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TLVs®
Threshold Limit Values
for
Chemical Substances
and
Physical Agents
in the
Workroom Environment
with
Intended Changes
for
1981

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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.

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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ACGIH
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TLVs®
Threshold Limit Values for Chemical Substances in Workroom Air Adopted by ACGIH for 1981

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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 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.

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 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 (e.g., employees of a single plant) are known to have potential exposure to possibly harmful concentrations.

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.

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,				

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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.

SC 008255

LAM009465

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	—	—

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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	—	—

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Footnotes (a thru f) see Page 32.
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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 (Dichlorodipheny!-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.

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	—	—
Dichlorotetrafluoro-ethane	1,000	7,000	1,250	8,750

Capital letters refer to Appendices.
Footnotes (a thru f) see Page 32.
*1981 Addition.

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				

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*1981 Addition.

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	—	—	—

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*1981 Addition.

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

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*1981 Addition.
**See Notice of Intended Changes.
Footnotes (a thru f) see Page 32.

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				

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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

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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				

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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 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)

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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 — 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				

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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				

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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
Sudium 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

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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®	—	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, 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.
**See Notice of Intended Changes.
m) See Page 35.

Capital letters refer to Appendices.
Footnotes (a thru f) see Page 32.
*1981 Addition.
**See Notice of Intended Changes.

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.

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[g]:

$$\frac{300^{h}}{\%\ \text{quartz} + 10}$$

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[g])

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

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.

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.

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.

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.

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	

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.

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.

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 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/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.

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.

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

B2 *Gasoline*. See Notice of Intended Change.

B3 *Welding Fumes — Total Particulate (NOC)***
TLV, 5 *mg/m*^{3}

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/m^3. 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,

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

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.

**Not otherwise classified (NOC).

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/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:

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

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)
Gypsum	Pentaerythritol
Vegetable oil mists (except castor, cashew nut, or similar irritant oils)	Plaster of Paris
	Silicon
	Silicon Carbide
	Starch
Kaolin	Sucrose
Limestone	**Tin Oxide
Magnesite	Titanium Dioxide
Marble	Zinc Stearate
Mineral Wool Fiber	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. 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.

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 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 $\times$ 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. $\times$ 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 $\times$ 10^6 part./m³
   wt. of 1 mppcf $\equiv$ 35.5 $\times$ 10^6 part./m³ $\times$ 4.425 $\times$ 10^{-9} mg/part.
   1 mppcf $\equiv$ 0.157 mg/m³
   or
   6.37 mppcf $\equiv$ 1 mg/m³
   or approximately 6 mpccf $\equiv$ 1 mg/m³.

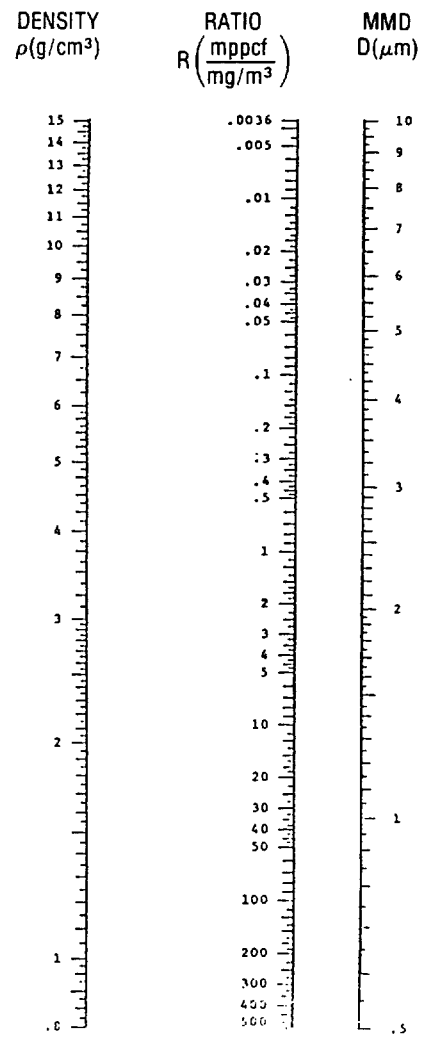

Figure 1 — Ratio of Particle Count — mppcf to Respirable Mass Concentration — mg/m³ (as function of density and mmd)†

†Prepared by P. E. Caplan and R. J. Smith

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 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

TLVs®
Threshold Limit Values
for
Physical Agents
Adopted by
ACGIH
for 1981

SC 008277

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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.

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 = 0.7 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.

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-

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.

(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.

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:

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

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 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

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.

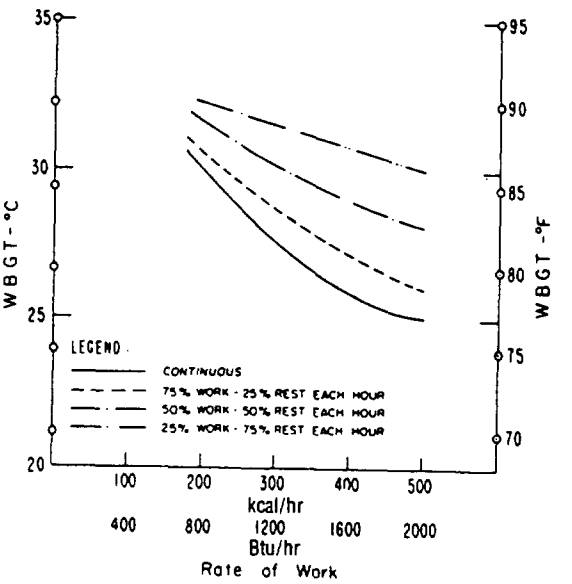

Figure 1 — Permissible Heat Exposure Threshold Limit Value

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-

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)

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.

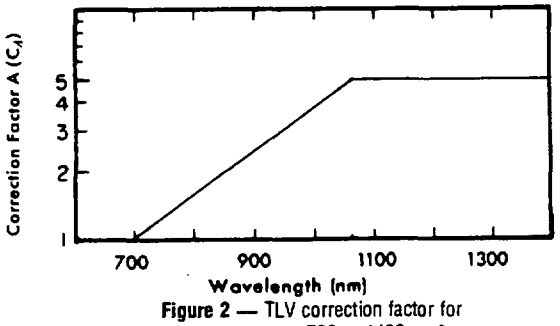

Figure 2 — TLV correction factor for $\lambda = 700 - 1400$ nm*

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

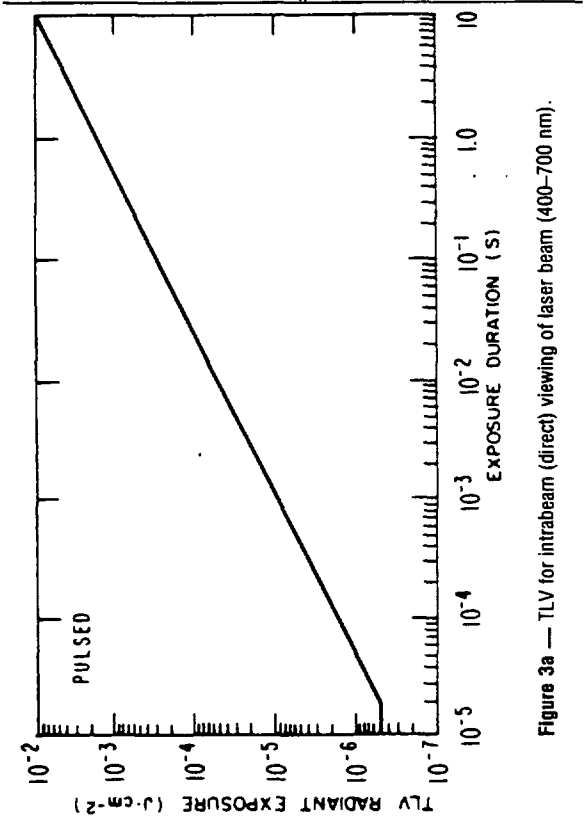

Figure 3a — TLV for intrabeam (direct) viewing of laser beam (400–700 nm).

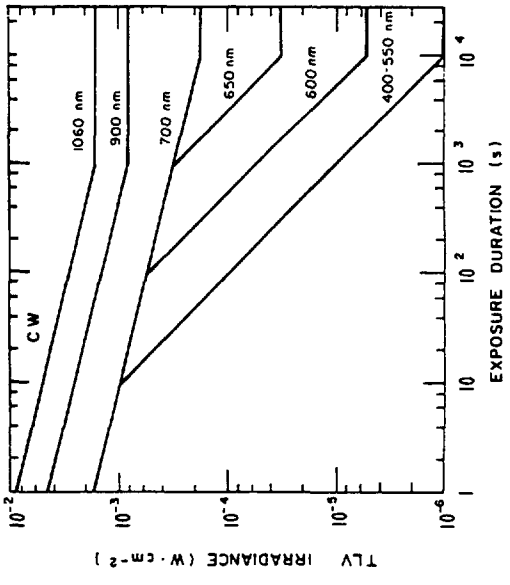

Figure 3b — TLV for intrabeam (direct) viewing of CW laser beam (400–1400 nm)

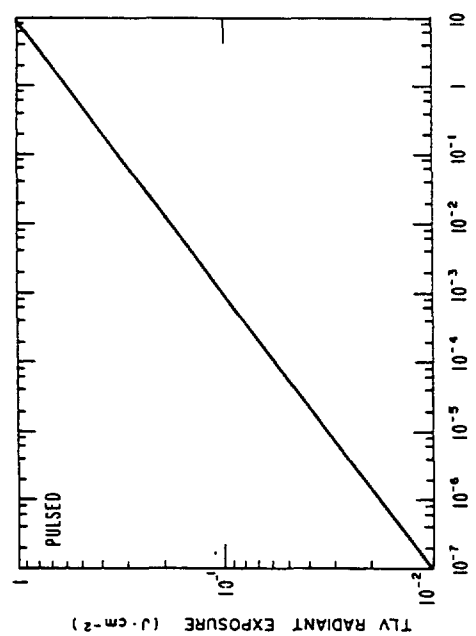

Figure 4a — TLV for laser exposure of skin and eyes for far-infrared radiation (wave-lengths greater than 1.4 μm).

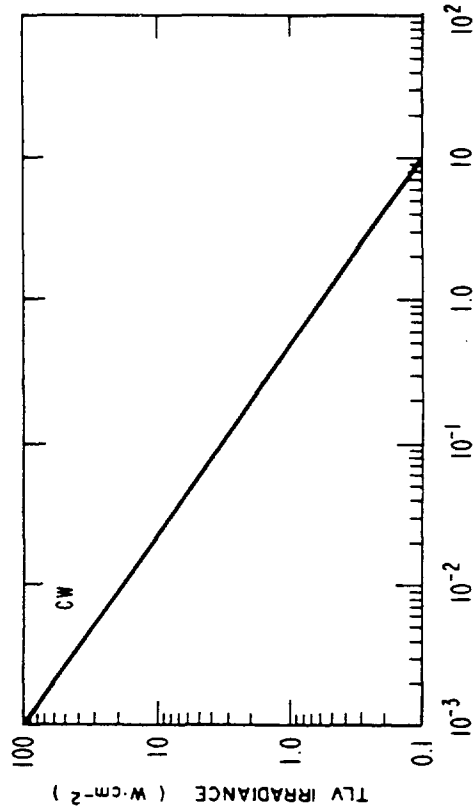

Figure 4b — TLV for CW laser exposure of skin and eyes for far-infrared radiation (wavelengths greater than 1.4 μm).

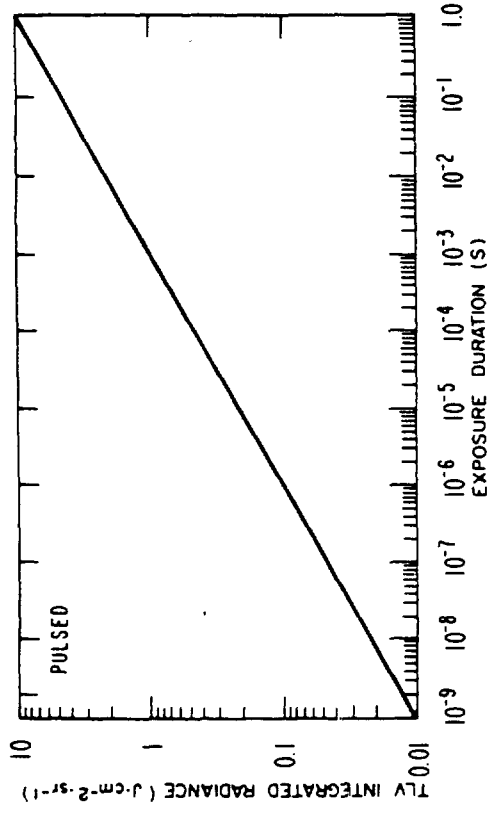

Figure 5a — TLV for extended sources or diffuse reflections of laser radiation (400–700 nm).

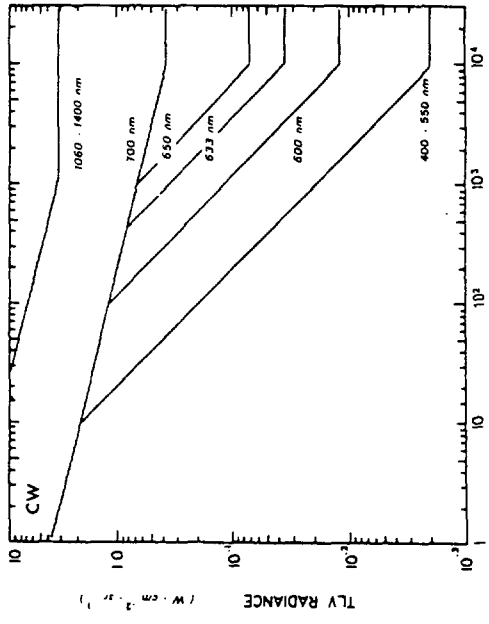

Figure 5b — TLV for extended sources or diffuse reflections of laser radiation (400–1400 nm).

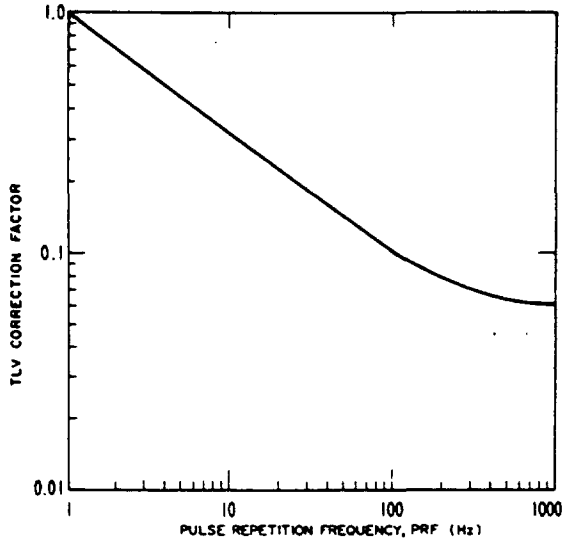

Figure 6 — Multiplicative correction factor for repetitively pulsed lasers having pulse durations less than 10^{-5} second. TLV for a single pulse of the pulse train is multiplied by the above correction factor. Correction factor for PRF greater than 1000 Hz is 0.06.

TABLE 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}	*not to exceed 0.56 $t^{1/4}$ J • cm^{-2} for $t \leq 10$ s.
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 "	

†1981 Addition

TABLE 3 (Cont.)

UVA	315 nm to 400 nm	10^{-9} to 10	.56 $t^{¼}$ 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.

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_Bt $\times 10^{-3}$ 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.
†1981 Addition

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^{-9} to 3×10^{4}	Same as Table 3
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	$1.1\ C_A \sqrt{t}$ 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

**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.
**See Notice of Intended Changes.

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:

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

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.

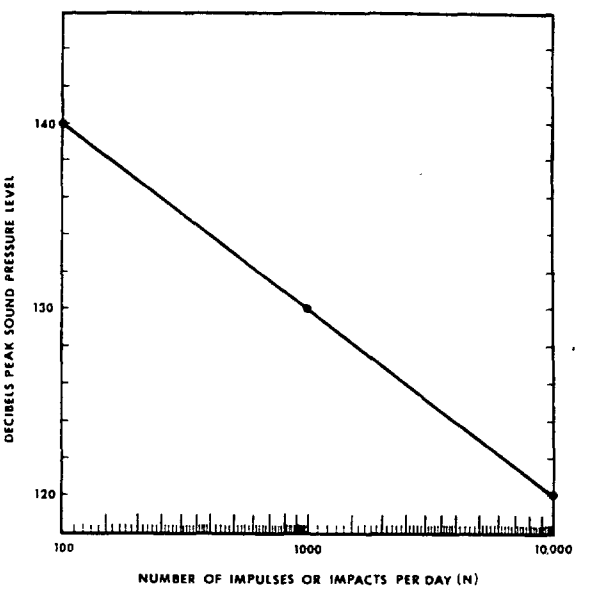

Figure 7 — Threshold Limit Values for Impulse/Impact Noise.

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

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

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.

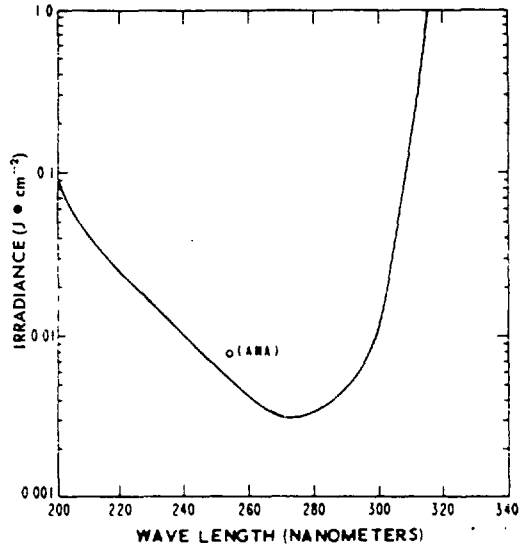

Figure 8 — Threshold Limit Values for Ultraviolet Radiation

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.

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:

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

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 cf 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:

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

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

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) $k_2 = 1\ W \bullet rad/(cm^2 \bullet sr)$.

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 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

equivalent plane wave power density can be calculated from the field strength measurement data as follows:

$$\text{PD in mW/cm}^2 = \frac{E^2}{3700}$$

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, 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/cm^2)†	Electric Field Strength Squared (V^2/m^2)	Magnetic Field Strength Squared (A^2/m^2)
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/cm^2 = milliwatts per centimeter squared
*f = frequency in MHz

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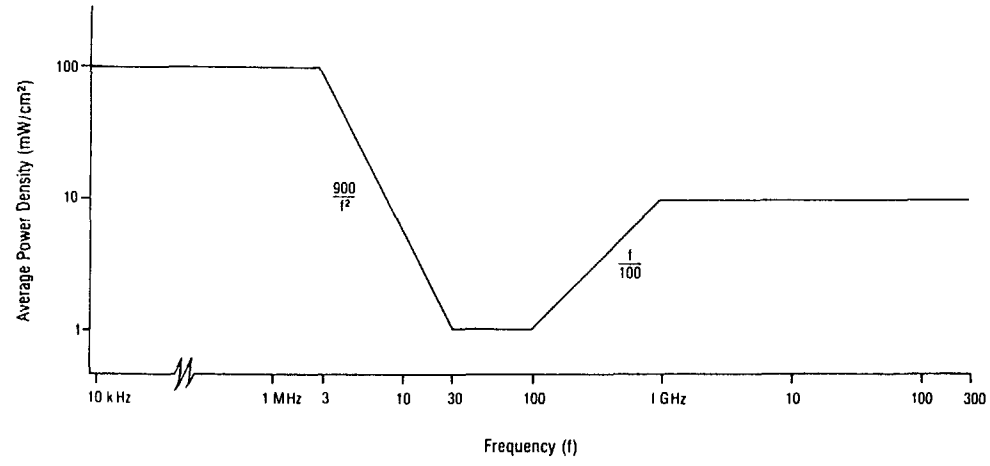

Figure 9 — Threshold Limit Values (TLV) for Radiofrequency/Microwave Radiation in Workplace (Whole Body SAR Less Than 0.4 W/kg).

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*.