

PLAINTIFF'S EXHIBIT

MON-2482

Hammann
TLVs®
Threshold Limit Values
for
Chemical Substances
and
Physical Agents
in the
Work Environment
with
Intended Changes
for
1983-84



SC

008146

LAM009356

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New material or revisions for 1983: The Chemical Substances Section — A section describing the rationale for the future reintroduction of operational excursion limits has been added. The definition of the "skin" notation has been expanded. Appendix II — Chemical Abstracts Service (CAS) Registry Numbers have been included for identification.

Interpretations of TLVs: All requests for interpretations of TLVs must be submitted in care of the Executive Secretary, ACGIH. Interpretations will be made only after committee review and approval. Interpretations will be published annually in the *Annals of the American Conference of Governmental Industrial Hygienists*. The volume which covers the annual meeting.

Documentation of the Threshold Limit Values: A separate companion piece to the TLVs is issued by ACGIH. This title, this publication gives the pertinent scientific information and data with reference to literature sources that were used to base each limit. Each document also contains a statement defining the value of exposure against which the limit is safeguarding against. For greater understanding of the TLVs it is suggested that the Documentation be consulted when the TLVs are requested.

The Fourth Edition (1980) which includes the Supplemental Interpretations for the years 1981-1984, may be obtained from the Publications Office, ACGIH, as hardcover or copies of the three Supplements.

Requests for interpretations or reproduction items should be accompanied by an order and use of proper address.

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ACGIH
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PREFACE CHEMICAL SUBSTANCES

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

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

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

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

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

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

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

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

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

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

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

A STEL is defined as a 15-minute time-weighted average exposure which should not be exceeded at any time during a work day even if the eight-hour

time-weighted average is within the TLV. Exposures at the STEL should not be longer than 15 minutes and should not be repeated more than four times per day. There should be at least 60 minutes between successive exposures at the STEL. An averaging period other than 15 minutes may be recommended when this is warranted by observed biological effects.

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

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

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

Time-Weighted Average vs Ceiling Limits. Time-weighted averages permit excursions above the limit provided they are compensated by equivalent excursions below the limit during the workday. In some instances it may be permissible to calculate the average concentration for a workweek rather than for a workday. The relationship between threshold limit and permissible excursion is a rule of thumb and in certain cases may not apply. The amount by which threshold limits may be exceeded for short periods without injury to health depends upon a number of factors such as the nature of the contaminant, whether very high concentrations — even for short periods — produce acute poisoning, whether the effects are cumulative, the frequency with which high concentrations occur, and the duration of such periods. All factors must be taken into consideration in arriving at a decision as to whether a hazardous condition exists.

Although the time-weighted average concentration provides the most satisfactory, practical way of monitoring airborne agents for compliance with the limits, there are certain substances for which it is inappropriate. In the latter group are substances which are predominantly fast acting and whose threshold limit is more appropriately based on this particular response. Substances with this type of response are

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

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

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

While no rigorous rationale was provided for these particular values, the basic concept was intuitive: in a well controlled process exposure, excursions should be held within some reasonable limits. Unfortunately, neither toxicology nor collective industrial hygiene experience provide a solid basis for quantifying what those limits should be. The approach here is that the maximum recommended excursion should be related to the variability generally observed in actual industrial processes. Leidel, Busch and Crouse,* in reviewing large numbers of industrial hygiene surveys conducted by NIOSH, found that short-term exposure measurements were generally log normally distributed with geometric standard deviations mostly in the range of 1.5 to 2.0.

While a complete discussion of the theory and properties of the log normal distribution is beyond the scope of this section, a brief description of some important terms is presented. The measure of central tendency in a log normal distribution is the antilog of the mean logarithm of the sample values. The distri-

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

bution is skewed and the geometric mean is always smaller than the arithmetic mean by an amount which depends on the geometric standard deviation. In the log normal distribution, the geometric standard deviation (sd_g) is the antilog of the standard deviation of the sample value logarithms and 68.26% of all values lie between m_g/sd_g and $m_g \times sd_g$.

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

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

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

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

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

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

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

Biological monitoring should be considered to de-

termine the relative contribution of dermal exposure to the total dose.

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

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

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

Excessive concentrations of nuisance dusts in the workroom air may seriously reduce visibility, may cause unpleasant deposits in the eyes, ears and nasal passages (Portland Cement dust), or cause injury to the skin or mucous membranes by chemical or mechanical action per se or by the rigorous skin cleansing procedures necessary for their removal.

A threshold limit of 10 mg/m³, or 30 mppcf, of total dust < 1% quartz, or, 5 mg/m³ respirable dust is recommended for substances in these categories and for which no specific threshold limits have been assigned. This limit, for a normal workday, does not apply to brief exposures at higher concentrations. Neither does it apply to those substances which may cause physiologic impairment at lower concentrations but for which a threshold limit has not yet been adopted. Some nuisance particulates are given in Appendix D.

Simple Asphyxiants — "Inert" Gases or Vapors. A number of gases and vapors, when present in high concentrations in air, act primarily as simple asphyx-

itants without other significant physiologic effects. A TLV may not be recommended for each simple asphyxiant because the limiting factor is the available oxygen. The minimal oxygen content should be 18 percent by volume under normal atmospheric pressure (equivalent to a partial pressure, pO_2 of 135 mm Hg). Atmospheres deficient in O_2 do not provide adequate warning and most simple asphyxiants are odorless. Several simple asphyxiants present an explosion hazard. Account should be taken of this factor in limiting the concentration of the asphyxiant. Specific examples are listed in Appendix E.

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

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

of the metabolite(s) of the substance in tissues and fluids; (3) determination of the amount of the substance in the exhaled breath. The biologic limits may be used as an adjunct to the TLVs for air, *or in place of them*. The BLVs, and their associated procedures for determining compliance with them, should thus be regarded as an effective means of providing health surveillance of the worker.

Tests are available (*J. Occup. Med.* 15:564, 1973; *Ann. N.Y. Acad. Sci.* 151, Art. 2:968, 1968) that may be used to detect those individuals hypersusceptible to a variety of industrial chemicals (respiratory irritants, hemolytic chemicals, organic isocyanates, carbon disulfide).

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

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

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

Operational Guidelines: The ACGIH Board of Directors has adopted operational guidelines for the Chemical Substances TLV Committee. These guidelines prescribe: charge, authority, policies, membership, organization, and operating procedures. The policies include the appeals procedures. Copies of the guidelines document are available from the Publications Office at a cost of \$5 per copy.

Substance	[CAS #]	ADOPTED VALUES			
		TWA		STEL	
		ppm ^{a)}	mg/m ^{3b)}	ppm ^{a)}	mg/m ^{3b)}
Acetaldehyde [75-07-0].....		100	180	150	270
Acetic acid [64-19-7]		10	25	15	37
Acetic anhydride					
[108-24-7].....		C 5	C 20	—	—
Acetone [67-64-1].....		750	1,780	1,000	2,375
Acetonitrile [75-05-8] —					
Skin		40	70	60	105
Acetylene [74-86-2]		E	—	—	—
Acetylene dichloride, see 1, 2-Dichloroethylene					
Acetylene tetrabromide					
[79-27-6].....		1	15	1.5	20
Acetylsalicylic acid (Asprin)					
[50-78-2].....		—	5	—	—
Acrolein [107-02-8]		0.1	0.25	0.3	0.8
Acrylamide [79-06-1] —					
Skin		—	0.3	—	0.6
Acrylic acid [79-10-7].....		10	30	—	—
‡Acrylonitrile [107-13-1] —					
Skin		(2, A1a)	(4.5, A1a)	—	—
Aldrin [309-00-2] — Skin ..		—	0.25	—	0.75
Allyl alcohol [107-18-6] —					
Skin		2	5	4	10
Allyl chloride [107-05-1] ...		1	3	2	6
Allyl glycidyl ether (AGE)					
[106-92-3] — Skin		5	22	10	44
Allyl propyl disulfide					
[2179-59-1].....		2	12	3	18
α-Alumina [1344-28-1].....		—	D	—	20
Aluminum [7429-90-5]					
Metal & oxide		—	10	—	20
Pyro powders		—	5	—	—
Welding fumes		—	5	—	—
Soluble salts		—	2	—	—
Alkyls (NOC†)		—	2	—	—
4-Aminodiphenyl [92-67-1]					
— Skin		—	A1b	—	A1b
2-Aminoethanol, see Ethanolamine					
2-Aminopyridine					
[504-29-0].....		0.5	2	2	4
3-Amino 1, 2, 4-triazole, see Amitrol					
Amitrol [61-82-5].....		A2	A2	—	—
Ammonia [7664-41-7].....		25	18	35	27

Capital letters A, B, D & E refer to Appendices; C denotes ceiling limit.

Footnotes (a thru f) see Page 35.

‡See Notices of Intended Changes.

†NOC = Not otherwise classified.

Substance	[CAS #]	ADOPTED VALUES			
		TWA		STEL	
		ppm ^{a)}	mg/m ^{3b)}	ppm ^{a)}	mg/m ^{3b)}
Ammonium chloride fume					
[12125-02-9].....		—	10	—	20
Ammonium sulfamate					
[7773-06-0].....		—	10	—	20
n-Amyl acetate [628-63-7] ..		100	530	150	800
sec-Amyl acetate					
[626-38-0].....		125	670	150	800
Aniline [62-53-3] &					
homologues — Skin		2	10	5	20
Anisidine [29191-52-4] (o-,					
p-isomers) — Skin		0.1	0.5	—	—
Antimony [7440-36-0] &					
compounds, as Sb		—	0.5	—	—
Antimony trioxide					
[1309-64-4]					
Handling and use, as Sb		—	0.5	—	—
Production		—	A2	—	—
ANTU [86-88-4]		—	0.3	—	0.9
Argon [7440-37-1]		E	—	—	—
Arsenic [7440-38-2] &					
soluble compounds, as					
As		—	0.2	—	—
Arsenic trioxide production					
[1327-53-3]		—	A2	—	—
Arsine [7784-42-1].....		0.05	0.2	—	—
Asbestos [1332-21-4], see					
MINERAL DUSTS		—	A1a	—	A1a
Asphalt (petroleum) fumes					
[8052-42-4]		—	5	—	10
*Atrazine [1912-24-9].....		—	5	—	—
Azinphos-methyl [86-50-0]					
— Skin		—	0.2	—	0.6
Barium [7440-39-3],					
soluble compounds, as					
Ba		—	0.5	—	—
Benomyl [17804-35-2]		0.8	10	1.3	15
Benzene [71-43-2]		10, A2	30, A2	25, A2	75, A2
Benzidine [92-87-5] —					
Skin		—	A1b	—	A1b
p-Benzoquinone, see Quinone					
Benzoyl peroxide [94-36-0]					
[94-36-0].....		—	5	—	—
Benzo(a)pyrene [50-32-8]..		—	A2	—	A2
Benzyl chloride [100-44-7].		1	5	—	—

Capital letters A, B, D & E refer to Appendices; C denotes ceiling limit.

Footnotes (a thru f) see Page 35.

*1983 Addition

Substance	[CAS #]	ADOPTED VALUES			
		TWA		STEL	
		ppm ^{a)}	mg/m ^{3b)}	ppm ^{a)}	mg/m ^{3b)}
Beryllium [7440-41-7]	—	0.002, A2	—	—	—
Biphenyl [92-52-4]	0.2	1.5	0.6	4	—
Bismuth telluride					
[1304-82-1]	—	10	—	20	—
Se-doped	—	5	—	10	—
Borates, tetra, sodium salts [1303-96-4],					
Anhydrous	—	1	—	—	—
Decahydrate	—	5	—	—	—
Pentahydrate	—	1	—	—	—
Boron oxide [1303-86-2] ...	—	10	—	20	—
Boron tribromide					
[10294-33-4]	1	10	3	30	—
Boron trifluoride					
[7637-07-2]	C 1	C 3	—	—	—
Bromacil [314-40-9]	1	10	2	20	—
Bromine [7726-95-6]	0.1	0.7	0.3	2	—
Bromine pentafluoride					
[7789-30-2]	0.1	0.7	0.3	2	—
Bromochloromethane, see Chlorobromomethane					
Bromoform [75-25-2] —					
Skin	0.5	5	—	—	—
‡ 1, 3-Butadiene [106-99-0] .	(1,000)	(2,200)	(1,250)	(2,750)	—
Butane [106-97-8]	800	1,900	—	—	—
Butanethiol, see Butyl mercaptan					
2-Butanone, see Methyl ethyl ketone (MEK)					
2-Butoxyethanol					
[111-76-2] — Skin	25	120	75	360	—
n-Butyl acetate [123-86-4] .	150	710	200	950	—
sec-Butyl acetate					
[105-46-4]	200	950	250	1,190	—
tert-Butyl acetate					
[540-88-5]	200	950	250	1,190	—
Butyl acrylate [141-32-2] ...	10	55	—	—	—
n-Butyl alcohol [71-36-3]					
— Skin	C 50	C 150	—	—	—
sec-Butyl alcohol [78-92-2]	100	305	150	455	—
tert-Butyl alcohol [75-65-0]	100	300	150	450	—
Butylamine [109-73-9] —					
Skin	C 5	C 15	—	—	—
tert-Butyl chromate, as CrO ₃ [1189-85-1] —					
Skin	—	C 0.1	—	—	—

Capital letters A, B, D & E refer to Appendices; C denotes ceiling limit.
Footnotes (a thru f) see Page 35.
‡See Notice of Intended Changes.

Substance	[CAS #]	ADOPTED VALUES			
		TWA		STEL	
		ppm ^{a)}	mg/m ^{3b)}	ppm ^{a)}	mg/m ^{3b)}
n-Butyl glycidyl ether (BGE)					
[2426-08-6]	25	135	—	—	—
n-Butyl lactate [138-22-7] ..	5	25	—	—	—
Butyl mercaptan					
[109-79-5]	0.5	1.5	—	—	—
o-sec-Butylphenol					
[89-72-5] — Skin	5	30	—	—	—
p-tert-Butyltoluene					
[98-51-1]	10	60	20	120	—
Cadmium [7440-43-9]					
Dust & salts, as Cd	—	0.05	—	0.2	—
Cadmium oxide					
[1306-19-0]	—	C 0.05	—	—	—
Fume, as Cd	—	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	—

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Footnotes (a thru f) see Page 35.
*1983 Addition.

Substance	[CAS #]	ADOPTED VALUES			
		TWA		STEL	
		ppm ^{a)}	mg/m ^{3b)}	ppm ^{a)}	mg/m ^{3b)}
Carbon tetrachloride [56-23-5] — Skin	5, A2		30, A2	20, A2	125, A2
Carbonyl chloride, see Phosgene					
Carbonyl fluoride [353-50-4]	2		5	5	15
Catechol (Pyrocatechol) [120-80-9]	5		20	—	—
Cellulose (paper fiber) [9004-34-6]	—		D	—	20
Cesium hydroxide [21351-79-1]	—		2	—	—
Chlordane [57-74-9] — Skin	—		0.5	—	2
Chlorinated camphene [8001-35-2] — Skin	—		0.5	—	1
Chlorinated diphenyl oxide [55720-99-5]	—		0.5	—	2
Chlorine [7782-50-5]	1		3	3	9
Chlorine dioxide [10049-04-4]	0.1		0.3	0.3	0.9
Chlorine trifluoride [7790-91-2]	C 0.1		C 0.4	—	—
Chloroacetaldehyde [107-20-0]	C 1		C 3	—	—
α -Chloroacetophenone [532-27-4] (Phenacyl chloride)	0.05		0.3	—	—
Chloroacetyl chloride [79-04-9]	0.05		0.2	—	—
Chlorobenzene [108-90-7] (Monochlorobenzene)	75		350	—	—
*o-Chlorobenzylidene malononitrile [2698-41-1] — Skin	C 0.05		C 0.4	—	—
Chlorobromomethane [74-97-5]	200		1,050	250	1,300
2-Chloro-1, 3-butadiene, see β Chloroprene					
Chlorodifluoromethane [75-45-6]	1,000		3,500	1,250	4,375
Chlorodiphenyl (42% Chlorine) [53449-21-9] — Skin	—		1	—	2

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*1983 Addition.

Substance	[CAS #]	ADOPTED VALUES			
		TWA		STEL	
		ppm ^{a)}	mg/m ^{3b)}	ppm ^{a)}	mg/m ^{3b)}
Chlorodiphenyl (54% Chlorine) [11097-69-1] — Skin	—		0.5	—	1
1-Chloro, 2, 3-epoxy-propane, see Epichlorohydrin					
2-Chloroethanol, see Ethylene chlorohydrin					
Chloroethylene, see Vinyl chloride					
Chloroform [67-66-3]	10, A2		50, A2	50, A2	225, A2
bis-Chloromethyl ether [542-88-1]	0.001, A1a		0.005, A1a	—	—
*Chloromethyl methyl ether [107-30-2]	A2		A2	—	—
1-Chloro-1-nitropropane [600-25-9]	2		10	—	—
Chloropentafluoroethane [76-15-3]	1,000		6,320	—	—
Chloropicrin [76-06-2]	0.1		0.7	0.3	2
β -Chloroprene [126-99-8] — Skin	10		45	—	—
o-Chlorostyrene [1331-28-8]	50		285	75	430
o-Chlorotoluene [95-49-8] — Skin	50		250	75	375
2-Chloro-6-(trichloromethyl) pyridine, see Nitrapyrin					
Chlorpyrifos [2921-88-2] — Skin	—		0.2	—	0.6
Chromite ore processing (Chromate), as Cr	—		0.05, A1a	—	—
Chromium [7440-47-3] Metal	—		0.5	—	—
Chromium (II) compounds, as Cr	—		0.5	—	—
Chromium (III) compounds, as Cr	—		0.5	—	—
Chromium (VI) compounds, as Cr	—		0.05	—	—
Water soluble	—		0.05, A1a	—	—
Certain water insoluble ..	—		0.05, A1a	—	—
Chromyl chloride [14977-61-8]	0.025		0.15	—	—
Chrysene [218-01-9]	A2		A2	—	—
Clopidol [2971-90-6]	—		10	—	20

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Substance	[CAS #]	ADOPTED VALUES			
		TWA		STEL	
		ppm ^(a)	mg/m ^{3(b)}	ppm ^(a)	mg/m ^{3(b)}
Coal tar pitch volatiles [8007-45-2], as benzene solubles.....	—	0.2, A1a	—	—	—
‡Cobalt [7440-48-4], as Co metal, dust & fume.....	—	(0.1)	—	—	—
*Cobalt carbonyl [00000-00-0], as Co.....	—	0.1	—	—	—
*Cobalt hydrocarbonyl [16842-03-8], as Co.....	—	0.1	—	—	—
Copper [7440-50-8] Fume.....	—	0.2	—	—	—
Dusts & mists, as Cu.....	—	1	—	2	—
Cotton dust, raw.....	—	0.2 ^{k)}	—	0.6	—
Cresol [1319-77-3], all isomers — Skin.....	5	22	—	—	—
Crotonaldehyde [123-73-9]	2	6	6	18	—
Cruformate [299-86-5].....	—	5	—	20	—
Cumene [98-82-8] — Skin.....	50	245	75	365	—
Cyanamide [420-04-2].....	—	2	—	—	—
Cyanides [151-50-8; 143-33-9], as CN — Skin.....	—	5	—	—	—
Cyanogen [460-19-5].....	10	20	—	—	—
Cyanogen chloride [506-77-4].....	C 0.3	C 0.6	—	—	—
Cyclohexane [110-82-7].....	300	1,050	375	1,300	—
Cyclohexanol [108-93-0].....	50	200	—	—	—
Cyclohexanone [108-94-1].....	25	100	100	400	—
Cyclohexene [110-83-8].....	300	1,015	—	—	—
Cyclohexylamine [108-91-8] — Skin.....	10	40	—	—	—
Cyclonite [121-82-4] — Skin.....	—	1.5	—	3	—
Cyclopentadiene [542-92-7].....	75	200	150	400	—
Cyclopentane [287-92-3].....	600	1,720	900	2,580	—
Cyhexatin [13121-70-5].....	—	5	—	10	—
2, 4-D [94-75-7].....	—	10	—	20	—
DDT (Dichlorodiphenyl- trichloroethane) [50-29-3].....	—	1	—	3	—

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Footnotes (a thru f) see Page 35.

* 1983 Addition.

‡ See Notice of Intended Changes.

k) See p. 38.

Substance	[CAS #]	ADOPTED VALUES			
		TWA		STEL	
		ppm ^(a)	mg/m ^{3(b)}	ppm ^(a)	mg/m ^{3(b)}
Decaborane [17702-41-9] — Skin.....	—	0.05	0.3	0.15	0.9
Demeton [8065-48-3] — Skin.....	—	0.01	0.1	0.03	0.3
Diacetone alcohol [123-42-2].....	50	240	75	360	—
1, 2-Diaminoethane, see Ethylenediamine	—	—	—	—	—
Diazinon [333-41-5] — Skin.....	—	0.1	—	0.3	—
Diazomethane [334-88-3] ..	0.2	0.4	—	—	—
Diborane [19287-45-7].....	0.1	0.1	—	—	—
1, 2-Dibromoethane, see Ethylene dibromide	—	—	—	—	—
2-N-Dibutylaminoethanol [102-81-8] — Skin.....	2	14	4	28	—
Dibutyl phosphate.....	1	5	2	10	—
Dibutyl phthalate [84-74-2]	—	5	—	10	—
Dichloroacetylene [7572-29-4].....	C 0.1	C 0.4	—	—	—
o-Dichlorobenzene [95-50-1].....	C 50	C 300	—	—	—
p-Dichlorobenzene [106-46-7].....	75	450	110	675	—
3, 3'-Dichlorobenzidine [91-94-11] — Skin.....	—	A2	—	A2	—
Dichlorodifluoromethane [75-71-8].....	1,000	4,950	1,250	6,200	—
1, 3-Dichloro-5, 5-dimethyl hydantoin [118-52-5].....	—	0.2	—	0.4	—
1, 1-Dichloroethane [75-34-3].....	200	810	250	1,010	—
1, 2-Dichloroethane, see Ethylene dichloride	—	—	—	—	—
1, 1-Dichloroethylene, see Vinylidene chloride	—	—	—	—	—
1, 2-Dichloroethylene [540-59-0].....	200	790	250	1,000	—
Dichloroethyl ether [111-44-4] — Skin.....	5	30	10	60	—
Dichlorofluoromethane [75-43-4].....	10	40	—	—	—
Dichloromethane, see Methylene chloride	—	—	—	—	—
1, 1-Dichloro-1-nitroethane [594-72-9].....	2	10	10	60	—
1, 2-Dichloropropane, see Propylene dichloride	—	—	—	—	—
Dichloropropene [542-75-6] — Skin.....	1	5	10	50	—

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Footnotes (a thru f) see Page 35.

Substance	[CAS #]	ADOPTED VALUES			
		TWA		STEL	
		ppm ^{a)}	mg/m ^{3b)}	ppm ^{a)}	mg/m ^{3b)}
2, 2-Dichloropropionic acid [75-99-0]	1	6	—	—	—
Dichlorotetrafluoroethane [76-14-2]	1,000	7,000	1,250	8,750	
Dichlorvos [62-73-7] — Skin	0.1	1	0.3	3	
Dicrotophos [141-66-2] — Skin	—	0.25	—	—	—
Dicyclopentadiene [77-73-6]	5	30	—	—	—
Dicyclopentadienyl iron [102-54-5]	—	10	—	20	
Dieldrin [60-57-1] — Skin	—	0.25	—	0.75	
Diethanolamine [111-42-2]	3	15	—	—	—
Diethylamine [109-89-7]	10	30	25	75	
Diethylaminoethanol [100-37-8] — Skin	10	50	—	—	—
Diethylene triamine [111-40-0] — Skin	1	4	—	—	—
Diethyl ether, see Ethyl ether					
Diethyl ketone [96-22-0]	200	705	—	—	—
Diethyl phthalate [84-66-2]	—	5	—	10	
Difluorodibromomethane [75-61-6]	100	860	150	1,290	
Diglycidyl ether (DGE) [2238-07-5]	0.1	0.5	—	—	—
Dihydroxybenzene, see Hydroquinone					
Diisobutyl ketone [108-83-8]	25	150	—	—	—
Diisopropylamine [108-18-9] — Skin	5	20	—	—	—
Dimethoxymethane, see Methylal					
Dimethyl acetamide [127-19-5] — Skin	10	35	15	50	
Dimethylamine [124-40-3]	10	18	—	—	—
Dimethylaminobenzene, see Xylidene					
Dimethylaniline [121-69-7] (N, N-Dimethylaniline) — Skin	5	25	10	50	
Dimethylbenzene, see Xylene					
Dimethyl carbamyl chloride [79-44-7]	A2	A2	—	—	—
Dimethyl-1, 2-dibromo-2-dichloroethyl phosphate, see Naled					
Dimethylformamide [68-12-2] — Skin	10	30	20	60	

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Footnotes (a thru f) see Page 35.

Substance	[CAS #]	ADOPTED VALUES			
		TWA		STEL	
		ppm ^{a)}	mg/m ^{3b)}	ppm ^{a)}	mg/m ^{3b)}
2, 6-Dimethyl-4-heptanone, see Diisobutyl ketone					
1, 1-Dimethylhydrazine [57-14-7] — Skin	0.5, A2	1, A2	1, A2	2, A2	
Dimethylphthalate [131-11-3]	—	5	—	10	
Dimethyl sulfate [77-78-1] — Skin	0.1, A2	0.5, A2	—	—	—
Dinitolmide [148-01-6]	—	5	—	10	
Dinitrobenzene [528-29-0] (all isomers) — Skin	0.15	1	0.5	3	
Dinitro-o-cresol [534-52-1] — Skin	—	0.2	—	0.6	
3, 5-Dinitro-o-toluidine, see Dinitolmide					
Dinitrotoluene [121-14-2] — Skin	—	1.5	—	5	
Dioxane, tech. grade [123-91-1] — Skin	25	90	100	360	
Dioxathion [78-34-2] — Skin	—	0.2	—	—	—
Diphenyl, see Biphenyl					
Diphenylamine [122-39-4]	—	10	—	20	
Diphenylmethane diisocyanate, see Methylene bisphenyl isocyanate					
Dipropylene glycol methyl ether [34590-94-8]	100	600	150	900	
Dipropyl ketone [123-19-3]	50	235	—	—	—
Diquat [85-00-7]	—	0.5	—	1	
Di-sec, octyl phthalate [117-81-7] (Di-2-ethyl-hexylphthalate)	—	5	—	10	
Disulfiram [97-77-8]	—	2	—	5	
Disulfoton [298-04-4]	—	0.1	—	0.3	
2, 6-Ditert. butyl-p-cresol [128-37-0]	—	10	—	20	
Diuron [330-54-1]	—	10	—	—	—
Divinyl benzene [108-57-6]	10	50	—	—	—
Emery [112-62-9]	—	D	—	20	
Endosulfan [115-29-7] — Skin	—	0.1	—	0.3	
Endrin [72-20-8] — Skin	—	0.1	—	0.3	
Epichlorohydrin [106-89-8] — Skin	2	10	5	20	
EPN [2104-64-5] — Skin	—	0.5	—	2	
1, 2-Epoxypropane, see Propylene oxide					
2, 3-Epoxy-1-propanol, see Glycidol					
Ethane [74-84-0]	E	—	—	—	—

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Substance	[CAS #]	ADOPTED VALUES			
		TWA		STEL	
		ppm ^{a)}	mg/m ^{3b)}	ppm ^{a)}	mg/m ^{3b)}
Ethanthiol, see Ethyl mercaptan					
Ethanolamine [141-43-5]...	3		8	6	15
Ethion [563-12-2] — Skin	—		0.4	—	—
‡2-Ethoxyethanol [110-80-5]					
— Skin.....	(50)		(185)	(100)	(370)
‡2-Ethoxyethyl acetate					
[111-15-9] — Skin.....	(50)		(270)	(100)	(540)
Ethyl acetate [141-78-6]....	400		1,400	—	—
Ethyl acrylate [140-88-5]					
— Skin.....	5		20	25	100
Ethyl alcohol (Ethanol)					
[64-17-5].....	1,000		1,900	—	—
Ethylamine [75-04-7].....	10		18	—	—
Ethyl amyl ketone					
[41-85-5].....	25		130	—	—
Ethyl benzene [100-41-4] ..	100		435	125	545
Ethyl bromide [74-96-4]....	200		890	250	1,110
Ethyl butyl ketone					
[106-35-4].....	50		230	75	345
Ethyl chloride [75-00-3]....	1,000		2,600	1,250	3,250
Ethylene [74-85-1].....	E		—	—	—
Ethylene chlorohydrin					
[107-07-3] — Skin.....	C 1		C 3	—	—
Ethylenediamine					
[107-15-3].....	10		25	—	—
Ethylene dibromide					
[106-93-4] — Skin.....	A2		A2	—	—
Ethylene dichloride					
[107-06-2].....	10		40	15	60
Ethylene glycol [107-21-1]					
‡ Particulate.....	—		(10)	—	(20)
Vapor.....	C 50		C 125	—	—
*‡Ethylene glycol dinitrate					
[628-96-6] — Skin.....	0.05		0.3	(0.1)	(0.6)
Ethylene glycol methyl ether acetate, see 2-Methoxyethyl acetate					
‡ Ethylene oxide [75-21-8] ...	(10)		(20)	—	—
Ethyleneimine [151-56-4]					
— Skin.....	0.5		1	—	—
Ethyl ether [60-29-7].....	400		1,200	500	1,500
Ethyl formate [109-94-4]....	100		300	150	450
Ethylidene chloride, see 1, 1-Dichloroethane					
Ethylidene norbornene					
[16219-75-3].....	C 5		C 25	—	—

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* 1983 Addition.
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Substance	[CAS #]	ADOPTED VALUES			
		TWA		STEL	
		ppm ^{a)}	mg/m ^{3b)}	ppm ^{a)}	mg/m ^{3b)}
Ethyl mercaptan [75-08-1] .		0.5	1	2	3
N-Ethylmorpholine					
[100-74-3] — Skin.....	5		23	20	95
Ethyl silicate [78-10-4]	10		85	30	255
Fensulfothion [115-90-2]....	—		0.1	—	—
*Fenthion [55-38-9] — Skin	—		0.2	—	—
Ferbam [14484-64-1].....	—		10	—	20
Ferrovandium dust					
[12604-58-9].....	—		1	—	3
Fibrous ^{b)} glass dust.....	—		10	—	—
Fluorides, as F.....	—		2.5	—	—
Fluorine [7782-41-4].....	1		2	2	4
Fluorotrichloromethane, see Trichlorofluoromethane					
Fonofos [944-22-9] —					
Skin.....	—		0.1	—	—
‡Formaldehyde [50-00-0]....	(C 2)		(C 3)	—	—
Formamide [75-12-7].....	20		30	30	45
Formic acid [64-18-6].....	5		9	—	—
Furfural [98-01-1] — Skin	2		8	10	40
Furfuryl alcohol [98-00-0]					
— Skin.....	10		40	15	60
Gasoline [8006-61-9].....	300		900	500	1,500
Germanium tetrahydride					
[7782-65-2].....	0.2		0.6	0.6	1.8
Glass, fibrous or dust, see Fibrous glass dust					
Glutaraldehyde [111-30-8] .	C 0.2		C 0.7	—	—
Glycerin mist [56-81-5]....	—		0	—	—
Glycidol [556-52-5].....	25		75	100	300
Glycol monoethyl ether, see 2-Ethoxyethanol					
Graphite (Natural) [7782-42-5], see MINERAL DUSTS					
Graphite (Synthetic).....	—		0	—	—
Gypsum [10101-4-4].....	—		0	—	20
Hafnium [7440-58-6].....	—		0.5	—	1.5
Helium [7440-59-7].....	E		—	—	—
Heptachlor [76-44-8] —					
Skin.....	—		0.5	—	2
Heptane [142-82-5]					
(n-Heptane).....	400		1,600	500	2,000
2-Heptanone, see Methyl n-amyl ketone					
3-Heptanone, see Ethyl butyl ketone					
Hexachlorobutadiene					
[76-68-3].....	0.02, A2		0.24, A2	—	—

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Substance	[CAS #]	ADOPTED VALUES			
		TWA		STEL	
		ppm ^{a)}	mg/m ^{3b)}	ppm ^{a)}	mg/m ^{3b)}
Hexachlorocyclopentadiene [77-47-4]		0.01	0.1	0.03	0.3
Hexachloroethane [67-72-1]		10	100	—	—
Hexachloronaphthalene [1335-87-1] — Skin		—	0.2	—	0.6
Hexafluoroacetone [684-16-2] — Skin		0.1	0.7	0.3	2
Hexamethyl phosphoramide [680-31-9] — Skin		A2	A2	—	—
Hexane (n-Hexane) [110-54-3]		50	180	—	—
Other isomers		500	1,800	1,000	3,600
2-Hexanone, see Methyl n-butyl ketone					
Hexone, see Methyl isobutyl ketone					
sec-Hexyl acetate [142-92-7]		50	300	—	—
Hexylene glycol [107-41-5]		C 25	C 125	—	—
Hydrazine [302-01-2] — Skin		0.1, A2	0.1, A2	—	—
Hydrogen [1333-74-0]		E	—	—	—
Hydrogenated terphenyls [92-94-4]		0.5	5	—	—
Hydrogen bromide [10035-10-6]		3	10	—	—
Hydrogen chloride [7647-01-0]		C 5	C 7	—	—
Hydrogen cyanide [74-90-8] — Skin		C 10	C 10	—	—
Hydrogen fluoride [7664-39-3], as F		3	2.5	6	5
Hydrogen peroxide [7722-84-1]		1	1.5	2	3
Hydrogen selenide [7783-07-5], as Se		0.05	0.2	—	—
Hydrogen sulfide [7783-06-4]		10	14	15	21
Hydroquinone [123-31-9] ..		—	2	—	4
4-Hydroxy-4-methyl-2-pentanone, see Diacetone alcohol					
2-Hydroxypropyl acrylate [999-61-1] — Skin		0.5	3	—	—
Indene [95-13-6]		10	45	15	70
Indium [7440-74-6] & compounds, as In		—	0.1	—	0.3

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Substance	[CAS #]	ADOPTED VALUES			
		TWA		STEL	
		ppm ^{a)}	mg/m ^{3b)}	ppm ^{a)}	mg/m ^{3b)}
Iodine [7553-56-2]		C 0.1	C 1	—	—
Iodoform [75-47-8]		0.6	10	1	20
Iron oxide fume (Fe ₂ O ₃) [1309-37-1], as Fe		83	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
Isocetyl alcohol [26952-21-6]		50	270	—	—
Isophorone [78-59-1]		C 5	C 25	—	—
Isophorone diisocyanate — Skin		0.01	0.09	—	—
Isopropoxyethanol [109-59-1]		25	105	75	320
Isopropyl acetate [108-21-4]		250	950	310	1,185
Isopropyl alcohol [67-63-0] ..		400	980	500	1,225
Isopropylamine [75-31-0] ..		5	12	10	24
N-Isopropylaniline [643-28-7] — Skin		2	10	5	20
Isopropyl ether [108-20-3] ..		250	1,050	310	1,320
Isopropyl glycidyl ether [4016-14-2] (IGE)		50	240	75	360
Kaolin		—	D	—	20
Ketene [463-51-4]		0.5	0.9	1.5	3
Lead [7439-92-1], inorg., dusts & fumes, as Pb		—	0.15	—	0.45
*‡Lead arsenate [10102-48-4], as Pb ₃ (AsO ₄) ₂		—	0.15	—	(0.45)
Lead chromate [18454-12-1], as Cr		—	0.05, A2	—	—
Limestone [1317-65-3]		—	D	—	20
Lindane [58-89-9] — Skin ..		—	0.5	—	1.5
Lithium hydride [7580-67-8]		—	0.025	—	—
L.P.G. (Liquified petroleum gas)		1,000	1,800	1,250	2,250
Magnesite [546-90-0]		—	D	—	20

Capital letters A, B, D & E refer to Appendices; C denotes ceiling limit.
Footnotes (a thru f) see Page 35.

*1983 Addition.

‡See Notice of Intended Changes.

Substance	[CAS #]	ADOPTED VALUES			
		TWA		STEL	
		ppm ^{a)}	mg/m ^{3b)}	ppm ^{a)}	mg/m ^{3b)}
Magnesium oxide fume [1309-48-4]	—	—	10	—	—
Malathion [121-75-5] — Skin	—	—	10	—	—
Maleic anhydride [108-31-6]	0.25	—	1	—	—
Manganese [7439-96-5], as Mn	—	—	—	—	—
Dust & compounds	—	—	C 5	—	—
Fume	—	—	1	—	3
Manganese cyclopentadienyl tricarbonyl [12079-65-1], as, Mn — Skin	—	—	0.1	—	0.3
Manganese tetroxide	—	—	1	—	—
Marble/calcium carbonate [1317-65-3]	—	—	D	—	20
Mercury [7439-97-6], as Hg — Skin	—	—	—	—	—
Alkyl compounds	—	—	0.01	—	0.03
All forms except alkyl Vapor	—	—	0.05	—	—
Aryl & inorganic compounds	—	—	0.1	—	—
Mesityl oxide [141-79-7] ...	15	—	60	25	100
Methacrylic acid [79-41-4] ..	20	—	70	—	—
Methane [74-82-8]	E	—	—	—	—
Methanethiol, see Methyl mercaptan	—	—	—	—	—
Methomyl [16752-77-5] — Skin	—	—	2.5	—	—
Methoxychlor [72-43-5]	—	—	10	—	—
‡2-Methoxyethanol [109-86-4] — Skin	(25)	—	(80)	(35)	(120)
‡2-Methoxyethyl acetate [110-49-6] — Skin	(25)	—	(120)	(35)	(170)
4-Methoxyphenol [150-76-5]	—	—	5	—	—
Methyl acetate [79-20-9] ...	200	—	610	250	760
Methyl acetylene [74-99-7] ..	1,000	—	1,650	1,250	2,040
Methyl acetylene-propadiene mixture (MAPP)	1,000	—	1,800	1,250	2,250
Methyl acrylate [96-33-3] — Skin	10	—	35	—	—
Methylacrylonitrile [126-98-7] — Skin	1	—	3	2	6

Capital letters A, B, D & E refer to Appendices; C denotes ceiling limit.
Footnotes (a thru f) see Page 35.
‡See Notice of Intended Changes.

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Substance	[CAS #]	ADOPTED VALUES			
		TWA		STEL	
		ppm ^{a)}	mg/m ^{3b)}	ppm ^{a)}	mg/m ^{3b)}
Methylal [109-87-5]	1,000	—	3,100	1,250	3,875
Methyl alcohol [67-56-1] (methanol) — Skin	200	—	260	250	310
Methylamine [74-89-5]	10	—	12	—	—
Methyl amyl alcohol, see Methyl isobutyl carbinol	—	—	—	—	—
Methyl n-amyl ketone [110-43-0]	50	—	235	100	465
N-Methyl aniline [100-61-8] — Skin	0.5	—	2	1	5
Methyl bromide [74-83-9] — Skin	5	—	20	15	60
Methyl n-butyl ketone [591-78-6]	5	—	20	—	—
Methyl chloride [74-87-3] ..	50	—	105	100	205
Methyl chloroform [71-55-6]	350	—	1,900	450	2,450
Methyl 2-cyanoacrylate [137-05-3]	2	—	8	4	16
Methylcyclohexane [108-87-2]	400	—	1,600	500	2,000
Methylcyclohexanol [25639-42-3]	50	—	235	75	350
o-Methylcyclohexanone [583-60-8] — Skin	50	—	230	75	345
Methylcyclopentadienyl manganese tricarbonyl, [12108-13-3] — Skin, as Mn	—	—	0.2	—	0.6
Methyl demeton [8022-00-2] — Skin	—	—	0.5	—	1.5
Methylene bisphenyl isocyanate (MDI) [101-68-8]	C 0.02	—	C 0.2	—	—
Methylene chloride [75-09-2]	100	—	350	500	1,740
4, 4'-Methylene bis (2-chloroaniline) [101-14-4] — Skin	0.02, A2	—	0.22, A2	—	—
Methylene bis(4-cyclohexylisocyanate) [5124-30-1]	C 0.01	—	C 0.11	—	—
4, 4-Methylene dianiline [101-77-9] — Skin	0.1	—	0.8	0.5	4

Capital letters A, B, D & E refer to Appendices; C denotes ceiling limit.
Footnotes (a thru f) see Page 35.
*1983 Addition.

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Substance	[CAS #]	ADOPTED VALUES			
		TWA		STEL	
		ppm ^{a)}	mg/m ^{3b)}	ppm ^{a)}	mg/m ^{3b)}
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 isobutyl ketone [110-12-3]	50	240	—	—	
Methyl isobutyl carbinol [105-30-6] — Skin	25	100	40	165	
Methyl isobutyl ketone [108-10-1]	50	205	75	300	
Methyl isocyanate [624-83-9] — Skin	0.02	0.05	—	—	
Methyl isopropyl ketone [563-80-4]	200	705	—	—	
Methyl mercaptan [74-93-1]	0.5	1	—	—	
Methyl methacrylate [80-62-6]	100	410	125	510	
Methyl parathion [298-00-0] — Skin	—	0.2	—	0.6	
Methyl propyl ketone [107-87-9]	200	700	250	875	
Methyl silicate [681-84-5] ..	1	6	5	30	
α-Methyl styrene [98-83-9] Mevinphos [7786-34-7] — Skin	50 0.01	240 0.1	100 0.03	485 0.3	
Molybdenum [7439-98-7], as Mo					
Soluble compounds	—	5	—	10	
Insoluble compounds	—	10	—	20	
Monocrotophos [6923-22-4]	—	0.25	—	—	
Morpholine [110-91-8] — Skin	20	70	30	105	
Naled [300-76-5]	—	3	—	6	
Naphthalene [91-20-3]	10	50	15	75	
β-Naphthylamine [91-59-8]	—	A1b	—	A1b	

Capital letters A, B, D & E refer to Appendices; C denotes ceiling limit.
Footnotes (a thru f) see Page 35.

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Substance	[CAS #]	ADOPTED VALUES			
		TWA		STEL	
		ppm ^{a)}	mg/m ^{3b)}	ppm ^{a)}	mg/m ^{3b)}
Neon [7440-01-9]	E	—	—	—	—
Nickel carbonyl, as Ni	0.05	0.35	—	—	—
Nickel [7440-02-0] Metal	—	1	—	—	—
Soluble compounds, as Ni	—	0.1	—	0.3	—
Nickel carbonyl [13463-39-3], as Ni	0.05	0.35	—	—	—
Nickel sulfide roasting, fume & dust, as Ni	—	1, A1a	—	—	—
Nicotine [54-11-5] — Skin ..	—	0.5	—	1.5	—
Nitrapyrin [1929-82-4]	—	10	—	20	—
Nitric acid [7697-37-2]	2	5	4	10	—
Nitric oxide [10102-43-9] ..	25	30	35	45	—
p-Nitroaniline [100-01-6] — Skin	—	3	—	—	—
Nitrobenzene — Skin	1	5	2	10	—
†p-Nitrochlorobenzene [100-00-5] — Skin	—	(1)	—	(2)	—
4-Nitrodiphenyl [92-93-3] ..	—	A1b	—	A1b	—
Nitroethane [79-24-3]	100	310	150	465	—
Nitrogen dioxide [10102-44-0]	3	6	5	10	—
Nitrogen trifluoride [7783-54-2]	10	30	15	45	—
*†Nitroglycerin (NG) [55-63-0] — Skin	0.05	0.5	(0.1)	(1)	—
Nitromethane [75-52-5]	100	250	150	375	—
1-Nitropropane [108-03-2] ..	25	90	35	135	—
†2-Nitropropane [79-46-9] ..	(C 25, A2)	(C 90, A2)	—	—	—
N-Nitrosodimethylamine [62-75-9] (dimethylnitro- soamine) — Skin	—	A2	—	A2	—
Nitrotoluene [99-08-1] — Skin	2	11	—	—	—
Nitrotrichloromethane, see Chloropicrin					
Nonane [111-84-2]	200	1,050	250	1,300	—
Octachloronaphthalene [2234-13-1] — Skin	—	0.1	—	0.3	—
Octane [111-65-9]	300	1,450	375	1,800	—
Oil mist, mineral	—	5 ^{e)}	—	10	—

Capital letters A, B, D & E refer to Appendices; C denotes ceiling limit.
Footnotes (a thru f) see Page 35.

*1983 Addition.

†See Notice of Intended Changes.

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Substance	[CAS #]	ADOPTED VALUES			
		TWA		STEL	
		ppm ^(a)	mg/m ^{3(b)}	ppm ^(a)	mg/m ^{3(b)}
Osmium tetroxide [20816-12-0], as Os	0.0002	0.002	0.0006	0.006	
Oxalic acid [144-62-7]	—	1	—	2	
Oxygen difluoride [7783-41-7]	0.05	0.1	0.15	0.3	
Ozone [10028-15-6]	0.1	0.2	0.3	0.6	
Paraffin wax fume [8002-74-2]	—	2	—	6	
Paraquat [1910-42-5], respirable sizes	—	0.1	—	—	
Parathion [56-38-2] — Skin	—	0.1	—	0.3	
Particulate polycyclic aromatic hydro-carbons (PPAH), see Coal tar pitch volatiles					
Pentaborane [19624-22-7]	0.005	0.01	0.015	0.03	
Pentachloronaphthalene [1321-64-8]	—	0.5	—	2	
Pentachlorophenol [87-86-5] — Skin	—	0.5	—	1.5	
Pentaerythritol [115-77-5]	—	0	—	20	
Pentane [109-66-0]	600	1,800	750	2,250	
2-Pentanone, see Methyl propyl ketone					
†Perchloroethylene [127-18-4]	50	335	(—)	(—)	
Perchloromethyl mercaptan [594-42-3]	0.1	0.8	—	—	
Perchloryl fluoride [7616-94-6]	3	14	6	28	
Phenol [108-95-2] — Skin	5	19	10	38	
Phenothiazine [92-84-2] — Skin	—	5	—	10	
N-Phenyl-beta-naphthyl-amine [135-88-6]	A2	A2	—	—	
p-Phenylene diamine [106-50-3] — Skin	—	0.1	—	—	
Phenyl ether [101-84-8], vapor	1	7	2	14	
Phenylethylene, see Styrene, monomer					
Phenyl glycidyl ether (PGE) [122-60-1]	1	6	—	—	
†Phenylhydrazine [100-63-0] — Skin	(5)	(20)	(10)	(45)	

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Footnotes (a thru f) see Page 35.
†See Notice of Intended Changes.

Substance	[CAS #]	ADOPTED VALUES			
		TWA		STEL	
		ppm ^(a)	mg/m ^{3(b)}	ppm ^(a)	mg/m ^{3(b)}
Phenyl mercaptan [108-98-5]	0.5	2	—	—	
Phenylphosphine [638-21-1]	C 0.05	C 0.25	—	—	
Phorate [298-02-2] — Skin	—	0.05	—	0.2	
Phosdrin, see Mevinphos					
Phosgene [75-44-5]	0.1	0.4	—	—	
Phosphine [3803-51-2]	0.3	0.4	1	1	
Phosphoric acid [7664-38-2]	—	1	—	3	
Phosphorus [7723-14-0] (yellow)	—	0.1	—	0.3	
Phosphorus oxychloride [10026-13-8]	0.1	0.6	0.5	3	
Phosphorus pentachloride [10026-13-8]	0.1	1	—	—	
Phosphorus pentasulfide [1314-80-3]	—	1	—	3	
Phosphorus trichloride [7719-12-2]	0.2	1.5	0.5	3	
Phthalic anhydride [85-44-9]	1	6	4	24	
m-Phthalodinitrile [626-17-5]	—	5	—	—	
Picloram [1918-02-1]	—	10	—	20	
Picric acid [88-89-1] — Skin	—	0.1	—	0.3	
Pindone [83-26-1]	—	0.1	—	0.3	
Piperazine dihydrochloride [142-64-3]	—	5	—	—	
2-Pivalyl-1, 3-indandione, see Pindone					
Plaster of Paris	—	D	—	20	
Platinum [7440-06-4] Metal	—	1	—	—	
Soluble salts, as Pt	—	0.002	—	—	
Polychlorobiphenyls, see Chlorodiphenyls					
Polytetrafluoroethylene decomposition products	—	B1	—	B1	
Potassium hydroxide [1310-58-3]	—	C 2	—	—	
Propane [74-98-6]	E	—	—	—	
Propane sulfone [1120-71-4]	A2	A2	—	—	

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Footnotes (a thru f) see Page 35.

Substance	[CAS #]	ADOPTED VALUES			
		TWA		STEL	
		ppm ^{a)}	mg/m ^{3b)}	ppm ^{a)}	mg/m ^{3b)}
Propargyl alcohol [107-19-7] — Skin		1	2	3	6
β -Propiolactone [57-57-8]	0.5, A2	1.5, A2	1, A2	3, A2	
Propionic acid [79-09-4] ...	10	30	15	45	
Propoxur [114-26-1]	—	0.5	—	2	
n-Propyl acetate [109-60-4]	200	840	250	1,050	
Propyl alcohol [71-23-8] — Skin	200	500	250	625	
n-Propyl nitrate [627-13-4]	25	105	40	170	
Propylene [115-07-1]	E	—	—	—	
Propylene dichloride [78-87-5]	75	350	110	510	
* $\ddagger$ Propylene glycol dinitrate [6423-43-4] — Skin	0.05	0.3	(0.1)	(0.6)	
Propylene glycol mono- methyl ether [107-98-2]	100	360	150	540	
*Propyleneimine [75-55-8] — Skin	2, A2	5, A2	—	—	
Propylene oxide [75-56-9]	20	50	—	—	
Propyne, see Methyl acetylene					
Pyrethrum [8003-34-7]	—	5	—	10	
Pyridine [110-86-1]	5	15	10	30	
Quinone [106-51-4]	0.1	0.4	0.3	1	
RDX, see Cyclonite					
Resorcinol [108-46-3]	10	45	20	90	
Rhodium [7440-16-6] Metal	—	1	—	—	
$\ddagger$ Soluble salts, as Rh	—	(0.001)	—	(0.003)	
Ronnel [299-84-3]	—	10	—	—	
Rosin core solder pyrolysis products, as formaldehyde	—	0.1	—	0.3	
Rotenone (commercial) [83-79-4]	—	5	—	10	
Rouge	—	D	—	20	
Rubber solvent (Naphtha) ..	400	1,600	—	—	
Selenium compounds [7782-49-2], as Se	—	0.2	—	—	
Selenium hexafluoride [7783-79-1], as Se	0.05	0.2	—	—	
Sesone [136-78-7]	—	10	—	20	

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*1983 Addition.

$\ddagger$ See Notice of Intended Changes.

Substance	[CAS #]	ADOPTED VALUES			
		TWA		STEL	
		ppm ^{a)}	mg/m ^{3b)}	ppm ^{a)}	mg/m ^{3b)}
Silane, see Silicon tetrahydride					
Silicon [7440-21-3]	—	D	—	—	20
Silicon carbide (409-21-2)	—	D	—	—	20
*Silicon tetrahydride (Silane) [7803-62-5]	5	7	—	—	
Silver [7440-22-4], as Ag Metal	—	0.1	—	—	
Soluble compounds	—	0.01	—	—	
Sodium azide [26628-22-8]	C 0.1	C 0.3	—	—	
Sodium bisulfite [7631-90-5]	—	5	—	—	
Sodium 2, 4-dichloro-phenoxyethyl sulfate, see Sesone					
Sodium fluoroacetate [62-74-8] — Skin	—	0.05	—	0.15	
Sodium hydroxide [1310-73-2]	—	C 2	—	—	
Sodium metabisulfite [7681-57-4]	—	5	—	—	
Starch [9005-84-9]	—	D	—	20	
Stibine [7803-52-3]	0.1	0.5	0.3	1.5	
Stoddard solvent [8052-41-3]	100	525	200	1,050	
Strychnine [57-24-9]	—	0.15	—	0.45	
Styrene, monomer [100-42-5]	50	215	100	425	
Subtilisins [1395-21-7] (Proteolytic enzymes as 100% pure crystalline enzyme)	—	C0.00006 ^{m)}	—	—	
Sucrose [57-50-1]	—	D	—	20	
Sulfotep [3689-24-5] — Skin	—	0.2	—	0.6	
Sulfur dioxide [7446-09-5] [2551-62-4]	2	5	5	10	
Sulfur hexafluoride [7664-93-9] ..	1,000	6,000	1,250	7,500	
Sulfur monochloride [10025-67-9]	—	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	

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Footnotes (a thru f) see Page 35.

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m) See Page 38.

Substance	[CAS #]	ADOPTED VALUES			
		TWA		STEL	
		ppm ^{a)}	mg/m ^{3b)}	ppm ^{a)}	mg/m ^{3b)}
Sulfuryl fluoride [2699-79-8]	5	20	10	40	
Systox, see Demeton					
2, 4, 5-T [93-76-5]	—	10	—	20	
Tantalum [7440-25-7]	—	5	—	10	
TEDP, see Sulfotep					
Tellurium & compounds					
[13494-80-9], as Te	—	0.1	—	—	
Tellurium hexafluoride [7783-80-4], as Te	0.02	0.2	—	—	
Temephos [3383-96-8]	—	10	—	20	
TEPP [107-49-3] — Skin	0.004	0.05	0.01	0.2	
Terphenyls [92-94-4]	C 0.5	C 5	—	—	
1, 1, 1, 2-Tetrachloro-2, 2- difluoroethane [76-11-9]	500	4,170	625	5,210	
1, 1, 2, 2-Tetrachloro-1, 2- difluoroethane [76-12-0]	500	4,170	625	5,210	
1, 1, 2, 2-Tetrachloro- ethane [79-34-5] — Skin	1	7	5	35	
Tetrachloroethylene, see Perchloroethylene					
Tetrachloromethane, see Carbon tetrachloride					
Tetrachloronaphthalene [1335-88-2]	—	2	—	4	
Tetraethyl lead [78-00-2], as Pb — Skin	—	0.100 ^{a)}	—	0.3	
Tetrahydrofuran [109-99-9]	200	590	250	735	
Tetramethyl lead [75-74-1], as Pb — Skin	—	0.150 ^{a)}	—	0.5	
Tetramethyl succinonitrile [3333-52-6] — Skin	0.5	3	2	9	
Tetranitromethane [509-14-8]	1	8	—	—	
Tetrasodium pyrophosphate [7722-88-5]	—	5	—	—	
Tetryl [479-45-8] (2, 4, 6-trinitrophenyl- methylnitramine) — Skin	—	1.5	—	3.0	
Thallium [7440-28-0] Soluble compounds, as Tl — Skin	—	0.1	—	—	
4, 4'-Thiobis(6-tert. butyl- m-cresol) [96-69-5]	—	10	—	20	
Thioglycolic acid [68-11-1]	1	5	—	—	

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Footnotes (a thru f) see Page 35.

Substance	[CAS #]	ADOPTED VALUES			
		TWA		STEL	
		ppm ^{a)}	mg/m ^{3b)}	ppm ^{a)}	mg/m ^{3b)}
Thiram [137-26-8]	—	5	—	10	
Tin [7440-31-5] Metal	—	2	—	4	
Oxide & inorganic compounds, except SnO ₂ , as Sn	—	2	—	4	
Organic compounds, as Sn — Skin	—	0.1	—	0.2	
Titanium dioxide [13463-67-7], as Ti	—	D	—	20	
o-Tolidine [119-93-7] — Skin	A2	A2	—	—	
Toluene [108-88-3] (toluol) — Skin	100	375	150	560	
* Toluene-2, 4-diisocyanate (TDI) [584-84-9]	0.005	0.04	0.02	0.15	
† o-Tolidine [95-53-4] — Skin	(2)	(9)	—	—	
Toxaphene, see Chlorinated camphene					
Tributyl phosphate [126-73-8]	0.2	2.5	0.4	5	
Trichloroacetic acid [76-03-9]	1	5	—	—	
1, 2, 4-Trichlorobenzene [120-82-1]	C 5	C 40	—	—	
1, 1, 1-Trichloroethane, see Methyl chloroform					
1, 1, 2-Trichloroethane [79-00-5] — Skin	10	45	20	90	
‡ Trichloroethylene [79-01-6]	50	270	(150)	(805)	
Trichlorofluoromethane [75-69-4]	C 1,000	C 5,600	—	—	
Trichloromethane, see Chloroform					
Trichloronaphthalene [1321-65-9]	—	5	—	10	
Trichloronitromethane, see Chloropicrin					
1, 2, 3-Trichloropropane [96-18-4]	50	300	75	450	
1, 1, 2-Trichloro-1, 2, 2- trifluoroethane [76-13-1]	1,000	7,600	1,250	9,500	
Tricyclohexyltin hydroxide, see Cyhexatin					
* Triethylamine [121-44-8] ...	10	40	15	60	
Trifluorobromomethane [75-63-8]	1,000	6,100	1,200	7,300	

Capital letters A, B, D & E refer to Appendices; C denotes ceiling limit.
Footnotes (a thru f) see Page 35.

* 1983 Addition.

‡ See Notice of Intended Changes.

Substance	[CAS #]	ADOPTED VALUES			
		TWA		STEL	
		ppm ^{a)}	mg/m ^{3b)}	ppm ^{a)}	mg/m ^{3b)}
Trimellitic anhydride [552-30-7].....		0.005	0.04	—	—
*Trimethylamine [75-50-3] ..		10	24	15	36
Trimethyl benzene [25551-13-7].....		25	125	35	170
Trimethyl phosphite [121-45-9].....		2	10	5	25
2, 4, 6-Trinitrophenol, see Picric acid					
2, 4, 6-Trinitrophenyl-methylnitramine, see Tetryl					
2, 4, 6-Trinitrotoluene (TNT) [118-96-7] —					
Skin		—	0.5	—	3
Triorthocresyl phosphate [78-30-8].....		—	0.1	—	0.3
Triphenyl amine [603-34-9].....		—	5	—	—
Triphenyl phosphate [115-86-6].....		—	3	—	6
Tungsten [7440-33-7], as W					
Insoluble compounds.....		—	5	—	10
Soluble compounds.....		—	1	—	3
Turpentine [8006-64-2].....		100	560	150	840
Uranium (natural) [7440-61-1], Soluble & Insoluble compounds, as U		—	0.2	—	0.6
Valeraldehyde [110-82-3] ..		50	175	—	—
Vanadium, as V ₂ O ₅ [1314-62-1], respirable dust & fume.....		—	0.05	—	—
Vegetable oil mists.....		—	D	—	—
Vinyl acetate [108-05-4].....		10	30	20	60
Vinyl benzene, see Styrene					
Vinyl bromide [593-60-2] ...		5, A2	20, A2	—	—
Vinyl chloride [75-01-4]		5, A1a	10, A1a	—	—
Vinyl cyanide, see Acrylonitrile					
Vinyl cyclohexene dioxide [106-87-6].....		10, A2	60, A2	—	—
‡Vinylidene chloride [75-35-4]		(10)	(40)	(20)	(80)
Vinyl toluene [25013-15-4] .		50	240	100	485
VM & P Naphtha [8030-30-6]		300	1,350	400	1,800
Warfarin [81-81-2].....		—	0.1	—	0.3

Capital letters A, B, D & E refer to Appendices; C denotes ceiling limit.
Footnotes (a thru f) see Page 35.
*1983 Addition.
‡See Notice of Intended Changes.

Substance	[CAS #]	ADOPTED VALUES			
		TWA		STEL	
		ppm ^{a)}	mg/m ^{3b)}	ppm ^{a)}	mg/m ^{3b)}
Welding fumes (NOC†).....		—	5, B2	—	—
Wood dust (certain hard woods as beech & oak) ..		—	1	—	—
Soft wood.....		—	5	—	10
Xylene [1330-20-7] (o-, m-, p-isomers).....		100	435	150	655
m-Xylene α , α' -diamine [1477-55-0] — Skin		—	C 0.1	—	—
Xylidine [1300-73-8] —					
Skin		2	10	—	—
Yttrium [7440-65-5]		—	1	—	3
Zinc chloride fume [7646-85-7]		—	1	—	2
Zinc chromate [13530-65-9], as Cr		—	0.05, A2	—	—
Zinc oxide [1314-13-2] Fume		—	5	—	10
Dust		—	D	—	—
Zinc stearate [557-05-1]		—	D	—	20
Zirconium compounds [7440-67-2], as Zr		—	5	—	10

Capital letters A, B, D & E refer to Appendices; C denotes ceiling limit.
Footnotes (a thru f) see Page 35.
†NOC = Not otherwise classified.

- a) Parts of vapor or gas per million parts of contaminated air by volume at 25°C and 760 mm Hg pressure.
- b) Approximate milligrams of substance per cubic meter of air.
- d) $< 7 \mu\text{m}$ in diameter.
- e) As sampled by method that does not collect vapor.
- f) For control of general room air, biologic monitoring is essential for personnel control.

Radioactivity: The Committee accepts the philosophy and recommendations of the National Council on Radiation Protection and Measurements (NCRP) for the ionizing radiation TLV. The NCRP is chartered by Congress to, in part, collect, analyze, develop and disseminate information and recommendations about protection against radiation and about radiation measurements, quantities and units, including devel-

opment of basic concepts in these areas. NCRP Report No. 39 (reference 1) provides basic philosophy and concepts leading to protection criteria established in the same report. Other NCRP reports address specific areas of radiation protection and, collectively, provide an excellent basis for establishing a sound program for radiation control. The Committee recommends the listed references as substantive documentation of a sound basis for ionizing radiation protection. The Committee also strongly recommends that all exposures to ionizing radiations be kept low as reasonably achievable within the stated guidance.

References:

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

The above documents, as well as information on numerous other NCRP Reports addressing specific subjects in ionizing radiation protection are available from: NCRP Publications, PO Box 30175, Washington, DC 20014.

MINERAL DUSTS

Substance	TLV
SILICA, SiO₂	
<i>Crystalline</i>	
‡Quartz [14808-60-7]	TLV in mppcf ^a : 300 ^a
	% quartz + 10
	TLV for respirable dust in mg/m ³ : 10 mg/m ³
	% Respirable quartz + 2
	TLV for "total dust," respirable and nonrespirable: 30 mg/m ³
	% quartz + 3
‡Cristobalite [14464-46-1]	Use one-half the value calculated from the count or mass formulae for quartz.

‡See Notice of Intended Changes.

- ‡Tridymite Use one-half the value calculated [15468-32-3] from formulae for quartz.
- ‡Silica, fused [60676-86-0] Use quartz formulae.
- ‡Tripoli Use respirable^a mass quartz formula [1317-95-9]
- ‡Amorphous [7631-86-9] (20 mppcf^a)

SILICATES (<1% quartz)

Asbestos^a

- Amosite [12172-73-5] 0.5 fiber/cc > 5 μm in length, A1a
- Chrysotile [12001-29-5] 2 fibers/cc > 5 μm in length, A1a
- Crocidolite [12001-28-4] 0.2 fiber/cc > 5 μm in length, A1a
- Other forms 2 fibers/cc > 5 μm in length, A1a

‡Graphite (natural)

- [7782-42-5] 15 mppcf
- ‡Mica [12001-26-2] 20 mppcf
- Mineral wool fiber 10 mg/m³
- ‡Perlite 30 mppcf
- ‡Portland Cement 30 mppcf
- ‡Soapstone 20 mppcf

*Talc (containing no asbestos fibers)

- [14807-96-6] 2 mg/m³, Respirable dust
- ‡Talc (fibrous), (use Asbestos limit.)

COAL DUST

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

NUISANCE PARTICULATES

(see Appendix D)

‡(30 mppcf) or 10 mg/m³

of total dust < 1% quartz, or, 5 mg/m³ respirable dust.

Conversion factors:

$$\text{mppcf} \times 35.3 = \text{Million particles per cubic meter} \\ = \text{particles per cc}$$

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

‡See Notice of Intended Changes.

*1983 Addition.

- h) The percentage of quartz in the formula is the amount determined from airborne samples, except in those instances in which other methods have been shown to be applicable.
- i) Both concentration and percent quartz for the application of this limit are to be determined from the fraction passing a size-selector with the following characteristics:

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

- ‡j) containing < 1% quartz; (if quartz content > 1%, use formulae for quartz.)
- k) Lint-free dust as measured by the vertical elutriator, cotton-dust sampler described in the *Transactions of the National Conference on Cotton Dust*, p. 33 by J. R. Lynch, (May 2, 1970).
- l) As determined by the membrane filter method at 400-450X magnification (4 mm objective) phase contrast illumination.
- m) Based on "high volume" sampling.
- n) "Respirable" dust as defined by the British Medical Research Council Criteria, ⁽¹⁾ and as sampled by a device producing equivalent results. ⁽²⁾
- (1) Hatch, T. E. and Gross: *Pulmonary Deposition and Retention of Inhaled Aerosols*, p. 149. Academic Press, New York, (1964).
- (2) AIHA Aerosol Technology Committee: Interim Guide for Respirable Mass Sampling. *Am. Ind. Hyg. Assoc. J.* 31(2):133 (1970).

NOTICE OF INTENDED CHANGES (for 1983-84)

These substances, with their corresponding values, comprise those for which either a limit has been proposed for the first time, or for which a change in the "Adopted" listing has been proposed. In both cases, the proposed limits should be considered trial

‡See Notice of Intended Changes.

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		STEL	
		ppm ^{a)}	mg/m ^{3b)}	ppm ^{a)}	mg/m ^{3b)}
Acrylonitrile [107-13-1] —					
Skin		2, A2	4.5, A2	—	—
† 1, 3-Butadiene [106-99-0] ..		A2	A2	—	—
Cobalt metal, dust & fume					
[7440-48-4], as Co.....		—	0.05	—	0.1
Enflurane [13838-16-9].....		75	575	—	—
2-Ethoxyethanol [110-80-5]					
— Skin.....		5	19	—	—
2-Ethoxyethyl acetate					
[111-15-9] — Skin.....		5	27	—	—
Ethylene glycol [107-21-1], particulate					
DELETE, see Appendix G					
† Ethylene glycol dinitrate					
[628-96-6] — Skin.....		0.05	0.3	—	—
Ethylene oxide [75-21-8] ...		1, A2	2, A2	—	—
Fenamiphos [22224-92-6]					
— Skin.....		—	0.1	—	—
† Formaldehyde [50-00-0]....		1, A2	1.5, A2	2, A2	3, A2
Grain dust		—	4	—	—
Halothane [151-67-7]		50	400	—	—
† Lead arsenate					
[10102-48-4],					
as Pb ₃ (AsO ₄) ₂		—	0.15	—	—
2-Methoxyethanol					
[109-86-4] — Skin.....		5	16	—	—
2-Methoxyethyl acetate					
[110-49-6] — Skin.....		5	24	—	—
Metribuzin [21087-64-9] ...		—	5	—	—
p-Nitrochlorobenzene					
[100-00-5] — Skin.....		0.5	3	—	—
† Nitroglycerin [55-63-0] —					
Skin		0.05	0.5	—	—
2-Nitropropane [79-46-9] ..		10, A2	35, A2	20, A2	70, A2
Perchloroethylene					
[127-18-4].....		50	335	200	1,340
Persulfates, alkali metal, as					
S ₂ O ₈		—	2	—	—

Capital letters A, B, D & E refer to Appendices; C denotes ceiling limit.
† 1983 Revision or Addition.

Substance	[CAS #]	TWA		STEL	
		ppm ^{a)}	mg/m ^{3b)}	ppm ^{a)}	mg/m ^{3b)}
Phenylhydrazine [100-63-0] — Skin		5, A2	20, A2	10, A2	45, A2
†Propylene glycol dinitrate [6423-43-4] — Skin		0.05	0.3	—	—
Rhodium, Insoluble compounds, as Rh		—	1	—	—
Soluble compounds, as Rh		—	0.01	—	—
Sulprofos [35400-43-2]		—	1	—	—
o-Toluidine [95-53-4] — Skin		2, A2	9, A2	—	—
Trichloroethylene [79-01-6] Vinylidene chloride [75-35-4]		50	270	200	1,080
		5	20	20	80

Capital letters A, B, D & E refer to Appendices; C denotes ceiling limit.
†1983 Revision or Addition.

NOTICE OF INTENDED CHANGES MINERAL DUSTS

Substance	TLV
<u>SILICA, SiO₂</u>	
<u>Crystalline</u>	
Quartz	0.1 mg/m ³ , Respirable dust
[14808-60-7]	0.3 mg/m ³ , Total dust
Cristobalite	0.05 mg/m ³ , Respirable dust
[14464-46-1]	0.15 mg/m ³ , Total dust
Tridymite	0.05 mg/m ³ , Respirable dust
[15468-32-3]	0.15 mg/m ³ , Total dust
Silica, fused	Use quartz values.
[60676-86-0]	
Tripoli	Use respirable quartz value.
[1317-95-9]	
Silica, amorphous ..	5 mg/m ³ , Respirable dust
[7631-86-9]	10 mg/m ³ , Total dust
<u>SILICATES (< 1% quartz)</u>	
Diatomaceous earth ..	5 mg/m ³ , Respirable dust
(uncalcined)	10 mg/m ³ , Total dust
[60676-86-0]	
Graphite (natural)...	2.5 mg/m ³ , Respirable dust
[7782-42-5]	5 mg/m ³ , Total dust

Mica [12001-26-2] ..	3 mg/m ³ , Respirable dust
	6 mg/m ³ , Total dust
Perlite	5 mg/m ³ , Respirable dust
	10 mg/m ³ , Total dust
Portland Cement....	5 mg/m ³ , Respirable dust
	10 mg/m ³ , Total dust
Precipitated silica ..	5 mg/m ³ , Respirable dust
and silica gel	10 mg/m ³ , Total dust
Soapstone	3 mg/m ³ , Respirable dust
	6 mg/m ³ , Total dust
Talc (containing ..	Use asbestos TLV. However,
asbestos fibers) ..	should not exceed 2 mg/m ³
	respirable dust.

COAL DUST

If > 5% quartz, use respirable quartz value.

Generic Listing

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

Footnote

j) Containing < 1% quartz; if quartz content > 1%, use quartz values.

APPENDIX A Carcinogens

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

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

	TLV
** Acrylonitrile — Skin.....	2 ppm
<u>Asbestos</u>	
Amosite	0.5 fiber > 5μm/cc
Chrysotile	2 fibers > 5μm/cc
Crocidolite	0.2 fiber > 5μm/cc
Other forms	2 fibers > 5μm/cc

**See Notice of Intended Changes.

bis (Chloromethyl) ether	0.001 ppm
Chromite ore processing (chromate)	0.05 mg/m ³ , as Cr
Chromium (VI), certain water insoluble compounds.....	0.05 mg/m ³ , as Cr
Coal tar pitch volatiles ..	0.2 mg/m ³ , as benzene solubles
Nickel sulfide roasting, fume & dust.....	1.0 mg/m ³ , as Ni
Vinyl chloride	5 ppm

* * *

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

4-Aminodiphenyl (p-Xenylamine) — Skin
Benzidine — Skin
β-Naphthylamine
4-Nitrodiphenyl

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

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

Acrylonitrile — Skin	2 ppm
Amitrol	—
Antimony trioxide production*	—
Arsenic trioxide production	—
Benzene	10 ppm
Benzo(a)pyrene	—
Beryllium	2.0 μg/m ³

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

† 1, 3-Butadiene	—
Cadmium oxide production	—
Carbon tetrachloride — Skin	5 ppm
Chloroform	10 ppm
‡ Chloromethyl methyl ether	—
Chromates of lead and zinc, as Cr	0.05 mg/m ³
Chrysene	—
3, 3'-Dichlorobenzidine — Skin	—
Dimethylcarbonyl chloride	—
1, 1-Dimethyl hydrazine — Skin	0.5 ppm
Dimethyl sulfate — Skin	0.1 ppm
Ethylene dibromide — Skin	—
Ethylene oxide	1 ppm
† Formaldehyde	1 ppm
Hexachlorobutadiene	0.02 ppm
Hexamethyl phosphoramide — Skin	—
Hydrazine — Skin	0.1 ppm
4, 4'-Methylene bis (2-chloroaniline) — Skin	0.02 ppm
Methyl hydrazine — Skin	0.2 ppm
Methyl iodide — Skin	2 ppm
2-Nitropropane	10 ppm
N-Nitrosodimethylamine — Skin	—
N-Phenyl-beta-naphthylamine	—
Phenylhydrazine — Skin	5 ppm
Propane sulfone	—
beta-Propiolactone	0.5 ppm
‡ Propyleneimine — Skin	2 ppm
o-Tolidine	—
o-Toluidine — Skin	2 ppm
Vinyl bromide	5 ppm
Vinyl cyclohexene dioxide	10 ppm

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

†1983 Addition.
‡1983 Adoption.

**THE COMMITTEE GUIDELINES FOR
CLASSIFICATION OF EXPERIMENTAL ANIMAL
CARCINOGENS**

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

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

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

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

Proposed Classification of Experimental Animal Carcinogens. Substances occurring in the occupational environment found carcinogenic for animals may be grouped into three classes, those of high, intermediate and low potency. In evaluating the incidence of animal cancers, sig-

nificant incidence of cancer is defined as a neoplastic response which represents, in the judgment of the Committee, a significant excess of cancers above that occurring in negative controls.

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

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

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

A. Industrial Substances of High Carcinogenic Potency in Experimental Animals.

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

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

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

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

OR

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

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

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

OR

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

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

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

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

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

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

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

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

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

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

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

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

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

OR

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

Examples: Shale tar, mouse, 0.1 ml $\times$ 50 = 5g T.D. 59/60 skin tumors

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

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

**APPENDIX B
SUBSTANCES OF VARIABLE COMPOSITION**

- B1 *Polytetrafluoroethylene* decomposition products*. Thermal decomposition of the fluorocarbon chain in air leads to the formation of oxidized products containing carbon, fluorine and oxygen. Because these products decompose in part by hydrolysis in alkaline solution, they can be quantitatively determined in air as fluoride to provide an index of exposure. No TLV is recommended pending de-

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

termination of the toxicity of the products, but air concentrations should be minimal.

B2 *Welding Fumes — Total Particulate*
(NOC)[†]
TLV, 5 mg/m³

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

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

APPENDIX C MIXTURES

C.1 THRESHOLD LIMIT VALUES FOR MIXTURES

When two or more hazardous substances, which act upon the same organ system, are present, their

[†]Not otherwise classified (NOC).

combined effect, rather than that of either individually, should be given primary consideration. In the absence of information to the contrary, the effects of the different hazards should be considered as additive. That is, if the sum of the following fractions,

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

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

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

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

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

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

C.1A Examples of THRESHOLD LIMIT VALUES FOR MIXTURES

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

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

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

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

Example No. 1A.a.: Air contains 400 ppm of acetone (TLV = 750 ppm) 150 ppm of sec-butyl acetate (TLV = 200 ppm) and 100 ppm of methyl ethyl ketone (TLV = 200 ppm)

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

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

Threshold Limit is exceeded.

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

Additive effects (approximate solution)

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

(Note: In order to evaluate compliance with this TLV, field sampling instruments should be calibrated, in the laboratory, for response to this specific quantitative and qualitative

air-vapor mixture, and also to fractional concentrations of this mixture; e.g., 1/2 the TLV; 1/10 the TLV; 2 × the TLV; 10 × the TLV; etc.)

TLV of mixture =

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

Example No. 1A.b.: Liquid contains (by weight)

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

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

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

$$\begin{aligned} \text{TLV of Mixture} &= \frac{1}{\frac{0.5}{1600} + \frac{0.3}{1900} + \frac{0.2}{335}} \\ &= \frac{1}{0.00031 + 0.00016 + 0.0006} \\ &= \frac{1}{0.00107} = 935 \text{ mg/m}^3 \end{aligned}$$

of this mixture

50% or (935) (0.5) = 468 mg/m³ is heptane

30% or (935) (0.3) = 281 mg/m³ is methyl chloroform

20% or (935) (0.2) = 187 mg/m³ is perchloroethylene

These values can be converted to ppm as follows:

heptane: 468 mg/m³ × 0.25 = 117 ppm

methyl chloroform: 281 mg/m³ × 0.18 = 51 ppm

perchloroethylene: 187 mg/m³ × 0.15 = 29 ppm

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

1A.c. *Independent effects.*

Air contains 0.15 mg/m³ of lead (TLV, 0.15) and 0.7 mg/m³ of sulfuric acid (TLV, 1).

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

Threshold limit is not exceeded.

1B. TLV for Mixtures of Mineral Dusts.

For mixtures of biologically active mineral dusts the general formula for mixtures given in 1A.b. may be used.

APPENDIX D

Some Nuisance Particulates^{o)}

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

α-Alumina (Al ₂ O ₃)	Plaster of Paris
Calcium carbonate	Portland Cement
Calcium silicate	Rouge
Cellulose (paper fiber)	Silicon
Emery	Silicon Carbide
Glycerin Mist	Starch
Graphite (synthetic)	Sucrose
Gypsum	Titanium Dioxide
Kaolin	Vegetable oil mists
Limestone	(except castor, cashew
Magnesite	nut, or similar irritant
Marble	oils)
Mineral Wool Fiber	Zinc Stearate
Pentaerythritol	Zinc oxide dust

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

APPENDIX E

Some Simple Asphyxiants^{p)}

Acetylene	Helium	Propane
Argon	Hydrogen	Propylene
Ethane	Methane	
Ethylene	Neon	

p) As defined on pg. 6.

‡See Notice of Intended Changes.

‡APPENDIX F

Conversion of mppcf to Mass Concentration

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

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

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

2. Basic assumptions:

a) Average density for silica containing dusts ≈ 2.5 g/cm³ (2500 mg/cm³). Pulmonary significant dust densities may vary from 1.2 g/cm³ for coal dust to 3.1 g/cm³ for Portland Cement. Silica densities vary from 2.2 (amorphous) to 2.3 (cristobalite and tridymite) to 2.5 (alpha-quartz.) gms per cm³.

b) The mass median diameter (mmd) of particles collected in midget impinger samplers and counted by the standard light field technique, and collected in a respirable sampler is approximately 1.5 μm or 1.5 × 10⁻⁴ cm. This assumption is, of course, quite arbitrary since the mmd of all dust clouds is quite variable, depending on many independent parameters, such as source of dust, age of dust cloud, meteorological conditions, processes and equipment changes, etc. If the density and the mass median diameter of the dust particles are known, the nomograph in Figure 1 can be used to convert dust count concentrations (mppcf) to respirable mass concentrations (mg/m³).

‡See Notice of Intended Changes.

3. Calculation:

a) vol. per particle: $\frac{4}{3} \pi r^3$; $r = 0.75 \times 10^{-4}$ cm

$$= \frac{4}{3} \pi \cdot (0.75 \times 10^{-4})^3$$

$$= 1.77 \times 10^{-12} \text{ cm}^3$$

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

c) 1 particle/ft.³ = 35.3 part./m³
 (since 35.5 cu ft = 1 cu m.)
 $10^6 \text{ part./ft}^3 = \text{mppcf} = 35.3 \times 10^6 \text{ part./m}^3$
 wt. of 1 mppcf = $35.3 \times 10^6 \text{ part./m}^3 \times 4.425 \times 10^{-9} \text{ mg/part.}$

$$1 \text{ mppcf} = 0.157 \text{ mg/m}^3$$

or

$$6.37 \text{ mppcf} = 1 \text{ mg/m}^3$$

or approximately 6 mpccf = 1 mg/m³.

Reference

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

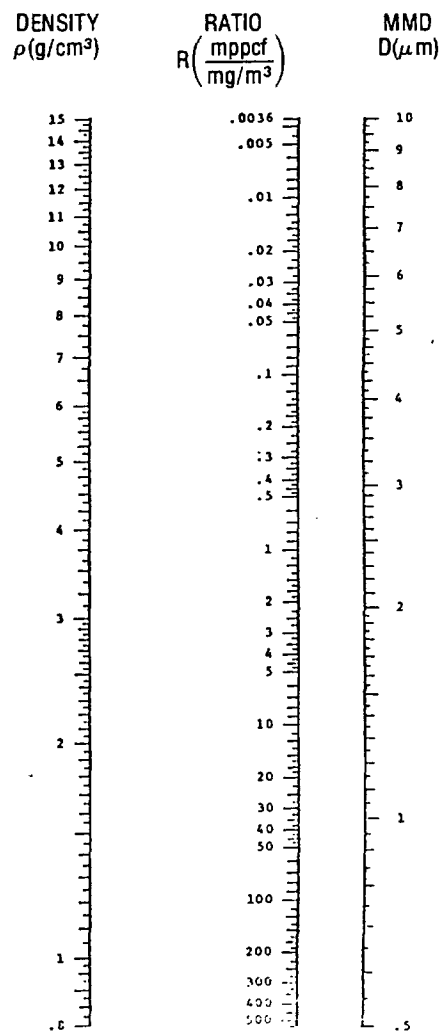


Figure 1 — Ratio of Particle Count — mppcf to Respirable Mass Concentration — mg/m³ (as function of density and mmd)†

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

Table 1
Equivalent TLVs in mppcf and mg/m³ (Respirable Mass)
for Mineral Dusts†

Substance	Threshold Limit Value		
	Count mppcf	Resp. Mass mg/m ³	Total Mass* mg/m ³
<i>Silica (SiO₂)</i>			
Amorphous	20	(3)**	(6)
Cristobalite	1.5	0.05	0.15
Fused silica	3	0.1	0.3
Quartz	3	0.1	0.3
Tridymite	1.5	0.05	0.15
Coal Dust	(12)	2	(4)
Diatomaceous earth, natural	—	1.5	—
Graphite (natural)	15	(2.5)	(5)
Mica	20	(3)	(6)
Mineral wool fiber	—	(5)	10
Nuisance particulates	30	(5)	10
Perlite	30	(5)	(10)
Portland Cement	30	(5)	(10)
Soapstone	20	(3)	(6)
Tripoli	(3)	0.1	(0.3)

†Assuming that the mass median diameter is 1.5 μ m and density is 2.5 g/cm³.

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

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

APPENDIX G

Chemical Substances and Other Issues Under Study¹

Chemical Substances

Acetonitrile	1,3-Butadiene
Acrolein	Carbonyl fluoride
Acrylic acid	Chlorinated naphthalenes
Allyl chloride	Chlorine
Amorphous silica	o-Chlorobenzlidene
Asbestos	bis-Chloromethyl ether
Atrazine	Chloromethyl methyl ether
Bismuth telluride	o-Chlorotoluene

Chrysene	Methyl methacrylate
Copper dust & fume	Methyl tertiary butyl ether
Cyclohexanone	Nickel, metal & soluble compounds
Diatomaceous earth	p-Nitrochlorobenzene
Diethylenetriamine	Osmium tetroxide
Epichlorohydrin	Perfluorinated chemicals
Ethyl chloride	Piperazine
Ethylene dichloride	Propylene chloride
Ethyl methacrylate	Propylene oxide
Gasoline	Styrene, monomer
Glycol ethers	Tetrachloronaphthalene
Graphite	Tin hydride
Hexachlorocyclopentadiene	1,2,3-Trichloropropane
Isocyanates	Trimellitic anhydride
Isoflurane	m-Xylene 2,2'-diamine
Isooctyl alcohol	(MXDA; meta-meta-xylenediamine)
Jet fuels	
Methylenedianiline	

Other Issues

1. Is the current aspect ratio better than other ratios for health protection and/or differentiation of asbestos fibers.
2. *Ceiling Limits* — In light of today's instrumentation (quick response) and STELS, are ceiling limits needed and, if so, what criteria would determine their appropriateness.
3. *Soluble Inorganic Compounds* — What quantitative criteria should be used in differentiating between soluble and insoluble for TLV use.
4. Dual vapor and particulate TLVs.²
5. Should welding fume value (not otherwise classified, NOC) be retained or should specific analytical determinations be made for metals and other compounds and these values be compared to specific TLVs?

¹Information, 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.

²Study papers appear in the *Annals of the American Conference of Governmental Industrial Hygienists*, Volume 4, ACGIH Transactions — 1982, pp. 153-155 (1983).

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	13121-70-5
Sencor	Metribuzin	21087-64-9
Sevin	Carbaryl	63-25-2
Teflon	Polytetrafluoroethylene	9002-84-0
Thimet	Phorate	298-02-2
Thiodan	Endosulfan	115-29-7
Tordon	Picloram	1918-02-1
Zoalene	Dinitolmide	148-01-6

TLVs®
Threshold Limit Values
for
Physical Agents
in the
Work Environment
Adopted by
ACGIH
for 1983-84



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SC

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PREFACE

PHYSICAL AGENTS

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

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

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

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

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

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

THRESHOLD LIMIT VALUES

HEAT STRESS

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

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

1. Outdoors with solar load:

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

$$WBGT = 0.7 NWB + 0.3 GT$$
- where:

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

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

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

EVALUATION AND CONTROL

I. Measurement of the Environment

The instruments required are a dry-bulb, a natural wet-bulb, a globe thermometer, and a stand. The

TABLE 1

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

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

measurement of the environmental factors shall be performed as follows:

A. The range of the dry and the natural wet bulb thermometer shall be -5°C to 50°C with an accuracy of ±0.5°C. The dry bulb thermometer must be shielded from the sun and the other radiant surfaces of the environment without restricting the airflow around the bulb. The wick of the natural wet-bulb thermometer shall be kept wet with distilled water for at least 1/2 hour before the temperature reading is made. It is not enough to immerse the other end of the wick into a reservoir of distilled water and wait until the whole wick becomes wet by capillarity. The wick shall be wetted by direct application of water from a syringe 1/2 hour before each reading. The wick shall extend over the bulb of the thermometer, covering the stem about one additional bulb length. The wick should always be clean and new wicks should be washed before using.

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

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

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

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

The methodology outlined above is more fully explained by Minard.⁽³⁻⁴⁾

II. Work Load Categories

Heat produced by the body and the environmental heat together determine the total heat load. Therefore, if work is to be performed under hot environmental conditions, the workload category of each job

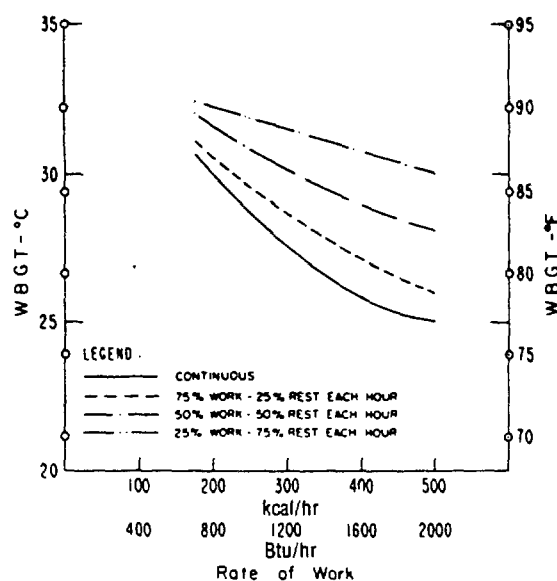


Figure 1 — Permissible Heat Exposure Threshold Limit Value

TABLE 2
Assessment of Work Load⁽⁹⁾

Average values of metabolic rate during different activities.			
A. Body position and movement			
Sitting		kcal/min	0.3
Standing			0.6
Walking			2.0-3.0
Walking up hill			add 0.8
		per meter (yard) rise	
B. Type of Work			
		Average kcal/min	Range kcal/min
Hand work			
	light	0.4	0.2-1.2
	heavy	0.9	
Work with one arm			
	light	1.0	0.7-2.5
	heavy	1.8	
Work with both arms			
	light	1.5	1.0-3.5
	heavy	2.5	
Work with body			
	light	3.5	2.5-15.0
	moderate	5.0	
	heavy	7.0	
	very heavy	9.0	

shall be established and the heat exposure limit pertinent to the work load evaluated against the applicable standard in order to protect the worker from exposure beyond the permissible limit.

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

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

TABLE 3
Activity Examples⁽⁹⁾

Light hand work: writing, hand knitting	
Heavy hand work: typewriting	
Heavy work with one arm: hammering in nails (shoe-maker, upholsterer)	
Light work with two arms: filing metal, planing wood, raking of a garden	
Moderate work with the body: cleaning a floor, beating a carpet	
Heavy work with the body: railroad track laying, digging, barking trees	
Sample Calculation	
Assembly line work using a heavy hand tool.	
A. Walking along	2.0 kcal/min
B. Intermediate value between heavy work with two arms and light work with the body	3.0 kcal/min
	5.0 kcal/min
C. Add for basal metabolism	1.0 kcal/min
Total	6.0 kcal/min

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

(3) heavy work (350-500 kcal/hr or 1400-2000 Btu/hr): e.g., pick and shovel work,

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

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

III. Work-Rest Regimen

The permissible exposure limits specified in Table 1 and Figure 1 are based on the assumption that the WBGT value of the resting place is the same or very close to that of the work place. Where the WBGT of the work area is different from that of the rest area a time-weighted average value should be used for both environmental and metabolic heat. When time-weighted average values are used the appropriate curve on Figure 1 is the solid line labeled "continuous."

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

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

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:

$$Av. WBGT = \frac{WBGT_1 \times t_1 + WBGT_2 \times t_2 + \dots + WBGT_n \times t_n}{t_1 + t_2 + \dots + t_n}$$

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., $t_1 + t_2 + \dots + t_n = 60$ minutes. Where the exposure is intermittent, the time-weighted averages shall be calculated as two-hour time-weighted averages, i.e., $t_1 + t_2 + \dots + t_n = 120$ minutes.

The permissible exposure limits for continuous work are applicable where there is a work-rest regimen of a 5-day work week and an 8-hour work day with a short morning and afternoon break (approximately 15 minutes) and a longer lunch break (approximately 30 minutes). Higher exposure limits are permitted if additional resting time is allowed. All breaks, including unscheduled pauses and administrative or operational waiting periods during work may be

counted as rest time when additional rest allowance must be given because of high environmental temperatures.

IV. Water and Salt Supplementation

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

The water shall be kept reasonably cool (10°-15°C or 50.0°-60.0°F) and shall be placed close to the workplace so that the worker can reach it without abandoning the work area.

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

V. Other Considerations

A. *Clothing*: The permissible heat exposure TLVs are valid for light summer clothing as customarily worn by workers when working under hot environmental conditions. If special 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 his first week of exposure to hot environmental conditions. The recommended heat stress TLVs are valid for acclimated workers who are physically fit. Extra caution must be employed when unacclimated or physically un-fit workers must be exposed to heat stress conditions.

References:

1. *Health Factors Involved in Working Under Conditions of Heat Stress*. WHO Technical Report Series No. 412 (1969).

2. *Dukacs-Dobos, F. N. and A. Henschel*: Development of Permissible Heat Exposure Limits for Occupational Work. *ASHRAE Journal* 15(9):57-62 (Sept. 1973).
3. *Minard, D.*: Prevention of Heat Casualties in Marine Corps Recruits, Period of 1955-60, with Comparative Incidence Rates and Climatic Heat Stresses in Other Training Categories. Research Report No. 4, Contract No. MR 005.01-0001.01, Naval Medical Research Institute, Bethesda, MD (Feb. 21, 1961). Published in *Military Medicine* 126(44):261-272 (April 1961).
4. *Minard, D. and R. L. O'Brien*: Heat Casualties in the Navy and Marine Corps 1959-1962 with Appendices on the Field Use of the Wet Bulb-Globe Temperature Index. Research Report No. 7, Contract No. MR 005.01-0001.01, Naval Medical Research Institute, Bethesda, MD (March 12, 1964).
5. *Astrand, Per-Olof and Kaare Rodahl*: *Textbook of Work Physiology*. McGraw-Hill Book Co., New York, San Francisco (1970).
6. *Ergonomics Guide to Assessment of Metabolic and Cardiac Costs of Physical Work*. *Am. Ind. Hyg. Assoc. J.* 32:560 (1971).
7. *Energy Requirements for Physical Work*. Research Progress Report No. 30. Purdue Farm Cardiac Project, Agricultural Experiment Station, West Lafayette, IN (1961).
8. *Durmin, J. V. G. A. and R. Passmore*: *Energy, Work and Leisure*. Heinemann Educational Books, Ltd., London (1967).
9. *Lehmann, G. E., A. Muller and H. Spitzer*: Der Kalorienbedarf bei 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 chartered 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 substantive documentation of a sound basis for ionizing radiation protection. The committee also strongly recommends that all exposures to ionizing radiations be kept as low as reasonably achievable within the stated guidance.

References:

1. *Basic Radiation Protection Criteria*. NCRP Report No. 39 (January 15, 1971).

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

The above documents, as well as information on numerous other NCRP Reports addressing specific subjects in ionizing radiation protection are available from: NCRP Publications, PO Box 30175, Washington, DC 20014.

LASERS

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

Limiting Apertures

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

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

Correction Factors A and B (C_A and C_B)

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

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

Repetitively Pulsed Lasers

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

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

(2) The average irradiance for a group of pulses is limited to the protection standard as given in Tables 4, 5, or 7 of a single pulse of the same duration as the entire pulse group.

(3) When the Instantaneous Pulse Repetition Frequency (PRF) of any pulses within a train exceeds one, the protection standard applicable to each pulse is reduced as shown in Figure 6 for pulse durations less than 10^{-5} second. For pulses of greater duration, the following formula should be followed:

$$\text{Standard} \left(\begin{array}{c} \text{single pulse} \\ \text{in train} \end{array} \right) = \frac{\text{Standard (pulse nr)}}{n}$$

where:

n = number of pulses in train

τ = duration of a single pulse in the train

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

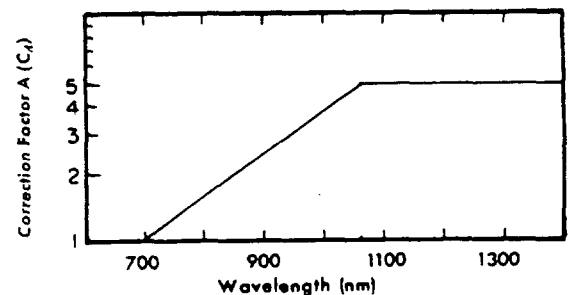


Figure 2 — TLV correction factor for $\lambda = 700 - 1400$ nm*

*For $\lambda = 700 - 1049$ nm, $C_A = 10^{[0.0021(\lambda - 700)]}$
For $\lambda = 1050 - 1400$ nm, $C_A = 5$

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^{-8} to 3×10^4	3 mJ • cm ⁻²
UVB	280 nm to 302 nm	"	3 "
	303 nm	"	4 "
	304 nm	"	6 "
	305 nm	"	10 "
	306 nm	"	16 "
	307 nm	"	25 "
	308 nm	"	40 "
	309 nm	"	63 "
	310 nm	"	100 "
	311 nm	"	160 "
	312 nm	"	250 "
	313 nm	"	400 "
	314 nm	"	630 "

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

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

C₁ - See fig. 2.
C₂ = 1 for λ = 400 to 549 nm; C₂ = 10¹⁰ nm Å⁻¹ Å⁻¹ for λ = 550 to 700 nm.
T₁ = 10 s for λ = 400 to 549 nm; T₁ = 10 × 10¹⁰ nm Å⁻¹ Å⁻¹ for λ = 550 to 700 nm.

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

Spectral Region	Wave Length	Exposure Time, (t) Seconds	TLV
UV Light	200 nm to 400 nm	10^{-9} to 3×10^4	Same as Table 3
	400 nm to 700 nm	10^{-9} to 10^4	$10 \sqrt{t} \text{ J} \cdot \text{cm}^{-2} \cdot \text{sr}^{-1}$
	400 nm to 549 nm	10 to 10^4	$21 \text{ J} \cdot \text{cm}^{-2} \cdot \text{sr}^{-1}$
	550 nm to 700 nm	10 to T_1	$3.83 (t/\sqrt{t}) \text{ J} \cdot \text{cm}^{-2} \cdot \text{sr}^{-1}$
	550 nm to 700 nm	T_1 to 10^4	$21 C_B \text{ J} \cdot \text{cm}^{-2} \cdot \text{sr}^{-1}$
IR-A	400 nm to 700 nm	10^4 to 3×10^4	$2.1 C_B t \times 10^{-3} \text{ W} \cdot \text{cm}^{-2} \cdot \text{sr}^{-1}$
	700 nm to 1400 nm	10^{-9} to 10^4	$10 C_A \sqrt{t} \text{ J} \cdot \text{cm}^{-2} \cdot \text{sr}^{-1}$
	700 nm to 1400 nm	10 to 10^3	$3.83 C_A (t/\sqrt{t}) \text{ J} \cdot \text{cm}^{-2} \cdot \text{sr}^{-1}$
	700 nm to 1400 nm	10^3 to 3×10^4	$0.64 C_A \text{ W} \cdot \text{cm}^{-2} \cdot \text{sr}^{-1}$
IR-B & C	$1.4 \mu\text{m}$ to $10^3 \mu\text{m}$	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}	$2 C_A \times 10^{-2} \text{ J} \cdot \text{cm}^{-2}$
IR-A	"	10^{-7} to 10	$1.1 C_A \sqrt{t} \text{ J} \cdot \text{cm}^{-2}$
IR-A	"	10 to 3×10^4	$0.2 C_A \text{ W} \cdot \text{cm}^{-2}$
IR-B & C	$1.4 \mu\text{m}$ to $10^3 \mu\text{m}$	10^{-9} to 3×10^4	Same as Table 4

$C_A = 1.0$ for $\lambda = 400\text{--}700 \text{ nm}$; see Figure 2 for $\lambda = 700$ to 1400 nm .

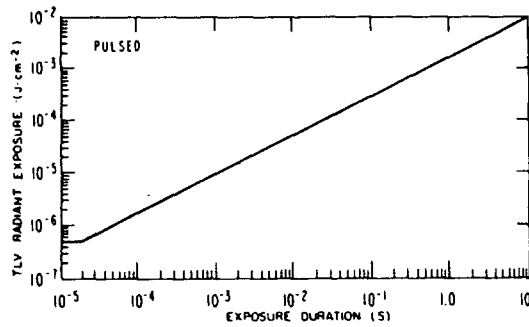


Figure 3a — TLV for intrabeam (direct) viewing of laser beam (400-700 nm).

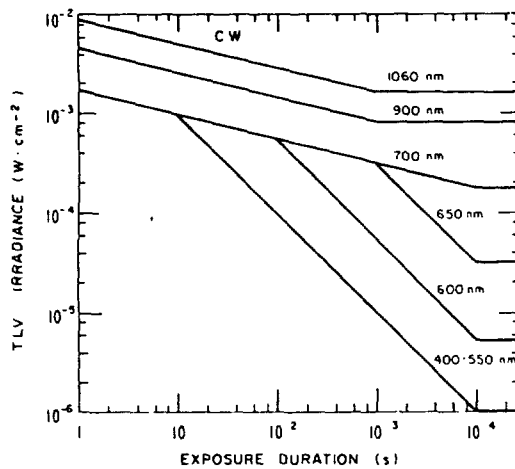


Figure 3b — TLV for intrabeam (direct) viewing of CW laser beam (400-1400 nm)

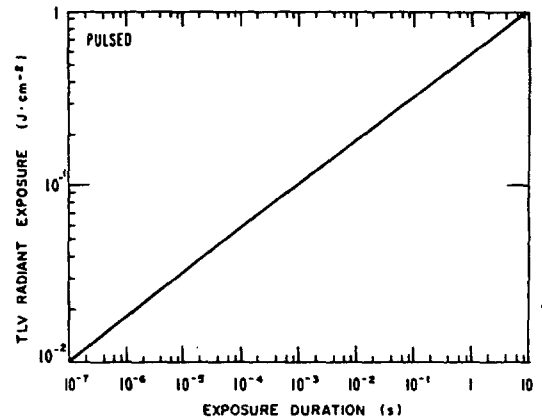


Figure 4a — TLV for laser exposure of skin and eyes for far-infrared radiation (wave-lengths greater than 1.4 μm).

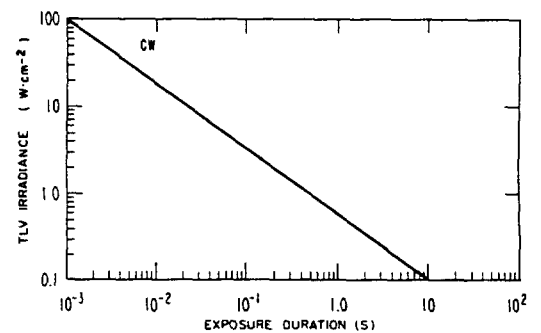


Figure 4b — TLV for CW laser exposure of skin and eyes for far-infrared radiation (wave-lengths greater than 1.4 μm).

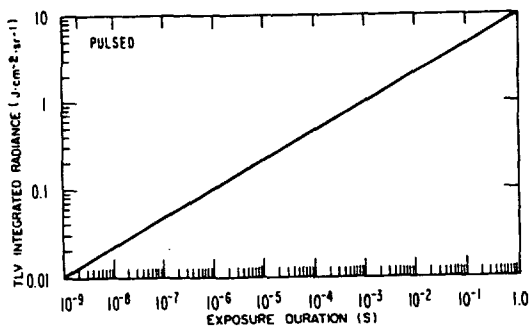


Figure 5a — TLV for extended sources or diffuse reflections of laser radiation (400–700 nm).

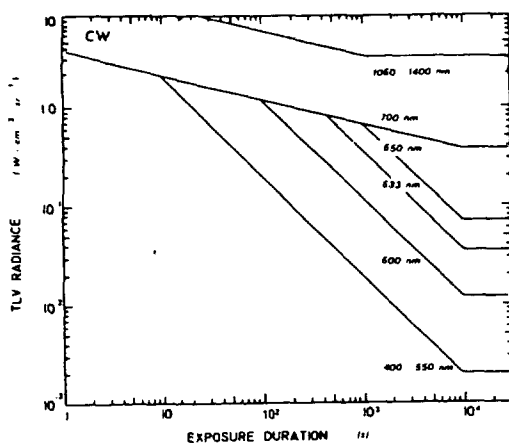


Figure 5b — TLV for extended sources or diffuse reflections of laser radiation (400–1400 nm).

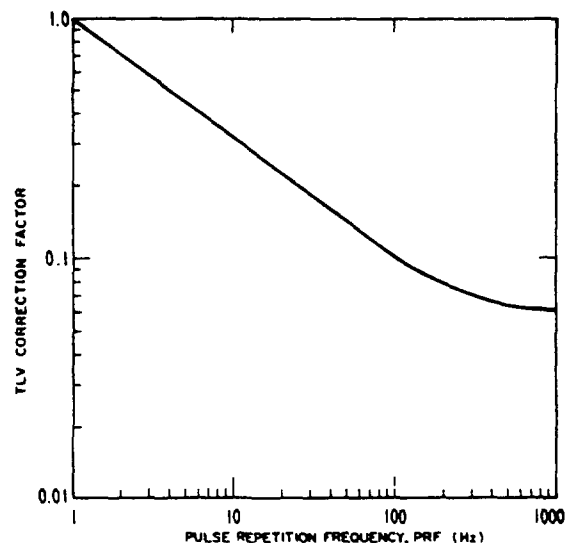


Figure 6 — Multiplicative correction factor for repetitively pulsed lasers having pulse durations less than 10^{-5} second. TLV for a single pulse of the pulse train is multiplied by the above correction factor. Correction factor for PRF greater than 1000 Hz is 0.06.

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

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

NOISE

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

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

Continuous or Intermittent

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

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

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

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

exceeds unity, then, the mixed exposure should be considered to exceed the threshold limit value, C_1 in-

^(a)In 1979, the American Academy of Ophthalmology and Otolaryngology (AAOO) included 3000 Hz in their hearing impairment formula.

Table 8
Threshold Limit Values

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

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

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

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.

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 μ Pa

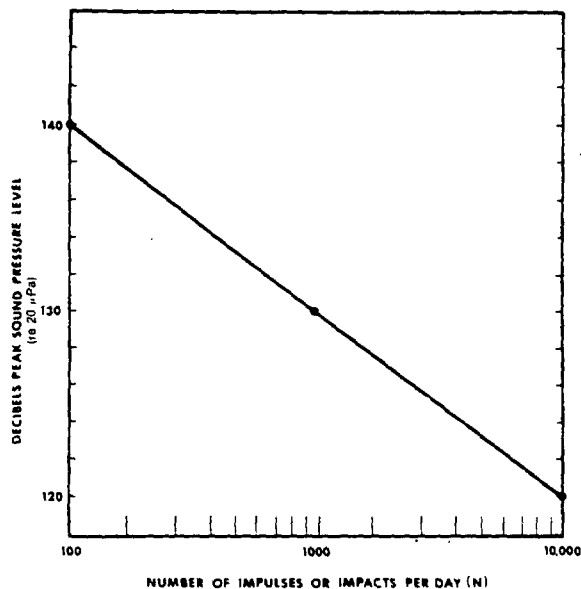


Figure 7 — Threshold Limit Values for Impulse/Impact Noise.

‡RADIOFREQUENCY/MICROWAVE RADIATION

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

Since it is usually impractical to measure the SAR, the TLVs are expressed in units that are measurable, viz, squares of the electric and magnetic field strengths, averaged over any 0.1 hour period. This

‡1983 Adoption.

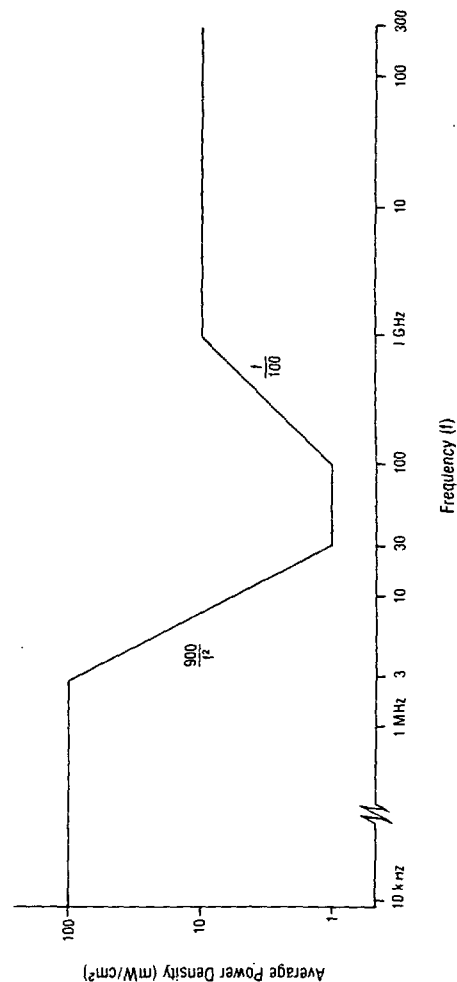


Figure 8 — Threshold Limit Values (TLV) for Radiofrequency/Microwave Radiation in Workplace (Whole Body SAR Less Than 0.4 W/kg).

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 × 900/f ² *	900/37.7 f ² *
30 MHz to 100 MHz	1	3770	0.027
100 MHz to 1000 MHz	f ² /100	3770 × f ² /100	f ² /37.7 × 100
1 GHz to 300 GHz	10	37,700	0.265

†mW/cm² = milliwatts per centimeter squared

*f = frequency in MHz

can be expressed in units of equivalent plane wave power density for convenience. The electric field strength (E) squared, magnetic field strength (H) squared, and power density (PD) values are shown in Table 10. For near field exposures PD cannot be measured directly, but equivalent plane wave power density can be calculated from the field strength measurement data as follows:

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

where:

E² is in volts squared (V²) per meter squared (m²).

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

where:

H² is in amperes squared (A²) per meter squared (m²).

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.

ULTRAVIOLET RADIATION*

These threshold limit values refer to ultraviolet radiation in the spectral region between 200 and 400 nm and represent conditions under which it is believed that nearly all workers may be repeatedly exposed without adverse effect. These values for exposure of the eye or the skin apply to ultraviolet radiation from arcs, gas, and vapor discharges, fluorescent, and incandescent sources, and solar radiation, but do not apply to ultraviolet lasers.* These values do not apply to ultraviolet radiation exposure of photosensitive individuals or of individuals concomitantly exposed to photosensitizing agents.⁽¹⁾ These values should be used as guides in the control of exposure to continuous sources where the exposure duration shall not be less than 0.1 sec.

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

Recommended Values:

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

1. For the near ultraviolet spectral region (320 to 400 nm) total irradiance incident upon the unprotected

*See Laser TLVs.

skin or eye should not exceed 1 mW/cm² for periods greater than 10³ seconds (approximately 16 minutes) and for exposure times less than 10³ seconds should not exceed one J/cm².

2. For the actinic ultraviolet spectral region (200 — 315 nm), radiant exposure incident upon the unprotected skin or eye should not exceed the values given in Table 11 within an 8-hour period.
3. To determine the effective irradiance of a broad-band source weighted against the peak of the spectral effectiveness curve (270 nm), the following weighting formula should be used:

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

where:

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

E_{λ} = spectral irradiance in W/cm²/nm

S_{λ} = relative spectral effectiveness (unitless)

$\Delta\lambda$ = band width in nanometers

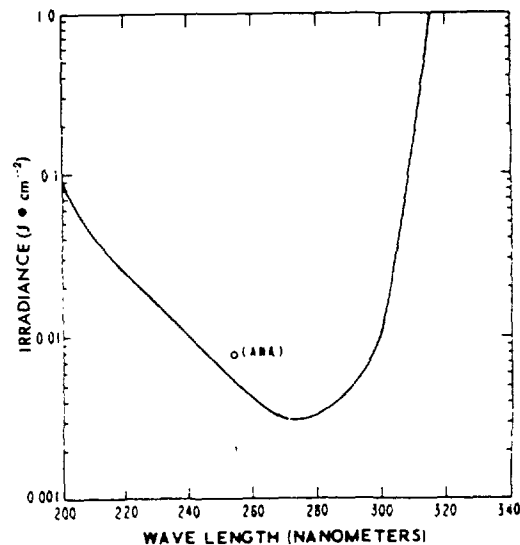


Figure 9 — Threshold Limit Values for Ultraviolet Radiation

TABLE 11
Relative Spectral Effectiveness
by Wavelength*

Wavelength (nm)	TLV (mJ/cm ²)	Relative Spectral Effectiveness S_{λ}
200	100	0.03
210	40	0.075
220	25	0.12
230	16	0.19
240	10	0.30
250	7.0	0.43
254	6.0	0.5
260	4.6	0.65
270	3.0	1.0
280	3.4	0.88
290	4.7	0.64
300	10	0.30
305	50	0.06
310	200	0.015
315	1000	0.003

*See Laser TLVs.

TABLE 12
Permissible Ultraviolet Exposures

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

4. Permissible exposure time in seconds for exposure to actinic ultraviolet radiation incident upon the unprotected skin or eye may be computed by dividing 0.003 J/cm² by E_{eff} in W/cm². The exposure time may also be determined using Table 12 which provides exposure times corresponding to effective irradiances in μ W/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 erythral effects. However, such conditioning may not protect persons against skin cancer.

Reference:

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

NOTICE OF INTENDED CHANGES
(for 1983-84)

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

NOTICE OF INTENT TO ESTABLISH
THRESHOLD LIMIT VALUES

LASERS

It is proposed that the following footnote be added to Table 6 (Threshold Limit Value for Skin Exposure from a Laser Beam).

The IR-B and IR-C exposures to skin surface areas A(cm²) exceeding 1000 cm², the TLV is

$$(100,000/A) \bullet (\text{mW/cm}^2);$$

for areas greater than 100,000/A, the TLV is 10 mW/cm².

LIGHT AND NEAR-INFRARED RADIATION

These Threshold Limit Values refer to visible and near-infrared radiation in the wavelength range of 400

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 mea-

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

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

sured 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 should not be exceeded.

The TLV's are:

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

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

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

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

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

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

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

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

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

The latter limits are greater than the maximum permissible exposure limits for 440 nm laser radiation (see Laser TLV) because a 2-3 mm pupil is assumed rather than a 7 mm pupil for the Laser TLV. For a light source subtending an angle α less than 11 mrd (0.011 radian) the above limits are relaxed such that the spectral irradiance weighted against the blue-light hazard function B_λ should not exceed $E(\text{blue})$.

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

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

For a source where the blue light weighted irradiance E (blue) exceeds $1 \mu\text{W} \cdot \text{cm}^{-2}$ is the maximum permissible exposure duration t_{max} in seconds is:

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

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

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

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

AIRBORNE UPPER SONIC AND ULTRASONIC ACOUSTIC RADIATION

These threshold limit values refer to sound pressure levels that represent conditions under which it is believed that nearly all workers may be repeatedly exposed without adverse effect. The values listed in Table 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 $k_1 = 1 \text{ W} \cdot \text{rad} \cdot \text{s}^{1/2}/(\text{cm}^2 \cdot \text{sr})$, and for formula (7) $k_2 = 1 \text{ W} \cdot \text{rad}/(\text{cm}^2 \cdot \text{sr})$.

TABLE 14

Permissible Ultrasound Exposure Levels

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

PHYSICAL AGENTS UNDER STUDY

The Physical Agents Committee of ACGIH has examined the current literature and has not found sufficient information to propose a TLV. However, these agents will remain under study during the coming year to examine new evidence indicating the need and feasibility for establishing a proposed TLV. Comments and suggestions, accompanied by substantive documentation are solicited and should be forwarded to the Executive Secretary, ACGIH. Documentation summarizing the current status of the biological effects literature is available on those agents preceded by an asterisk (*).

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

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

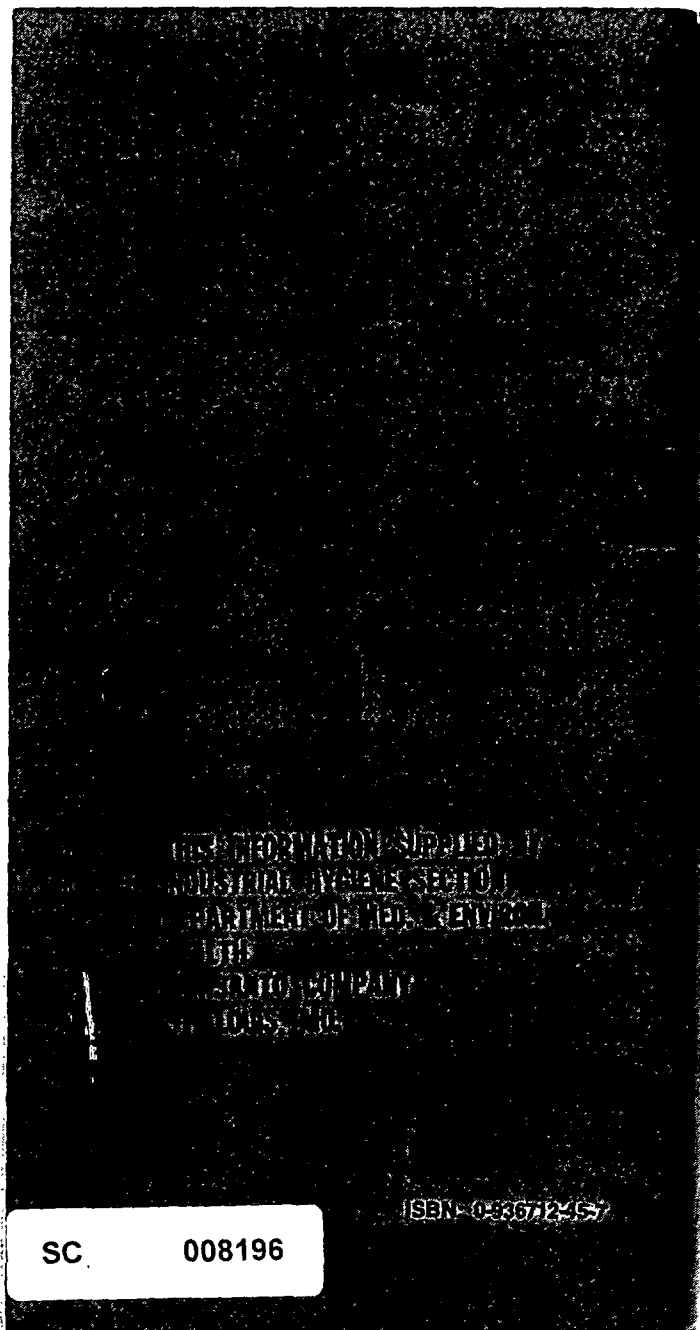
It is an organization devoted to the development of administrative and technical aspects of worker health protection. The association has contributed substantially to the development and improvement of official industrial health services to industry and labor. The committees on industrial ventilation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

Membership is limited to professional personnel in governmental agencies or educational institutions engaged in occupational safety and health programs. The more than 2600 members from across the United States and around the world give the organization an international scope.

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