE COMMITTEE GUIDELINES FOR CLASSIFICATION OF EXPERIMENTAL ANIMAL CARCINOGENS

The following guidelines are offered in the present state of knowledge as an aid in classifying substances in the occupational environment found to be carcinogenic in experimental animals. A need was felt by the Threshold Limits Committee for such a classification in order to take the first step in developing an appropriate TLV for occupational exposure.

Determination of Approximate Threshold of Response Requirement. In order to determine in which category to classify an experimental carcinogen for the purpose of assigning an industrial air limit (TLV), an approximate threshold of neoplastic response must be determined. Because of practical experimental difficulties, a precisely defined threshold cannot be attained. For the purposes of standard-setting, this is of little moment, as an appropriate risk, or safety, factor can be applied to the approximate threshold, the magnitude of which is dependent on the degree of potency of the carcinogenic response.

To obtain the best 'practical' threshold of neoplastic response, dosage decrements should be less than logarithmic. This becomes particularly important at levels greater than 10 ppm (or corresponding mg/m³). Accordingly, after a range-finding determination has been made by logarithmic decreases, two additional dosage levels are required within the levels of "effect" and "no effect" to approximate the true threshold of neoplastic response.

†1980 Addition.
††1980 Adoption.

The second step should attempt to establish a metabolic relationship between animal and man for the particular substance found carcinogenic in animals. If the metabolic pathways are found comparable, the substance should be classed highly suspect as a carcinogen for man. If no such relation is found, the substance should remain listed as an experimental animal carcinogen until evidence to the contrary is found.

Proposed Classification of Experimental Animal Carcinogens. Substances occurring in the occupational environment found carcinogenic for animals may be grouped into three classes, those of high, intermediate and low potency. In evaluating the incidence of animal cancers, significant incidence of cancer is defined as a neoplastic response which represents, in the judgment of the Committee, a significant excess of cancers above that occurring in negative controls.

EXCEPTIONS: No substance is to be considered an occupational carcinogen of any practical significance which reacts by the respiratory route at or above 1000 mg/m³ for the mouse, 2000 mg/m³ for the rat; by the dermal route, at or above 1500 mg/kg for the mouse, 3000 mg/kg for the rat; by the gastrointestinal route at or above 500 mg/kg/d for a lifetime, equivalent to about 100 g T.D. for the rat, 10g T.D. for the mouse.

These dosage limitations exclude such substances as dioxane and trichlorethylene from consideration as carcinogens.

Examples: Dioxane — rats, hepatocellular and nasal tumors from 1015 mg/kg/d, oral
Trichloroethylene — female mice, tumors (30/98 @ 900 mg/kg/d), oral

Industrial Substances of High Carcinogenic Potency in Experimental Animals.

1. A substance to qualify as a carcinogen of high potency must fulfill one of the three following conditions in two animal species:

   1a. *Respiratory.* Elicit cancer from (1) dosages below 1 mg/m³ (or equivalent ppm) via the respiratory tract in 6- 7-hour daily

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repeated inhalation exposures throughout lifetime; or (2) from a single intratracheally administered dose not exceeding 1 mg of particulate, or liquid, per 100 ml or less of animal minute respiratory volume;

Examples: bis-Chloromethyl ether, malignant tumors, rats, @ 0.47 mg/m³ (0.1 ppm) in 2 years;

Hexamethyl phosphoramide, nasal squamous cell carcinoma, rats, @ 0.05 ppm, in 13 months

OR

1b. *Dermal*. Elicit cancer within 20 weeks by skin-painting, twice weekly at 2 mg/kg body weight or less per application for a total dose equal to or less than 1.5 mg, in a biologically inert vehicle;

Examples: 7, 12-Dimethylbenz(a)anthracene — skin tumors @ 0.12-0.8 mg T.D. in four weeks

Benzo(a)pyrene, mice 12 μg, 3X/wk for 18 mos. T.D. 2.6 mg, 90.9% skin tumors

OR

1c. *Gastrointestinal*. Elicit cancer by daily intake via the gastrointestinal tract, within six months, with a six-month holding period, at a dosage below 1 mg/kg body weight per day; total dose, rat, ≤ 50 mg; mouse, ≤ 3.5 mg;

Examples: 7, 12-Dimethylbenz(a)anthracene — mammary tumors from 10 mg 1X

3-Methylcholanthrene — Tumors @ 3 sites from 8 mg in 89 weeks

Benzo(a)pyrene, mice, 3.9% leukemias, from 30 mg T.D. 198 days

2. Elicit cancer by all three routes in at least two animal species at dose levels prescribed for high or intermediate potency.

Industrial Substances of Intermediate Carcinogenic Potency in Experimental Animals.

To qualify as a carcinogen of intermediate potency, a substance should elicit cancer in two animal species at dosages intermediate between those described in A3a and A3c by two routes of administration.

Example: Carbamic acid ethyl ester
Dermal, mammary tumors, mice, 100%, 63 weeks, 500–1400 mg T.D.
Gastrointestinal, various type tumors, mice 42 weeks, 320 mg T.D.

Gastrointestinal, various type tumors, rats, 60 weeks, 110–930 mg T.D.

Industrial Substances of Low Carcinogenic Potency in Experimental Animals.

To qualify as a carcinogen of low potency, a substance should elicit cancer in one animal species by any *one* of three routes of administration at the following prescribed dosages and conditions:

1a. *Respiratory*. Elicit cancer from (1) dosages greater than 10 mg/m³ (or equivalent ppm) via the respiratory tract in 6- 7-hour, daily repeated inhalation exposures, for 12 months' exposure and 12 months' observation period; or (2) from intratracheally administered dosages totaling more than 10 mg of particulate or liquid per 100 ml or more of animal minute respiratory volume;

Examples: Beryl (beryllium aluminum silicate) malig. lung tumors, rats, @ 15 mg/m³ @ 17 months

Benzidine, var. tumors, rats, 10–20 mg/m³ @ > 13 mos.

OR

1b. *Dermal*. Elicit cancer by skin-painting of mice in twice weekly dosages of > 10 mg/kg body weight in a biologically inert vehicle for at least 75 weeks, i.e., ≥ 1.5g T.D.

Examples: Shale tar, mouse, 0.1 ml × 50 = 5g T.D. 59/60 skin tumors

Arsenic trioxide, man, dose unknown, but estimated to be high

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1c. *Gastrointestinal*. Elicit cancer from daily oral dosages of 50 mg/kg/day or greater during the lifetime of the animal.

APPENDIX B
SUBSTANCES OF VARIABLE COMPOSITION

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 minimal.

B2 *Gasoline*. See Notice of Intended Change.

B3 *Welding Fumes —Total Particulate (NOC)***
TLV, 5mg/m³

Welding fumes cannot be classified simply. The composition and quantity of both are dependent on the alloy being welded and the process and electrodes used. Reliable analysis of fumes cannot be made without considering the nature of the welding process and system being examined; reactive metals and alloys such as aluminum and titanium are arc-welded in a protective, inert atmosphere such as argon. These arcs create relatively little fume, but an intense radiation which can produce ozone. Similar processes are used to arc-weld steels, also creating a relatively low level of fumes. Ferrous alloys also are arc-welded in oxidizing environments which generate considerable fume, and can produce carbon monoxide instead of ozone. Such fumes generally are composed of discreet particles of amorphous slags containing iron, manganese, silicon and other metallic constituents depending on the alloy system involved. Chromium and nickel compounds are found in fumes when stainless steels are arc-welded. Some coated and flux-cored electrodes are formulated with fluorides and the fumes associated with them can contain significantly more fluorides than oxides. Because of the above factors, arc-welding fumes frequently must be tested for individual constituents which are likely to be present to determine whether specific TLV's are exceeded. Conclusions based on total fume concentration are generally adequate if no toxic elements are present in welding rod, metal, or metal coating and conditions are not conducive to the formation of toxic gases.

Most welding, even with primitive ventilation, does not produce exposures inside the welding helmet above 5 mg/m³. That which does, should be controlled.

*Trade Names: Algoflon, Fluon, Halon, Teflon, Tetran.
**Not otherwise classified (NOC).

APPENDIX C
MIXTURES

C.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,

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

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 a 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.).

Synergistic action or potentiation may occur with some combinations of atmospheric contaminants. Such cases at present must be determined individually. Potentiating or synergistic 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 a given operation or process characteristically emits a number of harmful dusts, 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

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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.

C.1A Examples of THRESHOLD LIMIT VALUES FOR MIXTURES

The following formulae apply only when the components in a mixture have similar toxicologic effects; they should not be used for mixtures with widely differing reactivities, e.g. hydrogen cyanide & sulfur dioxide. In such case the formula for Independent Effects (1A.c.) should be used.

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.)

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

Example No. 1A.a.: Air contains 400 ppm of acetone (TLV = 1000 ppm) 150 ppm of secbutyl acetate (TLV = 200 ppm) and 100 ppm of 2-butanone (TLV = 200 ppm)

Atmospheric concentration of mixture = 400 + 150 + 100 = 650 ppm of mixture

$$\frac{400}{1000} + \frac{150}{200} + \frac{100}{200} = 0.4 + 0.75 + 0.5 = 1.65$$

Threshold Limit is exceeded.

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 =

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

Example No. 1: Liquid contains (by weight)

50% heptane: TLV = 400 ppm or 1600 mg/m³
1 mg/m³ = 0.25 ppm

30% methyl chloroform: TLV = 350 ppm or 1900 mg/m³
1 mg/m³ = 0.28 ppm

20% perchloroethylene: TLV = 100 ppm or 670 mg/m³
1 mg/m³ = 0.15 ppm

$$\text{TLV of Mixture} = \frac{1}{\frac{0.5}{1600} + \frac{0.3}{1900} + \frac{0.2}{670}}$$

$$= \frac{1}{0.00031 + 0.00016 + 0.00030}$$

$$= \frac{1}{0.00077} = 1300 \text{ mg/m}^3$$

of this mixture

50% or (1300) (0.5) = 650 mg/m³ is heptane

30% or (1300) (0.3) = 390 mg/m³ is methyl chloroform

20% or (1300) (0.2) = 260 mg/m³ is perchloroethylene

These values can be converted to ppm as follows:

heptane: 650 mg/m³ × 0.25 = 162 ppm

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methyl chloroform: 390 mg/m³ × 0.18 = 70 ppm
perchloroethylene: 260 mg/m³ × 0.15 = 39 ppm

TLV of mixture = 162 + 70 + 39 = 271 ppm, or 1300 mg/m³

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. TLV for Mixtures of Mineral Dusts.

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

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

$$TLV = \frac{1}{\frac{0.8}{20} + \frac{0.2}{2.7}} = 9 \text{ mppcf}$$

TLV of nonasbestiform talc (pure) = 20 mppcf
TLV of quartz (pure) =

$$\frac{300}{100 + 10} = \frac{300}{110} = 2.7 \text{ mppcf}$$

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:

25% quartz — TLV (pure) = 2.7 mppcf
25% amorphous silica — TLV (pure) = mppcf
50% talc TLV (pure) = 20 mppcf

$$TLV = \frac{1}{\frac{0.25}{2.7} + \frac{0.25}{20} + \frac{0.5}{20}} = 8 \text{ mppcf}$$

The limit for 25% quartz approximates 9 mppcf.

APPENDIX E
Some Nuisance Particulates[o]

TLV, 30 mppcf or 10mg/m³ of total dust < 1% quartz, or, 5 mg/m³ respirable dust

Aluminum Oxide (Al_2O_3)	Kaolin
Calcium carbonate	Limestone
Calcium silicate	Magnesite
Cellulose (paper fiber)	Marble
Portland Cement	Mineral Wool Fiber
Emery	Pentaerythritol
Glycerin Mist	Plaster of Pans
Graphite (synthetic)	Silicon
Gypsum	Silicon Carbide
Vegetable oil mists (except castor, cashew nut, or similar irritant oils)	Starch
	Sucrose
	**Tin Oxide
	Titanium Dioxide
	Zinc Stearate
	Zinc oxide dust

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

APPENDIX F
Some Simple Asphyxiants[p]

Acetylene	Hydrogen
Argon	Methane
Butane	Neon
Ethane	Propane
Ethylene	Propylene
Helium	

p) As defined on pg. 6.

APPENDIX G
Conversion of mppcf to Mass Concentration

Calculations for Conversion of Particle Count Concentration (by Standard Light Field — Midget Impinger Techniques), in mppcf, to Respirable Mass Concentration (by Respirable Sampler) in mg/m³.†

1. **In 1967, Jacobsen and Tomb,† derived an empirical relationship of 5.6 mppcf to 1 milligram**

†"Relationship Between Gravimetric Respirable Dust Concentration and Midget Impinger Number Concentration," by Murray Jacobson and T. F. Tomb, AIHAJ, 28: Nov.–Dec. 1967.
**See Notice of Intended Changes.

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of respirable dust per cubic meter of air, based on 23 sets of samples, mostly coal dust. The following calculation results in an equivalence of 6.37 mppcf to 1 mg/m³ of respirable dust. Thus, an approximate ratio of 6 mppcf to 1 mg/m³ of respirable dust is suggested for conversion of TLVs from a count to a mass basis when the density and mass median diameter have not been determined.

2. Basic assumptions:

   a) Average density for silica containing dusts ≈ 2.5 gms/cm³ (2500 mg/cm³). Pulmonary significant dust densities may vary from 1.2 gm/cm³ for coal dust to 3.1 gms/cm³ for Portland Cement. Silica densities vary from 2.2 (amorphous) to 2.3 (cristobalite and tridymite) to 2.5 (alpha-quartz.) gms per cm³.

   b) The mass median diameter (mmd) of particles collected in midget impinger samplers and counted by the standard light field technique, *and* collected in a respirable sampler is approximately 1.5 μm or 1.5×10^{-4} cm. This assumption is, of course, quite arbitrary since the mmd of all dust clouds is quite variable, depending on many independent parameters, such as source of dust, age of dust cloud, meteorological conditions, etc.

3. Calculation:

   a) vol. per particle: $4/3\ \pi\ r^3$; $r = 0.75 \times 10^{-4}$ cm
   $= 4/3 * \pi * (0.75 \times 10^{-4})^3$
   $= 1.77 \times 10^{-12}$ cm³

   b) wt. per particle = vol. × density
   $= 1.77 \times 10^{-12}$ cm³ $\times\ 2.5 \times 10^3$ mg/cm³
   $= 4.425 \times 10^{-9}$ mg/particle

   c) 1 particle/ft.³ = 35.5 part./m³
   (since 35.5 cu ft = 1 cu m.)
   10^6 part./ft³ = mppcf = 35.5×10^6 part./m³

   wt. of 1 mppcf ≡ 35.5×10^6 part./m³ × 4.425×10^{-9} mg/part.

   1 mppcf ≡ 0.157 mg/m³
   or
   6.37 mppcf ≡ 1 mg/m³
   or approximately 6 mpccf ≡ 1 mg/m³.

4. Equivalent TLVs in mppcf and mg/m³ (respirable mass) for Mineral Dusts.

Substance	Threshold Limit Value		
	Count mppcf	Resp. Mass mg/m³	Total Mass* mg/m³
Silica (SiO_2)			
Amorphous	20	(3)**	(6)
Cristobalite	1.5	0.05	0.15
Fused silica	3	0.1	0.3
Quartz	3	0.1	0.3
Tridymite	1.5	0.05	0.15
Coal Dust	(12)	2	(4)
Diatomaceous earth, natural	—	1.5	—
Graphite (natural)	15	(2.5)	(5)
Mica	20	(3)	(6)
Mineral wool fiber	—	(5)	10
Nuisance particulates	30	(5)	10
Perlite	30	(5)	(10)
Portland Cement	30	(5)	(10)
Soapstone	20	(3)	(6)
Tripoli	(3)	0.1	(0.3)

*Unless otherwise specified, respirable mass is presumed to equal approximately 50% of total mass.

**All values in parentheses ( ) represent newly calculated values based on equivalence of 6 mppcf = 1 mg/m³ respirable mass and respirable mass = 50% total mass.

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TLVs®
Threshold Limit Values
for
Physical Agents
Adopted by
ACGIH
for 1980



MAP 000233

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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.

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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 1 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*; F. N. Dukes-Dobos and A. Henschel: *"Development of Permissible Heat Exposure Limits for Occupational Work."* ASHRAE Journal, Vol. 15: No. 9, September 1973, pp. 57–62.)

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 + 0.1 DB
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 1

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

	Work Load		
Work — Rest Regimen	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 1 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.

EVALUATION AND CONTROL

I. *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 −5°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

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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. A 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.

C. A 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 as that of 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 1964.

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

II. *Work Load Categories*

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 (up to 200 kcal/hr or 800 Btu/hr): e.g., sitting or standing to control machines, performing light hand or arm work,

(2) moderate work (200–350 kcal/hr or 800–1400 Btu/hr): e.g., walking about with moderate lifting and pushing,

(3) heavy work (350–500 kcal/hr or 1400–2000 Btu/hr): 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. When this method is used the permissible heat exposure limit can be determined by Figure 1.

1. Per-Olof 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.

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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 1 and Figure 1 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. Where the WBGT of the work area is different from that of the rest area a time-weighted average value should be used for both environmental and metabolic heat. When time-weighted average values are used the appropriate curve on Figure 1 is the solid line labeled "continuous."

The time-weighted average metabolic rate (M) shall be determined by the equation:

$$\text{Av. } M = \frac{(M_1) \times (t_1) + (M_2) \times (t_2) + \ldots + (M_n) \times (t_n)}{(t_1) + (t_2) + \ldots + (t_n)}$$

Where M_1 M_2, M_n are estimated or measured metabolic rates for the various activities of the worker during the total time period. t_1, t_2, t_n are the elapsed times in minutes spent at the corresponding metabolic rate as determined by a time study.

The time-weighted average WBGT shall be determined by the equation:

$$\text{Av. WBGT} = \frac{(WBGT_1) \times (t_1) + (WBGT_2) \times t_2 + \ldots + (WBGT_n) \times (t_n)}{(t_1) + (t_2) + \ldots + (t_n)}$$

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where $WBGT_1$, $WBGT_2$, $WBGT_n$ are calculated values of WBGT for the various work and rest areas occupied during total time periods. t_1, t_2, t_n are the elapsed times in minutes spent in the corresponding areas which are determined by a time study. Where exposure to hot environmental conditions is continuous for several hours or the entire work day, the time-weighted averages shall be calculated as hourly time-weighted average i.e., $t_1 + t_2 + \ldots + t_n = 60$ minutes. Where the exposure is intermittent, the time-weighted averages shall be calculated as two-hour time-weighted averages, i.e., $t_1 + t_2 + \ldots + t_n = 120$ minutes.

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.

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 shall be kept reasonably cool (10°–15°C or 50.0°–60.0°F) 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 cothing 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 1 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: Acclimatization to heat involves a series of physiological and psychological adjustments that occur in an individual during his first week of exposure to hot environmental conditions. The recommended heat stress TLVs are valid for acclimated workers who are physically fit. Extra caution must be employed when unacclimated or physically un-fit workers must be exposed to heat stress conditions.

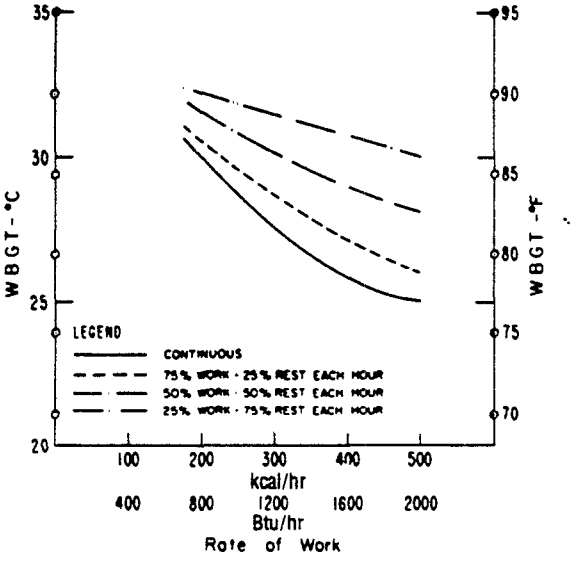


Figure 1 — Permissible Heat Exposure Threshold Limit Value

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IONIZING RADIATION

The Committee accepts the philosophy and recommendations of the National Council on Radiation Protection and Measurements (NCRP) for the ionizing radiation TLV. The NCRP is charted by Congress to, in part, collect, analyze, develop and disseminate information and recommendations about protection against radiation and about radiation measurements, quantities and units, including development of basic concepts in these areas. NCRP Report No. 39 (reference 1) provides basic philosophy and concepts leading to protection criteria established in the same report. Other NCRP reports address specific areas of radiation protection and, collectively, provide an excellent basis for establishing a sound program for radiation control. The Committee recommends the listed references as substantative documentation of a sound basis for ionizing radiation protection. The committee also strongly recommends that all exposures to ionizing radiations be kept as low as reasonably achievable within the stated guidance.

References:

1. "Basic Radiation Protection Criteria," NCRP Report No. 39, issued January 15, 1971.
2. Maximum Permissible Body Burdens and Maximum Permissible Concentrations of Radionuclides in Air and in Water for Occupational Exposure," US Department of Commerce, National Bureau of Standards Handbook 69, issued June 5, 1959, with Addendum 1 issued August 1963. Available as NCRP Report No. 22.
The above documents, as well as information on numerous other NCRP Reports addressing specific subjects in ionizing radiation protection are available from: NCRP Publications, PO Box 30175, Washington, DC 20014.

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); and except for all TLVs for wavelengths between 0.1–1 mm where the limiting aperture is 10 mm. 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 Factors A and B (C_A and C_B)

The TLVs for ocular exposure in Tables 3 and 4 are to be used as given for all wavelength ranges. The TLVs for wavelengths between 700 nm and 1049 nm are to be increased by a uniformly extrapolated factor (C_A) as shown in Figure 2. Between 1049 nm and 1400 nm, the TLV has been increased by a factor (C_A) of five. For certain exposure times at wavelengths between 550 nm and 700 nm, correction factor (C_B) must be applied.

The TLVs for skin exposure are given in Table 6. The TLVs are to be increased by a factor (C_A) as shown in Figure 2 for wavelengths between 700 nm and 1400 nm. To aid in the determination of TLVs for exposure durations requiring calculations of fractional powers Figures 3, 4, 5 and 6 may be used.

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^{-3} second. For pulses of greater duration, the following formula should be followed:

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

where:

n = number of pulses in train
τ = duration of a single pulse in the train
Standard ($n\tau$) = protection standard of one pulse having a duration equal to $n\tau$ seconds.

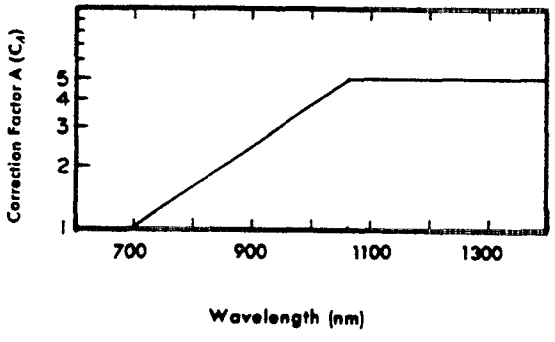


Figure 2 — TLV correction factor for $\lambda = 700 - 1400$ nm*

*For $\lambda = 700 - 1049$ nm, $C_A = 10^{[0.002(\lambda - 700)]}$
For $\lambda = 1050 - 1400$ nm, $C_A = 5$

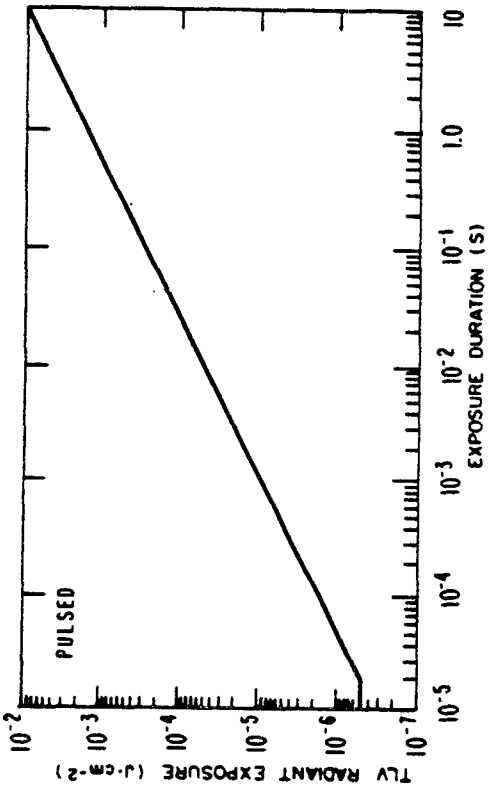


Figure 3a — TLV for intrabeam (direct) viewing of laser beam (400–700 nm).

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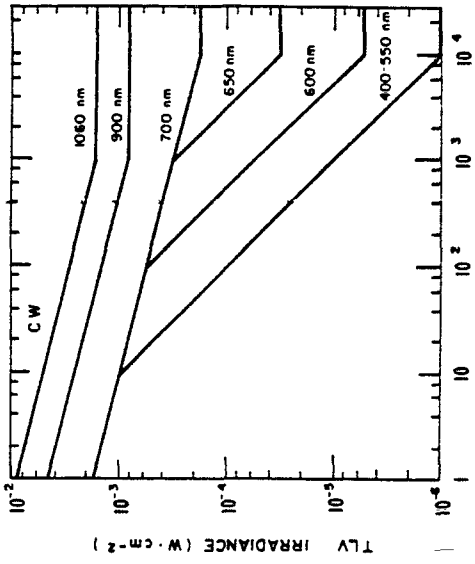


Figure 3b — TLV for intrabeam (direct) viewing of CW laser beam (400–1400 nm)

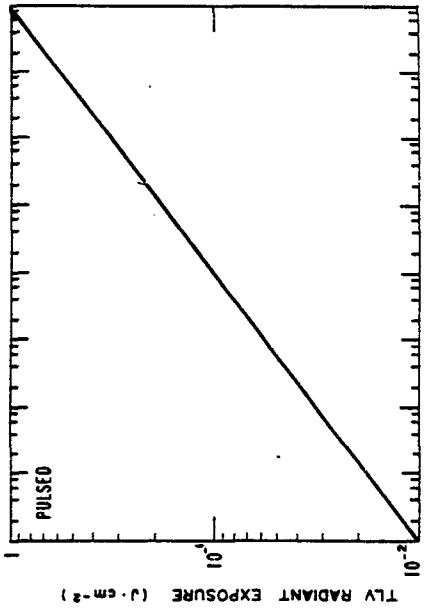


Figure 4a — TLV for laser exposure of skin and eyes for far-infrared radiation (wave-lengths greater than 1.4 μm).

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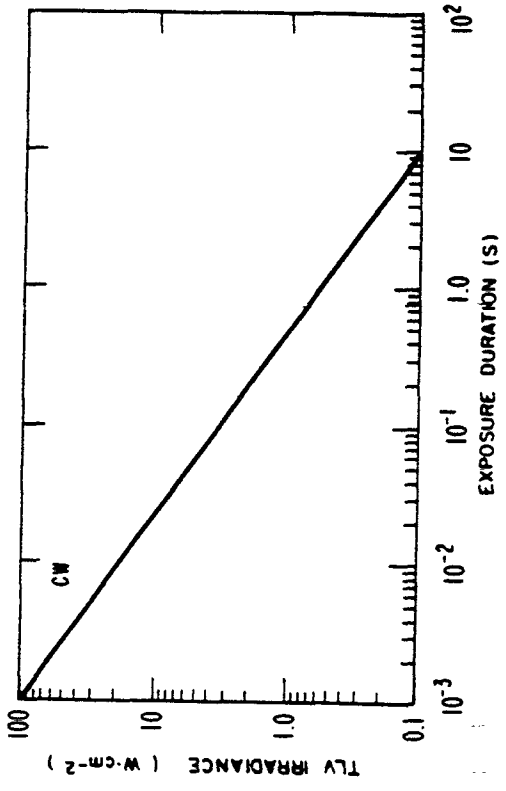


Figure 4b — TLV for CW laser exposure of skin and eyes for far-infrared radiation (wavelengths greater than 1.4 μm).

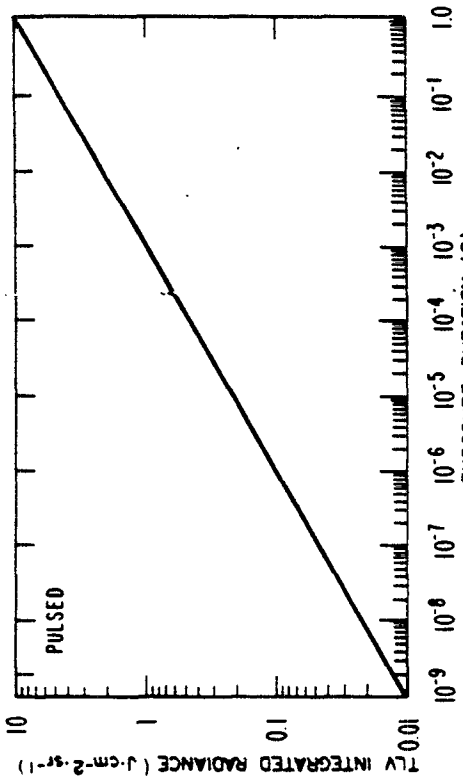


Figure 5a — TLV for extended sources or diffuse reflections of laser radiation (400–700 nm).

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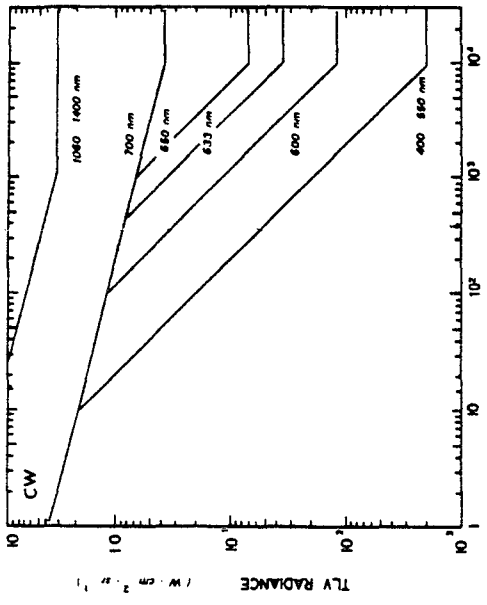


Figure 5b — TLV for intrabeam (direct) viewing of CW laser beam (400–1400 nm).

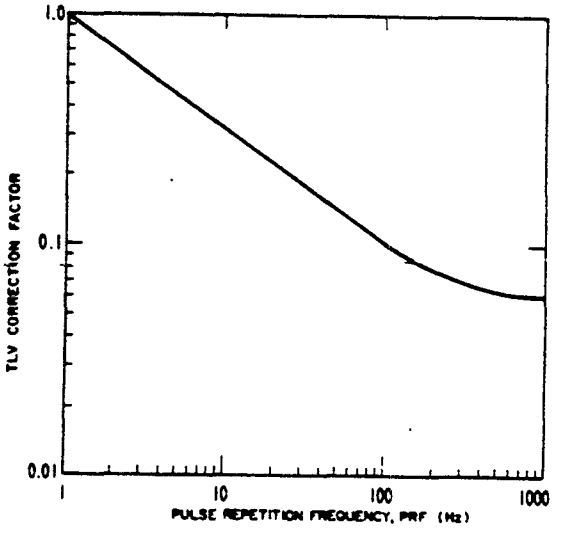


Figure 6 — Multiplicative correction factor for repetitively pulsed lasers having pulse durations less than 10^{-5} second. TLV for a single pulse of the pulse train is multiplied by the above correction factor. Correction factor for PRF greater than 1000 Hz is 0.06.

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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^{-3}) 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	"	*not to exceed $0.56\ t^{1/4}$ J • cm^{-2} for $t \leq 10$ s.
	308 nm	"	40	"	
	309 nm	"	63	"	
	310 nm	"	100	"	
	311 nm	"	160	"	
	312 nm	"	250	"	
	313 nm	"	400	"	
	314 nm	"	630	"	

**See Notice of Intended Changes.

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TABLE 3 (Cont.)

UVA	315 nm to 400 nm	10^{-9} to 10	$.56\ t^{1/4}$ J • cm^{-2}
	" "	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^{-7} J • cm^{-2}
	400 nm to 700 nm	1.8×10^{-5} to 10	$1.8\ (t/\sqrt[4]{t})$ mJ • cm^{-2}
	400 nm to 549 nm	10 to 10^{4}	10 mJ • cm^{-2}
	550 nm to 700 nm	10 to T_1	$1.8\ (t/\sqrt[4]{t})$ mJ • cm^{-2}
	550 nm to 700 nm	T_1 to 10^{4}	$10\ C_B$ mJ • cm^{-2}
	400 nm to 700 nm	10^{4} to 3×10^{4}	$C_B\ \mu$W • cm^{-2}
IR-A	700 nm to 1049 nm	10^{-9} to 1.8×10^{-5}	$5\ C_A \times 10^{-7}$ J • cm^{-2}
	700 nm to 1049 nm	1.8×10^{-5} to 10^{3}	$1.8\ C_A\ (t/\sqrt[4]{t})$ mJ • cm^{-2}
	1050 nm to 1400 nm	10^{-9} to 10^{-4}	5×10^{-6} J • cm^{-2}
	1050 nm to 1400 nm	10^{-4} to 10^{3}	$9(t/\sqrt[4]{t})$ mJ • cm^{-2}
	700 nm to 1400 nm	10^{3} to 3×10^{4}	$320\ C_A\ \mu$W • cm^{-2}
IR-B & C	1.4 μm to 10^{3} μm	10^{-9} to 10^{-7}	10^{-2} J • cm^{2}
	" "	10^{-7} to 10	$0.56\sqrt[4]{t}$ J • cm^{-2}
	" "	10 to 3×10^{4}	0.1 W • cm^{-2}

C_A – See Fig. 2.
$C_B = 1$ for λ = 400 to 549 nm; $C_B = 10^{[0.015\,(\lambda - 550)]}$ for λ = 550 to 700 nm.
$T_1 = 10$ s for λ = 400 to 549 nm; $T_1 = 10 \times 10^{[0.02\,(\lambda - 550)]}$ for λ = 550 to 700 n

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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^{-3}) to 3×10^{4}	Same as Table 3
Light	400 nm to 700 nm	10^{-9} to 10	$10\ \sqrt[4]{t}$ J • cm^{-2} • sr^{-1}
	400 nm to 549 nm	10 to 10^{4}	21 J • cm^{-2} • sr^{-1}
	550 nm to 700 nm	10 to T_1	$3.83\ (t/\sqrt[4]{t})$ J • cm^{-2} • sr^{-1}
	550 nm to 700 nm	T_1 to 10^{4}	21 C_B J • cm^{-2} • sr^{-1}
	400 nm to 700 nm	10^{4} to 3×10^{4}	2.1 $C_B t \times 10^{-3}$ W • cm^{-2} • sr^{-1}
IR-A	700 nm to 1400 nm	10^{-9} to 10	$10\ C_A\ \sqrt[4]{t}$ J • cm^{-2} • sr^{-1}
	700 nm to 1400 nm	10 to 10^{3}	$3.83\ C_A\ (t/\sqrt[4]{t})$ J • cm^{-2} • sr^{-1}
	700 nm to 1400 nm	10^{3} to 3×10^{4}	0.64 C_A W • cm^{-2} • sr^{-1}
IR-B & C	1.4 μm to 1 mm	10^{-9} to 3×10^{4}	Same as Table 3

C_A, C_B, and T_1 are the same as in footnote to Table 3.
**See Notice of Intended Changes.

TABLE 5

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

Exposure Duration(s)	Angle α (mrad)
10^{-9}	8.0
10^{-8}	5.4
10^{-7}	3.7
10^{-6}	2.5
10^{-5}	1.7
10^{-4}	2.2
10^{-3}	3.6
10^{-2}	5.7
10^{-1}	9.2
1.0	15
10	24
10^{2}	24
10^{3}	24
10^{4}	24

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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 & IR-A	400 nm to 1400 nm	10^{-9} to 10^{-7}	$2\ C_A \times 10^{-2}$ J • cm^{-2}
	"	10^{-7} to 10	$1.1\ C_A \sqrt{t}$ J • cm^{-2}
IR-B & C	1.4 μm to 1 mm	10^{-9} to 3×10^{4}	Same as Table 3

C_A = 1.0 for λ = 400–700 nm; see Figure 2 for λ = 700 to 1400 nm.
**See Notice of Intended Changes.

MICROWAVES

These Threshold Limit Values refer to microwave energy in the frequency range of 300 MHz to 300 GHz and represent conditions under which it is believed that nearly all workers may be repeatedly exposed without adverse effect.

Under conditions of moderate to severe heat stress, the recommended values may need to be reduced.* Therefore, these values should be used as guides in the control of exposure to microwave energy and should not be regarded as a fine line between safe and dangerous levels.

Recommended Values:

The Threshold Limit Value for occupational exposure to microwave energy, where power density or field intensity is known and exposure time is controlled, is as follows:

1. For exposure to continuous wave (CW) sources, the power density level shall not exceed 10 milliwatts per square centimeter (mW/cm^2) for continuous exposure, and the total exposure time shall be limited to an 8-hour workday. This power density is approximately equivalent to a free-space electric field strength of 200 volts-per-meter rms (V/m) and a free-space magnetic field strength of 0.5 ampere-per-meter rms (A/m).
2. Exposures to CW power density levels greater than 10 mW/cm^2 are permissible up to a maximum of 25 mW/cm^2 based upon an average energy density of 1 milliwatt-hour per square centimeter (mWh/cm^2) averaged over any 0.1 hour period. For example, at 25 mW/cm^2, the permissible exposure duration is approximately 2.4 minutes in any 0.1 hour period.
3. For repetitively pulsed microwave sources, the average field strength or power density is calculated by multiplying the peak-pulse value by the duty cycle. The duty cycle is equal to the pulse duration in seconds times the pulse repetition rate in Hertz. Exposure during an 8-hour workday shall not exceed the following values which are averaged over any 0.1 hour period:

Power Density	10 mW/cm^2
Energy Density	1 mWh/cm^2
Mean Squared Electric Field Strength	40,000 V^2/m^2
Mean Squared Magnetic Field Strength	0.25 A^2/m^2

*Mumford, W.W., "Heat Stress Due to R. F. Radiation," Proceedings of IEEE, Vol. 57, No. 2, Feb. 1969, pp. 171–178.

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4. Exposure is not permissible in CW or repetitively pulsed fields with an average power density in excess of 25 mW/cm² or approximate equivalent free-space field strengths of 300 V/m or 0.75 A/m.

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. Prior to 1979, the medical profession had 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.[a] 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.

It should be recognized that the application of the TLV for noise will not protect all workers from the adverse effects of noise exposure. A hearing conservation program with audiometric testing is necessary when workers are exposed to noise at or above the TLV 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 National 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 7.

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:

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

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

Table 7
Threshold Limit Values

Duration per day Hours	Sound Level dBA[b]
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

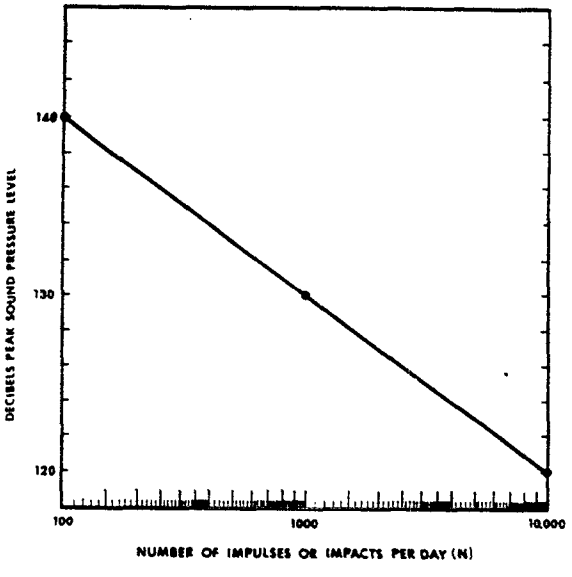


Figure 7 — Threshold Limit Values for Impulse/Impact Noise.

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a) In 1979, the American Academy of Ophthalmology and Otolargyngology (AAOO) included 3000 Hz in their hearing impairment formula.
b) 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.

IMPULSIVE OR IMPACT NOISE

It is recommended that exposure to impulsive or impact noise shall not exceed the limits listed in Table 8 or taken from Figure 7. No exposures in excess of 140 decibels peak sound pressure level are permitted. 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 8
Threshold Limit Values
Impulsive or Impact Noise

Sound Level dB**	Permitted Number of Impulses or Impacts per day
140	100
130	1000
120	10,000

**Decibels peak sound pressure level. re 20 μPa

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, and solar radiation, but do not apply to ultraviolet lasers.* These values do not apply to ultraviolet radiation exposure of photosensitive individuals or of individuals concomitantly exposed to photosensitizing agents (Fitzpatrick, et al., eds., Sunlight and Man, Univ. Tokyo Press, Tokyo, Japan, 1974). 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.

*See Laser TLVs

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 nm) 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 9 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 following weighting formula should be used:

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

where:

E_{eff} = effective irradiance relative to a monochromatic source at 270 nm in W/cm² (J/s/cm²)

E_λ = spectral irradiance in W/cm²/nm

S_λ = relative spectral effectiveness (unitless)

$\Delta\lambda$ = 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 10 which provides exposure times corresponding to effective irradiances in μW/cm².

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TABLE 9

Relative Spectral Effectiveness by Wavelength*

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
254	6.0	0.5
260	4.6	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

TABLE 10

Permissible Ultraviolet Exposures

Duration of Exposure Per Day	Effective Irradiance, E_{eff} (μW/cm²)
8 hrs.	0.1
4 hrs.	0.2
2 hrs.	0.4
1 hr.	0.8
30 min.	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°.

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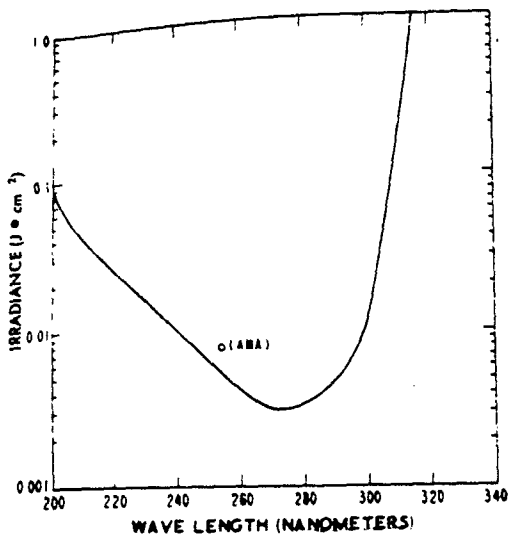


Figure 8 — Threshold Limit Values for Ultraviolet Radiation

Conditioned (tanned) individuals can tolerate skin exposure in excess of the TLV without erythemal effects. However, such conditioning may not protect persons against skin cancer.

NOTICE OF INTENDED CHANGES (for 1980)

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.

NOTICE OF INTENT TO ESTABLISH THRESHOLD LIMIT VALUES

LIGHT AND NEAR-INFRARED RADIATION

These Threshold Limit Values refer to visible and near-infrared radiation in the wavelength range of 400 nm to 1400 nm and represent conditions under which it is believed that nearly all workers may be exposed without adverse effect. These values should be used as guides in the control of exposure to light and should not be regarded as a fine line between safe and dangerous levels.

Recommended Values:

The Threshold Limit Value for occupational exposure to broad-band light and near-infrared radiation for the eye apply to exposure in any eight-hour workday and require knowledge of the spectral radiance (L_λ) and total irradiance (E) of the source as measured at the position(s) of the eye of the worker. Such detailed spectral data of a white light source is generally only required if the luminance of the source exceeds 1 cd cm^{-2}. At luminances less than this value the TLV would not be exceeded.

The TLV's are:

1. To protect against retinal thermal injury, the spectral radiance of the lamp weighted against the function R (Table 11) should not exceed:

$$\sum_{400}^{1400} L_\lambda R_\lambda \Delta\lambda \leq 1/\alpha t^{1/2} \qquad (1)^*$$

where L_λ is in W cm^{-2} sr^{-1} and t is the viewing duration (or pulse duration if the lamp is pulsed) limited to 1 μs to 10 s, and α is the angular subtense of the source in radians. If the lamp is oblong, α refers to the longest dimension that can be viewed. For instance, at a viewing distance r = 100 cm from a tubular lamp of length l = 50 cm, the viewing angle is:

$$\alpha = l/r = 50/100 = 0.5 \text{ rad} \qquad (2)$$

2. To protect against retinal photochemical injury from chronic blue-light exposure the integrated spectral radiance of light source weighted against the blue-light hazard function B_λ (Table 11) should not exceed:

$$\sum_{400}^{1400} L_\lambda t B_\lambda \Delta\lambda \leq 100 \text{ J cm}^{-2} \text{ sr}^{-1} \ (t \leq 10^4 \text{s}) \qquad (3a)$$

$$\sum_{400}^{1400} L_\lambda B_\lambda \Delta\lambda \leq 10^{-2} \text{ W cm}^{-2} \text{ sr}^{-1} \ (t > 10^4 \text{s}) \qquad (3b)$$

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For a source radiance L which exceeds 10 $mW/cm^{-2}\ sr^{-1}$ in the blue spectral region, the permissible exposure duration t_{max} in seconds is simply:

$$t_{max} = 100\ J\ cm^{-2}\ sr^{-1}/L\ (blue) \qquad (4)$$

The latter limits are greater than the maximum permissible exposure limits for 440 nm laser radiation (see Laser TLV) because a 2–3 mm pupil is assumed rather than a 7 mm pupil for the Laser TLV. For a light source subtending an angle α less than 11 mrd (0.011 radian) the above limits are relaxed such that the spectral irradiance weighted against the blue-light hazard function B_λ should not exceed:

$$\sum_{400}^{1400} E_\lambda \bullet t \bullet B_\lambda \bullet \Delta\lambda \leqq 10\ mJ \bullet cm^{-2}\ (t \leq 10^4\ s) \qquad (5a)$$

$$\sum_{400}^{1400} E_\lambda \bullet B_\lambda \bullet \Delta\lambda \leqq 1\ \mu W \bullet cm^{2}\ (t \geq 10^4\ s) \qquad (5b)$$

For a source where the blue light weighted irradiance E (blue) exceeds 1 $\mu W \bullet cm^{-2}$ is the maximum permissible exposure duration t max in seconds is:

$$t\ max = 10\ mJ \bullet cm^{-2}\ E\ (blue) \qquad (6)$$

3. *Infrared Radiation:* To avoid possible delayed effects upon the lens of the eye (cataractogenesis), the infrared radiation ($\lambda > 770$ nm) should be limited to 10 $mWcm^{-2}$. For an infrared heat lamp or any near-infrared source where a strong visual stimulus is absent, the near infrared (770–1400 nm) radiance as viewed by the eye should be limited to:

$$\sum_{770}^{1400} L_\lambda\ \Delta\lambda = 0.6/\alpha \qquad (7)^*$$

for extended duration viewing conditions. This limit is based upon a 7 mm pupil diameter.

*Formulae (1) and (7) are empirical and are not, strictly speaking, dimensionally correct. To make the formulae dimensionally correct, one would have to insert a dimensional correction factor k in the right hand numerator in each formula. For formula (1) this would be $k_1 = 1\ W \bullet rad \bullet s^{1/2}/(cm^2 \bullet sr)$, and for formula (7) $k_2 = 1\ W \bullet rad/(cm^2 \bullet sr)$

TABLE 11

SPECTRAL WEIGHTING FUNCTIONS FOR ASSESSING RETINAL HAZARDS FROM BROAD — BAND OPTICAL SOURCES

Wavelength (nm)	Blue-Light Hazard Function B_λ	Burn Hazard Function R_λ
400	0.10	1.0
405	0.20	2.0
410	0.40	4.0
415	0.80	8.0
420	0.90	9.0
425	0.95	9.5
430	0.98	9.8
435	1.0	10
440	1.0	10
445	0.97	9.7
450	0.94	9.4
455	0.90	9.0
460	0.80	8.0
465	0.70	7.0
470	0.62	6.2
475	0.55	5.5
480	0.45	4.5
485	0.40	4.0
490	0.22	2.2
495	0.16	1.6
500–600	$10^{[(450-\lambda)/50]}$	1.0
600–700	0.001	1.0
700–1049	0.001	$10^{[(700-\lambda)/505]}$
1050–1400	0.001	0.2

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Chemical Substances
and
Physical Agents
in the
Workroom Environment
with
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The Fourth Edition (1980), including the 1981 Supplemental Documentation, is available at $60.00 per single copy. The 1981 Supplemental Documentation is also available as a separate publication at $10.00 per single copy. Either may be ordered from the following:

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Adopted by
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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.

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 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.

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 control of community air pollution nuisances, (3) in estimating the toxic potential of continuous, uninterrupted exposures or other extended work periods, (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.

The TLV-TWA should be used as guides in the control of health hazards and should not be used as

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fine lines between safe and dangerous concentrations.

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.

Legal Status. The Threshold Limit Values, as issued by ACGIH, are recommendations and should be used as guidelines for good practices. Wherever these values (of whatever year) have been used or included by reference in Federal and/or State statutes and registers, the TLVs do have the force and effects of law.

"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. Values listed in parenthesis in the "Adopted" list are to be used during the period in which a proposed change for that Value is listed in the Notice of Intended Changes.

Definitions. Three categories of Threshold Limit Values (TLVs) are specified herein, as follows:

a) Threshold Limit Value-Time Weighted Average (TLV-TWA) — the time-weighted average concentration for a normal 8-hour workday and a 40-hour workweek, to which nearly all workers may be repeatedly exposed, day after day, without adverse effect.

b) Threshold Limit Value-Short Term Exposure Limit (TLV-STEL) — the maximal concentration to which workers can be exposed for a period up to 15 minutes continuously without suffering from 1) irritation, 2) chronic or irreversible tissue change, or 3) narcosis of sufficient degree to increase accident proneness, impair self-rescue, or materially reduce work efficiency, provided that no more than four excursions per day are permitted, with at least 60 minutes between exposure periods, and provided that the daily TLV-TWA also is not exceeded. The STEL should be considered a maximal allowable concentration, or ceiling, not to be exceeded at any time during the 15-minute excursion period.

c) Threshold Limit Value-Ceiling (TLV-C) — the concentration that should not be exceeded even instantaneously.

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For some substances, e.g., irritant gases, only one category, the TLV-Ceiling, may be relevant. For other substances, either two or three categories may be relevant, depending upon their physiologic action. It is important to observe that if any one of these three TLVs is exceeded, a potential hazard from that substance is presumed to exist.

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.

Time-Weighted Average vs Ceiling Limits. 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 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 a decision as to whether a hazardous condition exists.

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 noncompliance 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

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exceed, the time-weighted average limit requires an explicit limit to the excursions that are permissible above the listed values. It should be noted that the same factors are used by the Committee in determining the magnitude of the value of the STELs, or 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 mucous membranes and eye, either by air borne, 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, may cause unpleasant deposits in the eyes, ears and nasal 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 10 mg/m^3, or 30 mppcf, of total dust < 1% quartz, or, 5 mg/m^3 respirable dust is recommended for substances in these categories and for

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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 D.

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 E.

Physical Factors. It is recognized that such physical factors as heat, ultraviolet and ionizing 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 may be altered. Most of these stresses act adversely 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

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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 BLVs, and their associated procedures for determining compliance with them, should thus be regarded as an effective means of providing health surveillance of the worker.

Tests are available (J. Occup. Med. 15: 564, 1973; 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).

Unlisted Substances. Many substances present or handled in industrial processes do not appear on the TLV list. In a number of instances the material is rarely present as a particulate, vapor or other airborne contaminant, and a TLV is not necessary. In other cases sufficient information to warrant development of a TLV, even on a tentative basis, is not available to the Committee. Other substances, of low toxicity, could be included in Appendix D pertaining to nuisance particulates. This list (as well as Appendix E) is not meant to be all inclusive; the substances serve only as examples.

In addition there are some substances of not inconsiderable toxicity, which have been omitted primarily because only a limited number of workers (e.g., employees of a single plant) are known to have potential exposure to possibly harmful concentrations.

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Substance	ADOPTED VALUES TWA ppm[a]	TWA mg/m³[b]	STEL ppm[a]	STEL mg/m³[b]
Abate	—	10	—	20
Acetaldehyde	100	180	150	270
Acetic acid	10	25	15	37
C Acetic anhydride	5	20	—	—
** Acetone	(1,000)	(2,400)	(1,250)	(3,000)
Acetonitrile — Skin	40	70	60	105
Acetylene	E	—	—	—
Acetylene dichloride, see 1, 2-Dichloroethylene				
Acetylene tetrabromide	1	15	1.5	20
Acetylsalicylic acid (Asprin)	—	5	—	—
Acrolein	0.1	0.25	0.3	0.8
Acrylamide — Skin	—	0.3	—	0.6
* Acrylic acid	10	30	—	—
** Acrylonitrile — Skin	(A1b)	(A1b)	—	—
Aldrin — Skin	—	0.25	—	0.75
Allyl alcohol — Skin	2	5	4	10
Allyl chloride	1	3	2	6
Allyl glycidyl ether (AGE) — Skin	5	22	10	44
Allyl propyl disulfide	2	12	3	18
Aluminum metal and oxide	—	10	—	20
Aluminum pyro powders	—	5	—	—
Aluminum welding fumes	—	5	—	—
Aluminum, soluble salts	—	2	—	—
Aluminum, alkyls (NOC)*	—	2	—	—
Aluminum oxide (Al_2O_3)	—	D	—	20
4-Aminodiphenyl — Skin	—	A1b	—	A1b
2-Aminoethanol, see Ethanolamine				
2-Aminopyridine	0.5	2	2	4
3-Amino 1, 2, 4-triazole	A2	A2	—	—
Ammonia	25	18	35	27
Ammonium chloride-fume	—	10	—	20
Ammonium sulfamate (Ammate)	—	10	—	20
n-Amyl acetate	100	530	150	800
sec-Amyl acetate	125	670	150	800
Aniline & homologues — Skin	2	10	5	20

Capital letters refer to Appendices
Footnotes (a thru f) see Page 32
*1981 Addition
**See Notices of Intended Changes.

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Substance	ADOPTED VALUES TWA ppm[a]	TWA mg/m³[b]	STEL ppm[a]	STEL mg/m³[b]
Anisidine (o-, p-isomers) — Skin	0.1	0.5	—	—
Antimony & compounds, as Sb	—	0.5	—	—
Antimony trioxide, handling and use, as Sb	—	0.5	—	—
Antimony trioxide production	—	A2	—	—
ANTU (α-Naphthyl thiourea)	—	0.3	—	0.9
Argon	E	—	—	—
Arsenic & soluble compounds, as As	—	0.2	—	—
Arsenic trioxide production	—	A2	—	—
Arsine	0.05	0.2	—	—
Asbestos, see MINERAL DUSTS	—	A1a	—	A1a
Asphalt (petroleum) fumes	—	5	—	10
** Atrazine	—	(10)	—	—
Azinphos-methyl — Skin	—	0.2	—	0.6
Barium (soluble compounds), as Ba	—	0.5	—	—
Baygon (propoxur)	—	0.5	—	2
Baytex, see Fenthion				
Benomyl	0.8	10	1.3	15
Benzene	10, A2	30, A2	25, A2	75, A2
** Benzidine production — Skin	—	(A1b)	—	(A1b)
p-Benzoquinone, see Quinone				
Benzoyl peroxide	—	5	—	—
Benzo(a)pyrene	—	A2	—	A2
Benzyl chloride	1	5	—	—
Beryllium	—	0.002, A2	—	—
Biphenyl	0.2	1.5	0.6	4
Bismuth telluride	—	10	—	20
Bismuth telluride, Se-doped	—	5	—	10
Borates, tetra, sodium salts,				

Capital letters refer to Appendices.
Footnotes (a thru f) see Page 32.
**See Notices of Intended Changes.

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Substance	ADOPTED VALUES TWA ppm[a]	TWA mg/m³[b]	STEL ppm[a]	STEL mg/m³[b]
Anhydrous	—	1	—	—
Decahydrate	—	5	—	—
Pentahydrate	—	1	—	—
Boron oxide	—	10	—	20
Boron tribromide	1	10	3	30
C Boron trifluoride	1	3	—	—
Bromacil	1	10	2	20
Bromine	0.1	0.7	0.3	2
Bromine pentafluoride	0.1	0.7	0.3	2
Bromochloromethane, see Chlorobromomethane				
Bromoform — Skin	0.5	5	—	—
Butadiene (1, 3-butadiene)	1,000	2,200	1,250	2,750
* Butane	800	1,900	—	—
Butanethiol, see Butyl mercaptan				
2-Butanone, see Methyl ethyl ketone (MEK)				
* 2-Butoxyethanol — Skin	25	120	75	360
n-Butyl acetate	150	710	200	950
sec-Butyl acetate	200	950	250	1,190
tert-Butyl acetate	200	950	250	1,190
Butyl acrylate	10	55	—	—
C n-Butyl alcohol — Skin	50	150	—	—
* sec-Butyl alcohol	100	305	150	455
tert-Butyl alcohol	100	300	150	450
C Butylamine — Skin	5	15	—	—
Butyl Cellosolve,® see 2-Butoxyethanol				
C tert-Butyl chromate, as CrO_3 — Skin	—	0.1	—	—
* n-Butyl glycidyl ether (BGE)	25	135	—	—
n-Butyl lactate	5	25	—	—
Butyl mercaptan	0.5	1.5	—	—
o-sec-Butylphenol — Skin	5	30	—	—
p-tert-Butyltoluene	10	60	20	120
Cadmium, dust & salts, as Cd	—	0.05	—	0.2
C Cadmium oxide fume, as Cd	—	0.05	—	—

Capital letters refer to Appendices.
*1981 Addition.

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Substance	ADOPTED VALUES TWA ppm[a]	TWA mg/m³[b]	STEL ppm[a]	STEL mg/m³[b]
** Cadmium oxide production, as Cd	—	(A2)	—	—
Calcium carbonate/ marble	—	D	—	20
Calcium cyanamide	—	0.5	—	1
Calcium hydroxide	—	5	—	—
Calcium oxide	—	2	—	—
Camphor, synthetic	2	12	3	18
Caprolactam Dust	—	1	—	3
Vapor	5	20	10	40
Captafol (Difolatan®) — Skin	—	0.1	—	—
Captan	—	5	—	15
Carbaryl (Sevin®)	—	5	—	10
Carbofuran (Furadan®)	—	0.1	—	—
Carbon black	—	3.5	—	7
Carbon dioxide	5,000	9,000	15,000	27,000
Carbon disulfide — Skin	10	30	—	—
Carbon monoxide	50	55	400	440
Carbon tetrabromide	0.1	1.4	0.3	4
* Carbon tetrachloride — Skin	5, A2	30, A2	20, A2	125, A2
Carbonyl chloride, see Phosgene				
* Carbonyl fluoride	2	5	5	15
Catechol (Pyrocatechol)	5	20	—	—
Cellosolve® acetate, see 2-Ethoxyethyl acetate				
Cellulose (paper fiber)	—	D	—	20
Cesium hydroxide	—	2	—	—
Chlordane — Skin	—	0.5	—	2
Chlorinated camphene — Skin	—	0.5	—	1
Chlorinated diphenyl oxide	—	0.5	—	2
Chlorine	1	3	3	9
Chlorine dioxide	0.1	0.3	0.3	0.9
C Chlorine trifluoride	0.1	0.4	—	—
C Chloroacetaldehyde	1	3	—	—
α-Chloroacetophenone (Phenacyl chloride)	0.05	0.3	—	—
Chloroacetyl chloride	0.05	0.2	—	—

Capital letters refer to Appendices.
*1981 Addition.
**See Notice of Intended Changes.

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Substance	ADOPTED VALUES TWA ppm[a]	TWA mg/m³[b]	STEL ppm[a]	STEL mg/m³[b]
Chlorobenzene (Monochlorobenzene).	75	350	—	—
** o-Chlorobenzylidene malononitrile — Skin .	(0.05)	(0.4)	—	—
Chlorobromomethane	200	1,050	250	1,300
2-Chloro-1, 3-butadiene, see β Chloroprene				
Chlorodifluoromethane.	1,000	3,500	1,250	4,375
Chlorodiphenyl (42% Chlorine) — Skin	—	1	—	2
Chlorodiphenyl (54% Chlorine) — Skin	—	0.5	—	1
1-Chloro, 2, 3-epoxy-propane, see Epichlorohydrin				
2-Chloroethanol, see Ethylene chlorohydrin				
Chloroethylene, see Vinyl chloride				
Chloroform	10, A2	50, A2	50, A2	225, A2
bis-Chloromethyl ether...	0.001, A1a	0.005, A1a	—	—
* 1-Chloro-1-nitropropane	2	10	—	—
* Chloropentafluoroethane.	1,000	6,320	—	—
Chloropicrin	0.1	0.7	0.3	2
β-Chloroprene — Skin ..	10	45	—	—
o-Chlorostyrene	50	285	75	430
o-Chlorotoluene — Skin.	50	250	75	375
2-Chloro-6-(trichloromethyl) pyridine (N-Serve®) ...	—	10	—	20
Chlorpyrifos (Dursban®) — Skin ...	—	0.2	—	0.6
* Chromium metal	—	0.5	—	—
* Chromium (II) compounds, as Cr	—	0.5	—	—
* Chromium (III) compounds, as Cr	—	0.5	—	—
* Chromium (VI) compounds, as Cr Water soluble Cr VI compounds	—	0.05	—	—

Capital letters refer to Appendices.
Footnotes (a thru f) see Page 32.
*1981 Addition.
**See Notice of Intended Changes.

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Substance	ADOPTED VALUES TWA ppm[a]	TWA mg/m³[b]	STEL ppm[a]	STEL mg/m³[b]
Certain water insoluble Cr VI compounds	—	0.05, A1a	—	—
Chromite ore processing (chromate), as Cr	—	0.05, A1a	—	—
Chromium, soluble chromic, chromous salts, as Cr	—	0.5	—	—
* Chrysene	A2	A2	—	—
Clopidol (Coyden®)	—	10	—	20
Coal tar pitch volatiles, as benzene solubles	—	0.2, A1a	—	—
** Cobalt, metal, dust & fume, as Co	—	(0.1)	—	—
Copper fume	—	0.2	—	—
Dusts & mists, as Cu	—	1	—	2
Cotton dust, raw	—	0.2[k]	—	0.6
Crag® herbicide, see Sodium 2, 4-dichloro-phenoxyethyl sulfate				
Cresol, all isomers — Skin	5	22	—	—
Crotonaldehyde	2	6	6	18
Crufomate*	—	5	—	20
Cumene — Skin	50	245	75	365
Cyanamide	—	2	—	—
Cyanides, as CN — Skin	—	5	—	—
Cyanogen	10	20	—	—
Cyanogen chloride	0.3	0.6	—	—
Cyclohexane	300	1,050	375	1,300
Cyclohexanol	50	200	—	—
* Cyclohexanone	25	100	100	400
Cyclohexene	300	1,015	—	—
Cyclohexylamine — Skin	10	40	—	—
Cyclonite — Skin	—	1.5	—	3
Cyclopentadiene	75	200	150	400
* Cyclopentane	600	1,720	900	2,580
2, 4-D (2, 4-Dichloro-phenoxy-acetic acid)	—	10	—	20
DDT (Dichlorodiphenyl-trichloroethane)	—	1	—	3
DDVP, see Dichlorvos				
Decaborane — Skin	0.05	0.3	0.15	0.9
Demeton® — Skin	0.01	0.1	0.03	0.3

Capital letters refer to Appendices.
*1981 Addition.
**See Notice of Intended Changes
k) See p. 35.

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Substance	ADOPTED VALUES TWA ppm[a]	TWA mg/m³[b]	STEL ppm[a]	STEL mg/m³[b]
Diacetone alcohol (4-hydroxy-4-methyl-2-pentanone)	50	240	75	360
1, 2-Diaminoethane, see Ethylenediamine				
Diazinon — Skin	—	0.1	—	0.3
Diazomethane	0.2	0.4	—	—
Diborane	0.1	0.1	—	—
1, 2-Dibromoethane, see Ethylene dibromide				
Dibrom®	—	3	—	6
2-n-Dibutylaminoethanol — Skin	2	14	4	28
Dibutyl phosphate	1	5	2	10
Dibutyl phthalate	—	5	—	10
C Dichloroacetylene	0.1	0.4	—	—
C o-Dichlorobenzene	50	300	—	—
p-Dichlorobenzene	75	450	110	675
3, 3'-Dichlorobenzidene — Skin	—	A2	—	A2
Dichlorodifluoromethane	1,000	4,950	1,250	6,200
1, 3-Dichloro-5, 5-dimethyl hydantoin	—	0.2	—	0.4
1, 1-Dichloroethane	200	810	250	1,010
1, 2-Dichloroethane, see Ethylene dichloride				
1, 1-Dichloroethylene, see Vinylidene chloride				
1, 2-Dichloroethylene	200	790	250	1,000
Dichloroethyl ether — Skin	5	30	10	60
Dichlorofluoromethane	10	40	—	—
Dichloromethane, see Methylene chloride				
* 1, 1-Dichloro-1-nitroethane	2	10	10	60
1, 2-Dichloropropane, see Propylene dichloride				
Dichloropropene — Skin	1	5	10	50
2, 2-Dichloropropionic acid	1	6	—	—
Dichlorotetrafluoroethane	1,000	7,000	1,250	8,750

Capital letters refer to Appendices.
Footnotes (a thru f) see Page 32.
*1981 Addition

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Substance	ADOPTED VALUES TWA ppm[a]	TWA mg/m³[b]	STEL ppm[a]	STEL mg/m³[b]
Dichlorvos (DDVP) — Skin	0.1	1	0.3	3
Dicrotophos (Bidrin®) — Skin	—	0.25	—	—
Dicyclopentadiene	5	30	—	—
Dicyclopentadienyl iron	—	10	—	20
Dieldrin — Skin	—	0.25	—	0.75
Diethanolamine	3	15	—	—
* Diethylamine	10	30	25	75
Diethylaminoethanol — Skin	10	50	—	—
Diethylene triamine — Skin	1	4	—	—
Diethyl ether, see Ethyl ether				
* Diethyl ketone	200	705	—	—
Diethyl phthalate	—	5	—	10
Difluorodibromomethane	100	860	150	1,290
* Diglycidyl ether (DGE)	0.1	0.5	—	—
Dihydroxybenzene, see Hydroquinone				
Diisobutyl ketone	25	150	—	—
Diisopropylamine—Skin	5	20	—	—
Dimethoxymethane, see Methylal				
Dimethyl acetamide — Skin	10	35	15	50
Dimethylamine	10	18	—	—
Dimethylaminobenzene, see Xylidene				
Dimethylaniline (N, N-Dimethylaniline) — Skin	5	25	10	50
Dimethylbenzene, see Xylene				
Dimethyl carbamyl chloride	A2	A2	—	—
Dimethyl-1, 2-dibromo-2-dichloroethyl phosphate, see Dibrom				
Dimethylformamide — Skin	10	30	20	60
2, 6-Dimethyl-4-heptanone, see Diisobutyl ketone				

Capital letters refer to Appendices.
*1981 Addition.

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Substance	ADOPTED VALUES TWA ppm[a]	TWA mg/m³[b]	STEL ppm[a]	STEL mg/m³[b]
1, 1-Dimethylhydrazine — Skin	0.5, A2	1, A2	1, A2	2, A2
Dimethylphthalate	—	5	—	10
Dimethyl sulfate — Skin	0.1, A2	0.5, A2	—	—
Dinitrobenzene (all isomers) — Skin	0.15	1	0.5	3
Dinitro-o-cresol — Skin	—	0.2	—	0.6
3, 5-Dinitro-o-toluamide (Zoalene®)	—	5	—	10
Dinitrotoluene — Skin	—	1.5	—	5
* Dioxane, tech. grade — Skin	25	90	100	360
Dioxathion (Delnav®) — Skin	—	0.2	—	—
Diphenyl, see Biphenyl				
Diphenylamine	—	10	—	20
Diphenylmethane diisocyanate, see Methylene bisphenyl isocyanate (MDI)				
Dipropylene glycol methyl ether — Skin	100	600	150	900
* Dipropyl ketone	50	235	—	—
Diquat	—	0.5	—	1
Di-sec, octyl phthalate (Di-2-ethylhexyl-phthalate)	—	5	—	10
Disulfiram	—	2	—	5
Disulfoton (Disyston®)	—	0.1	—	0.3
2, 6-Ditert. butyl-p-cresol	—	10	—	20
Diuron	—	10	—	—
* Divinyl benzene	10	50	—	—
Dyfonate — Skin	—	0.1	—	—
Emery	—	E	—	20
Endosulfan (Thiodan®) — Skin	—	0.1	—	0.3
Endrin — Skin	—	0.1	—	0.3
Epichlorohydrin — Skin	2	10	5	20
EPN — Skin	—	0.5	—	2
1, 2-Epoxypropane, see Propylene oxide				
2, 3-Epoxy-1-propanol, see Glycidol				
Ethane	E	—	—	—

apital letters refer to Appendices.
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Substance	ADOPTED VALUES TWA ppm[a]	TWA mg/m³[b]	STEL ppm[a]	STEL mg/m³[b]
Ethanethiol, see Ethyl mercaptan				
Ethanolamine	3	8	6	15
Ethion (Nialate®) — Skin	—	0.4	—	—
* 2-Ethoxyethanol — Skin	50	185	100	370
* 2-Ethoxyethyl acetate — Skin	50	270	100	540
Ethyl acetate	400	1,400	—	—
* Ethyl acrylate — Skin	5	20	25	100
Ethyl alcohol (Ethanol)	1,000	1,900	—	—
Ethylamine	10	18	—	—
Ethyl amyl ketone	25	130	—	—
Ethyl benzene	100	435	125	545
Ethyl bromide	200	890	250	1,110
Ethyl butyl ketone	50	230	75	345
Ethyl chloride	1,000	2,600	1,250	3,250
Ethylene	E	—	—	—
C Ethylene chlorohydrin — Skin	1	3	—	—
Ethylenediamine	10	25	—	—
** Ethylene dibromide	(A1b)	(A1b)	—	—
Ethylene dichloride	10	40	15	60
Ethylene glycol, Particulate	—	10	—	20
°C Vapor	50	125	—	—
** Ethylene glycol dinitrate — Skin	(0.02)	(0.1)	(0.05)	(0.3)
Ethylene glycol methyl ether acetate — Skin	25	120	35	170
** Ethylene oxide	(10)	(20)	—	—
Ethyleneimine — Skin	0.5	1	—	—
Ethyl ether	400	1,200	500	1,500
Ethyl formate	100	300	150	450
Ethylidene chloride, see 1, 1-Dichloroethane				
C Ethylidene norbornene	5	25	—	—
Ethyl mercaptan	0.5	1	2	3
** N-Ethylmorpholine — Skin	(20)	(95)	—	—
Ethyl silicate	10	85	30	255
Fensulfothion (Dasanit)	—	0.1	—	—
** Fenthion	—	(0.1)	—	(0.3)
Ferbam	—	10	—	20

Capital letters refer to Appendices.
*1981 Addition.
**See Notice of Intended Changes.
Footnotes (a thru f) see Page 32.

MAP 000274

Substance	ADOPTED VALUES TWA ppm[a]	TWA mg/m³[b]	STEL ppm[a]	STEL mg/m³[b]
Ferrovanadium dust	—	1	—	0.3
Fluoride, as F	—	2.5	—	—
Fluorine	1	2	2	4
Fluorotrichloromethane, see Trichlorofluoromethane				
†C Formaldehyde	(2)	(3)	—	—
Formamide	20	30	30	45
Formic acid	5	9	—	—
* Furfural — Skin	2	8	10	40
** Furfuryl alcohol — Skin	(5)	(20)	(10)	(40)
** Gasoline	—	(B2)	—	(B2)
Germanium tetrahydride	0.2	0.6	0.6	1.8
Glass, fibrous[e] or dust	—	10	—	—
C Glutaraldehyde	0.2	0.7	—	—
Glycerin mist	—	D	—	—
* Glycidol	25	75	100	300
Glycol monoethyl ether, see 2-Ethoxyethanol				
Graphite (Synthetic)	—	D	—	—
Guthion®, see Azinphos-methyl				
Gypsum	—	D	—	20
Hafnium	—	0.5	—	1.5
Helium	E	—	—	—
Heptachlor — Skin	—	0.5	—	2
Heptane (n-Heptane)	400	1,600	500	2,000
3-Heptanone, see Ethyl butyl ketone				
Hexachlorocyclopentadiene	0.01	0.1	0.03	0.3
** Hexachloroethane — Skin	(1)	(10)	(3)	(30)
Hexachloronaphthalene — Skin	—	0.2	—	0.6
Hexafluoroacetone	0.1	0.7	0.3	2
** Hexane (n-hexane)	(100)	(360)	(125)	(450)
Hexamethyl phosphoramide — Skin	A2	A2	—	—
2-Hexanone, see Methyl n-butyl ketone				
Hexone, see Methyl				

[a] Capital letters refer to Appendices.
* 1981 Addition.
** See Notice of Intended Changes

MAP 000275

Substance	ADOPTED VALUES TWA ppm[a]	TWA mg/m³[b]	STEL ppm[a]	STEL mg/m³[b]
Isobutyl ketone				
sec-Hexyl acetate	50	300	—	—
C Hexylene glycol	25	125	—	—
Hydrazine — Skin	0.1, A2	0.1, A2	—	—
Hydrogen	E	—	—	—
Hydrogenated terphenyls	0.5	5	—	—
Hydrogen bromide	3	10	—	—
C Hydrogen chloride	5	7	—	—
C Hydrogen cyanide — Skin	10	10	—	—
Hydrogen fluoride, as F	3	2.5	6	5
Hydrogen peroxide	1	1.5	2	3
Hydrogen selenide, as Se	0.05	0.2	—	—
Hydrogen sulfide	10	14	15	21
Hydroquinone	—	2	—	4
2-Hydroxypropyl acrylate — Skin	0.5	3	—	—
Indene	10	45	15	70
Indium & compounds, as In	—	0.1	—	0.3
C Iodine	0.1	1	—	—
Iodoform	0.6	10	1	20
Iron oxide fume (Fe_2O_3), as Fe	B3	5	—	10
** Iron pentacarbonyl, as Fe	(0.01)	(0.08)	—	—
Iron salts, soluble, as Fe	—	1	—	2
Isoamyl acetate	100	525	125	655
Isoamyl alcohol	100	360	125	450
Isobutyl acetate	150	700	187	875
Isobutyl alcohol	50	150	75	225
C Isophorone	5	25	—	—
Isophorone diisocyanate — Skin	0.01	0.09	—	—
* Isopropoxyethanol	25	105	75	320
Isopropyl acetate	250	950	310	1,185
Isopropyl alcohol	400	980	500	1,225
Isopropylamine	5	12	10	24
N-Isopropylaniline — Skin	2	10	5	20
Isopropyl ether	250	1,050	310	1,320
Isopropyl glycidyl ether (IGE)	50	240	75	360
Kaolin	—	D	—	20

Capital letters refer to Appendices
*1981 Addition.
**See Notice of Intended Changes

MAP 000276

Substance	ADOPTED VALUES TWA ppm[a]	TWA mg/m³[b]	STEL ppm[a]	STEL mg/m³[b]
Ketene	0.5	0.9	1.5	3
Lead, inorg., fumes & dusts, as Pb	—	0.15	—	0.45
** Lead arsenate, as Pb	—	(0.15)	—	(0.45)
Lead chromate, as Cr	—	0.05, A2	—	—
Limestone	—	D	—	20
Lindane — Skin	—	0.5	—	1.5
Lithium hydride	—	0.025	—	—
L.P.G. (Liquified petroleum gas)	1,000	1,800	1,250	2,250
Magnesite	—	D	—	20
Magnesium oxide fume	—	10	—	—
Malathion — Skin	—	10	—	—
Maleic anhydride	0.25	1	—	—
C Manganese & compounds, as Mn	—	5	—	—
Manganese fume, as Mn	—	1	—	3
Manganese cyclopentadienyl tricarbonyl, as Mn — Skin	—	0.1	—	0.3
Manganese tetroxide	—	1	—	—
Marble/calcium carbonate	—	D	—	20
Mercury (Alkyl compounds) — Skin, as Hg	—	0.01	—	0.03
** Mercury (All forms except alkyl), as Hg	—	(0.05)	—	(0.15)
* Mesityl oxide	15	60	25	100
* Methacrylic acid	20	70	—	—
Methane	E	—	—	—
Methanethiol, see Methyl mercaptan				
Methomyl (Lannate®) — Skin	—	2.5	—	—
Methoxychlor	—	10	—	—
2-Methoxyethanol — Skin	25	80	35	120
Methyl acetate	200	610	250	760
Methyl acetylene	1,000	1,650	1,250	2,040
Methyl acetylene-propadiene				

Capital letters refer to Appendices.
*1981 Addition.
**See Notice of Intended Changes.

MAP 000277

Substance	ADOPTED VALUES TWA ppm[a]	TWA mg/m³[b]	STEL ppm[a]	STEL mg/m³[b]
mixture (MAPP)	1,000	1,800	1,250	2,250
Methyl acrylate — Skin	10	35	—	—
Methylacrylonitrile — Skin	1	3	2	6
Methylal	1,000	3,100	1,250	3,875
Methyl alcohol (methanol) — Skin	200	260	250	310
Methylamine	10	12	—	—
Methyl amyl alcohol, see Methyl isobutyl carbinol				
* Methyl n-amyl ketone	50	235	100	465
* Methyl bromide — Skin	5	20	15	60
* Methyl n-butyl ketone	5	20	—	—
Methyl Cellosolve®, see 2-Methoxyethanol				
Methyl Cellosolve® acetate, see Ethylene glycol monomethyl ether acetate				
* Methyl chloride	50	105	100	205
Methyl chloroform	350	1,900	450	2,450
Methyl 2-cyanoacrylate	2	8	4	16
Methylcyclohexane	400	1,600	500	2,000
Methylcyclohexanol	50	235	75	350
o-Methylcyclohexanone — Skin	50	230	75	345
Methylcyclopentadienyl manganese tricarbonyl, as Mn — Skin	—	0.2	—	0.6
Methyl demeton — Skin	—	0.5	—	1.5
C Methylene bisphenyl isocyanate (MDI)	0.02	0.2	—	—
* Methylene chloride	100	360	500	1,700
4, 4'-Methylene bis (2-chloroaniline) — Skin	0.02, A2	0.22, A2	—	—
C Methylene bis (4-cyclohexylisocyanate)	0.01	0.11	—	—
4, 4-Methylene dianiline — Skin	0.1	0.8	0.5	4
Methyl ethyl ketone (MEK)	200	590	300	885
C Methyl ethyl ketone				

Capital letters refer to Appendices.
*1981 Addition.

MAP 000278

Substance	ADOPTED VALUES TWA ppm[a]	TWA mg/m³[b]	STEL ppm[a]	STEL mg/m³[b]
peroxide	0.2	1.5	—	—
Methyl formate	100	250	150	375
5-Methyl-3-heptanone, see Ethyl amyl ketone				
C Methyl hydrazine — Skin	0.2, A2	0.35, A2	—	—
* Methyl iodide — Skin	2, A2	10, A2	5, A2	30, A2
* Methyl isoamyl ketone	(100)	(475)	(150)	(710)
Methyl isobutyl carbinol — Skin	25	100	40	165
* Methyl isobutyl ketone	50	205	75	300
Methyl isocyanate — Skin	0.02	0.05	—	—
* Methyl isopropyl ketone	200	705	—	—
Methyl mercaptan	0.5	1	—	—
Methyl methacrylate	100	410	125	510
Methyl parathion — Skin	—	0.2	—	0.6
Methyl propyl ketone	200	700	250	875
* Methyl silicate	1	6	5	30
* α-Methyl styrene	50	240	100	485
Molybdenum, as Mo				
Soluble compounds	—	5	—	10
Insoluble compounds	—	10	—	20
Monocrotophos (Azodrin®)	—	0.25	—	—
** Monomethyl aniline — Skin	(2)	(9)	(4)	(18)
Morpholine — Skin	20	70	30	105
Naphthalene	10	50	15	75
β-Naphthylamine	—	A1b	—	A1b
Neon	E	—	—	—
Nickel carbonyl, as Ni	0.05	0.35	—	—
Nickel, metal	—	1	—	—
Soluble compounds, as Ni	—	0.1	—	0.3
Nickel sulfide roasting, fume & dust, as Ni	—	1, A1a	—	—
Nicotine — Skin	—	0.5	—	1.5
Nitric acid	2	5	4	10
Nitric oxide	25	30	35	45
** p-Nitroaniline — Skin	(1)	(6)	(2)	(12)
Nitrobenzene — Skin	1	5	2	10
** p-Nitrochlorobenzene — Skin	—	(1)	—	(2)

Capital letters refer to Appendices
*1981 Addition
**See Notice of Intended Changes

MAP 000279

Substance	ADOPTED VALUES TWA ppm[a]	TWA mg/m³[b]	STEL ppm[a]	STEL mg/m³[b]
4-Nitrodiphenyl	—	A1b	—	A1b
Nitroethane	100	310	150	465
* Nitrogen dioxide	3	6	5	10
Nitrogen trifluoride	10	30	15	45
** Nitroglycerin (NG) — Skin	(0.02)	(0.2)	(0.05)	(0.5)
Nitromethane	100	250	150	375
** 1-Nitropropane	(25)	(90)	(35)	(135)
**C 2-Nitropropane	(25, A2)	(90, A2)	—	—
N-Nitrosodimethylamine (dimethylnitrosoamine) — Skin	—	A2	—	A2
** Nitrotoluene — Skin	(5)	(30)	(10)	(60)
Nitrotrichloromethane, see Chloropicrin				
Nonane	200	1,050	250	1,300
Octachloronaphthalene — Skin	—	0.1	—	0.3
Octane	300	1,450	375	1,800
Oil mist, mineral	—	5[e]	—	10
Osmium tetroxide, as Os	0.0002	0.002	0.0006	0.006
Oxalic acid	—	1	—	2
Oxygen difluoride	0.05	0.1	0.15	0.3
Ozone	0.1	0.2	0.3	0.6
Paraffin wax fume	—	2	—	6
Paraquat, respirable sizes	—	0.1	—	—
Parathion — Skin	—	0.1	—	0.3
Particulate polycyclic aromatic hydro-carbons (PPAH), see Coal tar pitch volatiles				
Pentaborane	0.005	0.01	0.015	0.03
Pentachloronaphthalene	—	0.5	—	2
Pentachlorophenol — Skin	—	0.5	—	1.5
Pentaerythritol	—	D	—	20
Pentane	600	1,800	750	2,250
2-Pentanone, see Methyl propyl ketone				
** Perchloroethylene —				

Capital letters refer to Appendices.
Footnotes (a thru f) see Page 32.
*1981 Addition.
**See Notice of Intended Changes.

MAP 000280

Substance	ADOPTED VALUES TWA ppm[a]	TWA mg/m³[b]	STEL ppm[a]	STEL mg/m³[b]
Skin	(100)	(670)	(150)	(1,000)
Perchloromethyl mercaptan	0.1	0.8	—	—
Perchloryl fluoride	3	14	6	28
Phenol — Skin	5	19	10	38
Phenothiazine — Skin	—	5	—	10
N-Phenyl-beta-naphthylamine	A2	A2	—	—
p-Phenylene diamine — Skin	—	0.1	—	—
Phenyl ether (vapor)	1	7	2	14
Phenylethylene, see Styrene, monomer				
** Phenyl glycidyl ether (PGE)	(10)	(60)	(15)	(90)
** Phenylhydrazine — Skin	(5)	(20)	(10)	(45)
Phenyl mercaptan	0.5	2	—	—
C Phenylphosphine	0.05	0.25	—	—
Phorate (Thimet®) — Skin	—	0.05	—	0.2
Phosdrin (Mevinphos®) — Skin	0.01	0.1	0.03	0.3
Phosgene	0.1	0.4	—	—
Phosphine	0.3	0.4	1	1
Phosphoric acid	—	1	—	3
Phosphorus (yellow)	—	0.1	—	0.3
Phosphorus pentachloride	0.1	1	—	—
Phosphorus pentasulfide	—	1	—	3
** Phosphorus trichloride	(0.5)	(3)	—	—
Phthalic anhydride	1	6	4	24
m-Phthalodinitrile	—	5	—	—
Picloram (Tordon®)	—	10	—	20
Picric acid — Skin	—	0.1	—	0.3
Pival® (2-Pivalyl-1, 3-indandione)	—	0.1	—	0.3
Plaster of Paris	—	D	—	20
* Platinum, metal	—	1	—	—
Soluble salts, as Pt	—	0.002	—	—
Polychlorobiphenyls, see Chlorodiphenyls				
Polytetrafluoroethylene				

apital letters refer to Appendices
ootnotes (a thru f) see Page 32
1981 Addition.
*See Notice of Intended Changes.

MAP 000281

Substance	ADOPTED VALUES TWA ppm[a]	TWA mg/m³[b]	STEL ppm[a]	STEL mg/m³[b]
decomposition products	—	B1	—	B1
C Potassium hydroxide	—	2	—	—
Propane	E	—	—	—
Propane sultone	A2	A2	—	—
Propargyl alcohol—Skin	1	2	3	6
* β-Propiolactone	0.5, A2	1.5, A2	1, A2	3, A2
* Propionic acid	10	30	15	45
n-Propyl acetate	200	840	250	1,050
Propyl alcohol — Skin	200	500	250	625
n-Propyl nitrate	25	105	40	470
Propylene	E	—	—	—
Propylene dichloride	75	350	110	510
** Propylene glycol dinitrate (PGDN) — Skin	(0.02)	(0.1)	(0.05)	(0.3)
Propylene glycol monomethyl ether	100	360	150	540
** Propylene imine — Skin	(2)	(5)	—	—
* Propylene oxide	20	50	—	—
Propyne, see Methyl acetylene				
Pyrethrum	—	5	—	10
Pyridine	5	15	10	30
Quinone	0.1	0.4	0.3	2
RDX, see Cyclonite				
Resorcinol	10	45	20	90
** Rhodium, metal fume & dusts, as Rh	—	(0.1)	—	(0.3)
Soluble salts, as Rh	—	0.001	—	0.003
Ronnel	—	10	—	—
Rosin core solder pyrolysis products, as formaldehyde	—	0.1	—	0.3
Rotenone (commercial)	—	5	—	10
Rouge	—	D	—	20
Rubber solvent (Naphtha)	400	1,600	—	—
Selenium compounds, as Se	—	0.2	—	—
Selenium hexafluoride, as Se	0.05	0.2	—	—
Sevin®, see Carbaryl				
Silane, see Silicon				

Capital letters refer to Appendices.
*1981 Addition.
**See Notice of Intended Changes.

MAP 000282

Substance	ADOPTED VALUES TWA ppm[a]	TWA mg/m³[b]	STEL ppm[a]	STEL mg/m³[b]
tetrahydride				
Silicon	—	D	—	20
Silicon carbide	—	D	—	20
** Silicon tetrahydride	(0.5)	(0.7)	(1)	(1.5)
Silver, metal	—	0.1	—	—
* Soluble compounds, as Ag	—	0.01	—	—
C Sodium azide	0.1	0.3	—	—
Sodium bisulfite	—	5	—	—
Sodium 2, 4-dichloro-phenoxyethyl sulfate	—	10	—	20
Sodium fluoroacetate (1080) — Skin	—	0.05	—	0.15
C Sodium hydroxide	—	2	—	—
Sodium metabisulfite	—	5	—	—
Starch	—	D	—	20
Stibine	0.1	0.5	0.3	1.5
** Stoddard solvent	100	(575)	(125)	(720)
Strychnine	—	0.15	—	0.45
* Styrene, monomer	50	215	100	425
C Subtilisins (Proteolytic enzymes as 100% pure crystalline enzyme)	—	0.00006[m]	—	—
Sucrose	—	D	—	20
Sulfur dioxide	2	5	5	10
Sulfur hexafluoride	1,000	6,000	1,250	7,500
Sulfuric acid	—	1	—	—
Sulfur monochloride	1	6	3	18
Sulfur pentafluoride	0.025	0.25	0.075	0.75
Sulfur tetrafluoride	0.1	0.4	0.3	1
Sulfuryl fluoride	5	20	10	40
Systox, see Demeton®				
2, 4, 5-T	—	10	—	20
Tantalum	—	5	—	10
TEDP — Skin	—	0.2	—	0.6
Teflon® decomposition products	—	B1	—	B1
Tellurium & compounds, as Te	—	0.1	—	—
Tellurium hexafluoride, as Te	0.02	0.2	—	—
TEPP — Skin	0.004	0.05	0.01	0.2

Capital letters refer to Appendices.
*1981 Addition.
**See Notice of Intended Changes.

MAP 000283

Substance	ADOPTED VALUES TWA ppm[a]	TWA mg/m³[b]	STEL ppm[a]	STEL mg/m³[b]
C Terphenyls	0.5	5	—	—
1, 1, 1, 2-Tetrachloro-2, 2-difluoroethane	500	4,170	625	5,210
1, 1, 2, 2-Tetrachloro-1, 2-difluoroethane	500	4,170	625	5,210
** 1, 1, 2, 2-Tetrachloroethane — Skin	(5)	(35)	(10)	(70)
Tetrachloroethylene, see Perchloroethylene				
Tetrachloromethane, see Carbon tetrachloride				
Tetrachloronaphthalene	—	2	—	4
Tetraethyl lead, as Pb — Skin	—	0.100[n]	—	0.3
Tetrahydrofuran	200	590	250	735
Tetramethyl lead, as Pb — Skin	—	0.150[n]	—	0.5
Tetramethyl succinonitrile — Skin	0.5	3	2	9
Tetrasodium pyrophosphate	—	5	—	—
Tetranitromethane	1	8	—	—
Tetryl (2, 4, 6-trinitrophenyl-methylnitramine) — Skin	—	1.5	—	3.0
Thallium, soluble compounds, as Tl — Skin	—	0.1	—	—
4, 4'-Thiobis (6-tert. butyl-m-cresol)	—	10	—	20
Thioglycolic acid	1	5	—	—
Thiram[g]	—	5	—	10
** Tin, inorganic compounds, except SnH_4 and SnO_2, as Sn	—	(2)	—	(4)
Tin, organic compounds, as Sn — Skin	—	0.1	—	0.2
** Tin oxide, as Sn	—	(D)	—	(20)
Titanium dioxide, as Ti	—	D	—	20
Toluene (toluol) — Skin	100	375	150	560
**C Toluene-2,				

Capital letters refer to Appendices
**See Notice of Intended Changes.
m) See Page 35.

MAP 000284

Substance	ADOPTED VALUES TWA ppm[a]	TWA mg/m³[b]	STEL ppm[a]	STEL mg/m³[b]
4-diisocyanate (TDI)	(0.02)	(0.14)	—	—
** o-Toluidine	(5)	(22)	(10)	(44)
Toxaphene, see Chlorinated camphene				
* Tributyl phosphate	0.2	2.5	0.4	5
Trichloroacetic acid	1	5	—	—
1, 2, 4-Trichlorobenzene	5	40	—	—
1, 1, 1-Trichloroethane, see Methyl chloroform				
1, 1, 2-Trichloroethane — Skin	10	45	20	90
** Trichloroethylene	(100)	(535)	(150)	(800)
** Trichlorofluoromethane	(1,000)	(5,600)	(1,250)	(7,000)
Trichloromethane, see Chloroform				
Trichloronaphthalene	—	5	—	10
Trichloronitromethane, see Chloropicrin				
1, 2, 3-Trichloropropane	50	300	75	450
1, 1, 2-Trichloro 1, 2, 2-trifluoroethane	1,000	7,600	1,250	9,500
Tricyclohexyltin hydroxide (Plictran®)	—	5	—	10
** Triethylamine	(25)	(100)	(40)	(160)
Trifluorobromomethane	1,000	6,100	1,200	7,300
* Trimellitic anhydride	0.005	0.04	—	—
Trimethyl benzene	25	125	35	170
** Trimethyl phosphite	(0.5)	(2.6)	—	—
2, 4, 6-Trinitrophenol, see Picric acid				
2, 4, 6-Trinitrophenyl-methylnitramine, see Tetryl				
**C 2, 4, 6-Trinitrotoluene (TNT)	—	(0.5)	—	—
Triorthocresyl phosphate	—	0.1	—	0.3
Triphenyl amine	—	5	—	—
Triphenyl phosphate	—	3	—	6
Tungsten & compounds, as W				
Soluble	—	1	—	3
Insoluble	—	5	—	10

Capital letters refer to Appendices.
Footnotes (a thru f) see Page 32.
*1981 Addition
**See Notice of Intended Changes

MAP 000285

Substance	ADOPTED VALUES TWA ppm[a]	TWA mg/m³[b]	STEL ppm[a]	STEL mg/m³[b]
Turpentine	100	560	150	840
Uranium (natural), soluble & insoluble compounds, as U	—	0.2	—	0.6
** Vanadium (V_2O_5), as V Dust	—	(0.5)	—	(1.5)
C Fume	—	(0.05)	—	—
Valeraldehyde	50	175	—	—
Vinyl acetate	10	30	20	60
Vinyl benzene, see Styrene				
Vinyl bromide	5, A2	20, A2	—	—
Vinyl chloride	5, A1a	10, A1a	—	—
Vinyl cyanide, see Acrylonitrile				
Vinyl cyclohexene dioxide	10	60	—	—
Vinylidene chloride	10	40	20	80
* Vinyl toluene	50	240	100	485
VM & P Naphtha	300	1,350	400	1,800
Warfarin	—	0.1	—	0.3
Welding fumes (NOC)†	—	5, B3	—	B3
* Wood dust (certain hard woods as beech & oak)	—	1	—	—
Soft wood	—	5	—	10
Xylene (o-, m-, p-isomers) — Skin	100	435	150	655
C m-Xylene α, α'-diamine	—	0.1	—	—
** Xylidene — Skin	(5)	(25)	(10)	(50)
Yttrium	—	1	—	3
Zinc chloride fume	—	1	—	2
Zinc chromate, as Cr	—	0.05, A2	—	—
Zinc oxide fume	—	5	—	10
Zinc stearate	—	D	—	20
Zirconium compounds, as Zr	—	5	—	10

Capital letters refer to Appendices.
*1980 Addition.
**See Notice of Intended Changes.

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

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b) Approximate milligrams of substance per cubic meter of air.
d) $< 7\ \mu m$ in diameter.
e) As sampled by method that does not collect vapor.
f) For control of general room air, biologic monitoring is essential for personnel control.

Radioactivity: The Committee accepts the philosophy and recommendations of the National Council on Radiation Protection and Measurements (NCRP) for the ionizing radiation TLV. The NCRP is charted by Congress to, in part, collect, analyze, develop and disseminate information and recommendations about protection against radiation and about radiation measurements, quantities and units, including development of basic concepts in these areas. NCRP Report No. 39 (reference 1) provides basic philosophy and concepts leading to protection criteria established in the same report. Other NCRP reports address specific areas of radiation protection and, collectively, provide an excellent basis for establishing a sound program for radiation control. The Committee recommends the listed references as substantative documentation of a sound basis for ionizing radiation protection. The Committee also strongly recommends that all exposures to ionizing radiations be kept low as reasonably achievable within the stated guidance.

References:

1. "Basic Radiation Protection Criteria," NCRP Report No. 39, issued January 15, 1971.
2. Maximum Permissible Body Burdens and Maximum Permissible Concentrations of Radionuclides in Air and in Water for Occupational Exposure," US Department of Commerce, National Bureau of Standards Handbook 69, issued June 5, 1959, with Addendum 1 issued August 1963. Available as NCRP Report No. 22.

The above documents, as well as information on numerous other NCRP Reports addressing specific subjects in ionizing radiation protection are available from: NCRP Publications, PO Box 30175, Washington, DC 20014.

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MINERAL DUSTS

Substance	
SILICA, SiO_2	
Crystalline	
Quartz	TLV in mppcf[2]: $\frac{300^{h}}{\%\ \text{quartz} + 10}$ TLV for respirable dust in mg/m³: $\frac{10\ \text{mg/m}^{3i}}{\%\ \text{Respirable quartz} + 2}$ TLV for "total dust," respirable and nonrespirable: $\frac{30\ \text{mg/m}^3}{\%\ \text{quartz} + 3}$
Cristobalite	Use one-half the value calculated from the count or mass formulae for quartz.
Tridymite	Use one-half the value calculated from formulae for quartz.
Silica, fused	Use quartz formulae.
Tripoli	Use respirable[a] mass quartz formula
****Amorphous**	(20 mppcf[2])

SILICATES (< 1% quartz)	
Asbestos	
Amosite	0.5 fiber > 5μm/cc, A1a
Chrysotile	2 fibers > 5μm/cc, A1a
Crocidolite	0.2 fiber > 5μm/cc, A1a
Other forms	2 fibers > 5μm/cc, A1a
Mica	20 mppcf
Mineral wool fiber	10 mg/m³
Perlite	30 mppcf
Portland Cement	30 mppcf
Soapstone	20 mppcf
****Talc (nonasbestiform)**	(20 mppcf)
****Talc (fibrous), (use Asbestos limit.)**	

**See notice of intended changes

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COAL DUST

2 mg/m³ (respirable dust fraction < 5% quartz).
If > 5% quartz, use respirable mass formula.

NUISANCE PARTICULATES
(see Appendix D)

30 mppcf or 10 mg/m³[j]
of total dust < 1% quartz, or, 5 mg/m³ respirable dust.

Conversion factors:
mppcf × 35.3 = Million particles per cubic meter
= particles per cc

---

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

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

i) Both concentration and percent quartz 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

j) containing < 1% quartz; if quartz content > 1%, use formulae for quartz.

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

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

m) Based on "high volume" sampling.

n) "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.

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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.

NOTICE OF INTENDED CHANGES (for 1981)

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. Documentation is available for each of these substances.

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Substance	TWA ppm[a]	TWA mg/m³[b]	STEL ppm[a]	STEL mg/m³[b]
Acetone	750	1780	1000	2375
Acrylonitrile	2, A1a	4.5, A1a	—	—
Atrazine	—	5	—	—
Benzidine — Skin	—	A1b	—	—
Cadmium oxide production	—	0.05	—	—
C o-Chlorobenzylidene malononitrile	0.05	0.4	—	—
Chloromethyl methyl ether	A2	A2	—	—
Chromyl chloride	0.025	0.15	—	—
† Cobalt carbonyl, as Co	—	0.1	—	—
† Cobalt hydrocarbonyl, as Co	—	0.1	—	—
Cobalt metal, dust & fume, as Co	—	0.05	—	0.1
Enflurane	75	575	—	—
Ethylene dibromide — Skin	A2	A2	—	—
† Ethylene glycol dinitrate (EGDN) — Skin	0.05	0.3	0.1	0.6
† Ethylene oxide	5, A2	10, A2	—	—
N-Ethylmorpholine — Skin	5	23	20	95
† Fenthion	—	0.2	—	—
† Formaldehyde	A2	A2	—	—
Furfuryl alcohol — Skin	10	40	15	60
Gasoline	300	900	500	1500
Halothane	50	400	—	—
Hexachlorobutadiene	0.02, A2	0.24, A2	—	—
Hexachloroethane — Skin	10	100	—	—
Hexane (n-Hexane)	50	180	—	—
Other isomers	500	1,800	1,000	3,600
Iron pentacarbonyl, as Fe	0.1	0.8	0.2	0.16
Isooctyl alcohol	50	270	—	—
Lead arsenate, as $Pb_3(AsO_4)_2$	—	0.15	—	0.45
Mercury (All forms except alkyl) — Skin, as Hg				
Vapor	—	0.05	—	—
Aryl & inorganic compounds	—	0.1	—	—
4-Methoxyphenol	—	5	—	—
N-Methyl aniline — Skin	0.5	2	1	5
Methyl isoamyl ketone	50	240	—	—

Capital letters refer to Appendices
†1981 Revision or Addition.

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Substance	TWA ppm[a]	TWA mg/m³[b]	STEL ppm[a]	STEL mg/m³[b]
p-Nitroaniline — Skin	—	3	—	—
p-Nitrochlorobenzene — Skin	0.5	3	—	—
⁻ Nitroglycerin (NG) — Skin	0.05	0.5	0.1	1
1-Nitropropane	15	55	25	90
† 2-Nitropropane	5, A2	35, A2	20, A2	70, A2
Nitrotoluene — Skin	2	11	—	—
Perchloroethylene — Skin	50	335	—	—
Persulfates, alkali metal, as S_2O_8	—	2	—	—
Phenyl glycidyl ether (PGE)	1	6	—	—
† Phenylhydrazine — Skin	5, A2	20, A2	10, A2	45, A2
Phosphorus oxychloride	0.1	0.6	0.5	3
Phosphorus trichloride	0.2	1.5	0.5	3
Piperazine dihydrochloride	—	5	—	—
† Propylene glycol dinitrate (PGDN) — Skin	0.05	0.3	0.1	0.6
Propylene imine — Skin	2, A2	5, A2	—	—
Rhodium, metal	—	1	—	—
insoluble compounds, as Rh	—	0.1	—	0.3
Silicon tetrahydride (Silane)	5	7	—	—
Stoddard solvent	100	525	200	1,050
1, 1, 2, 2-Tetrachloroethane — Skin	1	7	5	35
Tin, tin oxide & inorganic compounds, except SnH_4, as Sn	—	2	—	4
o-Tolidine	A2	A2	—	—
Toluene-2, 4-diisocyanate (TDI)	0.005	0.04	0.02	0.15
o-Toluidine	2	9	—	—
Trichloroethylene	50	270	150	805
C Trichlorofluoromethane	1,000	5,600	—	—
† Triethylamine	10	40	15	60
† Trimethylamine	10	40	15	60
Trimethyl phosphite	2	10	5	25
2, 4, 6-Trinitrotoluene (TNT) — Skin	—	0.5	—	3

Capital letters refer to Appendices
⁻1981 Revision or Addition.

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Substance	TWA ppm[a]	TWA mg/m³[b]	STEL ppm[a]	STEL mg/m³[b]
Vanadium, as V_2O_5, dust & fume	—	0.05	—	—
Xylidine — Skin	2	10	—	—

NOTICE OF INTENDED CHANGES
MINERAL DUSTS

Substance	TLV
Diatomaceous earth, natural	1.5 mg/m³, Respirable dust
Silica, amorphous	6 mg/m³, Total dust (all sampled sizes) 3 mg/m³, Respirable dust (< 5 μm)
Talc (containing no fibers)	15 mppcf or 2 mg/m³, Respirable Dust
Talc (fiber-containing)	2 fibers/cc, > 5 μm in length

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).

A1a. *Human Carcinogens*. Substances, or substances associated with industrial processes, recognized to have carcinogenic or cocarcinogenic potential, with an assigned TLV:

	TLV
Acrylonitrile	2 ppm
Asbestos	
Amosite	0.5 fiber > 5μm/cc
Chrysotile	2 fibers > 5μm/cc
Crocidolite	0.2 fiber > 5μm/cc
Other forms	2 fibers > 5μm/cc
bis (Chloromethyl) ether	0.001 ppm
Chromite ore	

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processing (chromate)	0.05 mg/m³, as Cr
†† Chromium (VI), certain water insoluble compounds.....	0.05 mg/m³, as Cr
Coal tar pitch volatiles ..	0.2 mg/m³, as benzene solubles
Nickel sulfide roasting, fume & dust.....	1.0 mg/m³, as Ni
Vinyl chloride	5 ppm

* * *

A1b. *Human Carcinogens.* Substances, or substances associated with industrial processes, recognized to have carcinogenic potential without an assigned TLV:

** Acrylonitrile
4-Aminodiphenyl (p-Xenylamine)
Benzidine — Skin
** Chloromethyl methyl ether
** Ethylene dibromide
β-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. The worker should be properly equipped to insure virtually no contact with the carcinogen.

A2. *Industrial Substances Suspect of Carcinogenic Potential for MAN.* Chemical substances or substances associated with industrial processes, which are suspect of inducing cancer, based on either (1) limited epidemiologic evidence, exclusive of clinical reports of single cases, or (2) demonstration of carcinogenesis in one or more animal species by appropriate methods.

3-Amino 1, 2, 4-triazole	
Antimony trioxide production*	——
Arsenic trioxide production	——
Benzene	10 ppm
Benzo(a)pyrene	——

*Cigarette smoking can enhance the incidence of respiratory cancers from this or others of these substances or processes.
††1981 Adoption.
**See Notice of Intended Changes

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	Beryllium	2.0 μg/m³
	Cadmium oxide production	—
‡‡	Carbon tetrachloride	5 ppm
	Chloroform	10 ppm
	Chloromethyl methyl ether	—
	Chromates of lead and zinc, as Cr	0.05 mg/m³
‡‡	Chrysene	—
	3, 3'-Dichlorobenzidine	—
	Dimethylcarbamyl chloride	—
	1, 1-Dimethyl hydrazine	0.5 ppm
	Dimethyl sulfate — Skin	0.1 ppm
	Ethylene dibromide — Skin	—
†	Ethylene oxide	5 ppm
†	Formaldehyde	—
	Hexachlorobutadiene	0.02 ppm
	Hexamethyl phosphoramide — Skin	—
	Hydrazine	0.1 ppm
	4, 4'-Methylene bis (2-chloroaniline) — Skin	0.02 ppm
	Methyl hydrazine	0.2 ppm
‡‡	Methyl iodide	2 ppm
†	2-Nitropropane	10 ppm
	N-Nitrosodimethylamine	—
	N-Phenyl-beta-naphthylamine	—
†	Phenylhydrazine	5 ppm
	Propane sultone	—
‡‡	beta-Propiolactone	0.5 ppm
	Propylene imine — Skin	2 ppm
	o-Tolidine	—
	Vinyl bromide	5 ppm
	Vinyl cyclohexene dioxide	10 ppm

For the above, worker exposure by all routes should be carefully controlled to levels consistent with the animal and human experience data (see Documentation), including those substances with a listed TLV.

THE COMMITTEE GUIDELINES FOR CLASSIFICATION OF EXPERIMENTAL ANIMAL CARCINOGENS

The following guidelines are offered in the present state of knowledge as an aid in classifying

‡1981 Addition.
‡‡1981 Adoption.

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substances in the occupational environment found to be carcinogenic in experimental animals. A need was felt by the Threshold Limits Committee for such a classification in order to take the first step in developing an appropriate TLV for occupational exposure.

Determination of Approximate Threshold of Response Requirement. In order to determine in which category to classify an experimental carcinogen for the purpose of assigning an industrial air limit (TLV), an approximate threshold of neoplastic response must be determined. Because of practical experimental difficulties, a precisely defined threshold cannot be attained. For the purposes of standard-setting, this is of little moment, as an appropriate risk, or safety, factor can be applied to the approximate threshold, the magnitude of which is dependent on the degree of potency of the carcinogenic response.

To obtain the best 'practical' threshold of neoplastic response, dosage decrements should be less than logarithmic. This becomes particularly important at levels greater than 10 ppm (or corresponding mg/m^3). Accordingly, after a range-finding determination has been made by logarithmic decreases, two additional dosage levels are required within the levels of "effect" and "no effect" to approximate the true threshold of neoplastic response.

The second step should attempt to establish a metabolic relationship between animal and man for the particular substance found carcinogenic in animals. If the metabolic pathways are found comparable, the substance should be classed highly suspect as a carcinogen for man. If no such relation is found, the substance should remain listed as an experimental animal carcino gen until evidence to the contrary is found.

Proposed Classification of Experimental Animal Carcinogens. Substances occurring in the occupational environment found carcinogenic for animals may be grouped into three classes, those of high, intermediate and low potency. In evaluating the incidence of animal cancers, significant incidence of cancer is defined as a neoplastic response which represents, in the judgment of the Committee, a significant excess of cancers above that occurring in negative controls.

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EXCEPTIONS: No substance is to be considered an occupational carcinogen of any practical significance which reacts by the respiratory route at or above 1000 mg/m³ for the mouse, 2000 mg/m³ for the rat; by the dermal route, at or above 1500 mg/kg for the mouse, 3000 mg/kg for the rat; by the gastrointestinal route at or above 500 mg/kg/d for a lifetime, equivalent to about 100 g T.D. for the rat, 10g T.D. for the mouse.

These dosage limitations exclude such substances as dioxane and trichlorethylene from consideration as carcinogens.

Examples: Dioxane — rats, hepatocellular and nasal tumors from 1015 mg/kg/d, oral

Trichloroethylene — female mice, tumors (30/98 @ 900 mg/kg/d), oral

Industrial Substances of High Carcinogenic Potency in Experimental Animals.

1. A substance to qualify as a carcinogen of high potency must fulfill one of the three following conditions in two animal species:

   1a. *Respiratory*. Elicit cancer from (1) dosages below 1 mg/m³ (or equivalent ppm) via the respiratory tract in 6- 7-hour daily repeated inhalation exposures throughout lifetime; or (2) from a single intratracheally administered dose not exceeding 1 mg of particulate, or liquid, per 100 ml or less of animal minute respiratory volume;

   Examples: bis-Chloromethyl ether, malignant tumors, rats, @ 0.47 mg/m³ (0.1 ppm) in 2 years;

   Hexamethyl phosphoramide, nasal squamous cell carcinoma, rats, @ 0.05 ppm, in 13 months

   OR

   1b. *Dermal*. Elicit cancer within 20 weeks by skin-painting, twice weekly at 2 mg/kg body weight or less per application for a total dose equal to or less than 1.5 mg, in

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a biologically inert vehicle;

Examples: 7, 12-Dimethylbenz(a)anthracene — skin tumors @ 0.12-0.8 mg T.D. in four weeks

Benzo(a)pyrene, mice 12 μg, 3X/wk for 18 mos. T.D. 2.6 mg, 90.9% skin tumors

OR

1c. *Gastrointestinal*. Elicit cancer by daily intake via the gastrointestinal tract, within six months, with a six-month holding period, at a dosage below 1 mg/kg body weight per day; total dose, rat, ≦ 50 mg; mouse, ≦ 3.5 mg;

Examples: 7, 12-Dimethylbenz(a)anthracene — mammary tumors from 10 mg 1X

3-Methylcholanthrene — Tumors @ 3 sites from 8 mg in 89 weeks

Benzo(a)pyrene, mice, 3.9% leukemias, from 30 mg T.D. 198 days

2. Elicit cancer by all three routes in at least two animal species at dose levels prescribed for high or intermediate potency.

Industrial Substances of Intermediate Carcinogenic Potency in Experimental Animals.

To qualify as a carcinogen of intermediate potency, a substance should elicit cancer in two animal species at dosages intermediate between those described in A3a and A3c by two routes of administration.

Example: Carbamic acid ethyl ester
Dermal, mammary tumors, mice, 100%, 63 weeks, 500–1400 mg T.D.
Gastrointestinal, various type tumors, mice 42 weeks, 320 mg T.D.

Gastrointestinal, various type tumors, rats, 60 weeks, 110–930 mg T.D.

Industrial Substances of Low Carcinogenic Potency in Experimental Animals.

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To qualify as a carcinogen of low potency, a substance should elicit cancer in one animal species by any *one* of three routes of administration at the following prescribed dosages and conditions:

1a. *Respiratory*. Elicit cancer from (1) dosages greater than 10 mg/m³ (or equivalent ppm) via the respiratory tract in 6- 7-hour, daily repeated inhalation exposures, for 12 months' exposure and 12 months' observation period; or (2) from intratracheally administered dosages totaling more than 10 mg of particulate or liquid per 100 ml or more of animal minute respiratory volume;

Examples: Beryl (beryllium aluminum silicate) malig. lung tumors, rats, @ 15 mg/m³ @ 17 months

Benzidine, var. tumors, rats, 10–20 mg/m³ @ > 13 mos.

OR

1b. *Dermal*. Elicit cancer by skin-painting of mice in twice weekly dosages of > 10 mg/kg body weight in a biologically inert vehicle for at least 75 weeks, i.e., ≧ 1.5g T.D.

Examples: Shale tar, mouse, 0.1 ml × 50 = 5g T.D. 59/60 skin tumors

Arsenic trioxide, man, dose unknown, but estimated to be high

1c. *Gastrointestinal*. Elicit cancer from daily oral dosages of 50 mg/kg/day or greater during the lifetime of the animal.

APPENDIX B
SUBSTANCES OF VARIABLE COMPOSITION

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 minimal.

*Trade Names: Algoflon, Fluon, Halon, Teflon, Tetran.

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B2 *Gasoline*. See Notice of Intended Change.

B3 *Welding Fumes — Total Particulate (NOC)***
TLV, 5 mg/m³

Welding fumes cannot be classified simply. The composition and quantity of both are dependent on the alloy being welded and the process and electrodes used. Reliable analysis of fumes cannot be made without considering the nature of the welding process and system being examined; reactive metals and alloys such as aluminum and titanium are arc-welded in a protective, inert atmosphere such as argon. These arcs create relatively little fume, but an intense radiation which can produce ozone. Similar processes are used to arc-weld steels, also creating a relatively low level of fumes. Ferrous alloys also are arc-welded in oxidizing environments which generate considerable fume, and can produce carbon monoxide instead of ozone. Such fumes generally are composed of discreet particles of amorphous slags containing iron, manganese, silicon and other metallic constituents depending on the alloy system involved. Chromium and nickel compounds are found in fumes when stainless steels are arc-welded. Some coated and flux-cored electrodes are formulated with fluorides and the fumes associated with them can contain significantly more fluorides than oxides. Because of the above factors, arc-welding fumes frequently must be tested for individual constituents which are likely to be present to determine whether specific TLV's are exceeded. Conclusions based on total fume concentration are generally adequate if no toxic elements are present in welding rod, metal, or metal coating and conditions are not conducive to the formation of toxic gases.

Most welding, even with primitive ventilation, does not produce exposures inside the welding helmet above 5 mg/m³. That which does, should be controlled.

APPENDIX C
MIXTURES

C.1 THRESHOLD LIMIT VALUES FOR MIXTURES

When two or more hazardous substances, which act upon the same organ system, are present, their combined effect, rather than that of either individual-

**Not otherwise classified (NOC).

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ly, 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,

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

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 a 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.).

Synergistic action or potentiation may occur with some combinations of atmospheric contaminants. Such cases at present must be determined individually. Potentiating or synergistic 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 a given operation or process characteristically emits a number of harmful dusts, 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.

MAP 000301

C.1A Examples of THRESHOLD LIMIT VALUES FOR MIXTURES

The following formulae apply only when the components in a mixture have similar toxicologic effects; they should not be used for mixtures with widely differing reactivities, e.g. hydrogen cyanide & sulfur dioxide. In such case the formula for Independent Effects (1A.c.) should be used.

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.)*

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

Example No. 1A.a.: Air contains 400 ppm of acetone (TLV = 1000 ppm) 150 ppm of sec-butyl acetate (TLV = 200 ppm) and 100 ppm of 2-butanone (TLV = 200 ppm)

Atmospheric concentration of mixture = 400 + 150 + 100 = 650 ppm of mixture

$$\frac{400}{1000} + \frac{150}{200} + \frac{100}{200} = 0.4 + 0.75 + 0.5 = 1.65$$

Threshold Limit is exceeded.

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/m^3.

(Note: In order to evaluate compliance with this TLV, field sampling instruments should be calibrated, in the laboratory, for response to

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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 =

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

Example No. 1: Liquid contains (by weight)

50% heptane: TLV = 400 ppm or 1600 mg/m³
1 mg/m³ ≡ 0.25 ppm

30% methyl chloroform: TLV = 350 ppm or 1900 mg/m³
1 mg/m³ ≡ 0.18 ppm

20% perchloroethylene: TLV = 100 ppm or 670 mg/m³
1 mg/m³ ≡ 0.15 ppm

$$\text{TLV of Mixture} = \frac{1}{\frac{0.5}{1600} + \frac{0.3}{1900} + \frac{0.2}{670}}$$

$$= \frac{1}{0.00031 + 0.00016 + 0.00030}$$

$$= \frac{1}{0.00077} = 1300 \text{ mg/m}^3$$

of this mixture

50% or (1300) (0.5) = 650 mg/m³ is heptane

30% or (1300) (0.3) = 390 mg/m³ is methyl chloroform

20% or (1300) (0.2) = 260 mg/m³ is perchloroethylene

These values can be converted to ppm as follows:

heptane: 650 mg/m³ × 0.25 = 162 ppm
methyl chloroform: 390 mg/m³ × 0.18 = 70 ppm
perchloroethylene: 260 mg/m³ × 0.15 = 39 ppm

TLV of mixture = 162 + 70 + 39 = 271 ppm, or 1300 mg/m³

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

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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. TLV for Mixtures of Mineral Dusts.

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

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

$$TLV = \frac{1}{\frac{0.8}{20} + \frac{0.2}{2.7}} = 9 \text{ mppcf}$$

TLV of nonasbestiform talc (pure) = 20 mppcf
TLV of quartz (pure) =

$$\frac{300}{100 + 10} = \frac{300}{110} = 2.7 \text{ mppcf}$$

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:

25% quartz — TLV (pure) = 2.7 mppcf
25% amorphous silica — TLV (pure) = 20 mppcf
50% talc TLV (pure) = 20 mppcf

$$TLV = \frac{1}{\frac{0.25}{2.7} + \frac{0.25}{20} + \frac{0.5}{20}} = 8 \text{ mppcf}$$

The limit for 25% quartz approximates 9 mppcf.

APPENDIX D

Some Nuisance Particulates[o]

TLV, 30 mppcf or 10 mg/m³ of total dust < 1% quartz, or, 5 mg/m³ respirable dust

Aluminum Oxide (Al_2O_3)	Portland Cement
Calcium carbonate	Emery
Calcium silicate	Glycerin Mist
Cellulose (paper fiber)	Graphite (synthetic)

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Gypsum
Vegetable oil mists (except castor, cashew nut, or similar irritant oils)
Kaolin
Limestone
Magnesite
Marble
Mineral Wool Fiber
Pentaerythritol
Plaster of Paris
Silicon
Silicon Carbide
Starch
Sucrose
**Tin Oxide
Titanium Dioxide
Zinc Stearate
Zinc oxide dust

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

APPENDIX E
Some Simple Asphyxiants[p]

Acetylene
Argon
Ethane
Ethylene
Helium
Hydrogen
Methane
Neon
Propane
Propylene

p) As defined on pg. 6.

APPENDIX F
Conversion of mppcf to Mass Concentration

Calculations for Conversion of Particle Count Concentration (by Standard Light Field — Midget Impinger Techniques), in mppcf, to Respirable Mass Concentration (by Respirable Sampler) in mg/m³.†

1. In 1967, Jacobsen and Tomb,† derived an empirical relationship of 5.6 mppcf to 1 milligram of respirable dust per cubic meter of air, based on 23 sets of samples, mostly coal dust. Studies on conversion factors have been undertaken and preliminary evidence suggests that the application of any single conversion factor may not be adequate for use in risk assessments, epidemiology studies, or setting TLVs.

   The following calculation results in an equivalence of 6.37 mppcf to 1 mg/m³ of respirable dust. Thus, an approximate ratio of 6 mppcf to 1 mg/m³ of respirable dust is suggested for conversion of TLVs from a count to a

**See Notice of Intended Changes.

†"Relationship Between Gravimetric Respirable Dust Concentration and Midget Impinger Number Concentration," by Murray Jacobson and T. F. Tomb, AIHAJ, 28: Nov.–Dec. 1967.

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mass basis when the density and mass median diameter have not been determined.

2. Basic assumptions:

   a) Average density for silica containing dusts ≈ 2.5 g/cm³ (2500 mg/cm³). Pulmonary significant dust densities may vary from 1.2 g/cm³ for coal dust to 3.1 g/cm³ for Portland Cement. Silica densities vary from 2.2 (amorphous) to 2.3 (cristobalite and tridymite) to 2.5 (alpha-quartz.) gms per cm³.

   b) The mass median diameter (mmd) of particles collected in midget impinger samplers and counted by the standard light field technique, *and* collected in a respirable sampler is approximately 1.5 μm or 1.5×10^{-4} cm. This assumption is, of course, quite arbitrary since the mmd of all dust clouds is quite variable, depending on many independent parameters, such as source of dust, age of dust cloud, meteorological conditions, processes and equipment changes, etc. If the density and the mass median diameter of the dust particles are known, the nomograph in Figure 1 can be used to convert dust count concentrations (mppcf) to respirable mass concentrations (mg/m³).

3. Calculation:

   a) vol. per particle: $4/3\ \pi\ r^3$; $r = 0.75 \times 10^{-4}$ cm
   $= 4/3 \cdot \pi \cdot (0.75 \times 10^{-4})^3$
   $= 1.77 \times 10^{-12}$ cm³

   b) wt. per particle = vol. × density
   $= 1.77 \times 10^{-12}$ cm³ $\times\ 2.5 \times 10^{3}$ mg/cm³
   $= 4.425 \times 10^{-9}$ mg/particle

   c) 1 particle/ft.³ = 35.5 part./m³
   (since 35.5 cu ft = 1 cu m.)
   10^6 part./ft³ = mppcf = 35.5×10^6 part./m³
   wt. of 1 mppcf ≡ 35.5×10^6 part./m³ × 4.425×10^{-9} mg/part.
   1 mppcf ≡ 0.157 mg/m³
   or
   6.37 mppcf ≡ 1 mg/m³
   or approximately 6 mppcf ≡ 1 mg/m³.

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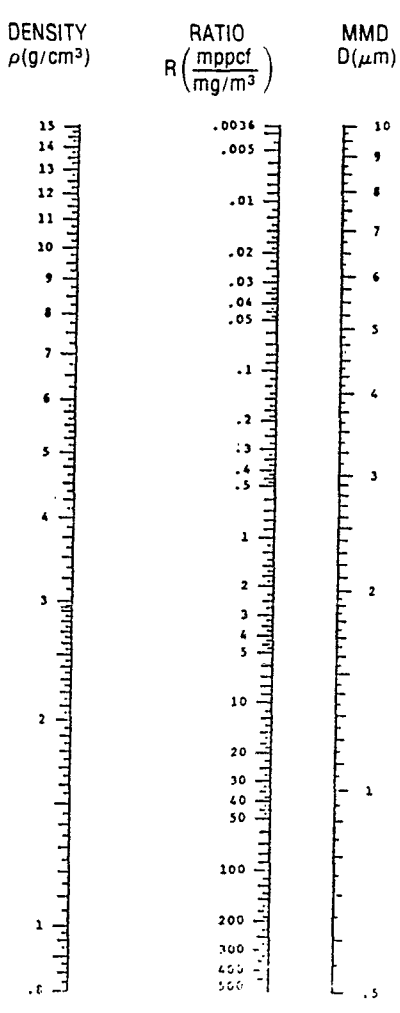


Figure 1 — Ratio of Particle Count — mppcf to Respirable Mass Concentration — mg/m³ (as function of density and mmd)÷

Prepared by P E Caplan and R J Smith

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Table 1

Equivalent TLVs in mppcf and mg/m³
(Respirable Mass) for Mineral Dusts†

Substance	Threshold Limit Value		
	Count mppcf	Resp. Mass mg/m³	Total Mass* mg/m³
Silica (SiO_2)			
Amorphous	20	(3)**	(6)
Cristobalite	1.5	0.05	0.15
Fused silica	3	0.1	0.3
Quartz	3	0.1	0.3
Tridymite	1.5	0.05	0.15
Coal Dust	(12)	2	(4)
Diatomaceous earth, natural	—	1.5	—
Graphite (natural)	15	(2.5)	(5)
Mica	20	(3)	(6)
Mineral wool fiber	—	(5)	10
Nuisance particulates	30	(5)	10
Perlite	30	(5)	(10)
Portland Cement	30	(5)	(10)
Soapstone	20	(3)	(6)
Tripoli	(3)	0.1	(0.3)

†Assuming that the mass median diameter is 1.5 μm and density is 2.5 g/cm³.

*Unless otherwise specified, respirable mass is presumed to equal approximately 50% of total mass.

**All values in parentheses ( ) represent newly calculated values based on equivalence of 6 mppcf = 1 mg/m³ respirable mass and respirable mass = 50% total mass.

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APPENDIX G
Chemical Substances Under Study

Acetonitrile
Acetophenone
Acetyl acetone
Allyl chloride
Asbestos
Bismuth telluride
Carbonyl fluoride
Chlorinated naphthalenes
Chlorine
bis-Chloromethyl ether
Chloromethyl methyl ether
Copper dust & fume
Diatomaceous earth
4,4'-Diphenylmethane diisocyanate (MDI)
Epichlorohydrin
Ethyl chloride
Ethylene dichloride
Ethylene glycol monobutyl ether
Ethylene glycol monoethyl ether
Ethylene glycol monomethyl ether
Ethylene oxide
Formaldehyde
Grain dust
Hexafluoroacetone
Hexamethylene diisocyanate (HMDI)
Isooctyl alcohol
Methyl methacrylate
Nichel, metal & soluble compounds
Nitrous oxide
Osium tetroxide
Propylene chloride
Proylene oxide
Rhodium
Silica, amorphous
Silicon tetrahydride (Silane)
Styrene, monomer
2,3,7,8-Tetrachlorodibenzo-p-dioxin (TCDD)
Tin hydride
Toluene-2,6,-diisocyanate
1,2,3-Trichloropropane
Trimellitic anhydride
Vinylidine chloride
Welding fumes

MAP 000309

TLVs®
Threshold Limit Values
for
Physical Agents
Adopted by
ACGIH
for 1981



MAP 000310

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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.

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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 1 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*; F. N. Dukes-Dobos and A. Henschel: *"Development of Permissible Heat Exposure Limits for Occupational Work."* ASHRAE Journal, Vol. 15: No. 9, September 1973, pp. 57–62.)

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 = 0.7 NWB + 0.2 GT + 0.1 DB
2. Indoors or Outdoors with no solar load:
   WBGT = 0.7 NWB + 0.3 GT

where:

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

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

Higher heat exposures than shown in Table 1 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.

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TABLE 1

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

	Work Load		
Work — Rest Regimen	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

EVALUATION AND CONTROL

I. *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 −5°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. A globe thermometer, consisting of a 15 cm. (6-

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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.

C. A 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 as that of 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. **Minard, D.:** *Prevention of Heat Casualties in Marine Corps Recruits, Period of 1955–60, with Comparative Incidence Rates and Climatic Heat Stresses in Other Training Categories*, Research Report No. 4, Contract No. MR 005.01–0001.01. Naval Medical Research Institute, Bethesda, MD (February 21, 1961). Published in *Military Medicine 126(4): 261-272 (April 1961).*
2. **Minard, D. and R. L. O'Brien:** *Heat Casualties in the Navy and Marine Corps 1959–1962 with Appendices on the Field Use of the Wet Bulb-Globe Temperature Index*, Research Report No. 7, Contract No. MR 005.01–0001.01, Naval Medical Research Institute, Bethesda, MD (March 12, 1964).

II. *Work Load Categories*

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.

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(1) light work (up to 200 kcal/hr or 800 Btu/hr): e.g., sitting or standing to control machines, performing light hand or arm work,

(2) moderate work (200–350 kcal/hr or 800–1400 Btu/hr): e.g., walking about with moderate lifting and pushing,

(3) heavy work (350–500 kcal/hr or 1400–2000 Btu/hr): 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. When this method is used the permissible heat exposure limit can be determined by Figure 1.

1. Per-Olof 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.

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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

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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 1 and Figure 1 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. Where the WBGT of the work area is different from that of the rest area a time-weighted average value should be used for both environmental and metabolic heat. When time-weighted average values are used the appropriate curve on Figure 1 is the solid line labeled "continuous."

The time-weighted average metabolic rate (M) shall be determined by the equation:

$$\text{Av. } M = \frac{(M_1) \times (t_1) + (M_2) \times (t_2) + \ldots + (M_n) \times (t_n)}{(t_1) + (t_2) + \ldots + (t_n)}$$

Where M_1 M_2, M_n are estimated or measured metabolic rates for the various activities of the worker during the total time period. t_1, t_2, t_n are the elapsed times in minutes spent at the corresponding metabolic rate as determined by a time study.

The time-weighted average WBGT shall be determined by the equation:

$$\text{Av. WBGT} = \frac{(WBGT_1) \times (t_1) + (WBGT_2) \times t_2 + \ldots + (WBGT_n) \times (t_n)}{(t_1) + (t_2) + \ldots + (t_n)}$$

where $WBGT_1$, $WBGT_2$, $WBGT_n$ are calculated values of WBGT for the various work and rest areas occupied during total time periods. t_1, t_2, t_n are the elapsed times in minutes spent in the corresponding areas

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which are determined by a time study. Where exposure to hot environmental conditions is continuous for several hours or the entire work day, the time-weighted averages shall be calculated as hourly time-weighted average i.e., $t_1 + t_2 + \ldots + t_n = 60$ minutes. Where the exposure is intermittent, the time-weighted averages shall be calculated as two-hour time-weighted averages, i.e., $t_1 + t_2 + \ldots + t_n = 120$ minutes.

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.

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 shall be kept reasonably cool (10°–15°C or 50.0°–60.0°F) 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 32 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 cothing 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

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permissible heat exposure limits indicated in Table 1 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: Acclimatization to heat involves a series of physiological and psychological adjustments that occur in an individual during his first week of exposure to hot environmental conditions. The recommended heat stress TLVs are valid for acclimated workers who are physically fit. Extra caution must be employed when unacclimated or physically un-fit workers must be exposed to heat stress conditions.

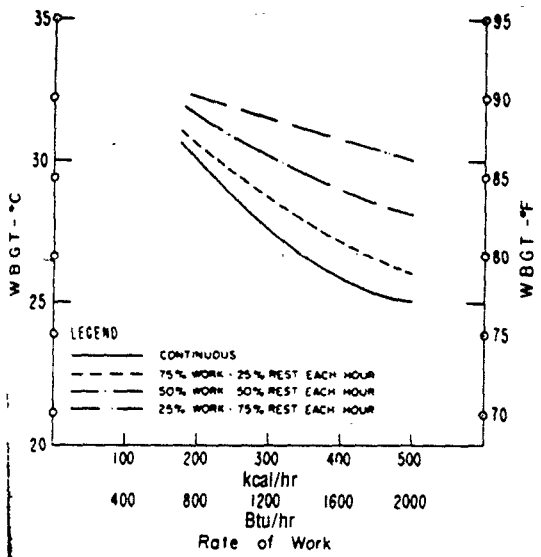


Figure 1 — Permissible Heat Exposure Threshold Limit Value

IONIZING RADIATION

The Committee accepts the philosophy and recommendations of the National Council on Radiation Protection and Measurements (NCRP) for the ionizing radiation TLV. The NCRP is charted by Congress to, in part, collect, analyze, develop and disseminate infor-

MAP 000320

mation and recommendations about protection against radiation and about radiation measurements, quantities and units, including development of basic concepts in these areas. NCRP Report No. 39 (reference 1) provides basic philosophy and concepts leading to protection criteria established in the same report. Other NCRP reports address specific areas of radiation protection and, collectively, provide an excellent basis for establishing a sound program for radiation control. The Committee recommends the listed references as substantative documentation of a sound basis for ionizing radiation protection. The committee also strongly recommends that all exposures to ionizing radiations be kept as low as reasonably achievable within the stated guidance.

References:

1. "Basic Radiation Protection Criteria," NCRP Report No. 39, issued January 15, 1971.
2. Maximum Permissible Body Burdens and Maximum Permissible Concentrations of Radionuclides in Air and in Water for Occupational Exposure," US Department of Commerce, National Bureau of Standards Handbook 69, issued June 5, 1959, with Addendum 1 issued August 1963. Available as NCRP Report No. 22.
The above documents, as well as information on numerous other NCRP Reports addressing specific subjects in ionizing radiation protection are available from: NCRP Publications, PO Box 30175, Washington, DC 20014.

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); and except for all TLVs for wavelengths between 0.1–1 mm where the limiting aperture is 10 mm. 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)

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which varies with exposure time. This angle is *not* the beam divergence of the source.

Correction Factors A and B (C_A and C_B)

The TLVs for ocular exposure in Tables 3 and 4 are to be used as given for all wavelength ranges. The TLVs for wavelengths between 700 nm and 1049 nm are to be increased by a uniformly extrapolated factor (C_A) as shown in Figure 2. Between 1049 nm and 1400 nm, the TLV has been increased by a factor (C_A) of five. For certain exposure times at wavelengths between 550 nm and 700 nm, correction factor (C_B) must be applied.

The TLVs for skin exposure are given in Table 6. The TLVs are to be increased by a factor (C_A) as shown in Figure 2 for wavelengths between 700 nm and 1400 nm. To aid in the determination of TLVs for exposure durations requiring calculations of fractional powers Figures 3, 4, 5 and 6 may be used.

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^{-5} second. For pulses of greater duration, the following formula should be followed:

$$\text{Standard}\begin{pmatrix}\text{single pulse}\\ \text{in train}\end{pmatrix} = \frac{\text{Standard (pulse } n\tau)}{n}$$

where:

n = number of pulses in train

τ = duration of a single pulse in the train

Standard ($n\tau$) = protection standard of one pulse having a duration equal to $n\tau$ seconds.

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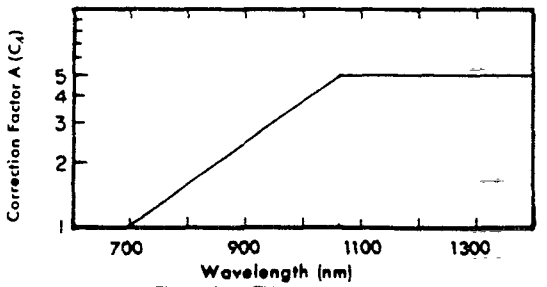


Figure 2 — TLV correction factor for $\lambda = 700 - 1400$ nm*

*For $\lambda = 700 - 1049$ nm, $C_A = 10^{[0.002(\lambda - 700)]}$
For $\lambda = 1050 - 1400$ nm, $C_A = 5$

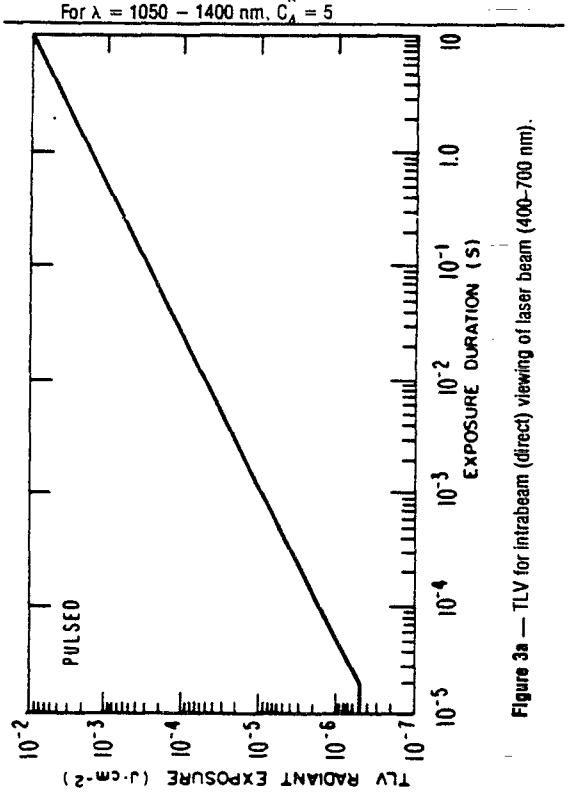


Figure 3a — TLV for intrabeam (direct) viewing of laser beam (400–700 nm).

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Figure 3b — TLV for intrabeam (direct) viewing of CW laser beam (400–1400 nm)

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Figure 4a — TLV for laser exposure of skin and eyes for far-infrared radiation (wave-lengths greater than 1.4 μm).

MAP 000325

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

MAP 000326

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

MAP 000327

Figure 5b — TLV for extended sources or diffuse reflections of laser radiation (400–1400 nm).

MAP 000328

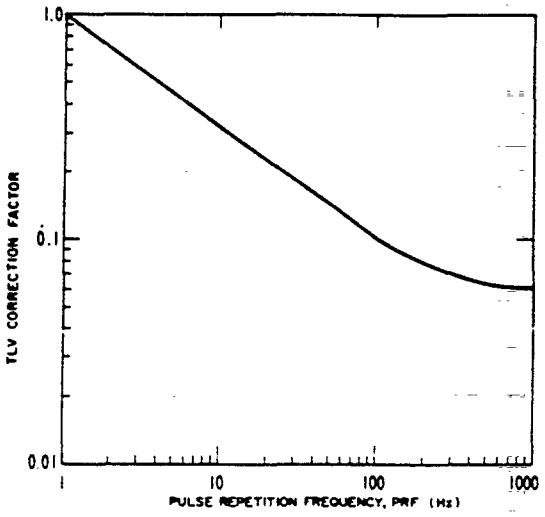


Figure 6 — Multiplicative correction factor for repetitively pulsed lasers having pulse durations less than 10^{-5} second. TLV for a single pulse of the pulse train is multiplied by the above correction factor. Correction factor for PRF greater than 1000 Hz is 0.06.

MAP 000329

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	"

*not to exceed 0.56 $t^{1/4}$ J • cm^{-2} for $t \leq 10$ s.

†1981 Addition

MAP 000330

TABLE 3 (Cont.)

UVA	315 nm to 400 nm	10^{9} to 10	$.56\ t^{\frac{1}{4}}$ J • cm^{-2}
	"	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^{-7}J • cm^{-2}
	400 nm to 700 nm	1.8×10^{-5} to 10	1.8 ($t/\sqrt{t}$) mJ • cm^{-2}
	400 nm to 549 nm	10 to 10^{4}	10 mJ • cm^{-2}
	550 nm to 700 nm	10 to T_1	1.8 ($t/\sqrt{t}$) mJ • cm^{-2}
	550 nm to 700 nm	T_1 to 10^{4}	10 C_B mJ • cm^{-2}
	400 nm to 700 nm	10^{4} to 3×10^{4}	C_B µW • cm^{-2}
IR-A	700 nm to 1049 nm	10^{-9} to 1.8×10^{-5}	5 $C_A \times 10^{-7}$ J • cm^{-2}
	700 nm to 1049 nm	1.8×10^{-5} to 10^{3}	1.8 C_A ($t/\sqrt{t}$) mJ • cm^{-2}
	1050 nm to 1400 nm	10^{-9} to 10^{-4}	5×10^{-6} J • cm^{-2}
	1050 nm to 1400 nm	10^{-4} to 10^{3}	9($t/\sqrt{t}$) mJ • cm^{-2}
	700 nm to 1400 nm	10^{3} to 3×10^{4}	320 C_A µW • cm^{-2}
IR-B & C	1.4 µm to 10^{3} µm	10^{-9} to 10^{-7}	10^{-2} J • cm^{2}
	"	10^{-7} to 10	0.56 $\sqrt{t}$ J • cm^{-2}
	"	10 to 3×10^{4}	0.1 W • cm^{-2}

C_A - See Fig. 2
C_B = 1 for λ = 400 to 549 nm; C_B = $10^{(0.015\ (\lambda\ -\ 550))}$ for λ = 550 to 700 nm.
T_1 = 10 s for λ = 400 to 549 nm; $T_1 = 10 \times 10^{(0.015\ (\lambda\ -\ 550))}$ for λ = 550 to 700 n.

MAP 000331

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	$10\ \sqrt[4]{t}$ J • cm^{-2} • sr^{-1}
	400 nm to 549 nm	10 to 10^{4}	21 J • cm^{-2} • sr^{-1}
	550 nm to 700 nm	10 to T_1	$3.83\ (t/\sqrt[4]{t})$ J • cm^{-2} • sr^{-1}
	550 nm to 700 nm	T_1 to 10^{4}	21 C_B J • cm^{-2} • sr^{-1}
	400 nm to 700 nm	10^{4} to 3×10^{4}	$2.1\ C_B t \times 10^{-3}$ W • cm^{-2} • sr^{-1}
IR-A	700 nm to 1400 nm	10^{-9} to 10	$10\ C_A\ \sqrt[4]{t}$ J • cm^{-2} • sr^{-1}
	700 nm to 1400 nm	10 to 10^{3}	$3.83\ C_A\ (t/\sqrt[4]{t})$ J • cm^{-2} • sr^{-1}
	700 nm to 1400 nm	10^{3} to 3×10^{4}	0.64 C_A W • cm^{-2} • sr^{-1}
IR-B & C	1.4 μm to 1 mm	10^{-9} to 3×10^{4}	Same as Table 3

C_A, C_B, and T_1 are the same as in footnote to Table 3.
†1981 Addition

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MAP 000332

TABLE 5

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

Exposure Duration(s)	Angle α (mrad)
10^{-9}	8.0
10^{-8}	5.4
10^{-7}	3.7
10^{-6}	2.5
10^{-5}	1.7
10^{-4}	2.2
10^{-3}	3.6
10^{-2}	5.7
10^{-1}	9.2
1.0	15
10	24
10^{2}	24
10^{3}	24
10^{4}	24

MAP 000333

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 & IR-A	400 nm to 1400 nm	10^{-9} to 10^{-7}	$2\ C_A \times 10^{-2}$ J • cm^{-2}
	" "	10^{-7} to 10	$1.1\ C_A \sqrt{t}$ J • cm^{-2}
IR-B & C	1.4 μm to 1 mm	10^{-9} to 3×10^{4}	Same as Table 3

C_A = 1.0 for λ = 400–700 nm; see Figure 2 for λ = 700 to 1400 nm.
†1981 Addition

MAP 000334

**MICROWAVES

These Threshold Limit Values refer to microwave energy in the frequency range of 300 MHz to 300 GHz and represent conditions under which it is believed that nearly all workers may be repeatedly exposed without adverse effect.

Under conditions of moderate to severe heat stress, the recommended values may need to be reduced.* Therefore, these values should be used as guides in the control of exposure to microwave energy and should not be regarded as a fine line between safe and dangerous levels.

Recommended Values:

The Threshold Limit Value for occupational exposure to microwave energy, where power density or field intensity is known and exposure time is controlled, is as follows:

1. For exposure to continuous wave (CW) sources, the power density level shall not exceed 10 milliwatts per square centimeter (mW/cm^2) for continuous exposure, and the total exposure time shall be limited to an 8-hour workday. This power density is approximately equivalent to a free-space electric field strength of 200 volts-per-meter rms (V/m) and a free-space magnetic field strength of 0.5 ampere-per-meter rms (A/m).
2. Exposures to CW power density levels greater than 10 mW/cm^2 are permissible up to a maximum of 25 mW/cm^2 based upon an average energy density of 1 milliwatt-hour per square centimeter (mWh/cm^2) averaged over any 0.1 hour period. For example, at 25 mW/cm^2, the permissible exposure duration is approximately 2.4 minutes in any 0.1 hour period.
3. For repetitively pulsed microwave sources, the average field strength or power density is calculated by multiplying the peak-pulse value by the duty cycle. The duty cycle is equal to the pulse duration in seconds times the pulse repetition rate in Hertz. Exposure during an 8-hour workday shall not exceed the following values which are averaged over any 0.1 hour period:

Power Density	10 mW/cm^2
Energy Density	1 mWh/cm^2

*Mumford, W.W., "Heat Stress Due to R. F. Radiation," Proceedings of IEEE, Vol. 57, No. 2, Feb 1969, pp. 171–178.
**See Notice of Intended Changes.

MAP 000335

Mean Squared Electric Field Strength	40,000 V^2/m^2
Mean Squared Magnetic Field Strength	0.25 A^2/m^2

4. Exposure is not permissible in CW or repetitively pulsed fields with an average power density in excess of 25 mW/cm^2 or approximate equivalent free-space field strengths of 300 V/m or 0.75 A/m.

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. Prior to 1979, the medical profession had 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.[a] 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.

It should be recognized that the application of the TLV for noise will not protect all workers from the adverse effects of noise exposure. A hearing conservation program with audiometric testing is necessary when workers are exposed to noise at or above the TLV 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 National 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 7.

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:

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

MAP 000336

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 on-the-job noise exposures of 80 dBA or greater shall be used in the above calculations.

Table 7
Threshold Limit Values

Duration per day Hours	Sound Level dBA[b)]
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) In 1979, the American Academy of Ophthalmology and Otolargyngology (AAOO) included 3000 Hz in their hearing impairment formula.
b) 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.

IMPULSIVE OR IMPACT NOISE

It is recommended that exposure to impulsive or impact noise shall not exceed the limits listed in Table 8 or taken from Figure 7. No exposures in excess of 140 decibels peak sound pressure level are permitted. 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.

MAP 000337

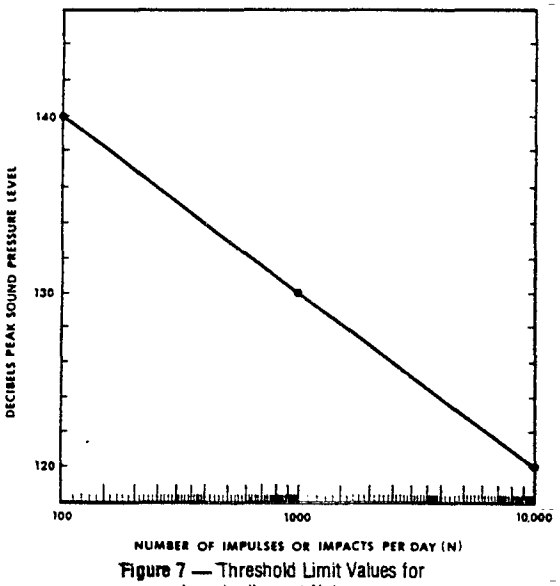


Figure 7 — Threshold Limit Values for Impulse/Impact Noise.

Table 8

Threshold Limit Values Impulsive or Impact Noise

Sound Level dB**	Permitted Number of Impulses or Impacts per day
140	100
130	1000
120	10,000

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, and solar radiation, but do not apply to ultraviolet lasers.* These values do not apply to ultraviolet radiation exposure of

*See Laser TLVs.
**Decibels peak sound pressure level re 20 μPa

MAP 000338

photosensitive individuals or of individuals concomitantly exposed to photosensitizing agents (Fitzpatrick, et al., eds., Sunlight and Man, Univ. Tokyo Press, Tokyo, Japan, 1974). 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 nm) total irradiance incident upon the unprotected skin or eye should not exceed 1 mW/cm^2 for periods greater than 10^3 seconds (approximately 16 minutes) and for exposure times less than 10^3 seconds should not exceed one J/cm^2.
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 9 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 following weighting formula should be used:

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

where:

E_{eff} = effective irradiance relative to a monochromatic source at 270 nm in W/cm^2 ($J/s/cm^2$)

E_λ = spectral irradiance in $W/cm^2/nm$

S_λ = relative spectral effectiveness (unitless)

$\Delta\lambda$ = 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/cm^2 by E_{eff} in W/cm^2. The exposure time may also be determined using Table 10 which provides exposure times corresponding to effective irradiances in $\mu W/cm^2$.

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TABLE 9
Relative Spectral Effectiveness
by Wavelength*

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
254	6.0	0.5
260	4.6	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

TABLE 10
Permissible Ultraviolet Exposures

Duration of Exposure Per Day	Effective Irradiance, E_{eff} (μW/cm²)
8 hrs.	0.1
4 hrs.	0.2
2 hrs.	0.4
1 hr.	0.8
30 min.	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°.

*See Laser TLVs

MAP 000340

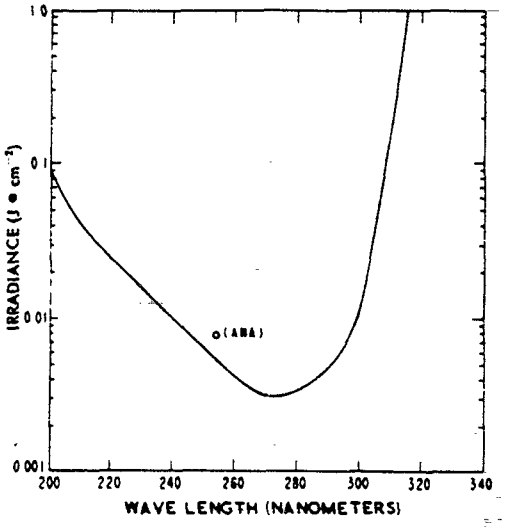


Figure 8 — Threshold Limit Values for Ultraviolet Radiation

Conditioned (tanned) individuals can tolerate skin exposure in excess of the TLV without erythemal effects. However, such conditioning may not protect persons against skin cancer.

NOTICE OF INTENDED CHANGES (1981)

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.

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NOTICE OF INTENT TO ESTABLISH THRESHOLD LIMIT VALUES

LIGHT AND NEAR-INFRARED RADIATION

These Threshold Limit Values refer to visible and near-infrared radiation in the wavelength range of 400 nm to 1400 nm and represent conditions under which it is believed that nearly all workers may be exposed without adverse effect. These values should be used as guides in the control of exposure to light and should not be regarded as a fine line between safe and dangerous levels.

Recommended Values:

The Threshold Limit Value for occupational exposure to broad-band light and near-infrared radiation for the eye apply to exposure in any eight-hour workday and require knowledge of the spectral radiance (L_λ) and total irradiance (E) of the source as measured at the position(s) of the eye of the worker. Such detailed spectral data of a white light source is generally only required if the luminance of the source exceeds 1 cd cm^{-2}. At luminances less than this value the TLV would not be exceeded.

The TLV's are:

1. To protect against retinal thermal injury, the spectral radiance of the lamp weighted against the function R (Table 11) should not exceed:

$$\sum_{400}^{1400} L_\lambda R_\lambda \Delta\lambda \leqq 1/\alpha\, t^{\frac{1}{2}} \qquad (1)^*$$

where L_λ is in W cm^{-2} sr^{-1} and t is the viewing duration (or pulse duration if the lamp is pulsed) limited to 1 μs to 10 s, and α is the angular subtense of the source in radians. If the lamp is oblong, α refers to the longest dimension that can be viewed. For instance, at a viewing distance r = 100 cm from a tubular lamp of length l = 50 cm, the viewing angle is:

$$\alpha = l/r = 50/100 = 0.5 \text{ rad} \qquad (2)$$

2. To protect against retinal photochemical injury from chronic blue-light exposure the integrated spectral radiance of light source weighted against the blue-light hazard function B_λ (Table 11) should not exceed:

$$\sum_{400}^{1400} L_\lambda\, t\, B_\lambda \Delta\lambda \leqq 100 \text{ Jcm}^{-2} \text{ sr}^{-1} \ (t \leqq 10^4 \text{s}) \qquad (3a)$$

$$\sum_{400}^{1400} L_\lambda B_\lambda \Delta\lambda \leqq 10^{-2} \text{ Wcm}^{-2} \text{ sr}^{-1} \ (t > 10^4 \text{s}) \qquad (3b)$$

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For a source radiance L which exceeds 10 $mW/cm^{-2}\ sr^{-1}$ in the blue spectral region, the permissible exposure duration t_{max} in seconds is simply:

$$t_{max} = 100\ J\ cm^{-2}\ sr^{-1}/L\ (blue) \qquad (4)$$

The latter limits are greater than the maximum permissible exposure limits for 440 nm laser radiation (see Laser TLV) because a 2–3 mm pupil is assumed rather than a 7 mm pupil for the Laser TLV. For a light source subtending an angle α less than 11 mrd (0.011 radian) the above limits are relaxed such that the spectral irradiance weighted against the blue-light hazard function B_λ should not exceed:

$$\sum_{400}^{1400} E_\lambda \bullet t \bullet B_\lambda \bullet \Delta\lambda \leqq 10\ mJ \bullet cm^{-2}\ (t \leqq 10^4\ s) \qquad (5a)$$

$$\sum_{400}^{1400} E_\lambda \bullet B_\lambda \bullet \Delta\lambda \leqq 1\mu W \bullet cm^2\ (t \geqq 10^4\ s) \qquad (5b)$$

For a source where the blue light weighted irradiance E (blue) exceeds 1 $\mu W \bullet cm^{-2}$ is the maximum permissible exposure duration t_{max} in seconds is:

$$t_{max} = 10\ mJ \bullet cm^{-2}\ E\ (blue) \qquad (6)$$

3. *Infrared Radiation:* To avoid possible delayed effects upon the lens of the eye (cataractogenesis), the infrared radiation ($\lambda > 770$ nm) should be limited to 10 $mWcm^{-2}$. For an infrared heat lamp or any near-infrared source where a strong visual stimulus is absent, the near infrared (770–1400 nm) radiance as viewed by the eye should be limited to:

$$\sum_{770}^{1400} L_\lambda \Delta\lambda = 0.6/\alpha \qquad (7)^*$$

for extended duration viewing conditions. This limit is based upon a 7 mm pupil diameter.

*Formulae (1) and (7) are empirical and are not, strictly speaking, dimensionally correct. To make the formulae dimensionally correct, one would have to insert a dimensional correction factor k in the right hand numerator in each formula. For formula (1) this would be $k_1 = 1\ W \bullet rad \bullet s^{1/2}/(cm^2 \bullet sr)$, and for formula (7) $k_2 = 1\ W \bullet rad/(cm^2 \bullet sr)$.

MAP 000343

TABLE 11

SPECTRAL WEIGHTING FUNCTIONS FOR ASSESSING RETINAL HAZARDS FROM BROAD — BAND OPTICAL SOURCES

Wavelength (nm)	Blue-Light Hazard Function B_λ	Burn Hazard Function R_λ
400	0.10	1.0
405	0.20	2.0
410	0.40	4.0
415	0.80	8.0
420	0.90	9.0
425	0.95	9.5
430	0.98	9.8
435	1.0	10
440	1.0	10
445	0.97	9.7
450	0.94	9.4
455	0.90	9.0
460	0.80	8.0
465	0.70	7.0
470	0.62	6.2
475	0.55	5.5
480	0.45	4.5
485	0.40	4.0
490	0.22	2.2
495	0.16	1.6
500–600	$10^{[(450-\lambda)/50]}$	1.0
600–700	0.001	1.0
700–1049	0.001	$10^{[(700-\lambda)/505]}$
1050–1400	0.001	0.2

MAP 000344

AIRBORNE UPPER SONIC AND ULTRASONIC ACOUSTIC RADIATION

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. The values listed in Table 12 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. The levels for the third octave bands centered below 20 kHz are below those which cause subjective effects. Those levels for 1/3 octaves above 20 kHz are for prevention of possible hearing losses from subharmonics of these frequencies.

TABLE 12

Permissible Ultrasound Exposure Levels

Mid-Frequency of Third-Octave Band kHz	One-Third Octave — Band Level in dB re 20 μPa
10	80
12.5	80
16	80
20	105
25	110
31.5	115
40	115
50	115

RADIOFREQUENCY/MICROWAVE RADIATION

These Threshold Limit Values (TLVs) refer to radiofrequency (RF) and microwave radiation in the frequency range from 0.01 MHz to 300 GHz, and represent conditions under which it is believed workers may be repeatedly exposed without adverse health effects. The TLVs shown in Table 13 are selected to limit the average whole body specific absorption rate (SAR) to 0.4 W/kg in any six minutes (0.1 hr) period for 3 MHz to 300 GHz, see Figure 9.

Since it is usually impractical to measure the SAR, the TLVs are expressed in units that are measurable, viz, squares of the electric and magnetic field strengths, averaged over any 0.1 hour period and this can be expressed in units of equivalent plane wave power density for convenience. The squared electric field (E), magnetic field (H) strength values, and power density (PD) are shown in Table 13. For near field exposures PD cannot be measured directly, but

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equivalent plane wave power density can be calculated from the field strength measurement data as follows:

$$PD \text{ in } mW/cm^2 = \frac{E^2}{3700}$$

where:

E^2 is in volts squared (V^2) per meter squared (m^2).

$$PD \text{ in } mW/cm^2 = 37.7\ H^2$$

where:

H^2 is in amperes squared (A^2) per meter squared (m^2).

These values should be used as guides in the evaluation and control of exposure to radiofrequency/microwave radiation, and should not be regarded as a fine line between safe and dangerous levels.

Notes:

1. All Radiofrequency Radiation (RFR) exposures should be kept as low as reasonably possible given the current state of knowledge on human effects, particularly non-thermal effects.
2. For fields consisting of a number of frequencies, the fraction of the protection guide incurred within each frequency level should be determined and the sum of all fractions should not exceed unity.
3. For pulsed and continuous wave fields, the power density is averaged over the six minute period, and should not exceed the values in Table 13, except as noted for partial body exposure.
4. For partial body exposures at frequencies between 0.01 MHz and 1.0 GHz, the protection guides in Table 13 may be exceeded if the output power of a radiating device is 7 watts or less. For example, if a hand held transmitter operating at 27 MHz has a maximum output of 5 watts, it would be excluded from any further field measurements.
5. No measurement should be made within 5 cm of any object.
6. All exposures should be limited to a maximum (peak) electric field intensity of 10 kV/m.

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TABLE 13

RADIOFREQUENCY/MICROWAVE THRESHOLD LIMIT VALUES

Frequency		Power Density (mW/cm²)†	Electric Field Strength Squared (V²/m²)	Magnetic Field Strength Squared (A²/m²)
0.01 MHz to	3 MHz	100	377,000	2.65
3 MHz to	30 MHz	$900/f^{2*}$	$3770 \times 900/f^{2*}$	$\frac{900}{37.7} \times f^{2*}$
30 MHz to	100 MHz	1	3770	0.027
100 MHz to	1000 MHz	$f^*/100$	$3770 \times f^*/100$	$f^*/37.7 \times 100$
1000 MHz to	3,000,000 MHz	10	37,700	0.265

†mW/cm² = milliwatts per centimeter squared
*f = frequency in MHz

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Figure 9 — Threshold Limit Values (TLV) for Radiofrequency/Microwave Radiation in Workplace (Whole Body SAR Less Than 0.4 W/kg).

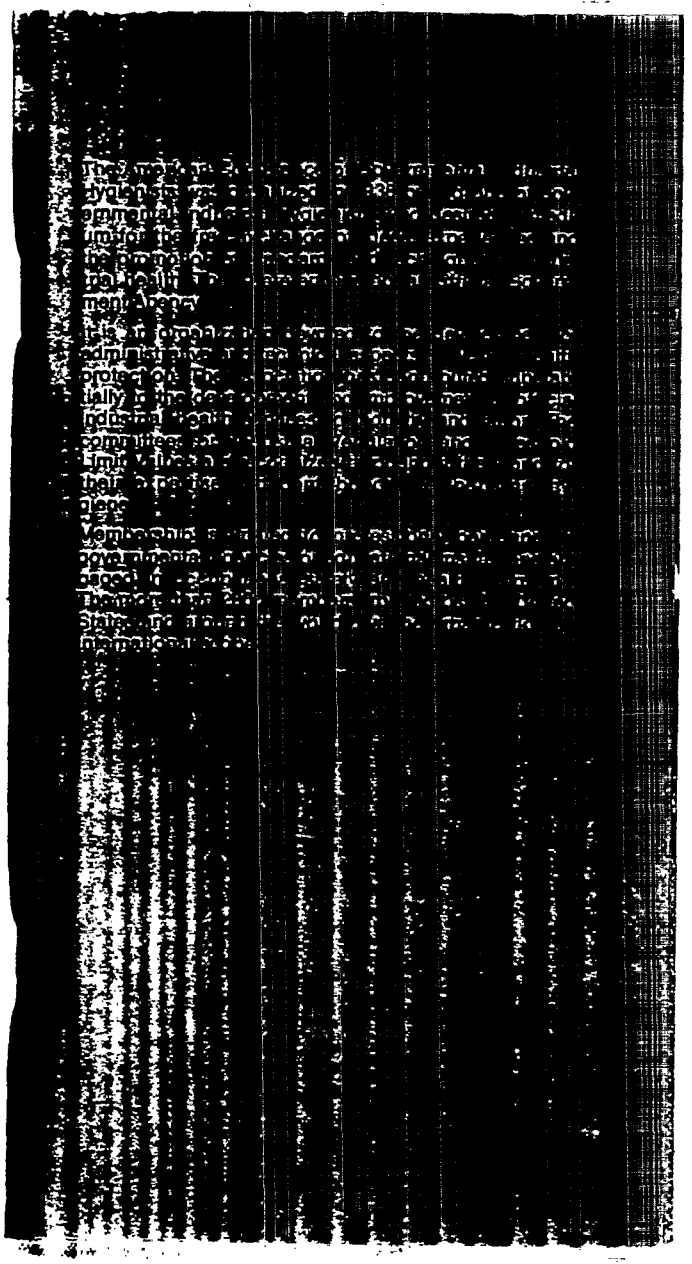
MAP 000348

PHYSICAL AGENTS UNDER STUDY

The Physical Agents Committee of ACGIH has examined the current literature and has not found sufficient information to propose a TLV. However, these agents will remain under study during the coming year to examine new evidence indicating the need and feasibility for establishing a proposed TLV. Comments and suggestions, accompanied by substantive documentation are solicited and should be forwarded to the Executive Secretary, ACGIH, Documentation summarizing the current status of the biological effects literature is available on those agents preceded by an asterisk (*).

1. **Extremely Low Frequency (ELF) Radiation*. Specifically, that portion of the spectrum from 0 to 300 Hz.
2. *Magnetic Fields*. Both pulsed and *continuous.
3. *Laser Radiation*. Specifically laser exposures of less than one (1) nanosecond.
4. *Vibration*. Segmental and whole-body.
5. *Cold Stress*.
6. *Pressure Variations*.

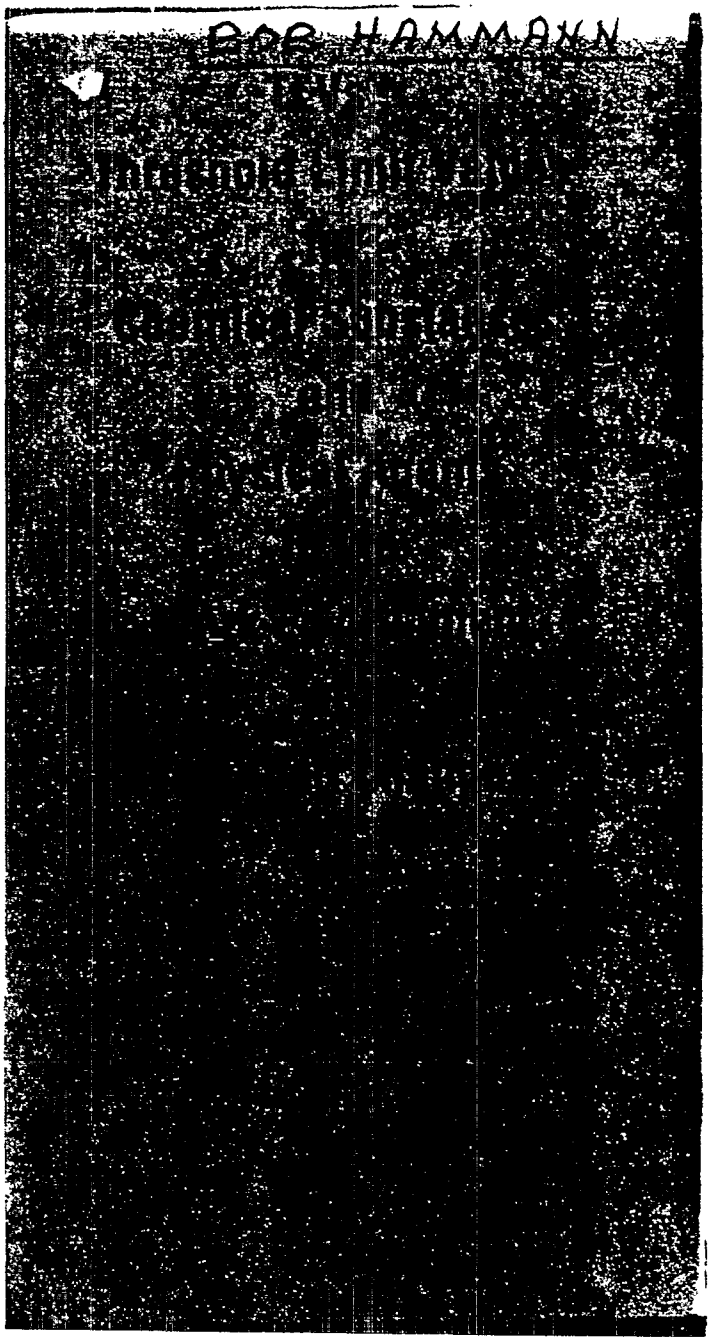
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MAP 000351



TLVs®
Threshold Limit Values
for
Chemical
Substances in
Work Air
Adopted by
ACGIH
for 1982

MAP 000353

1982 TLV AIRBORNE CONTAMINANTS COMMITTEE

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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.

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 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.

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 control of community air pollution nuisances, (3) in estimating the toxic potential of continuous, uninterrupted exposures or other extended work periods, (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.

The TLV-TWA should be used as guides in the control of health hazards and should not be used as fine lines between safe and dangerous concentrations.

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.

Legal Status. The Threshold Limit Values, as issued by ACGIH, are recommendations and should be used as guidelines for good practices. Wherever these values (of whatever year) have been used or included by reference in Federal and/or State statutes and registers, the TLVs do have the force and effects of law.

"*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. Values listed in parenthesis in the "Adopted" list are to be used during the period in which a proposed change for that Value is listed in the Notice of Intended Changes.

Definitions. Three categories of Threshold Limit Values (TLVs) are specified herein, as follows:

a) Threshold Limit Value-Time Weighted Average (TLV-TWA) — the time-weighted average concentration for a normal 8-hour workday and a 40-hour workweek, to which nearly all workers may be repeatedly exposed, day after day, without adverse effect.

b) Threshold Limit Value-Short Term Exposure Limit (TLV-STEL) — the concentration to which workers can be exposed continuously for a short period of time without suffering from 1) irritation, 2) chronic or irreversible tissue change, or 3) narcosis of sufficient degree to increase the likelihood of accidental injury, impair self-rescue or materially reduce work efficiency, and provided that the daily TLV-TWA also is not exceeded. It is not a separate independent exposure limit, rather it supplements the time-weighted average (TWA) limit where there are recognized acute effects from a substance whose toxic effects are primarily of a chronic nature. STELs are recommended only where toxic effects have been reported from high short-term exposures in either humans or animals.

A STEL is defined as a 15-minute time-weighted average exposure which should not be exceeded at any time during a work day even if the eight-hour time-weighted average is within the TLV. Exposures

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at the STEL should not be longer than 15 minutes and should not be repeated more than four times per day. There should be at least 60 minutes between successive exposures at the STEL. An averaging period other than 15 minutes may be recommended when this is warrented by observed biological effects.

c) Threshold Limit Value-Ceiling (TLV-C) — the concentration that should not be exceeded even instantaneously.

For some substances, e.g., irritant gases, only one category, the TLV-Ceiling, may be relevant. For other substances, either two or three categories may be relevant, depending upon their physiologic action. It is important to observe that if any one of these three TLVs is exceeded, a potential hazard from that substance is presumed to exist.

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.

Time-Weighted Average vs Ceiling Limits. 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 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 a decision as to whether a hazardous condition exists.

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 noncompliance 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. It should be noted that the same factors are used by the Committee in determining the magnitude of the value of the STELs, or 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 mucous membranes and eye, either by air borne, 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

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extent. (3) The tissue reaction is potentially reversible.

Excessive concentrations of nuisance dusts in the workroom air may seriously reduce visibility, may cause unpleasant deposits in the eyes, ears and nasal 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 10 mg/m^3, or 30 mppcf, of total dust < 1% quartz, or, 5 mg/m^3 respirable dust 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 D.

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 E.

Physical Factors. It is recognized that such physical factors as heat, ultraviolet and ionizing 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 may be altered. Most of these stresses act adversely 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 BLVs, and their associated procedures for determining compliance with them, should thus be regarded as an effective means of providing health surveillance of the worker.

Tests are available (J. Occup. Med. 15: 564, 1973; 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).

Unlisted Substances. Many substances present or handled in industrial processes do not appear on the TLV list. In a number of instances the material is rarely present as a particulate, vapor or other airborne contaminant, and a TLV is not necessary. In other cases sufficient information to warrant development of a TLV, even on a tentative basis, is not available to the Committee. Other substances, of low toxicity, could be included in Appendix D pertaining to nuisance particulates. This list (as well as Appendix E) is not meant to be all inclusive; the substances serve only as examples.

In addition there are some substances of not inconsiderable toxicity, which have been omitted primarily because only a limited number of workers

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(e.g., employees of a single plant) are known to have potential exposure to possibly harmful concentrations.

Operational Guidelines: The ACGIH Board of Directors has adopted operational guidelines for the Chemical Agents TLV Committee. These guidelines prescribe: charge, authority, policies, membership, organization, and operating procedures. The policies include the appeals procedures. Copies of the guidelines document are available from the Publications Office at a cost of $5 per copy.

		ADOPTED VALUES			
		TWA		STEL	
Substance	[CAS #]	ppm[a]	mg/m³[b]	ppm[a]	mg/m³[b]
Acetaldehyde	[75-07-0]	100	180	150	270
Acetic acid	[64-19-7]	10	25	15	37
Acetic anhydride	[108-24-7]	C 5	C 20	—	—
*Acetone	[67-64-1]	750	1,780	1,000	2,375
Acetonitrile	[75-05-8] — Skin	40	70	60	105
Acetylene	[74-86-2]	E	—	—	—
Acetylene dichloride, see 1, 2-Dichloroethylene					
Acetylene tetrabromide	[79-27-6]	1	15	1.5	20
Acetylsalicylic acid (Asprin)	[50-78-2]	—	5	—	—
Acrolein	[107-02-8]	0.1	0.25	0.3	0.8
Acrylamide	[79-06-1] — Skin	—	0.3	—	0.6
Acrylic acid	[79-10-7]	10	30	—	—
‡Acrylonitrile	[107-13-1] — Skin	(2, A1a)	(4.5, A1a)	—	—
Aldrin	[309-00-2] — Skin	—	0.25	—	0.75
Allyl alcohol	[107-18-6] — Skin	2	5	4	10
Allyl chloride	[107-05-1]	1	3	2	6
Allyl glycidyl ether (AGE)	[106-92-3] — Skin	5	22	10	44
Allyl propyl disulfide	[2179-59-1]	2	12	3	18
α-Alumina	[1344-28-1]	—	D	—	20
Aluminum	[7429-90-5]				
Metal & oxide		—	10	—	20
Pyro powders		—	5	—	—
Welding fumes		—	5	—	—
Soluble salts		—	2	—	—
Alkyls (NOC†)		—	2	—	—
4-Aminodiphenyl	[92-67-1] — Skin	—	A1b	—	A1b
2-Aminoethanol, see Ethanolamine					
2-Aminopyridine	[504-29-0]	0.5	2	2	4
3-Amino 1, 2, 4-triazole, see Amitrol					
Amitrol	[61-82-5]	A2	A2	—	—
Ammonia	[7664-41-7]	25	18	35	27
Ammonium chloride fume	[12125-02-9]	—	10	—	20

Capital letters A, B, D & E refer to Appendices. C denotes ceiling limit.
Footnotes (a thru f) see Page 34
*1982 Addition
‡See Notices of Intended Changes.

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Substance [CAS #]	ADOPTED VALUES TWA ppm[a]	TWA mg/m³[b]	STEL ppm[a]	STEL mg/m³[b]
Ammonium sulfamate [7773-06-0]	—	10	—	20
n-Amyl acetate [628-63-7]	100	530	150	800
sec-Amyl acetate [626-38-0]	125	670	150	800
Aniline [62-53-3] & homologues — Skin	2	10	5	20
Anisidine [29191-52-4] (o-, p-isomers) — Skin	0.1	0.5	—	—
Antimony [7440-36-0] & compounds, as Sb	—	0.5	—	—
Antimony trioxide [1327-33-9] Handling and use, as Sb	—	0.5	—	—
Production	—	A2	—	—
ANTU [86-88-4]	—	0.3	—	0.9
Argon [7440-37-1]	E	—	—	—
Arsenic [7440-38-2] & soluble compounds, as As	—	0.2	—	—
Arsenic trioxide production [1327-53-3]	—	A2	—	—
Arsine [7784-42-1]	0.05	0.2	—	—
Asbestos [1332-21-4], see MINERAL DUSTS	—	A1a	—	A1a
Asphalt (petroleum) fumes [8052-42-4]	—	5	—	10
‡Atrazine [1912-24-9]	—	(10)	—	—
Azinphos-methyl [86-50-0] — Skin	—	0.2	—	0.6
Barium [7440-39-3], soluble compounds, as Ba	—	0.5	—	—
Benomyl [17804-35-2]	0.8	10	1.3	15
Benzene [71-43-2]	10, A2	30, A2	25, A2	75, A2
*Benzidine [92-87-5] — Skin	—	A1b	—	A1b
p-Benzoquinone, see Quinone				
Benzoyl peroxide [94-36-0]	—	5	—	—
Benzo(a)pyrene [50-32-8]	—	A2	—	A2
Benzyl chloride [100-44-7]	1	5	—	—
Beryllium [7440-41-7]	—	0.002, A2	—	—
Biphenyl [92-52-4]	0.2	1.5	0.6	4
Bismuth telluride [1304-82-1]	—	10	—	20

Capital letters A, B, D & E refer to Appendices. C denotes ceiling limit
Footnotes (a thru f) see Page 34
*1982 Addition
‡See Notices of Intended Changes

Substance [CAS #]	ADOPTED VALUES TWA ppm[a]	TWA mg/m³[b]	STEL ppm[a]	STEL mg/m³[b]
Se-doped	—	5	—	10
Borates, tetra, sodium salts [1303-96-4], Anhydrous	—	1	—	—
Decahydrate	—	5	—	—
Pentahydrate	—	1	—	—
Boron oxide [1303-86-2]	—	10	—	20
Boron tribromide [10294-33-4]	1	10	3	30
Boron trifluoride [7637-07-2]	C 1	C 3	—	—
Bromacil [314-40-9]	1	10	2	20
Bromine [7726-95-6]	0.1	0.7	0.3	2
Bromine pentafluoride [7789-30-2]	0.1	0.7	0.3	2
Bromochloromethane, see Chlorobromomethane				
Bromoform [75-25-2] — Skin	0.5	5	—	—
Butadiene (1, 3-butadiene) [106-99-0]	1,000	2,200	1,250	2,750
Butane [106-97-8]	800	1,900	—	—
Butanethiol, see *Butyl mercaptan*				
2-Butanone, see Methyl ethyl ketone (MEK)				
2-Butoxyethanol [111-76-2] — Skin	25	120	75	360
n-Butyl acetate [123-86-4]	150	710	200	950
sec-Butyl acetate [105-46-4]	200	950	250	1,190
tert-Butyl acetate [540-88-5]	200	950	250	1,190
Butyl acrylate [141-32-2]	10	55	—	—
n-Butyl alcohol [71-36-3] — Skin	C 50	C 150	—	—
sec-Butyl alcohol [78-92-2]	100	305	150	455
tert-Butyl alcohol [75-65-0]	100	300	150	450
Butylamine [109-73-9] — Skin	C 5	C 15	—	—
tert-Butyl chromate, as CrO_3 [1189-85-1] — Skin	—	C 0.1	—	—
n-Butyl glycidyl ether (BGE) [2426-08-6]	25	135	—	—
n-Butyl lactate [138-22-7]	5	25	—	—
Butyl mercaptan [109-79-5]	0.5	1.5	—	—
o-sec-Butylphenol [89-72-5] — Skin	5	30	—	—
p-tert-Butyltoluene [98-51-1]	10	60	20	120

Capital letters A, B, D & E refer to Appendices. C denotes ceiling limit
Footnotes (a thru f) see Page 34

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Substance [CAS #]	ADOPTED VALUES TWA ppm[a]	TWA mg/m³[b]	STEL ppm[a]	STEL mg/m³[b]
Cadmium [7440-43-9] Dust & salts, as Cd	—	0.05	—	0.2
Cadmium oxide [1306-19-0] Fume, as Cd	—	C 0.05	—	—
‡ Production, as Cd	—	(A2)	—	—
Calcium carbonate/ marble [1317-65-3]	—	D	—	20
Calcium cyanamide [156-62-7]	—	0.5	—	1
Calcium hydroxide [1305-62-0]	—	5	—	—
Calcium oxide [1305-78-8]	—	2	—	—
Calcium silicate [1344-95-2]	—	D	—	—
Camphor, synthetic [76-22-2]	2	12	3	18
Caprolactam [105-60-2] Dust	—	1	—	3
Vapor	5	20	10	40
Captafol [2425-06-1] — Skin	—	0.1	—	—
Captan [133-06-2]	—	5	—	15
Carbaryl [63-25-2]	—	5	—	10
Carbofuran [1563-66-2]	—	0.1	—	—
Carbon black [7440-44-0]	—	3.5	—	7
Carbon dioxide [124-38-9]	5,000	9,000	15,000	27,000
Carbon disulfide [75-15-0] — Skin	10	30	—	—
Carbon monoxide [630-08-0]	50	55	400	440
Carbon tetrabromide [558-13-4]	0.1	1.4	0.3	4
Carbon tetrachloride [56-23-5] — Skin	5, A2	30, A2	20, A2	125, A2
Carbonyl chloride, see Phosgene				
Carbonyl fluoride [353-50-4]	2	5	5	15
Catechol (Pyrocatechol) [120-80-9]	5	20	—	—
Cellulose (paper fiber) [9004-34-6]	—	D	—	20
Cesium hydroxide [21351-79-1]	—	2	—	—
Chlordane [57-74-9] — Skin	—	0.5	—	2

Capital letters A, B, D & E refer to Appendices. C denotes ceiling limit
Footnotes (a thru f) see Page 34
‡See Notice of Intended Changes

Substance [CAS #]	ADOPTED VALUES TWA ppm[a]	TWA mg/m³[b]	STEL ppm[a]	STEL mg/m³[b]
Chlorinated camphene [8001-35-2] — Skin	—	0.5	—	1
Chlorinated diphenyl oxide [55720-99-5]	—	0.5	—	2
Chlorine [7782-50-5]	1	3	3	9
Chlorine dioxide [10049-04-4]	0.1	0.3	0.3	0.9
Chlorine trifluoride [7790-91-2]	C 0.1	C 0.4	—	—
Chloroacetaldehyde [107-20-0]	C 1	C 3	—	—
α-Chloroacetophenone [532-27-4] (Phenacyl chloride)	0.05	0.3	—	—
Chloroacetyl chloride [79-04-9]	0.05	0.2	—	—
Chlorobenzene [108-90-7] (Monochlorobenzene)	75	350	—	—
‡o-Chlorobenzylidene malononitrile [2698-41-1] — Skin	(0.05)	(0.4)	—	—
Chlorobromomethane [74-97-5]	200	1,050	250	1,300
2-Chloro-1, 3-butadiene, see β Chloroprene				
Chlorodifluoromethane [75-45-6]	1,000	3,500	1,250	4,375
Chlorodiphenyl (42% Chlorine) [53449-21-9] — Skin	—	1	—	2
Chlorodiphenyl (54% Chlorine) [11097-69-1] — Skin	—	0.5	—	1
1-Chloro, 2, 3-epoxy-propane, see Epichlorohydrin				
2-Chloroethanol, see Ethylene chlorohydrin				
Chloroethylene, see Vinyl chloride				
Chloroform [67-66-3]	10, A2	50, A2	50, A2	225, A2
bis-Chloromethyl ether [542-88-1]	0.001, A1a	0.005, A1a	—	—
1-Chloro-1-nitropropane [600-25-9]	2	10	—	—
Chloropentafluoroethane [76-15-3]	1,000	6,320	—	—

Capital letters A, B, D & E refer to Appendices. C denotes ceiling limit
Footnotes (a thru f) see Page 34
‡See Notice of Intended Changes.

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Substance [CAS #]	ADOPTED VALUES TWA ppm[a]	TWA mg/m³[b]	STEL ppm[a]	STEL mg/m³[b]
Chloropicrin [76-06-2]	0.1	0.7	0.3	2
β-Chloroprene [126-99-8] — Skin	10	45	—	—
o-Chlorostyrene [1331-28-8]	50	285	75	430
o-Chlorotoluene [95-49-8] — Skin	50	250	75	375
2-Chloro- 6-(trichloromethyl) pyridine, see Nitrapyrin				
Chlorpyrifos [2921-88-2] — Skin	—	0.2	—	0.6
Chromite ore processing (Chromate), as Cr	—	0.05, A1a	—	—
Chromium [7440-47-3] Metal	—	0.5	—	—
Soluble chromic, chromus salts, as Cr	—	0.5	—	—
Chromium (II) compounds, as Cr	—	0.5	—	—
Chromium (III) compounds, as Cr	—	0.5	—	—
Chromium (VI) compounds, as Cr				
Water soluble	—	0.05	—	—
Certain water insoluble	—	0.05, A1a	—	—
Chromyl chloride [14977-61-8]	0.025	0.15	—	—
Chrysene [218-01-9]	A2	A2	—	—
Clopidol [2971-90-6]	—	10	—	20
Coal tar pitch volatiles [8007-45-2], as benzene solubles	—	0.2, A1a	—	—
‡Cobalt [7440-48-4], as Co metal, dust & fume	—	(0.1)	—	—
Copper [7440-50-8] Fume	—	0.2	—	—
Dusts & mists, as Cu	—	1	—	2
Cotton dust, raw	—	0.2[k]	—	0.6
Cresol [1319-77-3], all isomeres — Skin	5	22	—	—
Crotonaldehyde [123-73-9]	2	6	6	18
Crufomate [299-86-5]	—	5	—	20
Cumene [98-82-8] — Skin	50	245	75	365

Capital letters A, B, D & E refer to Appendices. C denotes ceiling limit
Footnotes (a thru f) see Page 34
‡See Notice of Intended Changes
k) See p. 36

Substance [CAS #]	ADOPTED VALUES TWA ppm[a]	TWA mg/m³[b]	STEL ppm[a]	STEL mg/m³[b]
Cyanamide [420-04-2]	—	2	—	—
Cyanides [151-50-8, 143-33-9], as CN — Skin	—	5	—	—
Cyanogen [460-19-5]	10	20	—	—
Cyanogen chloride [506-77-4]	C 0.3	C 0.6	—	—
Cyclohexane [110-82-7]	300	1,050	375	1,300
Cyclohexanol [108-93-0]	50	200	—	—
Cyclohexanone [108-94-1]	25	100	100	400
Cyclohexene [110-83-8]	300	1,015	—	—
Cyclohexylamine [108-91-8] — Skin	10	40	—	—
Cyclonite [121-82-4] — Skin	—	1.5	—	3
Cyclopentadiene [542-92-7]	75	200	150	400
Cyclopentane [287-92-3]	600	1,720	900	2,580
Cyhexatin [13121-70-5]	—	5	—	10
2, 4-D [94-75-7]	—	10	—	20
DDT (Dichlorodiphenyl-trichloroethane) [50-29-3]	—	1	—	3
Decaborane [17702-41-9] — Skin	0.05	0.3	0.15	0.9
Demetron [8065-48-3] — Skin	0.01	0.1	0.03	0.3
Diacetone alcohol [123-42-2]	50	240	75	360
1, 2-Diaminoethane, see Ethylenediamine				
Diazinon [333-41-5] — Skin	—	0.1	—	0.3
Diazomethane [334-88-3]	0.2	0.4	—	—
Diborane [19287-45-7]	0.1	0.1	—	—
1, 2-Dibromoethane, see Ethylene dibromide				
2-N-Dibutylaminoethanol [102-81-8] — Skin	2	14	4	28
Dibutyl phosphate	1	5	2	10
Dibutyl phthalate [84-74-2]	—	5	—	10
Dichloroacetylene [7572-29-4]	C 0.1	C 0.4	—	—
o-Dichlorobenzene [95-50-1]	C 50	C 300	—	—
p-Dichlorobenzene [106-46-7]	75	450	110	675
3, 3'-Dichlorobenzidene [91-94-11] — Skin	—	A2	—	A2

Capital letters A, B, D, & E refer to Appendices. C denotes ceiling limit
Footnotes (a thru f) see Page 34

MAP 000361

Substance [CAS #]	ADOPTED VALUES TWA ppm[a]	TWA mg/m³[b]	STEL ppm[a]	STEL mg/m³[b]
Dichlorodifluoromethane [75-71-8]	1,000	4,950	1,250	6,200
1, 3-Dichloro-5, 5-dimethyl hydantoin [118-52-5]	—	0.2	—	0.4
1, 1-Dichloroethane [75-34-3]	200	810	250	1,010
1, 2-Dichloroethane, see Ethylene dichloride				
1, 1-Dichloroethylene, see Vinylidene chloride				
1, 2-Dichloroethylene [540-59-0]	200	790	250	1,000
Dichloroethyl ether [111-44-4] — Skin	5	30	10	60
Dichlorofluoromethane [75-43-4]	10	40	—	—
Dichloromethane, see Methylene chloride				
1, 1-Dichloro-1-nitroethane [594-72-9]	2	10	10	60
1, 2-Dichloropropane, see Propylene dichloride				
Dichloropropene [542-75-6] — Skin	1	5	10	50
2, 2-Dichloropropionic acid [75-99-0]	1	6	—	—
Dichlorotetrafluoroethane [76-14-2]	1,000	7,000	1,250	8,750
Dichlorvos [62-73-7] — Skin	0.1	1	0.3	3
Dicrotophos [141-66-2] — Skin	—	0.25	—	—
Dicyclopentadiene [77-73-6]	5	30	—	—
Dicyclopentadienyl iron [102-54-5]	—	10	—	20
Dieldrin [60-57-1] — Skin	—	0.25	—	0.75
Diethanolamine [111-42-2]	3	15	—	—
Diethylamine [109-89-7]	10	30	25	75
Diethylaminoethanol [100-37-8] — Skin	10	50	—	—
Diethylene triamine [111-40-0] — Skin	1	4	—	—
Diethyl ether, see Ethyl ether				
Diethyl ketone [96-22-0]	200	705	—	—
Diethyl phthalate [84-66-2]	—	5	—	10
Difluorodibromomethane [75-61-6]	100	860	150	1,290

Capital letters A, B, D & E refer to Appendices. C denotes ceiling limit
Footnotes (a thru f) see Page 34

Substance [CAS #]	ADOPTED VALUES TWA ppm[a]	TWA mg/m³[b]	STEL ppm[a]	STEL mg/m³[b]
Diglycidyl ether (DGE) [2238-07-5]	0.1	0.5	—	—
Dihydroxybenzene, see Hydroquinone				
Diisobutyl ketone [108-83-8]	25	150	—	—
Diisopropylamine [108-18-9] — Skin	5	20	—	—
Dimethoxymethane, see Methylal				
Dimethyl acetamide [127-19-5] — Skin	10	35	15	50
Dimethylamine [124-40-3]	10	18	—	—
Dimethylaminobenzene, see Xylidene				
Dimethylaniline [121-69-7] (N, N-Dimethylaniline) — Skin	5	25	10	50
Dimethylbenzene, see Xylene				
Dimethyl carbamyl chloride [79-44-7]	A2	A2	—	—
Dimethyl-1', 2-dibromo-2-dichloroethyl phosphate, see Naled				
Dimethylformamide [68-12-2] — Skin	10	30	20	60
2, 6-Dimethyl-4-heptanone, see Diisobutyl ketone				
1, 1-Dimethylhydrazine [57-14-7] — Skin	0.5, A2	1, A2	1, A2	2, A2
Dimethylphthalate [131-11-3]	—	5	—	10
Dimethyl sulfate [77-78-1] — Skin	0.1, A2	0.5, A2	—	—
Dinitolmide [148-01-6]	—	5	—	10
Dinitrobenzene [528-29-0] (all isomers) — Skin	0.15	1	0.5	3
Dinitro-o-cresol [534-52-1] — Skin	—	0.2	—	0.6
3, 5-Dinitro-o-toluamide, see Dinitolmide				
Dinitrotoluene [121-14-2] — Skin	—	1.5	—	5
Dioxane, tech. grade [123-91-1] — Skin	25	90	100	360
Dioxathion [78-34-2] — Skin	—	0.2	—	—
Diphenyl, see Biphenyl				
Diphenylamine [122-39-4]	—	10	—	20
Diphenylmethane diisocyanate, see Methylene bisphenyl isocyanate				

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Footnotes (a thru f) see Page 34.

MAP 000362

Substance [CAS #]	ADOPTED VALUES TWA ppm[a]	TWA mg/m³[b]	STEL ppm[a]	STEL mg/m³[b]
Dipropylene glycol methyl ether [34590-94-8] — Skin	100	600	150	900
Dipropyl ketone [123-19-3]	50	235	—	—
Diquat [85-00-7]	—	0.5	—	1
Di-sec. octyl phthalate [117-81-7] (Di-2-ethyl-hexylphthalate)	—	5	—	10
Disulfiram [97-77-8]	—	2	—	5
Disulfoton [298-04-4]	—	0.1	—	0.3
2, 6-Ditert. butyl-p-cresol [128-37-0]	—	10	—	20
Diuron [330-54-1]	—	10	—	—
Divinyl benzene [108-57-6]	10	50	—	—
Emery [112-62-9]	—	D	—	20
Endosulfan [115-29-7] — Skin	—	0.1	—	0.3
Endrin [72-20-8] — Skin	—	0.1	—	0.3
Epichlorohydrin [106-89-8] — Skin	2	10	5	20
EPN [2104-64-5] — Skin	—	0.5	—	2
1, 2-Epoxypropane, see Propylene oxide				
2, 3-Epoxy-1-propanol, see Glycidol				
Ethane [74-84-0]	E	—	—	—
Ethanethiol, see Ethyl mercaptan				
Ethanolamine [141-43-5]	3	8	6	15
Ethion [563-12-2] — Skin	—	0.4	—	—
‡2-Ethoxyethanol [110-80-5] — Skin	(50)	(185)	(100)	(370)
‡2-Ethoxyethyl acetate [111-15-9] — Skin	(50)	(270)	(100)	(540)
Ethyl acetate [141-78-6]	400	1,400	—	—
Ethyl acrylate [140-88-5] — Skin	5	20	25	100
Ethyl alcohol (Ethanol) [46-17-5]	1,000	1,900	—	—
Ethylamine [75-04-7]	10	18	—	—
Ethyl amyl ketone [41-85-5]	25	130	—	—
Ethyl benzene [100-41-4]	100	435	125	545
Ethyl bromide [74-96-4]	200	890	250	1,110
Ethyl butyl ketone [106-35-4]	50	230	75	345
Ethyl chloride [75-00-3]	1,000	2,600	1,250	3,250

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Footnotes (a thru f) see Page 34
‡See Notice of Intended Changes

Substance [CAS #]	ADOPTED VALUES TWA ppm[a]	TWA mg/m³[b]	STEL ppm[a]	STEL mg/m³[b]
Ethylene [74-85-1]	E	—	—	—
Ethylene chlorohydrin [107-07-3] — Skin	C 1	C 3	—	—
Ethylenediamine [107-15-3]	10	25	—	—
*Ethylene dibromide [106-93-4] — Skin	A2	A2	—	—
Ethylene dichloride [107-06-2]	10	40	15	60
Ethylene glycol [107-21-1]				
‡ Particulate	—	(10)	—	(20)
Vapor	C 50	C 125	—	—
‡Ethylene glycol dinitrate [628-96-6] — Skin	(0.02)	(0.1)	(0.05)	(0.3)
Ethylene glycol methyl ether acetate, see 2-Methoxyethyl acetate				
‡Ethylene oxide [75-21-8]	(10)	(20)	—	—
Ethyleneimine [151-56-4] — Skin	0.5	1	—	—
Ethyl ether [60-29-7]	400	1,200	500	1,500
Ethyl formate [109-94-4]	100	300	150	450
Ethylidene chloride, see 1, 1-Dichloroethane				
Ethylidene norbornene [16219-75-3]	C 5	C 25	—	—
Ethyl mercaptan [75-08-1]	0.5	1	2	3
*N-Ethylmorpholine [100-74-3] — Skin	5	40	20	95
Ethyl silicate [78-10-4]	10	85	30	255
Fensulfothion [115-90-2]	—	0.1	—	—
‡Fenthion [55-38-9]	—	(0.1)	—	(0.3)
Ferbam [14484-64-1]	—	10	—	20
Ferrovanadium dust [12604-58-9]	—	1	—	0.3
Fibrous [d] glass dust	—	10	—	—
Fluorides, as F	—	2.5	—	—
Fluorine [7782-41-4]	1	2	2	4
Fluorotrichloromethane, see Trichlorofluoromethane				
Fonofos [944-22-9] — Skin	—	0.1	—	—
‡Formaldehyde [50-00-0]	(C 2)	(C 3)	—	—
Formamide [75-12-7]	20	30	30	45
Formic acid [64-18-6]	5	9	—	—
Furfural [98-01-1] — Skin	2	8	10	40
*Furfuryl alcohol [98-00-0] — Skin	10	40	15	60
*Gasoline [8006-61-9]	300	900	500	1,500

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Footnotes (a thru f) see Page 34
*1982 Addition.
‡See Notice of Intended Changes.

MAP 000363

Substance [CAS #]	ADOPTED VALUES TWA ppm[a]	TWA mg/m³[b]	STEL ppm[a]	STEL mg/m³[b]
Germanium tetrahydride [7782-65-2]	0.2	0.6	0.6	1.8
Glass, fibrous or dust, see Fibrous glass dust				
Glutaraldehyde [111-30-8]	C 0.2	C 0.7	—	—
Glycerin mist [56-81-5]	—	D	—	—
Glycidol [556-52-5]	25	75	100	300
Glycol monoethyl ether, see 2-Ethoxyethanol				
Graphite (Natural) [7782-42-5], see MINERAL DUSTS				
Graphite (Synthetic)	—	D	—	—
Gypsum [10101-4-4]	—	D	—	20
Hafnium [7440-58-6]	—	0.5	—	1.5
Helium [7440-59-7]	E	—	—	—
Heptachlor [76-44-8] — Skin	—	0.5	—	2
Heptane [142-82-5] (n-Heptane)	400	1,600	500	2,000
2-Heptanone, see Methyl n-amyl ketone				
3-Heptanone, see Ethyl butyl ketone				
*Hexachlorobutadiene [76-68-3]	0.02, A2	0.24, A2	—	—
Hexachlorocyclopentadiene [77-47-4]	0.01	0.1	0.03	0.3
*Hexachloroethane [67-72-1] — Skin	10	100	—	—
Hexachloronaphthalene [1335-87-1] — Skin	—	0.2	—	0.6
Hexafluoroacetone [684-16-2]	0.1	0.7	0.3	2
Hexamethyl phosphoramide [680-31-9] — Skin	A2	A2	—	—
*Hexane (n-Hexane) [110-54-3]	50	180	—	—
* Other isomers	500	1,800	1,000	3,600
2-Hexanone, see Methyl n-butyl ketone				
Hexone, see Methyl isobutyl ketone				
sec-Hexyl acetate [142-92-7]	50	300	—	—
Hexylene glycol [107-41-5]	C 25	C 125	—	—
Hydrazine [302-01-2] — Skin	0.1, A2	0.1, A2	—	—
Hydrogen [1333-74-0]	E	—	—	—
Hydrogenated terphenyls [92-94-4]	0.5	5	—	—

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Footnotes (a thru f) see Page 34
*1982 Addition

Substance [CAS #]	ADOPTED VALUES TWA ppm[a]	TWA mg/m³[b]	STEL ppm[a]	STEL mg/m³[b]
Hydrogen bromide [10035-10-6]	3	10	—	—
Hydrogen chloride [7647-01-1]	C 5	C 7	—	—
Hydrogen cyanide [74-90-8] — Skin	C 10	C 10	—	—
Hydrogen fluoride [7664-39-3], as F	3	2.5	6	5
Hydrogen peroxide [7722-84-1]	1	1.5	2	3
Hydrogen selenide [7783-07-5], as Se	0.05	0.2	—	—
Hydrogen sulfide [7783-06-4]	10	14	15	21
Hydroquinone [123-31-9]	—	2	—	4
4-Hydroxy-4-methyl-2-pentanone, see Diacetone alcohol				
2-Hydroxypropyl acrylate [999-61-1] — Skin	0.5	3	—	—
Indene [95-13-6]	10	45	15	70
Indium [7440-74-6] & compounds, as In	—	0.1	—	0.3
Iodine [7553-56-2]	C 0.1	C 1	—	—
Iodoform [75-47-8]	0.6	10	1	20
Iron oxide fume (Fe_2O_3) [1309-37-1], as Fe	B3	5	—	10
*Iron pentacarbonyl [13463-40-6], as Fe	0.1	0.8	0.2	0.16
Iron salts, soluble, as Fe	—	1	—	2
Isoamyl acetate [123-92-2]	100	525	125	655
Isoamyl alcohol [123-51-3]	100	360	125	450
Isobutyl acetate [110-19-0]	150	700	187	875
Isobutyl alcohol [78-83-1]	50	150	75	225
Isooctyl alcohol [26952-21-6]	50	270	—	—
Isophorone [78-59-1]	C 5	C 25	—	—
Isophorone diisocyanate — Skin	0.01	0.09	—	—
Isopropoxyethanol [109-59-1]	25	105	75	320
Isopropyl acetate [108-21-4]	250	950	310	1,185
Isopropyl alcohol [67-63-0]	400	980	500	1,225
Isopropylamine [75-31-0]	5	12	10	24

Capital letters A, B, D & E refer to Appendices. C denotes ceiling limit
Footnotes (a thru f) see Page 34
*1982 Addition

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Substance [CAS #]	ADOPTED VALUES TWA ppm[a]	TWA mg/m³[b]	STEL ppm[a]	STEL mg/m³[b]
N-Isopropylaniline [643-28-7] — Skin	2	10	5	20
Isopropyl ether [108-20-3]	250	1,050	310	1,320
Isopropyl glycidyl ether [4016-14-2] (IGE)	50	240	75	360
Kaolin	—	D	—	20
Ketene [463-51-4]	0.5	0.9	1.5	3
Lead [7439-92-1], inorg., dusts & fumes, as Pb	—	0.15	—	0.45
‡Lead arsenate [10102-48-4], as Pb	—	(0.15)	—	(0.45)
Lead chromate [18454-12-1], as Cr	—	0.05, A2	—	—
Limestone [1317-65-3]	—	D	—	20
Lindane [58-89-9] — Skin	—	0.5	—	1.5
Lithium hydride [7580-67-8]	—	0.025	—	—
L.P.G. (Liquified petroleum gas)	1,000	1,800	1,250	2,250
Magnesite [546-90-0]	—	D	—	20
Magnesium oxide fume [1309-48-4]	—	10	—	—
Malathion [121-75-5] — Skin	—	10	—	—
Maleic anhydride [108-31-6]	0.25	1	—	—
Manganese [7439-96-5], as Mn				
Dust & compounds	—	C 5	—	—
Fume	—	1	—	3
Manganese cyclopentadienyl tricarbonyl [12108-13-3], as Mn — Skin	—	0.1	—	0.3
Manganese tetroxide	—	1	—	—
Marble calcium carbonate [1317-65-3]	—	D	—	20
Mercury [7439-97-6], as Hg — Skin				
Alkyl compounds	—	0.01	—	0.03
All forms except alkyl				
* Vapor	—	0.05	—	—
* Aryl & inorganic compounds	—	0.1	—	—
Mesityl oxide [141-79-7]	15	60	25	100
Methacrylic acid [79-41-4]	20	70	—	—

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Footnotes (a thru f) see Page 34
*1982 Addition
‡See Notice of Intended Changes

Substance [CAS #]	ADOPTED VALUES TWA ppm[a]	TWA mg/m³[b]	STEL ppm[a]	STEL mg/m³[b]
Methane [74-82-8]	E	—	—	—
Methanethiol, see Methyl mercaptan				
Methomyl [16752-77-5] — Skin	—	2.5	—	—
Methoxychlor [72-43-5]	—	10	—	—
‡2-Methoxyethanol [109-86-4] — Skin	(25)	(80)	(35)	(120)
‡2-Methoxyethyl acetate [110-49-6] — Skin	(25)	(120)	(35)	(170)
*4-Methoxyphenol [150-76-5]	—	5	—	—
Methyl acetate [79-20-9]	200	610	250	760
Methyl acetylene [74-99-7]	1,000	1,650	1,250	2,040
Methyl acetylene-propadiene mixture (MAPP)	1,000	1,800	1,250	2,250
Methyl acrylate [96-33-3] — Skin	10	35	—	—
Methylacrylonitrile [126-98-7] — Skin	1	3	2	6
Methylal [109-87-5]	1,000	3,100	1,250	3,875
Methyl alcohol [67-56-1] (methanol) — Skin	200	260	250	310
Methylamine [74-89-5]	10	12	—	—
Methyl amyl alcohol, see Methyl isobutyl carbinol				
Methyl n-amyl ketone [591-78-6]	50	235	100	465
*N-Methyl aniline [100-61-8] — Skin	0.5	2	1	5
Methyl bromide [74-83-9] — Skin	5	20	15	60
Methyl n-butyl ketone [591-78-6]	5	20	—	—
Methyl chloride [74-87-3]	50	105	100	205
Methyl chloroform [71-55-6]	350	1,900	450	2,450
Methyl 2-cyanoacrylate [137-05-3]	2	8	4	16
Methylcyclohexane [108-87-2]	400	1,600	500	2,000
Methylcyclohexanol [25639-42-3]	50	235	75	350
o-Methylcyclohexanone [583-60-8] — Skin	50	230	75	345

Capital letters A, B, D & E refer to Appendices; C denotes ceiling limit
Footnotes (a thru f) see Page 34
*1982 Addition
‡See Notice of Intended Changes

MAP 000365

Substance [CAS #]	ADOPTED VALUES TWA ppm[a]	TWA mg/m³[b]	STEL ppm[a]	STEL mg/m³[b]
Methylcyclopentadienyl manganese tricarbonyl, [12108-13-3] — Skin, as Mn	—	0.2	—	0.6
Methyl demeton [8022-00-2] — Skin	—	0.5	—	1.5
Methylene bisphenyl isocyanate (MDI) [101-68-8]	C 0.02	C 0.2	—	—
Methylene chloride [75-09-2]	100	360	500	1,700
4, 4'-Methylene bis (2-chloroaniline) [101-14-4] — Skin	0.02, A2	0.22, A2	—	—
Methylene bis(4-cyclohexylisocyanate) [101-68-8]	C 0.01	C 0.11	—	—
4, 4-Methylene dianiline [101-77-9] — Skin	0.1	0.8	0.5	4
Methyl ethyl ketone (MEK) [78-93-3]	200	590	300	885
Methyl ethyl ketone peroxide [1338-23-4]	C 0.2	C 1.5	—	—
Methyl formate [107-31-3]	100	250	150	375
5-Methyl-3-heptanone, see Ethyl amyl ketone				
Methyl hydrazine [60-34-4] — Skin	C 0.2, A2	C 0.35, A2	—	—
Methyl iodide [74-88-4] — Skin	2, A2	10, A2	5, A2	30, A2
*Methyl isoamyl ketone [110-12-3]	50	240	—	—
Methyl isobutyl carbinol [105-30-6] — Skin	25	100	40	165
Methyl isobutyl ketone [108-10-1]	50	205	75	300
Methyl isocyanate [624-83-9] — Skin	0.02	0.05	—	—
Methyl isopropyl ketone [563-80-4]	200	705	—	—
Methyl mercaptan [74-93-1]	0.5	1	—	—
Methyl methacrylate [80-62-6]	100	410	125	510

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Footnotes (a thru f) see Page 34
*1982 Addition

Substance [CAS #]	ADOPTED VALUES TWA ppm[a]	TWA mg/m³[b]	STEL ppm[a]	STEL mg/m³[b]
Methyl parathion [298-00-0] — Skin	—	0.2	—	0.6
Methyl propyl ketone [107-87-9]	200	700	250	875
Methyl silicate [681-84-5]	1	6	5	30
α-Methyl styrene [98-83-9]	50	240	100	485
Mevinphos [7786-34-7] — Skin	0.01	0.1	0.03	0.3
Molybdenum [7439-98-7], as Mo				
Soluble compounds	—	5	—	10
Insoluble compounds	—	10	—	20
Monocrotophos [6923-22-4]	—	0.25	—	—
Morpholine [110-91-8] — Skin	20	70	30	105
Naled [300-76-5]	—	3	—	6
Naphthalene [91-20-3]	10	50	15	75
β-Naphthylamine [91-59-8]	—	A1b	—	A1b
Neon [7440-01-9]	E	—	—	—
Nickel carbonyl, as Ni	0.05	0.35	—	—
Nickel [7440-02-0]				
Metal	—	1	—	—
Soluble compounds, as Ni	—	0.1	—	0.3
Nickel carbonyl [13463-39-3], as Ni	0.05	0.35	—	—
Nickel sulfide roasting, fume & dust, as Ni	—	1, A1a	—	—
Nicotine [54-11-5] — Skin	—	0.5	—	1.5
Nitrapyrin [1929-82-4]	—	10	—	20
Nitric acid [7697-37-2]	2	5	4	10
Nitric oxide [10102-43-9]	25	30	35	45
*p-Nitroaniline [100-01-6] — Skin	—	3	—	—
Nitrobenzene — Skin	1	5	2	10
‡p-Nitrochlorobenzene [98-95-3] — Skin	—	(1)	—	(2)
4-Nitrodiphenyl [92-93-3]	—	A1b	—	A1b
Nitroethane [79-24-3]	100	310	150	465
Nitrogen dioxide [10102-44-0]	3	6	5	10

Capital letters A, B, D & E refer to Appendices; C denotes ceiling limit.
Footnotes (a thru f) see Page 34.
*1982 Addition
‡See Notice of Intended Changes.

MAP 000366

Substance [CAS #]	ADOPTED VALUES TWA ppm[a]	TWA mg/m³[b]	STEL ppm[a]	STEL mg/m³[b]
Nitrogen trifluoride [7783-54-2]	10	30	15	45
‡Nitroglycerin (NG) [55-63-0] — Skin	(0.02)	(0.2)	(0.05)	(0.5)
Nitromethane [75-52-5]	100	250	150	375
†1-Nitropropane [108-03-2]	25	90	35	135
‡2-Nitropropane [79-46-9]	(C 25, A2)	(C 90, A2)	—	—
N-Nitrosodimethylamine [62-75-9] (dimethylnitrosoamine) — Skin	—	A2	—	A2
*Nitrotoluene [99-08-1] — Skin	2	11	—	—
Nitrotrichloromethane, see Chloropicrin				
Nonane [111-84-2]	200	1,050	250	1,300
Octachloronaphthalene [2234-13-1] — Skin	—	0.1	—	0.3
Octane [111-65-9]	300	1,450	375	1,800
Oil mist, mineral	—	5[e]	—	10
Osmium tetroxide [20816-12-0], as Os	0.0002	0.002	0.0006	0.006
Oxalic acid [144-62-7]	—	1	—	2
Oxygen difluoride [7783-41-7]	0.05	0.1	0.15	0.3
Ozone [10028-15-6]	0.1	0.2	0.3	0.6
Paraffin wax fume [8002-74-2]	—	2	—	6
Paraquat [1910-42-5], respirable sizes	—	0.1	—	—
Parathion [56-38-2] — Skin	—	0.1	—	0.3
Particulate polycyclic aromatic hydrocarbons (PPAH), see Coal tar pitch volatiles				
Pentaborane [19624-22-7]	0.005	0.01	0.015	0.03
Pentachloronaphthalene [1321-64-8]	—	0.5	—	2
Pentachlorophenol [87-86-5] — Skin	—	0.5	—	1.5
Pentaerythritol [115-77-5]	—	D	—	20
Pentane [109-66-0]	600	1,800	750	2,250
2-Pentanone, see Methyl propyl ketone				
‡Perchloroethylene [127-18-4]	50	335	(—)	(—)

Capital letters A, B, D & E refer to Appendices C denotes ceiling limit
Footnotes (a thru f) see Page 34
*1982 Addition
†NOC = Not otherwise classified
‡See Notice of Intended Changes

Substance [CAS #]	ADOPTED VALUES TWA ppm[a]	TWA mg/m³[b]	STEL ppm[a]	STEL mg/m³[b]
Perchloromethyl mercaptan [594-42-3]	0.1	0.8	—	—
Perchloryl fluoride [7616-94-6]	3	14	6	28
Phenol [108-95-2] — Skin	5	19	10	38
Phenothiazine [92-84-2] — Skin	—	5	—	10
N-Phenyl-beta-naphthylamine [135-88-6]	A2	A2	—	—
p-Phenylene diamine [106-50-3] — Skin	—	0.1	—	—
Phenyl ether [101-84-8], vapor	1	7	2	14
Phenylethylene, see Styrene, monomer				
*Phenyl glycidyl ether (PGE) [122-60-1]	1	6	—	—
‡Phenylhydrazine [100-63-0] — Skin	(5)	(20)	(10)	(45)
Phenyl mercaptan [108-98-5]	0.5	2	—	—
Phenylphosphine [638-21-1]	C 0.05	C 0.25	—	—
Phorate [298-02-2] — Skin	—	0.05	—	0.2
Phosdrin, see Mevinphos				
Phosgene [75-44-5]	0.1	0.4	—	—
Phosphine [3803-51-2]	0.3	0.4	1	1
Phosphoric acid [7664-38-2]	—	1	—	3
Phosphorus [7723-14-0] (yellow)	—	0.1	—	0.3
*Phosphorus oxychloride [10026-13-8]	0.1	0.6	0.5	3
Phosphorus pentachloride [10026-13-8]	0.1	1	—	—
Phosphorus pentasulfide [1314-80-3]	—	1	—	3
*Phosphorus trichloride [7719-12-2]	0.2	1.5	0.5	3
Phthalic anhydride [85-44-9]	1	6	4	24
m-Phthalodinitrile [626-17-5]	—	5	—	—
Picloram [1918-02-1]	—	10	—	20

Capital letters A, B, D & E refer to Appendices, C denotes ceiling limit
Footnotes (a thru f) see Page 34
*1982 Addition
‡See Notice of Intended Changes.

MAP 000367

Substance [CAS #]	ADOPTED VALUES TWA ppm[a]	TWA mg/m³[b]	STEL ppm[a]	STEL mg/m³[b]
Picric acid [88-89-1] — Skin	—	0.1	—	0.3
Pindone [83-26-1]	—	0.1	—	0.3
*Piperazine dihydrochloride [142-64-3]	—	5	—	—
2-Pivalyl-1, 3-indandione, see Pindone				
Plaster of Paris	—	D	—	20
Platinum [7440-06-4]				
Metal	—	1	—	—
Soluble salts, as Pt	—	0.002	—	—
Polychlorobiphenyls, see Chlorodiphenyls				
Polytetrafluoroethylene decomposition products	—	B1	—	B1
Potassium hydroxide [1310-58-3]	—	C 2	—	—
Propane [74-98-6]	E	—	—	—
Propane sultone [1120-71-4]	A2	A2	—	—
Propargyl alcohol [107-19-7] — Skin	1	2	3	6
β-Propiolactone [57-57-8]	0.5, A2	1.5, A2	1, A2	3, A2
Propionic acid [79-09-4]	10	30	15	45
Propoxur [114-26-1]	—	0.5	—	2
n-Propyl acetate [109-60-4]	200	840	250	1,050
Propyl alcohol [71-23-8] — Skin	200	500	250	625
n-Propyl nitrate [627-13-4]	25	105	40	470
Propylene [115-07-1]	E	—	—	—
Propylene dichloride [78-87-5]	75	350	110	510
‡Propylene glycol dinitrate [6423-43-4] (PGDN) — Skin	(0.02)	(0.1)	(0.05)	(0.3)
Propylene glycol monomethyl ether [107-98-2]	100	360	150	540
‡Propylene imine [75-55-8] — Skin	(2)	(5)	—	—
Propylene oxide [75-56-9]	20	50	—	—
Propyne, see Methyl acetylene				
Pyrethrum [8003-34-7]	—	5	—	10
Pyridine [110-86-1]	5	15	10	30
Quinone [106-51-4]	0.1	0.4	0.3	1
RDX, see Cyclonite				

Capital letters A, B, D & E refer to Appendices; C denotes ceiling limit
Footnotes (a thru f) see Page 34.
*1982 Addition
‡See Notice of Intended Changes

Substance [CAS #]	ADOPTED VALUES TWA ppm[a]	TWA mg/m³[b]	STEL ppm[a]	STEL mg/m³[b]
Resorcinol [108-46-3]	10	45	20	90
Rhodium [7440-16-6]				
* Metal	—	1	—	—
‡ Soluble salts, as Rh	—	(0.001)	—	(0.003)
Ronnel [299-84-3]	—	10	—	—
Rosin core solder pyrolysis products, as formaldehyde	—	0.1	—	0.3
Rotenone (commercial) [83-79-4]	—	5	—	10
Rouge	—	D	—	20
Rubber solvent (Naphtha)	400	1,600	—	—
Selenium compounds [7782-49-2], as Se	—	0.2	—	—
Selenium hexafluoride [7783-79-1], as Se	0.05	0.2	—	—
Sesone [136-78-7]	—	10	—	20
Silane, see Silicon tetrahydride				
Silicon [7440-21-3]	—	D	—	20
Silicon carbide [409-21-2]	—	D	—	20
‡Silicon tetrahydride [7803-62-5]	(0.5)	(0.7)	(1)	(1.5)
Silver [7440-22-4], as Ag				
Metal	—	0.1	—	—
Soluble compounds	—	0.01	—	—
Sodium azide [26628-22-8]	C 0.1	C 0.3	—	—
Sodium bisulfite [7631-90-5]	—	5	—	—
Sodium 2, 4-dichloro-phenoxyethyl sulfate, see Sesone				
Sodium fluoroacetate [62-74-8] — Skin	—	0.05	—	0.15
Sodium hydroxide [1310-73-2]	—	C 2	—	—
Sodium metabisulfite [7681-57-4]	—	5	—	—
Starch [9005-84-9]	—	D	—	20
Stibine [7803-52-3]	0.1	0.5	0.3	1.5
*Stoddard solvent [8052-41-3]	100	525	200	1,050
Strychnine [57-24-9]	—	0.15	—	0.45
Styrene, monomer [100-42-5]	50	215	100	425

Capital letters A, B, D & E refer to Appendices; C denotes ceiling limit
Footnotes (a thru f) see Page 34.
*1982 Addition.
‡See Notice of Intended Changes.

MAP 000368

Substance [CAS #]	ADOPTED VALUES TWA ppm[a]	TWA mg/m³[b]	STEL ppm[a]	STEL mg/m³[b]
Subtilisins [1395-21-7] (Proteolytic enzymes as 100% pure crystalline enzyme)	—C0.00006[m]		—	
Sucrose [57-50-1]	—	D	—	20
Sulfotep [3689-24-5] — Skin	—	0.2	—	0.6
Sulfur dioxide [7446-09-5]	2	5	5	10
Sulfur hexafluoride [2551-62-4]	1,000	6,000	1,250	7,500
Sulfuric acid [7864-93-9]	—	1	—	—
Sulfur monochloride [10025-67-9]	1	6	3	18
Sulfur pentafluoride [5714-22-7]	0.025	0.25	0.075	0.75
Sulfur tetrafluoride [7783-60-0]	0.1	0.4	0.3	1
Sulfuryl fluoride [2699-79-8]	5	20	10	40
Systox, see Demeton				
2, 4, 5-T [93-76-5]	—	10	—	20
Tantalum [7440-25-7]	—	5	—	10
TEDP, see Sulfotep				
Tellurium & compounds [13494-80-9], as Te	—	0.1	—	—
Tellurium hexafluoride [7783-80-4], as Te	0.02	0.2	—	—
Temephos [3383-96-8]	—	10	—	20
TEPP [107-49-3] — Skin	0.004	0.05	0.01	0.2
Terphenyls [92-94-4]	C 0.5	C 5	—	—
1, 1, 1, 2-Tetrachloro-2, 2-difluoroethane [76-11-9]	500	4,170	625	5,210
1, 1, 2, 2-Tetrachloro-1, 2-difluoroethane [76-12-0]	500	4,170	625	5,210
1, 1, 2, 2-Tetrachloroethane [79-34-5] — Skin	(5)	(35)	(10)	(70)
Tetrachloroethylene, see Perchloroethylene				
Tetrachloromethane, see Carbon tetrachloride				
Tetrachloronaphthalene [1335-88-2]	—	2	—	4
Tetraethyl lead [78-00-2], as Pb — Skin	—	0.100^	—	0.3
Tetrahydrofuran [109-99-9]	200	590	250	735

Capital letters A, B, D & E refer to Appendices. C denotes ceiling limit
Footnotes (a thru f) see Page 34
m) See Page 36

Substance [CAS #]	ADOPTED VALUES TWA ppm[a]	TWA mg/m³[b]	STEL ppm[a]	STEL mg/m³[b]
Tetramethyl lead [75-74-1], as Pb — Skin	—	0.150^	—	0.5
Tetramethyl succinonitrile [3333-52-6] — Skin	0.5	3	2	9
Tetranitromethane [509-14-8]	1	8	—	—
Tetrasodium pyrophosphate [7722-88-5]	—	5	—	—
Tetryl [479-45-8] (2, 4, 6-trinitrophenyl-methylnitramine) — Skin	—	1.5	—	3.0
Thallium [7440-28-0] Soluble compounds, as Tl — Skin	—	0.1	—	—
4, 4'-Thiobis(6-tert. butyl-m-cresol) [96-69-5]	—	10	—	20
Thioglycolic acid [68-11-1]	1	5	—	—
Thiram [137-26-8]	—	5	—	10
Tin [7440-31-5] * Metal	—	2	—	4
* Oxide & inorganic compounds, except SnO_2, as Sn	—	2	—	4
Organic compounds, as Sn — Skin	—	0.1	—	0.2
Titanium dioxide [13463-67-7], as Ti	—	D	—	20
o-Tolidine [119-93-7]	A2	A2	—	—
Toluene [108-88-3] (toluol) — Skin	100	375	150	560
‡Toluene-2, 4-diisocyanate (TDI) [584-84-9]	(C 0.02)	(C 0.14)	—	—
‡o-Toluidine [95-53-4] — Skin	(2)	(9)	—	—
Toxaphene, see Chlorinated camphene				
Tributyl phosphate [126-73-8]	0.2	2.5	0.4	5
Trichloroacetic acid [76-03-9]	1	5	—	—
1, 2, 4-Trichlorobenzene [120-82-1]	5	40	—	—
1, 1, 1-Trichloroethane, see Methyl chloroform				

Capital letters A, B, D & E refer to Appendices. C denotes ceiling limit
Footnotes (a thru f) see Page 34
*1982 Addition
‡See Notices of Intended Changes.

MAP 000369

Substance	[CAS #]	ADOPTED VALUES TWA ppm[a]	TWA mg/m³[b]	STEL ppm[a]	STEL mg/m³[b]
1, 1, 2-Trichloroethane	[79-00-5] — Skin	10	45	20	90
‡Trichloroethylene	[79-01-6]	50	270	(150)	(805)
*Trichlorofluoromethane	[75-69-4]	C 1,000	C 5,600	—	—
Trichloromethane, see Chloroform					
Trichloronaphthalene	[1321-65-9]	—	5	—	10
Trichloronitromethane, see Chloropicrin					
1, 2, 3-Trichloropropane	[96-18-4]	50	300	75	450
1, 1, 2-Trichloro-1, 2, 2-trifluoroethane	[76-13-1]	1,000	7,600	1,250	9,500
Tricyclohexyltin hydroxide, see Cyhexatin					
‡Triethylamine	[121-44-8]	(25)	(100)	(40)	(160)
Trifluorobromomethane	[75-63-8]	1,000	6,100	1,200	7,300
Trimellitic anhydride	[552-30-7]	0.005	0.04	—	—
Trimethyl benzene	[25551-13-7]	25	125	35	170
*Trimethyl phosphite	[121-45-9]	2	10	5	25
2, 4, 6-Trinitrophenol, see Picric acid					
2, 4, 6-Trinitrophenyl-methylnitramine, see Tetryl					
*2, 4, 6-Trinitrotoluene	(TNT) [118-96-7] — Skin	—	0.5	—	3
Triorthocresyl phosphate	[78-30-8]	—	0.1	—	0.3
Triphenyl amine	[603-34-9]	—	5	—	—
Triphenyl phosphate	[115-86-6]	—	3	—	6
Tungsten	[7440-33-7], as W				
Insoluble compounds		—	5	—	10
Soluble compounds		—	1	—	3
Turpentine	[8006-64-2]	100	560	150	840
Uranium (natural)	[7440-61-1], Soluble & insoluble compounds, as U	—	0.2	—	0.6
Valeraldehyde	[110-62-3]	50	175	—	—

Capital letters A, B, D & E refer to Appendices; C denotes ceiling limit.
Footnotes (a thru f) see Page 34
*1982 Addition
‡See Notices of Intended Changes

Substance	[CAS #]	ADOPTED VALUES TWA ppm[a]	TWA mg/m³[b]	STEL ppm[a]	STEL mg/m³[b]
*Vanadium, as V_2O_5	[1314-62-1], respirable dust & fume	—	0.05	—	—
Vegetable oil mists		—	D	—	—
Vinyl acetate	[108-05-4]	10	30	20	60
Vinyl benzene, see Styrene					
Vinyl bromide	[593-60-2]	5, A2	20, A2	—	—
Vinyl chloride	[75-01-4]	5, A1a	10, A1a	—	—
Vinyl cyanide, see Acrylonitrile					
Vinyl cyclohexene dioxide	[106-87-6]	10, A2	60, A2	—	—
‡Vinylidene chloride	[75-5-4]	(10)	(40)	(20)	(80)
Vinyl toluene	[25013-15-4]	50	240	100	485
VM & P Naphtha	[8030-30-6]	300	1,350	400	1,800
Warfarin	[81-81-2]	—	0.1	—	0.3
Welding fumes (NOC+)		—	5, B2	—	B2
Wood dust (certain hard woods as beech & oak)		—	1	—	—
Soft wood		—	5	—	10
Xylene	[1330-20-7] (o-, m-, p-isomers) — Skin	100	435	150	655
m-Xylene α, α'-diamine	[1477-55-0]	—	C 0.1	—	—
*Xylidene	[1300-73-8] — Skin	2	10	—	—
Yttrium	[7440-65-5]	—	1	—	3
Zinc chloride fume	[7646-85-7]	—	1	—	2
Zinc chromate	[13530-65-9], as Cr	—	0.05, A2	—	—
Zinc oxide	[1314-13-2]				
Fume		—	5	—	10
Dust		—	D	—	—
Zinc stearate	[557-05-1]	—	D	—	20
Zirconium compounds	[7440-67-2], as Zr	—	5	—	10

Capital letters A, B, D & E refer to Appendices; C denotes ceiling limit.
Footnotes (a thru f) see Page 34
*1982 Addition.
‡See Notice of Intended Changes.

MAP 000370

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 substance per cubic meter of air.
d) < 7 μm in diameter.
e) As sampled by method that does not collect vapor.
f) For control of general room air, biologic monitoring is essential for personnel control.

Radioactivity: The Committee accepts the philosophy and recommendations of the National Council on Radiation Protection and Measurements (NCRP) for the ionizing radiation TLV. The NCRP is charted by Congress to, in part, collect, analyze, develop and disseminate information and recommendations about protection against radiation and about radiation measurements, quantities and units, including development of basic concepts in these areas. NCRP Report No. 39 (reference 1) provides basic philosophy and concepts leading to protection criteria established in the same report. Other NCRP reports address specific areas of radiation protection and, collectively, provide an excellent basis for establishing a sound program for radiation control. The Committee recommends the listed references as substantative documentation of a sound basis for ionizing radiation protection. The Committee also strongly recommends that all exposures to ionizing radiations be kept low as reasonably achievable within the stated guidance.

References:

1. *Basic Radiation Protection Criteria*. NCRP Report No. 39, issued January 15, 1971.
2. *Maximum Permissible Body Burdens and Maximum Permissible Concentrations of Radionuclides in Air and in Water for Occupational Exposure*. US Department of Commerce, National Bureau of Standards Handbook 69, issued June 5, 1959, with Addendum 1 issued August 1963. Available as NCRP Report No. 22.

The above documents, as well as information on numerous other NCRP Reports addressing specific subjects in ionizing radiation protection are available from: NCRP Publications, PO Box 30175, Washington, DC 20014.

MINERAL DUSTS

Substance	
SILICA, SiO_2	
Crystalline	
Quartz [1480-60-7]	TLV in mppcf[o]: $\frac{300^{b}}{\%\ \text{quartz} + 10}$ TLV for respirable dust in mg/m³: $\frac{10\ \text{mg/m}^3[j]}{\%\ \text{Respirable quartz} + 2}$ TLV for "total dust," respirable and nonrespirable: $\frac{30\ \text{mg/m}^3}{\%\ \text{quartz} + 3}$
Cristobalite [14464-46-1]	Use one-half the value calculated from the count or mass formulae for quartz.
Tridymite [15468-32-3]	Use one-half the value calculated from formulae for quartz.
Silica, fused [60676-86-0]	Use quartz formulae.
Tripoli [1317-95-9]	Use respirable[n] mass quartz formula
‡*Amorphous* [7631-86-9]	(20 mppcf[o])
SILICATES (< 1% quartz)	
Asbestos	
Amosite [12172-73-5]	0.5 fiber > 5μm/cc, A1a
Chrysotile [12001-29-5]	2 fibers > 5μm/cc, A1a
Crocidolite [12001-28-4]	0.2 fiber > 5μm cc, A1a
Other forms	2 fibers > 5μm/cc, A1a
Graphite (natural) [7782-42-5]	15 mppcf
Mica [12001-26-2]	20 mppcf
Mineral wool fiber	10 mg/m³
Perlite	30 mppcf
Portland Cement	30 mppcf
Soapstone	20 mppcf
‡Talc (nonasbestiform) [14807-96-6]	(20 mppcf)
‡Talc (fibrous), (use Asbestos limit.)	

‡See Notice of Intended Changes

MAP 000371

COAL DUST

2 mg/m³ (respirable dust fraction < 5% quartz).
If > 5% quartz, use respirable mass formula.

NUISANCE PARTICULATES
(see Appendix D)

30 mppcf or 10 mg/m³[j]
of total dust < 1% quartz, or, 5 mg/m³ respirable dust.

Conversion factors:
mppcf × 35.3 = Million particles per cubic meter
= particles per cc

---

g) Millions of particles per cubic foot of air, based on impinger samples counted by light-field technics.
h) The percentage of quartz in the formula is the amount determined from airborne samples, except in those instances in which other methods have been shown to be applicable.
i) Both concentration and percent quartz 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

j) containing < 1% quartz; if quartz content > 1%, use formulae for quartz.
k) Lint-free dust as measured by the vertical elutriator, cotton-dust sampler described in the *Transactions of the National Conference on Cotton Dust*, p. 33 by J. R. Lynch, (May 2, 1970).
l) As determined by the membrane filter method at 400–450X magnification (4 mm objective) phase contrast illumination.
m) Based on "high volume" sampling.
n) "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 *Pulmonary Deposition and Retention of Inhaled Aerosols*, p. 149 Academic Press, New York, (1964).
(2) AIHA Aerosol Technology Committee, Interim Guide for Respirable Mass Sampling, *Am. Ind Hyg. Assoc. J. 31(2)*:133 (1970).

NOTICE OF INTENDED CHANGES
(for 1982)

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. Documentation is available for each of these substances.

		TWA		STEL	
Substance	**[CAS #]**	**ppm[a]**	**mg/m³[b]**	**ppm[a]**	**mg/m³[b]**
†Acrylonitrile [107-13-1] — Skin		2, A2	4.5, A2	—	—
Atrazine [1912-24-9]		—	5	—	—
Cadmium oxide production		—	0.05	—	—
o-Chlorobenzylidene malononitrile [2698-41-1]		C 0.05	C 0.4	—	—
Chloromethyl methyl ether [107-30-2]		A2	A2	—	—
Cobalt carbonyl, as Co		—	0.1	—	—
Cobalt hydrocarbonyl [16842-03-8], as Co		—	0.1	—	—
Cobalt metal, dust & fume [7440-48-4], as Co		—	0.05	—	0.1
Enflurane [13838-16-9]		75	575	—	—
†2-Ethoxyethanol [110-80-5] — Skin		5	19	—	—
†2-Ethoxyethyl acetate [111-15-9] — Skin		5	27	—	—
† Ethylene glycol [107-21-1], particulate DELETE. *see* Appendix G					
Ethylene glycol dinitrate (EGDN) [628-96-6] — Skin		0.05	0.3	0.1	0.6

Capital letters A, B, D & E refer to Appendices. C denotes ceiling limit
†1982 Revision or Addition.

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Substance [CAS #]	TWA ppm[a]	TWA mg/m³[b]	STEL ppm[a]	STEL mg/m³[b]
†Ethylene oxide [75-21-8]	1, A2	2, A2	—	—
†Fenamiphos [22224-92-6] — Skin	—	0.1	—	—
Fenthion [55-38-9]	—	0.2	—	—
†Formaldehyde [50-00-0]	C 1, A2	C 1.5, A2	—	—
†Grain dust	—	4	—	—
Halothane [151-67-7]	50	400	—	—
Lead arsenate [10102-48-4], as $Pb_3(AsO_4)_2$	—	0.15	—	0.45
†2-Methoxyethanol [109-86-4] — Skin	5	16	—	—
†2-Methoxyethyl acetate [110-49-6] — Skin	5	24	—	—
†Metribuzin [21087-64-9]	—	5	—	—
p-Nitrochlorobenzene [100-00-5] — Skin	0.5	3	—	—
Nitroglycerin (NG) [55-63-0] — Skin	0.05	0.5	0.1	1
2-Nitropropane [79-46-9]	10, A2	35, A2	20, A2	70, A2
†Perchloroethylene [127-18-4] — Skin	50	335	200	1,340
Persulfates, alkali metal, as S_2O_8	—	2	—	—
Phenylhydrazine [100-63-0] — Skin	5, A2	20, A2	10, A2	45, A2
Propylene glycol dinitrate (PGDN) [6423-43-4] — Skin	0.05	0.3	0.1	0.6
Propylene imine [75-55-8] — Skin	2, A2	5, A2	—	—
†Rhodium, Insoluble compounds, as Rh	—	1	—	—
Soluble compounds, as Rh	—	0.01	—	—
Silicon tetrahydride (Silane) [7803-62-5]	5	7	—	—
†Sulprofos [35400-43-2]	—	1	—	—
Toluene-2, 4-diisocyanate (TDI) [584-84-9]	0.005	0.04	0.02	0.15
†o-Toluidine [95-53-4] — Skin	2, A2	9, A2	—	—
†Trichloroethylene [79-01-6]	50	270	200	1,080
Triethylamine [121-44-8]	10	40	15	60
Trimethylamine [75-50-3]	10	40	15	60
†Vinylidine chloride [75-35-4]	5	20	20	80

Capital letters A, B, D & E refer to Appendices. C denotes ceiling limit
†1982 Revision or Addition

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MINERAL DUSTS

Substance	TLV
Diatomaceous earth, natural [60676-86-0]	1.5 mg/m³, Respirable dust
Silica, amorphous [7631-86-9]	6 mg/m³, Total dust (all sampled sizes) 3 mg/m³, Respirable dust (< 5 μm)
Talc (containing no fibers) [14807-96-6]	15 mppcf or 2 mg/m³, Respirable dust
Talc (fiber-containing)	2 fibers/cc, > 5 μm in length

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).

A1a. *Human Carcinogens*. Substances, or substances associated with industrial processes, recognized to have carcinogenic or cocarcinogenic potential, with an assigned TLV:

	TLV
** Acrylonitrile — Skin	2 ppm
Asbestos	
Amosite	0.5 fiber > 5μm/cc
Chrysotile	2 fibers > 5μm/cc
Crocidolite	0.2 fiber > 5μm/cc
Other forms	2 fibers > 5μm/cc
bis (Chloromethyl) ether	0.001 ppm
Chromite ore processing (chromate)	0.05 mg/m³, as Cr
Chromium (VI), certain water insoluble compounds	0.05 mg/m³, as Cr

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Coal tar pitch volatiles ..	0.2 mg/m³, as benzene solubles
Nickel sulfide roasting, fume & dust.....	1.0 mg/m³, as Ni
Vinyl chloride	5 ppm

* * *

A1b. *Human Carcinogens.* Substances, or substances associated with industrial processes, recognized to have carcinogenic potential without an assigned TLV:

4-Aminodiphenyl (p-Xenylamine) — Skin
‡ Benzidine — Skin
** Chloromethyl methyl ether
β-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. The worker should be properly equipped to insure virtually no contact with the carcinogen.

A2. *Industrial Substances Suspect of Carcinogenic Potential for MAN.* Chemical substances or substances associated with industrial processes, which are suspect of inducing cancer, based on either (1) limited epidemiologic evidence, exclusive of clinical reports of single cases, or (2) demonstration of carcinogenesis in one or more animal species by appropriate methods.

† Acrylonitrile — Skin	2 ppm
Amitrol	—
Antimony trioxide production*	—
Arsenic trioxide production	—
Benzene	10 ppm
Benzo(a)pyrene	—
Beryllium	2.0 μg/m³
Cadmium oxide production	—
Carbon tetrachloride — Skin	5 ppm
Chloroform	10 ppm
Chloromethyl methyl ether	—

*Cigarette smoking can enhance the incidence of respiratory cancers from this or others of these substances or processes.
†1982 Addition.
‡1982 Adoption
**See Notice of Intended Changes

Chromates of lead and zinc, as Cr	0.05 mg/m³
Chrysene	—
3, 3'-Dichlorobenzidine — Skin	—
Dimethylcarbamyl chloride	—
1, 1-Dimethyl hydrazine — Skin	0.5 ppm
Dimethyl sulfate — Skin	0.1 ppm
‡ Ethylene dibromide — Skin	—
Ethylene oxide	1 ppm
† Formaldehyde	C 1 ppm
‡ Hexachlorobutadiene	0.02 ppm
Hexamethyl phosphoramide — Skin	—
Hydrazine — Skin	0.1 ppm
4, 4'-Methylene bis (2-chloroaniline) — Skin	0.02 ppm
Methyl hydrazine — Skin	C 0.2 ppm
Methyl iodide — Skin	2 ppm
2-Nitropropane	10 ppm
N-Nitrosodimethylamine — Skin	—
N-Phenyl-beta-naphthylamine	—
Phenylhydrazine — Skin	5 ppm
Propane sultone	—
beta-Propiolactone	0.5 ppm
Propylene imine — Skin	2 ppm
‡ o-Tolidine	—
† o-Toluidine — Skin	2 ppm
Vinyl bromide	5 ppm
Vinyl cyclohexene dioxide	10 ppm

For the above, worker exposure by all routes should be carefully controlled to levels consistent with the animal and human experience data (see Documentation), including those substances with a listed TLV.

THE COMMITTEE GUIDELINES FOR CLASSIFICATION OF EXPERIMENTAL ANIMAL CARCINOGENS

The following guidelines are offered in the present state of knowledge as an aid in classifying substances in the occupational environment found to be carcinogenic in experimental animals. A need was felt by the Threshold Limits Committee for such a classification in order to

†1982 Addition.
‡1982 Adoption.

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take the first step in developing an appropriate TLV for occupational exposure.

Determination of Approximate Threshold of Response Requirement. In order to determine in which category to classify an experimental carcinogen for the purpose of assigning an industrial air limit (TLV), an approximate threshold of neoplastic response must be determined. Because of practical experimental difficulties, a precisely defined threshold cannot be attained. For the purposes of standard-setting, this is of little moment, as an appropriate risk, or safety, factor can be applied to the approximate threshold, the magnitude of which is dependent on the degree of potency of the carcinogenic response.

To obtain the best 'practical' threshold of neoplastic response, dosage decrements should be less than loganthmic. This becomes particularly important at levels greater than 10 ppm (or corresponding mg/m³). Accordingly, after a range-finding determination has been made by logarithmic decreases, two additional dosage levels are required within the levels of "effect" and "no effect" to approximate the true threshold of neoplastic response.

The second step should attempt to establish a metabolic relationship between animal and man for the particular substance found carcinogenic in animals. If the metabolic pathways are found comparable, the substance should be classed highly suspect as a carcinogen for man. If no such relation is found, the substance should remain listed as an experimental animal carcinogen until evidence to the contrary is found.

Proposed Classification of Experimental Animal Carcinogens. Substances occurring in the occupational environment found carcinogenic for animals may be grouped into three classes, those of high, intermediate and low potency. In evaluating the incidence of animal cancers, significant incidence of cancer is defined as a neoplastic response which represents, in the judgment of the Committee, a significant excess of cancers above that occurring in negative controls.

EXCEPTIONS: No substance is to be considered an occupational carcinogen of any practical significance which reacts by the respiratory route

at or above 1000 mg/m³ for the mouse, 2000 mg/m³ for the rat; by the dermal route, at or above 1500 mg/kg for the mouse, 3000 mg/kg for the rat; by the gastrointestinal route at or above 500 mg/kg/d for a lifetime, equivalent to about 100 g T.D. for the rat, 10 g T.D. for the mouse.

These dosage limitations exclude such substances as dioxane and trichlorethylene from consideration as carcinogens.

Examples: Dioxane — rats, hepatocellular and nasal tumors from 1015 mg/kg/d, oral

Trichloroethylene — female mice, tumors (30/98 @ 900 mg/kg/d), oral

Industrial Substances of High Carcinogenic Potency in Experimental Animals.

1. A substance to qualify as a carcinogen of high potency must fulfill one of the three following conditions in two animal species:

   1a. *Respiratory*. Elicit cancer from (1) dosages below 1 mg/m³ (or equivalent ppm) via the respiratory tract in 6- 7-hour daily repeated inhalation exposures throughout lifetime; or (2) from a single intratracheally administered dose not exceeding 1 mg of particulate, or liquid, per 100 ml or less of animal minute respiratory volume;

   Examples: bis-Chloromethyl ether, malignant tumors, rats, @ 0.47 mg/m³ (0.1 ppm) in 2 years;

   Hexamethyl phosphoramide, nasal squamous cell carcinoma, rats, @ 0.05 ppm, in 13 months

   OR

   1b. *Dermal*. Elicit cancer within 20 weeks by skin-painting, twice weekly at 2 mg/kg body weight or less per application for a total dose equal to or less than 1.5 mg, in a biologically inert vehicle;

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Examples: 7, 12-Dimethylbenz(a)anthracene — skin tumors @ 0.12-0.8 mg T.D. in four weeks

Benzo(a)pyrene, mice 12 μg, 3X/wk for 18 mos. T.D. 2.6 mg, 90.9% skin tumors

OR

1c. *Gastrointestinal*. Elicit cancer by daily intake via the gastrointestinal tract, within six months, with a six-month holding period, at a dosage below 1 mg/kg body weight per day; total dose, rat, ≦ 50 mg; mouse, ≦ 3.5 mg;

Examples: 7, 12-Dimethylbenz(a)anthracene — mammary tumors from 10 mg 1X

3-Methylcholanthrene — Tumors @ 3 sites from 8 mg in 89 weeks

Benzo(a)pyrene, mice, 3.9% leukemias, from 30 mg T.D. 198 days

2. Elicit cancer by all three routes in at least two animal species at dose levels prescribed for high or intermediate potency.

Industrial Substances of Intermediate Carcinogenic Potency in Experimental Animals.

To qualify as a carcinogen of intermediate potency, a substance should elicit cancer in two animal species at dosages intermediate between those described in A3a and A3c by two routes of administration.

Example: Carbamic acid ethyl ester
Dermal, mammary tumors, mice, 100%, 63 weeks, 500–1400 mg T.D.
Gastrointestinal, various type tumors, mice 42 weeks, 320 mg T.D.

Gastrointestinal, various type tumors, rats, 60 weeks, 110–930 mg T.D.

Industrial Substances of Low Carcinogenic Potency in Experimental Animals.

To qualify as a carcinogen of low potency, a substance should elicit cancer in one animal

species by any *one* of three routes of administration at the following prescribed dosages and conditions:

1a. *Respiratory*. Elicit cancer from (1) dosages greater than 10 mg m^3 (or equivalent ppm) via the respiratory tract in 6- 7-hour, daily repeated inhalation exposures, for 12 months' exposure and 12 months' observation period; or (2) from intratracheally administered dosages totaling more than 10 mg of particulate or liquid per 100 ml or more of animal minute respiratory volume;

Examples: Beryl (beryllium aluminum silicate) malig. lung tumors, rats, @ 15 mg/m^3 @ 17 months

Benzidine, var. tumors, rats, 10–20 mg/m^3 @ > 13 mos.

OR

1b. *Dermal*. Elicit cancer by skin-painting of mice in twice weekly dosages of > 10 mg/kg body weight in a biologically inert vehicle for at least 75 weeks, i.e., ≧ 1.5g T.D.

Examples: Shale tar, mouse, 0.1 ml × 50 = 5g T.D. 59/60 skin tumors

Arsenic trioxide, man, dose unknown, but estimated to be high

1c. *Gastrointestinal*. Elicit cancer from daily oral dosages of 50 mg/kg/day or greater during the lifetime of the animal.

APPENDIX B
SUBSTANCES OF VARIABLE COMPOSITION

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 minimal.

B2 *Welding Fumes — Total Particulate (NOC)†*
TLV, 5 mg/m^3

*Trade Names. Algoflon, Fluon, Halon, Teflon, Tetran.
†Not otherwise classified (NOC).

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Welding fumes cannot be classified simply. The composition and quantity of both are dependent on the alloy being welded and the process and electrodes used. Reliable analysis of fumes cannot be made without considering the nature of the welding process and system being examined; reactive metals and alloys such as aluminum and titanium are arc-welded in a protective, inert atmosphere such as argon. These arcs create relatively little fume, but an intense radiation which can produce ozone. Similar processes are used to arc-weld steels, also creating a relatively low level of fumes. Ferrous alloys also are arc-welded in oxidizing environments which generate considerable fume, and can produce carbon monoxide instead of ozone. Such fumes generally are composed of discreet particles of amorphous slags containing iron, manganese, silicon and other metallic constituents depending on the alloy system involved. Chromium and nickel compounds are found in fumes when stainless steels are arc-welded. Some coated and flux-cored electrodes are formulated with fluorides and the fumes associated with them can contain significantly more fluorides than oxides. Because of the above factors, arc-welding fumes frequently must be tested for individual constituents which are likely to be present to determine whether specific TLV's are exceeded. Conclusions based on total fume concentration are generally adequate if no toxic elements are present in welding rod, metal, or metal coating and conditions are not conducive to the formation of toxic gases.

Most welding, even with primitive ventilation, does not produce exposures inside the welding helmet above 5 mg/m³. That which does, should be controlled.

APPENDIX C
MIXTURES

C.1 THRESHOLD LIMIT VALUES FOR MIXTURES

When two or more hazardous substances, which act upon the same organ system, 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,

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

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 a 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.).

Synergistic action or potentiation may occur with some combinations of atmospheric contaminants. Such cases at present must be determined individually. Potentiating or synergistic 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 a given operation or process characteristically emits a number of harmful dusts, 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.

C.1A Examples of THRESHOLD LIMIT VALUES FOR MIXTURES

The following formulae apply only when the components in a mixture have similar toxicologic effects; they should not be used for mixtures with widely differing reactivities, e.g. hydrogen cyanide & sulfur dioxide. In such case the formula for Independent Effects (1A.c.) should be used.

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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 non-compliance with this calculated TLV.)*

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

Example No. 1A.a.: Air contains 400 ppm of acetone (TLV = 1000 ppm) 150 ppm of sec-butyl acetate (TLV = 200 ppm) and 100 ppm of 2-butanone (TLV = 200 ppm)

Atmospheric concentration of mixture = 400 + 150 + 100 = 650 ppm of mixture

$$\frac{400}{1000} + \frac{150}{200} + \frac{100}{200} = 0.4 + 0.75 + 0.5 = 1.65$$

Threshold Limit is exceeded.

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 =

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

Example No. 1: Liquid contains (by weight)

50% heptane: TLV = 400 ppm or 1600 mg/m³
1 mg/m³ ≡ 0.25 ppm

30% methyl chloroform: TLV = 350 ppm or 1900 mg/m³
1 mg/m³ ≡ 0.18 ppm

20% perchloroethylene: TLV = 100 ppm or 670 mg/m³
1 mg/m³ ≡ 0.15 ppm

$$\text{TLV of Mixture} = \frac{1}{\frac{0.5}{1600} + \frac{0.3}{1900} + \frac{0.2}{670}}$$

$$= \frac{1}{0.00031 + 0.00016 + 0.00030}$$

$$= \frac{1}{0.00077} = 1300 \text{ mg/m}^3$$

of this mixture
50% or (1300) (0.5) = 650 mg/m³ is heptane
30% or (1300) (0.3) = 390 mg/m³ is methyl chloroform
20% or (1300) (0.2) = 260 mg/m³ is perchloroethylene

These values can be converted to ppm as follows:

heptane: 650 mg/m³ × 0.25 = 162 ppm
methyl chloroform: 390 mg/m³ × 0.18 = 70 ppm
perchloroethylene: 260 mg/m³ × 0.15 = 39 ppm

TLV of mixture = 162 + 70 + 39 = 271 ppm, or 1300 mg/m³

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. TLV for Mixtures of Mineral Dusts.

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

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

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$$TLV = \frac{1}{\frac{0.8}{20} + \frac{0.2}{2.7}} = 9 \text{ mppcf}$$

TLV of nonasbestiform talc (pure) = 20 mppcf
TLV of quartz (pure) =

$$\frac{300}{100 - 10} = \frac{300}{110} = 2.7 \text{ mppcf}$$

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:

25% quartz — TLV (pure) = 2.7 mppcf
25% amorphous silica — TLV (pure) = 20 mppcf
50% talc TLV (pure) = 20 mppcf

$$TLV = \frac{1}{\frac{0.25}{2.7} + \frac{0.25}{20} + \frac{0.5}{20}} = 8 \text{ mppcf}$$

The limit for 25% quartz approximates 9 mppcf.

APPENDIX D
Some Nuisance Particulates[o]

TLV: 30 mppcf or 10 mg/m³ of total dust < 1% quartz, or, 5 mg/m³ respirable dust

α-Alumina (Al_2O_3)	Plaster of Paris
Calcium carbonate	Portland Cement
Calcium silicate	Rouge
Cellulose (paper fiber)	Silicon
Emery	Silicon Carbide
Glycerin Mist	Starch
Graphite (synthetic)	Sucrose
Gypsum	Titanium Dioxide
Kaolin	Vegetable oil mists (except castor, cashew nut, or similar irritant oils)
Limestone	
Magnesite	
Marble	
Mineral Wool Fiber	Zinc Stearate
Pentaerythritol	Zinc oxide dust

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

APPENDIX E
Some Simple Asphyxiants[p]

Acetylene	Helium	Propane
Argon	Hydrogen	Propylene
Ethane	Methane	
Ethylene	Neon	

p) As defined on pg. 6.

APPENDIX F
Conversion of mppcf to Mass Concentration

Calculations for Conversion of Particle Count Concentration (by Standard Light Field — Midget Impinger Techniques), in mppcf, to Respirable Mass Concentration (by Respirable Sampler) in mg/m³.[1]

1. In 1967, Jacobsen and Tomb,[1] derived an empirical relationship of 5.6 mppcf to 1 milligram of respirable dust per cubic meter of air, based on 23 sets of samples, mostly coal dust. Studies on conversion factors have been undertaken and preliminary evidence suggests that the application of any single conversion factor may not be adequate for use in risk assessments, epidemiology studies, or setting TLVs.

   The following calculation results in an equivalence of 6.37 mppcf to 1 mg/m³ of respirable dust. Thus, an approximate ratio of 6 mppcf to 1 mg/m³ of respirable dust is suggested for conversion of TLVs from a count to a mass basis when the density and mass median diameter have not been determined.

2. Basic assumptions:

   a) Average density for silica containing dusts ≈ 2.5 g/cm³ (2500 mg/cm³). Pulmonary significant dust densities may vary from 1.2 g/cm³ for coal dust to 3.1 g/cm³ for Portland Cement. Silica densities vary from 2.2 (amorphous) to 2.3 (cristobalite and tridymite) to 2.5 (alpha-quartz.) gms per cm³.

   b) The mass median diameter (mmd) of particles collected in midget impinger samplers and counted by the standard light field technique, *and* collected in a respirable sampler is approximately 1.5 μm or 1.5×10^{-4} cm. This assumption is, of course, quite arbitrary since the mmd of all dust clouds is quite variable, depending on many independent parameters, such as source of dust, age of

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dust cloud, meteorological conditions, processes and equipment changes, etc. If the density and the mass median diameter of the dust particles are known, the nomograph in Figure 1 can be used to convert dust count concentrations (mppcf) to respirable mass concentrations (mg/m³).

3. Calculation:

a) vol. per particle: $4/3\ \pi\ r^3$; r = 0.75×10^{-4} cm

$= 4/3 \cdot \pi \cdot (0.75 \times 10^{-4})^3$

$= 1.77 \times 10^{-12}$ cm³

b) wt. per particle = vol. × density

$= 1.77 \times 10^{-12}$ cm³ $\times\ 2.5 \times 10^3$ mg/cm³

$= 4.425 \times 10^{-9}$ mg/particle

c) 1 particle/ft.³ = 35.5 part./m³
(since 35.5 cu ft = 1 cu m.)
10^6 part./ft³ = mppcf = 35.5×10^6 part./m³

wt. of 1 mppcf = 35.5×10^6 part./m³ × 4.425×10^{-9} mg/part.

1 mppcf ≡ 0.157 mg/m³

or

6.37 mppcf ≡ 1 mg/m³

or approximately 6 mpccf ≡ 1 mg/m³.

Reference

1. **Jacobson, M. and T. F. Tomb:** Relationship Between Gravimetric Respirable Dust Concentration and Midget Impinger Number Concentration *Am. Ind. Hyg. Assoc J. 28*:554 (Nov – Dec 1967)

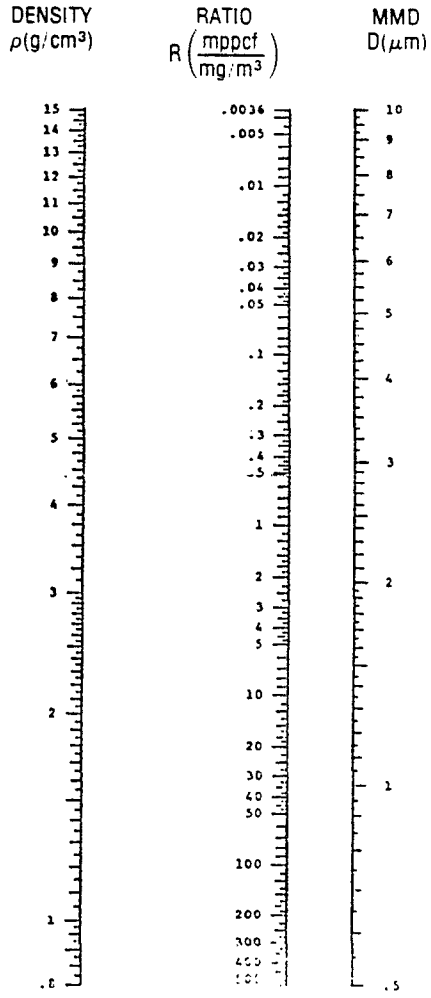


Figure 1 — Ratio of Particle Count — mppcf to Respirable Mass Concentration — mg/m³ (as function of density and mmd)*

*Prepared by P. E. Caplan and R. J. Smith

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Table 1

Equivalent TLVs in mppcf and mg/m³ (Respirable Mass) for Mineral Dusts†

Substance	Threshold Limit Value		
	Count mppcf	Resp. Mass mg/m³	Total Mass* mg/m³
Silica (SiO_2)			
Amorphous	20	(3)**	(6)
Cristobalite	1.5	0.05	0.15
Fused silica	3	0.1	0.3
Quartz	3	0.1	0.3
Tridymite	1.5	0.05	0.15
Coal Dust	(12)	2	(4)
Diatomaceous earth, natural	—	1.5	—
Graphite (natural)	15	(2.5)	(5)
Mica	20	(3)	(6)
Mineral wool fiber	—	(5)	10
Nuisance particulates	30	(5)	10
Perlite	30	(5)	(10)
Portland Cement	30	(5)	(10)
Soapstone	20	(3)	(6)
Tripoli	(3)	0.1	(0.3)

†Assuming that the mass median diameter is 1.5 μm and density is 2.5 g/cm³

*Unless otherwise specified, respirable mass is presumed to equal approximately 50% of total mass

**All values in parentheses ( ) represent newly calculated values based on equivalence of 6 mppcf ≈ 1 mg/m³ respirable mass and respirable mass = 50% total mass

APPENDIX G
Chemical Substances and Other Issues Under Study[1]

Chemical Substances

Acetonitrile
Acetophenone
Acetyl acetone
Allyl chloride
Aluminum oxide
Asbestos
Bismuth telluride
Carbonyl fluoride
Cellulose
Chlorinated camphene (60%)
Chlorinated naphthalenes
Chlorine
bis-Chloromethyl ether
Copper dust & fume
Diatomaceous earth
Diethylenetriamine
Emery
Epichlorohydrin
Ethyl chloride
Ethylene dichloride
Graphite
Hexafluoroacetone
Isocyantes
Jet fuel
Methylenedianiline
Methyl methacrylate
Methyl tertiary butyl ether
Nickel, metal & soluble compounds
Nitrous oxide
Osmium tetroxide
"Other" glycol ethers
Piperzine
Propylene chloride
Propylene oxide
Silica, all forms
Silicon carbide
Silicon tetrahydride (Silane)
Styrene, monomer
2,3,7,8-Tetrachlorodibenzo-p-dioxin (TCDD)
Tetrachloronaphthalene
Tin hydride
1,2,3-Trichloropropane
Trimellitic anhydride
m-Xylene 2,2'-diamine (MXDA, meta-meta-xylenediamine)

Other Issues

Dual vapor and particulate TLVs.[2]

Role of Biological Exposure Indices relative to airborne contaminant TLVs.[2]

Role of STELs and Excursion limits.[2] STELs will be used for specific health effects and Excursion limits will be used for substances without a specific STEL.

Should mppcf values be retained (Appendix F)?

Should welding fume value (not otherwise classified, NOC) be retained or should specific analytical determinations be made for metals and other compounds and these values be compared to specific TLVs?

[1]Information, data especially, and comments are solicited to assist the committee in its deliberations and in the development of draft documents. Draft documentations are used by the committee to decide what action, if any to recommend on a given substance or question.

[2]Study papers appear in the *Annals of the American Conference of Governmental Industrial Hygienists*, Volume 4, *Transactions of the 1982 Meeting* (available late 1982)

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APPENDIX H
Registered* Trade Names

Trade Name	Generic Name
Abate	Temephos
Ammate	Ammonium sulfamate
Azodrin	Monocrotophos
Baygon	Propoxur
Baytex	Fenthion
Bidrin	Dicrotophos
Bolstar	Sulprofos
Butyl Cellosolve	2-Butoxyethanol
Cellosolve acetate	2-Ethoxyethyl acetate
Coyden	Clopidol
Crag herbicide	Sesone
Dasanit	Fensulfothion
Delnav	Dioxathion
Dibrom	Naled
Difolatan	Captafol
Disyston	Disulfoton
Dursban	Chlorpyrifos
Dyfonate	Fonofos
Furadan	Carbofuran
Guthion	Azinphos-methyl
Lannate	Methomyl
Methyl Cellosolve	2-Methoxyethanol
Methyl Cellosolve acetate	2-Methoxyethyl acetate
Nemacur	Fenamiphos
Nialate	Ethion
N-Serve	Nitrapyrin
Pival	Pindone
Plictran	Cyhexatin
Sencor	Metribuzin
Sevin	Carbaryl
Teflon	Polytetrafluoroethylene
Thimet	Phorate
Thiodan	Endosulfan
Tordon	Picloram
Zoalene	Dinitolmide

TLVs®
Threshold Limit Values
for
Physical Agents
Adopted by
ACGIH
for 1982

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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.

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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 1 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.[1, 2]

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 = 0.7 NWB + 0.2 GT + 0.1 DB
2. Indoors or Outdoors with no solar load:
   WBGT = 0.7 NWB + 0.3 GT

where:

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

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

Higher heat exposures than shown in Table 1 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.

EVALUATION AND CONTROL

I. *Measurement of the Environment*

The instruments required are a dry-bulb, a natural wet-bulb, a globe thermometer, and a stand. The

TABLE 1

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

	Work Load		
Work — Rest Regimen	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

measurement of the environmental factors shall be performed as follows:

A. The range of the dry and the natural wet bulb thermometer shall be −5°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. A 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.

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C. A 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 as that of 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 by Minard.[3-4]

TABLE 2

Assessment of Work Load[9]

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	

TABLE 3

Activity Examples[9]

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

Assembly line work using a heavy hand tool.

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

II. *Work Load Categories*

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.

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(1) light work (up to 200 kcal/hr or 800 Btu/hr): e.g., sitting or standing to control machines, performing light hand or arm work,

(2) moderate work (200–350 kcal/hr or 800–1400 Btu/hr): e.g., walking about with moderate lifting and pushing,

(3) heavy work (350–500 kcal/hr or 1400–2000 Btu/hr): 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 with the use of Tables 2 and 3. Additional tables available in the literature[5–8] may be utilized also. When this method is used the permissible heat exposure limit can be determined by Figure 1.

III. *Work-Rest Regimen*

The permissible exposure limits specified in Table 1 and Figure 1 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. Where the WBGT of the work area is different from that of the rest area a time-weighted average value should be used for both environmental and metabolic heat. When time-weighted average values are used the appropriate curve on Figure 1 is the solid line labeled "continuous."

The time-weighted average metabolic rate (M) shall be determined by the equation:

$$\text{Av. } M = \frac{(M_1) \times (t_1) + (M_2) \times (t_2) + \ldots + (M_n) \times (t_n)}{(t_1) + (t_2) + \ldots + (t_n)}$$

Where M_1 M_2, M_n are estimated or measured metabolic rates for the various activities of the worker during the total time period. t_1, t_2, t_n are the elapsed times in minutes spent at the corresponding metabolic rate as determined by a time study.

The time-weighted average WBGT shall be determined by the equation:

$$\text{Av. WBGT} = \frac{(\text{WBGT}_1) \times (t_1) + (\text{WBGT}_2) \times t_2 + \ldots + (\text{WBGT}_n) \times (t_n)}{(t_1) + (t_2) + \ldots + (t_n)}$$

where WBGT_1, WBGT_2, WBGT_n are calculated values of WBGT for the various work and rest areas occupied during total time periods. t_1, t_2, t_n are the elapsed times in minutes spent in the corresponding areas which are determined by a time study. Where exposure to hot environmental conditions is continuous for several hours or the entire work day, the time-weighted averages shall be calculated as hourly time-weighted average i.e., $t_1 + t_2 + \ldots + t_n = 60$ minutes. Where the exposure is intermittent, the time-weighted averages shall be calculated as two-hour time-weighted averages, i.e., $t_1 + t_2 + \ldots + t_n = 120$ minutes.

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.

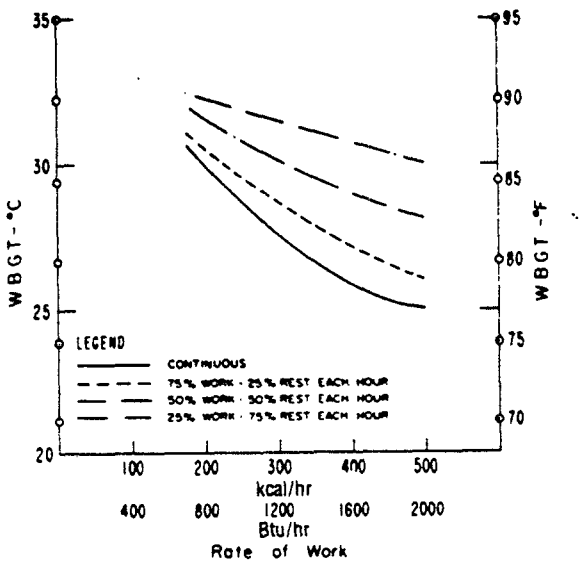


Figure 1 — Permissible Heat Exposure Threshold Limit Value

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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 shall be kept reasonably cool (10°–15°C or 50.0°–60.0°F) 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 cothing 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 1 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:* Acclimatization to heat involves a series of physiological and psychological adjustments that occur in an individual during his first week of exposure to hot environmental conditions. The recommended heat stress TLVs are valid for acclimated workers who are physically fit. Extra caution must be employed when unacclimated or physically un-fit workers must be exposed to heat stress conditions.

References:

1. *Health Factors Involved in Working Under Conditions of Heat Stress* WHO Technical Report Series No. 412 (1969)
2. **Dukes-Dobos, F. N. and A. Henschel:** Development of Permissible Heat Exposure Limits for Occupational Work. *ASHRAE Journal 15(9)*:57–62 (Sept. 1973)

3. **Minard, D.:** *Prevention of Heat Casualties in Marine Corps Recruits. Period of 1955–60, with Comparative Incidence Rates and Climatic Heat Stresses in Other Training Categories* Research Report No. 4 Contract No. MR 005.01-0001.01 Naval Medical Research Institute Bethesda, MD (Feb. 21, 1961) Published in *Military Medicine 126(44)* 261–272 (April 1961)
4. **Minard, D. and R. L. O'Brien:** *Heat Casualties in the Navy and Marine Corps 1959–1962 with Appendices on the Field Use of the Wet Bulb-Globe Temperature Index* Research Report No. 7 Contract No. MR 005.01-0001.01 Naval Medical Research Institute Bethesda, MD (March 12, 1964)
5. **Astrand, Per-Olof and Kaare Rodahl:** *Textbook of Work Physiology* McGraw-Hill Book Co., New York, San Francisco (1970)
6. Ergonomics Guide to Assessment of Metabolic and Cardiac Costs of Physical Work. *Am. Ind. Hyg. Assoc. J. 32* 560 (1971)
7. *Energy Requirements for Physical Work* Research Progress Report No. 30 Purdue Farm Cardiac Project, Agricultural Experiment Station, West Lafayette, IN (1961)
8. **Durnin, J. V. G. A. and R. Passmore:** *Energy, Work and Leisure* Heinemann Educational Books, Ltd., London (1967)
9. **Lehmann, G., E., A. Muller and H. Spitzer:** Der Kalorienbedarf bie Gewerblicher Arbeit. *Arbeitsphysiol 14* 166 (1950)

IONIZING RADIATION

The Committee accepts the philosophy and recommendations of the National Council on Radiation Protection and Measurements (NCRP) for the ionizing radiation TLV. The NCRP is charted by Congress to, in part, collect, analyze, develop and disseminate information and recommendations about protection against radiation and about radiation measurements, quantities and units, including development of basic concepts in these areas. NCRP Report No. 39 provides basic philosophy and concepts leading to protection criteria established in the same report.[1] Other NCRP reports address specific areas of radiation protection and, collectively, provide an excellent basis for establishing a sound program for radiation control. The Committee recommends the listed references as substantative documentation of a sound basis for ionizing radiation protection. The committee also strongly recommends that all exposures to ionizing radiations be kept as low as reasonably achievable within the stated guidance.

References:

1. *Basic Radiation Protection Criteria* NCRP Report No. 39 (January 15 1971)
2. *Maximum Permissible Body Burdens and Maximum Permissible Concentrations of Radionuclides in Air and in Water for Occupational Exposure.* National Bureau of Standards Handbook 69 (June 5 1959) with *Addendum 1* (August 1963) Available as NCRP Report No. 22.

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The above documents, as well as information on numerous other NCRP Reports addressing specific subjects in ionizing radiation protection are available from: NCRP Publications, PO Box 30175, Washington, DC 20014.

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); and except for all TLVs for wavelengths between 0.1–1 mm where the limiting aperture is 10 mm. 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 7) which varies with exposure time. This angle is *not* the beam divergence of the source.

Correction Factors A and B (C_A and C_B)

The TLVs for ocular exposure in Tables 4 and 5 are to be used as given for all wavelength ranges. The TLVs for wavelengths between 700 nm and 1049 nm are to be increased by a uniformly extrapolated factor (C_A) as shown in Figure 2. Between 1049 nm and 1400 nm, the TLV has been increased by a factor (C_A) of five. For certain exposure times at wavelengths between 550 nm and 700 nm, correction factor (C_B) must be applied.

The TLVs for skin exposure are given in Table 6. The TLVs are to be increased by a factor (C_A) as shown in Figure 2 for wavelengths between 700 nm and 1400 nm. To aid in the determination of TLVs for exposure durations requiring calculations of fractional powers Figures 3, 4, 5 and 6 may be used.

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 4, 5, or 7 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^{-5} second. For pulses of greater duration, the following formula should be followed:

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

where:

n = number of pulses in train
τ = duration of a single pulse in the train
Standard ($n\tau$) = protection standard of one pulse having a duration equal to $n\tau$ seconds.

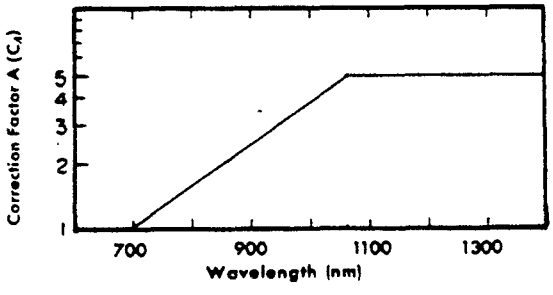


Figure 2 — TLV correction factor for $\lambda = 700 - 1400$ nm*

*For $\lambda = 700 - 1049$ nm, $C_A = 10^{[0.002(\lambda - 700)]}$
For $\lambda = 1050 - 1400$ nm, $C_A = 5$

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TABLE 4

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 "

*not to exceed 0.56 $t^{1/4}$ J • cm^{-2} for $t \leq 10$ s.

UVA	315 nm to 400 nm	10^{-9} to 10	.56 $t^{1/4}$ J • cm^{-2}
	" "	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^{-7} J • cm^{-2}
	400 nm to 700 nm	1.8×10^{5} to 10	1.8 ($t/\sqrt[4]{t}$) mJ • cm^{-2}
	400 nm to 549 nm	10 to 10^{4}	10 mJ • cm^{-2}
	550 nm to 700 nm	10 to T_1	1.8 ($t/\sqrt[4]{t}$) mJ • cm^{-2}
	550 nm to 700 nm	T_1 to 10^{4}	10 C_B mJ • cm^{-2}
	400 nm to 700 nm	10^{4} to 3×10^{4}	C_B μW • cm^{-2}
IR-A	700 nm to 1049 nm	10^{-9} to 1.8×10^{-5}	5 $C_A \times 10^{-7}$ J • cm^{-2}
	700 nm to 1049 nm	1.8×10^{5} to 10^{3}	1.8 C_A ($t/\sqrt[4]{t}$) mJ • cm^{-2}
	1050 nm to 1400 nm	10^{-9} to 10^{-4}	5×10^{-6} J • cm^{-2}
	1050 nm to 1400 nm	10^{-4} to 10^{3}	9($t/\sqrt[4]{t}$) mJ • cm^{-2}
	700 nm to 1400 nm	10^{3} to 3×10^{4}	320 C_A μW • cm^{-2}
IR-B & C	1.4 μm to 10^{3} μm	10^{-9} to 10^{-7}	10^{-2} J • cm^{2}
	" "	10^{-7} to 10	0.56 $\sqrt[4]{t}$ J • cm^{-2}
	" "	10 to 3×10^{4}	0.1 W • cm^{-2}

C_1 See Fig 2
C_A = 1 for λ 400 to 549 nm, C_A = $10^{[0.002(\lambda - 550)]}$ for λ = 550 to 700 nm
T_1 = 10 s for λ 400 to 549 nm, T_1 = $10 \times 10^{[0.002(\lambda - 550)]}$ for λ = 550 to 700 n

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TABLE 5

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	$10\ \sqrt[4]{t}$ J • cm^{-2} • sr^{-1}
	400 nm to 549 nm	10 to 10^{4}	21 J • cm^{-2} • sr^{-1}
	550 nm to 700 nm	10 to T_1	$3.83\ (t/\sqrt[4]{t})$ J • cm^{-2} • sr^{-1}
	550 nm to 700 nm	T_1 to 10^{4}	21 C_B J • cm^{-2} • sr^{-1}
	400 nm to 700 nm	10^{4} to 3×10^{4}	2.1 $C_B t \times 10^{-3}$ W • cm^{-2} • sr^{-1}
IR-A	700 nm to 1400 nm	10^{-9} to 10	$10\ C_A \sqrt[4]{t}$ J • cm^{-2} • sr^{-1}
	700 nm to 1400 nm	10 to 10^{3}	$3.83\ C_A\ (t/\sqrt[4]{t})$ J • cm^{-2} • sr^{-1}
	700 nm to 1400 nm	10^{3} to 3×10^{4}	0.64 C_A W • cm^{-2} • sr^{-1}
IR-B & C	1.4 μm to 1 mm	10^{-9} to 3×10^{4}	Same as Table 3

C_A, C_B, and T_1 are the same as in footnote to Table 4

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 4
Light &	400 nm to 1400 nm	10^{-9} to 10^{-7}	$2\ C_A \times 10^{-2}$ J • cm^{-2}
IR-A	" "	10^{-7} to 10	$1.1\ C_A \sqrt[4]{t}$ J • cm^{-2}
IR-A	" "	10 to 3×10^{4}	0.2 C_A W • cm^{-2}
IR-B & C	1.4 μm to 1 mm	10^{-9} to 3×10^{4}	Same as Table 4

$C_A = 1.0$ for λ = 400–700 nm, see Figure 2 for λ = 700 to 1400 nm

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TABLE 7

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

Exposure Duration(s)	Angle α (mrad)
10^{-9}	8.0
10^{-8}	5.4
10^{-7}	3.7
10^{-6}	2.5
10^{-5}	1.7
10^{-4}	2.2
10^{-3}	3.6
10^{-2}	5.7
10^{-1}	9.2
1.0	15
10	24
10^{2}	24
10^{3}	24
10^{4}	24

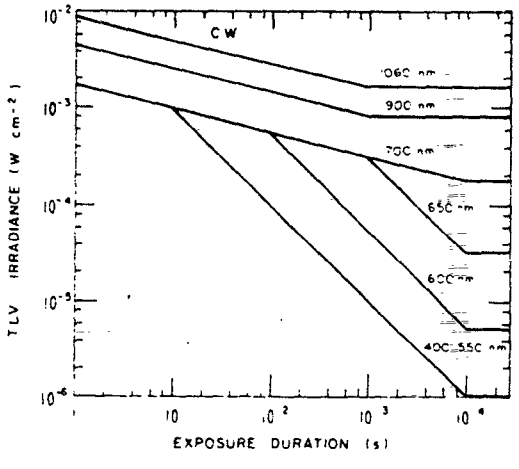


Figure 3a — TLV for infrabeam (direct) viewing of CW laser beam (400–1400 nm)

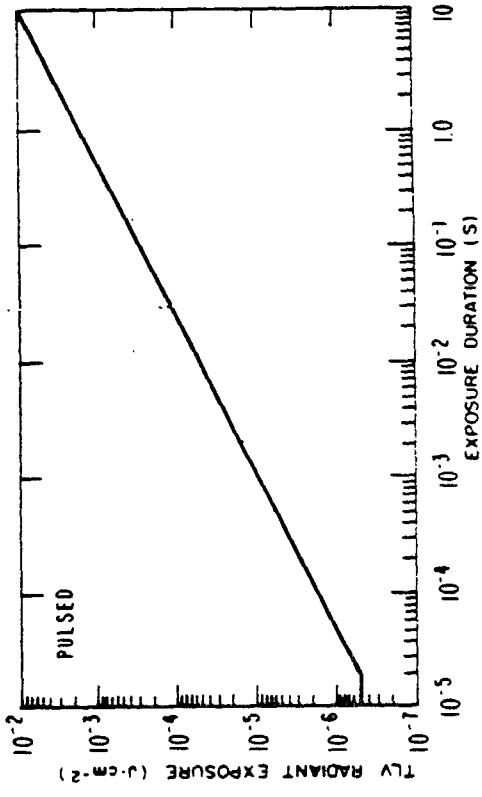


Figure 3b — TLV for infrabeam (direct) viewing of laser beam (400–700 nm)

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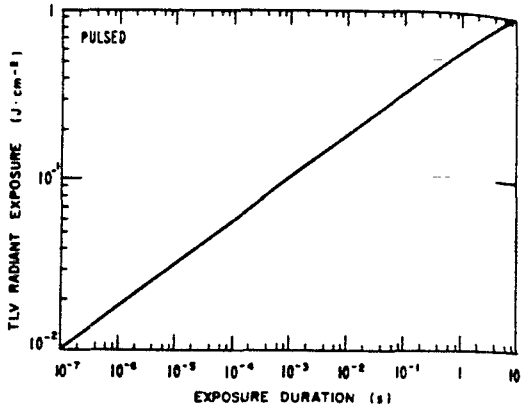


Figure 4a — TLV for laser exposure of skin and eyes for far-infrared radiation (wave-lengths greater than 1.4 μm).

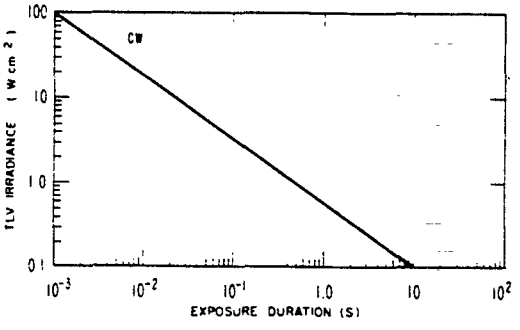


Figure 4b — TLV for CW laser exposure of skin and eyes for far-infrared radiation (wave-lengths greater than 1.4 μm).

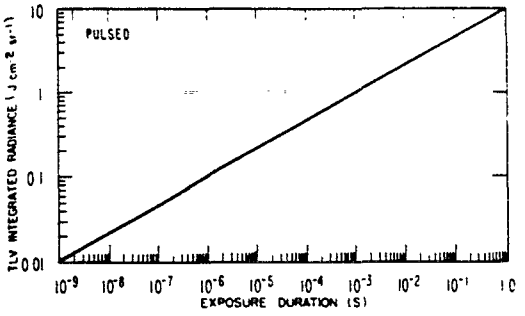


Figure 5a — TLV for extended sources or diffuse reflections of laser radiation (400–700 nm).

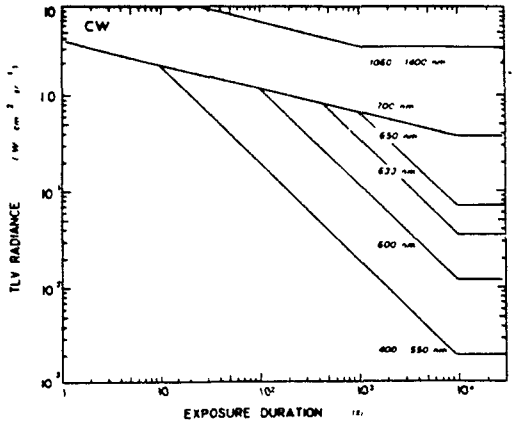


Figure 5b — TLV for extended sources or diffuse reflections of laser radiation (400–1400 nm).

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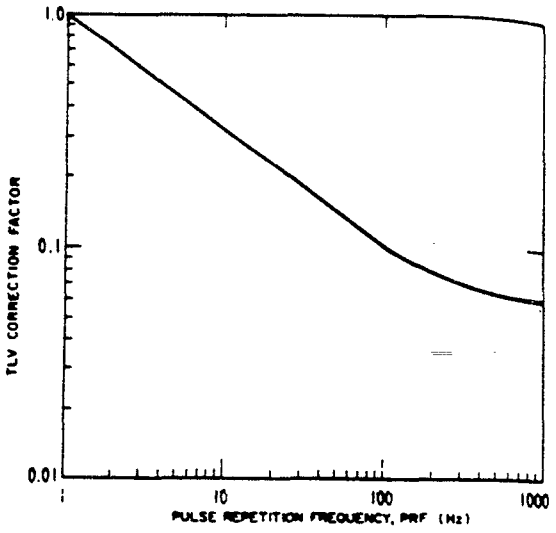


Figure 6 — Multiplicative correction factor for repetitively pulsed lasers having pulse durations less than 10^{-3} second. TLV for a single pulse of the pulse train is multiplied by the above correction factor. Correction factor for PRF greater than 1000 Hz is 0.06.

**MICROWAVES

These Threshold Limit Values refer to microwave energy in the frequency range of 300 MHz to 300 GHz and represent conditions under which it is believed that nearly all workers may be repeatedly exposed without adverse effect.

Under conditions of moderate to severe heat stress, the recommended values may need to be reduced.[1] Therefore, these values should be used as guides in the control of exposure to microwave energy and should not be regarded as a fine line between safe and dangerous levels.

Recommended Values:

The Threshold Limit Value for occupational exposure to microwave energy, where power density or field intensity is known and exposure time is controlled, is as follows:

1. For exposure to continuous wave (CW) sources, the power density level shall not exceed 10 milliwatts per square centimeter (mW/cm²) for continuous exposure, and the total exposure time shall be limited to an 8-hour workday. This power density is approximately equivalent to a free-space electric field strength of 200 volts-per-meter rms (V/m) and a free-space magnetic field strength of 0.5 ampere-per-meter rms (A/m).
2. Exposures to CW power density levels greater than 10 mW/cm² are permissible up to a maximum of 25 mW/cm² based upon an average energy density of 1 milliwatt-hour per square centimeter (mWh/cm²) averaged over any 0.1 hour period. For example, at 25 mW/cm², the permissible exposure duration is approximately 2.4 minutes in any 0.1 hour period.
3. For repetitively pulsed microwave sources, the average field strength or power density is calculated by multiplying the peak-pulse value by the duty cycle. The duty cycle is equal to the pulse duration in seconds times the pulse repetition rate in Hertz. Exposure during an 8-hour workday shall not exceed the following values which are averaged over any 0.1 hour period:

Power Density	10 mW/cm²
Energy Density	1 mWh/cm²
Mean Squared Electric Field Strength	40,000 V²/m²
Mean Squared Magnetic Field Strength	0.25 A²/m²

4. Exposure is not permissible in CW or repetitively pulsed fields with an average power density in excess of 25 mW/cm² or approximate equivalent free-space field strengths of 300 V/m or 0.75 A/m.

Reference:

1. **Mumford, W. W.:** Heat Stress Due to R F Radiation. *Proceedings of IEEE 57(2):* 171–178 (Feb. 1969)

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. Prior to 1979, the medical profession had defined hearing impairment as an average hearing threshold level in excess of 25 decibels (ANSI-S3.6-

**See Notice of Intended Changes

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Table 8
Threshold Limit Values

Duration per Day Hours	Sound Level dBA†
16	80
8	85
4	90
2	95
1	100
1/2	105
1/4	110
1/8	115*

†Sound level in decibels are 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.

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

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.[a] 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.

It should be recognized that the application of the TLV for noise will not protect all workers from the adverse effects of noise exposure. A hearing conservation program with audiometric testing is necessary when workers are exposed to noise at or above the TLV 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 National 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 8.

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 and does include the impact and impulsive type of noise that contributes to the sound level meter reading at slow response.

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 on-the-job noise exposures of 80 dBA or greater shall be used in the above calculations.

[a]In 1979, the American Academy of Ophthalmology and Otolargyngology (AAOO) included 3000 hz in their hearing impairment formula.

IMPULSIVE OR IMPACT NOISE

It is recommended that exposure to impulsive or impact noise shall not exceed the limits listed in Table 9 or taken from Figure 7. No exposures in ex-

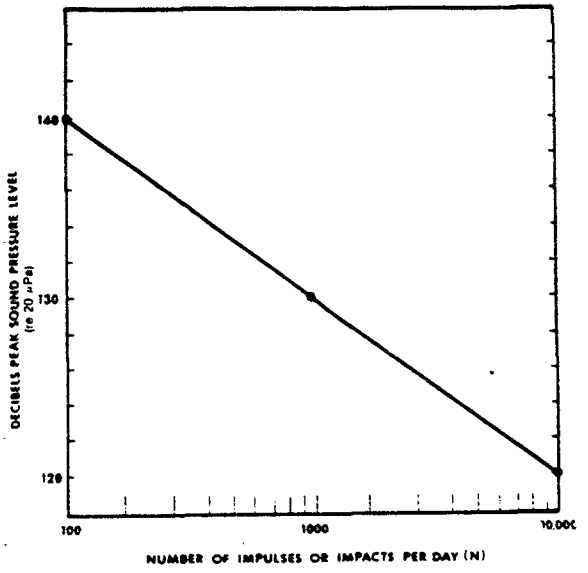


Figure 7 — Threshold Limit Values for Impulse/Impact Noise.

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cess of 140 decibels peak sound pressure level are permitted. 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 9
Threshold Limit Values Impulsive or Impact Noise

Sound Level dB**	Permitted Number of Impulses or Impacts per day
140	100
130	1000
120	10,000

**Decibels peak sound pressure level, re 20 μPa

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, and solar radiation, but do not apply to ultraviolet lasers.* These values do not apply to ultraviolet radiation exposure of photosensitive individuals or of individuals concomitantly exposed to photosensitizing agents.[1] 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 nm) total irradiance incident upon the unprotected skin or eye should not exceed 1 mW cm^2 for periods greater than 10^3 seconds (approximately 16 minutes) and for exposure times less than 10^3 seconds should not exceed one J/cm^2.
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 10 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 following weighting formula should be used:

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

where:

E_{eff} = effective irradiance relative to a monochromatic source at 270 nm in W/cm^2 (J/s/cm^2)

E_λ = spectral irradiance in W/cm^2/nm

S_λ = relative spectral effectiveness (unitless)

$\Delta\lambda$ = band width in nanometers

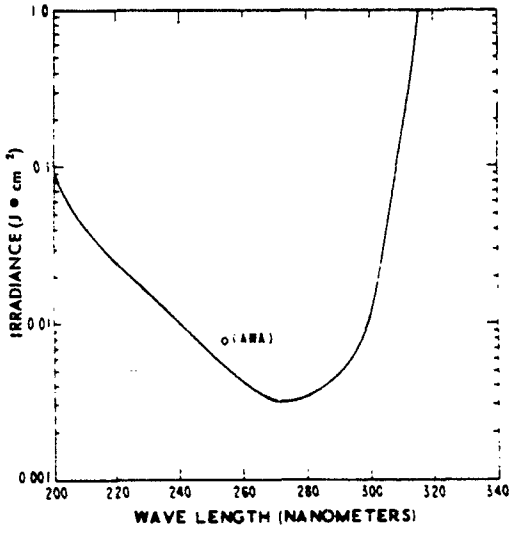


Figure 8 — Threshold Limit Values for Ultraviolet Radiation

*See Laser TLVs

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TABLE 10
Relative Spectral Effectiveness
by Wavelength*

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
254	6.0	0.5
260	4.6	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 Laser TLVs.

TABLE 11
Permissible Ultraviolet Exposures

Duration of Exposure Per Day	Effective Irradiance, E_{eff} (μW/cm²)
8 hrs.	0.1
4 hrs.	0.2
2 hrs.	0.4
1 hr.	0.8
30 min.	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

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 11 which provides exposure times corresponding to effective irradiances in μW/cm².
5. All the preceding TLVs 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°.

Conditioned (tanned) individuals can tolerate skin exposure in excess of the TLV without erythemal effects. However, such conditioning may not protect persons against skin cancer.

References:

1. *Sunlight and Man*. Fitzpatrick *et al*, Eds. Univ of Tokyo Press. Tokyo, Japan (1974).

NOTICE OF INTENDED CHANGES (1982)

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.

NOTICE OF INTENT TO ESTABLISH THRESHOLD LIMIT VALUES

LASERS

It is proposed that the following footnote be added to Table 7 (Threshold Limit Value for Skin Exposure from a Laser Beam).

The IR-B and IR-C exposures to skin surface areas A(cm²) exceeding 1000 cm², the TLV is 100,000/A mW/cm²; for areas greater than 100,000/A, the TLV is 10 mW/cm².

LIGHT AND NEAR-INFRARED RADIATION

These Threshold Limit Values refer to visible and near-infrared radiation in the wavelength range of 400

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nm to 1400 nm and represent conditions under which it is believed that nearly all workers may be exposed without adverse effect. These values should be used as guides in the control of exposure to light and should not be regarded as a fine line between safe and dangerous levels.

Recommended Values:

The Threshold Limit Value for occupational exposure to broad-band light and near-infrared radiation for the eye apply to exposure in any eight-hour workday and require knowledge of the spectral radiance (L_λ) and total irradiance (E) of the source as measured at the position(s) of the eye of the worker. Such detailed spectral data of a white light source is generally only required if the luminance of the source exceeds 1 cd cm^{-2}. At luminances less than this value the TLV would not be exceeded.

TABLE 12

Spectral Weighting Functions for Assessing Retinal Hazards from Broad-Band Optical Sources

Wavelength (nm)	Blue-Light Hazard Function B_λ	Burn Hazard Function R_λ
400	0.10	1.0
405	0.20	2.0
410	0.40	4.0
415	0.80	8.0
420	0.90	9.0
425	0.95	9.5
430	0.98	9.8
435	1.0	10
440	1.0	10
445	0.97	9.7
450	0.94	9.4
455	0.90	9.0
460	0.80	8.0
465	0.70	7.0
470	0.62	6.2
475	0.55	5.5
480	0.45	4.5
485	0.40	4.0
490	0.22	2.2
495	0.16	1.6
500–600	$10^{[(450-\lambda)/50]}$	1.0
600–700	0.001	1.0
700–1049	0.001	$10^{[(700-\lambda)/505]}$
1050–1400	0.001	0.2

The TLV's are:

1. To protect against retinal thermal injury, the spectral radiance of the lamp weighted against the function R (Table 12) should not exceed:

$$\sum_{400}^{1400} L_\lambda R_\lambda \Delta\lambda \leqq 1/\alpha t^{1/2} \qquad (1)^*$$

where L_λ is in W cm^{-2} sr^{-1} and t is the viewing duration (or pulse duration if the lamp is pulsed) limited to 1 μs to 10 s, and α is the angular subtense of the source in radians. If the lamp is oblong, α refers to the longest dimension that can be viewed. For instance, at a viewing distance r = 100 cm from a tubular lamp of length l = 50 cm, the viewing angle is:

$$\alpha = l/r = 50/100 = 0.5 \text{ rad} \qquad (2)$$

2. To protect against retinal photochemical injury from chronic blue-light exposure the integrated spectral radiance of light source weighted against the blue-light hazard function B_λ (Table 12) should not exceed:

$$\sum_{400}^{1400} L_\lambda t B_\lambda \Delta\lambda \leqq 100 \text{ Jcm}^{-2} \text{ sr}^{-1} \ (t \leqq 10^4 \text{s}) \qquad (3a)$$

$$\sum_{400}^{1400} L_\lambda B_\lambda \Delta\lambda \leqq 10^{-2} \text{ Wcm}^{-2} \text{ sr}^{-1} \ (t > 10^4 \text{s}) \qquad (3b)$$

The weighted product of L_λ and B_λ is termed L(blue). For a source radiance L weighted against the blue-light hazard function [L(blue)] which exceeds 10 mW/cm^{-2} sr^{-1} in the blue spectral region, the permissible exposure duration t_{max} in seconds is simply:

$$t_{max} = 100 \text{ J cm}^{-2} \text{ sr}^{-1}/\text{L (blue)} \qquad (4)$$

The latter limits are greater than the maximum permissible exposure limits for 440 nm laser radiation (see Laser TLV) because a 2–3 mm pupil is assumed rather than a 7 mm pupil for the Laser TLV. For a light source subtending an angle α less than 11 mrd (0.011 radian) the above limits are relaxed such that the spectral irradiance weighted against the blue-light hazard function B_λ [E(blue)] should not exceed:

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$$\sum_{400}^{1400} E_\lambda \bullet t \bullet B_\lambda \bullet \Delta\lambda \leqq 10\ mJ \bullet cm^{-2}\ (t \leqq 10^4\ s) \quad (5a)$$

$$\sum_{400}^{1400} E_\lambda \bullet B_\lambda \bullet \Delta\lambda \leqq 1\mu W \bullet cm^2\ (t \geqq 10^4\ s) \quad (5b)$$

For a source where the blue light weighted irradiance E (blue) exceeds 1 $\mu W \bullet cm^{-2}$ is the maximum permissible exposure duration t_{max} in seconds is:

$$t_{max} = 10mJ \bullet cm^{-2}\ E\ (blue) \quad (6)$$

3. *Infrared Radiation:* To avoid possible delayed effects upon the lens of the eye (cataractogenesis), the infrared radiation ($\lambda > 770$ nm) should be limited to 10 $mWcm^{-2}$. For an infrared heat lamp or any near-infrared source where a strong visual stimulus is absent, the near infrared (770–1400 nm) radiance as viewed by the eye should be limited to:

$$\sum_{770}^{1400} L_\lambda\ \Delta\lambda = 0.6/\alpha \quad (7)^*$$

for extended duration viewing conditions. This limit is based upon a 7 mm pupil diameter.

AIRBORNE UPPER SONIC AND ULTRASONIC ACOUSTIC RADIATION

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. The values listed in Table 13 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. The levels for the third octave bands centered below 20 kHz are below those which cause subjective effects. Those levels for 1/3 octaves above 20 kHz are for prevention of possible hearing losses from subharmonics of these frequencies.

*Formulae (1) and (7) are empirical and are not, strictly speaking, dimensionally correct. To make the formulae dimensionally correct, one would have to insert a dimensional correction factor k in the right hand numerator in each formula. For formula (1) this would be $k_1 = 1\ W \bullet rad \bullet s^{1/2}/(cm^2 \bullet sr)$, and for formula (7) $k_2 = 1\ W \bullet rad/(cm^2 \bullet sr)$

TABLE 13

Permissible Ultrasound Exposure Levels

Mid-Frequency of Third-Octave Band kHz	One-Third Octave — Band Level in dB re 20 μPa
10	80
12.5	80
16	80
20	105
25	110
31.5	115
40	115
50	115

RADIOFREQUENCY/MICROWAVE RADIATION

These Threshold Limit Values (TLVs) refer to radiofrequency (RF) and microwave radiation in the frequency range from 10 kHz to 300 GHz, and represent conditions under which it is believed workers may be repeatedly exposed without adverse health effects. The TLVs shown in Table 14 are selected to limit the average whole body specific absorption rate (SAR) to 0.4 W/kg in any six minutes (0.1 hr) period for 3 MHz to 300 GHz, see Figure 9. Between 10 kHz and 3 MHz the average whole body SAR is still limited to 0.4 W/kg, but the plateau at 100 mW/cm^2 was set to protect against shock and burn hazards.

Since it is usually impractical to measure the SAR, the TLVs are expressed in units that are measurable, viz, squares of the electric and magnetic field strengths, averaged over any 0.1 hour period. This can be expressed in units of equivalent plane wave power density for convenience. The electric field strength (E) squared, magnetic field strength (H) squared, and power density (PD) values are shown in Table 14. For near field exposures PD cannot be measured directly, but equivalent plane wave power density can be calculated from the field strength measurement data as follows:

$$PD\ in\ mW/cm^2 = \frac{E^2}{3770}$$

where:

E^2 is in volts squared (V^2) per meter squared (m^2).

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PD in $mW/cm^2 = 37.7\ H^2$

where:

H^2 is in amperes squared (A^2) per meter squared (m^2).

These values should be used as guides in the evaluation and control of exposure to radiofrequency/microwave radiation, and should not be regarded as a fine line between safe and dangerous levels.

Notes:

1. All Radiofrequency Radiation (RFR) exposures should be kept as low as reasonably possible given the current state of knowledge on human effects, particularly non-thermal effects.
2. For fields consisting of a number of frequencies, the fraction of the protection guide incurred within each frequency level should be determined and the sum of all fractions should not exceed unity.
3. For pulsed and continuous wave fields, the power density is averaged over the six minute period.
4. For partial body exposures at frequencies between 10 kHz and 1.0 GHz, the protection guides in Table 14 may be exceeded if the output power of a radiating device is 7 watts or less. For example, if a hand held transmitter operating at 27 MHz has a maximum output of 5 watts, it would be excluded from any further field measurements.
5. The TLVs in Table 14 may be exceeded if the exposure conditions can be demonstrated to produce a SAR of less than 0.4 W/kg as averaged over the whole body and spatial peak SAR values less than 8.0 W/kg as averaged over any 1.0 gram of tissue.

   For example, for frequencies from 3 to 30 MHz, the equivalent power density can be increased by a factor of 10 up to a limit of 100 mW/cm^2, if it can be assured that exposed individuals are not in contact with the ground plate.
6. At frequencies below 30 MHz, ungrounded objects such as vehicles, fences, etc., can strongly couple to RF fields. For field strengths near the TLV, shock and burn hazards can exist. Care should be taken to eliminate ungrounded objects, to ground such objects, or use insulated gloves when ungrounded objects must be handled.

TABLE 14

Radiofrequency/Microwave Threshold Limit Values

Frequency	Power Density (mW/cm^2)†	Electric Field Strength Squared (V^2/m^2)	Magnetic Field Strength Squared (A^2/m^2)
10 kHz to 3 MHz	100	377,000	2.65
3 MHz to 30 MHz	$900/f^{2*}$	$3770 \times 900/f^{2*}$	$900/37.7f^{2*}$
30 MHz to 100 MHz	1	3770	0.027
100 MHz to 1000 MHz	$f^*/100$	$3770 \times f^*/100$	$f^*/37.7 \times 100$
1 GHz to 300 GHz	10	37,700	0.265

† mW/cm^2 = milliwatts per centimeter squared
* f = frequency in MHz

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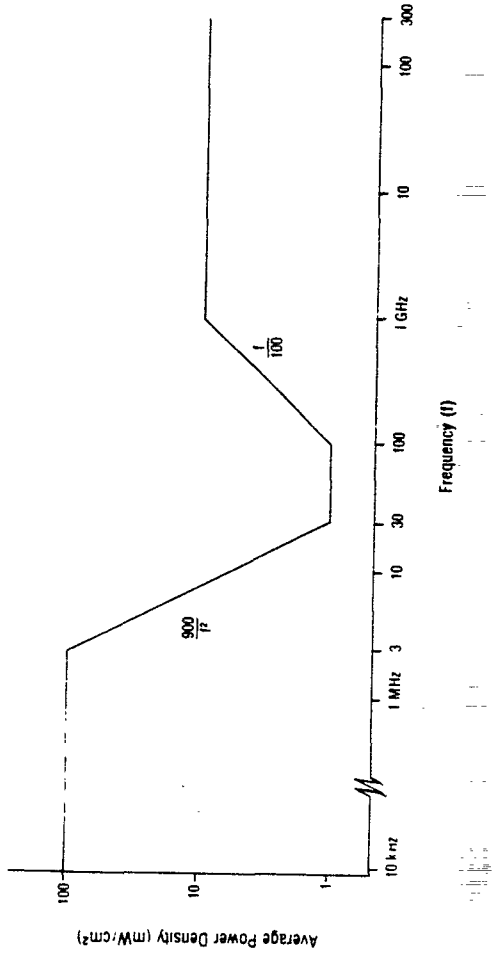


Figure 9 — Threshold Limit Values (TLV) for Radiofrequency/Microwave Radiation in Workplace (Whole Body SAR Less Than 0.4 W/kg).

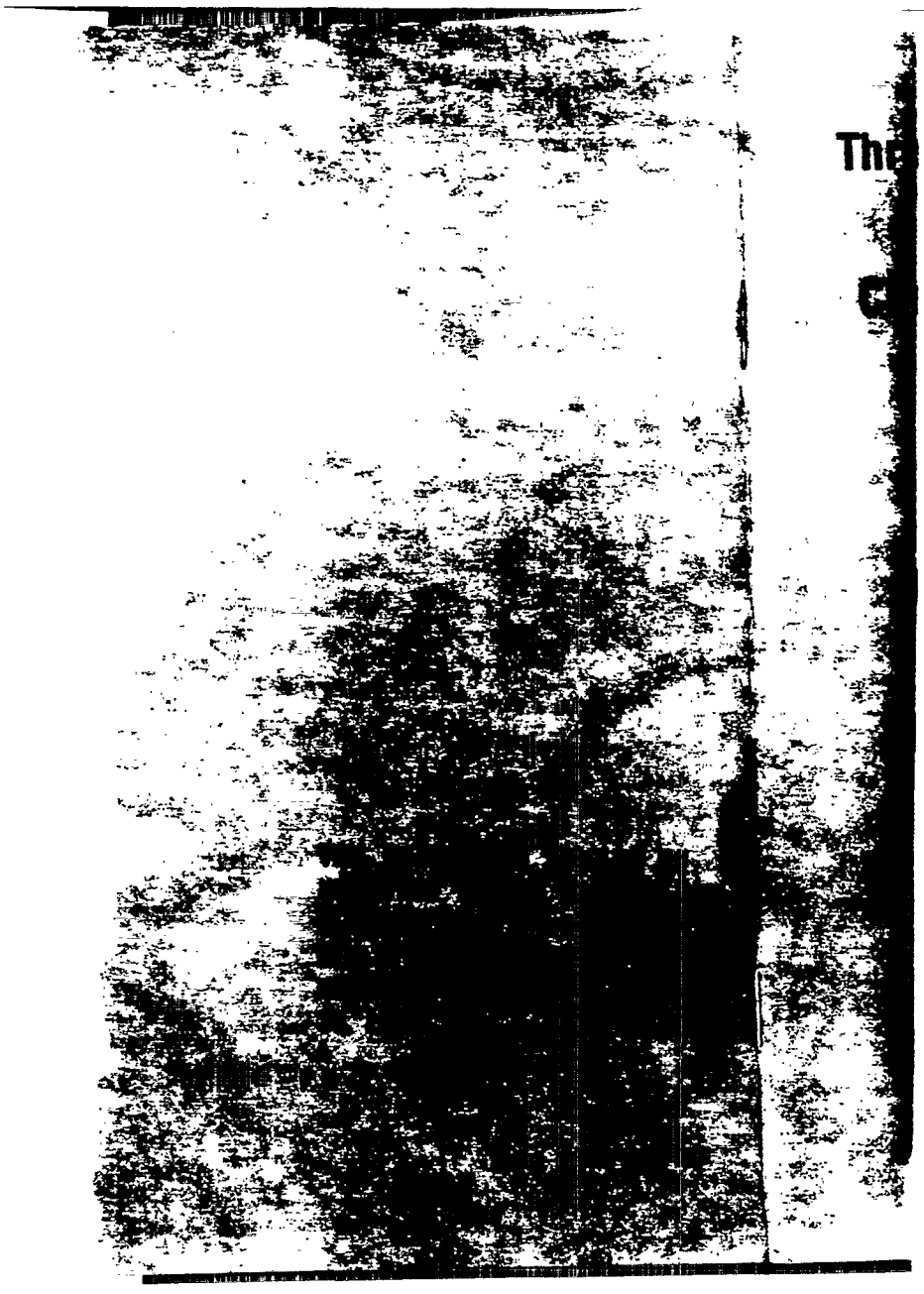
7. No measurement should be made within 5 cm of any object.
8. All exposures should be limited to a maximum (peak) electric field intensity of 100 kV/m.

PHYSICAL AGENTS UNDER STUDY

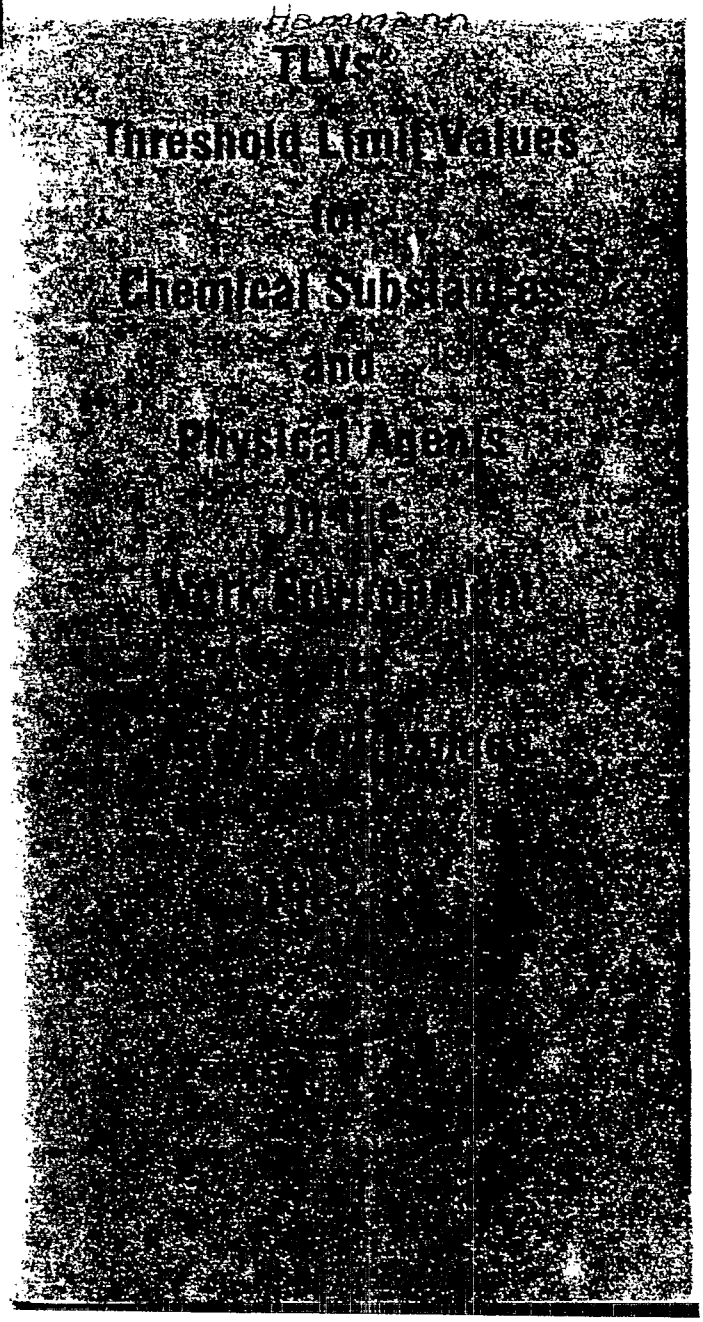
The Physical Agents Committee of ACGIH has examined the current literature and has not found sufficient information to propose a TLV. However, these agents will remain under study during the coming year to examine new evidence indicating the need and feasibility for establishing a proposed TLV. Comments and suggestions, accompanied by substantive documentation are solicited and should be forwarded to the Executive Secretary, ACGIH, Documentation summarizing the current status of the biological effects literature is available on those agents preceded by an asterisk (*).

1. **Extremely Low Frequency (ELF) Radiation*. Specifically, that portion of the spectrum from 0 to 300 Hz.
2. *Magnetic Fields*. Both pulsed and *continuous.
3. *Laser Radiation*. Specifically laser exposures of less than one (1) nanosecond.
4. *Vibration*. Segmental and whole-body.
5. *Cold Stress*.
6. *Pressure Variations*.

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for 1983-84



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PREFACE
CHEMICAL SUBSTANCES

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.

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 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.

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 control of community air pollution nuisances, (3) in estimating the toxic potential of continuous, uninterrupted exposures or other extended work periods, (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.

The TLV-TWA should be used as guides in the control of health hazards and should not be used as fine lines between safe and dangerous concentrations.

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.

Legal Status. The Threshold Limit Values, as issued by ACGIH, are recommendations and should be used as guidelines for good practices. Wherever these values (of whatever year) have been used or included by reference in Federal and or State statutes and registers, the TLVs do have the force and effects of law.

"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. Values listed in parenthesis in the "Adopted" list are to be used during the period in which a proposed change for that Value is listed in the Notice of Intended Changes.

Definitions. Three categories of Threshold Limit Values (TLVs) are specified herein, as follows:

a) The Threshold Limit Value-Time Weighted Average (TLV-TWA) — the time-weighted average concentration for a normal 8-hour workday and a 40-hour workweek, to which nearly all workers may be repeatedly exposed, day after day, without adverse effect.

b) Threshold Limit Value-Short Term Exposure Limit (TLV-STEL) — the concentration to which workers can be exposed continuously for a short period of time without suffering from 1) irritation, 2) chronic or irreversible tissue damage, or 3) narcosis of sufficient degree to increase the likelihood of accidental injury, impair self-rescue or materially reduce work efficiency, and provided that the daily TLV-TWA is not exceeded. It is not a separate independent exposure limit, rather it supplements the time-weighted average (TWA) limit where there are recognized acute effects from a substance whose toxic effects are primarily of a chronic nature. STELs are recommended only where toxic effects have been reported from high short-term exposures in either humans or animals.

A STEL is defined as a 15-minute time-weighted average exposure which should not be exceeded at any time during a work day even if the eight-hour

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time-weighted average is within the TLV. Exposures at the STEL should not be longer than 15 minutes and should not be repeated more than four times per day. There should be at least 60 minutes between successive exposures at the STEL. An averaging period other than 15 minutes may be recommended when this is warranted by observed biological effects.

c) Threshold Limit Value-Ceiling (TLV-C) — the concentration that should not be exceeded even instantaneously.

For some substances, e.g., irritant gases, only one category, the TLV-Ceiling, may be relevant. For other substances, either two or three categories may be relevant, depending upon their physiologic action. It is important to observe that if any one of these three TLVs is exceeded, a potential hazard from that substance is presumed to exist.

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.

Time-Weighted Average vs Ceiling Limits. 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 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 a decision as to whether a hazardous condition exists.

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 noncompliance 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. It should be noted that the same factors are used by the Committee in determining the magnitude of the value of the STELs, or whether to include or exclude a substance for a "C" listing.

Excursion Limits. For the vast majority of substances with a TLV, there is not enough toxicological data available to warrent a STEL. Nevertheless, excursions above the TWA-TLV should be controlled even where the eight-hour TWA is within recommended limits. Earlier editions of the TLV list included such limits whose values depended on the TWA-TLVs of the substance in question.

While no rigorous rationale was provided for these particular values, the basic concept was intuitive: in a well controlled process exposure, excursions should be held within some reasonable limits. Unfortunately, neither toxicology nor collective industrial hygiene experience provide a solid basis for quantifying what those limits should be. The approach here is that the maximum recommended excursion should be related to the variability generally observed in actual industrial processes. Leidel, Busch and Crouse,* in reviewing large numbers of industrial hygiene surveys conducted by NIOSH, found that short-term exposure measurements were generally log normally distributed with geometric standard deviations mostly in the range of 1.5 to 2.0.

While a complete discussion of the theory and properties of the log normal distribution is beyond the scope of this section, a brief description of some important terms is presented. The measure of central tendency in a log normal distribution is the antilog of the mean logarithm of the sample values. The distri-

*Leidel, N.A., K.A. Busch and W.E. Crouse: *Exposure Measurement, Action Level and Occupational Environmental Variability*. NIOSH Pub. No 76-131 (December 1975).

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bution is skewed and the geometric mean is always smaller than the arithmetic mean by an amount which depends on the geometric standard deviation. In the log normal distribution, the geometric standard deviation (sd_g) is the antilog of the standard deviation of the sample value logarithms and 68.26% of all values lie between m_g/sd_g and $m_g \times sd_g$.

If the short-term exposure values in a given situation have a geometric standard deviation of 2.0, 5% of all values exceed 3.13 times the geometric mean. If a process displays a variability greater than this, it is not under good control and efforts should be made to restore control. This concept is the basis for the new excursion limit recommendations which are as follows:

> *Short-term exposures should exceed three times the TLV-TWA for no more than a total of 30 minutes during a work day and under no circumstances should they exceed five times the TLV, provided that the TLV-TWA is not exceeded.*

The approach is a considerable simplification of the idea of the log normal concentration distribution but is considered more convenient to use by the practicing industrial hygienist. If exposure excursions are maintained within the recommended limits, the geometric standard deviation of the concentration measurements will be near two and the goal of the recommendation will be accomplished.

When the toxicologic data for a specific substance are available to establish a STEL, this value takes precedence over the excursion limit regardless of whether it is more or less stringent.

"Skin" Notation. Listed substances followed by the designation "Skin" refer to the potential contribution to the overall exposure by the cutaneous route including mucous membranes and eye, either by air borne, or more particularly, by direct contact with the substance. Vehicles can alter skin absorption.

Little quantitative data are available describing absorption of vapors and gases through the skin. The rate of absorption is a function of the concentration to which the skin is exposed.

Substances having a skin notation and a low TLV may present a problem at high airborne concentrations, particularly if a significant area of the skin is exposed for a long period of time. Protection of the respiratory tract, while the rest of the body surface is exposed to a high concentration, may present such a situation.

Biological monitoring should be considered to determine the relative contribution of dermal exposure to the total dose.

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, may cause unpleasant deposits in the eyes, ears and nasal 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 10 mg/m³, or 30 mppcf, of total dust < 1% quartz, or, 5 mg/m³ respirable dust 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 D.

Simple Asphyxiants — "Inert" Gases or Vapors. A number of gases and vapors, when present in high concentrations in air, act primarily as simple asphyx-

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iants 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 E.

Physical Factors. It is recognized that such physical factors as heat, ultraviolet and ionizing 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 may be altered. Most of these stresses act adversely 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 BLVs, and their associated procedures for determining compliance with them, should thus be regarded as an effective means of providing health surveillance of the worker.

Tests are available (*J. Occup. Med. 15*:564, 1973; *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).

Unlisted Substances. Many substances present or handled in industrial processes do not appear on the TLV list. In a number of instances the material is rarely present as a particulate, vapor or other airborne contaminant, and a TLV is not necessary. In other cases sufficient information to warrant development of a TLV, even on a tentative basis, is not available to the Committee. Other substances, of low toxicity could be included in Appendix D pertaining to nuisance particulates. This list (as well as Appendix E) is not meant to be all inclusive; the substances serve only as examples.

In addition there are some substances of not in considerable toxicity, which have been omitted primarily because only a limited number of workers (e.g., employees of a single plant) are known to have potential exposure to possibly harmful concentrations.

Trade names. Because many chemical substances are marketed under several trade names, the trade names have been replaced with their generic equivalent in the alphabetical listing. Appendix H was created to ease this transition and the CAS number appears with the generic name to aid identification.

Operational Guidelines: The ACGIH Board of Directors has adopted operational guidelines for the Chemical Substances TLV Committee. These guidelines prescribe: charge, authority, policies, membership, organization, and operating procedures. The policies include the appeals procedures. Copies of the guidelines document are available from the Publications Office at a cost of $5 per copy.

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Substance [CAS #]	ADOPTED VALUES TWA ppm[a]	TWA mg/m³[b]	STEL ppm[a]	STEL mg/m³[b]
Acetaldehyde [75-07-0]	100	180	150	270
Acetic acid [64-19-7]	10	25	15	37
Acetic anhydride [108-24-7]	C 5	C 20	—	—
Acetone [67-64-1]	750	1,780	1,000	2,375
Acetonitrile [75-05-8] — Skin	40	70	60	105
Acetylene [74-86-2]	E	—	—	—
Acetylene dichloride, see 1, 2-Dichloroethylene				
Acetylene tetrabromide [79-27-6]	1	15	1.5	20
Acetylsalicylic acid (Aspirin) [50-78-2]	—	5	—	—
Acrolein [107-02-8]	0.1	0.25	0.3	0.8
Acrylamide [79-06-1] — Skin	—	0.3	—	0.6
Acrylic acid [79-10-7]	10	30	—	—
‡Acrylonitrile [107-13-1] — Skin	(2, A1a)	(4.5, A1a)	—	—
Aldrin [309-00-2] — Skin	—	0.25	—	0.75
Allyl alcohol [107-18-6] — Skin	2	5	4	10
Allyl chloride [107-05-1]	1	3	2	6
Allyl glycidyl ether (AGE) [106-92-3] — Skin	5	22	10	44
Allyl propyl disulfide [2179-59-1]	2	12	3	18
α-Alumina [1344-28-1]	—	D	—	20
Aluminum [7429-90-5]				
Metal & oxide	—	10	—	20
Pyro powders	—	5	—	—
Welding fumes	—	5	—	—
Soluble salts	—	2	—	—
Alkyls (NOC†)	—	2	—	—
4-Aminodiphenyl [92-67-1] — Skin	—	A1b	—	A1b
2-Aminoethanol, see Ethanolamine				
2-Aminopyridine [504-29-0]	0.5	2	2	4
3-Amino 1, 2, 4-triazole, see Amitrol				
Amitrol [61-82-5]	A2	A2	—	—
Ammonia [7664-41-7]	25	18	35	27

Capital letters A, B, D & E refer to Appendices; C denotes ceiling limit.
Footnotes (a thru f) see Page 35
‡See Notices of Intended Changes
†NOC = Not otherwise classified

Substance [CAS #]	ADOPTED VALUES TWA ppm[a]	TWA mg/m³[b]	STEL ppm[a]	STEL mg/m³[b]
Ammonium chloride fume [12125-02-9]	—	10	—	20
Ammonium sulfamate [7773-06-0]	—	10	—	20
n-Amyl acetate [628-63-7]	100	530	150	800
sec-Amyl acetate [626-38-0]	125	670	150	800
Aniline [62-53-3] & homologues — Skin	2	10	5	20
Anisidine [29191-52-4] (o-, p-isomers) — Skin	0.1	0.5	—	—
Antimony [7440-36-0] & compounds, as Sb	—	0.5	—	—
Antimony trioxide [1309-64-4]				
Handling and use, as Sb	—	0.5	—	—
Production	—	A2	—	—
ANTU [86-88-4]	—	0.3	—	0.9
Argon [7440-37-1]	E	—	—	—
Arsenic [7440-38-2] & soluble compounds, as As	—	0.2	—	—
Arsenic trioxide production [1327-53-3]	—	A2	—	—
Arsine [7784-42-1]	0.05	0.2	—	—
Asbestos [1332-21-4], see MINERAL DUSTS	—	A1a	—	A1a
Asphalt (petroleum) fumes [8052-42-4]	—	5	—	10
*Atrazine [1912-24-9]	—	5	—	—
Azinphos-methyl [86-50-0] — Skin	—	0.2	—	0.6
Barium [7440-39-3], soluble compounds, as Ba	—	0.5	—	—
Benomyl [17804-35-2]	0.8	10	1.3	15
Benzene [71-43-2]	10, A2	30, A2	25, A2	75, A2
Benzidine [92-87-5] — Skin	—	A1b	—	A1b
p-Benzoquinone, see Quinone				
Benzoyl peroxide [94-36-0]	—	5	—	—
Benzo(a)pyrene [50-32-8]	—	A2	—	A2
Benzyl chloride [100-44-7]	1	5	—	—

Capital letters A, B, D & E refer to Appendices; C denotes ceiling limit.
Footnotes (a thru f) see Page 35.
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Substance [CAS #]	ADOPTED VALUES TWA ppm[a]	TWA mg/m³[b]	STEL ppm[a]	STEL mg/m³[b]
Beryllium [7440-41-7]	—	0.002, A2	—	—
Biphenyl [92-52-4]	0.2	1.5	0.6	4
Bismuth telluride [1304-82-1]	—	10	—	20
Se-doped	—	5	—	10
Borates, tetra, sodium salts [1303-96-4], Anhydrous	—	1	—	—
Decahydrate	—	5	—	—
Pentahydrate	—	1	—	—
Boron oxide [1303-86-2]	—	10	—	20
Boron tribromide [10294-33-4]	1	10	3	30
Boron trifluoride [7637-07-2]	C 1	C 3	—	—
Bromacil [314-40-9]	1	10	2	20
Bromine [7726-95-6]	0.1	0.7	0.3	2
Bromine pentafluoride [7789-30-2]	0.1	0.7	0.3	2
Bromochloromethane, see Chlorobromomethane				
Bromoform [75-25-2] — Skin	0.5	5	—	—
‡ 1, 3-Butadiene [106-99-0]	(1,000)	(2,200)	(1,250)	(2,750)
Butane [106-97-8]	800	1,900	—	—
Butanethiol, see Butyl mercaptan				
2-Butanone, see Methyl ethyl ketone (MEK)				
2-Butoxyethanol [111-76-2] — Skin	25	120	75	360
n-Butyl acetate [123-86-4]	150	710	200	950
sec-Butyl acetate [105-46-4]	200	950	250	1,190
tert-Butyl acetate [540-88-5]	200	950	250	1,190
Butyl acrylate [141-32-2]	10	55	—	—
n-Butyl alcohol [71-36-3] — Skin	C 50	C 150	—	—
sec-Butyl alcohol [78-92-2]	100	305	150	455
tert-Butyl alcohol [75-65-0]	100	300	150	450
Butylamine [109-73-9] — Skin	C 5	C 15	—	—
tert-Butyl chromate, as CrO_3 [1189-85-1] — Skin	—	C 0.1	—	—

Capital letters A, B, D & E refer to Appendices. C denotes ceiling limit.
Footnotes (a thru f) see Page 35
‡See Notice of Intended Changes

Substance [CAS #]	ADOPTED VALUES TWA ppm[a]	TWA mg/m³[b]	STEL ppm[a]	STEL mg/m³[b]
n-Butyl glycidyl ether (BGE) [2426-08-6]	25	135	—	—
n-Butyl lactate [138-22-7]	5	25	—	—
Butyl mercaptan [109-79-5]	0.5	1.5	—	—
o-sec-Butylphenol [89-72-5] — Skin	5	30	—	—
p-tert-Butyltoluene [98-51-1]	10	60	20	120
Cadmium [7440-43-9] Dust & salts, as Cd	—	0.05	—	0.2
Cadmium oxide [1306-19-0] Fume, as Cd	—	C 0.05	—	—
* Production	—	0.05	—	—
Calcium carbonate/ marble [1317-65-3]	—	D	—	20
Calcium cyanamide [156-62-7]	—	0.5	—	1
Calcium hydroxide [1305-62-0]	—	5	—	—
Calcium oxide [1305-78-8]	—	2	—	—
Calcium silicate [1344-95-2]	—	D	—	—
Camphor, synthetic [76-22-2]	2	12	3	18
Caprolactam [105-60-2] Dust	—	1	—	3
Vapor	5	20	10	40
Captafol [2425-06-1] — Skin	—	0.1	—	—
Captan [133-06-2]	—	5	—	15
Carbaryl [63-25-2]	—	5	—	10
Carbofuran [1563-66-2]	—	0.1	—	—
Carbon black [1333-86-4]	—	3.5	—	7
Carbon dioxide [124-38-9]	5,000	9,000	15,000	27,000
Carbon disulfide [75-15-0] — Skin	10	30	—	—
Carbon monoxide [630-08-0]	50	55	400	440
Carbon tetrabromide [558-13-4]	0.1	1.4	0.3	4

Capital letters A, B, D & E refer to Appendices; C denotes ceiling limit.
Footnotes (a thru f) see Page 35.
*1983 Addition.

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Substance [CAS #]	ADOPTED VALUES TWA ppm[a]	TWA mg/m³[b]	STEL ppm[a]	STEL mg/m³[b]
Carbon tetrachloride [56-23-5] — Skin	5, A2	30, A2	20, A2	125, A2
Carbonyl chloride, see Phosgene				
Carbonyl fluoride [353-50-4]	2	5	5	15
Catechol (Pyrocatechol) [120-80-9]	5	20	—	—
Cellulose (paper fiber) [9004-34-6]	—	D	—	20
Cesium hydroxide [21351-79-1]	—	2	—	—
Chlordane [57-74-9] — Skin	—	0.5	—	2
Chlorinated camphene [8001-35-2] — Skin	—	0.5	—	1
Chlorinated diphenyl oxide [55720-99-5]	—	0.5	—	2
Chlorine [7782-50-5]	1	3	3	9
Chlorine dioxide [10049-04-4]	0.1	0.3	0.3	0.9
Chlorine trifluoride [7790-91-2]	C 0.1	C 0.4	—	—
Chloroacetaldehyde [107-20-0]	C 1	C 3	—	—
α-Chloroacetophenone [532-27-4] (Phenacyl chloride)	0.05	0.3	—	—
Chloroacetyl chloride [79-04-9]	0.05	0.2	—	—
Chlorobenzene [108-90-7] (Monochlorobenzene)	75	350	—	—
*o-Chlorobenzylidene malononitrile [2698-41-1] — Skin	C 0.05	C 0.4	—	—
Chlorobromomethane [74-97-5]	200	1,050	250	1,300
2-Chloro-1, 3-butadiene, see β Chloroprene				
Chlorodifluoromethane [75-45-6]	1,000	3,500	1,250	4,375
Chlorodiphenyl (42% Chlorine) [53469-21-9] — Skin	—	1	—	2

Capital letters A, B, D & E refer to Appendices; C denotes ceiling limit.
Footnotes (a thru f) see Page 35
*1983 Addition.

Substance [CAS #]	ADOPTED VALUES TWA ppm[a]	TWA mg/m³[b]	STEL ppm[a]	STEL mg/m³[b]
Chlorodiphenyl (54% Chlorine) [11097-69-1] — Skin	—	0.5	—	1
1-Chloro, 2, 3-epoxy-propane, see Epichlorohydrin				
2-Chloroethanol, see Ethylene chlorohydrin				
Chloroethylene, see Vinyl chloride				
Chloroform [67-66-3]	10, A2	50, A2	50, A2	225, A2
bis-Chloromethyl ether [542-88-1]	0.001, A1a	0.005, A1a	—	—
*Chloromethyl methyl ether [107-30-2]	A2	A2	—	—
1-Chloro-1-nitropropane [600-25-9]	2	10	—	—
Chloropentafluoroethane [76-15-3]	1,000	6,320	—	—
Chloropicrin [76-06-2]	0.1	0.7	0.3	2
β-Chloroprene [126-99-8] — Skin	10	45	—	—
o-Chlorostyrene [1331-28-8]	50	285	75	430
o-Chlorotoluene [95-49-8] — Skin	50	250	75	375
2-Chloro- 6-(trichloromethyl) pyridine, see Nitrapyrin				
Chlorpyrifos [2921-88-2] — Skin	—	0.2	—	0.6
Chromite ore processing (Chromate), as Cr.	—	0.05, A1a	—	—
Chromium [7440-47-3] Metal	—	0.5	—	—
Chromium (II) compounds, as Cr	—	0.5	—	—
Chromium (III) compounds, as Cr.	—	0.5	—	—
Chromium (VI) compounds, as Cr				
Water soluble	—	0.05	—	—
Certain water insoluble	—	0.05, A1a	—	—
Chromyl chloride [14977-61-8]	0.025	0.15	—	—
Chrysene [218-01-9]	A2	A2	—	—
Clopidol [2971-90-6]	—	10	—	20

Capital letters A, B, D & E refer to Appendices; C denotes ceiling limit.
Footnotes (a thru f) see Page 35.
*1983 Addition.

MAP 000427

Substance [CAS #]	ADOPTED VALUES TWA ppm[a]	TWA mg/m³[b]	STEL ppm[a]	STEL mg/m³[b]
Coal tar pitch volatiles [8007-45-2], as benzene solubles	—	0.2, A1a	—	—
‡Cobalt [7440-48-4], as Co metal, dust & fume	—	(0.1)	—	—
*Cobalt carbonyl [00000-00-0], as Co	—	0.1	—	—
*Cobalt hydrocarbonyl [16842-03-8], as Co	—	0.1	—	—
Copper [7440-50-8] Fume	—	0.2	—	—
Dusts & mists, as Cu	—	1	—	2
Cotton dust, raw	—	0.2[k]	—	0.6
Cresol [1319-77-3], all isomeres — Skin	5	22	—	—
Crotonaldehyde [123-73-9]	2	6	6	18
Crufomate [299-86-5]	—	5	—	20
Cumene [98-82-8] — Skin	50	245	75	365
Cyanamide [420-04-2]	—	2	—	—
Cyanides [151-50-8, 143-33-9], as CN — Skin	—	5	—	—
Cyanogen [460-19-5]	10	20	—	—
Cyanogen chloride [506-77-4]	C 0.3	C 0.6	—	—
Cyclohexane [110-82-7]	300	1,050	375	1,300
Cyclohexanol [108-93-0]	50	200	—	—
Cyclohexanone [108-94-1]	25	100	100	400
Cyclohexene [110-83-8]	300	1,015	—	—
Cyclohexylamine [108-91-8] — Skin	10	40	—	—
Cyclonite [121-82-4] — Skin	—	1.5	—	3
Cyclopentadiene [542-92-7]	75	200	150	400
Cyclopentane [287-92-3]	600	1,720	900	2,580
Cyhexatin [13121-70-5]	—	5	—	10
2, 4-D [94-75-7]	—	10	—	20
DDT (Dichlorodiphenyl-trichloroethane) [50-29-3]	—	1	—	3

Capital letters A, B, D & E refer to Appendices; C denotes ceiling limit
Footnotes (a thru f) see Page 35
*1983 Addition.
‡See Notice of Intended Changes
k) See p. 38

Substance [CAS #]	ADOPTED VALUES TWA ppm[a]	TWA mg/m³[b]	STEL ppm[a]	STEL mg/m³[b]
Decaborane [17702-41-9] — Skin	0.05	0.3	0.15	0.9
Demeton [8065-48-3] — Skin	0.01	0.1	0.03	0.3
Diacetone alcohol [123-42-2]	50	240	75	360
1, 2-Diaminoethane, see Ethylenediamine				
Diazinon [333-41-5] — Skin	—	0.1	—	0.3
Diazomethane [334-88-3]	0.2	0.4	—	—
Diborane [19287-45-7]	0.1	0.1	—	—
1, 2-Dibromoethane, see Ethylene dibromide				
2-N-Dibutylaminoethanol [102-81-8] — Skin	2	14	4	28
Dibutyl phosphate	1	5	2	10
Dibutyl phthalate [84-74-2]	—	5	—	10
Dichloroacetylene [7572-29-4]	C 0.1	C 0.4	—	—
o-Dichlorobenzene [95-50-1]	C 50	C 300	—	—
p-Dichlorobenzene [106-46-7]	75	450	110	675
3, 3'-Dichlorobenzidine [91-94-11] — Skin	—	A2	—	A2
Dichlorodifluoromethane [75-71-8]	1,000	4,950	1,250	6,200
1, 3-Dichloro-5, 5-dimethyl hydantoin [118-52-5]	—	0.2	—	0.4
1, 1-Dichloroethane [75-34-3]	200	810	250	1,010
1, 2-Dichloroethane, see Ethylene dichloride				
1, 1-Dichloroethylene, see Vinylidene chloride				
1, 2-Dichloroethylene [540-59-0]	200	790	250	1,000
Dichloroethyl ether [111-44-4] — Skin	5	30	10	60
Dichlorofluoromethane [75-43-4]	10	40	—	—
Dichloromethane, see Methylene chloride				
1, 1-Dichloro-1-nitroethane [594-72-9]	2	10	10	60
1, 2-Dichloropropane, see Propylene dichloride				
Dichloropropene [542-75-6] — Skin	1	5	10	50

Capital letters A, B, D & E refer to Appendices, C denotes ceiling limit
Footnotes (a thru f) see Page 35.

MAP 000428

Substance [CAS #]	ADOPTED VALUES TWA ppm[a]	TWA mg/m³[b]	STEL ppm[a]	STEL mg/m³[b]
2, 2-Dichloropropionic acid [75-99-0]	1	6	—	—
Dichlorotetrafluoroethane [76-14-2]	1,000	7,000	1,250	8,750
Dichlorvos [62-73-7] — Skin	0.1	1	0.3	3
Dicrotophos [141-66-2] — Skin	—	0.25	—	—
Dicyclopentadiene [77-73-6]	5	30	—	—
Dicyclopentadienyl iron [102-54-5]	—	10	—	20
Dieldrin [60-57-1] — Skin	—	0.25	—	0.75
Diethanolamine [111-42-2]	3	15	—	—
Diethylamine [109-89-7]	10	30	25	75
Diethylaminoethanol [100-37-8] — Skin	10	50	—	—
Diethylene triamine [111-40-0] — Skin	1	4	—	—
Diethyl ether, see Ethyl ether				
Diethyl ketone [96-22-0]	200	705	—	—
Diethyl phthalate [84-66-2]	—	5	—	10
Difluorodibromomethane [75-61-6]	100	860	150	1,290
Diglycidyl ether (DGE) [2238-07-5]	0.1	0.5	—	—
Dihydroxybenzene, see Hydroquinone				
Diisobutyl ketone [108-83-8]	25	150	—	—
Diisopropylamine [108-18-9] — Skin	5	20	—	—
Dimethoxymethane, see Methylal				
Dimethyl acetamide [127-19-5] — Skin	10	35	15	50
Dimethylamine [124-40-3]	10	18	—	—
Dimethylaminobenzene, see Xylidene				
Dimethylaniline [121-69-7] (N, N-Dimethylaniline) — Skin	5	25	10	50
Dimethylbenzene, see Xylene				
Dimethyl carbamyl chloride [79-44-7]	A2	A2	—	—
Dimethyl-1, 2-dibromo-2-dichloroethyl phosphate, see Naled				
Dimethylformamide [68-12-2] — Skin	10	30	20	60

Capital letters A, B, D, & E refer to Appendices; C denotes ceiling limit.
Footnotes (a thru f) see Page 35.

Substance [CAS #]	ADOPTED VALUES TWA ppm[a]	TWA mg/m³[b]	STEL ppm[a]	STEL mg/m³[b]
2, 6-Dimethyl-4-heptanone, see Diisobutyl ketone				
1, 1-Dimethylhydrazine [57-14-7] — Skin	0.5, A2	1, A2	1, A2	2, A2
Dimethylphthalate [131-11-3]	—	5	—	10
Dimethyl sulfate [77-78-1] — Skin	0.1, A2	0.5, A2	—	—
Dinitolmide [148-01-6]	—	5	—	10
Dinitrobenzene [528-29-0] (all isomers) — Skin	0.15	1	0.5	3
Dinitro-o-cresol [534-52-1] — Skin	—	0.2	—	0.6
3, 5-Dinitro-o-toluamide, see Dinitolmide				
Dinitrotoluene [121-14-2] — Skin	—	1.5	—	5
Dioxane, tech. grade [123-91-1] — Skin	25	90	100	360
Dioxathion [78-34-2] — Skin	—	0.2	—	—
Diphenyl, see Biphenyl				
Diphenylamine [122-39-4]	—	10	—	20
Diphenylmethane diisocyanate, see Methylene bisphenyl isocyanate				
Dipropylene glycol methyl ether [34590-94-8]	100	600	150	900
Dipropyl ketone [123-19-3]	50	235	—	—
Diquat [85-00-7]	—	0.5	—	1
Di-sec, octyl phthalate [117-81-7] (Di-2-ethyl-hexyiphthalate)	—	5	—	10
Disulfiram [97-77-8]	—	2	—	5
Disulfoton [298-04-4]	—	0.1	—	0.3
2, 6-Ditert. butyl-p-cresol [128-37-0]	—	10	—	20
Diuron [330-54-1]	—	10	—	—
Divinyl benzene [108-57-6]	10	50	—	—
Emery [112-62-9]	—	D	—	20
Endosulfan [115-29-7] — Skin	—	0.1	—	0.3
Endrin [72-20-8] — Skin	—	0.1	—	0.3
Epichlorohydrin [106-89-8] — Skin	2	10	5	20
EPN [2104-64-5] — Skin	—	0.5	—	2
1, 2-Epoxypropane, see Propylene oxide				
2, 3-Epoxy-1-propanol, see Glycidol				
Ethane [74-84-0]	E	—	—	—

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Footnotes (a thru f) see Page 35.

MAP 000429

Substance [CAS #]	ADOPTED VALUES TWA ppm[a]	TWA mg/m³[b]	STEL ppm[a]	STEL mg/m³[b]
Ethanethiol, see Ethyl mercaptan				
Ethanolamine [141-43-5]	3	8	6	15
Ethion [563-12-2] — Skin	—	0.4	—	—
‡2-Ethoxyethanol [110-80-5] — Skin	(50)	(185)	(100)	(370)
‡2-Ethoxyethyl acetate [111-15-9] — Skin	(50)	(270)	(100)	(540)
Ethyl acetate [141-78-6]	400	1,400	—	—
Ethyl acrylate [140-88-5] — Skin	5	20	25	100
Ethyl alcohol (Ethanol) [64-17-5]	1,000	1,900	—	—
Ethylamine [75-04-7]	10	18	—	—
Ethyl amyl ketone [41-85-5]	25	130	—	—
Ethyl benzene [100-41-4]	100	435	125	545
Ethyl bromide [74-96-4]	200	890	250	1,110
Ethyl butyl ketone [106-35-4]	50	230	75	345
Ethyl chloride [75-00-3]	1,000	2,600	1,250	3,250
Ethylene [74-85-1]	E	—	—	—
Ethylene chlorohydrin [107-07-3] — Skin	C 1	C 3	—	—
Ethylenediamine [107-15-3]	10	25	—	—
Ethylene dibromide [106-93-4] — Skin	A2	A2	—	—
Ethylene dichloride [107-06-2]	10	40	15	60
Ethylene glycol [107-21-1]				
‡ Particulate	—	(10)	—	(20)
Vapor	C 50	C 125	—	—
*‡Ethylene glycol dinitrate [628-96-6] — Skin	0.05	0.3	(0.1)	(0.6)
Ethylene glycol methyl ether acetate, see 2-Methoxyethyl acetate				
‡ Ethylene oxide [75-21-8]	(10)	(20)	—	—
Ethyleneimine [151-56-4] — Skin	0.5	1	—	—
Ethyl ether [60-29-7]	400	1,200	500	1,500
Ethyl formate [109-94-4]	100	300	150	450
Ethylidene chloride, see 1, 1-Dichloroethane				
Ethylidene norbornene [16219-75-3]	C 5	C 25	—	—

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Footnotes (a thru f) see Page 35.
*1983 Addition
‡See Notice of Intended Changes.

Substance [CAS #]	ADOPTED VALUES TWA ppm[a]	TWA mg/m³[b]	STEL ppm[a]	STEL mg/m³[b]
Ethyl mercaptan [75-08-1]	0.5	1	2	3
N-Ethylmorpholine [100-74-3] — Skin	5	23	20	95
Ethyl silicate [78-10-4]	10	85	30	255
Fensulfothion [115-90-2]	—	0.1	—	—
*Fenthion [55-38-9] — Skin	—	0.2	—	—
Ferbam [14484-64-1]	—	10	—	20
Ferrovanadium dust [12604-58-9]	—	1	—	3
Fibrous[cn] glass dust	—	10	—	—
Fluorides, as F	—	2.5	—	—
Fluorine [7782-41-4]	1	2	2	4
Fluorotrichloromethane, see Trichlorofluoromethane				
Fonofos [944-22-9] — Skin	—	0.1	—	—
‡Formaldehyde [50-00-0]	(C 2)	(C 3)	—	—
Formamide [75-12-7]	20	30	30	45
Formic acid [64-18-6]	5	9	—	—
Furfural [98-01-1] — Skin	2	8	10	40
Furfuryl alcohol [98-00-0] — Skin	10	40	15	60
Gasoline [8006-61-9]	300	900	500	1,500
Germanium tetrahydride [7782-65-2]	0.2	0.6	0.6	1.8
Glass, fibrous or dust, see Fibrous glass dust				
Glutaraldehyde [111-30-8]	C 0.2	C 0.7	—	—
Glycerin mist [56-81-5]	—	D	—	—
Glycidol [556-52-5]	25	75	100	300
Glycol monoethyl ether, see 2-Ethoxyethanol				
Graphite (Natural) [7782-42-5], see MINERAL DUSTS				
Graphite (Synthetic)	—	D	—	—
Gypsum [10101-4-4]	—	D	—	20
Hafnium [7440-58-6]	—	0.5	—	1.5
Helium [7440-59-7]	E	—	—	—
Heptachlor [76-44-8] — Skin	—	0.5	—	2
Heptane [142-82-5] (n-Heptane)	400	1,600	500	2,000
2-Heptanone, see Methyl n-amyl ketone				
3-Heptanone, see Ethyl butyl ketone				
Hexachlorobutadiene [76-68-3]	0.02, A2	0.24, A2	—	—

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Footnotes (a thru f) see Page 35.
*1983 Addition.
‡See Notice of Intended Changes.

MAP 000430

Substance [CAS #]	ADOPTED VALUES TWA ppm[a]	TWA mg/m³[b]	STEL ppm[a]	STEL mg/m³[b]
Hexachlorocyclopenta-diene [77-47-4]	0.01	0.1	0.03	0.3
Hexachloroethane [67-72-1]	10	100	—	—
Hexachloronaphthalene [1335-87-1] — Skin	—	0.2	—	0.6
Hexafluoroacetone [684-16-2] — Skin	0.1	0.7	0.3	2
Hexamethyl phosphoramide [680-31-9] — Skin	A2	A2	—	—
Hexane (n-Hexane) [110-54-3]	50	180	—	—
Other isomeres	500	1,800	1,000	3,600
2-Hexanone, see Methyl n-butyl ketone				
Hexone, see Methyl isobutyl ketone				
sec-Hexyl acetate [142-92-7]	50	300	—	—
Hexylene glycol [107-41-5]	C 25	C 125	—	—
Hydrazine [302-01-2] — Skin	0.1, A2	0.1, A2	—	—
Hydrogen [1333-74-0]	E	—	—	—
Hydrogenated terphenyls [92-94-4]	0.5	5	—	—
Hydrogen bromide [10035-10-6]	3	10	—	—
Hydrogen chloride [7647-01-0]	C 5	C 7	—	—
Hydrogen cyanide [74-90-8] — Skin	C 10	C 10	—	—
Hydrogen fluoride [7664-39-3], as F	3	2.5	6	5
Hydrogen peroxide [7722-84-1]	1	1.5	2	3
Hydrogen selenide [7783-07-5], as Se	0.05	0.2	—	—
Hydrogen sulfide [7783-06-4]	10	14	15	21
Hydroquinone [123-31-9]	—	2	—	4
4-Hydroxy-4-methyl-2-pentanone, see Diacetone alcohol				
2-Hydroxypropyl acrylate [999-61-1] — Skin	0.5	3	—	—
Indene [95-13-6]	10	45	15	70
Indium [7440-74-6] & compounds, as In	—	0.1	—	0.3

Capital letters A, B, D & E refer to Appendices; C denotes ceiling limit.
Footnotes (a thru f) see Page 35.

Substance [CAS #]	ADOPTED VALUES TWA ppm[a]	TWA mg/m³[b]	STEL ppm[a]	STEL mg/m³[b]
Iodine [7553-56-2]	C 0.1	C 1	—	—
Iodoform [75-47-8]	0.6	10	1	20
Iron oxide fume (Fe_2O_3) [1309-37-1], as Fe	B3	5	—	10
Iron pentacarbonyl [13463-40-6], as Fe	0.1	0.8	0.2	1.6
Iron salts, soluble, as Fe	—	1	—	2
Isoamyl acetate [123-92-2]	100	525	125	655
Isoamyl alcohol [123-51-3]	100	360	125	450
Isobutyl acetate [110-19-0]	150	700	187	875
Isobutyl alcohol [78-83-1]	50	150	75	225
Isooctyl alcohol [26952-21-6]	50	270	—	—
Isophorone [78-59-1]	C 5	C 25	—	—
Isophorone diisocyanate — Skin	0.01	0.09	—	—
Isopropoxyethanol [109-59-1]	25	105	75	320
Isopropyl acetate [108-21-4]	250	950	310	1,185
Isopropyl alcohol [67-63-0]	400	980	500	1,225
Isopropylamine [75-31-0]	5	12	10	24
N-Isopropylaniline [643-28-7] — Skin	2	10	5	20
Isopropyl ether [108-20-3]	250	1,050	310	1,320
Isopropyl glycidyl ether [4016-14-2] (IGE)	50	240	75	360
Kaolin	—	D	—	20
Ketene [463-51-4]	0.5	0.9	1.5	3
Lead [7439-92-1], inorg., dusts & fumes, as Pb	—	0.15	—	0.45
*‡Lead aresnate [10102-48-4], as $Pb_3(AsO_4)_2$	—	0.15	—	(0.45)
Lead chromate [18454-12-1], as Cr	—	0.05, A2	—	—
Limestone [1317-65-3]	—	D	—	20
Lindane [58-89-9] — Skin	—	0.5	—	1.5
Lithium hydride [7580-67-8]	—	0.025	—	—
L.P.G. (Liquified petroleum gas)	1,000	1,800	1,250	2,250
Magnesite [546-90-0]	—	D	—	20

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Footnotes (a thru f) see Page 35.
*1983 Addition.
‡See Notice of Intended Changes.

MAP 000431

Substance [CAS #]	ADOPTED VALUES TWA ppm[a]	TWA mg/m³[b]	STEL ppm[a]	STEL mg/m³[b]
Magnesium oxide fume [1309-48-4]	—	10	—	—
Malathion [121-75-5] — Skin	—	10	—	—
Maleic anhydride [108-31-6]	0.25	1	—	—
Manganese [7439-96-5], as Mn				
Dust & compounds	—	C 5	—	—
Fume	—	1	—	3
Manganese cyclopentadienyl tricarbonyl [12079-65-1], as, Mn — Skin	—	0.1	—	0.3
Manganese tetroxide	—	1	—	—
Marble/calcium carbonate [1317-65-3]	—	D	—	20
Mercury [7439-97-6], as Hg — Skin				
Alkyl compounds	—	0.01	—	0.03
All forms except alkyl Vapor	—	0.05	—	—
Aryl & inorganic compounds	—	0.1	—	—
Mesityl oxide [141-79-7]	15	60	25	100
Methacrylic acid [79-41-4]	20	70	—	—
Methane [74-82-8]	E	—	—	—
Methanethiol, see Methyl mercaptan				
Methomyl [16752-77-5] — Skin	—	2.5	—	—
Methoxychlor [72-43-5]	—	10	—	—
‡2-Methoxyethanol [109-86-4]— Skin	(25)	(80)	(35)	(120)
‡2-Methoxyethyl acetate [110-49-6] — Skin	(25)	(120)	(35)	(170)
4-Methoxyphenol [150-76-5]	—	5	—	—
Methyl acetate [79-20-9]	200	610	250	760
Methyl acetylene [74-99-7]	1,000	1,650	1,250	2,040
Methyl acetylene-propadiene mixture (MAPP)	1,000	1,800	1,250	2,250
Methyl acrylate [96-33-3] — Skin	10	35	—	—
Methylacrylonitrile [126-98-7] — Skin	1	3	2	6

Capital letters A, B, D & E refer to Appendices; C denotes ceiling limit.
Footnotes (a thru f) see Page 35
‡See Notice of Intended Changes.

Substance [CAS #]	ADOPTED VALUES TWA ppm[a]	TWA mg/m³[b]	STEL ppm[a]	STEL mg/m³[b]
Methylal [109-87-5]	1,000	3,100	1,250	3,875
Methyl alcohol [67-56-1] (methanol) — Skin	200	260	250	310
Methylamine [74-89-5]	10	12	—	—
Methyl amyl alcohol, see Methyl isobutyl carbinol				
Methyl n-amyl ketone [110-43-0]	50	235	100	465
N-Methyl aniline [100-61-8] — Skin	0.5	2	1	5
Methyl bromide [74-83-9] — Skin	5	20	15	60
Methyl n-butyl ketone [591-78-6]	5	20	—	—
Methyl chloride [74-87-3]	50	105	100	205
Methyl chloroform [71-55-6]	350	1,900	450	2,450
Methyl 2-cyanoacrylate [137-05-3]	2	8	4	16
Methylcyclohexane [108-87-2]	400	1,600	500	2,000
Methylcyclohexanol [25639-42-3]	50	235	75	350
o-Methylcyclohexanone [583-60-8] — Skin	50	230	75	345
Methylcyclopentadienyl manganese tricarbonyl, [12108-13-3] — Skin, as Mn	—	0.2	—	0.6
Methyl demeton [8022-00-2] — Skin	—	0.5	—	1.5
Methylene bisphenyl isocyanate (MDI) [101-68-8]	C 0.02	C 0.2	—	—
Methylene chloride [75-09-2]	100	350	500	1,740
4, 4'-Methylene bis (2-chloroaniline) [101-14-4] — Skin	0.02, A2	0.22, A2	—	—
Methylene bis(4-cyclohexylisocyanate) [5124-30-1]	C 0.01	C 0.11	—	—
4, 4-Methylene dianiline [101-77-9] — Skin	0.1	0.8	0.5	4

Capital letters A, B, D & E refer to Appendices; C denotes ceiling limit.
Footnotes (a thru f) see Page 35.
*1983 Addition.

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Substance [CAS #]	ADOPTED VALUES TWA ppm[a]	TWA mg/m³[b]	STEL ppm[a]	STEL mg/m³[b]
Methyl ethyl ketone (MEK) [78-93-3]	200	590	300	885
Methyl ethyl ketone peroxide [1338-23-4]	C 0.2	C 1.5	—	—
Methyl formate [107-31-3]	100	250	150	375
5-Methyl-3-heptanone, see Ethyl amyl ketone				
Methyl hydrazine [60-34-4] — Skin	C 0.2, A2	C 0.35, A2	—	—
Methyl iodide [74-88-4] — Skin	2, A2	10, A2	5, A2	30, A2
Methyl isoamyl ketone [110-12-3]	50	240	—	—
Methyl isobutyl carbinol [105-30-6] — Skin	25	100	40	165
Methyl isobutyl ketone [108-10-1]	50	205	75	300
Methyl isocyanate [624-83-9] — Skin	0.02	0.05	—	—
Methyl isopropyl ketone [563-80-4]	200	705	—	—
Methyl mercaptan [74-93-1]	0.5	1	—	—
Methyl methacrylate [80-62-6]	100	410	125	510
Methyl parathion [298-00-0] — Skin	—	0.2	—	0.6
Methyl propyl ketone [107-87-9]	200	700	250	875
Methyl silicate [681-84-5]	1	6	5	30
α-Methyl styrene [98-83-9]	50	240	100	485
Mevinphos [7786-34-7] — Skin	0.01	0.1	0.03	0.3
Molybdenum [7439-98-7], as Mo				
Soluble compounds	—	5	—	10
Insoluble compounds	—	10	—	20
Monocrotophos [6923-22-4]	—	0.25	—	—
Morpholine [110-91-8] — Skin	20	70	30	105
Naled [300-76-5]	—	3	—	6
Naphthalene [91-20-3]	10	50	15	75
β-Naphthylamine [91-59-8]	—	A1b	—	A1b

Capital letters A, B, D & E refer to Appendices; C denotes ceiling limit.
Footnotes (a thru f) see Page 35.

Substance [CAS #]	ADOPTED VALUES TWA ppm[a]	TWA mg/m³[b]	STEL ppm[a]	STEL mg/m³[b]
Neon [7440-01-9]	E	—	—	—
Nickel carbonyl, as Ni	0.05	0.35	—	—
Nickel [7440-02-0]				
Metal	—	1	—	—
Soluble compounds, as Ni	—	0.1	—	0.3
Nickel carbonyl [13463-39-3], as Ni	0.05	0.35	—	—
Nickel sulfide roasting, fume & dust, as Ni	—	1, A1a	—	—
Nicotine [54-11-5] — Skin	—	0.5	—	1.5
Nitrapyrin [1929-82-4]	—	10	—	20
Nitric acid [7697-37-2]	2	5	4	10
Nitric oxide [10102-43-9]	25	30	35	45
p-Nitroaniline [100-01-6] — Skin	—	3	—	—
Nitrobenzene — Skin	1	5	2	10
‡p-Nitrochlorobenzene [100-00-5] — Skin	—	(1)	—	(2)
4-Nitrodiphenyl [92-93-3]	—	A1b	—	A1b
Nitroethane [79-24-3]	100	310	150	465
Nitrogen dioxide [10102-44-0]	3	6	5	10
Nitrogen trifluoride [7783-54-2]	10	30	15	45
*‡Nitroglycerin (NG) [55-63-0] — Skin	0.05	0.5	(0.1)	(1)
Nitromethane [75-52-5]	100	250	150	375
1-Nitropropane [108-03-2]	25	90	35	135
‡2-Nitropropane [79-46-9]	(C 25, A2)	(C 90, A2)	—	—
N-Nitrosodimethylamine [62-75-9] (dimethylnitrosoamine) — Skin	—	A2	—	A2
Nitrotoluene [99-08-1] — Skin	2	11	—	—
Nitrotrichloromethane, see Chloropicrin				
Nonane [111-84-2]	200	1,050	250	1,300
Octachloronaphthalene [2234-13-1] — Skin	—	0.1	—	0.3
Octane [111-65-9]	300	1,450	375	1,800
Oil mist, mineral	—	5[e]	—	10

Capital letters A, B, D & E refer to Appendices; C denotes ceiling limit.
Footnotes (a thru f) see Page 35.
*1983 Addition.
‡See Notice of Intended Changes.

MAP 000433

Substance [CAS #]	ADOPTED VALUES TWA ppm[a]	TWA mg/m³[b]	STEL ppm[a]	STEL mg/m³[b]
Osmium tetroxide [20816-12-0], as Os	0.0002	0.002	0.0006	0.006
Oxalic acid [144-62-7]	—	1	—	2
Oxygen difluoride [7783-41-7]	0.05	0.1	0.15	0.3
Ozone [10028-15-6]	0.1	0.2	0.3	0.6
Paraffin wax fume [8002-74-2]	—	2	—	6
Paraquat [1910-42-5], respirable sizes	—	0.1	—	—
Parathion [56-38-2] — Skin	—	0.1	—	0.3
Particulate polycyclic aromatic hydro-carbons (PPAH), see Coal tar pitch volatiles				
Pentaborane [19624-22-7]	0.005	0.01	0.015	0.03
Pentachloronaphthalene [1321-64-8]	—	0.5	—	2
Pentachlorophenol [87-86-5] — Skin	—	0.5	—	1.5
Pentaerythritol [115-77-5]	—	D	—	20
Pentane [109-66-0]	600	1,800	750	2,250
2-Pentanone, see Methyl propyl ketone				
‡Perchloroethylene [127-18-4]	50	335	(—)	(—)
Perchloromethyl mercaptan [594-42-3]	0.1	0.8	—	—
Perchloryl fluoride [7616-94-6]	3	14	6	28
Phenol [108-95-2] — Skin	5	19	10	38
Phenothiazine [92-84-2] — Skin	—	5	—	10
N-Phenyl-beta-naphthyl-amine [135-88-6]	A2	A2	—	—
p-Phenylene diamine [106-50-3] — Skin	—	0.1	—	—
Phenyl ether [101-84-8], vapor	1	7	2	14
Phenylethylene, see Styrene, monomer				
Phenyl glycidyl ether (PGE) [122-60-1]	1	6	—	—
‡Phenylhydrazine [100-63-0] — Skin	(5)	(20)	(10)	(45)

Capital letters A, B, D & E refer to Appendices; C denotes ceiling limit.
Footnotes (a thru f) see Page 35.
‡See Notice of Intended Changes.

Substance [CAS #]	ADOPTED VALUES TWA ppm[a]	TWA mg/m³[b]	STEL ppm[a]	STEL mg/m³[b]
Phenyl mercaptan [108-98-5]	0.5	2	—	—
Phenylphosphine [638-21-1]	C 0.05	C 0.25	—	—
Phorate [298-02-2] — Skin	—	0.05	—	0.2
Phosdrin, see Mevinphos				
Phosgene [75-44-5]	0.1	0.4	—	—
Phosphine [3803-51-2]	0.3	0.4	1	1
Phosphoric acid [7664-38-2]	—	1	—	3
Phosphorus [7723-14-0] (yellow)	—	0.1	—	0.3
Phosphorus oxychloride [10026-13-8]	0.1	0.6	0.5	3
Phosphorus pentachloride [10026-13-8]	0.1	1	—	—
Phosphorus pentasulfide [1314-80-3]	—	1	—	3
Phosphorus trichloride [7719-12-2]	0.2	1.5	0.5	3
Phthalic anhydride [85-44-9]	1	6	4	24
m-Phthalodinitrile [626-17-5]	—	5	—	—
Picloram [1918-02-1]	—	10	—	20
Picric acid [88-89-1] — Skin	—	0.1	—	0.3
Pindone [83-26-1]	—	0.1	—	0.3
Piperazine dihydrochloride [142-64-3]	—	5	—	—
2-Pivalyl-1, 3-indandione, see Pindone				
Plaster of Paris	—	D	—	20
Platinum [7440-06-4]				
Metal	—	1	—	—
Soluble salts, as Pt	—	0.002	—	—
Polychlorobiphenyls, see Chlorodiphenyls				
Polytetrafluoroethylene decomposition products	—	B1	—	B1
Potassium hydroxide [1310-58-3]	—	C 2	—	—
Propane [74-98-6]	E	—	—	—
Propane sultone [1120-71-4]	A2	A2	—	—

Capital letters A, B, D & E refer to Appendices; C denotes ceiling limit.
Footnotes (a thru f) see Page 35.

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Substance [CAS #]	ADOPTED VALUES TWA ppm[a]	TWA mg/m³[b]	STEL ppm[a]	STEL mg/m³[b]
Propargyl alcohol [107-19-7] — Skin	1	2	3	6
β-Propiolactone [57-57-8]	0.5, A2	1.5, A2	1, A2	3, A2
Propionic acid [79-09-4]	10	30	15	45
Propoxur [114-26-1]	—	0.5	—	2
n-Propyl acetate [109-60-4]	200	840	250	1,050
Propyl alcohol [71-23-8] — Skin	200	500	250	625
n-Propyl nitrate [627-13-4]	25	105	40	170
Propylene [115-07-1]	E	—	—	—
Propylene dichloride [78-87-5]	75	350	110	510
*‡Propylene glycol dinitrate [6423-43-4] — Skin	0.05	0.3	(0.1)	(0.6)
Propylene glycol monomethyl ether [107-98-2]	100	360	150	540
*Propyleneimine [75-55-8] — Skin	2, A2	5, A2	—	—
Propylene oxide [75-56-9]	20	50	—	—
Propyne, see Methyl acetylene				
Pyrethrum [8003-34-7]	—	5	—	10
Pyridine [110-86-1]	5	15	10	30
Quinone [106-51-4]	0.1	0.4	0.3	1
RDX, see Cyclonite				
Resorcinol [108-46-3]	10	45	20	90
Rhodium [7440-16-6] Metal	—	1	—	—
‡ Soluble salts, as Rh	—	(0.001)	—	(0.003)
Ronnel [299-84-3]	—	10	—	—
Rosin core solder pyrolysis products, as formaldehyde	—	0.1	—	0.3
Rotenone (commercial) [83-79-4]	—	5	—	10
Rouge	—	D	—	20
Rubber solvent (Naphtha)	400	1,600	—	—
Selenium compounds [7782-49-2], as Se	—	0.2	—	—
Selenium hexafluoride [7783-79-1], as Se	0.05	0.2	—	—
Sesone [136-78-7]	—	10	—	20

Capital letters A, B, D & E refer to Appendices; C denotes ceiling limit.
Footnotes (a thru f) see Page 35.
*1983 Addition.
‡See Notice of Intended Changes.

Substance [CAS #]	ADOPTED VALUES TWA ppm[a]	TWA mg/m³[b]	STEL ppm[a]	STEL mg/m³[b]
Silane, see Silicon tetrahydnde				
Silicon [7440-21-3]	—	D	—	20
Silicon carbide [409-21-2]	—	D	—	20
*Silicon tetrahydride (Silane) [7803-62-5]	5	7	—	—
Silver [7440-22-4], as Ag Metal	—	0.1	—	—
Soluble compounds	—	0.01	—	—
Sodium azide [26628-22-8]	C 0.1	C 0.3	—	—
Sodium bisulfite [7631-90-5]	—	5	—	—
Sodium 2, 4-dichloro-phenoxyethyl sulfate, see Sesone				
Sodium fluoroacetate [62-74-8] — Skin	—	0.05	—	0.15
Sodium hydroxide [1310-73-2]	—	C 2	—	—
Sodium metabisulfite [7681-57-4]	—	5	—	—
Starch [9005-84-9]	—	D	—	20
Stibine [7803-52-3]	0.1	0.5	0.3	1.5
Stoddard solvent [8052-41-3]	100	525	200	1,050
Strychnine [57-24-9]	—	0.15	—	0.45
Styrene, monomer [100-42-5]	50	215	100	425
Subtilisins [1395-21-7] (Proteolytic enzymes as 100% pure crystalline enzyme)	—C0.00006[m]		—	—
Sucrose [57-50-1]	—	D	—	20
Sulfotep [3689-24-5] — Skin	—	0.2	—	0.6
Sulfur dioxide [7446-09-5]	2	5	5	10
Sulfur hexafluoride [2551-62-4]	1,000	6,000	1,250	7,500
Sulfuric acid [7664-93-9]	—	1	—	—
Sulfur monochloride [10025-67-9]	1	6	3	18
Sulfur pentafluoride [5714-22-7]	0.025	0.25	0.075	0.75
Sulfur tetrafluoride [7783-60-0]	0.1	0.4	0.3	1

Capital letters A, B, D & E refer to Appendices; C denotes ceiling limit.
Footnotes (a thru f) see Page 35.
*1983 Addition.
m) See Page 38.

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Substance [CAS #]	ADOPTED VALUES TWA ppm[a]	TWA mg/m³[b]	STEL ppm[a]	STEL mg/m³[b]
Sulfuryl fluoride [2699-79-8]	5	20	10	40
Systox, see Demeton				
2, 4, 5-T [93-76-5]	—	10	—	20
Tantalum [7440-25-7]	—	5	—	10
TEDP, see Sulfotep				
Tellurium & compounds [13494-80-9], as Te	—	0.1	—	—
Tellurium hexafluoride [7783-80-4], as Te	0.02	0.2	—	—
Temephos [3383-96-8]	—	10	—	20
TEPP [107-49-3] — Skin	0.004	0.05	0.01	0.2
Terphenyls [92-94-4]	C 0.5	C 5	—	—
1, 1, 1, 2-Tetrachloro-2, 2-difluoroethane [76-11-9]	500	4,170	625	5,210
1, 1, 2, 2-Tetrachloro-1, 2-difluoroethane [76-12-0]	500	4,170	625	5,210
1, 1, 2, 2-Tetrachloroethane [79-34-5] — Skin	1	7	5	35
Tetrachloroethylene, see Perchloroethylene				
Tetrachloromethane, see Carbon tetrachloride				
Tetrachloronaphthalene [1335-88-2]	—	2	—	4
Tetraethyl lead [78-00-2], as Pb — Skin	—	0.100^	—	0.3
Tetrahydrofuran [109-99-9]	200	590	250	735
Tetramethyl lead [75-74-1], as Pb — Skin	—	0.150^	—	0.5
Tetramethyl succinonitrile [3333-52-6] — Skin	0.5	3	2	9
Tetranitromethane [509-14-8]	1	8	—	—
Tetrasodium pyrophosphate [7722-88-5]	—	5	—	—
Tetryl [479-45-8] (2, 4, 6-trinitrophenyl-methylnitramine) — Skin	—	1.5	—	3.0
Thallium [7440-28-0] Soluble compounds, as Tl — Skin	—	0.1	—	—
4, 4'-Thiobis(6-tert. butyl-m-cresol) [96-69-5]	—	10	—	20
Thioglycolic acid [68-11-1]	1	5	—	—

Capital letters A, B, D & E refer to Appendices. C denotes ceiling limit.
Footnotes (a thru f) see Page 35

Substance [CAS #]	ADOPTED VALUES TWA ppm[a]	TWA mg/m³[b]	STEL ppm[a]	STEL mg/m³[b]
Thiram [137-26-8]	—	5	—	10
Tin [7440-31-5] Metal	—	2	—	4
Oxide & inorganic compounds, except SnO_4, as Sn	—	2	—	4
Organic compounds, as Sn — Skin	—	0.1	—	0.2
Titanium dioxide [13463-67-7], as Ti	—	D	—	20
o-Tolidine [119-93-7] — Skin	A2	A2	—	—
Toluene [108-88-3] (toluol) — Skin	100	375	150	560
* Toluene-2, 4-diisocyanate (TDI) [584-84-9]	0.005	0.04	0.02	0.15
‡o-Toluidine [95-53-4] — Skin	(2)	(9)	—	—
Toxaphene, see Chlorinated camphene				
Tributyl phosphate [126-73-8]	0.2	2.5	0.4	5
Trichloroacetic acid [76-03-9]	1	5	—	—
1, 2, 4-Trichlorobenzene [120-82-1]	C 5	C 40	—	—
1, 1, 1-Trichloroethane, see Methyl chloroform				
1, 1, 2-Trichloroethane [79-00-5] — Skin	10	45	20	90
‡Trichloroethylene [79-01-6]	50	270	(150)	(805)
Trichlorofluoromethane [75-69-4]	C 1,000	C 5,600	—	—
Trichloromethane, see Chloroform				
Trichloronaphthalene [1321-65-9]	—	5	—	10
Trichloronitromethane, see Chloropicrin				
1, 2, 3-Trichloropropane [96-18-4]	50	300	75	450
1, 1, 2-Trichloro-1, 2, 2-trifluoroethane [76-13-1]	1,000	7,600	1,250	9,500
Tricyclohexyltin hydroxide, see Cyhexatin				
*Triethylamine [121-44-8]	10	40	15	60
Trifluorobromomethane [75-63-8]	1,000	6,100	1,200	7,300

Capital letters A, B, D & E refer to Appendices. C denotes ceiling limit.
Footnotes (a thru f) see Page 35.
*1983 Addition.
‡See Notice of Intended Changes.

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Substance [CAS #]	ADOPTED VALUES TWA ppm[a]	TWA mg/m³[b]	STEL ppm[a]	STEL mg/m³[b]
Trimellitic anhydride [552-30-7]	0.005	0.04	—	
*Trimethylamine [75-50-3]	10	24	15	36
Trimethyl benzene [25551-13-7]	25	125	35	170
Trimethyl phosphite [121-45-9]	2	10	5	25
2, 4, 6-Trinitrophenol, see Picric acid				
2, 4, 6-Trinitrophenyl-methylnitramine, see Tetryl				
2, 4, 6-Trinitrotoluene (TNT) [118-96-7] — Skin	—	0.5	—	3
Triorthocresyl phosphate [78-30-8]	—	0.1	—	0.3
Triphenyl amine [603-34-9]	—	5	—	—
Triphenyl phosphate [115-86-6]	—	3	—	6
Tungsten [7440-33-7], as W				
Insoluble compounds	—	5	—	10
Soluble compounds	—	1	—	3
Turpentine [8006-64-2]	100	560	150	840
Uranium (natural) [7440-61-1], Soluble & Insoluble compounds, as U	—	0.2	—	0.6
Valeraldehyde [110-62-3]	50	175	—	—
Vanadium, as V_2O_5 [1314-62-1], respirable dust & fume	—	0.05	—	—
Vegetable oil mists	—	D	—	—
Vinyl acetate [108-05-4]	10	30	20	60
Vinyl benzene, see Styrene				
Vinyl bromide [593-60-2]	5, A2	20, A2	—	—
Vinyl chloride [75-01-4]	5, A1a	10, A1a	—	—
Vinyl cyanide, see Acrylonitrile				
Vinyl cyclohexene dioxide [106-87-6]	10, A2	60, A2	—	—
‡Vinylidene chloride [75-35-4]	(10)	(40)	(20)	(80)
Vinyl toluene [25013-15-4]	50	240	100	485
VM & P Naphtha [8030-30-6]	300	1,350	400	1,800
Warfarin [81-81-2]	—	0.1	—	0.3

Capital letters A, B, D & E refer to Appendices; C denotes ceiling limit.
Footnotes (a thru f) see Page 35
*1983 Addition
‡See Notice of Intended Changes

Substance [CAS #]	ADOPTED VALUES TWA ppm[a]	TWA mg/m³[b]	STEL ppm[a]	STEL mg/m³[b]
Welding fumes (NOC†)	—	5, B2	—	—
Wood dust (certain hard woods as beech & oak)	—	1	—	—
Soft wood	—	5	—	10
Xylene [1330-20-7] (o-, m-, p-isomers)	100	435	150	655
m-Xylene α, α'-diamine [1477-55-0] — Skin	—	C 0.1	—	—
Xylidine [1300-73-8] — Skin	2	10	—	—
Yttrium [7440-65-5]	—	1	—	3
Zinc chloride fume [7646-85-7]	—	1	—	2
Zinc chromate [13530-65-9], as Cr	—	0.05, A2	—	—
Zinc oxide [1314-13-2]				
Fume	—	5	—	10
Dust	—	D	—	—
Zinc stearate [557-05-1]	—	D	—	20
Zirconium compounds [7440-67-2], as Zr	—	5	—	10

Capital letters A, B, D & E refer to Appendices. C denotes ceiling limit
Footnotes (a thru f) see Page 35.
†NOC = Not otherwise classified

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 substance per cubic meter of air.
d) $< 7\ \mu$m in diameter.
e) As sampled by method that does not collect vapor.
f) For control of general room air, biologic monitoring is essential for personnel control.

Radioactivity: The Committee accepts the philosophy and recommendations of the National Council on Radiation Protection and Measurements (NCRP) for the ionizing radiation TLV. The NCRP is charted by Congress to, in part, collect, analyze, develop and disseminate information and recommendations about protection against radiation and about radiation measurements, quantities and units, including devel-

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opment of basic concepts in these areas. NCRP Report No. 39 (reference 1) provides basic philosophy and concepts leading to protection criteria established in the same report. Other NCRP reports address specific areas of radiation protection and, collectively, provide an excellent basis for establishing a sound program for radiation control. The Committee recommends the listed references as substantative documentation of a sound basis for ionizing radiation protection. The Committee also strongly recommends that all exposures to ionizing radiations be kept low as reasonably achievable within the stated guidance.

References:

1. *Basic Radiation Protection Criteria*. NCRP Report No. 39, issued January 15, 1971.
2. *Maximum Permissible Body Burdens and Maximum Permissible Concentrations of Radionuclides in Air and in Water for Occupational Exposure*. US Department of Commerce, National Bureau of Standards Handbook 69, issued June 5, 1959, with Addendum 1 issued August 1963. Available as NCRP Report No. 22.

The above documents, as well as information on numerous other NCRP Reports addressing specific subjects in ionizing radiation protection are available from: NCRP Publications, PO Box 30175, Washington, DC 20014.

MINERAL DUSTS

Substance	TLV
SILICA, SiO_2	
Crystalline	
‡Quartz [14808-60-7]	TLV in mppcf[g]: $\frac{300^{h}}{\%\ \text{quartz} + 10}$ TLV for respirable dust in mg/m^3: $\frac{10\ mg/m^3}{\%\ \text{Respirable quartz} + 2}$ TLV for "total dust," respirable and nonrespirable: $\frac{30\ mg/m^3}{\%\ \text{quartz} + 3}$
‡Cristobalite [14464-46-1]	Use one-half the value calculated from the count or mass formulae for quartz.
‡Tridymite [15468-32-3]	Use one-half the value calculated from formulae for quartz.
‡Silica, fused [60676-86-0]	Use quartz formulae.
‡Tripoli [1317-95-9]	Use respirable[a] mass quartz formula
‡*Amorphous* [7631-86-9]	(20 mppcf[g])
SILICATES (< 1% quartz)	
Asbestos[f]	
Amosite [12172-73-5]	0.5 fiber/cc > 5 μm in length, A1a
Chrysotile [12001-29-5]	2 fibers/cc > 5 μm in length, A1a
Crocidolite [12001-28-4]	0.2 fiber/cc > 5 μm in length, A1a
Other forms	2 fibers/cc > 5 μm in length, A1a
‡Graphite (natural) [7782-42-5]	15 mppcf
‡Mica [12001-26-2]	20 mppcf
Mineral wool fiber	10 mg/m^3
‡Perlite	30 mppcf
‡Portland Cement	30 mppcf
‡Soapstone	20 mppcf
*Talc (containing no asbestos fibers) [14807-96-6]	2 mg/m^3. Respirable dust
‡Talc (fibrous), (use Asbestos limit.)	
COAL DUST	
2 mg/m^3 (respirable dust fraction < 5% quartz). ‡(If > 5% quartz, use respirable mass formula.)	

NUISANCE PARTICULATES

(see Appendix D)

‡(30 mppcf) or 10 mg/m^3[b]

of total dust < 1% quartz, or, 5 mg/m^3 respirable dust.

Conversion factors:

mppcf × 35.3 = Million particles per cubic meter = particles per cc

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

‡See Notice of Intended Changes

*1983 Addition.

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

i) Both concentration and percent quartz 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

‡j) containing < 1% quartz; (if quartz content > 1%, use formulae for quartz.)

k) Lint-free dust as measured by the vertical elutriator, cotton-dust sampler described in the *Transactions of the National Conference on Cotton Dust*, p. 33 by J. R. Lynch, (May 2, 1970).

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

m) Based on "high volume" sampling.

n) "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: *Pulmonary Deposition and Retention of Inhaled Aerosols*, p. 149. Academic Press, New York, (1964).

(2) AIHA Aerosol Technology Committee: Interim Guide for Respirable Mass Sampling. *Am. Ind. Hyg. Assoc. J. 31(2)*:133 (1970).

NOTICE OF INTENDED CHANGES (for 1983-84)

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. Documentation is available for each of these substances.

Substance [CAS #]	TWA ppm[a]	TWA mg/m³[b]	STEL ppm[a]	STEL mg/m³[b]
Acrylonitrile [107-13-1] — Skin	2, A2	4.5, A2	—	—
†1, 3-Butadiene [106-99-0]	A2	A2	—	—
Cobalt metal, dust & fume [7440-48-4], as Co	—	0.05	—	0.1
Enflurane [13838-16-9]	75	575	—	—
2-Ethoxyethanol [110-80-5] — Skin	5	19	—	—
2-Ethoxyethyl acetate [111-15-9] — Skin	5	27	—	—
Ethylene glycol [107-21-1], particulate	DELETE, see Appendix G			
†Ethylene glycol dinitrate [628-96-6] — Skin	0.05	0.3	—	—
Ethylene oxide [75-21-8]	1, A2	2, A2	—	—
Fenamiphos [22224-92-6] — Skin	—	0.1	—	—
†Formaldehyde [50-00-0]	1, A2	1.5, A2	2, A2	3, A2
Grain dust	—	4	—	—
Halothane [151-67-7]	50	400	—	—
†Lead arsenate [10102-48-4], as $Pb_3(AsO_4)_2$	—	0.15	—	—
2-Methoxyethanol [109-86-4] — Skin	5	16	—	—
2-Methoxyethyl acetate [110-49-6] — Skin	5	24	—	—
Metribuzin [21087-64-9]	—	5	—	—
p-Nitrochlorobenzene [100-00-5] — Skin	0.5	3	—	—
†Nitroglycerin [55-63-0] — Skin	0.05	0.5	—	—
2-Nitropropane [79-46-9]	10, A2	35, A2	20, A2	70, A2
Perchloroethylene [127-18-4]	50	335	200	1,340
Persulfates, alkali metal, as S_2O_8	—	2	—	—

‡See Notice of Intended Changes

Capital letters A, B, D & E refer to Appendices; C denotes ceiling limit.
†1983 Revision or Addition.

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Substance	[CAS #]	TWA ppm[a]	TWA mg/m³[a]	STEL ppm[a]	STEL mg/m³
Phenylhydrazine	[100-63-0] — Skin	5, A2	20, A2	10, A2	45 A2
†Propylene glycol dinitrate	[6423-43-4] — Skin	0.05	0.3	—	—
Rhodium, Insoluble compounds, as Rh		—	1	—	—
Soluble compounds, as Rh		—	0.01	—	—
Sulprofos	[35400-43-2]	—	1	—	—
o-Toluidine	[95-53-4] — Skin	2, A2	9, A2	—	—
Trichloroethylene	[79-01-6]	50	270	200	1,080
Vinylidene chloride	[75-35-4]	5	20	20	80

Capital letters A, B, D & E refer to Appendices. C denotes ceiling limit.
†1983 Revision or Addition.

NOTICE OF INTENDED CHANGES
MINERAL DUSTS

Substance	TLV
SILICA, SiO_2	
Crystalline	
Quartz [14808-60-7]	0.1 mg/m³, Respirable dust 0.3 mg/m³, Total dust
Cristobalite [14464-46-1]	0.05 mg/m³, Respirable dust 0.15 mg/m³, Total dust
Tridymite [15468-32-3]	0.05 mg/m³, Respirable dust 0.15 mg/m³, Total dust
Silica, fused [60676-86-0]	Use quartz values.
Tripoli [1317-95-9]	Use respirable quartz value.
Silica, amorphous [7631-86-9]	5 mg/m³, Respirable dust 10 mg/m³, Total dust
SILICATES (< 1% quartz)	
Diatomaceous earth (uncalcined) [60676-86-0]	5 mg/m³, Respirable dust 10 mg/m³, Total dust
Graphite (natural) [7782-42-5]	2.5 mg/m³, Respirable dust 5 mg/m³, Total dust
Mica [12001-26-2]	3 mg/m³, Respirable dust 6 mg/m³, Total dust
Perlite	5 mg/m³, Respirable dust 10 mg/m³, Total dust
Portland Cement	5 mg/m³, Respirable dust 10 mg/m³, Total dust
Precipitated silica and silica gel	5 mg/m³, Respirable dust 10 mg/m³, Total dust
Soapstone	3 mg/m³, Respirable dust 6 mg/m³, Total dust
Talc (containing asbestos fibers)	Use asbestos TLV. However, should not exceed 2 mg/m³ respirable dust.
COAL DUST	If > 5% quartz, use respirable quartz value.

Generic Listing

All mppcf values for mineral dusts will be eliminated in favor of equivalent respirable mass or total mass values, i.e., Appendix F.

Footnote

j) Containing < 1% quartz; if quartz content > 1%, use quartz values.

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).

A1a. *Human Carcinogens*. Substances, or substances associated with industrial processes, recognized to have carcinogenic or cocarcinogenic potential, with an assigned TLV:

	TLV
** Acrylonitrile — Skin	2 ppm
Asbestos	
Amosite	0.5 fiber > 5μm/cc
Chrysotile	2 fibers > 5μm/cc
Crocidolite	0.2 fiber > 5μm/cc
Other forms	2 fibers > 5μm/cc

**See Notice of Intended Changes.

MAP 000440

bis (Chloromethyl) ether	0.001 ppm
Chromite ore processing (chromate)	0.05 mg/m³, as Cr
Chromium (VI), certain water insoluble compounds	0.05 mg/m³, as Cr
Coal tar pitch volatiles	0.2 mg/m³, as benzene solubles
Nickel sulfide roasting, fume & dust	1.0 mg/m³, as Ni
Vinyl chloride	5 ppm

• • •

A1b. *Human Carcinogens*. Substances, or substances associated with industrial processes, recognized to have carcinogenic potential without an assigned TLV:

4-Aminodiphenyl (p-Xenylamine) — Skin
Benzidine — Skin
β-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. The worker should be properly equipped to insure virtually no contact with the carcinogen.

A2. *Industrial Substances Suspect of Carcinogenic Potential for MAN*. Chemical substances or substances associated with industrial processes, which are suspect of inducing cancer, based on either (1) limited epidemiologic evidence, exclusive of clinical reports of single cases, or (2) demonstration of carcinogenesis in one or more animal species by appropriate methods.

Acrylonitrile — Skin	2 ppm
Amitrol	——
Antimony trioxide production*	——
Arsenic trioxide production	——
Benzene	10 ppm
Benzo(a)pyrene	——
Beryllium	2.0 μg/m³

*Cigarette smoking can enhance the incidence of respiratory cancers from this or others of these substances or processes

†1, 3-Butadiene	——
Cadmium oxide production	——
Carbon tetrachloride — Skin	5 ppm
Chloroform	10 ppm
‡Chloromethyl methyl ether	——
Chromates of lead and zinc, as Cr	0.05 mg/m³
Chrysene	——
3, 3'-Dichlorobenzidine — Skin	——
Dimethylcarbamyl chloride	——
1, 1-Dimethyl hydrazine — Skin	0.5 ppm
Dimethyl sulfate — Skin	0.1 ppm
Ethylene dibromide — Skin	——
Ethylene oxide	1 ppm
†Formaldehyde	1 ppm
Hexachlorobutadiene	0.02 ppm
Hexamethyl phosphoramide — Skin	——
Hydrazine — Skin	0.1 ppm
4, 4'-Methylene bis (2-chloroaniline) — Skin	0.02 ppm
Methyl hydrazine — Skin	C 0.2 ppm
Methyl iodide — Skin	2 ppm
2-Nitropropane	10 ppm
N-Nitrosodimethylamine — Skin	——
N-Phenyl-beta-naphthylamine	——
Phenylhydrazine — Skin	5 ppm
Propane sultone	——
beta-Propiolactone	0.5 ppm
‡Propyleneimine — Skin	2 ppm
o-Tolidine	——
o-Toluidine — Skin	2 ppm
Vinyl bromide	5 ppm
Vinyl cyclohexene dioxide	10 ppm

For the above, worker exposure by all routes should be carefully controlled to levels consistent with the animal and human experience data (see Documentation), including those substances with a listed TLV.

†1983 Addition
‡1983 Adoption.

MAP 000441

THE COMMITTEE GUIDELINES FOR CLASSIFICATION OF EXPERIMENTAL ANIMAL CARCINOGENS

The following guidelines are offered in the present state of knowledge as an aid in classifying substances in the occupational environment found to be carcinogenic in experimental animals. A need was felt by the Threshold Limits Committee for such a classification in order to take the first step in developing an appropriate TLV for occupational exposure.

Determination of Approximate Threshold of Response Requirement. In order to determine in which category to classify an experimental carcinogen for the purpose of assigning an industrial air limit (TLV), an approximate threshold of neoplastic response must be determined. Because of practical experimental difficulties, a precisely defined threshold cannot be attained. For the purposes of standard-setting, this is of little moment, as an appropriate risk, or safety, factor can be applied to the approximate threshold, the magnitude of which is dependent on the degree of potency of the carcinogenic response.

To obtain the best 'practical' threshold of neoplastic response, dosage decrements should be less than logarithmic. This becomes particularly important at levels greater than 10 ppm (or corresponding mg/m³). Accordingly, after a range-finding determination has been made by logarithmic decreases, two additional dosage levels are required within the levels of "effect" and "no effect" to approximate the true threshold of neoplastic response.

The second step should attempt to establish a metabolic relationship between animal and man for the particular substance found carcinogenic in animals. If the metabolic pathways are found comparable, the substance should be classed highly suspect as a carcinogen for man. If no such relation is found, the substance should remain listed as an experimental animal carcinogen until evidence to the contrary is found.

Proposed Classification of Experimental Animal Carcinogens. Substances occurring in the occupational environment found carcinogenic for animals may be grouped into three classes, those of high, intermediate and low potency. In evaluating the incidence of animal cancers, significant incidence of cancer is defined as a neoplastic response which represents, in the judgment of the Committee, a significant excess of cancers above that occurring in negative controls.

EXCEPTIONS: No substance is to be considered an occupational carcinogen of any practical significance which reacts by the respiratory route at or above 1000 mg/m³ for the mouse, 2000 mg/m³ for the rat; by the dermal route, at or above 1500 mg/kg for the mouse, 3000 mg/kg for the rat; by the gastrointestinal route at or above 500 mg/kg/d for a lifetime, equivalent to about 100 g T.D. for the rat, 10 g T.D. for the mouse.

These dosage limitations exclude such substances as dioxane and trichlorethylene from consideration as carcinogens.

Examples: Dioxane — rats, hepatocellular and nasal tumors from 1015 mg/kg/d, oral

Trichloroethylene — female mice, tumors (30/98 @ 900 mg/kg/d), oral

A. *Industrial Substances of High Carcinogenic Potency in Experimental Animals.*

1. A substance to qualify as a carcinogen of high potency must fulfill one of the three following conditions in two animal species:

1a. *Respiratory*. Elicit cancer from (1) dosages below 1 mg/m³ (or equivalent ppm) via the respiratory tract in 6- 7-hour daily repeated inhalation exposures throughout lifetime; or (2) from a single intratracheally administered dose not exceeding 1 mg of particulate, or liquid, per 100 ml or less of animal minute respiratory volume;

Examples: bis-Chloromethyl ether, malignant tumors, rats, @ 0.47 mg/m³ (0.1 ppm) in 2 years;

Hexamethyl phosphoramide, nasal squamous cell carcinoma, rats, @ 0.05 ppm, in 13 months

OR

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1b. *Dermal*. Elicit cancer within 20 weeks by skin-painting, twice weekly at 2 mg/kg body weight or less per application for a total dose equal to or less than 1.5 mg, in a biologically inert vehicle;

Examples: 7, 12-Dimethylbenz(a)anthracene — skin tumors @ 0.12-0.8 mg T.D. in four weeks

Benzo(a)pyrene, mice 12 μg, 3X/wk for 18 mos. T.D. 2.6 mg, 90.9% skin tumors

OR

1c. *Gastrointestinal*. Elicit cancer by daily intake via the gastrointestinal tract, within six months, with a six-month holding period, at a dosage below 1 mg/kg body weight per day; total dose, rat, ≦ 50 mg; mouse, ≦ 3.5 mg;

Examples: 7, 12-Dimethylbenz(a)anthracene — mammary tumors from 10 mg 1X

3-Methylcholanthrene — Tumors @ 3 sites from 8 mg in 89 weeks

Benzo(a)pyrene, mice, 3.9% leukemias, from 30 mg T.D. 198 days

2. Elicit cancer by all three routes in at least two animal species at dose levels prescribed for high or intermediate potency.

B *Industrial Substances of Intermediate Carcinogenic Potency in Experimental Animals*.

To qualify as a carcinogen of intermediate potency, a substance should elicit cancer in two animal species at dosages intermediate between those described in A and C by two routes of administration.

Example: Carbamic acid ethyl ester
Dermal, mammary tumors, mice, 100%, 63 weeks, 500–1400 mg T.D.
Gastrointestinal, various type tumors, mice 42 weeks, 320 mg T.D.

Gastrointestinal, various type tumors, rats, 60 weeks, 110–930 mg T.D.

C. *Industrial Substances of Low Carcinogenic Potency in Experimental Animals*.

To qualify as a carcinogen of low potency, a substance should elicit cancer in one animal species by any *one* of three routes of administration at the following prescribed dosages and conditions:

1a. *Respiratory*. Elicit cancer from (1) dosages greater than 10 mg/m^3 (or equivalent ppm) via the respiratory tract in 6- 7-hour, daily repeated inhalation exposures, for 12 months' exposure and 12 months' observation period; or (2) from intratracheally administered dosages totaling more than 10 mg of particulate or liquid per 100 ml or more of animal minute respiratory volume;

Examples: Beryl (beryllium aluminum silicate) malig. lung tumors, rats, @ 15 mg/m^3 @ 17 months

Benzidine, var. tumors, rats, 10–20 mg/m^3 @ > 13 mos.

OR

1b. *Dermal*. Elicit cancer by skin-painting of mice in twice weekly dosages of > 10 mg/kg body weight in a biologically inert vehicle for at least 75 weeks, i.e., ≧ 1.5g T.D.

Examples: Shale tar, mouse, 0.1 ml × 50 = 5g T.D. 59/60 skin tumors

Arsenic trioxide, man, dose unknown, but estimated to be high

1c. *Gastrointestinal*. Elicit cancer from daily oral dosages of 50 mg/kg/day or greater during the lifetime of the animal.

APPENDIX B
SUBSTANCES OF VARIABLE COMPOSITION

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 de-

*Trade Names: Algoflon, Fluon, Halon, Teflon, Tetran.

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termination of the toxicity of the products, but air concentrations should be minimal.

B2 *Welding Fumes — Total Particulate (NOC)†*
TLV, 5 mg/m³

Welding fumes cannot be classified simply. The composition and quantity of both are dependent on the alloy being welded and the process and electrodes used. Reliable analysis of fumes cannot be made without considering the nature of the welding process and system being examined; reactive metals and alloys such as aluminum and titanium are arc-welded in a protective, inert atmosphere such as argon. These arcs create relatively little fume, but an intense radiation which can produce ozone. Similar processes are used to arc-weld steels, also creating a relatively low level of fumes. Ferrous alloys also are arc-welded in oxidizing environments which generate considerable fume, and can produce carbon monoxide instead of ozone. Such fumes generally are composed of discreet particles of amorphous slags containing iron, manganese, silicon and other metallic constituents depending on the alloy system involved. Chromium and nickel compounds are found in fumes when stainless steels are arc-welded. Some coated and flux-cored electrodes are formulated with fluorides and the fumes associated with them can contain significantly more fluorides than oxides. Because of the above factors, arc-welding fumes frequently must be tested for individual constituents which are likely to be present to determine whether specific TLV's are exceeded. Conclusions based on total fume concentration are generally adequate if no toxic elements are present in welding rod, metal, or metal coating and conditions are not conducive to the formation of toxic gases.

Most welding, even with primitive ventilation, does not produce exposures inside the welding helmet above 5 mg/m³. That which does, should be controlled.

APPENDIX C
MIXTURES

C.1 THRESHOLD LIMIT VALUES FOR MIXTURES

When two or more hazardous substances, which act upon the same organ system, are present, their

†Not otherwise classified (NOC)

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 a 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.).

Synergistic action or potentiation may occur with some combinations of atmospheric contaminants. Such cases at present must be determined individually. Potentiating or synergistic 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 a given operation or process characteristically emits a number of harmful dusts, 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.

MAP 000444

C.1A Examples of THRESHOLD LIMIT VALUES FOR MIXTURES

The following formulae apply only when the components in a mixture have similar toxicologic effects; they should not be used for mixtures with widely differing reactivities, e.g. hydrogen cyanide & sulfur dioxide. In such case the formula for Independent Effects (1A.c.) should be used.

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 non-compliance with this calculated TLV.)*

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

Example No. 1A.a.: Air contains 400 ppm of acetone (TLV = 750 ppm) 150 ppm of sec-butyl acetate (TLV = 200 ppm) and 100 ppm of methyl ethyl ketone (TLV = 200 ppm)

Atmospheric concentration of mixture = 400 + 150 + 100 = 650 ppm of mixture

$$\frac{400}{750} + \frac{150}{200} + \frac{100}{200} = 0.53 + 0.75 + 0.5 = 1.78$$

Threshold Limit is exceeded.

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 =

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

Example No. 1A.b.: Liquid contains (by weight)
50% heptane: TLV = 400 ppm or 1600 mg/m³
1 mg/m³ ≡ 0.25 ppm
30% methyl chloroform: TLV = 350 ppm or 1900 mg/m³
1 mg/m³ ≡ 0.18 ppm
20% perchloroethylene: TLV = 50 ppm or 335 mg/m³
1 mg/m³ ≡ 0.15 ppm

$$\text{TLV of Mixture} = \frac{1}{\frac{0.5}{1600} + \frac{0.3}{1900} + \frac{0.2}{335}}$$

$$= \frac{1}{0.00031 + 0.00016 + 0.0006}$$

$$= \frac{1}{0.00107} = 935 \text{ mg/m}^3$$

of this mixture
50% or (935) (0.5) = 468 mg/m³ is heptane
30% or (935) (0.3) = 281 mg/m³ is methyl chloroform
20% or (935) (0.2) = 187 mg/m³ is perchloroethylene

These values can be converted to ppm as follows:

heptane: 468 mg/m³ × 0.25 = 117 ppm
methyl chloroform: 281 mg/m³ × 0.18 = 51 ppm
perchloroethylene: 187 mg/m³ × 0.15 = 29 ppm

TLV of mixture = 117 + 51 + 29 = 197 ppm, or 935 mg/m³

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.

MAP 000445

1B. TLV for Mixtures of Mineral Dusts.

For mixtures of biologically active mineral dusts the general formula for mixtures given in 1A.b. may be used.

APPENDIX D
Some Nuisance Particulates[o]
‡TLV, (30 mppcf) or 10 mg/m³ of total dust < 1% quartz, or, 5 mg/m³ respirable dust

α-Alumina (Al_2O_3)	Plaster of Paris
Calcium carbonate	Portland Cement
Calcium silicate	Rouge
Cellulose (paper fiber)	Silicon
Emery	Silicon Carbide
Glycerin Mist	Starch
Graphite (synthetic)	Sucrose
Gypsum	Titanium Dioxide
Kaolin	Vegetable oil mists (except castor, cashew nut, or similar irritant oils)
Limestone	
Magnesite	
Marble	
Mineral Wool Fiber	Zinc Stearate
Pentaerythritol	Zinc oxide dust

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

APPENDIX E
Some Simple Asphyxiants[p]

Acetylene	Helium	Propane
Argon	Hydrogen	Propylene
Ethane	Methane	
Ethylene	Neon	

p) As defined on pg. 6.

‡See Notice of Intended Changes

‡APPENDIX F
Conversion of mppcf to Mass Concentration

Calculations for Conversion of Particle Count Concentration (by Standard Light Field — Midget Impinger Techniques), in mppcf, to Respirable Mass Concentration (by Respirable Sampler) in mg/m³.[1]

1. In 1967, Jacobsen and Tomb,[1] derived an empirical relationship of 5.6 mppcf to 1 milligram of respirable dust per cubic meter of air, based on 23 sets of samples, mostly coal dust. Studies on conversion factors have been undertaken and preliminary evidence suggests that the application of any single conversion factor may not be adequate for use in risk assessments, epidemiology studies, or setting TLVs.

   The following calculation results in an equivalence of 6.37 mppcf to 1 mg/m³ of respirable dust. Thus, an approximate ratio of 6 mppcf to 1 mg/m³ of respirable dust is suggested for conversion of TLVs from a count to a mass basis when the density and mass median diameter have not been determined.

2. Basic assumptions:

   a) Average density for silica containing dusts ≈ 2.5 g/cm³ (2500 mg/cm³). Pulmonary significant dust densities may vary from 1.2 g/cm³ for coal dust to 3.1 g/cm³ for Portland Cement. Silica densities vary from 2.2 (amorphous) to 2.3 (cristobalite and tridymite) to 2.5 (alpha-quartz.) gms per cm³.

   b) The mass median diameter (mmd) of particles collected in midget impinger samplers and counted by the standard light field technique, *and* collected in a respirable sampler is approximately 1.5 μm or 1.5 × 10^{-4} cm. This assumption is, of course, quite arbitrary since the mmd of all dust clouds is quite variable, depending on many independent parameters, such as source of dust, age of dust cloud, meteorological conditions, processes and equipment changes, etc. If the density and the mass median diameter of the dust particles are known, the nomograph in Figure 1 can be used to convert dust count concentrations (mppcf) to respirable mass concentrations (mg/m³).

‡See Notice of Intended Changes.

MAP 000446

3. Calculation:

a) vol. per particle: $4/3\ \pi\ r^3$; r = 0.75 × 10^{-4} cm
$= 4/3 \cdot \pi \cdot (0.75 \times 10^{-4})^3$
$= 1.77 \times 10^{-12}\ cm^3$

b) wt. per particle = vol. × density
$= 1.77 \times 10^{-12}\ cm^3 \times 2.5 \times 10^3\ mg/cm^3$
$= 4.425 \times 10^{-9}$ mg/particle

c) 1 particle/ft.^{3} = 35.3 part./m^3
(since 35.5 cu ft = 1 cu m.)
10^6 part./ft^3 = mppcf = 35.3 × 10^6 part./m^3

wt. of 1 mppcf ≡ 35.5 × 10^6 part./m^3 × 4.425 × 10^{-9} mg/part.

1 mppcf ≡ 0.157 mg/m^3
or
6.37 *mppcf* ≡ 1 *mg/m*^{3}
or approximately 6 mpccf ≡ 1 mg/m^3.

Reference

1. **Jacobson, M. and T. F. Tomb:** Relationship Between Gravimetric Respirable Dust Concentration and Midget Impinger Number Concentration. *Am. Ind. Hyg. Assoc. J. 28:*554 (Nov.–Dec. 1967).

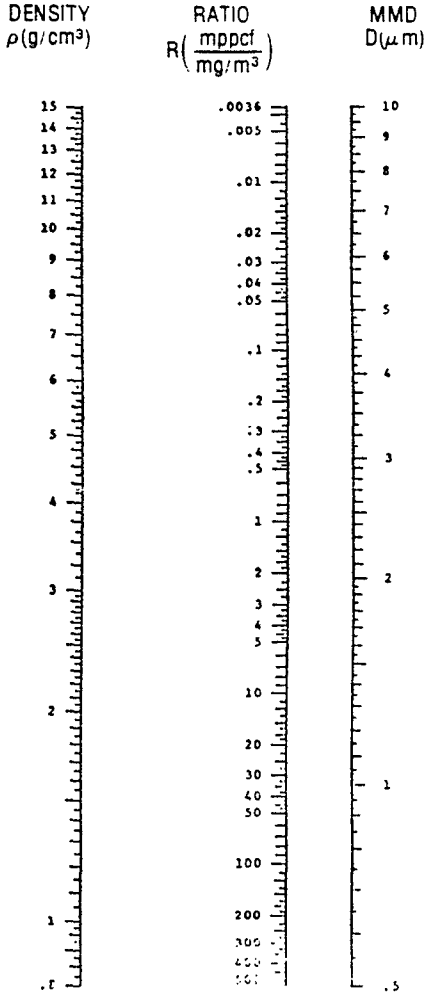


Figure 1 — Ratio of Particle Count — mppcf to Respirable Mass Concentration — mg/m^3 (as function of density and mmd)†

†Prepared by P. E. Caplan and R. J. Smith

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Table 1

Equivalent TLVs in mppcf and mg/m³ (Respirable Mass) for Mineral Dusts†

Substance	Threshold Limit Value		
	Count mppcf	Resp. Mass mg/m³	Total Mass* mg/m³
Silica (SiO_2)			
Amorphous	20	(3)**	(6)
Cristobalite	1.5	0.05	0.15
Fused silica	3	0.1	0.3
Quartz	3	0.1	0.3
Tridymite	1.5	0.05	0.15
Coal Dust	(12)	2	(4)
Diatomaceous earth, natural	—	1.5	—
Graphite (natural)	15	(2.5)	(5)
Mica	20	(3)	(6)
Mineral wool fiber	—	(5)	10
Nuisance particulates	30	(5)	10
Perlite	30	(5)	(10)
Portland Cement	30	(5)	(10)
Soapstone	20	(3)	(6)
Tripoli	(3)	0.1	(0.3)

†Assuming that the mass median diameter is 1.5 μm and density is 2.5 g cm³

*Unless otherwise specified, respirable mass is presumed to equal approximately 50% of total mass

**All values in parentheses ( ) represent newly calculated values based on equivalence of 6 mppcf = 1 mg/m³ respirable mass and respirable mass = 50% total mass

APPENDIX G

Chemical Substances and Other Issues Under Study[1]

Chemical Substances

Acetonitrile
Acrolein
Acrylic acid
Allyl chloride
Amorphous silica
Asbestos
Atrazine
Bismuth telluride
1,3-Butadiene
Carbonyl fluoride
Chlorinated naphthalenes
Chlorine
o-Chlorobenzlidene
bis-Chloromethyl ether
Chloromethyl methyl ether
o-Chlorotoluene
Chrysene
Copper dust & fume
Cyclohexanone
Diatomaceous earth
Diethylenetriamine
Epichlorohydrin
Ethyl chloride
Ethylene dichloride
Ethyl methacrylate
Gasoline
Glycol ethers
Graphite
Hexachlorocyclopentadiene
Isocyanates
Isoflurane
Isooctyl alcohol
Jet fuels
Methylenedianiline
Methyl methacrylate
Methyl tetiary butyl ether
Nickel, metal & soluble compounds
p-Nitrochlorobenzene
Osmium tetroxide
Perfluorinated chemicals
Piperizine
Propylene chloride
Propylene oxide
Styrene, monomer
Tetrachloronaphthalene
Tin hydride
1,2,3-Trichloropropane
Trimellitic anhydride
m-Xylene 2,2'-diamine (MXDA; meta-meta-xylenediamine)

Other Issues

1. Is the current aspect ratio better than other ratios for health protection and/or differentiation of asbestos fibers.
2. *Ceiling Limits* — In light of today's instrumentation (quick response) and STELS, are ceiling limits needed and, if so, what criteria would determine their appropriateness.
3. *Soluble Inorganic Compounds* — What quantitative criteria should be used in differentiating between soluble and insoluble for TLV use.
4. Dual vapor and particulate TLVs.[2]
5. Should welding fume value (not otherwise classified, NOC) be retained or should specific analytical determinations be made for metals and other compounds and these values be compared to specific TLVs?

[1]Information, data especially, and comments are solicited to assist the committee in its deliberations and in the development of draft documents. Draft documentations are used by the committee to decide what action, if any, to recommend on a given substance or question.

[2]Study papers appear in the *Annals of the American Conference of Governmental Industrial Hygienists*, Volume 4, *ACGIH Transactions – 1982*, pp. 153-155 (1983).

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APPENDIX H
Registered[a] Trade Names

Trade Name	Generic Name	CAS No.
Abate	Temephos	3383-96-8
Ammate	Ammonium sulfamate	7773-06-0
Azodrin	Monocrotophos	6923-22-4
Baygon	Propoxur	114-26-1
Baytex	Fenthion	55-38-9
Bidrin	Dicrotophos	141-66-2
Bolstar	Sulprofos	35400-43-2
Butyl Cellosolve	2-Butoxyethanol	111-76-2
Cellosolve acetate	2-Ethoxyethyl acetate	111-15-9
Coyden	Clopidol	2971-90-6
Crag herbicide	Sesone	136-78-7
Dasanit	Fensulfothion	115-90-2
Delnav	Dioxathion	78-34-2
Dibrom	Naled	300-76-5
Difolatan	Captafol	2425-06-1
Disyston	Disulfoton	298-04-4
Dursban	Chlorpyrifos	2921-88-2
Dyfonate	Fonofos	944-22-9
Furadan	Carbofuran	1563-66-2
Guthion	Azinphos-methyl	86-50-0
Lannate	Methomyl	16752-77-5
Methyl Cellosolve	2-Methoxyethanol	109-84-4
Methyl Cellosolve acetate	2-Methoxyethyl acetate	110-49-6
Nemacur	Fenamiphos	22224-92-6
Nialate	Ethion	563-12-2
N-Serve	Nitrapyrin	1929-82-4
Pival	Pindone	83-26-1
Plictran	Cyhexatin	13121-70-5
Sencor	Metribuzin	21087-64-9
Sevin	Carbaryl	63-25-2
Teflon	Polytetrafluoro-ethylene	9002-84-0
Thimet	Phorate	298-02-2
Thiodan	Endosulfan	115-29-7
Tordon	Picloram	1918-02-1
Zoalene	Dinitolmide	148-01-6

TLVs®
Threshold Limit Values for Physical Agents in the Work Environment Adopted by ACGIH for 1983-84

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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.

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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 1 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.[1, 2]

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 = 0.7 NWB + 0.2 GT + 0.1 DB
2. Indoors or Outdoors with no solar load:
   WBGT = 0.7 NWB + 0.3 GT

where:

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

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

Higher heat exposures than shown in Table 1 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.

EVALUATION AND CONTROL

I. *Measurement of the Environment*

The instruments required are a dry-bulb, a natural wet-bulb, a globe thermometer, and a stand. The

TABLE 1

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

	Work Load		
Work — Rest Regimen	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

measurement of the environmental factors shall be performed as follows:

A. The range of the dry and the natural wet bulb thermometer shall be −5°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. A 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.

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C. A 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 as that of 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 by Minard.[3-4]

II. *Work Load Categories*

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

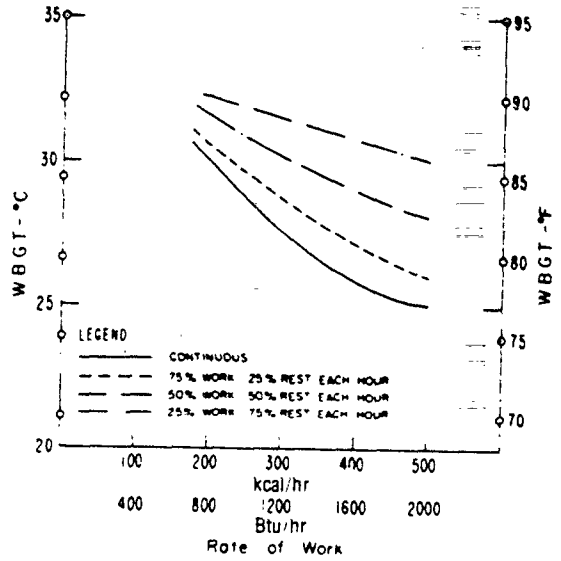


Figure 1 — Permissible Heat Exposure Threshold Limit Value

TABLE 2

Assessment of Work Load[9]

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	

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 (up to 200 kcal/hr or 800 Btu/hr): e.g., sitting or standing to control machines, performing light hand or arm work,

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TABLE 3

Activity Examples[9]

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	
Assembly line work using a heavy hand tool.	
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

(2) moderate work (200–350 kcal/hr or 800–1400 Btu/hr): e.g., walking about with moderate lifting and pushing,

(3) heavy work (350–500 kcal/hr or 1400–2000 Btu/hr): 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 with the use of Tables 2 and 3. Additional tables available in the literature[5–8] may be utilized also. When this method is used the permissible heat exposure limit can be determined by Figure 1.

III. *Work-Rest Regimen*

The permissible exposure limits specified in Table 1 and Figure 1 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. Where the WBGT of the work area is different from that of the rest area a time-weighted average value should be used for both environmental and metabolic heat. When time-weighted average values are used the appropriate curve on Figure 1 is the solid line labeled "continuous."

The time-weighted average metabolic rate (M) shall be determined by the equation:

$$\text{Av. } M = \frac{M_1 \times t_1 + M_2 \times t_2 + \ldots + M_n \times t_n}{t_1 + t_2 + \ldots + t_n}$$

where M_1, M_2 . . . and M_n are estimated or measured metabolic rates for the various activities and rest periods of the worker during the time periods t_1, t_2 . . . and t_n (in minutes) as determined by a time study.

The time-weighted average WBGT shall be determined by the equation:

$$\text{Av. WBGT} = \frac{WBGT_1 \times t_1 + WBGT_2 \times t_2 + \ldots + WBGT_n \times t_n}{t_1 + t_2 + \ldots + t_n}$$

where $WBGT_1$, $WBGT_2$ . . . and $WBGT_n$ are calculated values of WBGT for the various work and rest occupied during total time periods t_1, t_2 . . . and t_n are the elapsed times in minutes spent in the corresponding areas which are determined by a time study. Where exposure to hot environmental conditions is continuous for several hours or the entire work day, the time-weighted averages shall be calculated as hourly time-weighted average i.e., $t_1 + t_2 + \ldots + t_n = 60$ minutes. Where the exposure is intermittent, the time-weighted averages shall be calculated as two-hour time-weighted averages, i.e., $t_1 + t_2 + \ldots + t_n = 120$ minutes.

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

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counted as rest time when additional rest allowance must be given because of high environmental temperatures.

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 shall be kept reasonably cool (10°–15°C or 50.0°–60.0°F) 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 cothing 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 1 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:* Acclimatization to heat involves a series of physiological and psychological adjustments that occur in an individual during his first week of exposure to hot environmental conditions. The recommended heat stress TLVs are valid for acclimated workers who are physically fit. Extra caution must be employed when unacclimated or physically un-fit workers must be exposed to heat stress conditions.

References:

1. *Health Factors Involved in Working Under Conditions of Heat Stress* WHO Technical Report Series No. 412 (1969).
2. **Dubois-Dubois, F. N. and A. Henschel:** Development of Permissible Heat Exposure Limits for Occupational Work. *ASHRAE Journal 15(9)*: 57–62 (Sept. 1973)
3. **Minard, D.:** *Prevention of Heat Casualties in Marine Corps Recruits, Period of 1955–60, with Comparative Incidence Rates and Climatic Heat Stresses in Other Training Categories.* Research Report No. 4, Contract No. MR 005.01-0001.01, Naval Medical Research Institue Bethesda, MD (Feb. 21, 1961) Published in *Military Medicine 126(44)*:261–272 (April 1961).
4. **Minard, D. and R. L. O'Brien:** *Heat Casualties in the Navy and Marine Corps 1959–1962 with Appendices on the Field Use of the Wet Bulb-Globe Temperature Index.* Research Report No. 7, Contract No. MR 005.01-0001.01, Naval Medical Research Institute, Bethesda, MD (March 12, 1964).
5. **Astrand, Per-Olof and Kaare Rodahl:** *Textbook of Work Physiology* McGraw-Hill Book Co., New York, San Francisco (1970)
6. Ergonomics Guide to Assessment of Metabolic and Cardiac Costs of Physical Work. *Am. Ind. Hyg. Assoc. J. 32*:560 (1971).
7. *Energy Requirements for Physical Work*. Research Progress Report No. 30 Purdue Farm Cardiac Project, Agricultural Experiment Station, West Lafayette, IN (1961).
8. **Dernin, J. V. G. A. and R. Passmore:** *Energy, Work and Leisure* Heinemann Educational Books, Ltd., London (1967).
9. **Lehmann, G. E., A. Muller and H. Spitzer:** Der Kalorienbedarf bie Gewerblicher Arbeit. *Arbeitsphysiol. 14*:166 (1950).

IONIZING RADIATION

The Committee accepts the philosophy and recommendations of the National Council on Radiation Protection and Measurements (NCRP) for the ionizing radiation TLV. The NCRP is charted by Congress to, in part, collect, analyze, develop and disseminate information and recommendations about protection against radiation and about radiation measurements, quantities and units, including development of basic concepts in these areas. NCRP Report No. 39 provides basic philosophy and concepts leading to protection criteria established in the same report.[1] Other NCRP reports address specific areas of radiation protection and, collectively, provide an excellent basis for establishing a sound program for radiation control. The Committee recommends the listed references as substantative documentation of a sound basis for ionizing radiation protection. The committee also strongly recommends that all exposures to ionizing radiations be kept as low as reasonably achievable within the stated guidance.

References:

1. *Basic Radiation Protection Criteria*. NCRP Report No. 39 (January 15, 1971).

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2. *Maximum Permissible Body Burdens and Maximum Permissible Concentrations of Radionuclides in Air and in Water for Occupational Exposure.* National Bureau of Standards Handbook 69, (June 5, 1959), with *Addendum 1* (August 1963). Available as NCRP Report No. 22.

The above documents, as well as information on numerous other NCRP Reports addressing specific subjects in ionizing radiation protection are available from: NCRP Publications, PO Box 30175, Washington, DC 20014.

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); and except for all TLVs for wavelengths between 0.1–1 mm where the limiting aperture is 10 mm. 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 7) which varies with exposure time. This angle is *not* the beam divergence of the source.

Correction Factors A and B (C_A and C_B)

The TLVs for ocular exposure in Tables 4 and 5 are to be used as given for all wavelength ranges. The TLVs for wavelengths between 700 nm and 1049 nm are to be increased by a uniformly extrapolated factor (C_A) as shown in Figure 2. Between 1049 nm and 1400 nm, the TLV has been increased by a factor (C_A) of five. For certain exposure times at wavelengths between 550 nm and 700 nm, correction factor (C_B) must be applied.

The TLVs for skin exposure are given in Table 6. The TLVs are to be increased by a factor (C_A) as shown in Figure 2 for wavelengths between 700 nm and 1400 nm. To aid in the determination of TLVs for exposure durations requiring calculations of fractional powers Figures 3, 4, 5 and 6 may be used.

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 4, 5, or 7 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^{-5} second. For pulses of greater duration, the following formula should be followed:

$$\text{Standard}\begin{pmatrix}\text{single pulse}\\ \text{in train}\end{pmatrix} = \frac{\text{Standard (pulse } n\tau)}{n}$$

where:

n = number of pulses in train

τ = duration of a single pulse in the train

Standard ($n\tau$) = protection standard of one pulse having a duration equal to $n\tau$ seconds.

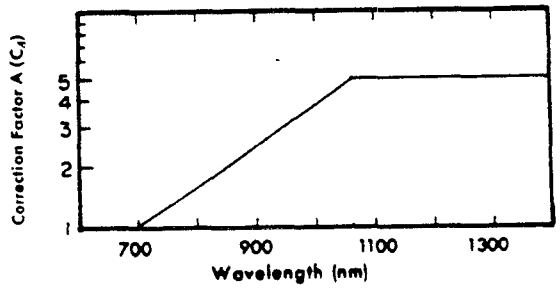


Figure 2 — TLV correction factor for λ = 700 − 1400 nm*

*For λ = 700 − 1049 nm, $C_A = 10^{[0.002(\lambda - 700)]}$
For λ = 1050 − 1400 nm, $C_A = 5$

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TABLE 4

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	"

*not to exceed $0.56\ t^{1/4}$ J • cm $^{-2}$ for t ≦ 10 s.

UVA	315 nm to 400 nm	10^{-9} to 10	$.56\ t^{1/4}$ J • cm $^{-2}$
	" "	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^{-7} J • cm $^{-2}$
	400 nm to 700 nm	1.8×10^{5} to 10	$1.8\ (t/\sqrt[4]{t})$ mJ • cm $^{-2}$
	400 nm to 549 nm	10 to 10^{4}	10 mJ • cm $^{-2}$
	550 nm to 700 nm	10 to T_1	$1.8\ (t/\sqrt[4]{t})$ mJ • cm $^{-2}$
	550 nm to 700 nm	T_1 to 10^{4}	$10\ C_B$ mJ • cm $^{-2}$
	400 nm to 700 nm	10^{4} to 3×10^{4}	$C_B\ \mu$W • cm $^{-2}$
IR-A	700 nm to 1049 nm	10^{-9} to 1.8×10^{5}	$5\ C_A \times 10^{-7}$ J • cm $^{-2}$
	700 nm to 1049 nm	1.8×10^{5} to 10^{9}	$1.8\ C_A\ (t/\sqrt[4]{t})$ mJ • cm $^{-2}$
	1050 nm to 1400 nm	10^{-9} to 10^{-1}	5×10^{-6} J • cm $^{-2}$
	1050 nm to 1400 nm	10^{-4} to 10^{9}	$9(t/\sqrt[4]{t})$ mJ • cm $^{-2}$
	700 nm to 1400 nm	10^{3} to 3×10^{4}	$320\ C_A\ \mu$W • cm $^{-2}$
IR-B & C	1.4 μm to 10^{3} μm	10^{-9} to 10^{-7}	10^{-2} J • cm^{2}
	" "	10^{-7} to 10	$0.56\sqrt{t}$ J • cm $^{-2}$
	" "	10 to 3×10^{4}	0.1 W • cm $^{-2}$

C_A See Fig 2
C_B 1 for λ 400 to 549 nm, C_B $10^{[illegible]}$ for λ 550 to 700 nm
T_1 10 s for λ 400 to 549 nm, T_1 10 - $10^{[illegible]}$ for λ 550 to 700 n

MAP 000456

TABLE 5

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	$10\sqrt[4]{t}$ J • cm^{-2} • sr^{-1}
	400 nm to 549 nm	10 to 10^{4}	21 J • cm^{-2} • sr^{-1}
	550 nm to 700 nm	10 to T_1	$3.83\,(t/\sqrt[4]{t})$ J • cm^{-2} • sr^{-1}
	550 nm to 700 nm	T_1 to 10^{4}	21 C_B J • cm^{-2} • sr^{-1}
	400 nm to 700 nm	10^{4} to 3×10^{4}	$2.1\,C_B t \times 10^{-3}$ W • cm^{-2} • sr^{-1}
IR-A	700 nm to 1400 nm	10^{-9} to 10	$10\,C_A\sqrt[4]{t}$ J • cm^{-2} • sr^{-1}
	700 nm to 1400 nm	10 to 10^{3}	$3.83\,C_A\,(t/\sqrt[4]{t})$ J • cm^{-2} • sr^{-1}
	700 nm to 1400 nm	10^{3} to 3×10^{4}	0.64 C_A W • cm^{-2} • sr^{-1}
IR-B & C	1.4 μm to 10^{3} μm	10^{-9} to 3×10^{4}	Same as Table 4

C_A, C_B, and T_1 are the same as in footnote to Table 4

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 4
Light &	400 nm to 1400 nm	10^{-9} to 10^{-7}	$2\,C_A \times 10^{-2}$ J • cm^{-2}
IR-A	" "	10^{-7} to 10	$1.1\,C_A\sqrt[4]{t}$ J • cm^{-2}
IR-A	" "	10 to 3×10^{4}	0.2 C_A W • cm^{-2}
IR-B & C	1.4 μm to 10^{3} μm	10^{-9} to 3×10^{4}	Same as Table 4

C_A = 1.0 for λ = 400-700 nm; see Figure 2 for λ = 700 to 1400 nm.

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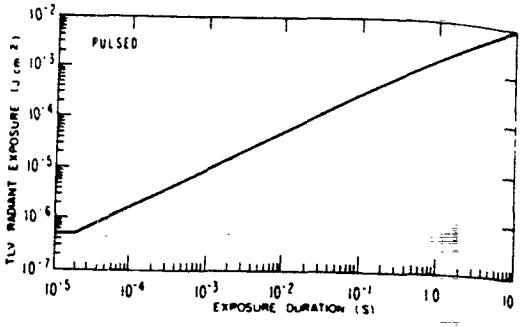


Figure 3a — TLV for intrabeam (direct) viewing of laser beam (400–700 nm).

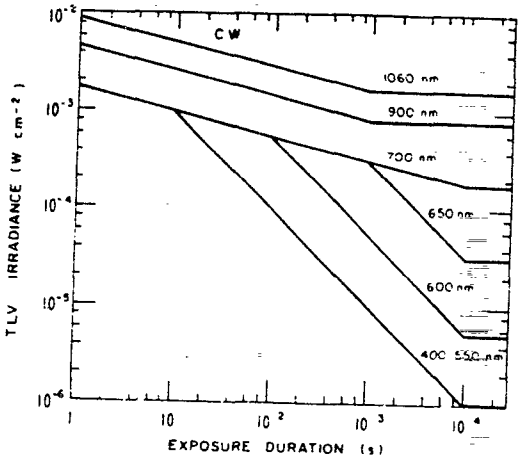


Figure 3b — TLV for intrabeam (direct) viewing of CW laser beam (400–1400 nm)

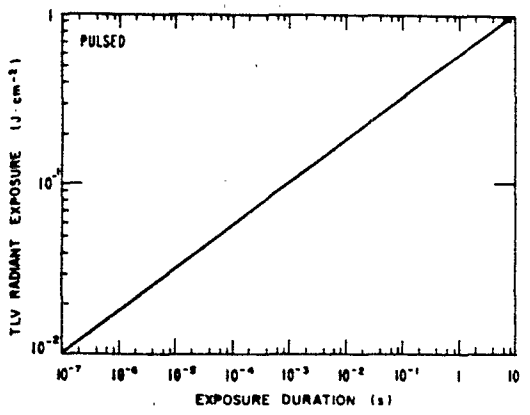


Figure 4a — TLV for laser exposure of skin and eyes for far-infrared radiation (wave-lengths greater than 1.4 μm).

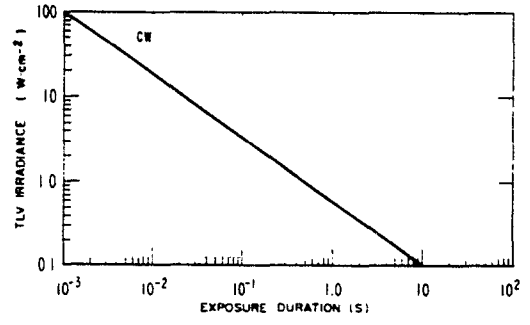


Figure 4b — TLV for CW laser exposure of skin and eyes for far-infrared radiation (wave-lengths greater than 1.4 μm).

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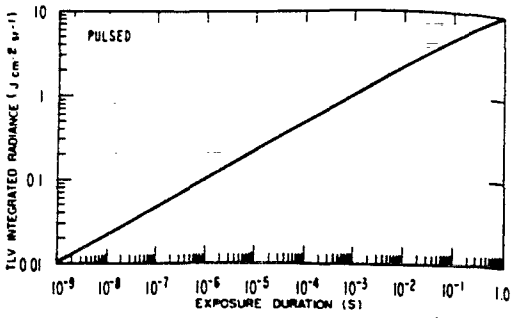


Figure 5a — TLV for extended sources or diffuse reflections of laser radiation (400–700 nm).

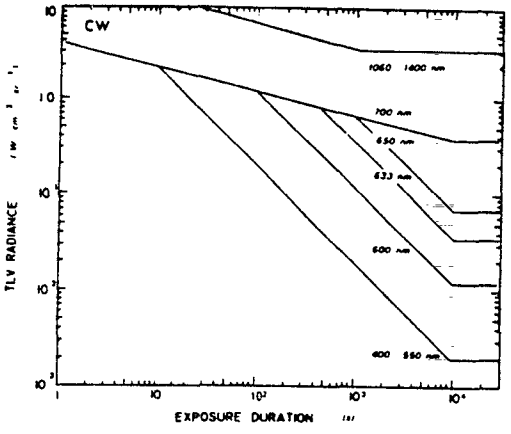


Figure 5b — TLV for extended sources or diffuse reflections of laser radiation (400–1400 nm).

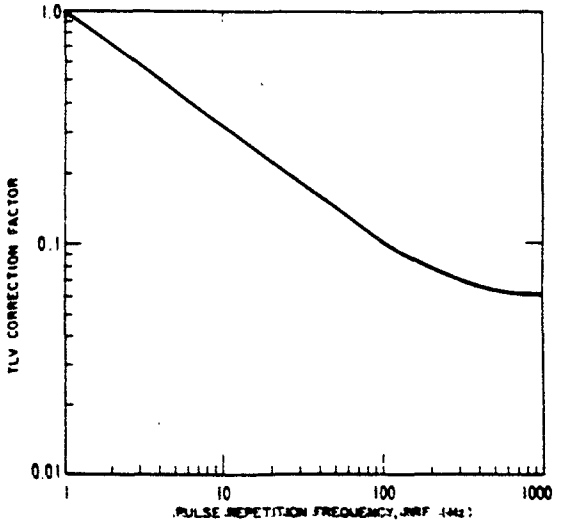


Figure 6 — Multiplicative correction factor for repetitively pulsed lasers having pulse durations less than 10^{-5} second. TLV for a single pulse of the pulse train is multiplied by the above correction factor. Correction factor for PRF greater than 1000 Hz is 0.06.

TABLE 7

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

Exposure Duration(s)	Angle α (mrad)	Exposure Duration(s)	Angle α (mrad)
10^{-9}	8.0	10^{-2}	5.7
10^{-8}	5.4	10^{-1}	9.2
10^{-7}	3.7	1.0	15
10^{-6}	2.5	10	24
10^{-5}	1.7	10^{2}	24
10^{-4}	2.2	10^{3}	24
10^{-3}	3.6	10^{4}	24

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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. Prior to 1979, the medical profession had 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.[a] 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.

It should be recognized that the application of the TLV for noise will not protect all workers from the adverse effects of noise exposure. A hearing conservation program with audiometric testing is necessary when workers are exposed to noise at or above the TLV 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 National 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 8.

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 and does include the impact and impulsive type of noise that contributes to the sound level meter reading at slow response.

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 on-the-job noise exposures of 80 dBA or greater shall be used in the above calculations.

[a] In 1979, the American Academy of Ophthalmology and Otolargyngology (AAOO) included 3000 Hz in their hearing impairment formula.

Table 8
Threshold Limit Values

Duration per Day Hours	Sound Level dBA†
16	80
8	85
4	90
2	95
1	100
1/2	105
1/4	110
1/8	115*

†Sound level in decibels are 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

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

IMPULSIVE OR IMPACT NOISE

It is recommended that exposure to impulsive or impact noise shall not exceed the limits listed in Table 9 or taken from Figure 7. No exposures in excess of 140 decibels peak sound pressure level are permitted. 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 9
Threshold Limit Values Impulsive or Impact Noise

Sound Level dB**	Permitted Number of Impulses or Impacts per day
140	100
130	1000
120	10,000

**Decibels peak sound pressure level, re 20 μPa

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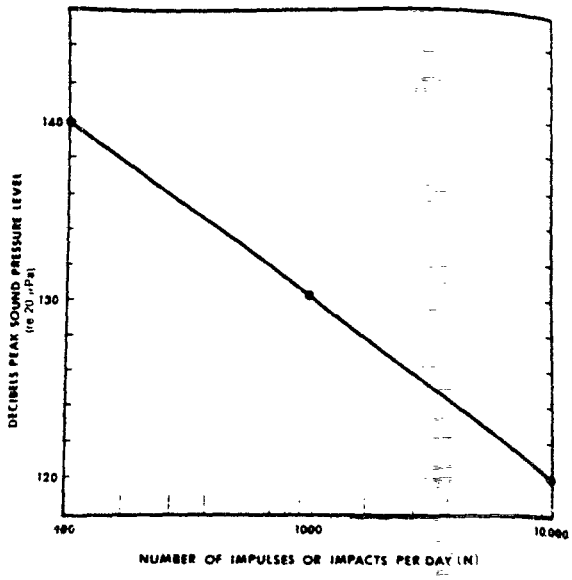


Figure 7 — Threshold Limit Values for Impulse/Impact Noise.

‡RADIOFREQUENCY/MICROWAVE RADIATION

These Threshold Limit Values (TLVs) refer to radiofrequency (RF) and microwave radiation in the frequency range from 10 kHz to 300 GHz, and represent conditions under which it is believed workers may be repeatedly exposed without adverse health effects. The TLVs shown in Table 10 are selected to limit the average whole body specific absorption rate (SAR) to 0.4 W/kg in any six minutes (0.1 hr) period for 3 MHz to 300 GHz, see Figure 8. Between 10 kHz and 3 MHz the average whole body SAR is still limited to 0.4 W/kg, but the plateau at 100 mW/cm² was set to protect against shock and burn hazards.

Since it is usually impractical to measure the SAR, the TLVs are expressed in units that are measurable, viz, squares of the electric and magnetic field strengths, averaged over any 0.1 hour period. This

‡1983 Adoption.

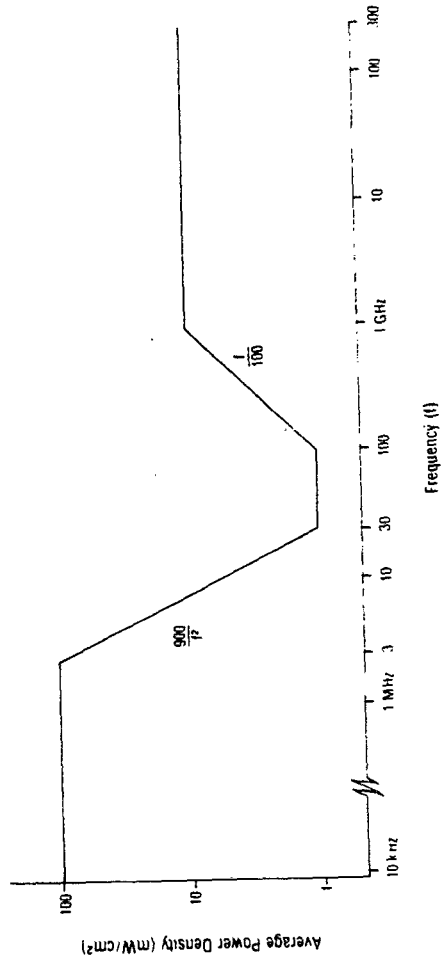


Figure 8 — Threshold Limit Values (TLV) for Radiofrequency/Microwave Radiation in Workplace (Whole Body SAR Less Than 0.4 W/kg).

MAP 000461

TABLE 10

Radiofrequency/Microwave Threshold Limit Values

Frequency	Power Density (mW/cm²)†	Electric Field Strength Squared (V²/m²)	Magnetic Field Strength Squared (A²/m²)
10 kHz to 3 MHz	100	377,000	2.65
3 MHz to 30 MHz	900/f²*	3770 × 900/f²*	900/37.7f²*
30 MHz to 100 MHz	1	3770	0.027
100 MHz to 1000 MHz	f*/100	3770 × f*/100	f*/37.7 × 100
1 GHz to 300 GHz	10	37,700	0.265

†mW/cm² = milliwatts per centimeter squared
*f = frequency in MHz

can be expressed in units of equivalent plane wave power density for convenience. The electric field strength (E) squared, magnetic field strength (H) squared, and power density (PD) values are shown in Table 10. For near field exposures PD cannot be measured directly, but equivalent plane wave power density can be calculated from the field strength measurement data as follows:

$$\text{PD in mW/cm}^2 = \frac{E^2}{3770}$$

where:

E^2 is in volts squared (V^2) per meter squared (m^2).

$$\text{PD in mW/cm}^2 = 37.7\ H^2$$

where:

H^2 is in amperes squared (A^2) per meter squared (m^2).

These values should be used as guides in the evaluation and control of exposure to radiofrequency/microwave radiation, and should not be regarded as a fine line between safe and dangerous levels.

Notes:

1. All Radiofrequency Radiation (RFR) exposures should be kept as low as reasonably possible given the current state of knowledge on human effects, particularly non-thermal effects.
2. For fields consisting of a number of frequencies, the fraction of the protection guide incurred within each frequency level should be determined and the sum of all fractions should not exceed unity.
3. For pulsed and continuous wave fields, the power density is averaged over the six minute period.
4. For partial body exposures at frequencies between 10 kHz and 1.0 GHz, the protection guides in Table 10 may be exceeded if the output power of a radiating device is 7 watts or less. For example, if a hand held transmitter operating at 27 MHz has a maximum output of 5 watts, it would be excluded from any further field measurements.
5. The TLVs in Table 10 may be exceeded if the exposure conditions can be demonstrated to produce a SAR of less than 0.4 W/kg as averaged over the whole body and spatial peak SAR values less than 8.0 W/kg as averaged over any 1.0 gram of tissue.

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For example, for frequencies from 3 to 30 MHz, the equivalent power density can be increased by a factor of 10 up to a limit of 100 mW/cm². if it can be assured that exposed individuals are not in contact with the ground plate.

6. At frequencies below 30 MHz, ungrounded objects such as vehicles, fences, etc., can strongly couple to RF fields. For field strengths near the TLV, shock and burn hazards can exist. Care should be taken to eliminate ungrounded objects, to ground such objects, or use insulated gloves when ungrounded objects must be handled.
7. No measurement should be made within 5 cm of any object.
8. All exposures should be limited to a maximum (peak) electric field intensity of 100 kV/m.

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, and solar radiation, but do not apply to ultraviolet lasers.* These values do not apply to ultraviolet radiation exposure of photosensitive individuals or of individuals concomitantly exposed to photosensitizing agents.[1] 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 nm) 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 11 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 following weighting formula should be used:

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

where:

E_{eff} = effective irradiance relative to a monochromatic source at 270 nm in W/cm² (J/s/cm²)

E_λ = spectral irradiance in W/cm²/nm

S_λ = relative spectral effectiveness (unitless)

$\Delta\lambda$ = band width in nanometers

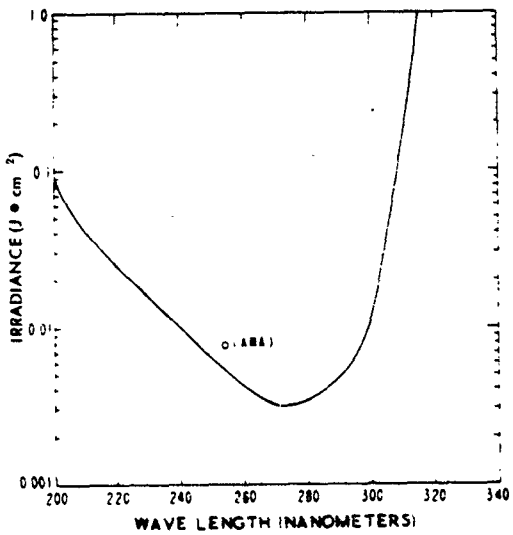


Figure 9 — Threshold Limit Values for Ultraviolet Radiation

*See Laser TLVs.

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TABLE 11

Relative Spectral Effectiveness by Wavelength*

Wavelength (nm)	TLV (mJ/cm^2)	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
254	6.0	0.5
260	4.6	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 Laser TLVs

TABLE 12

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
30 min.	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

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/cm^2 by E_{eff} in W/cm^2. The exposure time may also be determined using Table 12 which provides exposure times corresponding to effective irradiances in $\mu W/cm^2$.
5. All the preceding TLVs 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°.

Conditioned (tanned) individuals can tolerate skin exposure in excess of the TLV without erythemal effects. However, such conditioning may not protect persons against skin cancer.

References:

1. *Sunlight and Man* Fitzpatrick *et al.* Eds Univ. of Tokyo Press Tokyo, Japan (1974).

NOTICE OF INTENDED CHANGES (for 1983-84)

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.

NOTICE OF INTENT TO ESTABLISH THRESHOLD LIMIT VALUES

LASERS

It is proposed that the following footnote be added to Table 6 (Threshold Limit Value for Skin Exposure from a Laser Beam).

The IR-B and IR-C exposures to skin surface areas A(cm^2) exceeding 1000 cm^2, the TLV is

$$(100{,}000/A) \bullet (mW/cm^2);$$

for areas greater than 100,000/A, the TLV is 10 mW/cm^2.

LIGHT AND NEAR-INFRARED RADIATION

These Threshold Limit Values refer to visible and near-infrared radiation in the wavelength range of 400

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nm to 1400 nm and represent conditions under which it is believed that nearly all workers may be exposed without adverse effect. These values should be used as guides in the control of exposure to light and should not be regarded as a fine line between safe and dangerous levels.

Recommended Values:

The Threshold Limit Value for occupational exposure to broad-band light and near-infrared radiation for the eye apply to exposure in any eight-hour workday and require knowledge of the spectral radiance (L_λ) and total irradiance (E) of the source as measured at the position(s) of the eye of the worker. Such detailed spectral data of a white light source is generally only required if the luminance of the source exceeds 1 cd cm^{-2}. At luminances less than this value the TLV would not be exceeded.

TABLE 13

Spectral Weighting Functions for Assessing Retinal Hazards from Broad-Band Optical Sources

Wavelength (nm)	Blue-Light Hazard Function B_λ	Burn Hazard Function R_λ
400	0.10	1.0
405	0.20	2.0
410	0.40	4.0
415	0.80	8.0
420	0.90	9.0
425	0.95	9.5
430	0.98	9.8
435	1.0	10
440	1.0	10
445	0.97	9.7
450	0.94	9.4
455	0.90	9.0
460	0.80	8.0
465	0.70	7.0
470	0.62	6.2
475	0.55	5.5
480	0.45	4.5
485	0.40	4.0
490	0.22	2.2
495	0.16	1.6
500–600	$10^{(450-\lambda)/50}$	1.0
600–700	0.001	1.0
700–1049	0.001	$10^{(700-\lambda)/50}$
1050–1400	0.001	0.2

The TLV's are:

1. To protect against retinal thermal injury, the spectral radiance of the lamp weighted against the function R (Table 13) should not exceed:

$$\sum_{400}^{1400} L_\lambda R_\lambda \Delta\lambda \leqq 1/\alpha\, t^{1/2} \qquad (1)^*$$

where L_λ is in W cm^{-2} sr^{-1} and t is the viewing duration (or pulse duration if the lamp is pulsed) limited to 1 μs to 10 s, and α is the angular subtense of the source in radians. If the lamp is oblong, α refers to the longest dimension that can be viewed. For instance, at a viewing distance r = 100 cm from a tubular lamp of length l = 50 cm, the viewing angle is:

$$\alpha = l/r = 50/100 = 0.5 \text{ rad} \qquad (2)$$

2. To protect against retinal photochemical injury from chronic blue-light exposure the integrated spectral radiance of a light source weighted against the blue-light hazard function B_λ (Table 13) should not exceed:

$$\sum_{400}^{1400} L_\lambda\, t\, B_\lambda \Delta\lambda \leqq 100 \text{ J}cm^{-2}\, sr^{-1} \quad (t \leqq 10^4 s) \qquad (3a)$$

$$\sum_{400}^{1400} L_\lambda B_\lambda \Delta\lambda \leqq 10^{-2} \text{ W}cm^{-2}\, sr^{-1} \quad (t > 10^4 s) \qquad (3b)$$

The weighted product of L_λ and B_λ is termed L(blue). For a source radiance L weighted against the blue-light hazard function [L(blue)] which exceeds 10 mW•cm^{-2}•sr^{-1} in the blue spectral region, the permissible exposure duration t_{max} in seconds is simply:

$$t_{max} = 100 \text{ J } cm^{-2}\, sr^{-1}/\text{L (blue)} \qquad (4)$$

The latter limits are greater than the maximum permissible exposure limits for 440 nm laser radiation (see Laser TLV) because a 2–3 mm pupil is assumed rather than a 7 mm pupil for the Laser TLV. For a light source subtending an angle α less than 11 mrd (0.011 radian) the above limits are relaxed such that the spectral irradiance weighted against the blue-light hazard function B_λ should not exceed E(blue).

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$$\sum_{400}^{1400} E_\lambda \bullet t \bullet B_\lambda \bullet \Delta\lambda \leqq 10 \text{ mJ} \bullet \text{cm}^{-2} \quad (t \leqq 10^4 \text{ s}) \qquad (5a)$$

$$\sum_{400}^{1400} E_\lambda \bullet B_\lambda \bullet \Delta\lambda \leqq 1\mu\text{W} \bullet \text{cm}^2 \quad (t \geqq 10^4 \text{ s}) \qquad (5b)$$

For a source where the blue light weighted irradiance E (blue) exceeds 1 μW • cm^{-2} is the maximum permissible exposure duration t_{max} in seconds is:

$$t_{max} = 10 \text{ mJ} \bullet \text{cm}^{-2} \, E \text{ (blue)} \qquad (6)$$

3. *Infrared Radiation:* To avoid possible delayed effects upon the lens of the eye (cataractogenesis), the infrared radiation ($\lambda > 770$ nm) should be limited to 10 mWcm^{-2}. For an infrared heat lamp or any near-infrared source where a strong visual stimulus is absent, the near infrared (770–1400 nm) radiance as viewed by the eye should be limited to:

$$\sum_{770}^{1400} L_\lambda \Delta\lambda = 0.6/\alpha \qquad (7)^*$$

for extended duration viewing conditions. This limit is based upon a 7 mm pupil diameter.

AIRBORNE UPPER SONIC AND ULTRASONIC ACOUSTIC RADIATION

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. The values listed in Table 14 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. The levels for the third octave bands centered below 20 kHz are below those which cause subjective effects. Those levels for 1/3 octaves above 20 kHz are for prevention of possible hearing losses from subharmonics of these frequencies.

*Formulae (1) and (7) are empirical and are not, strictly speaking, dimensionally correct. To make the formulae dimensionally correct, one would have to insert a dimensional correction factor k in the right hand numerator in each formula. For formula (1) this would be k_1 = 1 W • rad • s$^{1/2}$/(cm^2 • sr), and for formula (7) k_2 = 1 W • rad/(cm^2 • sr).

TABLE 14

Permissible Ultrasound Exposure Levels

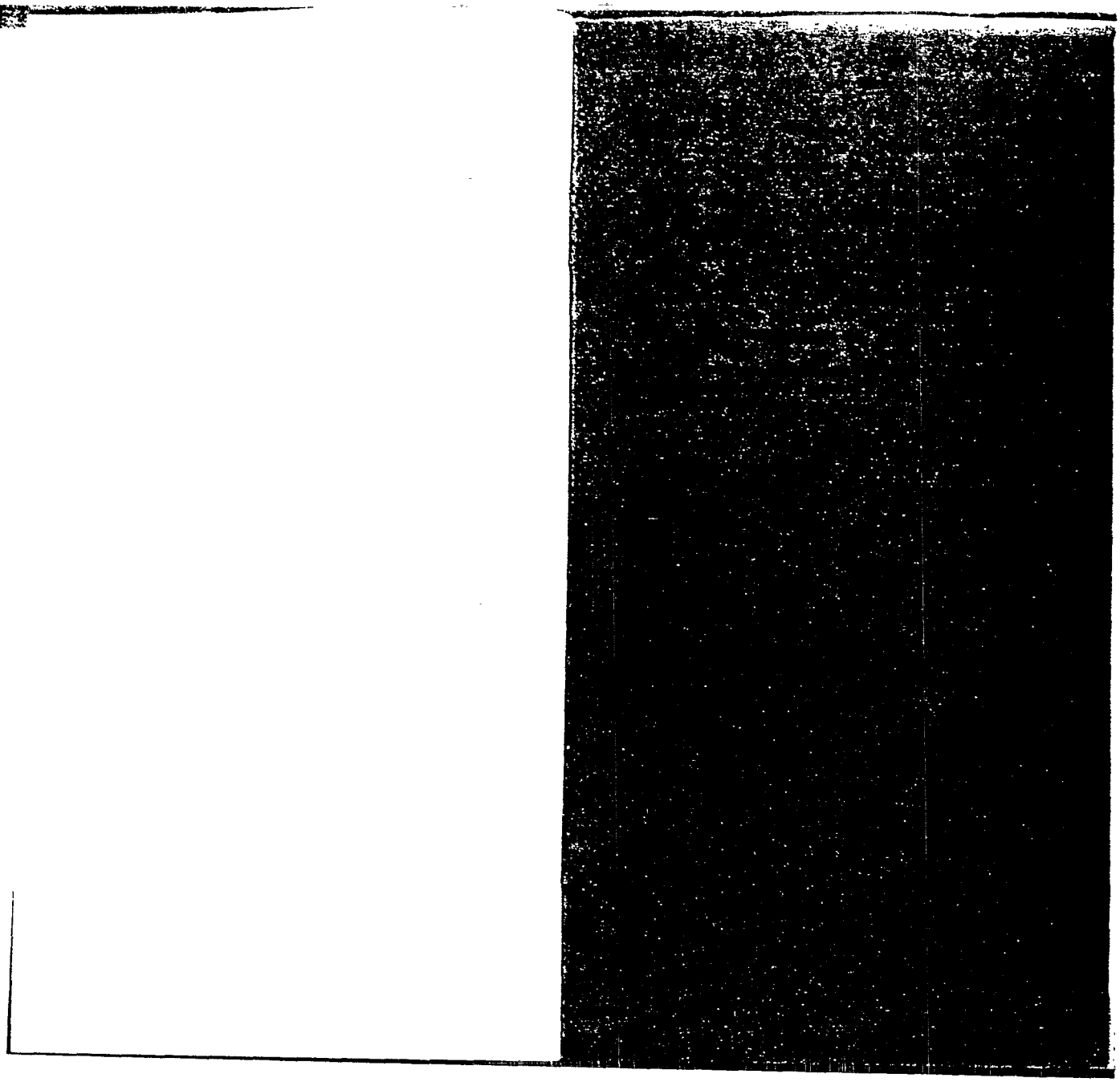
Mid-Frequency of Third-Octave Band kHz	One-Third Octave — Band Level in dB re 20 μPa
10	80
12.5	80
16	80
20	105
25	110
31.5	115
40	115
50	115

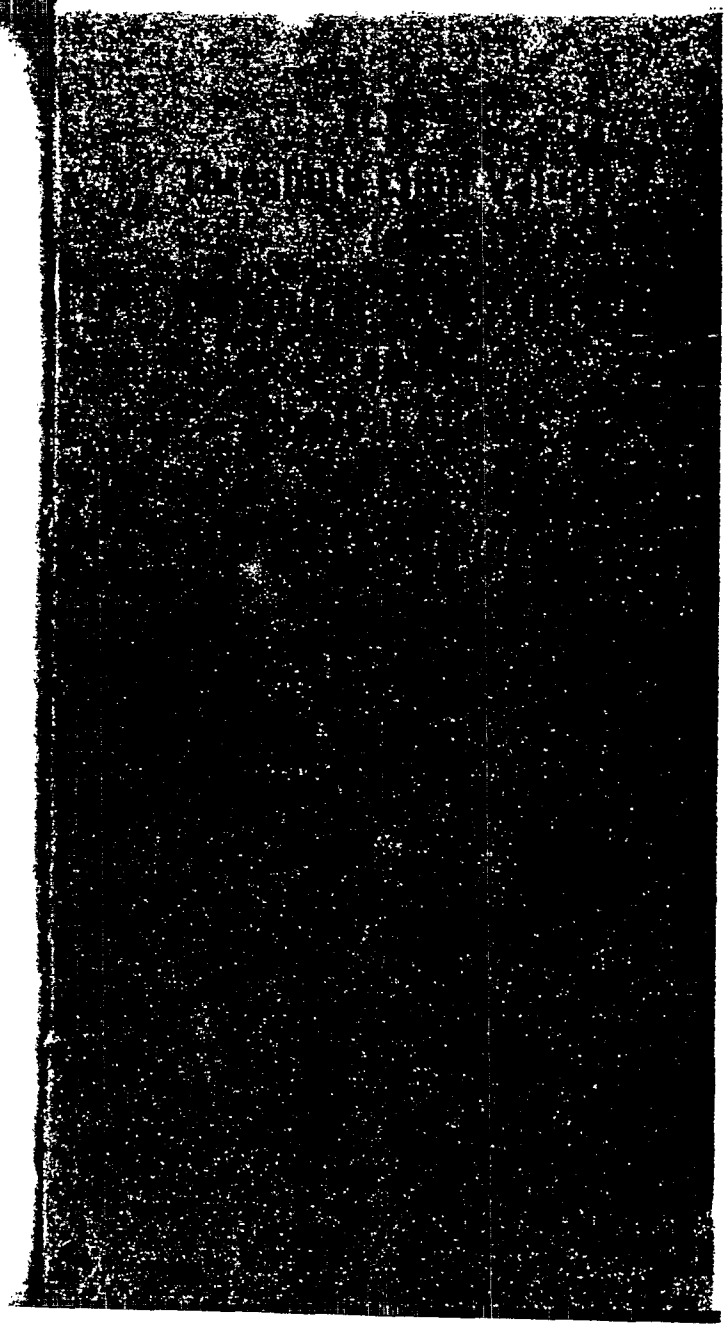
PHYSICAL AGENTS UNDER STUDY

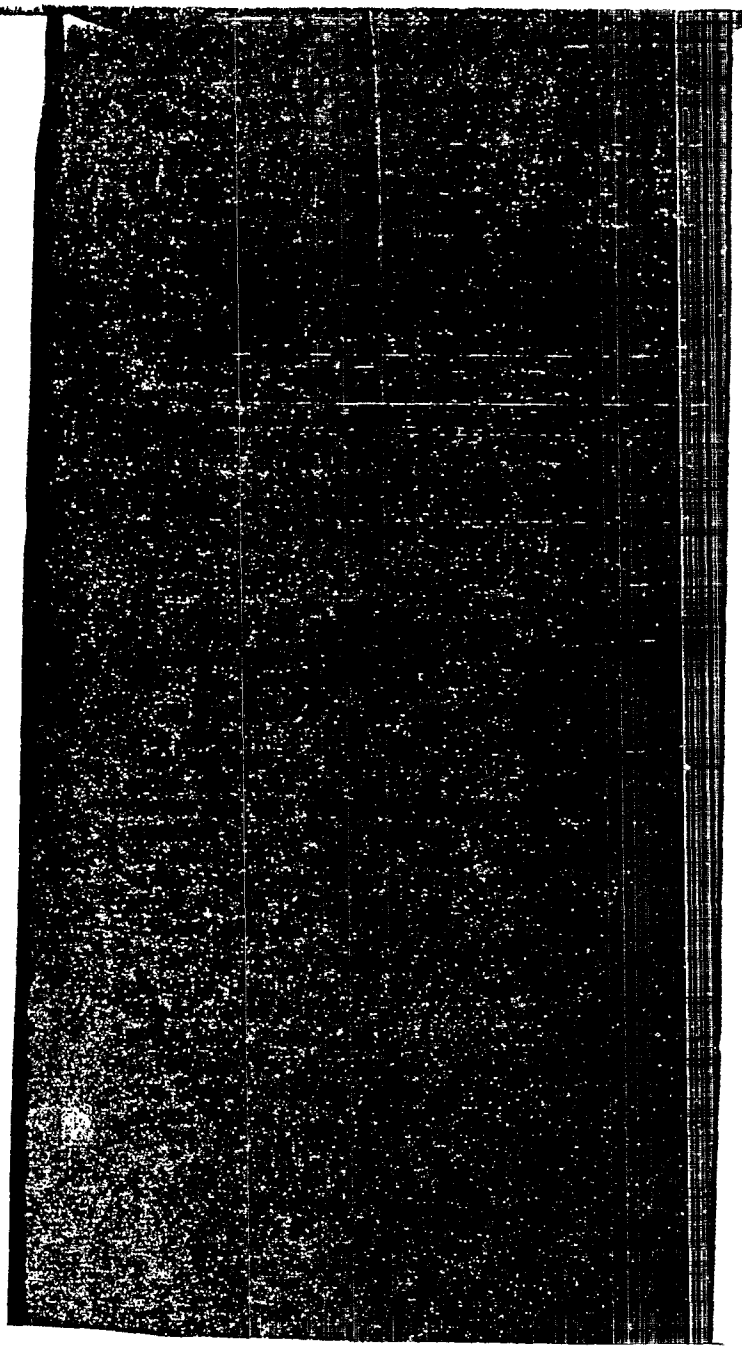
The Physical Agents Committee of ACGIH has examined the current literature and has not found sufficient information to propose a TLV. However, these agents will remain under study during the coming year to examine new evidence indicating the need and feasibility for establishing a proposed TLV. Comments and suggestions, accompanied by substantive documentation are solicited and should be forwarded to the Executive Secretary, ACGIH. Documentation summarizing the current status of the biological effects literature is available on those agents preceded by an asterisk (*).

1. **Extremely Low Frequency (ELF) Radiation.* Specifically, that portion of the spectrum from 0 to 300 Hz.
2. *Magnetic Fields.* Both pulsed and *continuous.
3. *Laser Radiation.* Specifically laser exposures of less than one (1) nanosecond.
4. *Vibration.* Segmental and whole-body.
5. *Cold Stress.*
6. *Pressure Variations.*

MAP 000466







Catan

TLVs®
Threshold Limit Values
for
Chemical Substances
in the
Work Environment
Adopted by
ACGIH
for 1984-85

MAP 000469

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PREFACE

CHEMICAL SUBSTANCES

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 preexisting condition or by development of an occupational illness.

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 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.

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 control of community air pollution nuisances, (3) in estimating the toxic potential of continuous, uninterrupted exposures or other extended work periods, (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.

The TLV-TWA should be used as guides in the control of health hazards and should not be used as fine lines between safe and dangerous concentrations.

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.

Legal Status. The Threshold Limit Values as issued by ACGIH, are recommendations and should be used as guidelines for good practices. Wherever these values (of whatever year) have been used or included by reference in Federal and/or State statutes and registers, the TLVs do have the force and effects of law.

"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. Values listed in parenthesis in the "Adopted" list are to be used during the period in which a proposed change for that Value is listed in the Notice of Intended Changes.

Definitions. Three categories of Threshold Limit Values (TLVs) are specified herein, as follows:

a) The Threshold Limit Value-Time Weighted Average (TLV-TWA) — the time-weighted average concentration for a normal 8-hour workday and a 40-hour workweek, to which nearly all workers may be repeatedly exposed, day after day, without adverse effect.

b) Threshold Limit Value-Short Term Exposure Limit (TLV-STEL) — the concentration to which workers can be exposed continuously for a short period of time without suffering from 1) irritation, 2) chronic or irreversible tissue damage, or 3) narcosis of sufficient degree to increase the likelihood of accidental injury, impair self-rescue or materially reduce work efficiency, and provided that the daily TLV-TWA is not exceeded. It is not a separate independent exposure limit, rather it supplements the time-weighted average (TWA) limit where there are recognized acute effects from a substance whose toxic effects are primarily of a chronic nature. STELs are recommended only where toxic effects have been reported from high short-term exposures in either humans or animals.

A STEL is defined as a 15-minute time-weighted average exposure which should not be exceeded at any time during a work day even if the eight-hour time-weighted average is within the TLV. Exposures at the STEL should not be longer than 15 minutes and should not be repeated more than four times per day. There should be at least 60 minutes between successive exposures at the STEL. An averaging period other than 15 minutes may be recommended when this is warranted by observed biological effects.

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c) Threshold Limit Value-Ceiling (TLV-C) — the concentration that should not be exceeded even instantaneously.

For some substances, e.g., irritant gases, only one category, the TLV-Ceiling, may be relevant. For other substances, either two or three categories may be relevant, depending upon their physiologic action. It is important to observe that if any one of these three TLVs is exceeded, a potential hazard from that substance is presumed to exist.

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.

Time-Weighted Average vs Ceiling Limits. 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 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 a decision as to whether a hazardous condition exists.

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 noncompliance 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. It should be noted that the same factors are used by the Committee in determining the magnitude of the value of the STELs, or whether to include or exclude a substance for a "C" listing.

Excursion Limits. For the vast majority of substances with a TLV, there is not enough toxicological data available to warrent a STEL. Nevertheless, excursions above the TWA-TLV should be controlled even where the eight-hour TWA is within recommended limits. Earlier editions of the TLV list included such limits whose values depended on the TWA-TLVs of the substance in question.

While no rigorous rationale was provided for these particular values, the basic concept was intuitive: in a well controlled process exposure, excursions should be held within some reasonable limits. Unfortunately, neither toxicology nor collective industrial hygiene experience provide a solid basis for quantifying what those limits should be. The approach here is that the maximum recommended excursion should be related to the variability generally observed in actual industrial processes. Leidel, Busch and Crouse,* in reviewing large numbers of industrial hygiene surveys conducted by NIOSH, found that short-term exposure measurements were generally log normally distributed with geometric standard deviations mostly in the range of 1.5 to 2.0.

While a complete discussion of the theory and properties of the log normal distribution is beyond the scope of this section, a brief description of some important terms is presented. The measure of central tendency in a log normal distribution is the antilog of the mean logarithm of the sample values. The distribution is skewed and the geometric mean is always smaller than the arithmetic mean by an amount which depends on the geometric standard deviation. In the log normal distribution, the geometric standard deviation (sd_g) is the antilog of the standard deviation of the sample value logarithms and 68.26% of all values lie between m_g/sd_g and $m_g \times sd_g$.

If the short-term exposure values in a given situation have a geometric standard deviation of 2.0, 5% of all values exceed 3.13 times the geometric mean. If a process displays a variability greater than this, it is not under good control and efforts should be made to restore con-

*Leidel, N.A., K.A. Busch and W.E. Crouse: *Exposure Measurement Action Level and Occupational Environmental Variability*. NIOSH Pub. No. 76-131 (December 1975)

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trol. This concept is the basis for the new excursion limit recommendations which are as follows

Short-term exposures should exceed three times the TLV-TWA for no more than a total of 30 minutes during a work day and under no circumstances should they exceed five times the TLV, provided that the TLV-TWA is not exceeded.

The approach is a considerable simplification of the idea of the log normal concentration distribution but is considered more convenient to use by the practicing industrial hygienist. If exposure excursions are maintained within the recommended limits, the geometric standard deviation of the concentration measurements will be near two and the goal of the recommendation will be accomplished.

When the toxicologic data for a specific substance are available to establish a STEL, this value takes precedence over the excursion limit regardless of whether it is more or less stringent.

"Skin" Notation. Listed substances followed by the designation "Skin" refer to the potential contribution to the overall exposure by the cutaneous route including mucous membranes and eye, either by air borne, or more particularly, by direct contact with the substance. Vehicles can alter skin absorption.

Little quantitative data are available describing absorption of vapors and gases through the skin. The rate of absorption is a function of the concentration to which the skin is exposed.

Substances having a skin notation and a low TLV may present a problem at high airborne concentrations, particularly if a significant area of the skin is exposed for a long period of time. Protection of the respiratory tract, while the rest of the body surface is exposed to a high concentration, may present such a situation.

Biological monitoring should be considered to determine the relative contribution of dermal exposure to the total dose.

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, may cause unpleasant deposits in the eyes, ears and nasal 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 10 mg/m^3, or 30 mppcf, of total dust < 1% quartz, or, 5 mg/m^3 respirable dust 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 D.

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 E.

Physical Factors. It is recognized that such physical factors as heat, ultraviolet and ionizing radiation, humidity, abnormal pressure (altitude) and like may place added stress on the body so that the effects from exposure at a threshold limit may be altered. Most of these

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stresses act adversely 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.

Unlisted Substances. Many substances present or handled in industrial processes do not appear on the TLV list in a number of instances the material is rarely present as a particulate, vapor or other airborne contaminant, and a TLV is not necessary. In other cases sufficient information to warrant development of a TLV, even on a tentative basis, is not available to the Committee. Other substances, of low toxicity, could be included in Appendix D pertaining to nuisance particulates. This list (as well as Appendix E) is not meant to be all inclusive; the substances serve only as examples.

In addition there are some substances of not in considerable toxicity, which have been omitted primarily because only a limited number of workers (e.g., employees of a single plant) are known to have potential exposure to possibly harmful concentrations.

Trade Names. Because many chemical substances are marketed under several trade names, the trade names have been replaced with their generic equivalent in the alphabetical listing. Appendix H was created to ease this transition and the CAS number appears with the generic name to aid identification.

Operational Guidelines: The ACGIH Board of Directors has adopted operational guidelines for the Chemical Substances TLV Committee. These guidelines prescribe: charge, authority, policies, membership, organization, and operating procedures. The policies include the appeals procedures. Copies of the guidelines document are available from the Publications Office at a cost of $5 per copy.

NOTE: In the interest of keeping this book as small as possible, the footnotes for adopted values appear on right hand pages only.

	ADOPTED VALUES			
	TWA		STEL	
Substance [CAS #]	ppm[a]	mg/m³[b]	ppm	mg/m³[b]
Acetaldehyde [75-07-0]	100	180	150	270
Acetic acid [64-19-7]	10	25	15	37
Acetic anhydride [108-24-7]	C 5	C 20	—	—
Acetone [67-64-1]	750	1,780	1,000	2,375
Acetonitrile [75-05-8] — Skin	40	70	60	105
Acetylene [74-86-2]	E	—	—	—
Acetylene dichloride, see 1,2-Dichloroethylene				
‡Acetylene tetrabromide [79-27-6]	1	15	(1.5)	(20)
Acetylsalicylic acid (Aspirin) [50-78-2]	—	5	—	—
Acrolein [107-02-8]	0.1	0.25	0.3	0.8
Acrylamide [79-06-1] — Skin	—	0.3	—	0.6
Acrylic acid [79-10-7]	10	30	—	—
*Acrylonitrile [107-13-1] — Skin	2, A2	4.5, A2	—	—
‡Aldrin [309-00-2] — Skin	—	0.25	—	(0.75)
Allyl alcohol [107-18-6] — Skin	2	5	4	10
Allyl chloride [107-05-1]	1	3	2	6
Allyl glycidyl ether (AGE) [106-92-3] — Skin	5	22	10	44
Allyl propyl disulfide [2179-59-1]	2	12	3	18
‡α-Alumina [1344-28-1]	—	D	—	(20)
Aluminum [7429-90-5],				
‡ Metal & oxide	—	10	—	(20)
Pyro powders	—	5	—	—
Welding fumes	—	5	—	—
Soluble salts	—	2	—	—
Alkyls (NOC†)	—	2	—	—
4-Aminodiphenyl [92-67-1] — Skin	—	A1b	—	—
2-Aminoethanol, see Ethanolamine				
‡2-Aminopyridine [504-29-0]	0.5	2	(2)	(4)

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 substance per cubic meter of air

‡ See Notice of Intended Changes

* 1984–1985 Addition

†NOC = Not otherwise classified

Capital letters A, B, D & E refer to Appendices. C denotes ceiling limit

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Substance [CAS #]	ADOPTED VALUES TWA ppm[a]	TWA mg/m³[b]	STEL ppm[a]	STEL mg/m³[b]
3-Amino 1, 2, 4-triazole, see Amitrole				
‡Amitrole [61-82-5]	(A2)	(A2)	—	—
Ammonia [7664-41-7]	25	18	35	27
Ammonium chloride fume [12125-02-9]	—	10	—	20
‡Ammonium sulfamate [7773-06-0]	—	10	—	(20)
n-Amyl acetate [628-63-7]	100	530	150	800
sec-Amyl acetate [626-38-0]	125	670	150	800
‡Aniline [62-53-3] & homologues — Skin	2	10	(5)	(20)
Anisidine [29191-52-4] (o-, p-isomers) — Skin	0.1	0.5	—	—
Antimony [7440-36-0] & compounds, as Sb	—	0.5	—	—
Antimony trioxide [1309-64-4]				
Handling and use, as Sb	—	0.5	—	—
Production	—	A2	—	—
‡ANTU [86-88-4]	—	0.3	—	(0.9)
Argon [7440-37-1]	E	—	—	—
Arsenic [7440-38-2] & soluble compounds, as As	—	0.2	—	—
Arsenic trioxide production [1327-53-3]	—	A2	—	—
Arsine [7784-42-1]	0.05	0.2	—	—
Asbestos [1332-21-4], see DUSTS	—	A1a	—	—
Asphalt (petroleum) fumes [8052-42-4]	—	5	—	10
Atrazine [1912-24-9]	—	5	—	—
‡Azinphos-methyl [86-50-0] — Skin	—	0.2	—	(0.6)
Barium [7440-39-3], soluble compounds, as Ba	—	0.5	—	—
‡Benomyl [17804-35-2]	0.8	10	(1.3)	(15)
Benzene [71-43-2]	10, A2	30, A2	25, A2	75, A2
Benzidine [92-87-5] — Skin	—	A1b	—	—
p-Benzoquinone, see Quinone				
Benzoyl peroxide [94-36-0]	—	5	—	—
Benzo(a)pyrene [50-32-8]	—	A2	—	—
Benzyl chloride [100-44-7]	1	5	—	—
Beryllium [7440-41-7]	—	0.002, A2	—	—

Substance [CAS #]	ADOPTED VALUES TWA ppm	TWA mg/m³[b]	STEL ppm	STEL mg/m³[b]
Biphenyl [92-52-4]	0.2	1.5	0.6	4
‡Bismuth telluride [1304-82-1]	—	10	—	(20)
‡ Se-doped	—	5	—	(10)
Borates, tetra, sodium salts [1303-96-4], Anhydrous	—	1	—	—
Decahydrate	—	5	—	—
Pentahydrate	—	1	—	—
‡Boron oxide [1303-86-2]	—	10	—	(20)
‡Boron tribromide [10294-33-4]	(1)	(10)	(3)	(30)
Boron trifluoride [7637-07-2]	C 1	C 3	—	—
‡Bromacil [314-40-9]	1	10	(2)	(20)
Bromine [7726-95-6]	0.1	0.7	0.3	2
‡Bromine pentafluoride [7789-30-2]	0.1	0.7	(0.3)	(2)
Bromochloromethane, see Chlorobromomethane				
Bromoform [75-25-2] — Skin	0.5	5	—	—
‡1, 3-Butadiene [106-99-0]	(1,000)	(2,200)	(1,250)	(2,750)
Butane [106-97-8]	800	1,900	—	—
Butanethiol, see Butyl mercaptan				
2-Butanone, see Methyl ethyl ketone (MEK)				
2-Butoxyethanol [111-76-2] — Skin	25	120	75	360
n-Butyl acetate [123-86-4]	150	710	200	950
sec-Butyl acetate [105-46-4]	200	950	250	1,190
tert-Butyl acetate [540-88-5]	200	950	250	1,190
Butyl acrylate [141-32-2]	10	55	—	—
n-Butyl alcohol [71-36-3] — Skin	C 50	C 150	—	—
sec-Butyl alcohol [78-92-2]	100	305	150	455
tert-Butyl alcohol [75-65-0]	100	300	150	450
Butylamine [109-73-9] — Skin	C 5	C 15	—	—
tert-Butyl chromate, as CrO_3 [1189-85-1] — Skin	—	C 0.1	—	—
n-Butyl glycidyl ether (BGE) [2426-08-6]	25	135	—	—

Capital letters A, B, D & E refer to Appendices. C denotes ceiling limit
‡ See Notice of Intended Changes

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Substance [CAS #]	ADOPTED VALUES TWA ppm[a]	TWA mg/m³[b]	STEL ppm[a]	STEL mg/m³
n-Butyl lactate [138-22-7]	5	25	—	—
Butyl mercaptan [109-79-5]	0.5	1.5	—	—
o-sec-Butylphenol [89-72-5] — Skin	5	30	—	—
p-tert-Butyltoluene [98-51-1]	10	60	20	120
‡Cadmium [7440-43-9] Dust & salts, as Cd	—	0.05	—	(0.2)
Cadmium oxide [1306-19-0] Fume, as Cd	—	C 0.05	—	—
Production	—	0.05	—	—
‡Calcium carbonate, marble [1317-65-3]	—	D	—	(20)
‡Calcium cyanamide [156-62-7]	—	0.5	—	(1)
Calcium hydroxide [1305-62-0]	—	5	—	—
Calcium oxide [1305-78-8]	—	2	—	—
Calcium silicate [1344-95-2]	—	D	—	—
Camphor, synthetic [76-22-2]	2	12	3	18
Caprolactam [105-60-2] Dust	—	1	—	3
Vapor	5	20	10	40
Captafol [2425-06-1] — Skin	—	0.1	—	—
‡Captan [133-06-2]	—	5	—	(15)
‡Carbaryl [63-25-2]	—	5	—	(10)
Carbofuran [1563-66-2]	—	0.1	—	—
‡Carbon black [1333-86-4]	—	3.5	—	(7)
‡Carbon dioxide [124-38-9]	5,000	9,000	(15,000)	(27,000)
Carbon disulfide [75-15-0] — Skin	10	30	—	—
Carbon monoxide [630-08-0]	50	55	400	440
Carbon tetrabromide [558-13-4]	0.1	1.4	0.3	4
‡Carbon tetrachloride [56-23-5] — Skin	5, A2	30, A2	(20, A2)	(125, A2)
Carbonyl chloride, see Phosgene				
Carbonyl fluoride [353-50-4]	2	5	5	15
Catechol (Pyrocatechol) [120-80-9]	5	20	—	—

Substance [CAS #]	ADOPTED VALUES TWA ppm	TWA mg/m³	STEL ppm	STEL mg/m³
‡Cellulose (paper fiber) [9004-34-6]	—	D	—	(20)
Cesium hydroxide [21351-79-1]	—	2	—	—
Chlordane [57-74-9] — Skin	—	0.5	—	2
Chlorinated camphene [8001-35-2] — Skin	—	0.5	—	1
Chlorinated diphenyl oxide [55720-99-5]	—	0.5	—	2
Chlorine [7782-50-5]	1	3	3	9
Chlorine dioxide [10049-04-4]	0.1	0.3	0.3	0.9
Chlorine trifluoride [7790-91-2]	C 0.1	C 0.4	—	—
Chloroacetaldehyde [107-20-0]	C 1	C 3	—	—
α-Chloroacetophenone [532-27-4] (Phenacyl chloride)	0.05	0.3	—	—
Chloroacetyl chloride [79-04-9]	0.05	0.2	—	—
Chlorobenzene [108-90-7] (Monochlorobenzene)	75	350	—	—
o-Chlorobenzylidene malononitrile [2698-41-1] — Skin	C 0.05	C 0.4	—	—
Chlorobromomethane [74-97-5]	200	1,050	250	1,300
2-Chloro-1, 3-butadiene, see β Chloroprene				
Chlorodifluoromethane [75-45-6]	1,000	3,500	1,250	4,375
Chlorodiphenyl (42% Chlorine) [53469-21-9] — Skin	—	1	—	2
Chlorodiphenyl (54% Chlorine) [11097-69-1] — Skin	—	0.5	—	1
1-Chloro, 2, 3-epoxy-propane, see Epichlorohydrin				
2-Chloroethanol, see Ethylene chlorohydrin				
Chloroethylene, see Vinyl chloride				
‡Chloroform [67-66-3]	10, A2	50, A2	(50, A2)	(225, A2)
bis-Chloromethyl ether [542-88-1]	0.001, A1a	0.005, A1a	—	—

Capital letters A, B, D & E refer to Appendices. C denotes ceiling limit
‡See Notice of Intended Changes.

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Substance [CAS #]	ADOPTED VALUES TWA ppm[a]	TWA mg/m³[b]	STEL ppm[a]	STEL mg/m³[b]
Chloromethyl methyl ether [107-30-2]	A2	A2	—	—
1-Chloro-1-nitropropane [600-25-9]	2	10	—	—
Chloropentafluoroethane [76-15-3]	1,000	6,320	—	—
Chloropicrin [76-06-2]	0.1	0.7	0.3	2
β-Chloroprene [126-99-8] — Skin	10	45	—	—
o-Chlorostyrene [1331-28-8]	50	285	75	430
o-Chlorotoluene [95-49-8]	50	250	75	375
2-Chloro- 6-(trichloromethyl) pyridine, see Nitrapyrin				
Chlorpyrifos [2921-88-2] — Skin	—	0.2	—	0 6
Chromite ore processing (Chromate), as Cr	—	0.05, A1a	—	—
Chromium [7440-47-3]; Metal	—	0.5	—	—
Chromium (II) compounds, as Cr	—	0.5	—	—
Chromium (III) compounds, as Cr	—	0.5	—	—
Chromium (VI) compounds, as Cr				
Water soluble	—	0 05	—	—
Certain water insoluble	—	0.05, A1a	—	—
Chromyl chloride [14977-61-8]	0 025	0 15	—	—
Chrysene [218-01-9]	A2	A2	—	—
Clopidol [2971-90-6]	—	10	—	20
Coal tar pitch volatiles [8007-45-2], as benzene solubles	—	0.2, A1a	—	—
‡Cobalt [7440-48-4], as Co metal, dust & fume	—	(0.1)	—	—
Cobalt carbonyl [00000-00-0], as Co	—	0.1	—	—
Cobalt hydrocarbonyl [16842-03-8], as Co	—	0.1	—	—
Copper [7440-50-8]; Fume	—	0.2	—	—
‡ Dusts & mists, as Cu	—	1	—	(2)
‡Cotton dust, raw	—	0.2[d]	—	(0 6)
Cresol [1319-77-3], all isomeres — Skin	5	22	—	—
Crotonaldehyde [123-73-9]	2	6	6	18

Substance [CAS #]	ADOPTED VALUES TWA ppm[a]	TWA mg/m³[b]	STEL ppm	STEL mg/m³
Crufomate [299-86-5]	—	5	—	20
Cumene [98-82-8] — Skin	50	245	75	365
Cyanamide [420-04-2]	—	2	—	—
Cyanides [151-50-8; 143-33-9], as CN — Skin	—	5	—	—
Cyanogen [460-19-5]	10	20	—	—
Cyanogen chloride [506-77-4]	C 0.3	C 0.6	—	—
Cyclohexane [110-82-7]	300	1,050	375	1,300
Cyclohexanol [108-93-0]	50	200	—	—
Cyclohexanone [108-94-1]	25	100	100	400
Cyclohexene [110-83-8]	300	1,015	—	—
Cyclohexylamine [108-91-8] — Skin	10	40	—	—
Cyclonite [121-82-4] — Skin	—	1.5	—	3
Cyclopentadiene [542-92-7]	75	200	150	400
Cyclopentane [287-92-3]	600	1,720	900	2,580
‡Cyhexatin [13121-70-5]	—	5	—	(10)
‡2, 4-D [94-75-7]	—	10	—	(20)
‡DDT (Dichlorodiphenyl-trichloroethane) [50-29-3]	—	1	—	(3)
Decaborane [17702-41-9] — Skin	0.05	0.3	0 15	0 9
‡Demeton [8065-48-3] — Skin	0.01	0.1	(0.03)	(0 3)
Diacetone alcohol [123-42-2]	50	240	75	360
1, 2-Diaminoethane, see Ethylenediamine				
‡Diazinon [333-41-5] — Skin	—	0.1	—	(0.3)
Diazomethane [334-88-3]	0.2	0 4	—	—
Diborane [19287-45-7]	0.1	0 1	—	—
1, 2-Dibromoethane, see Ethylene dibromide				
‡2-N-Dibutylaminoethanol [102-81-8] — Skin	2	14	(4)	(28)
Dibutyl phosphate	1	5	2	10
Dibutyl phthalate [84-74-2]	—	5	—	10

Capital letters A, B, D & E refer to Appendices. C denotes ceiling limit
‡ See Notice of Intended Changes
d/ Lint-free dust as measured by the vertical elutriator cotton-dust sampler described in the *Transactions of the National Conference on Cotton Dust*, p 33 by J R Lynch. (May 2 1970)

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Substance [CAS #]	ADOPTED VALUES TWA ppm[a]	TWA mg/m³[b]	STEL ppm[a]	STEL mg/m³[b]
Dichloroacetylene [7572-29-4]	C 0.1	C 0.4	—	—
o-Dichlorobenzene [95-50-1]	C 50	C 300	—	—
p-Dichlorobenzene [106-46-7]	75	450	110	675
3,3'-Dichlorobenzidine [91-94-1] — Skin	—	A2	—	A2
‡Dichlorodifluoromethane [75-71-8]	1,000	4,950	(1,250)	(6,200)
1,3-Dichloro-5,5-dimethyl hydantoin [118-52-5]	—	0.2	—	0.4
1,1-Dichloroethane [75-34-3]	200	810	250	1,010
1,2-Dichloroethane, see Ethylene dichloride				
1,1-Dichloroethylene, see Vinylidene chloride				
1,2-Dichloroethylene [540-59-0]	200	790	250	1,000
Dichloroethyl ether [111-44-4] — Skin	5	30	10	60
Dichlorofluoromethane [75-43-4]	10	40	—	—
Dichloromethane, see Methylene chloride				
‡1,1-Dichloro-1-nitroethane [594-72-9]	2	10	(10)	(60)
1,2-Dichloropropane, see Propylene dichloride				
‡Dichloropropene [542-75-6] — Skin	1	5	(10)	(50)
2,2-Dichloropropionic acid [75-99-0]	1	6	—	—
‡Dichlorotetrafluoroethane [76-14-2]	1,000	7,000	(1,250)	(8,750)
‡Dichlorvos [62-73-7] — Skin	0.1	1	(0.3)	(3)
Dicrotophos [141-66-2] — Skin	—	0.25	—	—
Dicyclopentadiene [77-73-6]	5	30	—	—
‡Dicyclopentadienyl iron [102-54-5]	—	10	—	(20)
‡Dieldrin [60-57-1] — Skin	—	0.25	—	(0.75)
Diethanolamine [111-42-2]	3	15	—	—
Diethylamine [109-89-7]	10	30	25	75
Diethylaminoethanol [100-37-8] — Skin	10	50	—	—
Diethylene triamine [111-40-0] — Skin	1	4	—	—

Substance [CAS #]	ADOPTED VALUES TWA ppm[a]	TWA mg/m³[b]	STEL ppm[a]	STEL mg/m³[b]
Diethyl ether, see Ethyl ether				
Diethyl ketone [96-22-0]	200	705	—	—
Diethyl phthalate [84-66-2]	—	5	—	10
‡Difluorodibromomethane [75-61-6]	100	860	(150)	(1,290)
Diglycidyl ether (DGE) [2238-07-5]	0.1	0.5	—	—
Dihydroxybenzene, see Hydroquinone				
Diisobutyl ketone [108-83-8]	25	150	—	—
Diisopropylamine [108-18-9] — Skin	5	20	—	—
Dimethoxymethane, see Methylal				
‡Dimethyl acetamide [127-19-5] — Skin	10	35	(15)	(50)
Dimethylamine [124-40-3]	10	18	—	—
Dimethylaminobenzene, see Xylidene				
Dimethylaniline [121-69-7] (N,N-Dimethylaniline) — Skin	5	25	10	50
Dimethylbenzene, see Xylene				
Dimethyl carbamyl chloride [79-44-7]	A2	A2	—	—
Dimethyl-1,2-dibromo-2-dichloroethyl phosphate, see Naled				
‡Dimethylformamide [68-12-2] — Skin	10	30	(20)	(60)
2,6-Dimethyl-4-heptanone, see Diisobutyl ketone				
‡1,1-Dimethylhydrazine [57-14-7] — Skin	0.5, A2	1, A2	(1, A2)	(2, A2)
‡Dimethylphthalate [131-11-3]	—	5	—	(10)
Dimethyl sulfate [77-78-1] — Skin	0.1, A2	0.5, A2	—	—
Dinitolmide [148-01-6]	—	5	—	10
‡Dinitrobenzene [528-29-0, 99-65-0; 100-25-4] (all isomers) — Skin	0.15	1	(0.5)	(3)
‡Dinitro-o-cresol [534-52-1] — Skin	—	0.2	—	(0.6)
3,5-Dinitro-o-toluamide, see Dinitolmide				
‡Dinitrotoluene [121-14-2] — Skin	—	1.5	—	(5)
‡Dioxane, tech. grade [123-91-1] — Skin	25	90	(100)	(360)

Capital letters A, B, D & E refer to Appendices. C denotes ceiling limit
‡See Notice of Intended Changes

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Substance [CAS #]	ADOPTED VALUES TWA ppm[a]	TWA mg/m³[b]	STEL ppm[a]	STEL mg/m³[b]
Dioxathion [78-34-2] — Skin	—	0.2	—	—
Diphenyl, see Biphenyl				
‡Diphenylamine [122-39-4]	—	10	—	(20)
Diphenylmethane diisocyanate, see Methylene bisphenyl isocyanate				
Dipropylene glycol methyl ether [34590-94-8]	100	600	150	900
Dipropyl ketone [123-19-3]	50	235	—	—
‡Diquat [85-00-7]	—	0.5	—	(1)
Di-sec. octyl phthalate [117-81-7] (Di-2-ethylhexylphthalate)	—	5	—	10
‡Disulfiram [97-77-8]	—	2	—	(5)
‡Disulfoton [298-04-4]	—	0.1	—	(0.3)
2, 6-Ditert. butyl-p-cresol [128-37-0]	—	10	—	20
Diuron [330-54-1]	—	10	—	—
Divinyl benzene [108-57-6]	10	50	—	—
‡Emery [112-62-9]	—	D	—	(20)
‡Endosulfan [115-29-7] — Skin	—	0.1	—	(0.3)
‡Endrin [72-20-8] — Skin	—	0.1	—	(0.3)
‡Epichlorohydrin [106-89-8] — Skin	2	10	(5)	(20)
‡EPN [2104-64-5] — Skin	—	0.5	—	(2)
1, 2-Epoxypropane, see Propylene oxide				
2, 3-Epoxy-1-propanol, see Glycidol				
Ethane [74-84-0]	E	—	—	—
Ethanethiol, see Ethyl mercaptan				
Ethanolamine [141-43-5]	3	8	6	15
Ethion [563-12-2] — Skin	—	0.4	—	—
*2-Ethoxyethanol [110-80-5] — Skin	5	9	—	—
*2-Ethoxyethyl acetate [111-15-9] — Skin	5	27	—	—
Ethyl acetate [141-78-6]	400	1,400	—	—
Ethyl acrylate [140-88-5] — Skin	5	20	25	100
Ethyl alcohol (Ethanol) [64-17-5]	1,000	1,900	—	—
Ethylamine [75-04-7]	10	18	—	—
Ethyl amyl ketone [541-85-5]	25	130	—	—
Ethyl benzene [100-41-4]	100	435	125	545
Ethyl bromide [74-96-4]	200	890	250	1,110
Ethyl butyl ketone [106-35-4]	50	230	75	345

Substance [CAS #]	ADOPTED VALUES TWA ppm[a]	TWA mg/m³[b]	STEL ppm	STEL mg/m³
‡Ethyl chloride [75-00-3]	1,000	2,600	(1,250)	(3,250)
Ethylene [74-85-1]	E	—	—	—
Ethylene chlorohydrin [107-07-3] — Skin	C 1	C 3	—	—
Ethylenediamine [107-15-3]	10	25	—	—
Ethylene dibromide [106-93-4] — Skin	A2	A2	—	—
‡Ethylene dichloride [107-06-2]	10	40	(15)	(60)
Ethylene glycol [107-21-1] Vapor	C 50	C 125	—	—
‡Ethylene glycol dinitrate [628-96-6] — Skin	0.05	0.3	(0.1)	(0.6)
Ethylene glycol methyl ether acetate, see 2-Methoxyethyl acetate				
* Ethylene oxide [75-21-8]	1,A2	2,A2	—	—
Ethyleneimine [151-56-4] — Skin	0.5	1	—	—
Ethyl ether [60-29-7]	400	1,200	500	1,500
Ethyl formate [109-94-4]	100	300	150	450
Ethylidene chloride, see 1, 1-Dichloroethane				
Ethylidene norbornene [16219-75-3]	C 5	C 25	—	—
‡Ethyl mercaptan [75-08-1]	0.5	1	(2)	(3)
‡N-Ethylmorpholine [100-74-3] — Skin	5	23	(20)	(95)
‡Ethyl silicate [78-10-4]	10	85	(30)	(255)
*Fenamiphos [22224-92-6] — Skin	—	0.1	—	—
Fensulfothion [115-90-2]	—	0.1	—	—
Fenthion [55-38-9] — Skin	—	0.2	—	—
‡Ferbam [14484-64-1]	—	10	—	(20)
Ferrovanadium dust [12604-58-9]	—	1	—	3
Fibrous glass dust	—	10	—	—
Fluorides, as F	—	2.5	—	—
Fluorine [7782-41-4]	1	2	2	4
Fluorotrichloromethane, see Trichlorofluoromethane				
Fonofos [944-22-9] — Skin	—	0.1	—	—
‡Formaldehyde [50-00-0]	(C 2)	(C 3)	—	—
‡Formamide [75-12-7]	20	30	(30)	(45)
Formic acid [64-18-6]	5	9	—	—

Capital letters A, B, D & E refer to Appendices. C denotes ceiling limit
*1984–1985 Addition
‡See Notice of Intended Changes

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Substance [CAS #]	ADOPTED VALUES TWA ppm[a]	TWA mg/m³[b]	STEL ppm[a]	STEL mg/m³
Furfural [98-01-1] — Skin	2	8	10	40
Furfuryl alcohol [98-00-0] — Skin	10	40	15	60
Gasoline [8006-61-9]	300	900	500	1,500
‡Germanium tetrahydride [7782-65-2]	0.2	0.6	(0.6)	(1.8)
Glass, fibrous or dust, see Fibrous glass dust				
Glutaraldehyde [111-30-8]	C 0.2	C 0.7	—	—
Glycerin mist [56-81-5]	—	D	—	—
Glycidol [556-52-5]	25	75	100	300
Glycol monoethyl ether, see 2-Ethoxyethanol				
Graphite (Natural) [7782-42-5], see DUSTS				
‡Graphite (Synthetic)	—	(D)	—	—
‡Gypsum [10101-41-4]	—	D	—	(20)
‡Hafnium [7440-58-6]	—	0.5	—	(1.5)
Helium [7440-59-7]	E	—	—	—
‡Heptachlor [76-44-8] — Skin	—	0.5	—	(2)
Heptane [142-82-5] (n-Heptane)	400	1,600	500	2,000
2-Heptanone, see Methyl n-amyl ketone				
3-Heptanone, see Ethyl butyl ketone				
Hexachlorobutadiene [87-68-3] — Skin	0.02, A2	0.24, A2	—	—
‡Hexachlorocyclopentadiene [77-47-4]	0.01	0.1	(0.03)	(0.3)
Hexachloroethane [67-72-1]	10	100	—	—
‡Hexachloronaphthalene [1335-87-1] — Skin	—	0.2	—	(0.6)
‡Hexafluoroacetone [684-16-2] — Skin	0.1	0.7	(0.3)	(2)
Hexamethyl phosphoramide [680-31-9] — Skin	A2	A2	—	—
Hexane (n-Hexane) [110-54-3]	50	180	—	—
Other isomers	500	1,800	1,000	3,600
2-Hexanone, see Methyl n-butyl ketone				
Hexone, see Methyl isobutyl ketone				
sec-Hexyl acetate [142-92-7]	50	300	—	—
Hexylene glycol [107-41-5]	C 25	C 125	—	—
Hydrazine [302-01-2] — Skin	0.1, A2	0.1, A2	—	—
Hydrogen [1333-74-0]	E	—	—	—
Hydrogenated terphenyls [92-94-4]	0.5	5	—	—

Substance [CAS #]	ADOPTED VALUES TWA ppm[a]	TWA mg/m³[b]	STEL ppm[a]	STEL mg/m³
‡Hydrogen bromide [10035-10-6]	(3)	(10)	—	—
Hydrogen chloride [7647-01-0]	C 5	C 7	—	—
Hydrogen cyanide [74-90-8] — Skin	C 10	C 10	—	—
‡Hydrogen fluoride [7664-39-3], as F	(3)	(2.5)	(6)	(5)
‡Hydrogen peroxide [7722-84-1]	1	1.5	(2)	(3)
Hydrogen selenide [7783-07-5], as Se	0.05	0.2	—	—
Hydrogen sulfide [7783-06-4]	10	14	15	21
Hydroquinone [123-31-9]	—	2	—	4
4-Hydroxy-4-methyl-2-pentanone, see Diacetone alcohol				
2-Hydroxypropyl acrylate [999-61-1] — Skin	0.5	3	—	—
Indene [95-13-6]	10	45	15	70
‡Indium [7440-74-6] & compounds, as In	—	0.1	—	(0.3)
Iodine [7553-56-2]	C 0.1	C 1	—	—
‡Iodoform [75-47-8]	0.6	10	(1)	(20)
‡Iron oxide fume (Fe_2O_3) [1309-37-1], as Fe	B2	5	—	(10)
Iron pentacarbonyl [13463-40-6], as Fe	0.1	0.8	0.2	1.6
‡Iron salts, soluble, as Fe	—	1	—	(2)
Isoamyl acetate [123-92-2]	100	525	125	655
Isoamyl alcohol [123-51-3]	100	360	125	450
Isobutyl acetate [110-19-0]	150	700	187	875
Isobutyl alcohol [78-83-1]	50	150	75	225
Isooctyl alcohol [26952-21-6]	50	270	—	—
Isophorone [78-59-1]	C 5	C 25	—	—
Isophorone diisocyanate — Skin	0.01	0.09	—	—
Isopropoxyethanol [109-59-1]	25	105	75	320
Isopropyl acetate [108-21-4]	250	950	310	1,185
Isopropyl alcohol [67-63-0]	400	980	500	1,225
Isopropylamine [75-31-0]	5	12	10	24

Capital letters A, B, D & E refer to Appendices. C denotes ceiling limit.
‡Notice of Intended Changes

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Substance [CAS #]	ADOPTED VALUES TWA ppm[1]	TWA mg/m³[2]	STEL ppm[1]	STEL mg/m³[2]
‡N-Isopropylaniline [643-28-7] — Skin	2	10	(5)	(20)
Isopropyl ether [108-20-3]	250	1,050	310	1,320
Isopropyl glycidyl ether [4016-14-2] (IGE)	50	240	75	360
‡Kaolin	—	D	—	(20)
Ketene [463-51-4]	0.5	0.9	1.5	3
‡Lead [7439-92-1], inorg. dusts & fumes, as Pb	—	0.15	—	(0.45)
‡Lead arsenate [10102-48-4], as $Pb_3(AsO_4)_2$	—	0.15	—	(0.45)
Lead chromate [18454-12-1], as Cr	—	0.05, A2	—	—
‡Limestone [1317-65-3]	—	D	—	(20)
‡Lindane [58-89-9] — Skin	—	0.5	—	(1.5)
Lithium hydride [7580-67-8]	—	0.025	—	—
L.P.G. (Liquified petroleum gas)	1,000	1,800	1,250	2,250
‡Magnesite [546-93-0]	—	D	—	(20)
Magnesium oxide fume [1309-48-4]	—	10	—	—
Malathion [121-75-5] — Skin	—	10	—	—
Maleic anhydride [108-31-6]	0.25	1	—	—
Manganese [7439-96-5], as Mn				
Dust & compounds	—	C 5	—	—
Fume	—	1	—	3
‡Maganese cyclopentadienyl tricarbonyl [12079-65-1], as Mn — Skin	—	0.1	—	(0.3)
Manganese tetroxide	—	1	—	—
‡Marble, calcium carbonate [1317-65-3]	—	D	—	(20)
Mercury [7439-97-6], as Hg — Skin				
Alkyl compounds	—	0.01	—	0.03
All forms except alkyl Vapor	—	0.05	—	—
Aryl & inorganic compounds	—	0.1	—	—
Mesityl oxide [141-79-7]	15	60	25	100
Methacrylic acid [79-41-4]	20	70	—	—
Methane [74-82-8]	E	—	—	—

Substance [CAS #]	ADOPTED VALUES TWA ppm[1]	TWA mg/m³[2]	STEL ppm[1]	STEL mg/m³[2]
Methanethiol, see Methyl mercaptan				
Methomyl [16752-77-5] — Skin	—	2.5	—	—
Methoxychlor [72-43-5]	—	10	—	—
*2-Methoxyethanol [109-86-4] — Skin	5	16	—	—
*2-Methoxyethyl acetate [110-49-6] — Skin	5	24	—	—
4-Methoxyphenol [150-76-5]	—	5	—	—
Methyl acetate [79-20-9]	200	610	250	760
Methyl acetylene [74-99-7]	1,000	1,650	1,250	2,040
Methyl acetylene-propadiene mixture (MAPP)	1,000	1,800	1,250	2,250
Methyl acrylate [96-33-3] — Skin	10	35	—	—
‡Methylacrylonitrile [126-98-7] — Skin	1	3	(2)	(6)
Methylal [109-87-5]	1,000	3,100	1,250	3,875
Methyl alcohol [67-56-1] (methanol) — Skin	200	260	250	310
Methylamine [74-89-5]	10	12	—	—
Methyl amyl alcohol, see Methyl isobutyl carbinol				
Methyl n-amyl ketone [110-43-0]	50	235	100	465
‡N-Methyl aniline [100-61-8] — Skin	0.5	2	(1)	(5)
‡Methyl bromide [74-83-9] — Skin	5	20	(15)	(60)
Methyl n-butyl ketone [591-78-6]	5	20	—	—
Methyl chloride [74-87-3]	50	105	100	205
Methyl chloroform [71-55-6]	350	1,900	450	2,450
Methyl 2-cyanoacrylate [137-05-3]	2	8	4	16
Methylcyclohexane [108-87-2]	400	1,600	500	2,000
Methylcyclohexanol [25639-42-3]	50	235	75	350
o-Methylcyclohexanone [583-60-8] — Skin	50	230	75	345

Capital letters A, B, D & E refer to Appendices. C denotes ceiling limit
‡ See Notice of Intended Changes
* 1984–1985 Addition

MAP 000481

Substance [CAS #]	ADOPTED VALUES TWA ppm[a]	TWA mg/m³[b]	STEL ppm[a]	STEL mg/m³
‡Methylcyclopentadienyl manganese tricarbonyl, [12108-13-3] — Skin, as Mn	—	0.2	—	(0.6)
‡Methyl demeton [8022-00-2] — Skin	—	0.5	—	(1.5)
Methylene bisphenyl isocyanate (MDI) [101-68-8]	C 0.02	C 0.2	—	—
‡Methylene chloride [75-09-2]	100	350	(500)	(1,740)
4, 4'-Methylene bis (2-chloroaniline) [101-14-4] — Skin	0.02, A2	0.22, A2	—	—
Methylene bis(4-cyclohexylisocyanate) [5124-30-1]	C 0.01	C 0.11	—	—
‡4, 4-Methylene dianiline [101-77-9] — Skin	(0.1)	(0.8)	(0.5)	(4)
Methyl ethyl ketone (MEK) [78-93-3]	200	590	300	885
Methyl ethyl ketone peroxide [1338-23-4]	C 0.2	C 1.5	—	—
Methyl formate [107-31-3]	100	250	150	375
5-Methyl-3-heptanone, see Ethyl amyl ketone				
Methyl hydrazine [60-34-4] — Skin	C 0.2, A2	C 0.35, A2	—	—
‡Methyl iodide [74-88-4] — Skin	2, A2	10, A2	(5, A2)	(30, A2)
Methyl isoamyl ketone [110-12-3]	50	240	—	—
Methyl isobutyl carbinol [108-11-2] — Skin	25	100	40	165
Methyl isobutyl ketone [108-10-1]	50	205	75	300
Methyl isocyanate [624-83-9]	0.02	0.05	—	—
Methyl isopropyl ketone [563-80-4]	200	705	—	—
Methyl mercaptan [74-93-1]	0.5	1	—	—
Methyl methacrylate [80-62-6]	100	410	125	510
‡Methyl parathion [298-00-0] — Skin	—	0.2	—	(0.6)

Substance [CAS #]	ADOPTED VALUES TWA ppm[a]	TWA mg/m³[b]	STEL ppm[a]	STEL mg/m³
Methyl propyl ketone [107-87-9]	200	700	250	875
‡Methyl silicate [681-84-5]	1	6	(5)	(30)
α-Methyl styrene [98-83-9]	50	240	100	485
*Metribuzin [21087-64-9]	—	5	—	—
Mevinphos [7786-34-7] — Skin	0.01	0.1	0.03	0.3
Molybdenum [7439-98-7], as Mo				
‡ Soluble compounds	—	5	—	(10)
‡ Insoluble compounds	—	10	—	(20)
Monocrotophos [6923-22-4]	—	0.25	—	—
Morpholine [110-91-8] — Skin	20	70	30	105
‡Naled [300-76-5]	—	3	—	(6)
Naphthalene [91-20-3]	10	50	15	75
β-Naphthylamine [91-59-8]	—	A1b	—	—
Neon [7440-01-9]	E	—	—	—
Nickel carbonyl, as Ni	0.05	0.35	—	—
Nickel [7440-02-0] Metal	—	1	—	—
‡ Soluble compounds, as Ni	—	0.1	—	(0.3)
Nickel carbonyl [13463-39-3], as Ni	0.05	0.35	—	—
Nickel sulfide roasting, fume & dust, as Ni	—	1, A1a	—	—
‡Nicotine [54-11-5] — Skin	—	0.5	—	(1.5)
Nitrapyrin [1929-82-4]	—	10	—	20
Nitric acid [7697-37-2]	2	5	4	10
‡Nitric oxide [10102-43-9]	25	30	(35)	(45)
p-Nitroaniline [100-01-6] — Skin	—	3	—	—
‡Nitrobenzene — Skin	1	5	(2)	(10)
‡p-Nitrochlorobenzene [100-00-5] — Skin	—	(1)	—	(2)
4-Nitrodiphenyl [92-93-3]	—	A1b	—	—
‡Nitroethane [79-24-3]	100	310	(150)	(465)
Nitrogen dioxide [10102-44-0]	3	6	5	10

Capital letters A, B, D & E refer to Appendices. C denotes ceiling limit.
‡ See Notices of Intended Changes
* 1984–1985 Addition

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Substance [CAS #]	ADOPTED VALUES TWA ppm[a]	TWA mg/m³[b]	STEL ppm[a]	STEL mg/m³
‡Nitrogen trifluoride [7783-54-2]	10	30	(15)	(45)
‡Nitroglycerin (NG) [55-63-0] — Skin	0.05	0.5	(0.1)	(1)
‡Nitromethane [75-52-5]	100	250	(150)	(375)
‡1-Nitropropane [108-03-2]	25	90	(35)	(135)
‡2-Nitropropane [79-46-9]	(C 25, A2)	(C 90, A2)	—	—
N-Nitrosodimethylamine [62-75-9] (dimethylnitrosoamine) — Skin	—	A2	—	—
Nitrotoluene [99-08-1] — Skin	2	11	—	—
Nitrotrichloromethane, see Chloropicrin				
Nonane [111-84-2]	200	1,050	250	1,300
Octachloronaphthalene [2234-13-1] — Skin	—	0.1	—	0.3
Octane [111-65-9]	300	1,450	375	1,800
Oil mist, mineral [8012-95-1]	—	5[e]	—	10
Osmium tetroxide [20816-12-0], as Os	0.0002	0.002	0.0006	0.006
Oxalic acid [144-62-7]	—	1	—	2
‡Oxygen difluoride [7783-41-7]	(0.05)	(0.1)	(0.15)	(0.3)
Ozone [10028-15-6]	0.1	0.2	0.3	0.6
Paraffin wax fume [8002-74-2]	—	2	—	6
Paraquat [1910-42-5], respirable sizes	—	0.1	—	—
‡Parathion [56-38-2] — Skin	—	0.1	—	(0.3)
Particulate polycyclic aromatic hydrocarbons (PPAH), see Coal tar pitch volatiles				
Pentaborane [19624-22-7]	0.005	0.01	0.015	0.03
‡Pentachloronaphthalene [1321-64-8]	—	0.5	—	(2)
‡Pentachlorophenol [87-86-5] — Skin	—	0.5	—	(1.5)
‡Pentaerythritol [115-77-5]	—	D	—	(20)
Pentane [109-66-0]	600	1,800	750	2,250
2-Pentanone, see Methyl propyl ketone				
*Perchloroethylene [127-18-4]	50	335	200	1,340
Perchloromethyl mercaptan [594-42-3]	0.1	0.8	—	—

Substance [CAS #]	ADOPTED VALUES TWA ppm	TWA mg/m³	STEL ppm	STEL mg/m³
Perchloryl fluoride [7616-94-6]	3	14	6	28
Phenol [108-95-2] — Skin	5	19	10	38
‡Phenothiazine [92-84-2] — Skin	—	5	—	(10)
N-Phenyl-beta-naphthylamine [135-88-6]	A2	A2	—	—
p-Phenylene diamine [106-50-3] — Skin	—	0.1	—	—
Phenyl ether [101-84-8], vapor	1	7	2	14
Phenylethylene, see Styrene, monomer				
Phenyl glycidyl ether (PGE) [122-60-1]	1	6	—	—
‡Phenylhydrazine [100-63-0] — Skin	(5)	(20)	(10)	(45)
Phenyl mercaptan [108-98-5]	0.5	2	—	—
Phenylphosphine [638-21-1]	C 0.05	C 0.25	—	—
Phorate [298-02-2] — Skin	—	0.05	—	0.2
Phosdrin, see Mevinphos				
Phosgene [75-44-5]	0.1	0.4	—	—
Phosphine [7803-51-2]	0.3	0.4	1	1
Phosphoric acid [7664-38-2]	—	1	—	3
‡Phosphorus [7723-14-0] (yellow)	—	0.1	—	(0.3)
Phosphorus oxychloride [10026-13-8]	0.1	0.6	0.5	3
Phosphorus pentachloride [10026-13-8]	0.1	1	—	—
Phosphorus pentasulfide [1314-80-3]	—	1	—	3
Phosphorus trichloride [7719-12-2]	0.2	1.5	0.5	3
Phthalic anhydride [85-44-9]	1	6	4	24
m-Phthalodinitrile [626-17-5]	—	5	—	—
Picloram [1918-02-1]	—	10	—	20

Capital letters A, B, D & E refer to Appendices. C denotes ceiling limit
‡ See Notice of Intended Changes
* 1984–1985 Addition
e) As sampled by method that does not collect vapor

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Substance [CAS #]	ADOPTED VALUES TWA ppm*	TWA mg/m³*	STEL ppm*	STEL mg/m³*
Picric acid [88-89-1] — Skin	—	0.1	—	0.3
Pindone [83-26-1]	—	0.1	—	0.3
Piperazine dihydrochloride [142-64-3]	—	5	—	—
2-Pivalyl-1,3-indandione, see Pindone				
‡Plaster of Paris	—	D	—	(20)
Platinum [7440-06-4]				
Metal	—	1	—	—
Soluble salts, as Pt	—	0.002	—	—
Polychlorobiphenyls, see Chlorodiphenyls				
Polytetrafluoroethylene decomposition products	—	B1	—	—
Portland cement	—	D	—	—
Potassium hydroxide [1310-58-3]	—	C 2	—	—
Propane [74-98-6]	E	—	—	—
Propane sultone [1120-71-4]	A2	A2	—	—
Propargyl alcohol [107-19-7] — Skin	1	2	3	6
β-Propiolactone [57-57-8]	0.5, A2	1.5, A2	1, A2	3, A2
Propionic acid [79-09-4]	10	30	15	45
Propoxur [114-26-1]	—	0.5	—	2
n-Propyl acetate [109-60-4]	200	840	250	1,050
Propyl alcohol [71-23-8] — Skin	200	500	250	625
n-Propyl nitrate [627-13-4]	25	105	40	170
Propylene [115-07-1]	E	—	—	—
Propylene dichloride [78-87-5]	75	350	110	510
‡Propylene glycol dinitrate [6423-43-4] — Skin	0.05	0.3	(0.1)	(0.6)
Propylene glycol monomethyl ether [107-98-2]	100	360	150	540
Propyleneimine [75-55-8] — Skin	2, A2	5, A2	—	—
Propylene oxide [75-56-9]	20	50	—	—
Propyne, see Methyl acetylene				
Pyrethrum [8003-34-7]	—	5	—	10
Pyridine [110-86-1]	5	15	10	30
Quinone [106-51-4]	0.1	0.4	0.3	1
RDX, see Cyclonite				
Resorcinol [108-46-3]	10	45	20	90
Rhodium [7440-16-6]				
Metal	—	1	—	—
*Insoluble compounds, as Rh	—	1	—	—
*Soluble compounds, as Rh	—	0.01	—	—
Ronnel [299-84-3]	—	10	—	—
Rosin core solder pyrolysis products, as formaldehyde	—	0.1	—	0.3
Rotenone (commercial) [83-79-4]	—	5	—	10
‡Rouge	—	D	—	(20)
Rubber solvent (Naphtha)	400	1,600	—	—
Selenium compounds [7782-49-2], as Se	—	0.2	—	—
Selenium hexafluoride [7783-79-1], as Se	0.05	0.2	—	—
‡Sesone [136-78-7]	—	10	—	(20)
Silane, see Silicon tetrahydride				
‡Silicon [7440-21-3]	—	D	—	(20)
‡Silicon carbide [409-21-2]	—	D	—	(20)
Silicon tetrahydride (Silane) [7803-62-5]	5	7	—	—
Silver [7440-22-4], as Ag				
Metal	—	0.1	—	—
Soluble compounds	—	0.01	—	—
Sodium azide [26628-22-8]	C 0.1	C 0.3	—	—
Sodium bisulfite [7631-90-5]	—	5	—	—
Sodium 2, 4-dichloro-phenoxyethyl sulfate, see Sesone				
Sodium fluoroacetate [62-74-8] — Skin	—	0.05	—	0.15
Sodium hydroxide [1310-73-2]	—	C 2	—	—
Sodium metabisulfite [7681-57-4]	—	5	—	—
‡Starch [9005-25-8]	—	D	—	(20)
‡Stibine [7803-52-3]	0.1	0.5	(0.3)	(1.5)
Stoddard solvent [8052-41-3]	100	525	200	1,050
‡Strychnine [57-24-9]	—	0.15	—	(0.45)
Styrene, monomer [100-42-5]	50	215	100	425

Capital letters A, B, D & E refer to Appendices; C denotes ceiling limit
*1984–1985 Addition
‡See Notice of Intended Changes

MAP 000484

Substance [CAS #]	ADOPTED VALUES TWA ppm[a]	TWA mg/m³[b]	STEL ppm[a]	STEL mg/m³[b]
Subtilisins [1395-21-7] (Proteolytic enzymes as 100% pure crystalline enzyme)	—	C0.00006[c]	—	—
Sucrose [57-50-1]	—	D	—	20
‡Sulfotep [3689-24-5] — Skin	—	0.2	—	(0.6)
‡Sulfur dioxide [7446-09-5]	2	5	(5)	(10)
‡Sulfur hexafluoride [2551-62-4]	1.000	6.000	(1.250)	(7.500)
Sulfuric acid [7664-93-9]	—	1	—	—
‡Sulfur monochloride [10025-67-9]	(1)	(6)	(3)	(18)
‡Sulfur pentafluoride [5714-22-7]	(0.025)	(0.25)	(0.075)	(0.75)
‡Sulfur tetrafluoride [7783-60-0]	(0.1)	(0.4)	(0.3)	(1)
Sulfuryl fluoride [2699-79-8]	5	20	10	40
*Sulprofos [35400-43-2]	—	1	—	—
Systox, see Demeton				
‡2, 4, 5-T [93-76-5]	—	10	—	(20)
‡Tantalum [7440-25-7]	—	5	—	(10)
TEDP, see Sulfotep				
Tellurium & compounds [13494-80-9], as Te	—	0.1	—	—
Tellurium hexafluoride [7783-80-4], as Te	0.02	0.2	—	—
‡Temephos [3383-96-8]	—	10	—	(20)
‡TEPP [107-49-3] — Skin	0.004	0.05	(0.01)	(0.2)
Terphenyls [92-94-4]	C 0.5	C 5	—	—
‡1, 1, 1, 2-Tetrachloro-2, 2-difluoroethane [76-11-9]	500	4.170	(625)	(5.210)
‡1, 1, 2, 2-Tetrachloro-1, 2-difluoroethane [76-12-0]	500	4.170	(625)	(5.210)
‡1, 1, 2, 2-Tetrachloroethane [79-34-5] — Skin	1	7	(5)	(35)
Tetrachloroethylene, see Perchloroethylene				
Tetrachloromethane, see Carbon tetrachloride				
‡Tetrachloronaphthalene [1335-88-2]	—	2	—	(4)
‡Tetraethyl lead [78-00-2], as Pb — Skin	—	0.1[g]	—	(0.3)
Tetrahydrofuran [109-99-9]	200	590	250	735
‡Tetramethyl lead [75-74-1], as Pb — Skin	—	0.15[g]	—	(0.5)

Substance [CAS #]	ADOPTED VALUES TWA ppm[a]	TWA mg/m³[b]	STEL ppm[a]	STEL mg/m³[b]
‡Tetramethyl succinonitrile [3333-52-6] — Skin	0.5	3	(2)	(9)
Tetranitromethane [509-14-8]	1	8	—	—
Tetrasodium pyrophosphate [7722-88-5]	—	5	—	—
‡Tetryl [479-45-8] (2, 4, 6-trinitrophenylmethylnitramine) — Skin	—	1.5	—	(3 0)
Thallium [7440-28-0] Soluble compounds, as Tl — Skin	—	0.1	—	—
‡4, 4'-Thiobis(6-tert. butyl-m-cresol) [96-69-5]	—	10	—	(20)
Thioglycolic acid [68-11-1]	1	5	—	—
‡Thiram [137-26-8]	—	5	—	(10)
Tin [7440-31-5]				
‡ Metal	—	2	—	(4)
‡ Oxide & inorganic compounds, except SnH_4, as Sn	—	2	—	(4)
‡ Organic compounds, as Sn — Skin	—	0.1	—	(0 2)
‡Titanium dioxide [13463-67-7], as Ti	—	D	—	(20)
o-Tolidine [119-93-7] — Skin	— A2	A2	—	—
Toluene [108-88-3] (toluol)	100	375	150	560
Toluene-2, 4-diisocyanate (TDI) [584-84-9]	0.005	0.04	0.02	0 15
*o-Toluidine [95-53-4] — Skin	2. A2	9. A2	—	—
Toxaphene, see Chlorinated camphene				
‡Tributyl phosphate [126-73-8]	0.2	2.5	(0 4)	(5)
Trichloroacetic acid [76-03-9]	1	5	—	—
1, 2, 4-Trichlorobenzene [120-82-1]	C 5	C 40	—	—

Capital letters A, B, D & E refer to Appendices; C denotes ceiling limit
‡ See Notice of Intended Changes
* 1984–1985 Addition
[a] Based on high volume sampling
[g] For control of general room air, biologic monitoring is essential for personnel control.

MAP 000485

Substance	[CAS #]	ADOPTED VALUES TWA ppm[a]	TWA mg/m³[b]	STEL ppm[a]	STEL mg/m³
1, 1, 1-Trichloroethane, see Methyl chloroform					
‡1, 1, 2-Trichloroethane	[79-00-5] — Skin	10	45	(20)	(90)
*Trichloroethylene	[79-01-6]	50	270	200	1,080
Trichlorofluoromethane	[75-69-4]	C 1,000	C 5,600	—	—
Trichloromethane, see Chloroform					
‡Trichloronaphthalene	[1321-65-9]	—	5	—	(10)
Trichloronitromethane, see Chloropicrin					
1, 2, 3-Trichloropropane	[96-18-4]	50	300	75	450
1, 1, 2-Trichloro-1, 2, 2-trifluoroethane	[76-13-1]	1,000	7,600	1,250	9,500
Tricyclohexyltin hydroxide, see Cyhexatin					
Triethylamine	[121-44-8]	10	40	15	60
‡Trifluorobromomethane	[75-63-8]	1,000	6,100	(1,200)	(7,300)
Trimellitic anhydride	[552-30-7]	0.005	0.04	—	—
Trimethylamine	[75-50-3]	10	24	15	36
Trimethyl benzene	[25551-13-7]	25	125	35	170
‡Trimethyl phosphite	[121-45-9]	2	10	(5)	(25)
2, 4, 6-Trinitrophenol, see Picric acid					
2, 4, 6-Trinitrophenyl-methylnitramine, see Tetryl					
‡2, 4, 6-Trinitrotoluene (TNT)	[118-96-7] — Skin	—	0.5	—	(3)
‡Trior thocresyl phosphate	[78-30-8]	—	0.1	—	(0.3)
Triphenyl amine	[603-34-9]	—	5	—	—
‡Triphenyl phosphate	[115-86-6] — Skin	—	3	—	(6)
Tungsten	[7440-33-7], as W				
Insoluble compounds		—	5	—	10
Soluble compounds		—	1	—	3
Turpentine	[8006-64-2]	100	560	150	840
Uranium (natural)	[7440-61-1], Soluble & insoluble compounds, as U	—	0.2	—	0.6
Valeraldehyde	[110-62-3]	50	175	—	—

Substance	[CAS #]	ADOPTED VALUES TWA ppm[a]	TWA mg/m³[b]	STEL ppm[a]	STEL mg/m³
Vanadium, as V_2O_5	[1314-62-1], respirable dust & fume	—	0.05	—	—
Vegetable oil mists		—	D	—	—
Vinyl acetate	[108-05-4]	10	30	20	60
Vinyl benzene, see Styrene					
Vinyl bromide	[593-60-2]	5, A2	20, A2	—	—
Vinyl chloride	[75-01-4]	5, A1a	10, A1a	—	—
Vinyl cyanide, see Acrylonitrile					
Vinyl cyclohexene dioxide	[106-87-6]	10, A2	60, A2	—	—
*Vinylidene chloride	[75-35-4]	5	20	20	80
Vinyl toluene	[25013-15-4]	50	240	100	485
VM & P Naphtha	[8030-30-6]	300	1,350	400	1,800
Warfarin	[81-81-2]	—	0.1	—	0.3
Welding fumes	(NOC†)	—	5, B2	—	—
Wood dust (certain hard woods as beech & oak)		—	1	—	—
Soft wood		—	5	—	10
Xylene	[1330-20-7] (o-, m-, p-isomers)	100	435	150	655
m-Xylene α, α'-diamine	[1477-55-0] - Skin	—	C 0.1	—	—
Xylidine	[1300-73-8] — Skin	2	10	—	—
Yttrium	[7440-65-5]	—	1	—	3
Zinc chloride fume	[7646-85-7]	—	1	—	2
Zinc chromate	[13530-65-9], as Cr	—	0.05, A2	—	—
Zinc oxide	[1314-13-2]				
Fume		—	5	—	10
Dust		—	D	—	—
‡Zinc stearate	[557-05-1]	—	D	—	(20)
Zirconium compounds	[7440-67-2], as Zr	—	5	—	10

Capital letters A, B, D & E refer to Appendices C denotes ceiling limit
‡See Notice of Intended Changes
* 1984–1985 Addition
† NOC = Not otherwise classified.

Radioactivity: See Physical Agents section on Ionizing Radiation.

MAP 000486

DUSTS

Substance	TLV
SILICA, SiO_2	
Crystalline	
‡Quartz [14808-60-7]	TLV in mppcf [h]: $\frac{300}{\%\ \text{quartz} + 10}$ TLV for respirable dust in mg/m³: $\frac{10\ \text{mg/m}^3\ [j]}{\%\ \text{Respirable quartz} + 2}$ TLV for "total dust," respirable and nonrespirable: $\frac{30\ \text{mg/m}^3}{\%\ \text{quartz} + 3}$
‡Cristobalite [14464-46-1]	Use one-half the value calculated from the count or mass formulae for quartz.
‡Tridymite [15468-32-3]	Use one-half the value calculated from formulae for quartz.
‡Tripoli [1317-95-9]	Use respirable [k] mass quartz formula
‡*Amorphous* [7631-86-9]	(20 mppcf [h])
‡Silica, fused [60676-86-0]	Use quartz formulae.
SILICATES and OTHER DUSTS (< 1% quartz)	
Asbestos	
Amosite [12172-73-5]	0.5 fiber cc > 5 μm in length, A1a
Chrysotile [12001-29-5]	2 fibers cc > 5 μm in length, A1a
Crocidolite [12001-28-4]	0.2 fiber cc > 5 μm in length, A1a
Other forms	2 fibers cc > 5 μm in length, A1a
‡Graphite (natural) [7782-42-5]	15 mppcf
‡Mica [12001-26-2]	20 mppcf
Mineral wool fiber	10 mg/m³
‡Perlite	30 mppcf
‡Portland Cement	30 mppcf
‡Soapstone	20 mppcf
Talc (containing no asbestos fibers) [14807-96-6]	2 mg/m³, Respirable dust

‡Talc (fibrous), (use Asbestos limit.)	
Nuisance particles (see Appendix D)	‡(30 mppcf) or 10 mg/m³ [j] of total dust < 1% quartz, or ‡(5 mg/m³ respirable dust.)

Conversion factors:
mppcf × 35.3 = Million particles per cubic meter
= particles per cc

COAL DUST	
2 mg/m³ (respirable dust fraction < 5% quartz). ‡(If > 5% quartz, use respirable mass formula.)	

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

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

j) Both concentration and percent quartz 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

k) "Respirable" dust as defined by the British Medical Research Council Criteria, [l] and as sampled by a device producing equivalent results.
- (1) Hatch, T. F. and Gross *Pulmonary Deposition and Retention of Inhaled Aerosols*, p. 149. Academic Press, New York, (1964).
- (2) AIHA Aerosol Technology Committee, Interim Guide for Respirable Mass Sampling. *Am. Ind. Hyg. Assoc. J. 31(2)*:133 (1970).

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

‡m) containing < 1% quartz; (if quartz content > 1%, use formulae for quartz.)

‡See Notice of Intended Changes

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NOTICE OF INTENDED CHANGES (for 1984-85)

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. Documentation is available for each of these substances.

Substance [CAS #]	TWA ppm[a]	TWA mg/m³[b]	STEL ppm[a]	STEL mg/m³
†Amitrole [61-82-5]	—	0.2	—	—
†Ammonium persulfate [7727-54-1], as S_2O_8	—	5	—	—
†Boron tribromide [10294-33-4]	C 1	C 10	—	—
†1, 3-Butadiene [106-99-0]	10. A2	22. A2	—	—
†Carbon dioxide [124-38-9]	5.000	9.000	30.000	54.000
Cobalt metal, dust & fume [7440-48-4], as Co	—	0.05	—	0.1
Enflurane [13838-16-9]	75	575	—	—
Ethylene glycol dinitrate [628-96-6] — Skin	0.05	0.3	—	—
Formaldehyde [50-00-0]	1. A2	1.5. A2	2. A2	3. A2
Grain dust	—	4	—	—
Halothane [151-67-7]	50	400	—	—
†Hydrogen bromide [10035-10-6]	C 3	C 10	—	—
†Hydrogen fluoride 7664-39-3], as F	C3	C 2.5	—	—
Lead arsenate [10102-48-4], as $Pb_3(AsO_4)_2$	—	0 15	—	—
†4 4-Methylene dianiline [101-77-9]	0 1. A2	0.8. A2	—	—
p-Nitrochlorobenzene [100-00-5] — Skin	0.5	3	—	—
Nitroglycerin [55-63-0] — Skin	0 05	0.5	—	—
2-Nitropropane [79-46-9]	10. A2	35. A2	20. A2	70. A2
†Oxygen difluoride [7783-41-7]	C 0.05	C 0.1	—	—
†Persulfates, alkali metal as S_2O_8	—	5	—	—

Substance [CAS #]	TWA ppm[a]	TWA mg/m³[b]	STEL ppm[a]	STEL mg/m³[b]
Phenylhydrazine [100-63-0] — Skin	5 A2	20 A2	10. A2	45. A2
†Potassium persulfate [7727-21-1], as S_2O_8	—	5	—	—
Propylene glycol dinitrate [6423-43-4] — Skin	0.05	0.3	—	—
†Sodium persulfate [7775-27-1], as S_2O_8	—	5	—	—
†Sulfur monochloride [10025-67-9]	C 1	C 6	—	—
†Sulfur pentafluonde [5714-22-7]	C 0.01	C 0 1	—	—
†Sulfur tetrafluoride [7783-60-0]	C 0 1	C 0.4	—	—
†Thionyl chloride [7719-09-7]	C 1	C 5	—	—
†m-Toluidine [108-44-1] — Skin	2	9	—	—
†p-Toluidine [108-49-0] — Skin	2. A2	9. A2	—	—

Capital letters A, B, D & E refer to Appendices C denotes ceiling limit
†1984–1985 Revision or Addition.

STEL VALUES DELETED FROM THE FOLLOWING:

Acetylene tetrabromide	Cellulose (paper fiber)
Aldrin	Chloroform
α-Alumina	Copper dusts & mists
Aluminum metal & oxide	Cotton dust, raw
2-Aminopyridine	Cyhexatin
Ammonium sulfamate	2,4-D
Aniline & homologues	DDT
ANTU	Demeton
Azinphos-methyl	Diazinon
Benomyl	2-N-Dibutylaminoethanol
Bismuth telluride & Se-doped	Dichlorodifluoromethane
Boron oxide	1,1-Dichloro-1-nitroethane
Bromacil	Dichloropropene
Bromine pentafluoride	Dichlorotetrafluorethane
Cadmium dusts & salts	Dichlorvos
Calcium carbonate/marble	Dicyclopentadienyl iron
Calcium cyanamide	Diedrin
Captan	Difluorodibromomethane
Carbaryl	Dimethyl acetamide
Carbon black	Dimethylformamide
Carbon tetrachloride	1,1-Dimethylhydrazine

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Dimethylphthalate
Dinitrobenzene
Dinitro-o-cresol
Dinitrotoluene
Dioxane, tech grade
Diphenylamine
Diquat
Disulfiram
Disulfoton
Emery
Endosulfan
Endrin
Epichlorohydrin
EPN
Ethyl chloride
Ethylene dichloride
Ethyl mercaptan
N-Ethylmorpholine
Ethyl silicate
Ferbam
Formamide
Germanium tetrahydride
Gypsum
Hafnium
Heptachlor
Hexachlorocyclopentadiene
Hexachloronaphthalene
Hexafluoroacetone
Hydrogen peroxide
Indium & compounds
Iodoform
Iron oxide fume
Iron salts, soluble
N-Isopropylaniline
Kaolin
Lead, inorganic dusts & fumes
Limestone
Lindane
Magnesite
Manganese cyclopentadienyl tricarbonyl
Marble calcium carbonate
Methylacrylonitrile
N-Methyl aniline
Methyl bromide
Methylcyclopentadienyl manganese tricarbonyl
Methyl demeton
Methylene chloride
Methyl iodide
Methyl parathion
Methyl silicate
Molybdenum, soluble & insoluble compounds
Naled
Nickel soluble compounds
Nicotine
Nitric oxide
Nitrobenzene
Nitroethane
Nitrogen trifluoride
Nitromethane
1-Nitropropane
Parathion
Pentachloronapthalene
Pentachlorophenol
Pentaerythritol
Phenothiazine
Phosphorus (yellow)
Plaster of Paris
Rouge
Sesone
Silicon
Silicon carbide
Starch
Stibine
Strychnine
Sulfotep
Sulfur dioxide
Sulfur hexafluoride
2,4,5-T
Tantalum
Temephos
TEPP
1,1,1,2-Tetrachloro-2,2-difluoroethane
1,1,2,2-Tetrachloro-1,2,difluoroethane
1,1,2,2-Tetrachloroethane
Tetrachloronaphthalene
Tetraethyl lead
Tetramethyl lead
Tetramethyl succinonitrile
Tetryl
4,4'-Thiobis(6-tert. butyl-m-cresol)
Thiram
Tin, metal, oxide, & insoluble compounds
Tin, organic compounds
Titanium dioxide
Tributyl phosphate
1,1,2-Trichloroethane
Trichloronaphthalene

Trifluorobromomethane
Trimethyl phosphite
2,4,6-Trinitrotoluene (TNT)
Triorthocresyl phosphate
Triphenyl phosphate
Zinc stearate

NOTICE OF INTENDED CHANGES

DUSTS

Substance	TLV
SILICA, SiO_2	
Crystalline	
†Quartz [14808-60-7]	0.1 mg/m³, Respirable dust
†Cristobalite [14464-46-1]	0.05 mg/m³, Respirable dust
†Tridymite [15468-32-3]	0.05 mg/m³, Respirable dust
Silica, fused [60676-86-0]	Use quartz value
Tripoli [1317-95-9]	0.1 mg/m³ of contained quartz, respirable dust
Amorphous	
†Diatomaceous earth (uncalcined) [60676-86-0]	10 mg/m³, Total dust
Precipitated silica and silica gel	5 mg/m³, Respirable dust 10 mg/m³, Total dust
SILICATES and OTHER DUSTS (< 1% quartz)	
†Barium sulfate [7727-43-7]	10 mg/m³ Total dust
Graphite (natural) [7782-42-5]	2.5 mg/m³, Respirable dust 5 mg/m³ Total dust
†Graphite (synthetic)	10 mg/m³, Total dust
†Mica [12001-26-2]	3 mg/m³, Respirable dust
†Perlite	10 mg/m³, Total dust
†Portland Cement	10 mg/m³, Total dust
Soapstone	3 mg/m³, Respirable dust 6 mg/m³, Total dust
Talc (containing asbestos fibers)	Use asbestos TLV However should not exceed 2 mg/m³ respirable dust

† 1984–1985 Revision or Addition

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†Nuisance particulates (see Appendix D)
10 mg/m³ m) of total dust < 1% quartz

COAL DUST

If > 5% quartz, use respirable quartz value.

Generic Listing

All mppcf values for mineral dusts will be eliminated in favor of equivalent respirable mass or total mass values, i.e. Appendix F.

Footnote:

m) Containing < 1% quartz; if quartz content > 1%, use quartz value.

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).

A1a. *Human Carcinogens*. Substances, or substances associated with industrial processes, recognized to have carcinogenic or cocarcinogenic potential, with an assigned TLV:

	TLV
Asbestos	
Amosite	0.5 fiber > 5μm cc
Chrysotile	2 fibers > 5μm cc
Crocidolite	0.2 fiber > 5μm cc
Other forms	2 fibers > 5μm cc
bis (Chloromethyl) ether	0.001 ppm
Chromite ore processing (chromate)	0.05 mg/m³, as Cr
Chromium (VI), certain water insoluble compounds	0.05 mg/m³, as Cr
Coal tar pitch volatiles	0.2 mg/m³, as benzene solubles
Nickel sulfide roasting, fume & dust	1.0 mg/m³, as Ni
Vinyl chloride	5 ppm

A1b. *Human Carcinogens* Substances, or substances associated with industrial processes recognized to have carcinogenic potential without an assigned TLV:

4-Aminodiphenyl (p-Xenylamine) — Skin
Benzidine — Skin
β-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. The worker should be properly equipped to insure virtually no contact with the carcinogen.

A2. *Industrial Substances Suspect of Carcinogenic Potential for MAN*. Chemical substances or substances associated with industrial processes, which are suspect of inducing cancer, based on either (1) limited epidemiologic evidence, exclusive of clinical reports of single cases, or (2) demonstration of carcinogenesis in one or more animal species by appropriate methods.

‡Acrylonitrile — Skin	2 ppm
**Amitrole	—
Antimony trioxide production*	—
Arsenic trioxide production	—
Benzene	10 ppm
Benzo(a)pyrene	—
Beryllium	2.0 μg/m³
†1, 3-Butadiene	10 ppm
Carbon tetrachloride — Skin	5 ppm
Chloroform	10 ppm
Chloromethyl methyl ether	—
Chromates of lead and zinc, as Cr	0.05 mg/m³
Chrysene	—
3, 3'-Dichlorobenzidine — Skin	—
Dimethylcarbamyl chloride	—
1, 1-Dimethyl hydrazine — Skin	0.5 ppm

*1984–1985 Revision or Addition

**See Notice of Intended Changes
+1984–1985 Addition
‡1984–1985 Adoption
*Cigarette smoking can enhance the incidence of respiratory cancers from this or others of these substances or processes

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Dimethyl sulfate — Skin	0.1 ppm
Ethylene dibromide — Skin	—
‡Ethylene oxide	1 ppm
Formaldehyde	1 ppm
Hexachlorobutadiene	0.02 ppm
Hexamethyl phosphoramide — Skin	—
Hydrazine — Skin	0.1 ppm
4, 4'-Methylene bis (2-chloroaniline) — Skin	0.02 ppm
†4,4-Methylene dianiline	0.1 ppm
Methyl hydrazine — Skin	C 0.2 ppm
Methyl iodide — Skin	2 ppm
2-Nitropropane	10 ppm
N-Nitrosodimethylamine — Skin	—
N-Phenyl-beta-naphthylamine	—
Phenylhydrazine — Skin	5 ppm
Propane sultone	—
beta-Propiolactone	0.5 ppm
Propyleneimine — Skin	2 ppm
o-Tolidine	—
‡p-Toluidine — Skin	2 ppm
†p-Toluidine — Skin	2 ppm
Vinyl bromide	5 ppm
Vinyl cyclohexene dioxide	10 ppm

For the above, worker exposure by all routes should be carefully controlled to levels consistent with the animal and human experience data (see Documentation), including those substances with a listed TLV.

* * *

THE COMMITTEE GUIDELINES FOR CLASSIFICATION OF EXPERIMENTAL ANIMAL CARCINOGENS

The following guidelines are offered in the present state of knowledge as an aid in classifying substances in the occupational environment found to be carcinogenic in experimental animals. A need was felt by the Threshold Limits Committee for such a classification in order to take the first step in developing an appropriate TLV for occupational exposure.

Determination of Approximate Threshold of Response Requirement. In order to determine in which category to classify an experimental carcinogen for the purpose of assigning an industrial air limit (TLV) an approximate threshold of neoplastic response must be determined. Because of practical experimental difficulties, a precisely defined threshold cannot be attained. For the purposes of standard-setting, this is of little moment, as an appropriate risk or safety factor can be applied to the approximate threshold, the magnitude of which is dependent on the degree of potency of the carcinogenic response

To obtain the best practical threshold of neoplastic response, dosage decrements should be less than logarithmic. This becomes particularly important at levels greater than 10 ppm (or corresponding mg m^3). Accordingly, after a range-finding determination has been made by logarithmic decreases, two additional dosage levels are required within the levels of "effect" and "no effect" to approximate the true threshold of neoplastic response.

The second step should attempt to establish a metabolic relationship between animal and man for the particular substance found carcinogenic in animals. If the metabolic pathways are found comparable, the substance should be classed highly suspect as a carcinogen for man. If no such relation is found, the substance should remain listed as an experimental animal carcino gen until evidence to the contrary is found.

Proposed Classification of Experimental Animal Carcinogens. Substances occurring in the occupational environment found carcinogenic for animals may be grouped into three classes, those of high, intermediate and low potency. In evaluating the incidence of animal cancers, significant incidence of cancer is defined as a neoplastic response which represents, in the judgment of the Committee, a significant excess of cancers above that occurring in negative controls.

EXCEPTIONS: No substance is to be considered an occupational carcinogen of any practical significance which reacts by the respiratory route at or above 1000 mg m^3 for the mouse, 2000 mg.m^3 for the rat; by the dermal route, at or above 1500 mg/kg for the mouse, 3000 mg/kg for the rat; by the gastrointestinal route at or above 500 mg/kg/d for a lifetime, equivalent to about 100 g T.D. for the rat, 10 g T.D. for the mouse. These dosage limitations exclude such substances as dioxane and trichlorethylene from consideration as carcinogens.

Examples: Dioxane — rats, hepatocellular and nasal tumors from 1015 mg/kg/d, oral

†1984 Addition
‡1984 Adoption

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Trichloroethylene — female mice. tumors (30/98 @ 900 mg/kg d), oral

A *Industrial Substances of High Carcinogenic Potency in Experimental Animals.*

1. A substance to qualify as a carcinogen of high potency must fulfill one of the three following conditions in two animal species:

1a. *Respiratory*. Elicit cancer from (1) dosages below 1 mg/m³ (or equivalent ppm) via the respiratory tract in 6- to 7-hour daily repeated inhalation exposures throughout lifetime; or (2) from a single intratracheally administered dose not exceeding 1 mg of particulate, or liquid, per 100 ml or less of animal minute respiratory volume;

Examples: bis-Chloromethyl ether, malignant tumors, rats, @ 0.47 mg/m³ (0.1 ppm) in 2 years:

Hexamethyl phosphoramide, nasal squamous cell carcinoma, rats, @ 0.05 ppm, in 13 months

OR

1b. *Dermal*. Elicit cancer within 20 weeks by skin-painting, twice weekly at 2 mg/kg body weight or less per application for a total dose equal to or less than 1.5 mg, in a biologically inert vehicle;

Examples: 7, 12-Dimethylbenz(a)anthracene — skin tumors @ 0.12-0.8 mg T.D. in four weeks

Benzo(a)pyrene, mice 12 μg, 3X/wk for 18 mos. T.D. 2.6 mg, 90.9% skin tumors

OR

1c. *Gastrointestinal*. Elicit cancer by daily intake via the gastrointestinal tract, within six months, with a six-month holding period, at a dosage below 1 mg/kg body weight per day; total dose, rat, ≦ 50 mg; mouse, ≦ 3.5 mg;

Examples: 7, 12-Dimethylbenz(a)anthracene — mammary tumors from 10 mg 1X

3-Methylcholanthrene — Tumors @ 3 sites from 8 mg in 89 weeks

Benzo(a)pyrene, mice, 3.9% leukemias, from 30 mg T.D. 198 days

2. Elicit cancer by all three routes in at least two animal species at dose levels prescribed for high or intermediate potency.

B. *Industrial Substances of Intermediate Carcinogenic Potency in Experimental Animals*

To qualify as a carcinogen of intermediate potency, a substance should elicit cancer in two animal species at dosages intermediate between those described in A and C by two routes of administration.

Example: Carbamic acid ethyl ester

Dermal, mammary tumors, mice, 100%, 63 weeks, 500–1400 mg T.D. Gastrointestinal, various type tumors, mice 42 weeks 320 mg T.D.

Gastrointestinal, various type tumors, rats, 60 weeks, 110–930 mg T.D.

C. *Industrial Substances of Low Carcinogenic Potency in Experimental Animals.*

To qualify as a carcinogen of low potency, a substance should elicit cancer in one animal species by any *one* of three routes of administration at the following prescribed dosages and conditions:

1a. *Respiratory*. Elicit cancer from (1) dosages greater than 10 mg/m³ (or equivalent ppm) via the respiratory tract in 6- 7-hour, daily repeated inhalation exposures, for 12 months' exposure and 12 months' observation period; or (2) from intratracheally administered dosages totaling more than 10 mg of particulate or liquid per 100 ml or more of animal minute respiratory volume;

Examples: Beryl (beryllium aluminum silicate) malig. lung tumors, rats, @ 15 mg m³ @ 17 months

Benzidine, var. tumors, rats, 10–20 mg/m³ @ > 13 mos.

OR

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1b. *Dermal*. Elicit cancer by skin-painting of mice in twice weekly dosages of > 10 mg kg body weight in a biologically inert vehicle for at least 75 weeks, i.e., ≧ 1.5g T.D.

Examples: Shale tar, mouse. 0.1 ml × 50 = 5g T.D. 59 60 skin tumors

Arsenic trioxide, man, dose unknown, but estimated to be high

1c. *Gastrointestinal*. Elicit cancer from daily oral dosages of 50 mg/kg/day or greater during the lifetime of the animal.

APPENDIX B
SUBSTANCES OF VARIABLE COMPOSITION

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 minimal.

B2 *Welding Fumes — Total Particulate (NOC)** TLV, 5 mg/m³*

Welding fumes cannot be classified simply. The composition and quantity of both are dependent on the alloy being welded and the process and electrodes used. Reliable analysis of fumes cannot be made without considering the nature of the welding process and system being examined; reactive metals and alloys such as aluminum and titanium are arc-welded in a protective, inert atmosphere such as argon. These arcs create relatively little fume, but an intense radiation which can produce ozone. Similar processes are used to arc-weld steels, also creating a relatively low level of fumes. Ferrous alloys also are arc-welded in oxidizing environments which generate considerable fume, and can produce carbon monoxide instead of ozone. Such fumes generally are composed of discreet particles of amorphous slags containing iron, manganese, silicon and other metallic constituents depending on the alloy system involved. Chromium and nickel compounds are found in fumes when stainless steels are arc-welded. Some coated and flux-cored electrodes are formulated with fluorides and the fumes associated with them can contain significantly more fluorides than oxides. Because of the above factors, arc-welding fumes frequently must be tested for individual constituents which are likely to be present to determine whether specific TLV's are exceeded. Conclusions based on total fume concentration are generally adequate if no toxic elements are present in welding rod, metal, or metal coating and conditions are not conducive to the formation of toxic gases.

Most welding, even with primitive ventilation, does not produce exposures inside the welding helmet above 5 mg m³. That which does, should be controlled.

* Trade Names: Algoflon, Fluon, Halon, Teflon, Tetran

** Not otherwise classified (NOC)

APPENDIX C
MIXTURES

C.1 THRESHOLD LIMIT VALUES FOR MIXTURES

When two or more hazardous substances, which act upon the same organ system, 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_n indicates the observed atmospheric concentration, and T_n the corresponding threshold limit (See Example 1A.a. and 1A.c.).

Exceptions to the above rule may be made when there is a 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.).

Synergistic action or potentiation may occur with some combinations of atmospheric contaminants. Such cases at present must be determined individually. Potentiating or synergistic agents are not neces-

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sarily 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 a given operation or process characteristically emits a number of harmful dusts, 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.

C.1A *Examples of* THRESHOLD LIMIT VALUES FOR MIXTURES

The following formulae apply only when the components in a mixture have similar toxicologic effects; they should not be used for mixtures with widely differing reactivities, e.g., hydrogen cyanide and sulfur dioxide. In such case the formula for Independent Effects (1A.c.) should be used.

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.)*

$$\frac{C_1}{T_1} - \frac{C_2}{T_2} - \frac{C_3}{T_3} - \ldots = 1$$

Example No. 1A.a.: Air contains 400 ppm of acetone (TLV = 750 ppm), 150 ppm of sec-butyl acetate (TLV = 200 ppm) and 100 ppm of methyl ethyl ketone (TLV = 200 ppm)

Atmospheric concentration of mixture = 400 + 150 + 100 = 650 ppm of mixture

$$\frac{400}{750} + \frac{150}{200} + \frac{100}{200} = 0.53 + 0.75 + 0.5 = 1.78$$

Threshold Limit is exceeded.

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 m^3

(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 =

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

Example No. 1A.b.: Liquid contains (by weight)
50% heptane: TLV = 400 ppm or 1600 mg m^3
1 mg m^3 ≡ 0.25 ppm
30% methyl chloroform: TLV = 350 ppm or 1900 mg m^3
1 mg m^3 ≡ 0.18 ppm
20% perchloroethylene: TLV = 50 ppm or 335 mg·m^3
1 mg m^3 ≡ 0.15 ppm

$$\text{TLV of Mixture} = \frac{1}{\frac{0.5}{1600} + \frac{0.3}{1900} + \frac{0.2}{335}}$$

$$= \frac{1}{0.00031 + 0.00016 + 0.0006}$$

$$= \frac{1}{0.00107} = 935 \text{ mg m}^3$$

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of this mixture
50% or (935) (0.5) = 468 mg/m³ is heptane
30% or (935) (0.3) = 281 mg/m³ is methyl chloroform
20% or (935) (0.2) = 187 mg m³ is perchloroethylene

These values can be converted to ppm as follows:

heptane: 468 mg/m³ × 0.25 = 117 ppm
methyl chloroform: 281 mg/m³ × 0.18 = 51 ppm
perchloroethylene: 187 mg/m³ × 0.15 = 29 ppm

TLV of mixture = 117 + 51 + 29 = 197 ppm, or 935 mg/m³

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 TLV for Mixtures of Mineral Dusts.

For mixtures of biologically active mineral dusts the general formula for mixtures given in 1A.b. may be used.

APPENDIX D
Some Nuisance Particulates[n]

‡TLV, (30 mppcf or) 10 mg/m³ of total dust < 1% quartz, (or, 5 mg/m³ respirable dust)

α-Alumina (Al_2O_3)	Plaster of Paris
Calcium carbonate	Portland Cement
Calcium silicate	Rouge
Cellulose (paper fiber)	Silicon
Emery	Silicon carbide
Glycerin mist	Starch
‡Graphite (synthetic)	Sucrose
Gypsum	Titanium dioxide
Kaolin	Vegetable oil mists (except castor, cashew nut, or similar irritant oils)
Limestone	
Magnesite	
Marble	
Mineral wool fiber	Zinc stearate
Pentaerythritol	Zinc oxide dust

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

APPENDIX E
Some Simple Asphyxiants[o]

Acetylene	Helium	Propane
Argon	Hydrogen	Propylene
Ethane	Methane	
Ethylene	Neon	

o) As defined in the preface.

‡APPENDIX F
Conversion of mppcf to Mass Concentration

Calculations for Conversion of Particle Count Concentration (by Standard Light Field — Midget Impinger Techniques), in mppcf, to Respirable Mass Concentration (by Re spirable Sampler) in mg m³

1. In 1967, Jacobsen and Tomb,[1] derived an empirical relationship of 5.6 mppcf to 1 milligram of respirable dust per cubic meter of air, based on 23 sets of samples, mostly coal dust. Studies on conversion factors have been undertaken and preliminary evidence suggests that the application of any single conversion factor may not be adequate for use in risk assessments epidemiology studies, or setting TLVs.

   The following calculation results in an equivalence of 6.37 mppcf to 1 mg m³ of respirable dust. Thus, an approximate ratio of 6 mppcf to 1 mg m³ of respirable dust is suggested for conversion of TLVs from a count to a mass basis when the density and mass median diameter have not been determined.

2. Basic assumptions:

   a) Average density for silica containing dusts ≈ 2.5 g/cm³ (2500 mg cm³). Pulmonary significant dust densities may vary from 1.2 g/cm³ for coal dust to 3.1 g/cm³ for Portland Cement. Silica densities vary from 2.2 (amorphous) to 2.3 (cristobalite and tridymite) to 2.5 (alpha-quartz.) gms per cm³.

   b) The mass median diameter (mmd) of particles collected in midget impinger samplers and counted by the standard light field technique, *and* collected in a respirable sampler is approximately 1.5 μm or 1.5 × 10^{-4} cm. This assumption is, of course, quite arbitrary since the mmd of all dust clouds is quite

‡See Notice of Intended Changes

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variable, depending on many independent parameters, such as source of dust, age of dust cloud, meteorological conditions, processes and equipment changes, etc. If the density and the mass median diameter of the dust particles are known, the nomograph in Figure 1 can be used to convert dust count concentrations (mppcf) to respirable mass concentrations (mg m³).

3. Calculation

a) vol. per particle: $4/3\ \pi\ r^3$; $r = 0.75 \times 10^{-4}$ cm

$= 4\ 3 \cdot \pi \cdot (0\ 75 \times 10^{-4})^3$

$= 1.77 \times 10^{-12}\ cm^3$

b) wt. per particle = vol. × density

$= 1.77 \times 10^{-12}\ cm^3 \times 2.5 \times 10^3$ mg/cm³

$= 4\ 425 \times 10^{-9}$ mg/particle

c) 1 particle/ft.³ = 35.3 part./m³ (since 35.5 cu ft = 1 cu m.)

10^6 part./ft³ = mppcf = 35.3×10^6 part./m³

wt. of 1 mppcf ≡ 35.5×10^6 part./m³ × 4.425×10^{-9} mg/part

1 mppcf ≡ 0.157 mg/m³

or

6.37 mppcf ≡ 1 mg/m³

or approximately 6 mppcf ≡ 1 mg/m³.

Reference

1 **Jacobson, M., and T. F. Tomb:** Relationship Between Gravimetric Respirable Dust Concentration and Midget Impinger Number Concentration, *Am. Ind. Hyg. Assoc. J. 28:554* (Nov.–Dec. 1967).

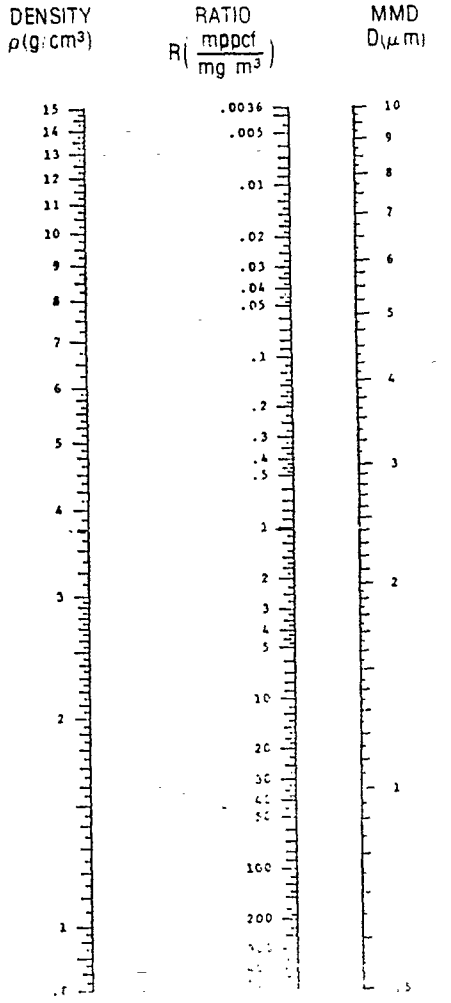


Figure 1 — Ratio of Particle Count — mppcf to Respirable Mass Concentration — mg/m³ (as function of density and mmd)†

†Prepared by P. E. Caplan and R. J. Smith

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Table 1

Equivalent TLVs in mppcf and mg m³ (Respirable Mass) for Mineral Dusts†

Substance	Threshold Limit Value		
	Count mppcf	Resp. Mass mg m³	Total Mass* mg m³
Silica (SiO_2)			
Amorphous	20	(3)**	(6)
Cristobalite	1.5	0.05	0.15
Fused silica	3	0.1	0.3
Quartz	3	0.1	0.3
Tridymite	1.5	0.05	0.15
Coal Dust	(12)	2	(4)
Diatomaceous earth, natural	—	1.5	—
Graphite (natural)	15	(2.5)	(5)
Mica	20	(3)	(6)
Mineral wool fiber	—	(5)	10
Nuisance particulates	30	(5)	10
Perlite	30	(5)	(10)
Portland Cement	30	(5)	(10)
Soapstone	20	(3)	(6)
Tripoli	(3)	0.1	(0.3)

*Assuming that the mass median diameter is 1.5 μm and density is 2.5 g cm³

†Unless otherwise specified, respirable mass is presumed to equal approximately 50% of total mass

**All values in parentheses ( ) represent newly calculated values based on equivalence of 6 mppcf = 1 mg m³ respirable mass and respirable mass = 50% total mass

APPENDIX G

Chemical Substances and Other Issues Under Study*

Chemical Substances

Acetonitrile
Acrolein
Acrylic acid
Allyl chloride
Asbestos
Atrazine
Carbon black
Chlorine
bis-Chloromethyl ether
Chloromethyl methyl ether
o-Chlorotoluene
Chrysene
Copper dust & fume
Cyclohexanone
Diethylenetriamine
Epichlorohydrin

Ethyl benzene
Ethyl chloride
Ethylene dichloride
Ethyl methacrylate
Gasoline (unleaded)
Glycidol
Glycol ethers
Graphite
Hexachlorocyclopentadiene
Isocyanates
Isoamyl alcohol
Jet fuels
Nickel, metal & soluble compounds
Osmium tetroxide
Perfluorinated chemicals
Petroleum fuels
Petroleum solvents
Piperizine
Propylene chloride
Propylene oxide
1,2,3-Trichloropropane
m-Xylene 2,2'-diamine (MXDA, meta-meta-xylenediamine)
Zinc chromates

Other Issues

1. Is the current aspect ratio better than other ratios for health protection and or differentiation of asbestos fibers.
2. *Ceiling Limits* — In light of today's instrumentation (quick response) and STELS, are ceiling limits needed and, if so, what criteria would determine their appropriateness.
3. *Soluble Inorganic Compounds* — What quantitative criteria should be used in differentiating between soluble and insoluble for TLV use.
4. Should welding fume value (not otherwise classified NOC) be retained or should specific analytical determinations be made for metals and other compounds and these values be compared to specific TLVs?

*Information, data especially, and comments are solicited to assist the committee in its deliberations and in the development of draft documents. Draft documentations are used by the committee to decide what action, if any, to recommend on a given substance or question.

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APPENDIX H
Registered* Trade Names

Trade Name	Generic Name	CAS No.
Abate	Temephos	3383-96-8
Ammate	Ammonium sulfamate	7773-06-0
Azodrin	Monocrotophos	6923-22-4
Baygon	Propoxur	114-26-1
Baytex	Fenthion	55-38-9
Bidrin	Dicrotophos	141-66-2
Bolstar	Sulprofos	35400-43-2
Butyl Cellosolve	2-Butoxyethanol	111-76-2
Cellosolve acetate	2-Ethoxyethyl acetate	111-15-9
Coyden	Clopidol	2971-90-6
Crag herbicide	Sesone	136-78-7
Dasanit	Fensulfothion	115-90-2
Delnav	Dioxathion	78-34-2
Dibrom	Naled	300-76-5
Difolatan	Captafol	2425-06-1
Disyston	Disulfoton	298-04-4
Dursban	Chlorpyrifos	2921-88-2
Dyfonate	Fonofos	944-22-9
Furadan	Carbofuran	1563-66-2
Guthion	Azinphos-methyl	86-50-0
Lannate	Methomyl	16752-77-5
Methyl Cellosolve	2-Methoxyethanol	109-84-4
Methyl Cellosolve acetate	2-Methoxyethyl acetate	110-49-6
Nemacur	Fenamiphos	22224-92-6
Nialate	Ethion	563-12-2
N-Serve	Nitrapyrin	1929-82-4
Pival	Pindone	83-26-1
Pictran	Cyhexatin	13121-70-5
Sencor	Metribuzin	21087-64-9
Sevin	Carbaryl	63-25-2
Teflon	Polytetrafluoro-ethylene	9002-84-0
Thimet	Phorate	298-02-2
Thiodan	Endosulfan	115-29-7
Tordon	Picloram	1918-02-1
Zoalene	Dinitolmide	148-01-6

Biological Exposure Indices

Proposed by ACGIH for 1984-85

MAP 000498

1983-84 BIOLOGICAL EXPOSURE INDICES COMMITTEE

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PREFACE

BIOLOGICAL EXPOSURE INDICES

Biological Exposure Indices (BEIs) represent warning levels of biological response to the chemical, or warning levels of the chemical or its metabolic product(s) in tissues, fluids, or exhaled air of exposed workers, regardless of whether the chemical was inhaled, ingested, or absorbed via skin. Introduction of the BEI is a step in the evolution of the concept of TLVs. The BEI provides health personnel with an additional tool to provide protection for the worker. Use of body fluids and appendages such as hair or nails for measuring the absorbed amount of a substance has long been a standard practice for certain substances. Lead is a classical example of a substance for which blood concentrations have long been considered the critical value in determining "safe" versus "unsafe" exposures. Two problems hindered the wider use of biological measurements as indicators of "safe" environmental exposures: 1) the relatively wide range in individual response to a substance and the wide range of "normal" that has to be considered; and 2) The lack of simple specific analytical methods of sufficient sensitivity. Both problems are capable of solution, and we believe that sufficient progress has been made to begin utilizing selected BEIs which can be used as a guide to "safe" exposures to toxic chemicals. The BEI is considered supplementary to an airborne TLV.

TLVs are intended to provide the industrial hygienist with an additional measure to aid in the design of engineering controls or for temporary use of personal protective equipment which will protect almost all exposed workers from untoward effects of chemical exposure. In principle, TWA-TLVs are designed to prevent exposures which may cause acute or chronic adverse effects. They are also intended to avoid attendant deterioration of normal physiological function. This approach is based on the assumption that for nearly all workers there is a tolerable exposure limit and a tolerable body burden of airborne material. If this assumption is valid, there should be a range of safe biologically insignificant changes of various measures of body function.

The TLVs are a measure of the composition of the external environment surrounding the worker. BEIs are a measure of the amount of chemical *absorbed* into the body. The concept of the BEI is particularly useful in evaluating exposures to substances with significant absorption through the skin.

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The biological determinant on which the BEIs are based can furnish two kinds of information useful in the control of worker exposure, 1) measure of the worker s individual response, and 2) measure of the worker s individual overall exposure. Measurements of response furnish an estimate of the physiological status of the worker and can be made by, *a)* determining changes in the amount of a critical biochemical constituent, *b)* determining changes in activity of a critical enzyme, and *c)* determining changes in a physiological function. Measurements of exposure can be made by, *a)* determining the chemical in exhaled air, urine, blood, hair, nails, body tissues and fluids, *b)* determining the metabolite(s) of the chemical in tissues and fluids, and *c)* determining the extent of specific biochemical and physiological changes induced by the chemical.

Recommended values of BEIs are based on data obtained in epidemiological and field studies or determined as bioequivalent to a TLV by means of pharmacokinetic analysis of data from controlled human studies. Most chemicals (including organic solvents) are initially absorbed and eliminated fairly rapidly — usually with initial half-life values measured in a few hours or even minutes. Rapidly changing concentrations in body fluids complicate the interpretation of data and the average body burden of a chemical attained during a work shift can easily be over-predicted or under-predicted. Furthermore, biological measurements fail in most instances to detect transient periods of over-exposure during the work shift. Because elimination of chemicals and their metabolic products, as well as biological changes induced by exposure to the chemical, are kinetic events, the listed BEIs are strictly related to 8-hour exposures and to the specified timing for the collection of biological samples.

There are other factors to be considered when the BEI is applied. Among the factors which must be considered in using BEIs are: *a)* changes induced by strenuous physical activity; *b)* changes induced by environmental conditions (altitude, heat, diet, etc.); *c)* changes induced by water intake, *d)* changes in physiological functions induced by preexisting disease or congenital variation; *e)* changes in metabolism induced by congenital variation of metabolic pathways; and *f)* changes in metabolic pathway induced by simultaneous administration of another chemical (induction or inhibition of activity of a critical enzyme by medication or by preexposure or coexposure to another chemical).

For BEIs based on urine analysis, simple measurements of concentrations can provide sufficient information on exposure, but in many instances, measurements of elimination rates provide more precise information.

Urinary concentrations related to creatinine represent a reasonable compromise between the accuracy of the information and the technical means of obtaining the data

Some BEIs are not protective of an identified population, or are nonspecific, or the correlation between the exposure and biological determinant is weakened by variables introduced by large interindividual variation in response to the chemical or by timing and fluctuation of exposure concentration. In such cases the BEIs carry the following notations:

"R" Notation. Indicates that an identifiable population group might have an increased susceptibility to the effect of the chemical which leaves it unprotected by the recommended BEI. The specific documentation should be consulted for detailed information.

"" Notation.* Some determinants are nonspecific, since different chemicals may bear the same biological response. Such BEIs carry "*" notation. These nonspecific tests are preferred because they are easy to use and, in many instances, offer a better correlation between exposure and response than specific tests. In such instances, a BEI for a specific less quantitative biological determinant is recommended as a confirmatory test. The documentation should be consulted for information on factors affecting interpretation of such a BEI.

*"**" Notation.* Indicates that the biological determinant is a specific indicator of exposure to the chemical, but the quantitative interpretation of the measurements is very ambiguous, and that the relationship between the TLV and BEI is markedly weakened by variables in timing, fluctuation of exposure concentrations, and by other circumstantial variables. Such biological determinants should be used as confirmatory tests; and their BEIs should be applied cautiously, mainly for confirmation of exposures indicated by nonspecific BEIs.

"G" Notation Because of the wide interindividual variation in response to some chemicals, the BEI is, in some instances, recommended as a mean value of a group test for workers subjected to a similar level of occupational exposure, rather than as an index for an individual. Such BEIs carry "G" notation.

The table includes BEIs for which a sufficient data base is available and on which the committee took action. Some BEIs are more suitable for correlation with TLV-TWAs than others. Other BEIs are preferable for evaluating recent exposure or for confirmation of exposure For specific instances the documentation should be consulted.

Workers are not expected to suffer any ill effects as long as the described measurements of the determinants

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are maintained within limits of the recommended BEIs. Measurements outside these limits are not necessarily indicators of a disease process. However, if these deviate measurements persist, it is an indication that the individual should be examined by a physician to determine whether there is any health effect. The workplace and work practices should be investigated further.

NOTICE OF INTENT TO ESTABLISH BIOLOGICAL EXPOSURE INDICES†

Airborne Chemical [CAS #] / Indices	Timing	BEI	
CARBON MONOXIDE [630-08-0]			R
* Carboxyhemoglobin in blood	End of shift	less than 8%	
* CO in end-exhaled air	End of shift	less than 40 ppm	
ETHEYL BENZENE [100-41-4]			
* Mandelic acid in urine	End of shift and End of workweek	2 g/L 1.5 g g creat.	G G
** Ethyl benzene in end-exhaled air	Prior to shift	2 ppm	
STYRENE, monomer [100-42-5]			
* Mandelic acid in urine	End of shift	1.0 g/L 0.8 g/g creat.	G G
Styrene in mixed-exhaled air	Prior to shift	40 ppb	
* Phenylglyoxylic acid in urine	End of shift	250 mg L 240 mg g creat	G G
** Styrene in mixed-exhaled air	During shift	18 ppm	
** Styrene in venous blood	End of shift Prior to shift	0.55 mg L 0.02 mg L	
TOLUENE [108-88-3]			
* Hippuric acid in urine	End of shift Last 4 hrs of shift	2.5 g/g creat. 3 mg/min	G G
** Toluene in venous blood	End of shift	1.0 mg/L	

Airborne Chemical [CAS #] / Indices	Timing	BEI	
* Toluene in end-exhaled air	During shift	20 ppm	
TRICHLOROETHYLENE [79-01-6]			
* Trichloroacetic acid in urine	End of workweek	100 mg L	G
* Trichloroacetic acid and trichloroethanol in urine	End of shift and End of workweek	320 mg g creat. 300 mg L	G G
* Free trichloroethanol in blood	End of shift and End of workweek	4 mg L	
* Trichloroethylene in end-exhaled air	Prior to shift and End of workweek	0.5 ppm	
XYLENES [1330-20-7]			
Methylhippuric acids in urine	End of shift Last 4 hrs of shift	1.5 g g creat 2 mg min	

† It is strongly advisable to consult the specific documentation before invoking BEI

MAP 000501

TLVs®
Threshold Limit Values
for
Physical Agents
in the
Work Environment
Adopted by
ACGIH
for 1984-85



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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.

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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 1 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.[1,2]

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 = 0.7 NWB + 0.2 GT + 0.1 DB
2. Indoors or Outdoors with no solar load:
   WBGT = 0.7 NWB + 0.3 GT

where:

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

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

Higher heat exposures than shown in Table 1 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.

EVALUATION AND CONTROL

1. *Measurement of the Environment*

The instruments required are a dry-bulb, a natural wet-bulb, a globe thermometer, and a stand. The

TABLE 1

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

	Work Load		
Work — Rest Regimen	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

measurement of the environmental factors shall be performed as follows:

A. The range of the dry and the natural wet bulb thermometer shall be −5°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. A 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.

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C. A 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 as that of 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 by Minard.[3-4]

II. Work Load Categories

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

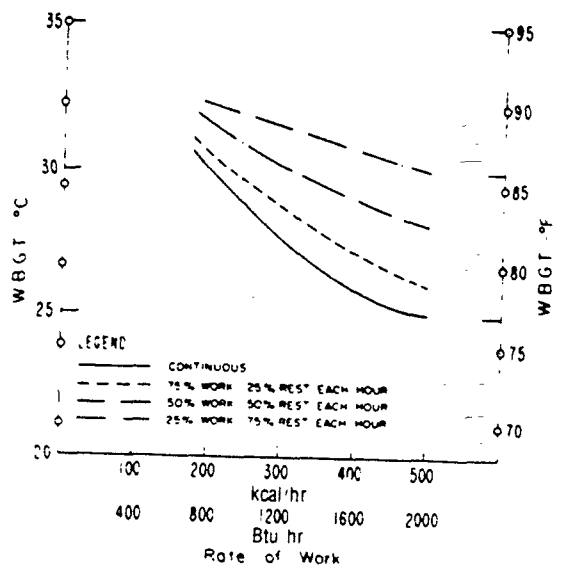


Figure 1 — Permissible Heat Exposure Threshold Limit Value

TABLE 2

Assessment of Work Load[8,9]

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	

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 (up to 200 kcal/hr or 800 Btu/hr): e.g., sitting or standing to control machines, performing light hand or arm work,

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TABLE 3

Activity Examples[39]

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

Assembly line work using a heavy hand tool.

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

(2) moderate work (200–350 kcal/hr or 800–1400 Btu/hr): e.g., walking about with moderate lifting and pushing,

(3) heavy work (350–500 kcal/hr or 1400–2000 Btu/hr): 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 with the use of Tables 2 and 3. Additional tables available in the literature[5-7] may be utilized also. When this method is used the permissible heat exposure limit can be determined by Figure 1.

III. *Work-Rest Regimen*

The permissible exposure limits specified in Table 1 and Figure 1 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. Where the WBGT of the work area is different from that of the rest area a time-weighted average value should be used for both environmental and metabolic heat. When time-weighted average values are used the appropriate curve on Figure 1 is the solid line labeled "continuous."

The time-weighted average metabolic rate (M) shall be determined by the equation:

$$\text{Av. } M = \frac{M_1 \times t_1 + M_2 \times t_2 + \ldots + M_n \times t_n}{t_1 + t_2 + \ldots + t_n}$$

where M_1, M_2 . . . and M_n are estimated or measured metabolic rates for the various activities and rest periods of the worker during the time periods t_1, t_2 . . . and t_n (in minutes) as determined by a time study.

The time-weighted average WBGT shall be determined by the equation:

$$\text{Av. WBGT} = \frac{WBGT_1 \times t_1 + WBGT_2 \times t_2 + \ldots + WBGT_n \times t_n}{t_1 + t_2 + \ldots + t_n}$$

where $WBGT_1$, $WBGT_2$ . . . and $WBGT_n$ are calculated values of WBGT for the various work and rest occupied during total time periods t_1, t_2 . . . and t_n are the elapsed times in minutes spent in the corresponding areas which are determined by a time study. Where exposure to hot environmental conditions is continuous for several hours or the entire work day, the time-weighted averages shall be calculated as hourly time-weighted average i.e., $t_1 + t_2 + \ldots + t_n = 60$ minutes. Where the exposure is intermittent, the time-weighted averages shall be calculated as two-hour time-weighted averages, i.e., $t_1 + t_2 + \ldots + t_n = 120$ minutes.

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

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counted as rest time when additional rest allowance must be given because of high environmental temperatures.

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 shall be kept reasonably cool (10°–15°C or 50.0°–60.0°F) 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 cothing 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 1 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:* Acclimatization to heat involves a series of physiological and psychological adjustments that occur in an individual during his first week of exposure to hot environmental conditions. The recommended heat stress TLVs are valid for acclimated workers who are physically fit. Extra caution must be employed when unacclimated or physically un-fit workers must be exposed to heat stress conditions.

References:

1. *Health Factors Involved in Working Under Conditions of Heat Stress* WHO Technical Report Series No. 412 (1969).

2. **Dubois-Dubois, F. N. and A. Henschel:** Development of Permissible Heat Exposure Limits for Occupational Work *ASHRAE Journal 15(9)*:57–62 (Sept 1973)
3. **Minard, D.:** *Prevention of Heat Casualties in Marine Corps Recruits Period of 1955–60, with Comparative Incidence Rates and Climatic Heat Stresses in Other Training Categories* Research Report No 4 Contract No. MR 005.01-0001.01, Naval Medical Research Institue Bethesda, MD (Feb 21 1961) Published in *Military Medicine 126(44)*:261–272 (April 1961)
4. **Minard, D. and R. L. O'Brien:** *Heat Casualties in the Navy and Marine Corps 1959–1962 with Appendices on the Field Use of the Wet Bulb-Globe Temperature Index*. Research Report No 7, Contract No. MR 005.01-0001.01, Naval Medical Research Institute, Bethesda, MD (March 12, 1964).
5. **Astrand, Per-Olof and Kaare Rodahl:** *Textbook of Work Physiology* McGraw-Hill Book Co., New York, San Francisco (1970)
6. Ergonomics Guide to Assessment of Metabolic and Cardiac Costs of Physical Work. *Am. Ind Hyg Assoc. J. 32*:560 (1971).
7. *Energy Requirements for Physical Work* Research Progress Report No. 30, Purdue Farm Cardiac Project, Agricultural Experiment Station, West Lafayette, IN (1961).
8. **Durnin, J. V. G. A. and R. Passmore:** *Energy, Work and Leisure* Heinemann Educational Books, Ltd., London (1967)
9. **Lehmann, G. E., A. Muller and H. Spitzer:** Der Kalorienbedarf die Gewerblicher Arbeit. *Arbeitsphysiol 14* 166 (1950)

IONIZING RADIATION

The Committee accepts the philosophy and recommendations of the National Council on Radiation Protection and Measurements (NCRP) for the ionizing radiation TLV. The NCRP is charted by Congress to, in part, collect, analyze, develop and disseminate information and recommendations about protection against radiation and about radiation measurements, quantities and units, including development of basic concepts in these areas. NCRP Report No. 39 provides basic philosophy and concepts leading to protection criteria established in the same report.[1] Other NCRP reports address specific areas of radiation protection and, collectively, provide an excellent basis for establishing a sound program for radiation control. The Committee recommends the listed references as substantative documentation of a sound basis for ionizing radiation protection. The committee also strongly recommends that all exposures to ionizing radiations be kept as low as reasonably achievable within the stated guidance.

References:

1. *Basic Radiation Protection Criteria* NCRP Report No 39 (January 15, 1971)

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2. *Maximum Permissible Body Burdens and Maximum Permissible Concentrations of Radionuclides in Air and in Water for Occupational Exposure* National Bureau of Standards Handbook 69 (June 5 1959) with *Addendum 1* (August 1963) Available as NCRP Report No 22

The above documents, as well as information on numerous other NCRP Reports addressing specific subjects in ionizing radiation protection are available from: NCRP Publications, PO Box 30175, Washington, DC 20014.

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); and except for all TLVs for wavelengths between 0.1–1 mm where the limiting aperture is 10 mm. 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 7) which varies with exposure time. This angle is *not* the beam divergence of the source.

Correction Factors A and B (C_A and C_B)

The TLVs for ocular exposure in Tables 4 and 5 are to be used as given for all wavelength ranges. The TLVs for wavelengths between 700 nm and 1049 nm are to be increased by a uniformly extrapolated factor (C_A) as shown in Figure 2. Between 1049 nm and 1400 nm, the TLV has been increased by a factor (C_A) of five. For certain exposure times at wavelengths between 550 nm and 700 nm, correction factor (C_B) must be applied.

The TLVs for skin exposure are given in Table 6. The TLVs are to be increased by a factor (C_A) as shown in Figure 2 for wavelengths between 700 nm and 1400 nm. To aid in the determination of TLVs for exposure durations requiring calculations of fractional powers Figures 3, 4, 5 and 6 may be used.

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 4, 5, or 7 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^{-5} second. For pulses of greater duration, the following formula should be followed:

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

where:

n = number of pulses in train

τ = duration of a single pulse in the train

Standard ($n\tau$) = protection standard of one pulse having a duration equal to $n\tau$ seconds.

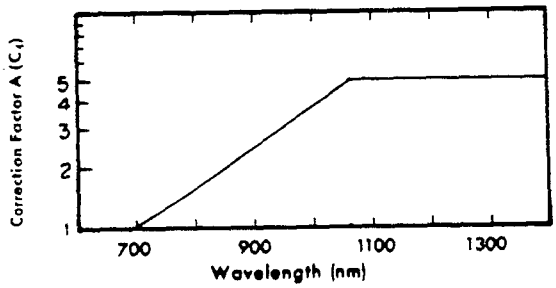


Figure 2 — TLV correction factor for λ = 700 – 1400 nm*

*For λ = 700 – 1049 nm, $C_A = 10^{[0.002(\lambda - 700)]}$
For λ = 1050 – 1400 nm, $C_A = 5$

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TABLE 4

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 "	*not to exceed 0.56 $t^{1/4}$ J • cm^{-2} for $t \leq 10$ s.
	308 nm	"	40 "	
	309 nm	"	63 "	
	310 nm	"	100 "	
	311 nm	"	160 "	
	312 nm	"	250 "	
	313 nm	"	400 "	
	314 nm	"	630 "	
UVA	315 nm to 400 nm	10^{-9} to 10	$.56\ t^{1/4}$ J • cm^{-2}	
	" "	10 to 10^{3}	1 0 J • cm^{-2}	
Light	400 nm to 700 nm	10^{3} to 3×10^{4}	1 0 mW • cm^{-2}	
	400 nm to 700 nm	10^{-9} to 1.8×10^{-5}	5×10^{-7} J • cm^{-2}	
	400 nm to 549 nm	1.8×10^{-5} to 10	1.8 ($t/\sqrt{t}$) mJ • cm^{-2}	
	550 nm to 700 nm	10 to T_1	10 mJ • cm^{-2}	
	550 nm to 700 nm	T_1 to 10^{4}	1.8 ($t/\sqrt{t}$) mJ • cm^{-2}	
	400 nm to 700 nm	10^{4} to 3×10^{4}	10 C_B mJ • cm^{-2}	
IR-A	700 nm to 1049 nm	10^{-9} to 1.8×10^{-5}	C_B μW • cm^{-2}	
	700 nm to 1049 nm	1.8×10^{-5} to 10^{3}	5 $C_1 \times 10^{-7}$ J • cm^{-2}	
	1050 nm to 1400 nm	10^{-9} to 10^{-1}	1 8 C_1 ($t/\sqrt{t}$) mJ • cm^{-2}	
	1050 nm to 1400 nm	10^{-1} to 10^{3}	5×10^{-6} J • cm^{-2}	
	700 nm to 1400 nm	10^{4} to 3×10^{4}	9($t/\sqrt{t}$) mJ • cm^{-2}	
IR-B & C	1.4 μm to 10^{-1} μm	10^{-9} to 10^{-7}	320 C_1 μW • cm^{-2}	
	" "	10^{-7} to 10	10^{-2} J • cm^{2}	
	" "	10 to 3×10^{4}	0 56 $\sqrt{t}$ J • cm^{-2}	
			0 1 W • cm^{-2}	

C_1 See Fig 2
C_B 1 for λ 400 to 549 nm, C_B $10^{...}$ for λ 550 to 700 nm
T_1 10 s for λ 400 to 549 nm, T_1 $10 \cdot 10^{...}$ for λ 550 to 700 n

MAP 000509

TABLE 5

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 4
Light	400 nm to 700 nm	10^{-9} to 10	$10\sqrt{t}$ J • cm^{-2} • sr^{-1}
	400 nm to 549 nm	10 to 10^{4}	21 J • cm^{-2} • sr^{-1}
	550 nm to 700 nm	10 to T_1	$3.83\,(t/\sqrt{t})$ J • cm^{-2} • sr^{-1}
	550 nm to 700 nm	T_1 to 10^{4}	$21\,C_B$ J • cm^{-2} • sr^{-1}
	400 nm to 700 nm	10^{4} to 3×10^{4}	$2.1\,C_B t \times 10^{-3}$ W • cm^{-2} • sr^{-1}
IR-A	700 nm to 1400 nm	10^{-9} to 10	$10\,C_1\sqrt{t}$ J • cm^{-2} • sr^{-1}
	700 nm to 1400 nm	10 to 10^{4}	$3.83\,C_1\,(t/\sqrt{t})$ J • cm^{-2} • sr^{-1}
	700 nm to 1400 nm	10^{4} to 3×10^{4}	$0.64\,C_1$ W • cm^{-2} • sr^{-1}
IR-B & C	1.4 μm to 10^{3} μm	10^{-9} to 3×10^{4}	Same as Table 4

C_1, C_B, and T_1 are the same as in footnote to Table 4

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 4
Light &	400 nm to 1400 nm	10^{-9} to 10^{-7}	$2\,C_1 \times 10^{-2}$ J • cm^{-2}
IR-A	" "	10^{-7} to 10	$1.1\,C_1\sqrt{t}$ J • cm^{-2}
IR-A	" "	10 to 3×10^{4}	$0.2\,C_1$ W • cm^{-2}
IR-B & C	1.4 μm to 10^{3} μm	10^{-9} to 3×10^{4}	Same as Table 4

C_1 1.0 for λ 400-700 nm, see Figure 2 for λ 700 to 1400 nm

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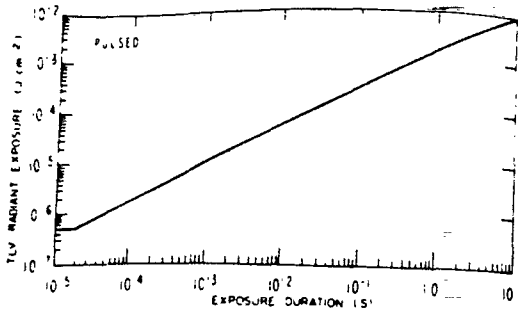


Figure 3a — TLV for intrabeam (direct) viewing of laser beam (400–700 nm).

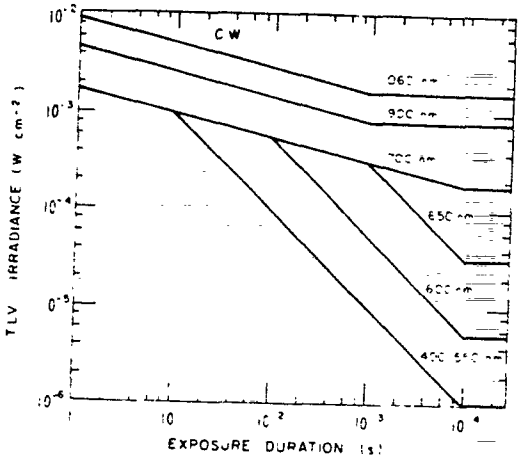


Figure 3b — TLV for intrabeam (direct) viewing of CW laser beam (400–1400 nm)

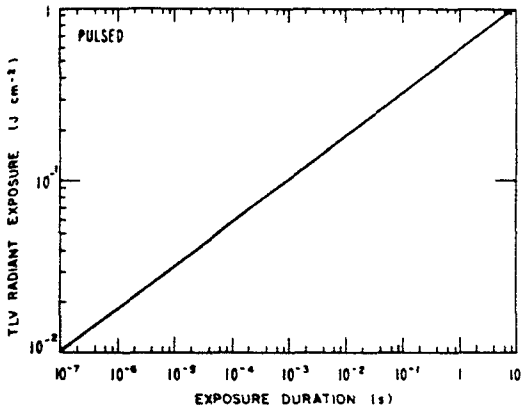


Figure 4a — TLV for laser exposure of skin and eyes for far-infrared radiation (wave-lengths greater than 1.4 μm).

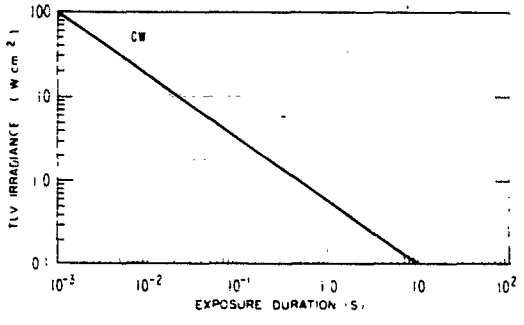


Figure 4b — TLV for CW laser exposure of skin and eyes for far-infrared radiation (wave-lengths greater than 1.4 μm).

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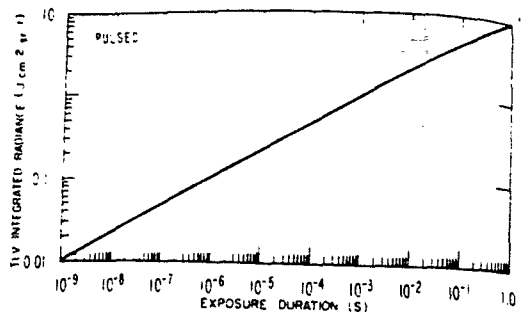


Figure 5a — TLV for extended sources or diffuse reflections of laser radiation (400–700 nm).

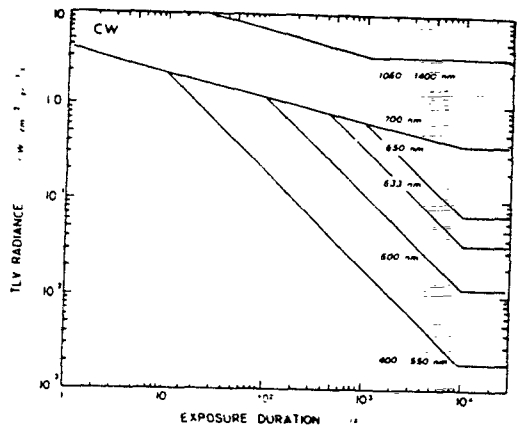


Figure 5b — TLV for extended sources or diffuse reflections of laser radiation (400–1400 nm).

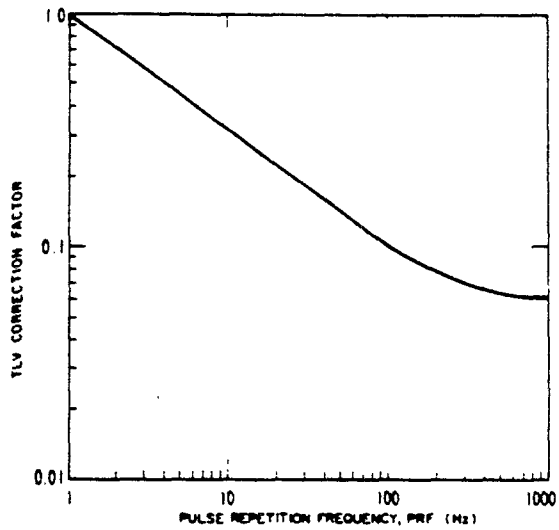


Figure 6 — Multiplicative correction factor for repetitively pulsed lasers having pulse durations less than 10^{-5} second. TLV for a single pulse of the pulse train is multiplied by the above correction factor. Correction factor for PRF greater than 1000 Hz is 0.06.

TABLE 7

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

Exposure Duration(s)	Angle α (mrad)	Exposure Duration(s)	Angle α (mrad)
10^{-9}	8.0	10^{-2}	5.7
10^{-8}	5.4	10^{-1}	9.2
10^{-7}	3.7	1.0	15
10^{-6}	2.5	10	24
10^{-5}	1.7	10^{2}	24
10^{-4}	2.2	10^{3}	24
10^{-3}	3.6	10^{4}	24

MAP 000512

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. Prior to 1979, the medical profession had 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.[a] 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.

It should be recognized that the application of the TLV for noise will not protect all workers from the adverse effects of noise exposure. A hearing conservation program with audiometric testing is necessary when workers are exposed to noise at or above the TLV 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 National 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 8.

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 and does include the impact and impulsive type of noise that contributes to the sound level meter reading at slow response.

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 on-the-job noise exposures of 80 dBA or greater shall be used in the above calculations.

[a] In 1979, the American Academy of Ophthalmology and Otolargyngology (AAOO) included 3000 Hz in their hearing impairment formula

Table 8
Threshold Limit Values

Duration per Day Hours	Sound Level dBA†
16	80
8	85
4	90
2	95
1	100
1/2	105
1/4	110
1/8	115*

†Sound level in decibels are 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.

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

IMPULSIVE OR IMPACT NOISE

It is recommended that exposure to impulsive or impact noise shall not exceed the limits listed in Table 9 or taken from Figure 7. No exposures in excess of 140 decibels peak sound pressure level are permitted. 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 9
Threshold Limit Values Impulsive or Impact Noise

Sound Level dB**	Permitted Number of Impulses or Impacts per day
140	100
130	1000
120	10,000

**Decibels peak sound pressure level, re 20 μPa

MAP 000513

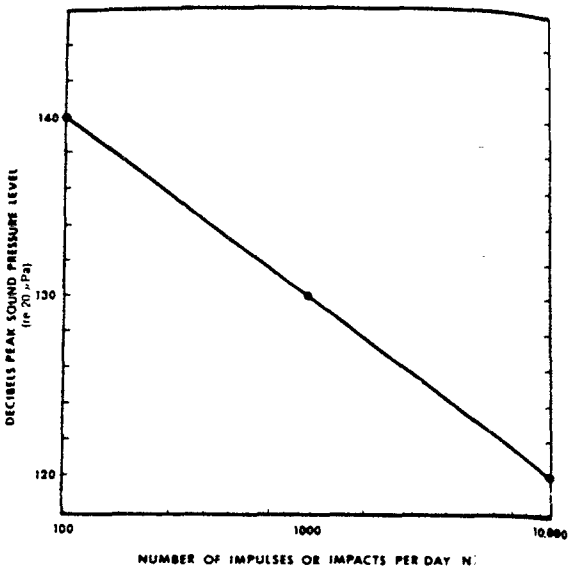


Figure 7 — Threshold Limit Values for Impulse/Impact Noise.

RADIOFREQUENCY/MICROWAVE RADIATION

These Threshold Limit Values (TLVs) refer to radiofrequency (RF) and microwave radiation in the frequency range from 10 kHz to 300 GHz, and represent conditions under which it is believed workers may be repeatedly exposed without adverse health effects. The TLVs shown in Table 10 are selected to limit the average whole body specific absorption rate (SAR) to 0.4 W/kg in any six minutes (0.1 hr) period for 3 MHz to 300 GHz, see Figure 8. Between 10 kHz and 3 MHz the average whole body SAR is still limited to 0.4 W/kg, but the plateau at 100 mW/cm² was set to protect against shock and burn hazards.

Since it is usually impractical to measure the SAR, the TLVs are expressed in units that are measurable, viz, squares of the electric and magnetic field strengths, averaged over any 0.1 hour period. This

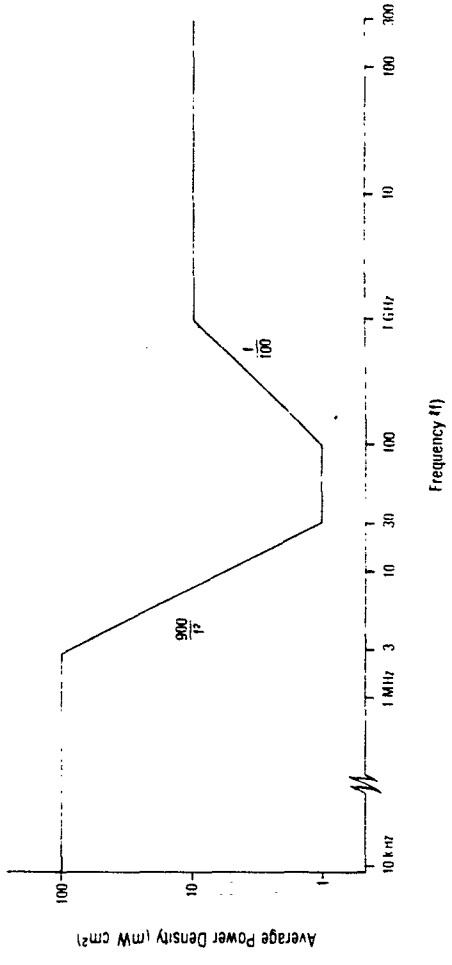


Figure 8 — Threshold Limit Values (TLV) for Radiofrequency/Microwave Radiation in Workplace (Whole Body SAR Less Than 0 4 W/kg).

MAP 000514

TABLE 10

Radiofrequency/Microwave Threshold Limit Values

Frequency	Power Density (mW/cm^2)	Electric Field Strength Squared (V^2/m^2)	Magnetic Field Strength Squared (A^2/m^2)
10 kHz to 3 MHz	100	377,000	2.65
3 MHz to 30 MHz	$900/f^{2*}$	$3770 \times 900/f^{2*}$	$900/(37.7 \times f^{2*})$
30 MHz to 100 MHz	1	3770	0.027
100 MHz to 1000 MHz	$f^*/100$	$3770 \times f^*/100$	$f^*/37.7 \times 100$
1 GHz to 300 GHz	10	37,700	0.265

*1 frequency in MHz

can be expressed in units of equivalent plane wave power density for convenience. The electric field strength (E) squared, magnetic field strength (H) squared, and power density (PD) values are shown in Table 10. For near field exposures PD cannot be measured directly, but equivalent plane wave power density can be calculated from the field strength measurement data as follows:

$$PD \text{ in } mW/cm^2 = \frac{E^2}{3770}$$

where:

E^2 is in volts squared (V^2) per meter squared (m^2).

$$PD \text{ in } mW/cm^2 = 37.7\ H^2$$

where:

H^2 is in amperes squared (A^2) per meter squared (m^2).

These values should be used as guides in the evaluation and control of exposure to radiofrequency/microwave radiation, and should not be regarded as a fine line between safe and dangerous levels.

Notes:

1. All Radiofrequency Radiation (RFR) exposures should be kept as low as reasonably possible given the current state of knowledge on human effects, particularly non-thermal effects.
2. For fields consisting of a number of frequencies, the fraction of the protection guide incurred within each frequency level should be determined and the sum of all fractions should not exceed unity.
3. For pulsed and continuous wave fields, the power density is averaged over the six minute period.
4. For partial body exposures at frequencies between 10 kHz and 1.0 GHz, the protection guides in Table 10 may be exceeded if the output power of a radiating device is 7 watts or less. For example, if a hand held transmitter operating at 27 MHz has a maximum output of 5 watts, it would be excluded from any further field measurements.
5. The TLVs in Table 10 may be exceeded if the exposure conditions can be demonstrated to produce a SAR of less than 0.4 W/kg as averaged over the whole body and spatial peak SAR values less than 8.0 W/kg as averaged over any 1.0 gram of tissue.

MAP 000515

For example, for frequencies from 3 to 30 MHz, the equivalent power density can be increased by a factor of 10 up to a limit of 100 mW/cm^2, if it can be assured that exposed individuals are not in contact with the ground plate.

6. At frequencies below 30 MHz, ungrounded objects such as vehicles, fences, etc., can strongly couple to RF fields. For field strengths near the TLV, shock and burn hazards can exist. Care should be taken to eliminate ungrounded objects, to ground such objects, or use insulated gloves when ungrounded objects must be handled.
7. No measurement should be made within 5 cm of any object.
8. All exposures should be limited to a maximum (peak) electric field intensity of 100 kV/m.

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, and solar radiation, but do not apply to ultraviolet lasers.* These values do not apply to ultraviolet radiation exposure of photosensitive individuals or of individuals concomitantly exposed to photosensitizing agents.[1] 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 nm) total irradiance incident upon the unprotected skin or eye should not exceed 1 mW cm^2 for periods greater than 10^3 seconds (approximately 16 minutes) and for exposure times less than 10^3 seconds should not exceed one J/cm^2.
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 11 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 following weighting formula should be used:

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

where:

E_{eff} = effective irradiance relative to a monochromatic source at 270 nm in W/cm^2 (J/s/cm^2)

E_λ = spectral irradiance in W/cm^2/nm

S_λ = relative spectral effectiveness (unitless)

$\Delta\lambda$ = band width in nanometers

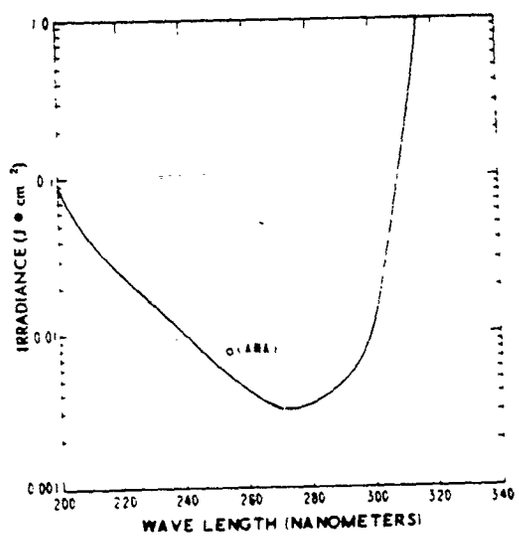


Figure 9 — Threshold Limit Values for Ultraviolet Radiation

*See Laser TLVs

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TABLE 11

Relative Spectral Effectiveness by Wavelength*

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
254	6.0	0.5
260	4.6	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 Laser TLVs

TABLE 12

Permissible Ultraviolet Exposures

Duration of Exposure Per Day	Effective Irradiance, E_{eff} (μW cm²)
8 hrs.	0.1
4 hrs.	0.2
2 hrs.	0.4
1 hr.	0.8
30 min	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

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 12 which provides exposure times corresponding to effective irradiances in μW cm².
5. All the preceding TLVs 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°.

Conditioned (tanned) individuals can tolerate skin exposure in excess of the TLV without erythemal effects. However, such conditioning may not protect persons against skin cancer

Reference:

1. *Sunlight and Man* Fitzpatrick *et al* Eds Univ of Tokyo Press Tokyo Japan (1974)

NOTICE OF INTENDED CHANGES (for 1984–85)

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.

NOTICE OF INTENT TO ESTABLISH THRESHOLD LIMIT VALUES

LASERS

It is proposed that the following footnote be added to Table 6 (Threshold Limit Value for Skin Exposure from a Laser Beam).

The IR-B and IR-C exposures to skin surface areas A(cm²) exceeding 1000 cm², the TLV is

$$(100{,}000/A) \bullet (mW/cm^2);$$

for areas greater than 10,000 cm², the TLV is 10 mW cm².

LIGHT AND NEAR-INFRARED RADIATION

These Threshold Limit Values refer to visible and near-infrared radiation in the wavelength range of 400

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nm to 1400 nm and represent conditions under which it is believed that nearly all workers may be exposed without adverse effect. These values should be used as guides in the control of exposure to light and should not be regarded as a fine line between safe and dangerous levels.

Recommended Values:

The Threshold Limit Value for occupational exposure to broad-band light and near-infrared radiation for the eye apply to exposure in any eight-hour workday and require knowledge of the spectral radiance (L_λ) and total irradiance (E) of the source as measured at the position(s) of the eye of the worker. Such detailed spectral data of a white light source is generally only required if the luminance of the source exceeds 1 cd cm^{-2}. At luminances less than this value the TLV would not be exceeded.

TABLE 13

Spectral Weighting Functions for Assessing Retinal Hazards from Broad-Band Optical Sources

Wavelength (nm)	Blue-Light Hazard Function B_λ	Burn Hazard Function R_λ
400	0.10	1.0
405	0.20	2.0
410	0.40	4.0
415	0.80	8.0
420	0.90	9.0
425	0.95	9.5
430	0.98	9.8
435	1.0	10.0
440	1.0	10.0
445	0.97	9.7
450	0.94	9.4
455	0.90	9.0
460	0.80	8.0
465	0.70	7.0
470	0.62	6.2
475	0.55	5.5
480	0.45	4.5
485	0.40	4.0
490	0.22	2.2
495	0.16	1.6
500–600	$10^{(1450-\lambda)/50}$	1.0
600–700	0.001	1.0
700–1049	0.001	$10^{(700-\lambda)/500}$
1050–1400	0.001	0.2

The TLV's are:

1. To protect against retinal thermal injury, the spectral radiance of the lamp weighted against the function R (Table 13) should not exceed:

$$\sum_{400}^{1400} L_\lambda R_\lambda \Delta\lambda \leqq 1/\alpha\, t^{1/2} \qquad (1)^*$$

where L_λ is in W cm^{-2} sr^{-1} nm^{-1} and t is the viewing duration (or pulse duration if the lamp is pulsed) limited to 1 μs to 10 s, and α is the angular subtense of the source in radians. If the lamp is oblong, α refers to the longest dimension that can be viewed. For instance, at a viewing distance r = 100 cm from a tubular lamp of length l = 50 cm, the viewing angle is:

$$\alpha = l/r = 50/100 = 0.5 \text{ rad} \qquad (2)$$

2. To protect against retinal photochemical injury from chronic blue-light exposure the integrated spectral radiance of a light source weighted against the blue-light hazard function B_λ (Table 13) should not exceed:

$$\sum_{400}^{1400} L_\lambda\, t\, B_\lambda \Delta\lambda \leqq 100 \text{ Jcm}^{-2}\text{ sr}^{-1} \quad (t \leqq 10^4\text{s}) \qquad (3a)$$

$$\sum_{400}^{1400} L_\lambda B_\lambda \Delta\lambda \leqq 10^{-2} \text{ Wcm}^{-2}\text{ sr}^{-1} \quad (t > 10^4\text{s}) \qquad (3b)$$

The weighted product of L_λ and B_λ is termed L(blue). For a source radiance L weighted against the blue-light hazard function [L(blue)] which exceeds 10 mW•cm^{-2}•sr^{-1} in the blue spectral region, the permissible exposure duration t_{max} in seconds is simply:

$$t_{max} = 100 \text{ J cm}^{-2}\text{ sr}^{-1}/\text{L (blue)} \qquad (4)$$

The latter limits are greater than the maximum permissible exposure limits for 440 nm laser radiation (see Laser TLV) because a 2–3 mm pupil is assumed rather than a 7 mm pupil for the Laser TLV. For a light source subtending an angle α less than 11 mrd (0.011 radian) the above limits are relaxed such that the spectral irradiance weighted against the blue-light hazard function B_λ should not exceed E(blue).

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$$\sum_{400}^{1400} E_\lambda \bullet t \bullet B_\lambda \bullet \Delta\lambda \leqq 10 \text{ mJ} \bullet \text{cm}^{-2} \quad (t \leqq 10^4 \text{ s}) \quad (5a)$$

$$\sum_{400}^{1400} E_\lambda \bullet B_\lambda \bullet \Delta\lambda \leqq 1 \mu\text{W} \bullet \text{cm}^2 \quad (t \geqq 10^4 \text{ s}) \quad (5b)$$

For a source where the blue light weighted irradiance E (blue) exceeds 1 μW • cm^{-2} is the maximum permissible exposure duration t_{max} in seconds is:

$$t_{max} = 10 \text{ mJ} \bullet \text{cm}^{-2} \text{ E (blue)} \quad (6)$$

3. *Infrared Radiation:* To avoid possible delayed effects upon the lens of the eye (cataractogenesis), the infrared radiation (λ > 770 nm) should be limited to 10 mWcm^{-2}. For an infrared heat lamp or any near-infrared source where a strong visual stimulus is absent, the near infrared (770–1400 nm) radiance as viewed by the eye should be limited to:

$$\sum_{770}^{1400} L_\lambda \Delta\lambda \leqq 0.6/\alpha \quad (7)^*$$

for extended duration viewing conditions. This limit is based upon a 7 mm pupil diameter.

AIRBORNE UPPER SONIC AND ULTRASONIC ACOUSTIC RADIATION

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. The values listed in Table 14 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. The levels for the third octave bands centered below 20 kHz are below those which cause subjective effects. Those levels for 1/3 octaves above 20 kHz are for prevention of possible hearing losses from subharmonics of these frequencies.

*Formulae (1) and (7) are empirical and are not, strictly speaking, dimensionally correct. To make the formulae dimensionally correct, one would have to insert a dimensional correction factor k in the right hand numerator in each formula. For formula (1) this would be k_1 = 1 W • rad • s$^{1/2}$ • (cm^2 • sr), and for formula (7) k_2 = 1 W • rad (cm^2 • sr)

TABLE 14

Permissible Ultrasound Exposure Levels

Mid-Frequency of Third-Octave Band kHz	One-Third Octave — Band Level in dB re 20 μPa
10	80
12.5	80
16	80
20	105
25	110
31.5	115
40	115
50	115

COLD STRESS

These Threshold Limit Values (TLVs) are intended to protect workers from the severest effects of cold stress (hypothermia) and cold injury and to describe exposures to cold working conditions under which it is believed that nearly all workers can be repeatedly exposed without adverse health effects. The TLV objective is to prevent the deep body core temperature from falling below 36°C and to prevent cold injury to body extremities. Deep body temperature is the core temperature of the body as determined by rectal temperature measurements. For a single, occasional exposure to a cold environment a drop in core temperature of no lower than 35°C should be permitted. In addition to provisions for total body protection, the TLV objective is to protect all parts of the body with emphasis on hands, feet and head from cold injury.

Introduction to Cold Stress

Fatal exposures to cold among workmen have almost always resulted from accidental exposures involving failure to escape from low environmental air temperatures or from immersion in low temperature water. The single most important aspect of life-threatening hypothermia is the fall in the deep core temperature of the body. The clinical presentations of victims of hypothermia are shown in Table 15 (taken from Dembert in AFP, January 1982). Workmen should be protected from expoure to cold so that the deep core temperature does not fall below 36°C

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TABLE 15

Progressive Clinical Presentations of Hypothermia*

Core Temperature °C	Core Temperature °F	Clinical Signs
37.6	99.6	"Normal" rectal temperature
37	98.6	"Normal" oral temperature
36	96.8	Metabolic rate increases in an attempt to compensate for heat loss
35	95.0	Maximum shivering
34	93.2	Victim conscious and responsive, with normal blood pressure
33	91.4	Severe hypothermia below this temperature
32	89.6	Consciousness clouded; blood pressure becomes difficult to obtain; pupils dilated but react to light; shivering ceases
31	87.8	
30	86.0	Progressive loss of consciousness; muscular rigidity increases; pulse and blood pressure difficult to obtain; respiratory rate decreases
29	84.2	
28	82.4	Ventricular fibrillation possible with myocardial irritability
27	80.6	Voluntary motion ceases; pupils nonreactive to light; deep tendon and superficial reflexes absent
26	78.8	Victim seldom conscious
25	77.0	Ventricular fibrillation may occur spontaneously
24	75.2	Pulmonary edema
22	71.6	Maximum risk of ventricular fibrillation
21	69.8	
20	68.0	Cardiac standstill
18	64.4	Lowest accidental hypothermia victim to recover
17	62.6	Isoelectric electroencephalogram
9	48.2	Lowest artificially cooled hypothermia patient to recover

* Presentations approximately related to core temperature

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(96.8°F); lower body temperatures will very likely result in reduced mental alertness, reduction in rational decision making or loss of consciousness with the threat of fatal consequences.

Pain in the extremities may be the first early warning of danger to cold stress. During exposure to cold, maximum severe shivering develops when the body temperature has fallen to 35°C (95°F). This must be taken as a sign of danger to the workmen and exposure to cold should be immediately terminated for any workman when severe shivering becomes evident. Useful physical or mental work is limited when severe shivering occurs.

Since prolonged exposure to cold air, or to immersion in cold water, at temperatures well above freezing can lead to dangerous hypothermia, whole body protection must be provided.

1. Adequate insulating clothing to maintain core temperatures above 36°C must be provided to workers if work is performed in air temperatures below 4°C (40°F). Wind chill* or the cooling power of the air is a critical factor. The higher the wind speed and the lower the temperature in the work area, the greater the insulation value of the protective clothing required. An equivalent chill temperature chart relating the actual dry bulb air temperature and the wind velocity is presented in Table 16. The equivalent chill temperature should be used when estimating the combined cooling effect of wind and low air temperatures on exposed skin or when determining clothing insulation requirements to maintain the deep body core temperature.
2. Unless there are unusual or extenuating circumstances cold injury to other than hands, feet, and head is not likely to occur without the development of the initial signs of hypothermia. Older workers or workers with circulatory problems require special precautionary protection against cold injury. The use of extra insulating clothing and or a reduction in the duration of the exposure period are among the special precautions which should be considered. The precautionary actions to be taken will depend upon the physical condition of the worker and should be determined with the advice of a physician with knowledge of the cold

* Wind chill factor is a unit of heat loss from a body defined in watts per meter squared per hour being a function of the air temperature and wind velocity upon the exposed body

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TABLE 16

Cooling Power of Wind on Exposed Flesh Expressed as an Equivalent Temperature (under calm conditions)*

Estimated Wind Speed (in mph)	Actual Temperature Reading (°F)											
	50	40	30	20	10	0	−10	−20	−30	−40	−50	60
	Equivalent Chill Temperature (°F)											
calm	50	40	30	20	10	0	−10	−20	−30	−40	−50	60
5	48	37	27	16	6	−5	−15	−26	−36	−47	−57	−68
10	40	28	16	4	−9	−24	−33	−46	−58	−70	−83	−95
15	36	22	9	−5	−18	−32	−45	−58	−72	−85	−99	112
20	32	18	4	−10	−25	−39	−53	−67	−82	−96	−110	121
25	30	16	0	−15	−29	−44	−59	−74	−88	−104	−118	−133
30	28	13	−2	−18	−33	−48	−63	−79	−94	−109	−125	−140
35	27	11	−4	−20	−35	−51	−67	−82	−98	−113	129	145
40	26	10	6	−21	−37	−53	−69	−85	−100	−116	−132	148
(Wind speeds greater than 40 mph have little additional effect.)	LITTLE DANGER In < hr with dry skin. Maximum danger of false sense of security.			INCREASING DANGER Danger from freezing of exposed flesh within one minute.						GREAT DANGER Flesh may freeze within 30 seconds.		
	Trenchfoot and immersion foot may occur at any point on this chart											

*Developed by U S Army Research Institute of Environmental Medicine, Natick, MA

stress factors and the medical condition of the worker.

Evaluation and Control

For exposed skin, continuous exposure should not be permitted when the air speed and temperature results in an equivalent chill temperature of −32°C (−25°F). Superficial or deep local tissue freezing will occur only at temperatures below −1°C regardless of wind speed.

At air temperatures of 2°C (35.6°F) or less it is imperative that workers who become immersed in water or whose clothing becomes wet be immediately provided a change of clothing and be treated for hypothermia.

Recommended limits for properly clothed workers for periods of work at temperatures below freezing are shown in Table 17.

Special protection of the hands is required to maintain manual dexterity for the prevention of accidents:

1. If fine work is to be performed with bare hands for more than 10–20 minutes in an environment below 16°C (60°F), special provisions should be established for keeping the workers' hands warm. For this purpose, warm air jets, radiant heaters (fuel burner or electric radiator) or contact warm plates may be utilized. Metal handles of tools and control bars shall be covered by thermal insulating material at temperatures below −1°C (30°F).
2. If the air temperature falls below 16°C (60°F) for sedentary, 4°C (40°F) for light, −7°C (20°F) for moderate work and fine manual dexterity is not required then gloves shall be used by the workers.

To prevent contact frostbite, the workers should wear anti-contact gloves.

1. When cold surfaces below −7°C (20°F) are within reach, a warning should be given to each worker by his supervisor to prevent inadvertent contact by bare skin.
2. If the air temperature is −17.5°C (0°F) or less, the hands should be protected by mittens. Machine controls and tools for use in cold conditions should be designed so that they can be handled without removing the mittens.

Provisions for additional total body protection is required if work is performed in an environment at or below 4°C (40°F). The workers shall wear cold protec-

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TABLE 17

Work/Warm-up Schedule for Four-Hour Shift*

Air Temperature — Sunny Sky		No Noticeable Wind		5 mph Wind		10 mph Wind		15 mph Wind		20 mph Wind	
—°C (approx.)	—°F	Max. Work Period	No. of Breaks	Max. Work Period	No. of Breaks	Max. Work Period	No. of Breaks	Max. Work Period	No. of Breaks	Max. Work Period	No. of Breaks
1. -26°C to -28°C	15°F to 19°F	(Norm. breaks)	1	(Norm. breaks)	1	75 mins.	2	55 mins.	3	40 mins.	4
2. -29°C to -31°C	20°F to -24°F	(Norm. breaks)	1	75 mins.	2	55 mins.	3	40 mins.	4	30 mins.	5
3. -32°C to -34°C	-25°F to -29°F	75 mins.	2	55 mins.	3	40 mins.	4	30 mins.	5	Non-emergency work should cease	
4. -35°C to -37°C	-30°F to -34°F	55 mins.	3	40 mins.	4	30 mins.	5	Non-emergency work should cease			
5. -38°C to -39°C	-35°F to -39°F	40 mins.	4	30 mins.	5	Non-emergency work should cease					
6. -40°C to -42°C	-40°F to -44°F	30 mins.	5	Non-emergency work should cease							
7. -43°C & below	45°F & below	Non-emergency work should cease									

Notes for Table 17:

1. Schedule applies to moderate to heavy work activity with warm-up breaks of ten (10) minutes in a warm location. For Light-to-Moderate Work (limited physical movement): apply the schedule one step lower. For example, at 30°F with no noticeable wind (Step 4), a worker at a job with little physical movement should have a maximum work period of 40 minutes with 4 breaks in a 4-hour period (Step 5).

2. The following is suggested as a guide for estimating wind velocity. If accurate information is not available:

   5 mph: light flag moves; 10 mph: light flag fully extended; 15 mph: raises newspaper sheet; 20 mph: blowing and drifting snow.

3. If only the Wind Chill Factor is available, a rough rule of thumb for applying it rather than the temperature and wind velocity factors given above would be: 1) special warm-up breaks should be initiated at a wind chill of about 1750 W/m²/hr; 2) All non-emergency work should have ceased at or before a wind chill of 2250 W/m²/hr. In general the warm-up schedule provided above slightly under-compensates for the wind at the warmer temperatures, assuming acclimatization and clothing appropriate for winter work. On the other hand, the chart slightly over-compensates for the absolute temperatures in the colder ranges, since windy conditions rarely prevail at extremely low temperatures.

* From Occupational Health & Safety Division, Saskatchewan Dept of Labour

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tive clothing appropriate for the level of cold and physical activity

1. If the air velocity at the job site is increased by wind, draft, or artificial ventilating equipment, the cooling effect of the wind shall be reduced by shielding the work area, or by wearing an easily removable outer windbreak layer garment. Wind chill cooling rates are illustrated in Figure 10 and Table 18.
2. If only light work is involved and if the clothing on the worker may become wet on the job site, the outer layer of the clothing in use may be of a type impermeable to water. With more severe work under such conditions the outer layer should be water repellent, and the outerwear should be changed as it becomes wetted. The outer garments must include provisions for easy ventilation in order to prevent wetting of inner layers by sweat. If work is done at normal temperatures or in a hot environment before entering the cold area, the employee shall make sure that his clothing is not wet as a consequence of sweating. If his clothing is wet, the employee shall change into dry clothes before entering the cold area. The workers shall change socks and any removable felt insoles at regular daily intervals or use vapor barrier boots. The optimal frequency of change shall be determined empirically and will vary individually and according to the type of shoe worn and how much the individual's feet sweat.
3. If extremities, ears, toes and nose, cannot be protected sufficiently to prevent sensation of excessive cold or frostbite by handware, footwear and face masks, these protective items shall be supplied in auxiliary heated versions.
4. If the available clothing does not give adequate protection to prevent hypothermia or frostbite, work shall be modified or suspended until adequate clothing is made available or until weather conditions improve.
5. Workers handling evaporative liquid (gasoline, alcohol or cleaning fluids) at air temperatures below 40°F shall take special precautions to avoid soaking of clothing or gloves with the liquids because of the added danger of cold injury due to evaporative cooling. Special note should be taken of the particularly acute effects of splashes of "cryogenic fluids" or those liquids with a boiling point only just above ambient temperatures.

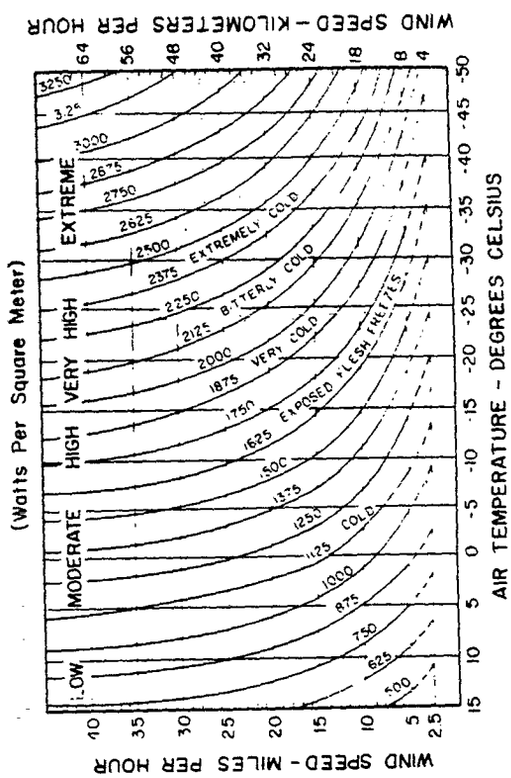


Figure 10 — Wind chill cooling rates. Adapted from Canadian Department of the Environment, Atmospheric Environment Service

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TABLE 18

Wind Chill Cooling Rate Effects*

Wind Chill Rates (Watts/m².hr)	Comments/Effects
700	Conditions considered comfortable when dressed for skiing.
1200	Conditions no longer pleasant for outdoor activities on overcast days.
1400	Conditions no longer pleasant for outdoor activities on sunny days.
1600	Freezing of exposed skin begins for most people depending on the degree of activity and the amount of sunshine.
2300	Conditions for outdoor travel such as walking become dangerous. Exposed areas of the face freeze in less than 1 minute for the average person.
2700	Exposed flesh will freeze within half a minute for the average person.

*From Canadian Department of the Environment, Atmospheric Environment Service.

Work-Warming Regimen

If work is performed continuously in the cold at an equivalent chill temperature (ECT) or below −7°C (20°F) heated warming shelters (tents, cabins, rest rooms, etc.) shall be made available nearby and the workers should be encouraged to use these shelters at regular intervals, the frequency depending on the severity of the environmental exposure. The onset of heavy shivering, frostnip, the feeling of excessive fatigue, drowsiness, irritability, or euphoria, are indications for immediate return to the shelter. When entering the heated shelter the outerlayer of clothing shall be removed and the remainder of the clothing loosened to permit sweat evaporation or a change of dry work clothing provided. A change of dry work clothing shall be provided as necessary to prevent workers from returning to their work with wet clothing. Dehydration, or the loss of body fluids occurs insidiously in the cold environment and may increase the susceptibility of the worker to cold injury due to a significant change in blood flow to the extremities. Warm sweet drinks and soups should be provided at

the work site to provide caloric intake and fluid volume. The intake of coffee should be limited because of a diuretic and circulatory effect.

For work practices at or below −12°C (10°F) ECT the following shall apply:

1. The worker shall be under constant protective observation (buddy system or supervision).
2. The work rate should not be so high as to cause heavy sweating that will result in wet clothing. If heavy work must be done, rest periods must be taken in heated shelters and opportunity for changing into dry clothing shall be provided.
3. New employees shall not be required to work full-time in cold in the first days until they become accustomed to the working conditions and required protective clothing.
4. The weight and bulkiness of clothing shall be included in estimating the required work performance and weights to be lifted by the worker.
5. The work shall be arranged in such a way that sitting still or standing still for long periods is minimized. Unprotected metal chair seats shall not be used. The worker should be protected from drafts to the greatest extent possible.
6. The workers shall be instructed in safety and health procedures. The training program shall include as a minimum instruction in:
   a. Proper rewarming procedures and appropriate first aid treatment.
   b. Proper clothing practices.
   c. Proper eating and drinking habits.
   d. Recognition of impending frostbite.
   e. Recognition signs and symptoms of impending hypothermia or excessive cooling of the body even when shivering does not occur.
   f. Safe work practices.

Special Workplace Recommendations

Special design requirements for refrigerator rooms include the following:

1. In refrigerator rooms, the air velocity should be minimized as much as possible and should not exceed 1 meter/sec (200 fpm) at the job site. This can be achieved by properly designed air distribution systems.

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2. Special wind protective clothing shall be provided based upon existing air velocities to which workers are exposed.

Special caution shall be excercised when working with toxic substances and when workers are exposed to vibration. Cold exposure may require reduced exposure limits.

Eye protection for workers employed out-of-doors in a snow and/or ice-covered terrain shall be supplied. Special safety goggles to protect against ultraviolet light and glare (which can produce temporary conjuntivitis and/or temporary loss of vision) and blowing ice crystals are required when there is an expanse of snow coverage causing a potential eye exposure hazard.

Workplace monitoring is required as follows:

1. Suitable thermometry should be arranged at any workplace where the environmental temperature is below 16°C (60°F) to enable overall compliance with the requirements of the TLV to be maintained.
2. Whenever the air temperature at a workplace falls below −1°C (30°F), the dry bulb temperature should be measured and recorded at least every 4 hours.
3. In indoor workplaces, the wind speed should also be recorded at least every 4 hours whenever the rate of air movement exceeds 2 meters per second (5 mph).
4. In outdoor work situations, the windspeed should be measured and recorded together with the air temperature whenever the air temperature is below −1°C (30°F).
5. The equivalent chill temperature shall be obtained from Table 16 in all cases where air movement measurements are required, and shall be recorded with the other data whenever the equivalent chill temperature is below −7°C (20°F).

Employees shall be excluded from work in cold at −1°C (30°F) or below if they are suffering from diseases or taking medication which interferes with normal body temperature regulation or reduces tolerance to work in cold environments. Workers who are routinely exposed to temperatures below −24°C (−10°F) with wind speeds less than five miles per hour, or air temperatures below −18°C (0°F) with wind speeds above five miles per hour should be medically certified as suitable for such exposures.

Trauma sustained in freezing or subzero conditions requires special attention because an injured worker is predisposed to secondary cold injury. Special provisions must be made to prevent hypothermia and secondary freezing of damaged tissues in addition to providing for first aid treatment.

HAND-ARM (SEGMENTAL) VIBRATION

These threshold limit values (Table 19) refer to component accelerations levels and durations of exposure that represent conditions under which it is believed that most workers may be exposed repeatedly without progressing beyond Stage 3 of the Taylor-Pelmear Classification System for Vibration-Induced White Finger (VWF, also known as Raynaud's Phenomenon of Occupational Origin). Since there is a paucity of dose-response relationships for VWF, these recommendations have been derived from epidemiological data from forestry, mining, and metal working. These values should be used as guides in the control of hand-arm vibration exposure and because of individual susceptibility, should not be regarded as defining a boundry between safe and dangerous levels.

It should be recognized that the application of the TLV alone for hand-arm vibration will not protect all workers from the adverse effects of hand-arm vibration exposure. The use of: 1) antivibration tools, 2) antivibration gloves, 3) proper work practices which keep the worker's hands and remaining body warm and also minimize the vibration coupling between the worker and the vibration tool are necessary to minimize vibration exposure, and 4) a conscienciously applied medical surveillance program are ALL necessary to rid VWF from the workplace.

Continuous, Intermittent, Impulsive, or Impact Hand-arm Vibration

The measurement of vibration should be performed in accordance with the procedures and instrumentation specified by the Second Draft International Standard ISO/DIS 5349 (1984), *Guide for the Measurement and the Assessment of Human Exposure to Vibration Transmitted to the Hand*, and summarized below:

The acceleration of a vibration handle or work piece should be determined in three mutually orthogonal directions at a point close to where vibration enters the hand. The directions shall preferably be

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those forming the ISO biodynamic coordinate system, but may be a closely related basicentric system with its origin at the interface between the hand and the vibrating surface (see Figure 11) to accommodate different handles or work piece configurations. A small and lightweight transducer shall be mounted so as to record accurately one or more orthogonal components of the source vibration in the frequency range from 5 to 1500 Hz. Each component should be frequency-weighted by a filter network with gain characteristics specified by the ISO for human-response vibration measuring instrumentation, to account for the change in vibration hazard with frequency (see Figure 12).

Assessment of vibration exposure should be made for EACH applicable direction (X_h, Y_h, Z_h) since vibration is a vector quantity (magnitude and direction). In each direction, the magnitude of the vibration during normal operation of the power tool, machine or work piece shall be expressed by the root-mean-square (rms) value of the frequency-weighted component accelerations, in units of meters per second squared (m/s^2), or gravitational units (g), the largest of which, a_h, forms the basis for exposure assessment.

For each direction being measured, linear integration shall be employed for vibrations that are of extremely short duration or vary substantially in time. If the total daily vibration exposure in a given direction is composed of several exposures at different rms accelerations, then the equivalent, frequency-weighted component acceleration in that direction shall be determined in accordance with the following equation:

$$(a_{h_{eq}}) = \left[\frac{1}{T}\sum_{i=1}^{n}(a_{h_i})^2 T_i\right]^{1/2}$$

$$= \sqrt{(a_{h_1})^2\frac{T_1}{T} + (a_{h_2})^2\frac{T_2}{T} + \cdots (a_{h_n})^2\frac{T_n}{T}}$$

where: $T = \sum_{i=1}^{n} T_i$

T = total daily exposure duration

a_h = ith frequency-weighted, rms acceleration component with duration T_i.

These computations may be performed by commercially available human-response vibration measuring instruments.

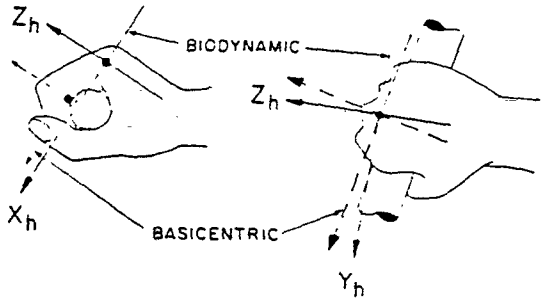


Figure 11 — Biodynamic and basicentric coordinate systems for the hand, showing the directions of the acceleration components (ISO 5349).

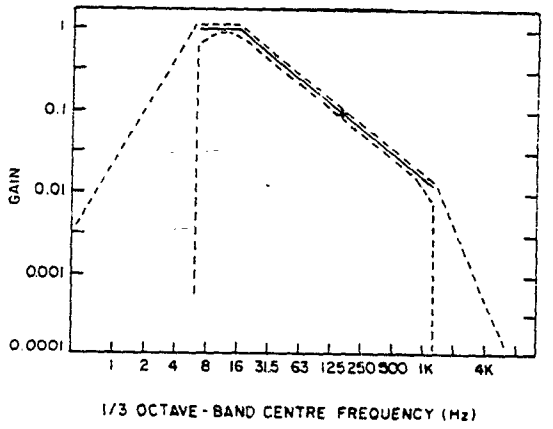


Figure 12 — Gain characteristics of the filter network used to frequency-weight acceleration components (continuous line). The filter tolerances (dashed lines) are provisional, and are those contained in ISO 5349.

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TABLE 19

Threshold Limit Values for Exposure of the Hand to Vibration in Either X_h, Y_h, Z_h Directions

Total Daily Exposure Duration*	Values of the Dominant,† Frequency-Weighted, rms, Component Acceleration Which Shall not be exceeded** a_h,($a_{h_{eq}}$)	
	m/s²	g
4 hours and less than 8	4	0.40
2 hours and less than 4	6	0.61
1 hour and less than 2	8	0.81
Less than 1 hour	12	1.22

*The total time vibration enters the hand per day, whether continuously or intermittently.

†Usually one axis of vibration is dominant over the remaining two axis if one or more vibration axis exceeds the Total Daily Exposure then the TLV has been exceeded

**1 g = 9.81 m·s²

Notes: Table 19:

1. Hardly any person exposed at or below the TLVs for vibration contained in Table 19 has progressed to *Stage 3* Vibration White Finger, in the Taylor-Pelmear classification, i.e., the point at which extensive blanching of all fingers has occurred and there is definite interference at work, home, and restricted social activities.[2-7]
2. Acute exposures to frequency-weighted, rms, component accelerations in excess of the TLVs for infrequent periods of time (e.g., 1 day per week, or several days over a two-week period) are not necessarily more harmful.[2-4]
3. Acute exposures to frequency-weighted, rms, component accelerations of three times the magnitude of the TLVs are expected to result in the same health effects after between 5 and 6 years of exposure.[2-4]
4. Preventive measures, including specialized preemployment and annual medical examinations to identify persons susceptible to vibration, should be implemented in situations in which workers are or will be exposed to hand-arm vibration.[3-7]

5. To moderate the adverse effects of vibration exposure, workers should be advised to avoid *continuous* vibration exposure by cessation of vibration exposure for approximately 10 minutes per continuous vibration hour.
6. Good work practices should be used, and should include instructing workers to employ a minimum hand grip force consistent with safe operation of the power tool or process, keep their body and hands warm and dry, and avoid smoking.[2,3]
7. A transducer and its device for attachment to the vibrating source suitable for measurement purposes together should weigh less than 15 grams, and should possess a cross-axis sensitivity of less than 10%.
8. The measurement by many (mechanically underdamped) piezoelectric accelerometers of repetitive, large displacement, impulsive vibrations, such as those produced by percussive pneumatic tools, is subject to error. The insertion of a suitable, low-pass, mechanical filter between the accelerometer and the source of vibration with a cut-off frequency of 1500 Hz or greater (and cross-axis sensitivity of less than 10%) can help eliminate incorrect readings.[3,4]
9. The manufacturer and type number of all apparatus used to measure vibration should be reported, as well as the value of the dominant direction and frequency-weighted, rms, component acceleration.

References:

1. **Pyykko I.:** Vibration Syndrome A Review *Vibration and Work* pp 124 O Dorhonen, Ed Institute of Occupational Health: Helsinki (1976)
2. *Vibration White Finger in Industry*, W Taylor and P L Pelmear, Eds Academic Press, London (1975)
3. **NIOSH:** *Proceedings of the International Occupational Hand-Arm Vibration Conference* D E Wasserman and W Taylor, Eds DHEW NIOSH Pub No 77-170 (1977)
4. **Brammer, J. J.:** Threshold Limit for Hand-Arm Vibration Exposure Throughout the Workday *Vibration Effects on the Hand and Arm in Industry*, pp 291-301, A J Brammer and W Taylor Eds John Wiley & Sons New York (1982)
5. **Wasserman, D. E. and W. Taylor:** *Environmental and Occupational Medicine*, Chap 68, *Occupational Vibration*, pp 743-749 W N Rom Ed Little, Brown and Co , Boston (1982)
6. **NIOSH:** *Current Intelligence Bulletin #38, Vibration Syndrome*, DHHS (NIOSH) Pub No 83-110 (1983)
7. **NIOSH:** *Vibration Syndrome* NIOSH Videotape #177 (27 minutes) Cincinnati, OH.

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8. **International Organization for Standardization:** *Guide for the Measurement and the Assessment of Human Exposure to Vibration Transmitted to the Hand.* Second DIS 5349. International Organization for Standardization, Geneva (in press, 1983).
9. **International Organization for Standardization:** *Human-Response Vibration Measuring Instrumentation.* Second Draft Proposal DP 8041. ISO TC 108/SC 3 n 99. International Organization for Standardization, Geneva (unpublished, 1982).

PHYSICAL AGENTS UNDER STUDY

The Physical Agents Committee of ACGIH has examined the current literature and has not found sufficient information to propose a TLV. However, these agents will remain under study during the coming year to examine new evidence indicating the need and feasibility for establishing a proposed TLV. Comments and suggestions, accompanied by substantive documentation are solicited and should be forwarded to the Executive Secretary, ACGIH. Documentation summarizing the current status of the biological effects literature is available on those agents preceded by an asterisk (*).

1. **Extremely Low Frequency (ELF) Radiation*.* Specifically, that portion of the spectrum from 0 to 300 Hz.
2. *Magnetic Fields*. Both pulsed and *continuous.
3. *Laser Radiation*. Specifically laser exposures of less than one (1) nanosecond.
4. *Vibration*. Whole-body.
5. *Pressure Variations.*

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AIHA WEEL GUIDES - 1985

Agent	8-Hr TWA	Short-Term TWA
Benzaldehyde	2 ppm	4 ppm, 15 min
Bis-(2-chloroiso-propyl) ether	3 ppm	--
Chlorosulfonic acid	0.3 ppm	--
Decabromodiphenyl oxide	5 mg/m	--
Diethylene glycol	50 ppm, total 10 mg/m^3, aerosol only	--
Diisobutylene	600 ppm	--
Dimethyl ether	500 ppm	--
Dimethyl terephthalate	10 mg/m^3, total 5 mg/m^3, respirable	--
Erythromycin	3 mg/m^3	--
Hexadiene	100 ppm	--
Hexandiol diacrylate	1 mg/m^3	--
Lithium hydroxide	--	1 mg/m^3, 1 min
Lithium oxide	--	1 mg/m^3, 1 min
3-Methoxypropylamine	10 ppm	20 ppm, 15 min
Monochloroacetic acid	0.3 ppm, skin	1 ppm, 15 min
Pentaerythritol triacrylate	1 mg/m^3	--
Piperidine	1 ppm	--
Polyethylene glycols	10 mg/m^3	--
Polypropylene glycols	10 mg/m^3	--
Potassium bromate	0.1 mg/m^3	--
Propylene glycol	50 ppm, total 10 mg/m^3, aerosol only	--
Quinoline	0.1 ppm, skin	--
Tetraethyleneglycol Diacrylate	1 mg/m^3	--
p-Toluene sulfonyl chloride	--	5 mg/m^3, 15 min
Triethyleneglycol diacrylate	1 mg/m^3	--
Trimethylamine	1 ppm	--
Trimethylolpropane triacrylate	1 mg/m^3	--
Trimethylolpropane trimethylacrylate	1 mg/m^3	--
Trisodium phosphate	--	5 mg/m^3, 15 min

WEELs

Workplace Environmental Exposure Level Guides (WEELs) are developed by the AIHA WEEL Committee for agents which have no current exposure guidelines established by other organizations. They represent the workplace exposure levels to which, it is believed, nearly all employees could be repeatedly exposed without adverse effects. All WEELs are expressed as time-weighted average concentrations, however, different time periods are specified depending on the properties of the agent

An 8-hr TWA indicates a time-weighted average concentration for a normal 8-hr workday and 40-hr workweek. When it is believed that excursion levels should be more limited, a one to 30 minute TWA may be recommended — either in conjunction with, or in place of an 8-hr TWA value. The time specified is relevant to exposure, not necessarily to sampling

The word "skin" indicates that the material may be absorbed through the skin. Therefore, skin contact can contribute to the overall exposure and invalidate the TWA exposure evaluations

Candidate WEELs

The following materials are currently undergoing study for future WEELs Guides. Information and comments are welcome, as are suggestions of other materials for study. If you have any input on candidate or completed WEELs, contact M. G. Swank, Dow Chemical U.S.A., 1803 Building, Midland, Michigan 48640, 517/636-3976

Acetophenone	Isocyanuric acid
Amyl alcohol	2-Mercaptobenzothiazole
Bisphenol A	n-Methylpyrrolidone
Chloramphenicol	Octanol
Dichloropropanols	Picolines
3,3-Dimethoxybenzidine	Toluenediamine
Dimethyl sulfide	Triethylenetetramine
Dipropylene glycol	Tripropylene glycol
Hexamethylenediamine	Urea
n-Hexyl alcohol	Vinyl cyclohexene

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COPIES

Documentations for completed WEEL Guides summarize the available toxicology and human experience information. Copies can be ordered from AIHA, 475 Wolf Ledges Parkway, Akron, OH 44311 for $2.00 each Binder $5.00

April, 1985

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