TLVs®

THRESHOLD LIMIT VALUES and BIOLOGICAL EXPOSURE INDICES for 1985-86

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of Governmental
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New material or revisions for 1985-86: *Chemical Substances:* 1) Redefinition of Ceiling Limit in the Introduction; 2) Proposed removal of an additional 50 STELs—the substances involved are listed in the section following the traditional table under the Notice of Intended Changes; 3) Notice of Intent to Change the definition of Appendix A. *Biological Exposure Indices:* Proposal of BEIs for benzene, n-hexane, lead, and phenol. *Physical Agents:* 1) Notice of Intent to Change Repetitively Pulsed Lasers; 2) Modification in the proposed footnote to Table 6.

The limits listed in this book are intended for use in the practice of industrial hygiene as guidelines or recommendations in the control of potential health hazards and for no other use. These limits *are not* fine lines between safe and dangerous concentration and *should not* be used by anyone untrained in the discipline of industrial hygiene. It is imperative that the user of this book read the introduction to each section before applying the recommendations contained herein as this is an integral part to the understanding and use of this book. The ACGIH disclaims liabilty with respect to the use of the TLVs in a manner inconsistent with their intended use.

Interpretation of TLVs: All requests for interpretations of TLVs must be in writing, in care of the Executive Secretary ACGIH. Interpretations will be made only after full committee review and approval. Interpretations will be published annually in the *Annals of ACGIH,* the volume which covers the annual meeting.

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 better understanding of the TLVs it is essential that the Documentation be consulted when the TLVs are being used. For further information contact the Publications Office, ACGIH.

Requests for interpretations, reproduction permission, information, and/or placement of an order may use the following address: ACGIH, 6500 Glenway Ave., Bldg. D-7, Cincinnati, OH 45211; 513/661-7881.

TLVs®

Threshold Limit Values for Chemical Substances in the Work Environment Adopted by ACGIH with Intended Changes for 1985-86

1984-85 CHEMICAL SUBSTANCES TLV COMMITTEE

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INTRODUCTION TO THE CHEMICAL SUBSTANCES

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

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

The amount and nature of the information available for establishing a TLV varies from substance to substance; consequently, the precision of the estimated TLV is also subject to variation and the latest *Documentation* should be consulted in order to assess the extent of the data available for a given substance.

These limits are intended for use in the practice of industrial hygiene as guidelines or recommendations in the control of potential health hazards and for no other use, e.g., in the evaluation or control of community air pollution nuisances, in estimating the toxic potential of continuous, uninterrupted exposures or other extended work periods, as proof or disproof of an existing disease or physical condition, or adoption by countries whose working conditions differ from those in the United States of America and where substances and processes differ. These limits *are not* fine lines between safe and dangerous concentration and *should not* be used by anyone untrained in the discipline of industrial hygiene.

The Threshold Limit Values, as issued by ACGIH, are recommendations and should be used as guidelines for good practices. 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.

The ACGIH disclaims liability with respect to the use of TLVs in a manner inconsistent with their intended use as stated herein.

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

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

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

b) *Threshold Limit Value-Short Term Exposure Limit (TLV-STEL)*—the concentration to which workers can be exposed continuously for a short period of time without suffering from 1) irritation, 2) chronic or irreversible tissue damage, or 3) narcosis of sufficient degree to increase the likelihood of accidental injury, impair self-rescue or materially reduce work efficiency, and provided that the daily TLV-TWA is not exceeded. It is not a separate independent exposure limit, rather it supplements the time-weighted average (TWA) limit where there are recognized acute effects from a substance whose toxic effects are primarily of a chronic nature. STELs are recommended only where toxic effects have been reported from high short-term exposures in either humans or animals.

A STEL is defined as a 15-minute time-weighted average exposure which should not be exceeded at any time during a work day even if the eight-hour time-weighted average is within the TLV. Exposures at the STEL should not be longer than 15 minutes and should not be repeated more than four times per day. There should be at least 60 minutes between successive exposures at the STEL. An averaging period other than 15 minutes may be recommended when this is warranted by observed biological effects.

c) *Threshold Limit Value-Ceiling (TLV-C)*—the concentration that should not be exceeded during any part of the working exposure.

Conventional industrial hygiene practice in the assessment of a TLV-C is to sample over a 15-minute period except for those substances which may cause immediate irritation with exceedingly short exposures.

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. Sustances with this type of response are best controlled by a ceiling "C" limit that should not be exceeded. It is implicit in these definitions that the manner of sampling to determine noncompliance with the limits for each group must differ; a single brief sample, that is applicable to a "C" limit, is not appropriate to the time-weighted limit; here, a sufficient number of samples are needed to permit a time-weighted average concentration throughout a complete cycle of operations or throughout the work shift.

Whereas the ceiling limit places a definite boundary which concentrations should not be permitted to exceed, the time-weighted average limit requires an explicit limit to the excursions that are permissible above the listed values. It should be noted that the same factors are used by the Committee in determining the magnitude of the value of the STELs, or whether to include or exclude a substance for a "C" listing.

Excursion Limits. For the vast majority of substances with a TLV-TWA, there is not enough toxicological data available to warrant a STEL. Nevertheless, excursions above the TLV-TWA should be controlled even where the eight-hour TWA is within recommended limits. Earlier editions of the TLV list included such limits whose values depended on the TLV-TWAs of the substance in question.

While no rigorous rationale was provided for these particular values, the basic concept was intuitive: in a well controlled process exposure, excursions should be held within some reasonable limits. Unfortunately, neither toxicology nor collective industrial hygiene experience provide a solid basis for quantifying what those limits should be. The approach here is that the maximum recommended

excursion should be related to variability generally observed in actual industrial processes. Leidel, Busch and Crouse,* in reviewing large numbers of industrial hygiene surveys conducted by NIOSH, found that short-term exposure measurements were generally log normally distributed with geometric standard deviation mostly in the range of 1.5 to 2.0.

While a complete discussion of the theory and properties of the log normal distribution is beyond the scope of this section, a brief description of some important terms is presented. The measure of central tendency in a log normal description is the antilog of the mean logarithm of the sample values. The distribution is skewed and the geometric mean is always smaller than the arithmetic mean by an amount which depends on the geometric standard deviation. In the log normal distribution, the geometric standard deviation (sd_g) is the antilog of the standard deviation of the sample value logarithms and 68.26% of all values lie between m_g/sd_g and $m_g \times sd_g$.

If the short-term exposure values in a given situation have a geometric standard deviation of 2.0, 5% of all values exceed 3.13 times the geometric mean. If a process displays a variability greater than this, it is not under good control and efforts should be made to restore control. This concept is the basis for the new excursion limit recommendations which are as follows:

> *Short-term exposures should exceed three times the TLV-TWA for no more than a total of 30 minutes during a work day and under no circumstances should they exceed five times the TLV-TWA, provided that the TLV-TWA is not exceeded.*

The approach is a considerable simplification of the idea of the log normal concentration distribution but is considered more convenient to use by the practicing industrial hygienist. If exposure excursions are maintained within the recommended limits, the geometric standard deviation of the concentration measurements will be near 2.0 and the goal of the recommendations will be accomplished.

When the toxicological data for a specific substance are available to establish a STEL, this value takes precedence over the excursion limit regardless of whether it is more or less stringent.

"Skin" Notation. Listed substances followed by the designation "Skin" refer to the potential contribution to the overall exposure by the cutaneous route including mucous membranes and eye, either by airborne, or more particularly, by direct contact with the substance. Vehicles can alter skin absorption.

Little quantitative data are available describing absorption of vapors and gases through the skin. The rate of absorption is a function of the concentration to which the skin is exposed.

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* Leidel, N.A., K.A. Busch and W.E. Crouse: *Exposure Measurement, Action Level and Occupational Environmental Variability.* NIOSH Pub. No. 76-131 (December 1975).

Substances having a skin notation and a low TLV may present a problem at high airborne concentrations, particularly if a significant area of the skin is exposed for a long period of time. Protection of the respiratory tract, while the rest of the body surface is exposed to a high concentration, may present such a situation.

Biological monitoring should be considered to determine the relative contribution of dermal exposure to the total dose.

This attention-calling designation is intended to suggest appropriate measures for the prevention of cutaneous absorption so that the threshold limit is not invalidated.

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

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

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. This list is not meant to be all inclusive; the substances serve only as examples.

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.

Hypersusceptibility. 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 contaimnant, 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.

Trade names. Because many chemical substances are marketed under several trade names, the trade names have been replaced with their generic equivalent in the alphabetical listing. Appendix H was created to ease this transition and the CAS number appears with the generic name to aid identification.

Operational Guidelines. The ACGIH Board of Directors has adopted operational guidelines for Chemical Substances TLV Committee. These guidelines prescribe: charge, authority, policies, membership, organization, and operating procedures. The policies

include the appeals procedures. Copies of the guidelines document are available from the Publications Office at a cost of $5 per copy.

NOTE: In the interest of keeping this book as small as possible, the footnotes for the adopted values appear on right hand pages only.

Substance	ADOPTED VALUES TWA ppm[a]	TWA mg/m³[b]	ADOPTED VALUES STEL ppm[a]	STEL mg/m³[b]
Acetaldehyde [75-07-0]	100	180	150	270
Acetic acid [64-19-7]	10	25	15	37
Acetic anhydride [108-24-7]	C 5	C 20	—	—
Acetone [67-64-1]	750	1,780	1,000	2,375
Acetonitrile [75-05-8] — Skin	40	70	60	105
Acetylene [74-86-2]	E	—	—	—
Acetylene dichloride, *see* 1,2-Dichloroethylene				
‡Acetylene tetrabromide [79-27-6]	1	15	(1.5)	(20)
Acetylsalicylic acid (Aspirin) [50-78-2]	—	5	—	—
Acrolein [107-02-8]	0.1	0.25	0.3	0.8
‡Acrylamide [79-06-1] — Skin	—	(0.3)	—	(0.6)
Acrylic acid [79-10-7]	10	30	—	—
Acrylonitrile [107-13-1] — Skin	2,A2	4.5,A2	—	—
‡Aldrin [309-00-2] — Skin	—	0.25	—	(0.75)
Allyl alcohol [107-18-6] — Skin	2	5	4	10
Allyl chloride [107-5-1]	1	3	2	6
Allyl glycidyl ether (AGE) [106-92-3] — Skin	5	22	10	44
Allyl propyl disulfide [2179-59-1]	2	12	3	18
‡α-Alumina [1344-28-1]	—	D	—	(20)
Aluminum [7429-90-5]				
‡ Metal & oxide	—	10	—	(20)
Pyro powders	—	5	—	—
Welding fumes	—	5	—	—
Soluble salts	—	2	—	—
Alkyls (NOC†)	—	2	—	—
4-Aminodiphenyl [92-67-1] — Skin	—	A1b	—	—
2-Aminoethanol, *see* Ethanolamine				
‡2-Aminopyridine [504-29-0]	0.5	2	(2)	(4)
3-Amino 1,2,4-triazole, *see* Amitrole				
‡Amitrole [61-82-5]	(A2)	(A2)	—	—
Ammonia [7664-41-7]	25	18	35	27

(a) Parts of vapor or gas per million parts of contaminated air by volume at 25°C and 1 torr.
(b) Approximate milligrams of substance per cubic meter of air.
‡ See Notice of Intended Changes.
Capital letters A, B, C & E refer to Appendices; C denotes ceiling limit.

Substance	ADOPTED VALUES TWA ppm[a]	TWA mg/m³[b]	ADOPTED VALUES STEL ppm[a]	STEL mg/m³[b]
Ammonium chloride fume [12125-02-9]	—	10	—	20
‡Ammonium sulfamate [7773-06-0]	—	10	—	(20)
‡n-Amyl acetate [628-63-7]	100	530	(150)	(800)
‡sec-Amyl acetate [626-38-0]	125	665	(150)	(800)
‡Aniline [62-53-3] & homologues — Skin	2	10	(5)	(20)
Anisidine [29191-52-4] (o-, p-isomers) — Skin	0.1	0.5	—	—
Antimony [7440-36-0] & compounds, as Sb	—	0.5	—	—
Antimony trioxide [1309-64-4]				
Handling and use, as Sb	—	0.5	—	—
Production	—	A2	—	—
‡ANTU [86-88-4]	—	0.3	—	(0.9)
Argon [7440-37-1]	E	—	—	—
Arsenic [7440-38-2] & soluble compounds, as As	—	0.2	—	—
Arsenic trioxide production [1327-53-3]	—	A2	—	—
Arsine [7784-42-1]	0.05	0.2	—	—
Asbestos [1332-21-4], *see* DUSTS	—	A1a	—	—
‡*Asphalt (petroleum) fumes* [8052-42-4]	—	5	—	(10)
Atrazine [1912-24-9]	—	5	—	—
‡Azinphos-methyl [86-50-0] — Skin	—	0.2	—	(0.6)
Barium [7440-39-3], soluble compounds, as Ba	—	0.5	—	—
‡Benomyl [17804-35-2]	0.8	10	(1.3)	(15)
‡Benzene [71-43-2]	10,A2	30,A2	(25,A2)	(75,A2)
Benzidine [92-87-5] — Skin	—	A1b	—	—
p-Benzoquinone, *see* Quinone				
Benzoyl peroxide [94-36-0]	—	5	—	—
Benzo(a)pyrene [50-32-8]	—	A2	—	—
Benzyl chloride [100-44-7]	1	5	—	—
Beryllium [7440-41-7]	—	0.002,A2	—	—
‡Biphenyl [92-52-4]	0.2	1.5	(0.6)	(4)
‡Bismuth telluride [1304-82-1]	—	10	—	(20)
‡ Se-doped	—	5	—	(10)

Substance	ADOPTED VALUES TWA ppm[a]	TWA mg/m³[b]	ADOPTED VALUES STEL ppm[a]	STEL mg/m³[b]
Borates, tetra, sodium salts [1303-96-4]				
Anhydrous	—	1	—	—
Decahydrate	—	5	—	—
Pentahydrate	—	1	—	—
‡Boron oxide [1303-86-2]	—	10	—	(20)
‡Boron tribromide [10294-33-4]	(1)	(10)	(3)	(30)
Boron trifluoride [7637-07-2]	C 1	C 3	—	—
‡Bromacil [314-40-9]	1	10	(2)	(20)
Bromine [7726-95-6]	0.1	0.7	0.3	2
‡Bromine pentaflouride [7789-30-2]	0.1	0.7	(0.3)	(2)
Bromochloromethane, *see* Chlorobromomethane				
Bromoform [75-25-2] — Skin	0.5	5	—	—
‡1,3-Butadiene [106-99-0]	(1,000)	(2,200)	(1,250)	(2,750)
Butane [106-97-8]	800	1,900	—	—
Butanethiol, *see* Butyl mercaptan				
2-Butanone, *see* Methyl ethyl ketone (MEK)				
‡2-Butoxyethanol [111-76-2] — Skin	25	120	(75)	(360)
n-Butyl acetate [123-86-4]	150	710	200	950
‡sec-Butyl acetate [105-46-4]	200	950	(250)	(1,190)
‡tert-Butyl acetate [540-88-5]	200	950	(250)	(1,190)
Butyl acrylate [141-32-2]	10	55	—	—
n-Butyl alcohol [71-36-3] — Skin	C 50	C 150	—	—
sec-Butyl alcohol [78-92-2]	100	305	150	455
tert-Butyl alcohol [75-65-0]	100	300	150	450
Butylamine [109-73-9] — Skin	C 5	C 15	—	—
tert-Butyl chromate, as CrO_3 [1189-85-1] — Skin	—	C 0.1	—	—
n-Butyl glycidyl ether (BGE) [2426-08-6]	25	135	—	—
n-Butyl lactate [138-22-7]	5	25	—	—
Butyl mercaptan [109-79-5]	0.5	1.5	—	—
o-sec-Butylphenol [89-72-5] — Skin	5	30	—	—
p-tert-Butyltoluene [98-51-1]	10	60	20	120
‡Cadmium [7440-43-9] Dusts & salts, as Cd	—	0.05	—	(0.2)

Capital letters A, B, C & E refer to Appendices; C denotes ceiling limit
‡ See Notice of Intended Changes.

Substance	ADOPTED VALUES TWA ppm[a]	TWA mg/m³[b]	ADOPTED VALUES STEL ppm[a]	STEL mg/m³[b]
Cadmium oxide [1306-19-0]				
Fume, as Cd	—	C 0.05	—	—
Production	—	0.05	—	—
‡Calcium carbonate/marble [1317-65-3]	—	D	—	(20)
‡Calcium cyanamide [156-62-7]	—	0.5	—	(1)
Calcium hydroxide [1305-62-0]	—	5	—	—
Calcium oxide [1305-78-8]	—	2	—	—
Calcium silicate [1344-95-2]	—	D	—	—
Camphor, synthetic [76-22-2]	2	12	3	18
Caprolactam [105-60-2]				
Dust	—	1	—	3
Vapor	5	20	10	40
Captafol [2425-06-1] — Skin	—	0.1	—	—
‡Captan [133-06-2]	—	5	—	(15)
‡Carbaryl [63-25-2]	—	5	—	(10)
Carbofuran [1563-66-2]	—	0.1	—	—
‡Carbon black [1333-86-4]	—	3.5	—	(7)
‡Carbon dioxide [124-38-9]	5,000	9,000	(15,000)	(27,000)
Carbon disulfide [75-15-0] — Skin	10	30	—	—
Carbon monoxide [630-08-0]	50	55	400	440
Carbon tetrabromide [558-13-4]	0.1	1.4	0.3	4
‡Carbon tetrachloride [56-23-5] — Skin	5,A2	30,A2	(20,A2)	(125,A2)
Carbonyl chloride, *see* Phosgene				
Carbonyl fluoride [353-50-4]	2	5	5	15
Catechol [120-80-9]	5	20	—	—
‡Cellulose (paper fiber) [9004-34-6]	—	D	—	(20)
Cesium hydroxide [21351-79-1]	—	2	—	—
Chlordane [57-74-9] — Skin	—	0.5	—	2
Chlorinated camphene [8001-35-2] — Skin	—	0.5	—	1
Chlorinated diphenyl oxide [55720-99-5]	—	0.5	—	2
Chlorine [7782-50-5]	1	3	3	9
Chlorine dioxide [10049-04-4]	0.1	0.3	0.3	0.9
Chlorine trifluoride [7790-91-2]	C 0.1	C 0.4	—	—

Substance	ADOPTED VALUES TWA ppm[a]	TWA mg/m³[b]	ADOPTED VALUES STEL ppm[a]	STEL mg/m³[b]
Chloroacetaldehyde [107-20-0]	C 1	C 3	—	—
α-Chloroacetophenone [532-27-4]	0.05	0.3	—	—
Chloroacetyl chloride [79-04-9]	0.05	0.2	—	—
Chlorobenzene [108-90-7]	75	350	—	—
o-Chlorobenzylidene malononitrile [2698-41-1] — Skin	C 0.05	C 0.4	—	—
Chlorobromomethane [74-97-5]	200	1,050	250	1,300
2-Chloro-1,3-butadiene, *see* β-Chloroprene				
Chlorodifluoromethane [75-45-6]	1,000	3,500	1,250	4,375
Chlorodiphenyl (42% Chlorine) [53469-21-9] — Skin	—	1	—	2
Chlorodiphenyl (54% Chlorine) [11097-69-1] — Skin	—	0.5	—	1
1-Chloro,2,3-epoxy-propane, *see* Epichlorohydrin				
2-Chloroethanol, *see* Ethylene chlorohydrin				
Chloroethylene, *see* Vinyl chloride				
‡Chloroform [67-66-3]	10,A2	50,A2	(50,A2)	(225,A2)
bis(Chloromethyl) ether [542-88-1]	0.001, A1a	0.005, A1a	—	—
Chloromethyl methyl ether [107-30-2]	A2	A2	—	—
1-Chloro-1-nitropropane [600-25-9]	2	10	—	—
Chloropentafluoroethane [76-15-3]	1,000	6,320	—	—
Chloropicrin [76-06-2]	0.1	0.7	0.3	2
β-Chloroprene [126-99-8] — Skin	10	35	—	—
o-Chlorostyrene [1331-28-8]	50	285	75	430
o-Chlorotoluene [95-49-8]	50	250	75	375

Capital letters A, B, C & E refer to Appendices; C denotes ceiling limit
‡ See Notice of Intended Changes.

Substance	ADOPTED VALUES TWA ppm[a]	TWA mg/m³[b]	ADOPTED VALUES STEL ppm[a]	STEL mg/m³[b]
2-Chloro-6-(trichloromethyl) pyridine, *see* Nitrapyrin				
Chlorpyrifos [2921-88-2]—Skin	—	0.2	—	0.6
Chromite ore processing (Chromate), as Cr	—	0.05,A1a	—	—
Chromium [7440-47-3] Metal	—	0.5	—	—
Chromium (II) compounds, as Cr	—	0.5	—	—
Chromium (III) compounds, as Cr	—	0.5	—	—
Chromium (VI) compounds, as Cr				
Water soluble	—	0.05	—	—
Certain water insoluble	—	0.05,A1a	—	—
Chromyl chloride [14977-61-8]	0.025	0.15	—	—
Chyrsene [218-01-9]	A2	A2	—	—
Clopidol [2971-90-6]	—	10	—	20
Coal tar pitch volatiles [8007-45-2], as benzene solubles	—	0.2,A1a	—	—
‡Cobalt [7440-48-4], as Co Metal, dust & fume	—	(0.1)	—	—
Cobalt carbonyl [00000-00-0], as Co	—	0.1	—	—
Cobalt hydrocarbonyl [16842-03-8], as Co	—	0.1	—	—
Copper [7440-50-8] Fume	—	0.2	—	—
‡ Dusts & mists, as Cu	—	1	—	(2)
‡Cotton dust, raw	—	0.2[d]	—	(0.6)
Cresol [1319-77-3], all isomers—Skin	5	22	—	—
‡Crotonaldehyde [123-73-9]	2	6	(6)	(18)
Crufomate [299-86-5]	—	5	—	20
‡Cumene [98-82-8]—Skin	50	245	(75)	(365)
Cyanamide [420-04-2]	—	2	—	—
Cyanides [151-50-8; 143-33-9], as CN—Skin	—	5	—	—
Cyanogen [460-19-5]	10	20	—	—
Cyanogen chloride [506-77-4]	C 0.3	C 0.6	—	—
‡Cyclohexane [110-82-7]	300	1,050	(375)	(1,300)
Cyclohexanol [108-93-0]	50	200	—	—

Substance	ADOPTED VALUES TWA ppm[a]	TWA mg/m³[b]	ADOPTED VALUES STEL ppm[a]	STEL mg/m³[b]
‡Cyclohexanone [108-94-1]—Skin	25	100	(100)	(400)
Cyclohexene [110-83-8]	300	1,015	—	—
Cyclohexylamine [108-91-8]—Skin	10	40	—	—
Cyclonite [121-82-4]—Skin	—	1.5	—	3
‡Cyclopentadiene [542-92-7]	75	200	(150)	(400)
‡Cyclopentane [287-92-3]	600	1,720	(900)	(2,580)
‡Cyhexatin [13121-70-5]	—	5	—	(10)
‡2,4-D [94-75-7]	—	10	—	(20)
‡DDT (Dichlorodiphenyl-trichloroethane) [50-29-3]	—	1	—	(3)
Decaborane [17702-41-9]—Skin	0.05	0.3	0.15	0.9
‡Demeton [8065-48-3]—Skin	0.01	0.1	(0.03)	(0.3)
Diacetone alcohol [123-42-2]	50	240	75	360
1,2-Diaminoethane, *see* Ethylenediamine				
‡Diazinon [333-41-5]—Skin	—	0.1	—	(0.3)
Diazomethane [334-88-3]	0.2	0.4	—	—
Diborane [19287-45-7]	0.1	0.1	—	—
1,2-Dibromoethane, *see* Ethylene dibromide				
‡2-N-Dibutylaminoethanol [102-81-8]—Skin	2	14	(4)	(28)
Dibutyl phosphate [107-66-4]	1	5	2	10
‡Dibutyl phthalate [84-74-2]	—	5	—	(10)
Dichloroacetylene [7572-29-4]	C 0.1	C 0.4	—	—
o-Dichlorobenzene [95-50-1]	C 50	C 300	—	—
p-Dichlorobenzene [106-46-7]	75	450	110	675
3,3'-Dichlorobenzidine [91-94-1]—Skin	—	A2	—	—
‡Dichlorodifluoromethane [75-71-8]	1,000	4,950	(1,250)	(6,200)
1,3-Dichloro-5,5-dimethyl hydantoin [118-52-5]	—	0.2	—	0.4

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‡ See Notice of Intended Changes.

* 1985-1986 Addition.

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

Substance	ADOPTED VALUES TWA ppm[a]	TWA mg/m³[b]	ADOPTED VALUES STEL ppm[a]	STEL mg/m³[b]
1,1-Dichloroethane [75-34-3]	200	810	250	1,010
1,2-Dichloroethane, *see* Ethylene dichloride				
1,1-Dichloroethylene, *see* Vinylidene chloride				
1,2-Dichloroethylene [540-59-0]	200	790	250	1,000
Dichloroethyl ether [111-44-4]—Skin	5	30	10	60
Dichlorofluoromethane [75-43-4]	10	40	—	—
Dichloromethane, *see* Methylene chloride				
‡1,1-Dichloro-1-nitroethane [594-72-9]	2	10	(10)	(60)
1,2-Dichloropropane, *see* Propylene dichloride				
‡Dichloropropene [542-75-6]—Skin	1	5	(10)	(50)
2,2-Dichloropropionic acid [75-99-0]	1	6	—	—
‡Dichlorotetrafluoroethane [76-14-2]	1,000	7,000	(1,250)	(8,750)
‡Dichlorvos [62-73-7]—Skin	0.1	1	(0.3)	(3)
Dicrotophos [141-66-2]—Skin	—	0.25	—	—
Dicyclopentadiene [77-73-6]	5	30	—	—
‡Dicyclopentadienyl iron [102-54-5]	—	10	—	(20)
‡Dieldrin [60-57-1]—Skin	—	0.25	—	(0.75)
Diethanolamine [111-42-2]	3	15	—	—
Diethylamine [109-89-7]	10	30	25	75
Diethylaminoethanol [100-37-8]—Skin	10	50	—	—
Diethylene triamine [111-40-0]—Skin	1	4	—	—
Diethyl ether, *see* Ethyl ether				
Di-2-ethylhexylphthalate, *see* Di-sec, octyl phthalate				
Diethyl ketone [96-22-0]	200	705	—	—
‡Diethyl phthalate [84-66-2]	—	5	—	(10)
‡Difluorodibromomethane [75-61-6]	100	860	(150)	(1,290)
Diglycidyl ether (DGE) [2238-07-5]	0.1	0.5	—	—
Dihydroxybenzene, *see* Hydroquinone				
Diisobutyl ketone [108-83-8]	25	250	—	—
Diisopropylamine [108-18-9]—Skin	5	20	—	—

Substance	ADOPTED VALUES TWA ppm[a]	TWA mg/m³[b]	ADOPTED VALUES STEL ppm[a]	STEL mg/m³[b]
Dimethoxymethane, *see* Methylal				
‡Dimethyl acetamide [127-19-5]—Skin	10	35	(15)	(50)
Dimethylamine [124-40-3]	10	18	—	—
Dimethylaminobenzene, *see* Xylidene				
Dimethylaniline [121-69-7] (N,N-Dimethylaniline)—Skin	5	25	10	50
Dimethylbenzene, *see* Xylene				
Dimethyl carbamoyl chloride [79-44-7]	A2	A2	—	—
Dimethyl-1,2-dibromo-2-dichloroethyl phospate, *see* Naled				
‡Dimethylformamide [68-12-2]—Skin	10	30	(20)	(60)
2,6-Dimethyl-4-heptanone, *see* Diisobutyl ketone				
‡1,1-Dimethylhydrazine [57-14-7]—Skin	0.5,A2	1,A2	(1,A2)	(2,A2)
Dimethylnitrosoamine, *see* N-Nitrosodimethylamine				
‡Dimethylphthalate [131-11-3]	—	5	—	(10)
Dimethyl sulfate [77-78-1]—Skin	0.1,A2	0.5,A2	—	—
Dinitolmide [148-01-6]	—	5	—	10
‡Dinitrobenzene [528-29-0; 99-65-0; 100-25-4] (all isomers)—Skin	0.15	1	(0.5)	(3)
‡Dinitro-o-cresol [534-52-1]—Skin	—	0.2	—	(0.6)
3,5-Dinitro-o-toluamide, *see* Dinitolmide				
‡Dinitrotoluene [121-14-2]—Skin	—	1.5	—	(5)
‡Dioxane, tech. grade [123-91-1]—Skin	25	90	(100)	(360)
Dioxathion [78-34-2]—Skin	—	0.2	—	—
Diphenyl, *see* Biphenyl				
‡Diphenylamine [122-39-4]	—	10	—	(20)
Diphenylmethane diisocyanate, *see* Methylene bisphenyl isocyanate				
Dipropylene glycol methyl ether [34590-94-8]	100	600	150	900
Dipropyl ketone [123-19-3]	50	235	—	—
‡Diquat [85-00-7]	—	0.5	—	(1)

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‡ See Notice of Intended Changes.

Substance	ADOPTED VALUES TWA ppm[a]	TWA mg/m³[b]	ADOPTED VALUES STEL ppm[a]	STEL mg/m³[b]
Di-sec, octyl phthalate [117-81-7]	—	5	—	10
‡Disulfiram [97-77-8]	—	2	—	(5)
‡Disulfoton [298-04-4]	—	0.1	—	(0.3)
‡2,6-Ditert. butyl-p-cresol [128-37-0]	—	10	—	(20)
Diuron [330-54-1]	—	10	—	—
Divinyl benzene [108-57-6]	10	50	—	—
‡Emery [112-62-9]	—	D	—	(20)
‡Endosulfan [115-29-7] — Skin	—	0.1	—	(0.3)
‡Endrin [72-20-8] — Skin	—	0.1	—	(0.3)
‡Epichlorohydrin [106-89-8] — Skin	2	10	(5)	(20)
‡EPN [2104-64-5] — Skin	—	0.5	—	(2)
1,2-Epoxypropane, *see* Propylene oxide				
2,3-Epoxy-1-propanol, *see* Glycidol				
Ethane [74-84-0]	—	E	—	—
Ethanethiol, *see* Ethyl mercaptan				
Ethanol, *see* Ethyl alcohol				
Ethanolamine [141-43-5]	3	8	6	15
Ethion [563-12-2] — *Skin*	—	0.4	—	—
2-Ethoxyethanol [110-80-5] — Skin	5	19	—	—
2-Ethoxyethyl acetate [111-15-9] — Skin	5	27	—	—
Ethyl acetate [141-78-6]	400	1,400	—	—
‡Ethyl acrylate [140-88-5] — Skin	5	20	(25)	(100)
Ethyl alcohol [64-17-5]	1,000	1,900	—	—
Ethylamine [75-04-7]	10	18	—	—
Ethyl amyl ketone [541-85-5]	25	130	—	—
Ethyl benzene [100-41-4]	100	435	125	545
Ethyl bromide [74-96-4]	200	890	250	1,110
‡Ethyl butyl ketone [106-35-4]	50	230	(75)	(345)
‡Ethyl chloride [75-00-3]	1,000	2,600	(1,250)	(3,250)
Ethylene [74-85-1]	E	—	—	—
Ethylene chlorohydrin [107-07-3] — Skin	C 1	C 3	—	—
Ethylenediamine [107-15-3]	10	25	—	—
Ethylene dibromide [106-93-4] — Skin	A2	A2	—	—

Substance	ADOPTED VALUES TWA ppm[a]	TWA mg/m³[b]	ADOPTED VALUES STEL ppm[a]	STEL mg/m³[b]
‡Ethylene dichloride [107-06-2]	10	40	(15)	(60)
Ethylene glycol [107-21-1] Vapor	C 50	C 125	—	—
*Ethylene glycol dinitrate [628-96-6] — Skin	0.05	0.3	—	—
Ethylene glycol methyl ether acetate, *see* 2-Methoxyethyl acetate				
Ethylene oxide [75-21-8]	1,A2	2,A2	—	—
Ethylenimine [151-56-4] — Skin	0.5	1	—	—
Ethyl ether [60-29-7]	400	1,200	500	1,500
‡Ethyl formate [109-94-4]	100	300	(150)	(450)
Ethylidene chloride, *see* 1,1-Dichloroethane				
Ethylidene norbornene [16219-75-3]	C 5	C 25	—	—
‡Ethyl mercaptan [75-08-1]	0.5	1	(2)	(3)
‡N-Ethylmorpholine [100-74-3] — Skin	5	23	(20)	(95)
‡Ethyl silicate [78-10-4]	10	85	(30)	(255)
Fenamiphos [22224-92-6] — Skin	—	0.1	—	—
Fensulfothion [115-90-2]	—	0.1	—	—
Fenthion [55-38-9] — *Skin*	—	0.2	—	—
‡Ferbam [14484-64-1]	—	10	—	(20)
Ferrovanadium dust [12604-58-9]	—	1	—	3
Fibrous glass dust	—	10	—	—
Fluorides, as F	—	2.5	—	—
Fluorine [7782-41-4]	1	2	2	4
Fluorotrichloromethane, *see* Trichlorofluoromethane				
Fonofos [944-22-9] — Skin	—	0.1	—	—
*Formaldehyde [50-00-0]	1,A2	1.5,A2	2,A2	3,A2
‡Formamide [75-12-7]	20	30	(30)	(45)
Formic acid [64-18-6]	5	9	—	—
‡Furfural [98-01-1] — Skin	2	8	(10)	(40)
Furfuryl alcohol [98-00-0] — Skin	10	40	15	60
Gasoline [8006-61-9]	300	900	500	1,500
‡Germanium tetrahydride [7782-65-2]	0.2	0.6	(0.6)	(1.8)

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* 1985-1986 Addition.

Substance	ADOPTED VALUES TWA ppm[a]	TWA mg/m³[b]	ADOPTED VALUES STEL ppm[a]	STEL mg/m³[b]
Glass, fibrous or dust, *see* Fibrous glass dust				
Glutaraldehyde [111-30-8]	C 0.2	C 0.7	—	—
Glycerin mist [56-81-5]	—	D	—	—
‡Glycidol [556-52-5]	25	75	(100)	(300)
Glycol monoethyl ether, *see* 2-Ethoxyethanol				
‡Graphite (Natural) [7782-42-5], *see* DUSTS				
‡Graphite (Synthetic)	—	(D)	—	—
‡Gypsum [10101-4-4]	—	D	—	(20)
‡Hafnium [7440-58-6]	—	0.5	—	(1.5)
Helium [7440-59-7]	E	—	—	—
‡Heptachlor [76-44-8] — Skin	—	0.5	—	(2)
Heptane [142-82-5] (n-Heptane)	400	1,600	500	2,000
2-Heptanone, *see* Methyl n-amyl ketone				
3-Heptanone, *see* Ethyl butyl ketone				
Hexachlorobutadiene [87-68-3] — Skin	0.02,A2	0.24,A2	—	—
‡Hexachlorocyclopentadiene [77-47-4]	0.01	0.1	(0.03)	(0.3)
Hexachloroethane [67-72-1]	10	100	—	—
‡Hexachloronaphthalene [1335-87-1] — Skin	—	0.2	—	(0.6)
‡Hexafluoroacetone [684-16-2] — Skin	0.1	0.7	(0.3)	(2)
Hexamethyl phosphoramide [680-31-9] — Skin	A2	A2	—	—
Hexane (n-Hexane) [100-54-3]	50	180	—	—
Other isomers	500	1,800	1,000	3,600
2-Hexanone, *see* Methyl n-butyl ketone				
Hexone, *see* Methyl isobutyl ketone				
sec-Hexyl acetate [108-84-9]	50	300	—	—
Hexylene glycol [107-41-5]	C 25	C 125	—	—
Hydrazine [302-01-2] — Skin	0.1,A2	0.1,A2	—	—
Hydrogen [1333-74-0]	E	—	—	—
Hydrogenated terphenyls [61788-32-7]	0.5	5	—	—
‡Hydrogen bromide [10035-10-6]	(3)	(10)	—	—
Hydrogen chloride [7647-01-0]	C 5	C 7	—	—
Hydrogen cyanide [74-90-8] — Skin	C 10	C 10	—	—

Substance	ADOPTED VALUES TWA ppm[a]	TWA mg/m³[b]	ADOPTED VALUES STEL ppm[a]	STEL mg/m³[b]
‡Hydrogen fluoride [7664-39-3], as F	(3)	(2.5)	(6)	(5)
‡Hydrogen peroxide [7722-84-1]	1	1.5	(2)	(3)
Hydrogen selenide [7783-07-5], as Se	0.05	0.2	—	—
Hydrogen sulfide [7783-06-4]	10	14	15	21
‡Hydroquinone [123-31-9]	—	2	—	(4)
4-Hydroxy-4-methyl-2-pentatnone, *see* Diacetone alcohol				
2-Hydroxypropyl acrylate [999-61-1] — Skin	0.5	3	—	—
‡Indene [95-13-6]	10	45	(15)	(70)
‡Indium [7440-74-6] & compounds, as In	—	0.1	—	(0.3)
Iodine [7553-56-2]	C 0.1	C 1	—	—
‡Iodoform [75-47-8]	0.6	10	(1)	(20)
‡Iron oxide fume (Fe_2O_3) [1309-37-1], as Fe	B2	5	—	(10)
Iron pentacarbonyl [13463-40-6], as Fe	0.1	0.8	0.2	1.6
‡Iron salts, soluble, as Fe	—	1	—	(2)
‡Isoamyl acetate [123-92-2]	100	525	(125)	(655)
Isoamyl alcohol [123-51-3]	100	360	125	450
Isobutyl acetate [110-19-0]	150	700	187	875
‡Isobutyl alcohol [78-83-1]	50	150	(75)	(225)
Isoocyl alcohol [26952-21-6]—Skin	50	270	—	—
Isophorone [78-59-1]	C 5	C 25	—	—
Isophorone diisocyanate [4098-71-9] — Skin	0.01	0.09	—	—
‡Isopropoxyethanol [109-59-1]	25	105	(75)	(320)
Isopropyl acetate [108-21-4]	250	950	310	1,185
Isopropyl alcohol [67-63-0]	400	980	500	1,225
Isopropylamine [75-31-0]	5	12	10	24
‡N-Isopropylaniline [768-52-5] — Skin	2	10	(5)	(20)
Isopropyl ether [108-20-3]	250	1,050	310	1,320
Isopropyl glycidyl ether (IGE) [4016-14-2]	50	240	75	360

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Substance	ADOPTED VALUES TWA ppm[a]	TWA mg/m³[b]	ADOPTED VALUES STEL ppm[a]	STEL mg/m³[b]
‡Kaolin	—	D	—	(20)
Ketene [463-51-4]	0.5	0.9	1.5	3
‡Lead [7439-92-1], inorg. dusts & fumes, as Pb	—	0.15	—	(0.45)
*Lead arsenate [10102-48-4], as $Pb_3(AsO_4)_2$	—	0.15	—	—
Lead chromate [7758-97-6], as Cr	—	0.05,A2	—	—
‡Limestone [1317-65-3]	—	D	—	(20)
‡Lindane [58-89-9] — Skin	—	0.5	—	(1.5)
Lithium hydride [7580-67-8]	—	0.025	—	—
‡L.P.G. (Liquified petroleum gas)	1,000	1,800	(1,250)	(2,250)
‡Magnesite [546-93-0]	—	D	—	(20)
Magnesium oxide fume [1309-48-4]	—	10	—	—
Malathion [121-75-5] — Skin	—	10	—	—
Maleic anhydride [108-31-6]	0.25	1	—	—
Manganese [7439-96-5], as Mn				
Dust & compounds	—	C 5	—	—
Fume	—	1	—	3
‡Manganese cyclopentadienyl tricarbonyl [12079-65-1], as Mn — Skin	—	0.1	—	(0.3)
Manganese tetroxide [0000-00-0]	—	1	—	—
‡Marble/calcium carbonate [1317-65-3]	—	D	—	(20)
Mercury [7439-97-6], as Hg — Skin				
Alkyl compounds	—	0.01	—	0.03
All forms expect alkyl Vapor	—	0.05	—	—
Aryl & inorganic compounds	—	0.1	—	—
Mesityl oxide [141-79-7]	15	60	25	100
Methacrylic acid [79-41-4]	20	70	—	—
Methane [74-82-8]	E	—	—	—
Methanethiol, *see* Methyl mercaptan				
Methanol, *see* Methyl alcohol				
Methomyl [16752-77-5] — Skin	—	2.5	—	—
Methoxychlor [72-43-5]	—	10	—	—

Substance	ADOPTED VALUES TWA ppm[a]	TWA mg/m³[b]	ADOPTED VALUES STEL ppm[a]	STEL mg/m³[b]
2-Methoxyethanol [109-86-4] — Skin	5	16	—	—
2-Methoxyethyl acetate [110-49-6] — Skin	5	24	—	—
4-Methoxyphenol [150-76-5]	—	5	—	—
Methyl acetate [79-20-9]	200	610	250	760
Methyl acetylene [74-99-7]	1,000	1,650	1,250	2,040
Methyl acetylene-propadiene mixture (MAPP)	1,000	1,800	1,250	2,250
Methyl acrylate [96-33-3] — Skin	10	35	—	—
‡Methylacrylonitrile [126-98-7] — Skin	1	3	(2)	(6)
‡Methylal [109-87-5]	1,000	3,100	(1,250)	(3,875)
Methyl alcohol [67-56-1] — Skin	200	260	250	310
Methylamine [74-89-5]	10	12	—	—
Methyl amyl alcohol, *see* Methyl isobutyl carbinol				
‡Methyl n-amyl ketone [110-43-0]	50	235	(100)	(465)
‡N-Methyl aniline [100-61-8] — Skin	0.5	2	(1)	(5)
‡Methyl bromide [74-83-9] — Skin	5	20	(15)	(60)
Methyl n-butyl ketone [591-78-6]	5	20	—	—
Methyl chloride [74-87-3]	50	105	100	205
Methyl chloroform [71-55-6]	350	1,900	450	2,450
Methyl 2-cyanoacrylate [137-05-3]	2	8	4	16
‡Methylcyclohexane [108-87-2]	400	1,600	(500)	(2,000)
‡Methylcyclohexanol [25639-42-3]	50	235	(75)	(350)
o-Methylcyclohexanone [583-60-8] — Skin	50	230	75	345
‡Methylcyclopentadienyl manganese tricarbonyl [12108-13-3] — Skin, as Mn	—	0.2	—	(0.6)

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‡ See Notice of Intended Changes.

Substance	ADOPTED VALUES TWA ppm[a]	TWA mg/m³[b]	ADOPTED VALUES STEL ppm[a]	STEL mg/m³[b]
‡Methyl demeton [8022-00-2] — Skin	—	0.5	—	(1.5)
Methylene bisphenyl isocyanate (MDI) [101-68-8]	C 0.02	C 0.2	—	—
‡Methylene chloride [75-09-2]	100	350	(500)	(1,740)
4,4'-Methylene bis(2-chloroaniline) [101-14-4] — Skin	0.02,A2	0.22,A2	—	—
Methylene bis(4-cyclohexylisocyanate) [5124-30-1]	C 0.01	C0.11	—	—
‡4,4'-Methylene dianiline [107-77-9] — Skin	(0.1)	(0.8)	(0.5)	(4)
Methyl ethyl ketone (MEK) [78-93-3]	200	590	300	885
Methyl ethyl ketone peroxide [1338-23-4]	C 0.2	C 1.5	—	—
Methyl formate [107-31-3]	100	250	150	375
5-Methyl-3-heptanone, *see* Ethyl amyl ketone				
Methyl hydrazine [60-34-4] — Skin	C 0.2,A2	C 0.35,A2	—	—
‡Methyl iodide [74-88-4] — Skin	2,A2	10,A2	(5,A2)	(30,A2)
Methyl isoamyl ketone [110-12-3]	50	240	—	—
Methyl isobutyl carbinol [108-11-2] — Skin	25	100	40	165
Methyl isobutyl ketone [108-10-1]	50	205	75	300
Methyl isocyanate [624-83-9] — Skin	0.02	0.05	—	—
Methyl isopropyl ketone [563-80-4]	200	705	—	—
Methyl mercaptan [74-93-1]	0.5	1	—	—
‡Methyl methacrylate [80-62-6]	100	410	(125)	(510)
‡Methyl parathion [298-00-0] — Skin	—	0.2	—	(0.6)
Methyl propyl ketone [107-87-9]	200	700	250	875
‡Methyl silicate [681-84-5]	1	6	(5)	(30)
α-Methyl styrene [98-83-9]	50	240	100	485
Metribuzin [21087-64-9]	—	5	—	—

Substance	ADOPTED VALUES TWA ppm[a]	TWA mg/m³[b]	ADOPTED VALUES STEL ppm[a]	STEL mg/m³[b]
Mevinphos [7786-34-7] — Skin	0.01	0.1	0.03	0.3
Molybdenum [7439-98-7], as Mo				
‡ Soluble compounds	—	5	—	(10)
‡ Insoluble compounds	—	10	—	(20)
Monochlorobenzene, *see* Chlorobenzene				
Monocrotophos [6923-22-4]	—	0.25	—	—
Morpholine [110-91-8] — Skin	20	70	30	105
‡Naled [300-76-5] — Skin	—	3	—	(6)
Naphthalene [91-20-3]	10	50	15	75
β-Naphthylamine [91-59-8]	—	A1b	—	—
Neon [7440-01-9]	E	—	—	—
Nickel [7440-02-0] Metal	—	1	—	—
‡ Soluble compounds, as Ni	—	0.1	—	(0.3)
Nickel carbonyl [13463-39-3], as Ni	0.05	0.35	—	—
Nickel sulfide roasting, fume & dust, as Ni	—	1,A1a	—	—
‡Nicotine [54-11-5] — Skin	—	0.5	—	(1.5)
Nitrapyrin [1929-82-4]	—	10	—	20
Nitric acid [7697-37-2]	2	5	4	10
‡Nitric oxide [10102-43-9]	25	30	(35)	(45)
p-Nitroaniline [100-01-6] — Skin	—	3	—	—
‡Nitrobenzene [98-95-3] — Skin	1	5	(2)	(10)
*p-Nitrochlorobenzene [100-00-5] — Skin	0.5	3	—	—
4-Nitrodiphenyl [92-93-3]	—	A1b	—	—
‡Nitroethane [79-24-3]	100	310	(150)	(465)
Nitrogen dioxide [10102-44-0]	3	6	5	10
‡Nitrogen trifluoride [7783-54-2]	10	30	(15)	(45)
*Nitroglycerin (NG) [55-63-0] — Skin	0.05	0.5	—	—

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‡ See Notice of Intended Changes.
* 1985-1986 Addition.

Substance	ADOPTED VALUES TWA ppm[a]	TWA mg/m³[b]	ADOPTED VALUES STEL ppm[a]	STEL mg/m³[b]
‡Nitromethane [75-52-5]	100	250	(150)	(375)
‡1-Nitropropane [108-03-2]	25	90	(35)	(135)
‡2-Nitropropane [79-46-9]	(C 25, A2)	C 90 A2)	—	—
N-Nitrosodimethylamine [62-75-9] — Skin	—	A2	—	—
Nitrotoluene [99-08-1] — Skin	2	11	—	—
Nitrotrichloromethane, *see* Chloropicrin				
‡Nonane [111-84-2]	200	1,050	(250)	(1,300)
Octachloronaphthalene [2234-13-1] — Skin	—	0.1	—	0.3
Octane [111-65-9]	300	1,450	375	1,800
Oil mist, mineral [8012-95-1]	—	5[e]	—	10
Osmium tetroxide [20816-12-0], as Os	0.0002	0.002	0.0006	0.006
Oxalic acid [144-62-7]	—	1	—	2
‡Oxygen difluoride [7783-41-7]	(0.05)	(0.1)	(0.15)	(0.3)
Ozone [10028-15-6]	0.1	0.2	0.3	0.6
‡Paraffin wax fume [8002-74-2]	—	2	—	(6)
Paraquat [1910-42-5], respirable sizes	—	0.1	—	—
‡Parathion [56-38-2] — Skin	—	0.1	—	(0.3)
Particulate polycyclic aromatic hydrocarbons (PPAH); *see* Coal tar pitch volatiles				
Pentaborane [19624-22-7]	0.005	0.01	0.015	0.03
‡Pentachloronaphthalene [1321-64-8]	—	0.5	—	(2)
‡Pentachlorophenol [87-86-5] — Skin	—	0.5	—	(1.5)
‡Pentaerythritol [115-77-5]	—	D	—	(20)
Pentane [109-66-0]	600	1,800	750	2,250
2-Pentanone, *see* Methyl propyl ketone				
Perchloroethylene [127-18-4]	50	335	200	1,340
Perchloromethyl mercaptan [594-42-3]	0.1	0.8	—	—
Perchloryl fluoride [7616-94-6]	3	14	6	28
Phenacyl chloride, *see* α-Chloroacetophenone				
‡Phenol [108-95-2] — Skin	5	19	(10)	(38)

Substance	ADOPTED VALUES TWA ppm[a]	TWA mg/m³[b]	ADOPTED VALUES STEL ppm[a]	STEL mg/m³[b]
‡Phenothiazine [92-84-2] — Skin	—	5	—	(10)
N-Phenyl-beta-naphthyl-amine [135-88-6]	A2	A2	—	—
p-Phenylene diamine [106-50-3] — Skin	—	0.1	—	—
Phenyl ether [101-84-8], vapor	1	7	2	14
Phenylethylene, *see* Styrene, monomer				
Phenyl glycidyl ether (PGE) [122-60-1]	1	6	—	—
*Phenylhydrazine [100-63-0] — Skin	5,A2	20,A2	10,A2	45,A2
Phenyl mercaptan [108-98-5]	0.5	2	—	—
Phenylphosphine [638-21-1]	C 0.05	C 0.25	—	—
Phorate [298-02-2] — Skin	—	0.05	—	0.2
Phosdrin, *see* Mevinphos				
Phosgene [75-44-5]	0.1	0.4	—	—
Phosphine [7803-51-2]	0.3	0.4	1	1
Phosphoric acid [7664-38-2]	—	1	—	3
‡Phosphorus (yellow) [7723-14-0]	—	0.1	—	(0.3)
Phosphorus oxychloride [10025-87-3]	0.1	0.6	0.5	3
Phosphorus pentachloride [10026-13-8]	0.1	1	—	—
Phosphorus pentasulfide [1314-80-3]	—	1	—	3
Phosphorus trichloride [7719-12-2]	0.2	1.5	0.5	3
‡Phthalic anhydride [85-44-9]	1	6	(4)	(24)
m-Phthalodinitrile [626-17-5]	—	5	—	—
Picloram [1918-02-1]	—	10	—	20
Picric acid [88-89-1] — Skin	—	0.1	—	0.3
‡Pindone [83-26-1]	—	0.1	—	(0.3)
Piperazine dihydrochloride [142-64-3]	—	5	—	—
2-Pivalyl-1,3-indandione, *see* Pindone				

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‡ See Notice of Intended Changes.
* 1985-1986 Addition.
(e) As Sampled by method that does not collect vapor.

Substance	ADOPTED VALUES TWA ppm[a]	TWA mg/m³[b]	ADOPTED VALUES STEL ppm[a]	STEL mg/m³[b]
‡Plaster of Paris	—	D	—	(20)
Platinum [7440-06-4]				
Metal	—	1	—	—
Soluble salts, as Pt	—	0.002	—	—
Polychlorobiphenyls, *see* Chlorodiphenyls				
Polytetrafluoroethylene decomposition products	—	B1	—	—
Portland cement	—	D	—	—
Potassium hydroxide [1310-58-3]	—	C 2	—	—
Propane [74-98-6]	E	—	—	—
Propane sultone [1120-71-4]	A2	A2	—	—
‡Propargyl alcohol [107-19-7] — Skin	1	2	(3)	(6)
‡β-Propiolactone [57-57-8]	0.5,A2	1.5,A2	(1,A2)	(3,A2)
‡Propionic acid [79-09-4]	10	30	(15)	(45)
‡Propoxur [114-26-1]	—	0.5	—	(2)
n-Propyl acetate [109-60-4]	200	840	250	1,050
Propyl alcohol [71-23-8] — Skin	200	500	250	625
Propylene [115-07-1]	E	—	—	—
Propylene dichloride [78-87-5]	75	350	110	510
*Propylene glycol dinitrate [6423-43-4] — Skin	0.05	0.3	—	—
Propylene glycol monomethyl ether [107-98-2]	100	360	150	540
Propylene imine [75-55-8] — Skin	2,A2	5,A2	—	—
Propylene oxide [75-56-9]	20	50	—	—
n-Propyl nitrate [627-13-4]	25	105	40	170
Propyne, *see* Methyl acetylene				
‡Pyrethrum [8003-34-7]	—	5	—	(10)
‡Pyridine [110-86-1]	5	15	(10)	(30)
Pyrocatechol, *see* Catechol				
‡Quinone [106-51-4]	0.1	0.4	(0.3)	(1)
RDX, *see* Cyclonite				
Resorcinol [108-46-3]	10	45	20	90
Rhodium [7440-16-6]				
Metal	—	1	—	—
Insoluble compounds, as Rh	—	1	—	—
Soluble compounds, as Rh	—	0.01	—	—

Substance	ADOPTED VALUES TWA ppm[a]	TWA mg/m³[b]	ADOPTED VALUES STEL ppm[a]	STEL mg/m³[b]
Ronnel [299-84-3]	—	10	—	—
‡Rosin core solder pyrolysis products, as formaldehyde	—	0.1	—	(0.3)
‡Rotenone (commercial) [83-79-4]	—	5	—	(10)
‡Rouge	—	D	—	(20)
Rubber solvent (Naphtha)	400	1,600	—	—
Selenium compounds [7782-49-2], as Se	—	0.2	—	—
Selenium hexafluoride [7783-79-1], as Se	0.05	0.2	—	—
‡Sesone [136-78-7]	—	10'	—	(20)
Silane, *see* Silicon tetrahydride				
‡Silicon [7440-21-3]	—	D	—	(20)
‡Silicon carbide [409-21-2]	—	D	—	(20)
Silicon tetrahydride [7803-62-5]	5	7	—	—
Silver [7440-22-4]				
Metal	—	0.1	—	—
Soluble compounds, as Ag	—	0.01	—	—
Sodium azide [26628-22-8]	C 0.1	C 0.3	—	—
Sodium bisulfite [7631-90-5]	—	5	—	—
Sodium 2,4-dichloro-phenoxyethyl sulfate, *see* Sesone				
Sodium fluoroacetate [62-74-8] — Skin	—	0.05	—	0.15
Sodium hydroxide [1310-73-2]	—	C 2	—	—
Sodium metabisulfite [7681-57-4]	—	5	—	—
‡Starch [9005-25-8]	—	D	—	(20)
‡Stibine [7803-52-3]	0.1	0.5	(0.3)	(1.5)
‡Stoddard solvent [8052-41-3]	100	525	(200)	(1,050)
‡Strychnine [57-24-9]	—	0.15	—	(0.45)
Styrene, monomer [100-42-5]	50	215	100	425

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‡ See Notice of Intended Changes.
* 1985-1986 Addition.

Substance	ADOPTED VALUES TWA ppm[a]	TWA mg/m³[b]	ADOPTED VALUES STEL ppm[a]	STEL mg/m³[b]
Subtilisins [1395-21-7] (Proteolytic enzymes as 100% pure crystalline enzyme)	—C 0.00006[f]		—	—
‡Sucrose [57-50-1]	—	D	—	(20)
‡Sulfotep [3689-24-5] — Skin	—	0.2	—	(0.6)
‡Sulfur dioxide [7446-09-5]	2	5	(5)	(10)
‡Sulfur hexafluoride [2551-62-4]	1,000	6,000	(1,250)	(7,500)
Sulfuric acid [7664-93-9]	—	1	—	—
‡Sulfur monochloride [10025-67-9]	(1)	(6)	(3)	(18)
‡Sulfur pentafluoride [5714-22-7]	(0.025)	(0.25)	(0.075)	(0.75)
‡Sulfur tetrafluoride [7783-60-0]	(0.1)	(0.4)	(0.3)	(1)
Sulfuryl fluoride [2699-79-8]	5	20	10	40
Sulprofos [35400-43-2]	—	1	—	—
Systox, *see* Demeton				
‡2,4,5-T [93-76-5]	—	10	—	(20)
‡Tantalum [7440-25-7]	—	5	—	(10)
TEDP, *see* Sulfotep				
Tellurium & compounds [13494-80-9], as Te	—	0.1	—	—
Tellurium hexafluoride [7783-80-4], as Te	0.02	0.2	—	—
‡Temephos [3383-96-8]	—	10	—	(20)
‡TEPP [107-49-3] — Skin	0.004	0.05	(0.01)	(0.2)
Terphenyls [26140-60-3]	C 0.5	C 5	—	—
‡1,1,1,2-Tetrachloro-2,2-difluoroethane [76-11-9]	500	4,170	(625)	(5,210)
‡1,1,2,2-Tetrochloro-1,2-difluoroethane [76-12-0]	500	4,170	(625)	(5,210)
‡1,1,2,2-Tetrachloroethane [79-34-5] — Skin	1	7	(5)	(35)
Tetrachloroethylene, *see* Perchloroethylene				
Tetrachloromethane, *see* Carbon tetrachloride				
‡Tetrachloronaphthalene [1335-88-2]	—	2	—	(4)
‡Tetraethyl lead [78-00-2], as Pb — Skin	—	0.1[g]	—	(0.3)
Tetrahydrofuran [109-99-9]	200	590	250	735
‡Tetramethyl lead [75-74-1], as Pb — Skin	—	0.15[g]	—	(0.5)

Substance	ADOPTED VALUES TWA ppm[a]	TWA mg/m³[b]	ADOPTED VALUES STEL ppm[a]	STEL mg/m³[b]
‡*Tetramethyl succinonitrile* [3333-52-6] — Skin	0.5	3	(2)	(9)
Tetranitromethane [509-14-8]	1	8	—	—
Tetrasodium pyrophosphate [7722-88-5]	—	5	—	—
‡Tetryl [479-45-8] — Skin	—	1.5	—	(3)
Thallium [7440-28-0] *Soluble compounds*, as Tl — Skin	—	0.1	—	—
‡4,4'-Thiobis(6-tert, butyl-m-cresol) [96-69-5]	—	10	—	(20)
Thioglycolic acid [68-11-1] — Skin	1	4	—	—
‡Thiram [137-26-8]	—	5	—	(10)
Tin [7440-31-5]				
‡ Metal	—	2	—	(4)
‡ Oxide & inorganic compounds, except SnH_4, as Sn	—	2	—	(4)
‡ Organic compounds, as Sn — Skin	—	0.1	—	(0.2)
‡Titanium dioxide [13463-67-7]	—	D	—	(20)
o-Tolidine [119-93-7] — Skin	A2	A2	—	—
Toluene (toluol) [108-88-3]	100	375	150	560
Toluene-2,4-diisocyanate (TDI) [584-84-9]	0.005	0.04	0.02	0.15
o-Toluidine [95-53-4] — Skin	2,A2	9,A2	—	—
Toxaphene, *see* Chlorinated camphene				
‡Tributyl phosphate [126-73-8]	0.2	2.5	(0.4)	(5)
Trichloroacetic acid [76-03-9]	1	7	—	—
1,2,4-Trichlorobenzene [120-82-1]	C 5	C 40	—	—

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‡ See Notice of Intended Changes.
* 1985-1986 Addition.
(f) Based on "high Volume" sampling.
(g) For control of general room air, biologic monitoring is essential for personnel control.

Substance	ADOPTED VALUES TWA ppm[a]	TWA mg/m³[b]	ADOPTED VALUES STEL ppm[a]	STEL mg/m³[b]
1,1,1-Trichloroethane, *see* Methyl chloroform				
‡1,1,2-Trichloroethane [79-00-5]—Skin	10	45	(20)	(90)
Trichloroethylene [79-01-6]	50	270	200	1,080
Trichlorofluoromethane [75-69-4]	C 1,000	C 5,600	—	—
Trichloromethane, *see* Chloroform				
‡Trichloronaphthalene [1321-65-9]—Skin	—	5	—	(10)
Trichloronitromethane, *see* Chloropicrin				
‡1,2,3-Trichloropropane [96-18-4]—Skin	(50)	(300)	(75)	(450)
1,1,2-Trichloro-1,2,2-trifluoroethane [76-13-1]	1,000	7,600	1,250	9,500
Tricyclohexyltin hydroxide, *see* Cyhexatin				
Triethylamine [121-44-8]	10	40	15	60
‡Trifluorobromomethane [75-63-8]	1,000	6,100	(1,200)	(7,300)
Trimellitic anhydride [552-30-7]	0.005	0.04	—	—
Trimethylamine [75-50-3]	10	24	15	36
‡Trimethyl benzene [2551-13-7]	25	125	(35)	(170)
‡Trimethyl phosphite [121-45-9]	2	10	(5)	(25)
2,4,6-Trinitrophenol, *see* Picric acid				
2,4,6-Trinitrophenylmethylnitramine, *see* Tetryl				
‡2,4,6-Trinitrotoluene (TNT) [118-96-7]—Skin	—	0.5	—	(3)
‡Triorthocresyl phosphate [78-30-8]—Skin	—	0.1	—	(0.3)
Triphenyl amine [603-34-9]	—	5	—	—
‡Triphenyl phosphate [115-86-6]	—	3	—	(6)
Tungsten [7440-33-7], as W				
Insoluble compounds	—	5	—	10
Soluble compounds	—	1	—	3
‡Turpentine [8006-64-2]	100	560	(150)	(840)
Uranium (natural) [7440-61-1]				
Soluble & insoluble compounds, as U	—	0.2	—	0.6
n-Valeraidehyde [110-62-3]	50	175	—	—

Substance	ADOPTED VALUES TWA ppm[a]	TWA mg/m³[b]	ADOPTED VALUES STEL ppm[a]	STEL mg/m³[b]
Vanadium, as V_2O_5 [1314-62-1]				
Respirable dust & fume	—	0.05	—	—
Vegetable oil mists	—	D	—	—
Vinyl acetate [108-05-4]	10	30	20	60
Vinyl benezene, *see* Styrene				
Vinyl bromide [593-60-2]	5,A2	20,A2	—	—
Vinyl chloride [75-01-4]	5,A1a	10,A1a	—	—
Vinyl cyanide, *see* Acrylonitrile				
Vinyl cyclohexene dioxide [106-87-6]—Skin	10,A2	60,A2	—	—
Vinylidene chloride [75-35-4]	5	20	20	80
Vinyl toluene [25013-15-4]	50	240	100	485
‡VM & P Naphtha [8032-32-4]	300	1,350	(400)	(1,800)
‡Warfarin [81-81-2]	—	0.1	—	(0.3)
Welding fumes (NOC†)	—	5,B2	—	—
Wood dust (certain hard woods as beech & oak)	—	1	—	—
Soft wood	—	5	—	10
Xylene [1330-20-7] (o-, m-, p-isomers)	100	435	150	655
m-Xylene α,α'-diamine [1477-55-0]—Skin	—	C 0.1	—	—
Xylidine [1300-73-8]—Skin	2	10	—	—
Yttrium [7440-65-5]	—	1	—	3
Zinc chloride fume [7646-86-7]	—	1	—	2
Zinc chromate [13530-65-9], as Cr	—	0.05,A2	—	—
Zinc oxide [1314-13-2]				
Fume	—	5	—	10
Dust	—	D	—	—
‡Zinc stearate [557-05-1]	—	D	—	(10)
Zirconium compounds [7440-67-2], as Zr	—	5	—	10

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‡ See Notice of Intended Changes.
* 1985-1986 Addition.
† NOC = Not otherwise classified.

Radioactivity: See Physical Agents section on Ionizing Radiation.

DUSTS

Substance	TLV-TWA
SILICA, SiO_2	
Crystalline	
‡ Quartz [14808-60-7]	In mppcf:[h] $\frac{300^{[i]}}{\%\ \text{quartz} + 10}$ For respirable dust in mg/m³: $\frac{10\ \text{mg/m}^{3[j]}}{\%\ \text{Respirable quartz} + 2}$ For "total dust," respirable and nonrespirable: $\frac{30\ \text{mg/m}^3}{\%\ \text{quartz} + 3}$
‡ Cristobalite [14464-46-1]	Use one-half value calculated from the count or mass formulae for quartz.
* Silica, fused [60676-86-0]	0.1 mg/m³, Respirable dust
‡ Tridymite [15468-32-3]	Use one-half the value calculated from formulae for quartz.
* Tripoli [1317-95-9]	0.1 mg/³ of contained respirable quartz dust.
‡ Amorphous [7631-86-9]	(20 mppcf[h])
*‡ Precipitated silica	‡(5mg/m³, Respirable dust) *10 mg/m³, Total dust
*‡ Silica gel	‡(5 mg/m³, Respirable dust) *10 mg/m³, Total dust

‡ *SILCATES and OTHER DUSTS (< 1% quartz)*

Asbestos[k]	
Amosite [12172-73-5]	0.5 fiber/cc,[l] A1a
Chrysotile [12001-29-5]	2 fibers/cc,[l] A1a
Crocidolite [12001-28-4]	0.2 fiber/cc,[l] A1a
Other forms	2 fibers/cc,[l] A1a
*‡Graphite (natural) [7782-42-5]	*2.5 mg/m³, Respirable dust ‡(5 mg/m³, Total dust)
‡Mica [12001-25-2]	(20 mppcf)
Mineral wool fiber	10 mg/m³
‡Perlite	(30 mppcf)
‡Portland cement	(30 mppcf)
*Soapstone	3 mg/m³, Respirable dust 6 mg/m³, Total dust
Talc (containing no asbestos fibers) [14807-96-6]	2 mg/m³, Respirable dust
*Talc (containing asbestos fibers)	Use asbestos TLV. However, should not exceed 2 mg/m³ respirable dust.
Nuisance particulates (see Appendix D):	
‡	(30 mppcf) or 10 mg/m³[m] of total dust < 1% quartz, or, ‡(5 mg/m³ respirable dust.)
Conversion factors: mppcf × 35.3 = Million particles per cubic meter = Particles per cc	
*‡*COAL DUST*	
‡	(2 mg/m³ (respirable dust fraction < 5% quartz).
*	If > 5% quartz, use respirable quartz value.

FOOTNOTES FOR DUSTS

(h) Millions of particles per cubic foot of air, based on impinger samples counted by light-field techniques.

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

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

Aerodynamic Diameter (μm) (unit density sphere)	% Passing Selector
≤ 2.0	90
2.5	75
3.5	50
5.0	25
10	0

(k) As determined by the membrane filter method at 400-450 x magnification (4 mm objective) phase contrast illumination.

(l) Fibers longer than 5 μm and with an aspect ratio equal to or greater than 3:1.

‡(m) (Containing less than 1% quartz; if quartz content > 1%, use formulae for quartz.)

NOTICE OF INTENDED CHANGES (for 1985-86)

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

Substance	[CAS #]	TWA ppm[a]	TWA mg/m³[b]	STEL ppm[a]	STEL mg/m³[b]
†Acrylamide	[79-06-1] — Skin	—	0.03,A2	—	—
Amitrole	[61-82-5]	—	0.2	—	—
Ammonium persulfate	[7727-54-1], as S_2O_8	—	5	—	—
Boron tribromide	[10294-33-4]	C 1	C 10	—	—
1,3-Butadiene	[106-99-9]	10,A2	22,A2	—	—
Carbon dioxide	[124-38-9]	5,000	9,000	30,000	54,000
Cobalt metal, dust & fume	[7440-48-4], as Co	—	0.05	—	0.1
Enflurane	[13838-16-9]	75	575	—	—
Grain dust		—	4	—	—
Halothane	[151-67-7]	50	400	—	—
Hydrogen bromide	[10035-10-6]	C 3	C 10	—	—
Hydrogen fluoride	[7664-39-3], as F	C 3	C 2.5	—	—
4,4-Methylene dianiline	[101-77-9]	0.1,A2	0.8,A2	—	—
†2-Nitropropane	[79-46-9]	10,A2	35,A2	(20,A2)	(70,A2)
Oxygen difluoride	[7783-41-7]	C 0.05	C 0.1	—	—
Persulfates, alkali metal, as	S_2O_8	—	5	—	—
Potassium persulfate	[7727-21-1], as S_2O_8	—	5	—	—
Sodium persulfate	[7775-27-1], as S_2O_8	—	5	—	—
Sulfur monochloride	[10025-67-9]	C 1	C 6	—	—
Sulfur pentafluoride	[5714-22-7]	C 0.01	C 0.1	—	—
Sulfur tetrafluoride	[7783-60-0]	C 0.1	C 0.4	—	—
Thionyl chloride	[7719-09-7]	C 1	C 5	—	—

Substance	[CAS #]	TWA ppm[a]	TWA mg/m³[b]	STEL ppm[a]	STEL mg/m³[b]
m-Toluidine	[108-44-1] — Skin	2	9	—	—
p-Toluidine	[106-49-0] — Skin	2,A2	9,A2	—	—
†1,2,3-Trichloropropane	[96-18-4] — Skin	10	60	—	—

DELETE THE TLV-STELs FOR THE FOLLOWING SUBSTANCES:

Acetylene tetrabromide
Aldrin
α-Alumina
Aluminum metal & oxide
2-Aminopyridine
Ammonium sulfamate
†n-Amyl acetate
†sec-Amyl acetate
Aniline & homologues
ANTU
†Asphalt (petroleum) fumes
Azinphos-methyl
Benomyl
†Benzene
†Biphenyl
Bismuth telluride & Se-doped
Boron oxide
Bromacil
Bromine pentafluoride
†2-Butoxyethanol
†sec-Butyl acetate
†tert-Butyl acetate
Cadmium dusts & salts
Calcium carbonate/marble
Calcium cyanamide
Captan
Carbaryl
Carbon black
Carbon tetrachloride
Cellulose (paper fiber)
Chloroform
Copper dusts & mists
Cotton dust, raw
†Crotonaldehyde
†Cumene
†Cyclohexane
†Cyclohexanone
†Cyclopentadiene
†Cyclopentane
Cyhexatin
2,4-D
DDT
Demeton
Diazinon
2-N-Dibutylaminoethanol
†Dibutyl phthalate
Dichlorodifluoromethane
1,1-Dichloro-1-nitroethane
Dichloropropene
Dichlorotetrafluoroethane
Dichlorvos
Dicyclopentadienyl iron
Dieldrin
†Diethyl phthalate
Difluorodibromomethane
Dimethyl acetamide
Dimethylformamide
1,1-Dimethylhydrazine
Dimethylphthalate
Dinitrobenzene

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[a] Parts of vapor or gas per million parts of contaminated air by volume at 25°C and 1 torr.
[b] Approximate milligrams of substance per cubic meter of air.
† 1985-1986 Revision or Addition.
Capital letters A, B, C & E refer to Appendices; C denotes ceiling limit.

Dinitro-o-cresol
Dinitrotoluene
Dioxane, tech. grade.
Diphenylamine
Diquat
Disulfiram
Disulfoton
†2,6-Ditert. butyl-p-cresol
Emery
Endosulfan
Endrin
Epichlorohydrin
EPN
†Ethyl acrylate
†Ethylbutyl ketone
Ethyl chloride
Ethylene dichloride
†Ethyl formate
Ethyl mercaptan
N-Ethylmorpholine
Ethyl silicate
Febram
Formamide
†Furfural
Germanium tetrahydride
†Glycidol
Gypsum
Hafnium
Heptachlor
Hexachlorocyclopentadiene
Hexachloronaphthalene
Hexafluoroacetone
Hydrogen peroxide
†Hydroquinone
†Indene
Indium & compounds
Iodoform
Iron oxide fume
Iron salts, soluble
†Isoamyl acetate
†Isobutyl alcohol
†Isopropoxyethanol
N-Isopropylaniline
Kaolin
Lead, inorganic dust & fumes
Limestone
Lindane
†L.P.G. (liquified petroleum gas)
Magnesite
Manganese cyclopentadienyl tricarbonyl
Marble/calcium carbonate
Methylacrylonitrile
†Methylal
†Methyl n-amyl ketone
N-Methyl aniline
Methyl bromide
†Methylcyclohexane
†Methylcyclohexanol
Methycyclopentadienyl manganese tricarbonyl
Methyl demeton
Methylene chloride
Methyl iodide
†Methyl methacrylate
Methyl parathion
Methyl silicate
Molybdenum, soluble & insoluble compounds
Naled
Nickel soluble compounds
Nicotine
Nitric oxide
Nitrobenzene
Nitroethane
Nitrogen trifluoride
Nitromethane
1-Nitropropane
†Nonane
†Parafffin wax fume
Parathion
Pentachloronaphthalene
Pentachlorophenol
Pentaerythritol
†Phenol
Phenothiazine
Phosphorus (yellow)
†Phthalic anhydride
†Pindone
Plaster of Paris
†Propargyl alcohol
†β-Propiolactone
†Propionic acid
†Propoxur
†Pyrethrum
†Pyridine
†Quinone
†Rosin core solder pyrolysis products
†Rotenone (commercial)
Rouge
Sesone

Silicon
Silicon carbide
Starch
Stibine
†Stoddard solvent
Strychnine
Sucrose
Sulfotep
Sulfur dioxide
Sulfur hexafluoride
2,4,5-T
Tantalum
Temephos
TEPP
1,1,1,2-Tetrachloro-2,2-difluoroethane
1,1,2,2-Tetrachloro-1,2-difluoroethane
1,1,2,2-Tetrachloroethane
Tetrachloronaphthalene
Tetraethyl lead
Tetramethyl lead
Tetramethyl succinonitrile
Tetryl
4,4'-Thiobis (6-tert. butyl-m-cresol)
Thiram
Tin, metal, oxide & insoluble compounds
Tin, organic compounds
Titanium dioxide
Tributyl phosphate
1,1,2-Trichloroethane
Trichloronaphthalene
Trifluorobromomethane
†Trimethyl benzene
Trimethyl phosphite
2,4,6-Trinitrotoluene (TNT)
Triorthocresyl phosphate
Triphenyl phosphate
†Turpentine
†VM & P naphtha
†Warfarin
Zinc stearate

NOTICE OF INTENDED CHANGES

DUSTS

Substance	TLV-TWA
SILICA, SiO_2	
Crystalline	
Quartz [14808-60-7]	0.1 mg/m³, Respirable dust
Cristobalite [14464-46-1]	0.05 mg/m³, Respirable dust
Tridymite [15468-32-3]	0.05 mg/m³, Respirable dust
Amorphous	
Diatomaceous earth (uncalcined) [68855-54-9]	10 mg/m³, Total dust
† Precipitated silica(m)	10 mg/m³, Total dust
† Silica gel(m)	10 mg/m³, Total dust

† 1985-1986 Revision or Addition.

†SILICATES and OTHER DUSTS[m]

Barium sulfate [7727-43-7]	10 mg/m³, Total dust
† Coal dust	2 mg/m³ respirable dust fraction[m]
† Graphite (natural) [7782-42-5]	2.5 mg/m³, Respirable dust
Graphite (synthetic)	10 mg/m³, Total dust
Mica [12001-26-2]	3 mg/m³, Respirable dust
Nuisance particulates (see Appendix D)	10 mg/m³, Total dust[m]
Perlite	10 mg/m³, Total dust
Portland Cement	10 mg/m³, Total dust

GENERIC LISTING

All mppcf values for mineral dusts will be eliminated in favor of equivalent respirable mass or total mass values, i.e., Appendix F.

FOOTNOTE(s)

(m) For silicates and other dusts, the values are for dust containing <1% quartz in the total dust. For coal dust, the value is for coal dust containing < 5% quartz in the respirable fraction. For materials containing more than these percentages of quartz, the environment should be evaluated against the TLV of 0.1 mg/m³ for respirable quartz. Even where the respirable quartz concentration is less than 0.1 mg/m³, the level of the major component should not exceed its TLV.

NOTICE OF INTENT TO CHANGE

APPENDIX A
Carcinogens

The guidelines explain how the Chemical Substances Threshold Limit Values Committee classifies substances found in the occupational environment as either carcinogenic in man or experimental animals. Scientific debate over the existence of biological thresholds for carcinogens is unlikely to be resolved in the near future. For most substances determined to be carcinogenic by the Committee, a value is given to provide practical guidelines for the industrial hygienist to control exposures in the workplace.

The Chemical Substances TLV Committee considers information from the following kinds of studies to be indicators of a substance's potential to be a carcinogen in humans: epidemiology studies, toxicology studies and, to a lesser extent, case histories. Because of the long latent period for many carcinogens, and for ethical reasons, it is often timely and prudent to base risk-management decisions on results from human toxicological studies. In order to recognize the qualitative differences in research results, two categories of carcinogens are designated in this booklet: A1—Confirmed Human Carcinogens; and A2—Suspected Human Carcinogens. All steps must be taken to keep exposures to any carcinogens to a minimum. Workers exposed to A1 carcinogens without a TLV should be properly equipped to insure virtually no contact with the carcinogen. Please see the section covering this Notice of Intent to Change in the *Documentation of the Threshold Limit Values* for a more complete description of these designations.

ADOPTED APPENDICES

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:

Substance	TLV
Asbestos	
Amosite	0.5 fiber[n]
Chrysotile	2 fibers[n]
Crocidolite	0.2 fiber[n]
Other forms	2 fibers[n]
bis-(Chloromethyl) ether	0.001 ppm
Chromite ore processing (chromate)	0.05 mg/m³, as Cr
Chromium (VI), certain water soluble compounds	0.05 mg/m³, as Cr
Coal tar pitch volatiles	0.2 mg/m³, as benzene solubles
Nickel sulfide roasting, fume and dust	1 mg/m³, as Ni
Vinyl chloride	5 ppm

† 1985-1986 Revision or Addition.

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

4-Aminodiphenyl — Skin
Benzidine — Skin
β-Naphthylamine
4-Nitrodiphenyl

For the substances in 1b, no exposure or contact by any route — respiratory, skin or oral, as detected by the most sensitive methods — shall be permitted. The worker should be properly equipped to insure virtually no contact with the carcinogen.

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

†Acrylamide — Skin	0.03 ppm
Acrylonitrile — Skin	2 ppm
**Amitrole	—
Antimony trioxide production	—
Arsenic trioxide production	—
Benzene	10 ppm
Benzo(a)pyrene	—
Beryllium	2 $\mu g/m^3$
1,3-Butadiene	10 ppm
Carbon tetrachloride — Skin	5 ppm
Chloroform	10 ppm
Chlormethyl methyl ether	—
Chromates of lead and zinc, as Cr	0.05 mg/m^3
Chrysene	—
3,3'-Dichlorobenzidine — Skin	—
Dimethyl carbamoyl chloride	—
1,1-Dimethylhydrazine — Skin	0.5 ppm
Dimethyl sulfate — Skin	0.1 ppm
Ethylene dibromide — Skin	—
Ethylene oxide	1 ppm
‡Formaldehyde	1 ppm
Hexachlorobutadiene	0.02 ppm
Hexamethyl phosphoramide — Skin	—
Hydrazine — Skin	0.1 ppm
4,4'-Methylene bis(2-chloroaniline) — Skin	0.02 ppm
4,4'-Methylene dianiline	0.1 ppm
Methyl hydrazine — Skin	C 0.2 ppm
Methyl iodide — Skin	2 ppm

2-Nitropropane	10 ppm
N-Nitrosodimethylamine — Skin	—
N-Phenyl-beta-naphthylamine	—
‡Phenylhydrazine — Skin	5 ppm
Propane sultone	—
β-Propiolactone	0.5 ppm
Propylene imine — Skin	2 ppm
o-Tolidine — Skin	—
o-Toluidine — Skin	2 ppm
p-Toluidine — Skin	2 ppm
Vinyl bromide	5 ppm
Vinyl cyclohexene dioxide — Skin	10 ppm

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

* * * * *

The Committee Guidelines for Classification of Experimental Animal Carcinogens

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

Determination of Approximate Threshold 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 purpose of standard-setting, this is of little moment, as an appropriate risk, or safety, factor can be applied to the approximate threshold, the magnitude of which is dependent on the degree of potency of the carcinogenic response.

To obtain the best "practical" threshold of neoplastic response, dosage decrements should be less than logarithmic. This becomes particularly important at levels greater than 10 ppm (or corresponding mg/m^3). Accordingly, after a range-finding determination has been made by logarithmic decreases, two additional

** See Notice of Intended Changes.
† 1985-1986 Addition.
‡ 1985-1986 Adoption.

dosage levels are required within the levels of "effect" and "no effect" to approximate the true threshold of neoplastic response.

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

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

EXCEPTIONS: No substance is to considered an occupational carcinogen of any practical significance which reacts by the respiratory route at or above 1000 mg/m³ for the mouse, 2000 mg/m³ for the rat; by the dermal route, at or above 1500 mg/kg for the mouse, 3000 mg/kg for the rat; by the gastrointestinal route at or above 500 mg/kg/d for a lifetime, equivalent to about 100 g T.D. for the rat, 10 g T.D. for the mouse. These dosage limitations exclude such substances as dioxane and trichlorethylene from consideration as carcinogens.

Examples: **1)** Dioxane — rats, hepatocellular and nasal tumors from 1015 mg/kg/d, oral; **2)** Trichloroethylene — female mice, tumors (30/98 at 900 mg/kg/d), oral.

A. *Industrial Substances of High Carcinogenic Potency in Experiemental Animals.*

1. A substance to qualify as a carcinogen of high potency must fulfill *one* of the three following conditions (a, b, or c) in two animal species:

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

Examples: **1)** bis(chloromethyl) ether — malignant tumors, rats, at 0.47 mg/m³ (0.1 ppm) in 2 years; **2)** Hexamethyl phosphoramide — nasal squamous cell carcinoma, rats at 0.05 ppm, in 13 months.

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

Examples: **1)** 7,12-Dimethylbenz(a)anthracene — skin tumors at 0.12-0.8 mg T.D. in four weeks; **2)** Benzo(a)pyrene — mice 12 μg, 3 ×/wk for 18 mos. T.D. 2.6 mg, 90.9% skin tumors.

   c. ***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: **1)** 7,12-Dimethylbenz(a)anthracene — mammary tumors from 10 mg 1X; **2)** 3-Methylcholanthrene — Tumors at 3 sites from 8 mg in 89 weeks; **3)** Benzo(a)pyrene — mice, 3.9% leukemias, from 30 mg T.D. 198 days.

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

B. *Industrial Substances of Intermediate Carcinogenic Potency in Experimental Animals.*

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

Example: Carbamic acid ethyl ester — dermal, mammary tumors, mice, 100%, 63 weeks, 500-1400 mg T.D. Gastrointestinal, various type tumors, mice 42 weeks, 320 mg T.D. Gastrointestinal, various type tumors, rats, 60 weeks, 110-930 mg T.D.

C. *Industrial Substances of Low Carcinogenic Potency in Experimental Animals.*

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

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

Examples: **1)** Beryl (beryllium aluminum silicate) — malignant lung tumors, rats, at 15 mg/m³ at 17 months; **2)** Benzidine — various tumors, rats, 10-20 mg/m³ at > 13 months.

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

Examples: **1)** Shale tar — mouse, 0.1 ml × 50 = 5 g T.D. 59/60 skin tumors; **2)** Arsenic trioxide — man, dose unknown, but estimated to be high.

3. ***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 concentraiton should be minimal.

B2. ***Welding Fumes — Total Particulate (NOC)†***
TLV-TWA, 5 mg/m³

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

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

* Trade Names: Algoflon, Fluon, Teflon, Tetran.
† Not otherwise classified (NOC).

APPENDIX C
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 A.1 and B.1).

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 or 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 (C_1/T_1 + or + C_2/T_2, etc.) itself has a value exceeding unity (*see* Example B.1).

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.

Examples of TLVs for Mixtures

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

1. General case, where air is analyzed for each component, the TLV of mixture =

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

Note: It is essential that the atmosphere be analyzed both qualitatively and quantitatively for each component present, in order to evaluate compliance or non-compliance with this calculated TLV.

Example A.1: Air contains 400 ppm of acetone (TLV, 750 ppm), 150 ppm of sec-butyl acetate (TLV, 200 ppm) and 100 ppm of methyl ethel ketone (TLV, 200 ppm).

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

$$\frac{400}{750} + \frac{150}{200} + \frac{100}{200} = 0.53 + 0.75 + 0.5 = 1.78$$

Threshold Limit is exceeded.

2. 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. When the percent composition (by weight) of the liquid mixture is known, the TLVs of the constituents must be listed in mg/m³. TLV of mixture =

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

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.)

Example A.2: Liquid contains (by weight):

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

30% methyl chloroform: TLV = 350 ppm or 1900 mg/m³
1 mg/m³ ≡ 0.18 ppm

20% perchloroethylene: TLV = 50 ppm or 335 mg/m³
1 mg/m³ ≡ 0.15 ppm

$$\text{TLV of Mixture} = \frac{1}{\frac{0.5}{1600} + \frac{0.3}{1900} + \frac{0.2}{335}}$$

$$= \frac{1}{0.00031 + 0.00016 + 0.0006}$$

$$= \frac{1}{0.00107} = 935 \text{ mg/m}^3$$

of this mixture
50% or (935)(0.5) = 468 mg/m³ is heptane
30% or (935)(0.3) = 281 mg/m³ is methyl chloroform
20% or (935)(0.2) = 187 mg/m³ is perchloroethylene

These values can be converted to ppm as follows:

heptane: 468 mg/m³ × 0.25 = 117 ppm
methyl chloroform: 281 mg/m³ × 0.18 = 51 ppm
perchloroethylene: 187 mg/m³ × 0.15 = 29 ppm

TLV of mixture = 117 + 51 + 29 = 197 ppm, or 935 mg/m³

B. *Independent effects.* TLV for mixture =

$$\frac{C_1}{T_1} = 1; \quad \frac{C_2}{T_2} = 1 \quad \frac{C_3}{T_3} = 1; \text{ etc.}$$

Example B.1: 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.

C. *TLV for mixtures of mineral dusts.* For mixtures of biologically active mineral dusts the general formula for mixtures given in A.2.

APPENDIX D

Some Nuisance Particulates[m]

‡TLV-TWA, (30 mppcf) or
10 mg/m³ of total dust[m] or, (5 mg/m³ respirable dust)

α-Alumina (Al_2O_3)	Marble
Calcium carbonate	Mineral wool fiber
Calcium silicate	Pentaerythritol
Cellulose (paper fiber)	Piaster of Paris
Emery	Portland cement
Glycerin mist	Rouge
‡Graphite (synthetic)	Silicon
Gypsum	Silicon carbide
Kaolin	Starch
Limestone	Sucrose
Magnesite	Titanium dioxide

Vegetable oil mists (except castor oil, cashew nut or similar irritant oils)	Zinc stearate Zinc oxide dust

APPENDIX E
Some Simple Asphyxiants[o]

Acetylene	Hydrogen
Argon	Methane
Ethane	Neon
Ethylene	Propane
Helium	Propylene

‡APPENDIX F
Conversion of mppcf to Mass Concentration

Calculations for Conversion of Particle Count Concentration (by Standard Light Field — Midget Impinger Techniques), in mppcf, to Respirable Mass Concentration (by Respirable Sampler) in mg/m³.[1]

1. In 1967, Jacobson and Tomb,[1] derived an empirical relationship of 5.6 mppcf to 1 milligram of respirable dust per cubic meter of air, based on 23 sets of samples, mostly coal dust. Studies on conversion factors have been undertaken and preliminary evidence suggests that the application of any single conversion factor may not be adequate for use in risk assessments, epidemiology studies, or setting TLVs.

   The following calculations result in an equivalence of 6.37 mppcf to 1 mg/m³ of respirable dust. Thus, an approximate ratio of 6 mppcf to 1 mg/m³ of respirable dust is suggested for conversion of TLVs from a count to a mass basis when the density and mass median diameter have not been determined.

2. Basic assumptions:

   a. Average density for silica containing dusts ≈ 2.5 g/cm³ (2500 mg/cm³). Pulmonary significant dust densities may vary from 1.2 g/cm³ for coal dust to 3.1 g/cm³ for Portland cement. Silica densities vary from 2.2 (amorphous) to 2.3 (cristobalite and tridymite) to 2.5 (α-quartz) g/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
   $= 4/3 \bullet \pi \bullet (0.75 \times 10^{-4})^3$
   $= 1.77 \times 10^{-12}$ cm³

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

   c. 1 particle/ft³ = 35.5 part./m³ (since 35.5 ft³ = 1 m³)
   10^6 part./ft³ = mppcf = 35.3×10^6 part./m³
   wt. of 1 mppcf ≡ 35.5×10^6 part./m³ $\times\ 4.425 \times 10^{-9}$ mg/part.
   1 mppcf ≡ 0.157 mg/m³, or
   6.37 mppcf ≡ 1 mg/m³, or
   ≈ 6 mppcf ≡ 1 mg/m³

Reference

1. **Jacobson, M. and T.F. Tomb:** Relationship between Gravimetric Respirable Dust and Concentration and Midget Impinger Number Concentration. *Am. Ind. Hyg. Assoc. J. 28*:554 (Nov.-Dec. 1967).

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

(o) As defined in the Introduction.

‡ See Notice of Intended Changes.

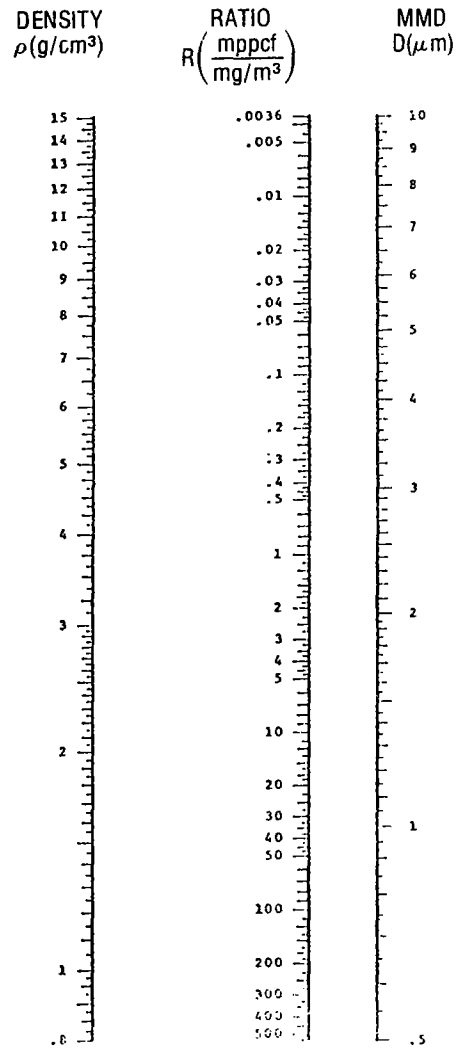

Figure 1—Ratio of Particle Count—mppcf to Respirable Mass Concentration—mg/m³ (as function of density and mmd). (Prepared by P.E. Caplan and R.J. Smith.)

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	—
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 specific, respirable mass is presumed to equal approximately 50% of total mass.

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

APPENDIX G

Chemical Substances and Other Issues Under Study*

Chemical Substances

Acetonitrile
Amines (mono, di- & tri-)
Allyl chloride
Asbestos
Atrazine
Captafol
o-Chlorotoluene
Copper dust & fume
Cyclohexanone
Diethylenetriamine
Epichlorohydrin
Ethyl chloride

Ethylene dichloride
Gasoline (unleaded)
Hexachlorocyclopentadiene
Isocyanates
Jet fuels
Methyl chloride
Nickel, metal & soluble compounds
Osmium tetroxide
Perfluorinated chemicals
Petroleum fuels
Petroleum solvents
Piperizine
Propylene chloride
1,1,2,2-Tetrachloro-1,2-difluoroethane
1,1,2,2-Tetrachlorethane
Tetrachloronaphthalene
m-Xylene 2,2'-diamine (MXDA; meta-meta-xylenediamine)

Other Issues

1. Is the current aspect ratio better than other ratios for health protection and/or differentiation of asbestos fibers?
2. *Ceiling Limits*—In light of today's instrumentation (quick response) and STELs, are ceiling limits needed and, if so, what criteria would determine their appropriateness?
3. *Soluble and Insoluble Compounds* — What quantitative criteria should be used in differentiating between soluble and insoluble for TLV use?

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* Information, data especially, and comments are solicited to assist the committee in its deliberations and in the development of draft documents. Draft documentations are used by the committee to decide what action, if any, to recommend on a given substance or question.

APPENDIX H
Registered Trade Names

Trade Name	Generic Name	CAS No.
Abate	Temephos	3383-96-8
Ammate	Ammonium sulfamate	7773-06-0
Azodrin	Monocrotophos	6923-22-4
Baygon	Propoxur	114-26-1
Baytex	Fenthion	55-38-9
Bidrin	Dicrotophos	141-66-2
Bolstar	Sulprofos	35400-43-2
Butyl Cellosolve	2-Butoxyethanol	111-76-2
Cellosolve acetate	2-Ethoxyethyl acetate	111-15-9
Coyden	Clopidol	2971-90-6
Crag herbicide	Sesone	136-78-7
Dasanit	Fensulfothion	115-90-2
Delnav	Dioxathion	78-34-2
Dibrom	Naled	300-76-5
Difolatan	Captafol	2425-06-1
Disyston	Disulfoton	298-04-4
Dursban	Chlorpyrifos	2921-88-2
Dyfonate	Fonofos	944-22-9
Furadan	Carbofuran	1563-66-2
Guthion	Azinphos-methyl	86-50-0
Lannate	Methomyl	16752-77-5
Methyl Cellosolve	2-Methoxyethanol	109-84-4
Methyl Cellosolve acetate	2-Methoxyethyl acetate	110-49-6
Nemacur	Fenamiphos	22224-92-6
Nialate	Ethion	563-12-2
N-Serve	Nitrapyrin	1929-82-4
Pival	Pindone	83-26-1
Plictran	Cyhexatin	1312 1-70-5
Sencor	Metribuzin	21087-64-9
Sevin	Carbaryl	63-25-2
Teflon	Polytetrafluoro-ethylene	9002-84-0
Thimet	Phorate	298-02-2
Thiodan	Endosulfan	115-29-7
Tordon	Picloram	1918-02-1
Zoalene	Dinitolmide	148-01-6

Biological Exposure Indices

Proposed by ACGIH for 1985-86

1984-85 BIOLOGICAL EXPOSURE INDICES COMMITTEE

Vera F. Thomas, Ph.D., University of Miami—*Chair*
Larry K. Lowry, Ph.D., NIOSH
J. Thomas Pierce, Ph.D., University of North Alabama
Jon Rosenberg, M.D., California Dept. of Health Services/Dept. of Industrial Relations
Anthony A. Thomas, M.D., Retired
Janice W. Yager, Ph.D., University of California-Berkeley

CONSULTANTS

Mitchell R. Zavon, M.D.

INTRODUCTION

BIOLOGICAL EXPOSURE INDICES

Biological Exposure Indices (BEIs) represent warning levels of biological response to the chemical, or warning levels of the chemical or its metabolic product(s) in tissues, fluids, or exhaled air of exposed workers, regardless of whether the chemical was inhaled, ingested, or absorbed via skin. Introduction of the BEI is a step in the evolution of the concept of TLVs. The BEI provides the health personnel with an additional tool to provide protection for the worker. Use of body fluids and appendages such as hair or nails for measuring the absorbed amount of a substance has long been a standard practice for certain substances. Lead is a classical example of a substance for which blood concentrations have long been considered the critical value in determining "safe" versus "unsafe" exposures. Two problems hindered the wider use of biological measurements as indicators of "safe" environmental exposures: 1) the relatively wide range in individual response to a substance and the wide range of "normal" that has to be considered; and 2) the lack of simple specific analytical methods of sufficient sensitivity. Both problems are capable of solution, and we believe that sufficient progress has been made to begin utilizing selected BEIs which can be used as a guide to "safe" exposures to toxic chemicals. The BEI is considered supplementary to an airborne TLV.

TLVs are intended to provide the industrial hygienist with an additional measure to aid in the design of engineering controls or for temporary use of personnel protective equipment which will protect almost all exposed workers from untoward effects of chemical exposure. In principle, TWA-TLVs are designed to prevent exposures which may cause acute or chronic adverse effects. They are also intended to avoid attendant deterioration of normal physiological function. This approach is based on the assumption that for nearly all workers there is a tolerable exposure limit and a tolerable body burden of airborne material. If this assumption is valid, there should be a range of safe biologically insignificant changes of various measures of body function.

TLVs are a measure of the composition of the external environment surrounding the worker. BEIs are a measure of the amount of chemical *absorbed* into the body. The concept of the BEI is particularly useful in evaluating exposures to substances with significant absorption through the skin.

The biological determinant on which the BEIs are based can furnish two kinds of information useful in the control of worker exposure; 1) measure of the worker's individual response, and 2)

measure of the worker's individual overall exposure. Measurements of response furnish an estimate of the physiological status of the worker and can be made by, *a)* determining changes in the amount of a critical biochemical constituent, *b)* determining changes in activity of a critical enzyme, and *c)* determining changes in a physiological function. Measurements of exposure can be made by, *a)* determining the chemical in exhaled air, urine, blood, hair, nails, body tissues and fluids, *b)* determining the metabolite(s) of the chemical in tissues and fluids, and *c)* determining the extent of specific biochemical and physiological changes induced by the chemical.

Recommended values of BEIs are based on data obtained in epidemiological and field studies or determined as bioequivalent to a TLV by means of pharmacokinetic analysis of data from controlled human studies. Most chemicals (including organic solvents) are initially absorbed and eliminated fairly rapidly — usually with initial half-life values measured in a few hours or even minutes. Rapidly changing concentrations in body fluids complicate the interpretation of data and the average body burden of a chemical attained during a work shift can easily be over-predicted or under-predicted. Furthermore, biological measurements fail in most instances to detect transient periods of over-exposure during the work shift. Because elimination of chemicals and their metabolic products, as well as biological changes induced by exposure to the chemical, are kinetic events, the listed BEIs are strictly related to 8-hour exposures and to the specified timing for the collection of biological samples.

Factors to be considered. There are other factors to be considered when the BEI is applied. Among the factors which must be considered in using BEIs are: *a)* changes induced by strenuous physical activity; *b)* changes induced by environmental conditions (altitude, heat, diet, etc.); *c)* changes induced by water intake; *d)* changes in physiological functions induced by preexisting disease or congenital variation; *e)* changes in metabolism induced by congenital variation of metabolic pathways; and *f)* changes in metabolic pathway induced by simultaneous administration of another chemical (induction or inhibition of activity of a critical enzyme by medication or by preexposure or coexposure to another chemical).

For BEIs based on urine analysis, a simple measurements of concentrations can provide sufficient information on exposure, but in many instances, measurements of elimination rates provide more precise information. Urinary concentrations related to creatinine represent a reasonable compromise between the accuracy of the information and the technical means of obtaining the data.

Some BEIs are not protective of an identified population, or are nonspecific. The correlation between the exposure and biological determinant is weakened by variables introduced by large interindividual variation in response to the chemical or by time factors and fluctuation of exposure concentration. In such cases the BEIs carry the following notations:

"R" Notation. Indicates that an identifiable population group might have an increased susceptibility to the effect of the chemical which leaves it unprotected by the recommended BEI. The specific documentation should be consulted for detailed information.

"*" Notation. Some determinants are nonspecific, since different chemicals may bear the same biological response. Such BEIs carry "*" notation. These nonspecific tests are preferred because they are easy to use and, in many instances, offer a better correlation between exposure and response than specific tests. In such instances, a BEI for a specific less quantitative biological determinant is recommended as a confirmatory test. The documentation should be consulted for information on factors affecting interpretation of such a BEI.

"" Notation.*** Indicates that the biological determinant is a specific indicator of exposure to the chemical but the quantitative interpretation of the measurements is very ambiguous, and that the relationship between the TLV and BEI is markedly weakened by variables in timing, fluctuation of exposure concentrations, and by other circumstantial variables. Such biological determinants should be used as confirmatory tests; and their BEIs should be applied cautiously, mainly for confirmation of exposures indicated by nonspecific BEIs.

"†" Notation. The determinant is usually present in the biological specimens collected from subjects without occupational exposure. For information on background levels consult the documentation.

"G" Notation. Because of the wide interindividual variation in response to some chemicals, the BEI is in some instances recommended as a mean value of a group test for workers subjected to a similar level of occupational exposure, rather than as an index for an individual. Such BEIs carry "G" notation.

The table includes BEIs for which a sufficient data base is available and on which the committee took action. Some BEIs are more suitable for correlation with TLV-TWAs than others. Other BEIs are preferable for evaluating recent exposure or for confirmation of exposure. For specific instances the documentation should be consulted.

Workers are not expected to suffer any ill effects as long as the described measurement of the determinants are maintained within limits of the recommended BEIs. Measurements outside these limits are not necessarily indicators of a disease process. However, if these deviate measurements persist, it is an indication that the individual should be examined by a physician to determine whether there is any health effect. The workplace and work practices should be investigated further.

NOTE: *It is strongly advisable to consult the specific documentation before invoking the BEIs listed in the the following table.*

Indices	Timing	BEI	Additional Notation
** Toluene in venous blood	End of shift	1 mg/L	
** Toluene in end-exhaled air	During shift	20 ppm	
TRICHLOROETHYLENE [79-01-6]			
* Trichloroacetic acid in urine	End of workweek	100 mg/L	G
* Trichloroacetic acid and trichloroethanol in urine	End of workweek and end of shift	300 mg/L 320 mg/g creat.	G G
* Free trichloroethanol in blood	End of shift and end of workweek	4 mg/L	
** Trichloroethylene in end-exhaled air	Prior to shift and end of workweek	0.5 ppm	
XYLENES [1330-20-7]			
Methylhippuric acids in urine	End of shift Last 4 hrs of shift	1.5 g/g creat. 2 mg/min	

‡1985-86 Addition or Revision.

TLVs®

Threshold Limit Values for Physical Agents in the Work Environment Adopted by ACGIH with Intended Changes for 1985-86

1984-85 PHYSICAL AGENTS TLV COMMITTEE

Herbert H. Jones, Retired—*Chair*
Peter A. Breysse, University of Washington
Irving H. Davis, Michigan Dept. of Public Health
Zory R. Glaser, Ph.D., National Center for Devices & Radiological Health/FDA
Allan P. Heins, Ph.D., OSHA—*Secretary*
Edward J. Largent, Retired
John C. Mitchell, USAF
Anthony M. Muc, Ph.D. Ontario Ministry of Labour
William E. Murray, NIOSH
Wordie H. Parr, Ph.D., Retired
David H. Sliney, USAEHA
Jukka Pekka Starck, Finnish Institute of Occupational Health
COL Robert T. Wangemann, US Army
Donald E. Wasserman, Wright State University
Thomas K. Wilkinson, National Institutes of Health

CONSULTANTS

Gerald V. Coles
Richard A. Ilka, M.D.
Robert N. Ligo, M.D.

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 physiocal 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 revision 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 also solicits suggestions of physical agents to be added to the list. The suggestions should be accompanied by substantiating evidence.

ADOPTED

THRESHOLD LIMIT VALUES

HEAT STRESS

These Threshold Limit Values (TLVs) refer to heat stress conditions under which it is believed that nearly all workers may be repeatedly exposed without adverse health effects. The TLVs shown in Table 1 are based on the assumption that nearly all acclimatized, fully clothed workers with adequate water and salt intake should be able to function effectively under the given working conditions without exceeding a deep body temperature of 38°C.[1,2]

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

1. Outdoors with solar load:
   $WBGT = 0.7\ NWB + 0.2\ GT + 0.1\ DB$
2. Indoors or Outdoors with no solar load:
   $WBGT = 0.7\ NWB + 0.3\ GT$

where:

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

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

Higher heat exposures than shown in Table 1 are permissible if the workers have been undergoing medical surveillance and it has been established that they are more tolerant to work in heat than the average worker. Workers should not be permitted to continue their work when their deep body temperature exceeds 38.0°C.

Evaluation and Control

I. *Measurement of the Environment*

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

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

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° 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 by Minard.[3,4]

II. *Work Load Categories*

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

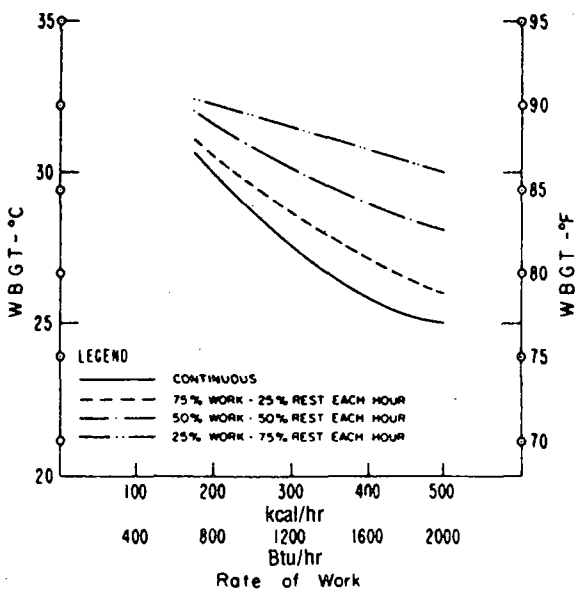

Figure 1—Permissible Heat Exposure Threshold Limit Values.

TABLE 2
Assessment of Work Load[9]

Average values of metabolic rate during different activities.

A. Body position and movement	**kcal/min**
Sitting	0.3
Standing	0.
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	1.7	
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	

(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, or

(3) heavy work (359-500 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 I.

B. The ranking of the job may be performed either by measuring the worker's metabolic rate while performing his job or by estimating his metabolic rate with the use of Tables 2 and 3. Additional tables available in the literature[5-8] may be utilized also. When this method is used the permissible heat exposure limit can be determined by Figure 1.

TABLE 3
Activity Examples[9]

- Light hand work: writing, hand knitting
- Heavy hand work: typewriting
- Heavy work with one arm: hammering in nails (shoemaker, upholsterer)
- Light work with two arms: filing metal, planing wood, raking of a garden
- Moderate work with the body: cleaning a floor, beating a carpet
- Heavy work with the body: railroad track laying digging, barking trees

Simple Calculation

Assembly line work using a heavy hand tool.

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

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

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

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

where M_1, M_2...and M_n are estimated or measured metabolic rates for the various activities and rest periods of the worker during the time periods t_1, t_2...and t_n (in minutes) as determined by a time study.

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

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

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

The permissible exposure limits for continuous work are applicable where there is a work-rest regimen of a 5-day work week and an 8-hour work day with a short morning and afternoon break (approximately 15 minutes) and a longer lunch break (approximately 30 minutes). Higher exposure limits are permitted if additional resting time is allowed. All breaks, including unscheduled pauses and administrative or operational waiting periods during work, may be 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 whall 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% (1 g NaCl to 1.0 liter or 1 level tablespoon of salt to 15 quarts of water). The added salt shall be completely dissolved before the water is distributed, and the water shall be kept reasonably cool.

V. *Other Considerations*

A. *Clothing:* The permissible heat exposure TLVs are valid for light summer clothing as customarily worn by workers when working

under hot environmental conditions. If special clothing is required for performing a particular job and this clothing is heavier or it impedes sweat evaporation or has higher insulation value, the worker's heat tolerance is reduced, and the permissible heat exposure limits indicated in Table 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 this 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 unfit workers must be exposed to heat stress conditions.

References

1. *Health Factors Involved in Working Under Conditions of Heat Stress.* WHO Technical Report Series No. 412 (1969).
2. **Dukes-Dobos, F.N. and A. Henschel:** Development of Permissible Heat Exposure Limits for Occupational Work. *ASHRAE Journal 15(9):*57-62 (Sept. 1973).
3. **Minard, D.:** *Prevention of Heat Casualities in Marine Corps Recruits, Period of 1955-60, with Comparative Incidence Rates and Climatic Heat Stresses in Other Training Categories.* Research Report No. 4, Contract No. MR 005.01-0001.01, Naval Medical Research Institute, Bethesda, MD (Feb. 21 1961). Published in *Military Medicine 126(44):*261-272 (April 1961).
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5. **Astrand, Per-Olof and Kaare Rodahl:** *Textbook of Work Physiology.* McGraw-Hill Book Co., New York, San Francisco (1970).
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8. **Durnin, J.V.G.A. and R. Passmore:** *Energy, Work and Leisure.* Heinemann Educational Books, Ltd., London (1967).
9. **Lehmann, G.E., A. Muller and H. Spitzer:** Der Kalorienbedarb bie Gewerblicher Arbeit. *Arbeitsphysiol. 14:*166 (1950).

IONIZING RADIATION

The Committee accepts the philosophy and recommendations of the National Council on Radiation Protection and Measurements (NCRP) for the ionizing radiation TLV. The NCRP is charted by Congress to, in part, collect analyze, develop and disseminate information and recommendations about protection against radiation and about radiation measurements, quantities and units, including development of basic concepts in these areas. NCRP Report No. 39 provides basic philosophy and concepts leading to protection criteria established in the same report.[1] Other NCRP reports address specific areas of radiation protection and, collectively, provide an excellent basis for establishing a sound program for radiation control. The Committee recommends the listed references as substantative documentation of a sound basis for ionizing radiation protection. The Committee also strongly recommends that all exposure to ionizing radiation be kept as low as reasonably achievable within the stated guidance.

References

1. *Basic Radiation Protection Criteria.* NCRP Report No. 39 (January 15, 1971).
2. *Maximum Permissible Body Burdens and Maximum Permissible Concentrations of Radionuclides in Air and in Water for Occupational Exposure.* National Bureau of Standards Handbook 69, (June 5, 1959), with *Addendum 1* (August 1963). Available as NCRP Report No. 22.

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

Limiting Apertures

The TLVs expressed as radiant exposure or irradiance in this section may be averaged over an aperture of 1 mm except for TLVs for the eye in the spectral range of 400-1400 nm, which should be averaged over a 7 mm limiting aperture (pupil); and except for all TLVs for wavelengths between 0.1-1 mm where the limiting aperture is 10 mm. No modification of the TLVs is permitted for pupil sizes less than 7 mm.

The TLVs for "extended sources" apply to sources which subtend an angle greater than α (Table 7) which varies with exposure time. This angle is *not* the beam divergence of the source.

Correction Factors A and B (C_A and C_B)

The TLVs for ocular exposure in Tables 4 and 5 are to be used as given for all wavelength ranges. The TLVs for wavelengths between 700 nm and 1049 nm are to be increased by a uniformly extrapolated factor (C_A) as shown in Figure 2. Between 1049 nm and 1400 nm, the TLV has been increased by a factor (C_A) of five. For certain exposure times at wavelengths between 550 nm and 700 nm, correction factor (C_B) must be applied.

The TLVs for skin exposure are given in Table 6. The TLVs are to be increased by a factor (C_A) as shown in Figure 2 for

wavelengths between 700 nm and 1400 nm. To aid in the determination of TLVs for exposure durations requiring calculations of fractional powers Figures 3, 4, 5 and 6 may be used.

‡*Repetitively Pulsed Lasers*

Since there are few experimental data for multiple pulses, caution must used be 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 IV, V or VII or 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.

‡ See Notice of Intended Changes.

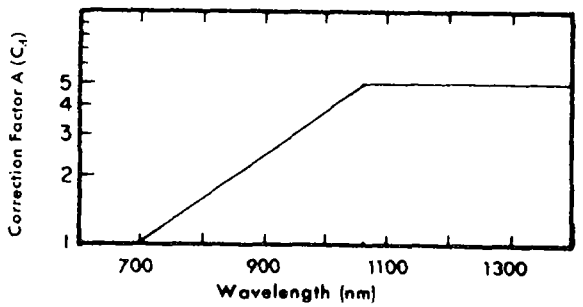

Figure 2—TLV correction factor for λ = 700–1400 nm.* (* For λ = 700–1049 nm, $C_A = 10^{[0.002(\lambda-700)]}$; For λ = 1050–1400 nm, C_A = 5.)

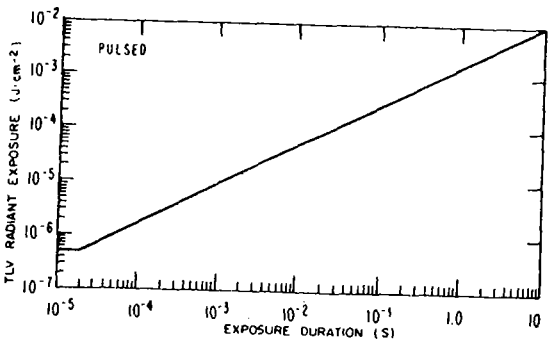

Figure 3a—TLV for intrabeam (direct) viewing of laser beam (400-700 nm).

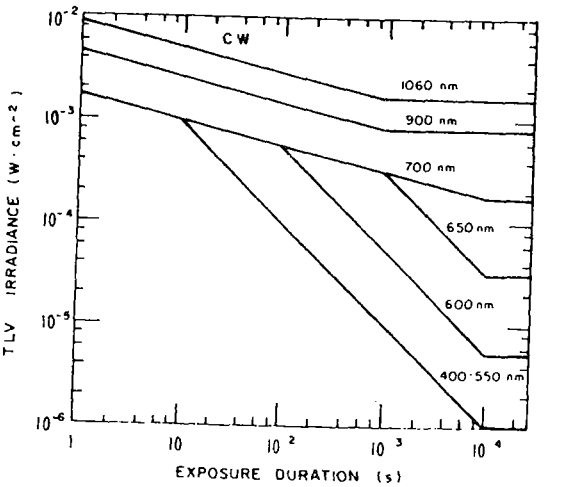

Figure 3b—TLV for intrabeam (direct) viewing of CW laser beam (400-1400 nm).

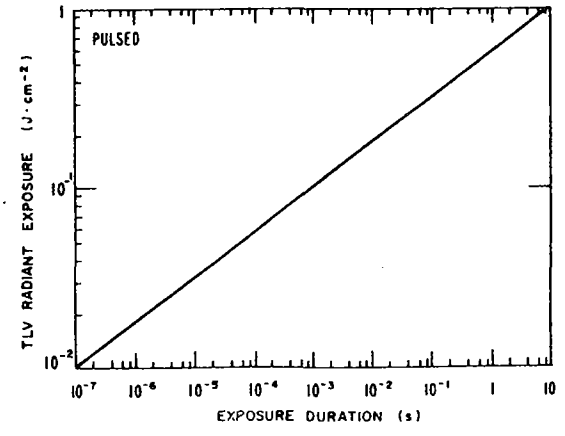

Figure 4a — TLV for laser exposure of skin and eyes for far-infrared radiation (wave-lengths greater than 1.4 μm).

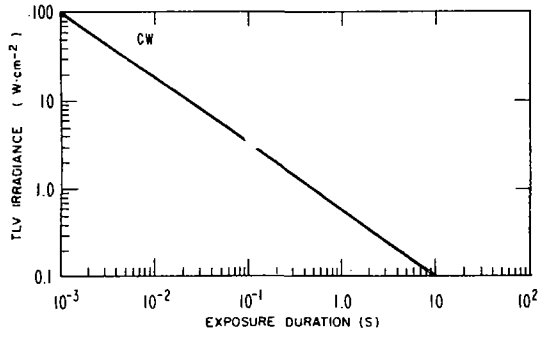

Figure 4b — TLV for CW laser exposure of skin and eyes for far-infrared radiation (wave-lengths greater than 1.4 μm).

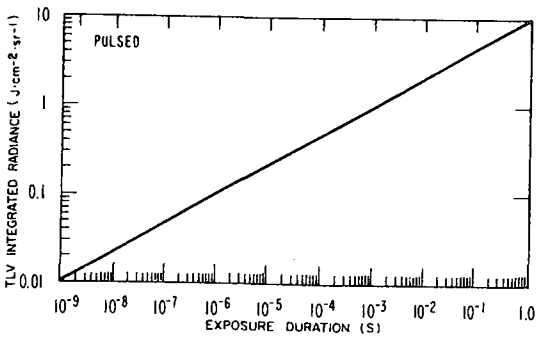

Figure 5a — TLV for extended sources or diffuse reflections of laser radiation (400-700 nm).

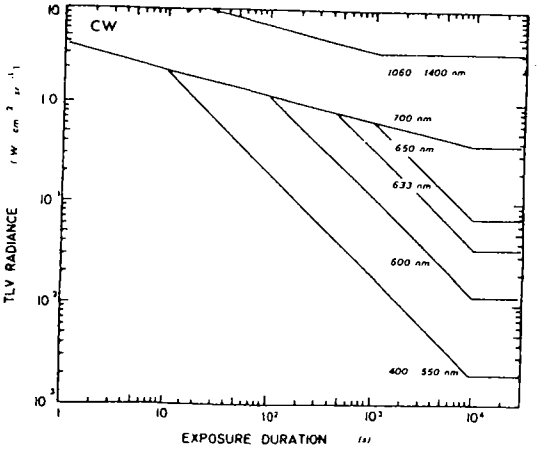

Figure 5b — TLV for extended sources or diffuse reflections of laser radiations (400-1400 nm).

TABLE 4
Threshold Limit Value for Direct Ocular Exposures (Intrabeam Viewing) from a Laser Beam

Spectral Region	Wave Length	Exposure Time, (t) Seconds	TLV	
UVC	200 nm to 280 nm	10^{-9} to 3×10^{4}	3	mJ • cm^{-2}
UVB	280 nm to 302 nm	"	3	"
	303 nm	"	4	"
	304 nm	"	6	"
	305 nm	"	10	"
	306 nm	"	16	"
	307 nm	"	25	"
	308 nm	"	40	"
	309 nm	"	63	"
	310 nm	"	100	"
	311 nm	"	160	"
	312 nm	"	250	"
	313 nm	"	400	"
	314 nm	"	630	"

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

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UVA	315 nm to 400 nm	10^{-9} to 10	.56 $t^{1/4}$ J • cm^{-2}
	" "	10 to 10^{3}	1.0 J • cm^{-2}
	" "	10^{3} to 3×10^{4}	1.0 mW • cm^{-2}
Light	400 nm to 700 nm	10^{-9} to 1.8×10^{-5}	5×10^{-7}J • cm^{-2}
	400 nm to 700 nm	1.8×10^{-5} to 10	1.8 (t/ $\sqrt[4]{t}$) mJ • cm^{-2}
	400 nm to 549 nm	10 to 10^{4}	10 mJ • cm^{-2}
	550 nm to 700 nm	10 to T_1	1.8 (t/ $\sqrt[4]{t}$) mJ • cm^{-2}
	550 nm to 700 nm	T_1 to 10^{4}	10 C_B mJ • cm^{-2}
	400 nm to 700 nm	10^{4} to 3×10^{4}	C_B μW • cm^{-2}
IR-A	700 nm to 1049 nm	10^{-9} to 1.8×10^{-5}	5 $C_A \times 10^{-7}$ J • cm^{-2}
	700 nm to 1049 nm	1.8×10^{-5} to 10^{3}	1.8 C_A (t/ $\sqrt[4]{t}$) mJ • cm^{-2}
	1050 nm to 1400 nm	10^{-9} to 10^{-4}	5×10^{-6} J • cm^{-2}
	1050 nm to 1400 nm	10^{-4} to 10^{3}	9(t/ $\sqrt[4]{t}$) mJ • cm^{-2}
	700 nm to 1400 nm	10^{3} to 3×10^{4}	320 C_A μW • cm^{-2}
IR-B & C	1.4 μm to 10^{3} μm	10^{-9} to 10^{-7}	10^{-2} J • cm^{2}
	" "	10^{-7} to 10	0.56 $\sqrt[4]{t}$ J • cm^{-2}
	" "	10 to 3×10^{4}	0.1 W • cm^{-2}

81

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 5
Threshold Limit Values for Viewing a Diffuse Reflection of a Laser Beam or an Extended Source Laser

Spectral Region	Wave Length	Exposure Time, (t) Seconds	TLV
UV	200 nm to 400 nm	10^{-9} to 3×10^{4}	Same as Table 4
Light	400 nm to 700 nm	10^{-9} to 10	$10\ \sqrt[4]{t}$ J • cm^{-2} • sr^{-1}
	400 nm to 549 nm	10 to 10^{4}	21 J • cm^{-2} • sr^{-1}
	550 nm to 700 nm	10 to T_1	$3.83\ (t/\sqrt[4]{t})$ J • cm^{-2} • sr^{-1}
	550 nm to 700 nm	T_1 to 10^{4}	21 C_B J • cm^{-2} • sr^{-1}
	400 nm to 700 nm	10^{4} to 3×10^{4}	2.1 $C_B t \times 10^{-3}$ W • cm^{-2} • sr^{-1}
IR-A	700 nm to 1400 nm	10^{-9} to 10	$10\ C_A\ \sqrt[4]{t}$ J • cm^{-2} • sr^{-1}
	700 nm to 1400 nm	10 to 10^{3}	$3.83\ C_A\ (t/\sqrt[4]{t})$ J • cm^{-2} • sr^{-1}
	700 nm to 1400 nm	10^{3} to 3×10^{4}	0.64 C_A W • cm^{-2} • sr^{-1}
IR-B & C	1.4 μm to 10^{3} μm	10^{-9} to 3×10^{4}	Same as Table 4

C_A, C_B, and T_1 are the same as in footnote to Table 4.

Table 6
Threshold Limit Value for Skin Exposure from a Laser Beam

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

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

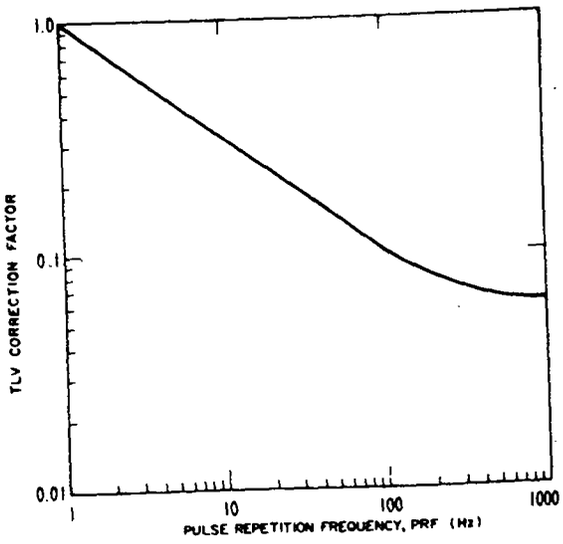

Figure 6 — Multiplicative correction factor for repetitively pulsed lasers having pulse durations less than 10^{-5} second. TLV for a single pulse of the pulse train is multiplied by the above correction factor. Correction factor for PRF greater than 1000 Hz is 0.06.

TABLE 7
Limiting Angle to Extended Source
Which May Be Used For Applying Extended Source TLVs

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

NOISE

These Threshold Limit Values (TLVs) refer to sound pressure levels and durations of exposure that represent conditions under which it is believed that nearly all workers may be repeatedly exposed without adverse effect on their ability to hear and understand normal speech. Prior to 1979, the medical profession had defined hearing impairment as an average hearing threshold level in excess of 25 decibels (ANSI-S3.6-1969) at 500, 1000, and 2000 Hz, and the limits which are given have been established to prevent a hearing loss in excess of this level.[a] The values should be used as guides in the control of noise exposure and, due to individual susceptibility, should not be regarded as fine lines between safe and dangerous levels.

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

Continuous or Intermittent

The sound level shall be determined by a sound level meter, conforming as a minimum to the requirements of the American National Standard Specification for Sound Level Meters, S1.4 (1971) Type S2A, and set to use the A-weighted network with slow meter response. Duration of exposure shall not exceed that shown in Table 8.

These values apply to total duration of exposure per working day regardless of whether this is one continuous exposure or a number of short-term exposures and does include the impact and impulsive type of noise that contributes to the sound level meter reading at slow response.

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

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

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

[a] In 1979 the American Academy of Ophthalmology and Otolargyngology (AAOO) included 3000 Hz in their hearing impairment formula.

TABLE 8
Threshold Limit Values for Noise

Duration per Day Hours	Sound Level dBA†
16	80
8	85
4	90
2	95
1	100
1/2	105
1/4	110
1/8	115*

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

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

IMPULSIVE OR IMPACT NOISE

It is recommended that exposure to impulsive or impact noise shall not exceed the limits listed in Table 9 or taken from Figure 7. No exposures in excess of 140 decibels peak sound pressure level are permitted. Impulsive or impact noise is considered to be those variations in noise levels that involve maxima at intervals of greater than one per second. Where the intervals are less than one second, it should be considered continuous.

TABLE 9
Threshold Limit Values Impulsive or Impact Noise

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

* Decibels peak sound pressure level; re 20 uPa.

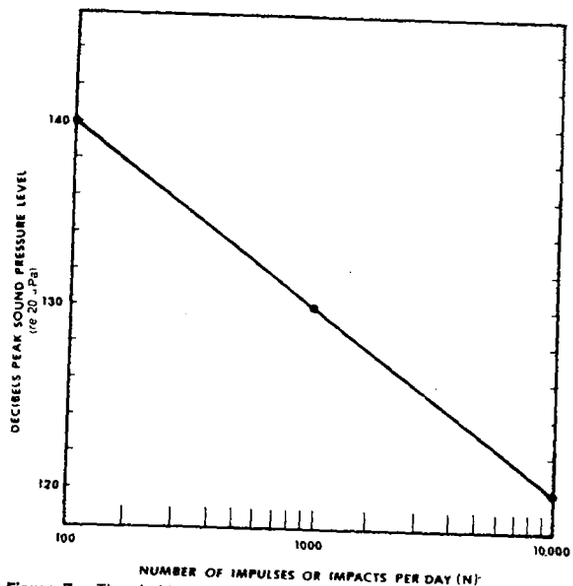

Figure 7— Threshold Limit Values for Impulse/Impact Noise.

RADIOFREQUENCY/MICROWAVE RADIATION

These Threshold Limit Values (TLVs) refer to radiofrequency (RF) and microwave radiation in the frequency range from 10 kHz to 300 GHz, and represent conditions under which it is believed workers may be repeatedly exposed without adverse health effects. The TLVs shown in Table 10 are selected to limit the average whole body specific absorption rate (SAR) to 0.4 W/kg in any six-minute (0.1 hr) period for 3 MHz to 300 GHz, see Figure 8. Between 10 kHz and 3 MHz the average whole body SAR is still limited to 0.4 W/kg, but the plateau at 100 mW/cm² was set to protect against shock and burn hazards.

Since it is usually impractical to measure the SAR, the TLVs are expressed in units that are measurable, viz, squares of the electric and magnetic field strength, averaged over any 0.1 hour period. This can be expressed in units of equivalent plane wave power density for convenience. The electric field strength (E) squared, magnetic field strength (H) squared, and power density (PD) values are shown in Table 10. For near field exposures PD cannot be measured directly, but equivalent plane wave power density can be calculated from the field strength measurement data as follows:

$$\text{PD in mW/cm}^2 = \frac{E^2}{3770}$$

where:

E^2 is in volts squared (V^2) per meter squared (m^2).

$$\text{PD in mW/cm}^2 = 37.7\ H^2$$

where:

H^2 is in amperes squared (A^2) per meter squared (m^2).

These values should be used as guides in the evaluation and control of exposure to radiofrequency/microwave radiation, and should not be regarded as a fine line between safe and dangerous levels.

Notes:

1. All Radiofrequency Radiation (RFR) exposures should be kept as low as reasonably possible given the current state of knowledge on human effects, particularly non-thermal effects.
2. For fields consisting of a number of frequencies, the fraction of the protection guide incurred within each frequency level should be determined and the sum of all fractions should not exceed unity.
3. For pulsed and continuous wave fields, the power density is averaged over the six-minute period.
4. For partial body exposures at frequencies between 10 kHz and 1.0 GHz, the protection guides in Table 10 may be exceeded if the output power of a radiating device is 7 watts or less. For example, if a hand held transmitter operating at 27 MHz has a maximum output of 5 watts, it would be excluded from any further field measurements.
5. The TLVs in Table 10 may be exceeded if the exposure conditions can be demonstrated to produce a SAR of less than 0.4 W/kg as averaged over the whole body and spatial peak SAR values less than 8.0 W/kg as averaged over any 1.0 gram of tissue. For example, for frequencies from 3 to 30 MHz, the equivalent power density can be increased by a factor of 10 up to a limit of 100 mW/cm², if it can be assured that exposed individuals are not in contact with the ground plate.
6. At frequencies below 30 MHz, ungrounded objects such as vehicles, fences, etc., can strongly couple to RF fields. For field strengths near the TLV, shock and burn hazards can exist. Care should be taken to eliminate ungrounded objects, to ground such objects, or use insulated gloves when ungrounded objects must be handled.
7. No measurement should be made within 5 cm of any object.
8. All exposures should be limited to a maximum (peak) electric field intensity of 100 kV/m.

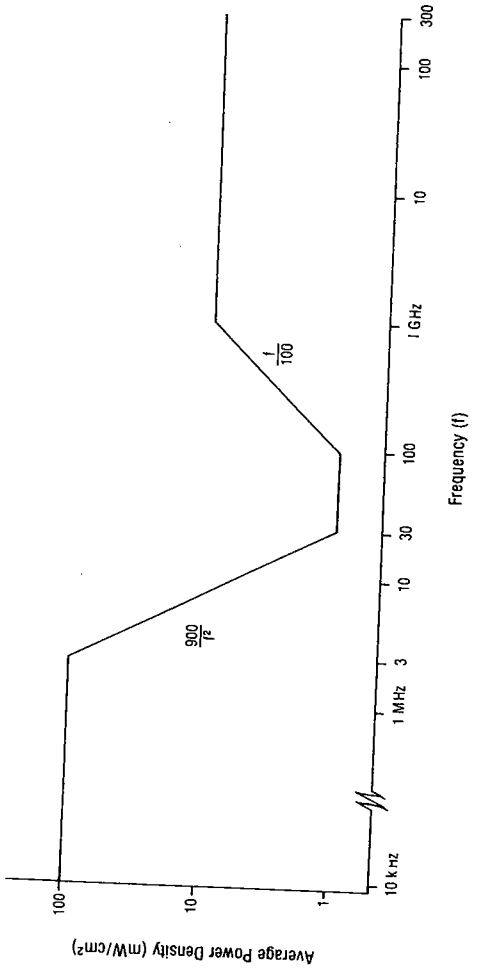

Figure 8 — Threshold Limit Values (TLV) for Radiofrequency/Microwave Radiation in the workplace (whole body SAR less than 0.4 W/kg).

TABLE 10
Radiofrequency/Microwave Threshold Limit Values

Frequency	Power Density (mW/cm^2)	Electric Field Strength Squared (V^2/m^2)	Magnetic Field Strength Squared (A^2/m^2)
10 KHz to 3 MHz	100	377,000	2.65
3 MHz to 30 MHz	$900/f^2$*	$3770 \times 900/f^2$	$900/(37.7 \times f^2)$
30 MHz to 100 MHz	1	3770	0.027
100 MHz to 1000 MHz	f/100	$3770 \times f/100$	$f/37.7 \times 100$
1 GHz to 300 GHz	10	37,700	0.265

*f = frequency in MHz.

ULTRAVIOLET RADIATION*

These Threshold Limit Values (TLVs) 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 dischrages, fluorescent and incandescent sources, and solar radiation, but do not apply to ultraviolet lasers.* These values do not apply to ultraviolet radiation exposure of photosenitive individuals or of individuals concomitantly exposed to photosensitizing agents.[1] These values should be used as guides in the control of exposure to continuous sources where the exposure duration shall not be less than 0.1 sec.

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

Recommended Values:

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

1. For the near ultraviolet spectral region (320 to 400 nm) total irradiance incident upon the unprotected skin or eye should not exceed 1 mW/cm^2 for periods greater than 10^3 seconds (approximately 16 minutes) and for exposure times less than 10^3 seconds should not exceed one J/cm^2.
2. For the actinic ultraviolet spectral region (200-315 nm), radiant exposure incident upon the unprotected skin or eye should not exceed the values given in Table 11 within an 8-hour period.
3. To determine the effective irradiance of a broadband source weighted against the peak of the spectral effectiveness curve (270 nm), the following weighting formula should be used:

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

where:

E_{eff} = effective irradiance relative to a monochromatic source at 270 nm in W/cm^2 ($J/s/cm^2$)

E_λ = spectral irradiance in $W/cm^2/nm$

S_λ = relative spectral effectiveness (unitless)

$\Delta\lambda$ = band width in nanometers

4. Permissible exposure time in seconds for exposure to actinic ultraviolet radiation incident upon the unprotected skin or eye may be computed by dividing 0.003 J/cm^2 by E_{eff} in W/cm^2.

* See Laser TLVs.

TABLE 11
Relative Spectrial Effectiveness by Wavelength*

Wavelength (nm)	TLV (mJ/cm²)	Relative Spectral Effectiveness S_λ
200	100	0.03
210	40	0.075
220	25	0.12
230	16	0.19
240	10	0.30
250	7.0	0.43
254	6.0	0.5
260	4.6	0.65
270	3.0	1.0
280	3.4	0.88
290	4.7	0.64
300	10	0.30
305	50	0.06
310	200	0.015
315	1000	0.003

*See Laser TLVs.

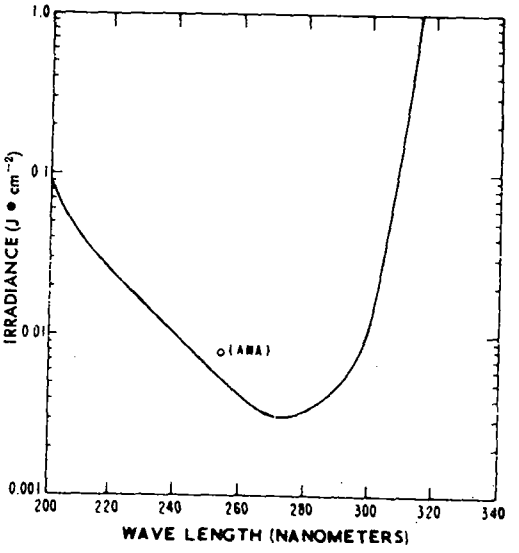

Figure 9—Threshold Limit Values for Ultraviolet Radiation.

TABLE 12
Permissible Ultraviolet Exposures

Duration of Exposure Per Day	Effective Irradiance, E_{eff} (μW/cm²)
8 hrs	0.1
4 hr	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

The exposure time may also be determined using Table 12 which provides exposure times corresponding to effective irradiances in μW/cm².

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

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

Reference

1. *Sunlight and Man.* Fitzpatrick *et al*, Eds. Univ. of Tokyo Press, Tokyo, Japan (1974).

NOTICE OF INTENDED CHANGES (for 1985-86)

hese physical agents, with their corresponding values, comprise ıose for which either a limit has been proposed for the first time, · for which a change in the "Adopted" listing has been proposed. both cases, the proposed limits should be considered trial limits ıat will remain in the listing for a period of at least one year. If ter one year no evidence comes to light that questions the ɔpropriateness of the values herein the values will be recon-dered for the the "Adopted" list.

LASERS

It is proposed that the existing section on *Repetitively Pulsed sers* (including Figure 6) be replaced with the following:

petitively Pulsed Exposures

Scanned CW lasers or repetitively pulsed lasers can both ɔduce repetitively pulsed exposure conditions. The TLV for rabeam viewing which is applicable to a single-pulse exposure pulse duration *t*) is modified in this instance by a correction tor determined by the number of pulses in the exposure. First, culate the number of pulses (n) in an expected exposure situ-ɔn; this is the pulse repetitition frequency (PRF in Hz) multi-ed by the duration of exposure. The corrected TLV on a -pulse basis is:

$$\text{TLV} = (n^{-¼})\ (\text{TLV for single-pulse}) \qquad (1)$$

is approach applies only to thermal-injury conditions, i.e., all ɔosures at wavelengths greater than 700 nm, and for many ɔosures at shorter wavelengths. For wavelengths less than or ıal to 700 nm, the corrected TLV from equation 1 above applies ıe average irradiance does not exceed the TLV for continu-; exposure. The average irradiance (i.e., the total accumulated ɔosure for *nt* seconds) shall not exceed the radiant exposure en in Table 4 for exposure durations of 10 seconds to T_1.

Furthermore, it is proposed that the additional footnote for ɔle 6 (Threshold Limit Values for Skin Exposure from a Laser ɜm) be modified to read as follows:

wavelengths greater than 1400 nm, for beam cross-sectional as exceeding 100 cm² the TLV for exposure durations ex-ıding 10 seconds is:

$$\text{TLV} = (10{,}000/A_s)\ \text{mW/cm}^2 \qquad (2)$$

ɜre A_s is the irradiated skin area for 100 to 1000 cm², and the / for irradiated skin areas exceeding 1000 cm² is 10 mW/cm² for irradiated skin areas less than 100 cm² is 100 mW/cm².

NOTICE OF INTENT TO ESTABLISH THRESHOLD LIMIT VALUES

LIGHT AND NEAR-INFRARED RADIATION

These Threshold Limit Values (TLVs) refer to visible and near-infrared radiaton 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 TLVs are:

1. To protect against retinal thermal injury, the spectral radiance of the lamp weighted against the function R (Table 13) should not exceed:

$$\sum_{400}^{1400} L_\lambda \bullet R_\lambda \bullet \Delta\lambda \leqslant 1/\alpha t^{½} \qquad (1)^*$$

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

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

2. To protect against retinal photochemical injury from chronic blue-light exposure the integrated spectral radiance of a light source weighted against the blue-light hazard function B_λ (Table 13) should not exceed:

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

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

TABLE 13
Spectral Weighting Functions for Assessing Retinal Hazards from Broad-Band Optical Sources

Wavelength (nm)	Blue-Light Hazard-Function B_λ	Burn Hazard Function R_λ
400	0.10	1.0
405	0.20	2.0
410	0.40	4.0
415	0.80	8.0
420	0.90	9.0
425	0.95	9.5
430	0.98	9.8
435	1.0	10.0
440	1.0	10.0
445	0.97	9.7
450	0.94	9.4
455	0.90	9.0
460	0.80	8.0
465	0.70	7.0
470	0.62	6.2
475	0.55	5.5
480	0.45	4.5
485	0.40	4.0
490	0.22	2.2
495	0.16	1.6
500-600	$10^{[(450-\lambda)/50]}$	1.0
600-700	0.001	1.0
700-1049	0.001	$10^{[(700-\lambda)/505]}$
1050-1400	0.001	0.2

The weighted product of L_λ and B_λ is termed L (blue). For a source radiance L weighted against the blue-light hazard function (L [blue]) which exceeds 10 mW cm^{-2} sr^{-1} in the blue spectral region, the permissible exposure duration t_{max} in seconds is simply:

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

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

for the Laser TLV. For a light source subtending an angle α less than 11 mrd (0.011 radian) the above limits are relaxed such that the spectral irradiance weighted against the blue-light hazard function B_λ should not exceed E (blue).

$$\sum_{400}^{1400} E_\lambda \bullet t \bullet B_\lambda \bullet \Delta\lambda \leqslant 10 \text{ mJ} \bullet \text{cm}^{-2} \quad (t \leqslant 10^4 \text{ s}) \quad (5a)$$

$$\sum_{400}^{1400} E_\lambda \bullet B_\lambda \bullet \Delta\lambda \leqslant 1 \ \mu\text{W} \bullet \text{cm}^2 \quad (t \geqslant 10^4 \text{ s}) \quad (5b)$$

For a source where the blue light weighted irradiance E (blue) exceeds 1 μW • cm^{-2} is the maximum permissible exposure duration t_{max} in seconds is:

$$t_{max} = 10 \text{ mJ} \bullet \text{cm}^{-2} \text{ E (blue)} \quad (6)$$

3. *Infrared radiation:* To avoid possible delayed effects upon the lens of the eye (cataractogenesis), the infrared radiation (λ = 770 nm) should be limited to 10 mW cm^{-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:

$$\sum_{770}^{1400} L_\lambda \bullet \Delta\lambda \leqslant 0.6/\alpha \quad (7)^*$$

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

AIRBORNE UPPER SONIC AND ULTRASONIC ACOUSTIC RADIATION

These Threshold Limit Values (TLVs) refer to sound pressure levels that represent conditions under which it is believed that nearly all workers may be repeatedly exposed without adverse effect. The values listed in Table 14 should be used as guides in the control of noise exposure and, due to individual susceptibility, should not be regarded as fine lines between safe and dangerous levels. The levels for the third-octave bands centered below 20 kHz are below those which cause subjective effects. Those levels for 1/3 octaves above 20 kHz are for prevention of possible hearing losses from subharmonics of these frequencies.

* Formulae (1) and (7) are empirical and are not, strictly speaking, dimensionally correct. To make the formulae dimensionally correct, one would have to insert a dimensional correction factor *k* in the right hand numerator in each formula. For formula (1) this would be k_1 = 1 W • rad • s½/(cm^2 • sr), and for formula (7) K_2 = 1 W • rad/(cm^2 • sr).

TABLE 14
Permissible Ultrasound Exposure Levels

Mid-Frequency of Third-Octave Band kHz	One-Third Octave—Band Level in dB re 20 μPa
10	80
12.5	80
16	80
20	105
25	110
31.5	115
40	115
50	115

COLD STRESS

These Threshold Limit Values (TLVs) are intended to protect workers from the severest effects of cold stress (hypothermia) and cold injury and to describe exposures to cold working conditions under which it is believed that nearly all workers can be repeatedly exposed without adverse health effects. The TLV objective is to prevent the deep body core temperature from falling below 36°C and to prevent cold injury to body extremities. Deep body temperature is the core temperataure of the body as determined by rectal temperature measurements. For a single, occasional exposure to a cold environment a drop in core temperature of no lower that 35°C should be permitted. In addition to provisions for total body protection, the TLV objective is to protect all parts of the body with emphasis on hands, feet and head from cold injury.

Introduction

Fatal exposures to cold among workmen have almost always resulted from accidental exposures involving failure to escape from low environmental air temperatures or from immersion in low temperature water. The single most important aspect of life-threatening hypothermia is the fall in the deep core temperature of the body. The clinical presentations of victims of hypothermia are shown in Table 15 (taken from Dembert in *AFP*, January 1982). Workmen should be protected from exposure to cold so that the deep core temperature does not fall below 36°C (96.8°F); lower body temperatures will very likely result in reduced mental alertness, reduction in rational decision making, or loss of consciousness with the threat of fatal consequences.

TABLE 15
Progressive Clinical Presentations of Hypothermia*

Core Temperature °C	Core Temperature °F	Clinical Signs
37.6	99.6	"Normal" rectal temperature
37	98.6	"Normal" oral temperature
36	96.8	Metabolic rate increases in an attempt to compensate for heat loss
35	95.0	Maximum shivering
34	93.2	Victim conscious and responsive, with normal blood pressure
33	91.4	Severe hypothermia below this temperature
32	89.6	Consciousness clouded; blood pressure becomes difficult to obtain; pupils dilated but react to light; shivering ceases
31	87.8	
30	86.0	Progressive loss of consciousness; muscular rigidity increases; pulse and blood pressure difficult to obtain; respiratory rate decreases
29	84.2	
28	82.4	Ventricular fibrillation possible with myocardial irritability
27	80.6	Voluntary motion ceases; pupils nonreactive to light; deep tendon and superficial reflexes absent
26	78.8	Victim seldom conscious
25	77.0	Ventricular fibrillation may occur spontaneously
24	75.2	Pulmonary edema
22	71.6	Maximum risk of ventricular fibrilation
21	69.8	
20	68.0	Cardiac standstill
18	64.4	Lowest accidental hypothermia victim to recover
17	62.6	Isoelectric electroencephalogram
9	48.2	Lowest artificially cooled hypothermia patient to recover

* Presentations approximately related to core temperature. Reprinted from the January 1982 issue of *American Family Physician*, published by the American Academy of Family Physicians.

Pain in the extremities may be the first early warning of danger to cold stress. During exposure to cold, maximum severe shivering develops when the body temperature has fallen to 35°C (95°F). This must be taken as a sign of danger to the workmen and exposure to cold should be immediately terminated for any workman when severe shivering becomes evident. Useful physical or mental work is limited when severe shivering occurs.

Since prolonged exposure to cold air, or to immersion in cold water, at temperatures well above freezing can lead to dangerous hypothermia, whole body protection must be provided.

1. Adequate insulating clothing to maintain core temperatures above 36°C must be provided to workers if work is performed in air temperatures below 4°C (40°F). Wind chill* or the cooling power of the air is a critical factor. The higher the wind speed and the lower the temperature in the work area, the greater the insulation value of the protective clothing required. An equivalent chill temperature chart relating the actual dry bulb air temperature and the wind velocity is presented in Table 16. The equivalent chill temperature should be used when estimating the combined cooling effect of wind and low air temperatures on exposed skin or when determining clothing insulation requirements to maintain the deep body core temperature.
2. Unless there are unusual or extenuating circumstances cold injury to other than hands, feet, and head is not likely to occur without the development of the initial signs of hypothermia. Older workers or workers with circulatory problems require special precautionary protection against cold injury. The use of extra insulating clothing and/or a reduction in the duration of the exposure period are among the special precautions which should be considered. The precautionary actions to be taken will depend upon the physical condition of the worker and should be determined with the advice of a physician with knowledge of the cold stress factors and the medical condition of the worker.

Evaluation and Control

For exposed skin, continuous exposure should not be permitted when the air speed and temperature results in an equivalent chill temperature of –32°C (–25°F). Superficial or deep local tissue freezing will occur only at temperatures below –1°C regardless of wind speed.

At air temperatures of 2°C (35.6°F) or less it is imperative that workers who become immersed in water or whose clothing becomes wet be immediately provided a change of clothing and be treated for hypothermia.

* Wind chill factor is a unit of heat loss from a body defined in watts per meter squared per hour being a function of the air temperature and wind velocity upon the exposed body.

TABLE 16
Cooling Power of Wind on Exposed Flesh Expressed as an equivalent Temperature (under calm conditions)*

Estimated Wind Speed (in mph)	Actual Temperature Reading (°F)											
	50	40	30	20	10	0	–10	–20	–30	–40	–50	–60
	Equivalent Chill Temperature (°F)											
calm	50	40	30	20	10	0	–10	–20	–30	–40	–50	–60
5	48	37	27	16	6	–5	–15	–26	–36	–47	–57	–68
10	40	28	16	4	–9	–24	–33	–46	–58	–70	–83	–95
15	36	22	9	–5	–18	–32	–45	–58	–72	–85	–99	–112
20	32	18	4	–10	–25	–39	–53	–67	–82	–96	–110	–121
25	30	16	0	–15	–29	–44	–59	–74	–88	–104	–118	–133
30	28	13	–2	–18	–33	–48	–63	–79	–94	–109	–125	–140
35	27	11	–4	–20	–35	–51	–67	–82	–98	–113	–129	–145
40	26	10	–6	–21	–37	–53	–69	–85	–100	–116	–132	–148
(Wind speeds greater than 40 mph have little additional effect.)	*LITTLE DANGER* In < hr with dry skin. Maximum danger of false sense of security				*INCREASING DANGER* Danger from freezing of exposed flesh within one minute.				*GREAT DANGER* Flesh may freeze within 30 seconds.			
	Trenchfoot and immersion foot may occur at any point on this chart.											

* Developed by U.S. Army Research Institute of Environmental Medicine, Natick, MA.

TABLE 17
Work/Warm-up Schedule for Four-Hour Shift*

Air Temperature — Sunny Sky		No Noticeable Wind		5 mph Wind		10 mph Wind		15 mph Wind		20 mph Wind	
°C (approx.)	°F	Max. Work Period	No. of Breaks	Max. Work Period	No. of Breaks	Max. Work Period	No. of Breaks	Max. Work Period	No. of Breaks	Max. Work Period	No. of Breaks
1. -26° to -28°	-15° to -19°	(Norm. Breaks)	1	(Norm. Breaks)	1	75 min	2	55 min	3	40 min	4
2. -29° to -31°	-20° to -24°	(Norm. Breaks)	1	75min	2	55 min	3	40 min	4	30 min	5
3. -32° to -34°	-25° to -29°	75 min	2	55 min	3	40 min	4	30 min	5	Non-emergency work should cease	
4. -35° to -37°	-30° to -34°	55 min	3	40 min	4	30 min	5	Non-emergency work should cease			
5. -38° to -39°	-35° to -39°	40 min	4	30 min	5	Non-emergency work should cease					
6. -40° to -42°	-40° to -44°	30 min	5	Non-emergency work should cease							
7. -43° & below	-45° & below	Non-emergency work should cease									

Notes for Table 17:

1. Schedule applies to moderate to heavy work activity with warm-up breaks of ten (10) minutes in a warm location. For Light-to-Moderate Work (limited physical movement): apply the schedule one step lower. For example, at -30°F with no noticeable wind (Step 4), a worker at a job with little physical movement should have a maximum work period of 40 minutes with 4 breaks in a 4-hour period (Step 5).

2. The following is suggested as a guide for estimating wind velocity. If accurate information is not available:
   5 mph: light flag moves; 10 mph: light flag fully extended; 15 mph: raises newspaper sheet; 20 mph: blowing and drifting snow.

3. If only the Wind Chill Factor is available, a rough rule of thumb for applying it rather than the temperature and wind velocity factors given above would be: 1) special warm-up breaks should be initiated at a wind chill of about 1750 W/m²/hr; 2) all non-emergency work should have ceased at or before a wind chill of 2250 W/m²/hr. In general the warm-up schedule provided above slightly under-compensates for the wind at the warmer temperatures, assuming acclimatization and clothing appropriate for winter work. On the other hand, the chart slightly over-compensates for the absolute temperatures in the colder ranges, since windy conditions rarely prevail at extremely low temperatures.

* From Occupational Health & Safety Division, Saskatchewan Department of Labour.

Recommended limits for properly clothed workers for periods of work at temperatures below freezing are shown in Table 17.

Special protection of the hands is required to maintain manual dexterity for the prevention accidents:

1. If fine work is to be performed with bare hands for more than 10-20 minutes in an environment below 16°C (60°F), special provisions should be established for keeping the workers' hands warm. For this purpose, warm air jets, radiant heaters (fuel burner or electric radiator), or contact warm plates may be utilized. Metal handles of tools and control bars shall be covered by thermal insulating material at temperatures below −1°C (30°F).
2. If the air temperature falls below 16°C (60°F) for sedentary, 4°C (40°F) for light, −7°C (20°F) for moderate work and fine manual dexterity is not required then gloves shall be used by the workers.

To prevent contact frostbite, the workers should wear anti-contact gloves.

1. When cold surfaces below −7°C (20°F) are within reach, a warning should be given to each worker by his supervisor to prevent inadvertent contact by bare skin.
2. If the air temperature is −17.5°C (0°F) or less, the hands should be protected by mittens. Machine controls and tools for use in cold conditions should be designed so that they can be handled without removing the mittens.

Provisions for additional total body protection is required if work is performed in an environment at or below 4°C (40°F). The workers shall wear cold protective clothing appropriate for the evel of cold and physical activity:

- If the air velocity at the job site is increased by wind, draft, or artificial ventilating equipment, the cooling effect of the wind shall be reduced by shielding the work area, or by wearing an easily removable outer windbreak layer garment. Wind chill cooling rates are illustrated in Figure 10 and Table 18.
- If only light work is involved and if the clothing on the worker may become wet on the job site, the outer layer of the clothing in use may be of a type impermeable to water. With more severe work under such conditions the outer layer should be water repellent, and the outerwear should be changed as it becomes wetted. The outer garments must include provisions for easy ventilation in order to prevent wetting of inner layers by sweat. If work is done at normal temperatures or in a hot environment before entering the cold area, the employee shall make sure that his clothing is not wet as a consequence of sweating. If his clothing is wet, the employee shall change into dry clothes before entering the cold area. The workers shall change socks and any removable felt insoles at regular daily intervals or use vapor barrier boots. The optimal frequency of change shall be determined empirically and will vary individually and according to the type of shoe worn and how much the individual's feet sweat.

3. If extremities, ears, toes and nose, cannot be protected sufficiently to prevent sensation of excessive cold or frostbite by handware, footwear and face masks, these protective items shall be supplied in auxiliary heated versions.
4. If the available clothing does not give adequate protection to prevent hypothermia or frostbite, work shall be modified or suspended until adequate clothing is made available or until weather conditons improve.
5. Workers handling evaporative liquid (gasoline, alcohol or cleaning fluids) at air temperatures below 40°F shall take special precautions to avoid soaking of clothing or gloves with the liquids because of the added danger of cold injury due to evaporative cooling. Special note should be taken of the particularly acute effects of splashes of "cryogenic fluids" or those liquids with a boiling point only just above ambient temperatures.

Work-Warming Regimen

If work is performed continuously in the cold at an equivalent chill temperature (ECT) or below −7°C (20°F) heated warming shelters (tents, cabins, rest rooms, etc.) shall be made available nearby and the workers should be encouraged to use these shelters at regular intervals, the frequency depending on the severity of the environmental exposure. The onset of heavy shivering, frostnip, the feeling of excessive fatique, drowsiness, irritability, or euphoria, are indications for immediate return to the shelter. When entering the heated shelter the outerlayer of clothing shall be removed and the remainder of the clothing loosened to permit sweat evaporation or a change of dry work clothing provided. A change of dry work clothing shall be provided as necessary to prevent workers from returning to their work with wet clothing. Dehydration, or the loss of body fluids, occurs insidiously in the cold environment and may increase the susceptibility of the worker to cold injury due to a significant change in blood flow to the extremities. Warm sweet drinks and soups should be provided at the work site to provide caloric intake and fluid volume. The intake of coffee should be limited because of a diuretic and circulatory effect.

For work practices at or below −12°F (10°F) ECT the following shall apply:

1. The worker shall be under constant protective observation (buddy system or supervision).
2. The work rate should not be so high as to cause heavy sweating that will result in wet clothing; if heavy work must be done, rest periods must be taken in heated shelters and opportunity for changing into dry clothing shall be provided.

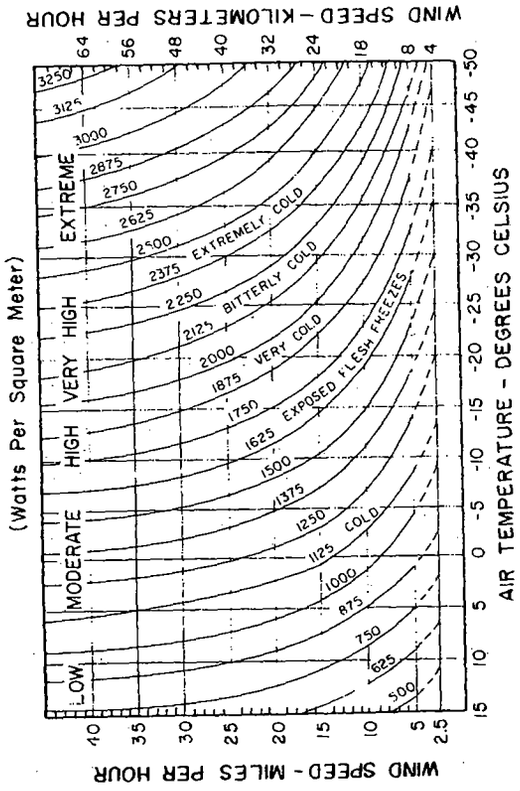

Figure 10 — Wind chill cooling rates. Adapted from Canadian Department of the Environment, Atmospheric Environment Service.

TABLE 18
Wind Chill Cooling Rate Effects*

Wind Chill Rates (Watts/m²/hr)	Comments/Effects
700	Conditions considered comfortable when dressed for skiing.
1200	Conditions no longer pleasant for outdoor activities on overcast days.
1400	Conditions no longer pleasant for outdoor activities on sunny days.
1600	Freezing of exposed skin begins for most people depending on the degree of activity and the amount of sunshine.
2300	Conditions for outdoor travel such as walking become dangerous. Exposed areas of the face freeze in less than 1 minute for the average person.
2700	Exposed flesh will freeze within half a minute for the average person.

* From Canadian Department of the Environment, Atmospheric Environment Service.

3. New employees shall not be required to work full-time in cold in the first days until they become accustomed to the working conditions and required protective clothing.
4. The weight and bulkiness of clothing shall be included in estimating the required work performance and weights to be lifted by the worker.
5. The work shall be arranged in such a way that sitting still or standing still for long periods is minimized. Unprotected metal chair seats shall not be used. The worker should be protected from drafts to the greatest extent possible.
6. The workers shall be instructed in safety and health procedures. The training program shall include as a minimum instruction in:
   a. Proper rewarming procedures and appropriate first aid treatment.
   b. Proper clothing practices.
   c. Proper eating and drinking habits.
   d. Recognition of impending frostbite.

e. Recognition signs and symptoms of impending hypothermia or excessive cooling of the body even when shivering does not occur.
f. Safe work practices.

Special Workplace Recommendations

Special design requirements for refrigerator rooms include the following:

1. In refrigerator rooms, the air velocity should be minimized as much as possible and should not exceed 1 meter/sec (200 fpm) at the job site. This can be achieved by properly designed air distribution systems.
2. Special wind protective clothing shall be provided based upon existing air velocities to which workers are exposed.

Special caution shall be exercised when working with toxic substances and when workers are exposed to vibration. Cold exposure may require reduced exposure limits.

Eye protection for workers employed out-of-doors in a snow and/or ice-covered terrain shall be supplied. Special safety goggles to protect against ultraviolet light and glare (which can produce temperary conjuntivitis and/or temporary loss of vision) and blowing ice crystals are required when there is an expanse of snow coverage causing a potential eye exposure hazard.

Workplace monitoring is required as follows:

1. Suitable thermometry should be arranged at any workplace where the environmental temperature is below 16°C (60°F) to enable overall compliance with the requirements of the TLV to be maintained.
2. Whenever the air temperature at a workplace falls below –1°C (30°F), the dry bulb temperature should be measured and recorded at least every 4 hours.
3. In indoor workplaces, the wind speed should also be recorded at least every 4 hours whenever the rate of air movement exceeds 2 meters per second (5 mph).
4. In outdoor work situations, the windspeed should be measured and recorded together with the air temperature whenever the air temperature is below –1°C (30°F).
5. The equivalent chill temperature shall be obtained from Table 16 in all cases where air movement measurements are required, and shall be recorded with the other data whenever the equivalent chill temperature is below –7°C (20°F).

Employees shall be excluded from work in cold at –1°C (30°F) or below if they are suffering from diseases or taking medication which interferes with normal body temperature regulation or reduces tolerance to work in cold environments. Workers who are routinely exposed to temperatures below –24°C (–10°F) with wind speeds less than five miles per hour, or air tempeatures

below –18°C (0°F) with wind speeds above five miles per hour should be medically certified as suitable for such exposures.

Trauma sustained in freezing or subzero conditions requires special attention because an injured worker is predisposed to secondary cold injury. Special provisions must be made to prevent hypothermia and secondary freezing of damaged tissues in addition to providing for first aid treatment.

HAND-ARM (SEGMENTAL) VIBRATION

These Threshold Limit Values (Table 19) refer to component accelerations levels and durations of exposure that represent conditions under which it is believed that most workers may be exposed repeatedly without progressing beyond Stage 3 of the Taylor-Pelmear Classification System for Vibration-induced White Finger (VWF, also known as Raynaud's Phenomenon of Occupational Origin). Since there is a paucity of dose-response relationships for VWF, these recommendations have been derived from epidemiological data from forestry, mining, and metal working. These values should be used as guides in the control of hand-arm vibration exposure and because of individual susceptibility, should not be regarded as defining a boundry between safe and dangerous levels.

It should be recognized that the application of the TLV alone for hand-arm vibration will not protect all workers from the adverse effects of hand-arm vibration exposure. The use of: 1) antivibration tools, 2) antivibration gloves, 3) proper work practices which keep the worker's hands and remaining body warm and also minimize the vibration coupling between the worker and the vibration tool are necessary to minimize vibration exposure, and 4) a conscienciously applied medical surveillance program are ALL necessary to rid VWF from the workplace.

Continuous, Intermittent, Impulsive, or Impact Hand-arm Vibration

The measurement of vibration should be performed in accordance with the procedures and instrumentation specified by the Second Draft International Standard ISO/DIS 5349 (1984), *Guide for the Measurement and the Assessment of Human Exposure to Vibration Transmitted to the Hand,* and summarized below:

The acceleration of a vibration handle or work piece should be determined in three mutually orthogonal directions at a point close to where vibration enters the hand. The directions shall preferably be those forming the ISO biodynamic coordinate system, but may be a closely related basicentric system with its origin at the interface between the hand and the vibrating surface (see Figure 11) to accommodate different handle or work piece configurations. A small and lightweight transducer shall be mounted so as to record accurately one or more orthogonal com-

ponents of the source vibration in the frequency range from 5 to 1500 Hz. Each component should be frequency-weighted by a filter network with gain characteristics specified by the ISO for human-response vibration measuring instrumentation, to account for the change in vibration hazard with frequency (see Figure 12).

Assessment of vibration exposure should be made for EACH applicable direction (X_h, Y_h, Z_h) since vibration is a vector quantity (magnitude and direction). In each direction, the magnitude of the vibration during normal operation of the power tool, machine or work piece shall be expressed by the root-mean-square (rms) value of the frequency-weighted component accelerations, in units of meters per second squared (m/s^2), or gravitational units (g), the largest of which, a_K, forms the basis for exposure assessment.

For each direction being measured, linear integration shall be employed for vibrations that are of extremely short duration or vary substantially in time. If the total daily vibration exposure in a given direction is composed of several exposures at different rms accelerations, then the equivalent, frequency-weighted component acceleration in that direction shall be determined in accordance with the following equation:

$$\left(a_{K_{eq}}\right) = \left[\frac{1}{T}\sum_{i=1}^{n}\left(a_{K_i}\right)^2 T_i\right]^{1/2}$$

$$= \sqrt{\left(a_{K_1}\right)^2 \frac{T_1}{T} + \left(a_{K_2}\right)^2 \frac{T_2}{T} + \ldots \left(a_{K_n}\right)^2 \frac{T_n}{T}}$$

where: $T = \sum_{i=1}^{n} T_i$

T = total daily exposure duration

a_{K_i} = ith frequency-weighted, rms acceleration component with duration T_i

These computations may be performed by commercially available human-response vibration measuring instruments.

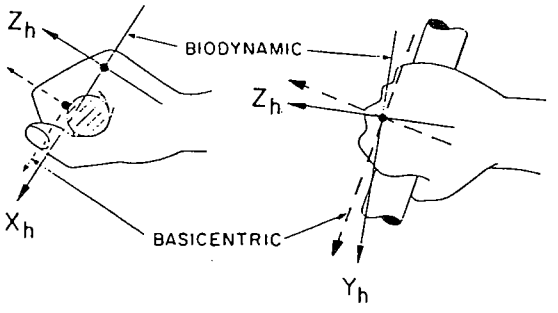

Figure 11 — Biodynamic and basicentric coordinate systems for the hand, showing the directions of the acceleration components (ISO 5349).

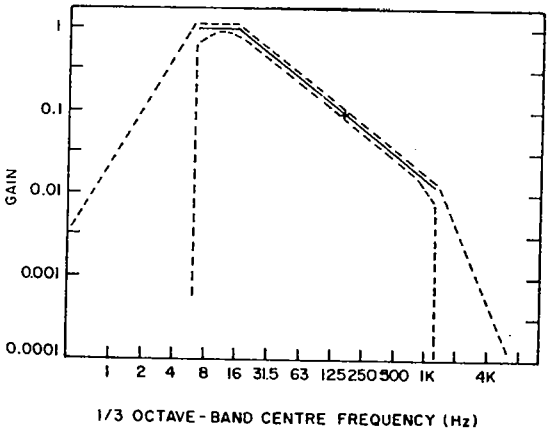

Figure 12 — Gain characteristics of the filter network used to frequency-weight acceleration components (continuous line). The filter tolerances (dashed lines) are provisional, and are those contained in ISO 5349.

TABLE 19
Threshold Limit Values for Exposure of the Hand to Vibration in Either X_h, Y_h, Z_h Directions

Total Daily Exposure Duration[a]	Values of the Dominant,[b] Frequency-Weighted, rms, Component Acceleration Which Shall not be Exceeded[c] a_K,($a_{K_{eq}}$)	
	m/s²	g
4 hours and less than 8	4	0.40
2 hours and less than 4	6	0.61
1 hour and less than 2	8	0.81
less than 1 hour	12	1.22

[a] The total time vibration enters the hand per day, whether continuously or intermittently.

[b] Usually one axis of vibration is dominant over the remaining two axis. If one or more vibration axis exceeds the Total Daily Exposure then the TLV has been exceeded.

[c] g = 9.81 m/s².

Notes: Table 19:

1. Hardly any person exposed at or below the TLVs for vibration contained in Table 19 has progressed to *Stage 3* Vibration White Finger, in the Taylor-Pelmear classification, i.e., the point at which extension blanching of all fingers has occurred and there is definite interference at work, home, and restricted social activities.(2-7)
2. Acute exposures to frequency-weighted, rms, component accelerations in excess of the TLVs for infrequent periods of time (e.g., 1 day per week, or several days over a two-week period) are not necessarily more harmful.(2-4)
3. Acute exposures to frequency-weighted, rms, component accelerations of three times the magnitude of the TLVs are expected to result in the same health effects after between 5 and 6 years of exposure.(2-4)
4. Preventive measures, including specialized preemployment and annual medical examinations to identify persons susceptible to vibration, should be implemented in situations in which workers are or will be exposed to hand-arm vibration.(3-7)
5. To moderate the adverse effects of vibration exposure, workers should be advised to avoid *continuous* vibration exposure by cessation of vibration exposure for approximately 10 minutes per continuous vibration hour.

6. Good work practices should be used, and should include instructing workers to employ a minimum hand grip force consistent with safe operation of the power tool or process, keep their body and hands warm and dry, and avoid smoking.(2,3)
7. A transducer and its device for attachment to the vibrating source suitable for measurement purposes together should weigh less than 15 grams, and should possess a cross-axis sensitivity of less than 10%.
8. The measurement by many (mechanically underdamped) piezoelectric accelerometers of repetitive, large displacement, impulsive vibrations, such as those produced by percussive pneumatic tools, is subject to error. The insertion of a suitable, low-pass, mechanical filter between the accelerometer and the source of vibration with a cut-off frequency of 1500 Hz or greater (and cross-axis sensitivity of less than 10%) can help eliminate incorrect readings.(3,4)
9. The manufacturer and type number of all apparatus used to measure vibration should be reported, as well as the value of the dominant direction and frequency-weighted, rms, component acceleration.

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PHYSICAL AGENTS UNDER STUDY

The Physical Agents TLV Committee of ACGIH has examined the current literature and has not found sufficient information to propose a TLV. However, these agents will remain under study during the coming year to examine new evidence indicating the

need and feasibility for establishing a proposed TLV. Comments and suggestions, accompanied by substantive documentation are solicited and should be forwarded to the Executive Secretary, ACGIH. Documentation summarizing the current status of the biological effects literature is available on those agents preceded by an asterisk (*).

1. **Extremely Low Frequency (ELF) Radiation.* Specifically, that portion of the spectrum from 0 to 300 Hz.
2. *Magnetic Fields.* Both pulsed and *continuous.
3. *Laser Radiation.* Specifically laser exposures of less than one (1) nanosecond.
4. *Vibration.* Whole-body.
5. *Pressure Variations.*

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

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

Membership is limited to professional personnel in governmental agencies or educational institutions engaged in occupational safety and health programs. The more than 3100 members from across the United States and around the world give the organization an international scope.