

PLAINTIFF'S EXHIBIT

MON-2429

**TLVs®**

**THRESHOLD  
LIMIT VALUES  
and  
BIOLOGICAL  
EXPOSURE INDICES  
for  
1985-86**



**American  
Conference  
of Governmental  
Industrial Hygienists**

SC

008084

LAM009294

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

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

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

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

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TLVs®

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



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## 1984-85 CHEMICAL SUBSTANCES TLV COMMITTEE

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 Meier Schneider, P.E., CIH, Metropolitan Water District of Southern  
     California  
 Robert Spirtas, Dr. PH, National Cancer Institute  
 Vera F. Thomas, Ph.D., University of Miami  
 William D. Wagner, NIOSH

## CONSULTANTS

Gerald L. Kennedy, Jr.  
 Georg Kimmerle, M.D., German MAK Commission Liaison  
 William S. Lainhart, M.D.  
 Ernest Mastromatteo, M.D.  
 George Roush, Jr., M.D.  
 Marshall Steinberg, Ph.D.  
 Theodore R. Torkelson, Sc.D.  
 Ralph C. Wands  
 Elizabeth K. Weisburger, Ph.D.  
 Mitchell R. Zavon, M.D.

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## INTRODUCTION TO THE CHEMICAL SUBSTANCES

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

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

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

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

The Threshold Limit Values, as issued by ACGIH, are recommendations and should be used as guidelines for good practices. In spite of the fact that serious injury is not believed likely as a result of exposure to the threshold limit concentrations, the best practice is to maintain concentrations of all atmospheric contaminants as low as is practical.

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

**Notice of Intent.** At the beginning of each year, proposed actions of the Committee for the forthcoming year are issued in the form of a "Notice of Intended Changes." This Notice provides not only an opportunity for comment, but solicits suggestions of

substances to be added to the list. The suggestions should be accompanied by substantiating evidence. The list of Intended Changes follows the Adopted Values in the TLV booklet. Values listed in parenthesis in the "Adopted" list are to be used during the period in which a proposed change for that Value is listed in the Notice of Intended Changes.

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

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

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

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

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

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

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

The Committee holds to the opinion that limits based on physical irritation should be considered no less binding than those based on physical impairment. There is increasing evidence that

physical irritation may initiate, promote or accelerate physical impairment through interaction with other chemical or biologic agents.

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

Although the time-weighted average concentration provides the most satisfactory, practical way of monitoring airborne agents for compliance with the limits, there are certain substances for which it is inappropriate. In the latter group are substances which are predominantly fast acting and whose threshold limit is more appropriately based on this particular response. 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-TWA, there is not enough toxicological data available to warrant a STEL. Nevertheless, excursions above the TLV-TWA should be controlled even where the eight-hour TWA is within recommended limits. Earlier editions of the TLV list included such limits whose values depended on the TLV-TWAs of the substance in question.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

A threshold limit of 10 mg/m<sup>3</sup>, or 30 mppcf, of total dust < 1% quartz, or, 5 mg/m<sup>3</sup> respirable dust is recommended for substances in these categories and for which no specific threshold limits have been assigned. (The mppcf and the respirable values are currently on the Notice of Intended Changes.) This limit, for a normal workday, does not apply to brief exposures at higher concentrations. Neither does it apply to those substances which may cause physiologic impairment at lower concentrations but for which a threshold limit has not yet been adopted. Some nuisance particulates are given in Appendix D. This list is not meant to be all inclusive; the substances serve only as examples.

**Simple Asphyxiants — "Inert" Gases or Vapors.** A number of gases and vapors, when present in high concentrations in air, act primarily as simple asphyxiants without other significant physiologic effects. A TLV may not be recommended for each simple asphyxiant because the limiting factor is the available oxygen. The

minimal oxygen content should be 18 percent by volume under normal atmospheric pressure (equivalent to a partial pressure, pO<sub>2</sub> of 135 mm Hg). Atmospheres deficient in O<sub>2</sub> do not provide adequate warning and most simple asphyxiants are odorless. Several simple asphyxiants present an explosion hazard. Account should be taken of this factor in limiting the concentration of the asphyxiant. Specific examples are listed in Appendix E. This list is not meant to be all inclusive; the substances serve only as examples.

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

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

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

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

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

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

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

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

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

(a) Parts of vapor or gas per million parts of contaminated air by volume at 25°C and 1 torr.

(b) Approximate milligrams of substance per cubic meter of air.

† See Notice of Intended Changes.

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

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

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| Substance                                                          | ADOPTED<br>VALUES         |                      | ADOPTED<br>VALUES          |                      |
|--------------------------------------------------------------------|---------------------------|----------------------|----------------------------|----------------------|
|                                                                    | TWA<br>ppm <sup>(a)</sup> | mg/m <sup>3(b)</sup> | STEL<br>ppm <sup>(a)</sup> | mg/m <sup>3(b)</sup> |
| Borates, tetra, sodium salts<br>[1303-96-4] .....                  | —                         | 1                    | —                          | —                    |
| Anhydrous .....                                                    | —                         | 5                    | —                          | —                    |
| Decahydrate .....                                                  | —                         | 1                    | —                          | —                    |
| Pentahydrate .....                                                 | —                         | 10                   | —                          | (20)                 |
| †Boron oxide [1303-86-2] .....                                     | —                         | 10                   | —                          | (20)                 |
| †Boron tribromide<br>[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<br>[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<br>[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]—<br>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 <sub>3</sub><br>[1189-85-1]—Skin ..... | —                         | C 0.1                | —                          | —                    |
| n-Butyl glycidyl ether (BGE)<br>[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<br>[89-72-5]—Skin .....                          | 5                         | 30                   | —                          | —                    |
| p-tert-Butyltoluene [98-51-1] .....                                | 10                        | 60                   | 20                         | 120                  |
| †Cadmium [7440-43-9] Dusts<br>& salts, as Cd .....                 | —                         | 0.05                 | —                          | (0.2)                |

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

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| Substance                                  | ADOPTED<br>VALUES       |                                | ADOPTED<br>VALUES        |                                |
|--------------------------------------------|-------------------------|--------------------------------|--------------------------|--------------------------------|
|                                            | TWA<br>ppm <sup>a</sup> | mg/m <sup>3</sup> <sup>b</sup> | STEL<br>ppm <sup>a</sup> | mg/m <sup>3</sup> <sup>b</sup> |
| Cadmium oxide [1306-19-0]                  | —                       | C 0.05                         | —                        | —                              |
| Fume, as Cd                                | —                       | 0.05                           | —                        | —                              |
| Production                                 | —                       | —                              | —                        | —                              |
| ‡Calcium carbonate/marble<br>[1317-65-3]   | —                       | D                              | —                        | (20)                           |
| ‡Calcium cyanamide<br>[156-62-7]           | —                       | 0.5                            | —                        | (1)                            |
| Calcium hydroxide<br>[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]                     | —                       | 1                              | —                        | 3                              |
| Dust                                       | —                       | —                              | —                        | —                              |
| 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] —<br>Skin       | 10                      | 30                             | —                        | —                              |
| Carbon monoxide [630-08-0]                 | 50                      | 55                             | 400                      | 440                            |
| Carbon tetrabromide<br>[558-13-4]          | 0.1                     | 1.4                            | 0.3                      | 4                              |
| ‡Carbon tetrachloride<br>[56-23-5] — Skin  | 5,A2                    | 30,A2                          | (20,A2)                  | (125,A2)                       |
| Carbonyl chloride, see Phosgene            | —                       | —                              | —                        | —                              |
| Carbonyl fluoride [353-50-4]               | 2                       | 5                              | 5                        | 15                             |
| Catechol [120-80-9]                        | 5                       | 20                             | —                        | —                              |
| ‡Cellulose (paper fiber)<br>[9004-34-6]    | —                       | D                              | —                        | (20)                           |
| Cesium hydroxide<br>[21351-79-1]           | —                       | 2                              | —                        | —                              |
| Chlordane [57-74-9] — Skin                 | —                       | 0.5                            | —                        | 2                              |
| Chlorinated camphene<br>[8001-35-2] — Skin | —                       | 0.5                            | —                        | 1                              |
| Chlorinated diphenyl oxide<br>[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<br>[7790-91-2]        | C 0.1                   | C 0.4                          | —                        | —                              |

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| Substance                                                  | ADOPTED<br>VALUES       |                                | ADOPTED<br>VALUES        |                                |
|------------------------------------------------------------|-------------------------|--------------------------------|--------------------------|--------------------------------|
|                                                            | TWA<br>ppm <sup>a</sup> | mg/m <sup>3</sup> <sup>b</sup> | STEL<br>ppm <sup>a</sup> | mg/m <sup>3</sup> <sup>b</sup> |
| Chloroacetaldehyde<br>[107-20-0]                           | C 1                     | C 3                            | —                        | —                              |
| o-Chloroacetophenone<br>[532-27-4]                         | 0.05                    | 0.3                            | —                        | —                              |
| Chloroacetyl chloride<br>[79-04-9]                         | 0.05                    | 0.2                            | —                        | —                              |
| Chlorobenzene [108-90-7]                                   | 75                      | 350                            | —                        | —                              |
| o-Chlorobenzylidene<br>malononitrile<br>[2698-41-1] — Skin | C 0.05                  | C 0.4                          | —                        | —                              |
| Chlorobromomethane<br>[74-97-5]                            | 200                     | 1,050                          | 250                      | 1,300                          |
| 2-Chloro-1,3-butadiene, see $\beta$ -Chloroprene           | —                       | —                              | —                        | —                              |
| Chlorodifluoromethane<br>[75-45-6]                         | 1,000                   | 3,500                          | 1,250                    | 4,375                          |
| Chlorodiphenyl<br>(42% Chlorine)<br>[53469-21-9] — Skin    | —                       | 1                              | —                        | 2                              |
| Chlorodiphenyl<br>(54% Chlorine)<br>[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<br>[542-88-1]                       | 0.001,<br>A1a           | 0.005,<br>A1a                  | —                        | —                              |
| Chloromethyl methyl ether<br>[107-30-2]                    | A2                      | A2                             | —                        | —                              |
| 1-Chloro-1-nitropropane<br>[600-25-9]                      | 2                       | 10                             | —                        | —                              |
| Chloropentafluoroethane<br>[76-15-3]                       | 1,000                   | 6,320                          | —                        | —                              |
| Chloropicrin [76-06-2]                                     | 0.1                     | 0.7                            | 0.3                      | 2                              |
| $\beta$ -Chloroprene<br>[126-99-8] — Skin                  | 10                      | 35                             | —                        | —                              |
| o-Chlorostyrene<br>[1331-28-8]                             | 50                      | 285                            | 75                       | 430                            |
| o-Chlorotoluene<br>[95-49-8]                               | 50                      | 250                            | 75                       | 375                            |

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

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

| Substance                                                | ADOPTED<br>VALUES         |                      | ADOPTED<br>VALUES          |                      |
|----------------------------------------------------------|---------------------------|----------------------|----------------------------|----------------------|
|                                                          | TWA<br>ppm <sup>(a)</sup> | mg/m <sup>3(b)</sup> | STEL<br>ppm <sup>(a)</sup> | mg/m <sup>3(b)</sup> |
| †Cyclohexanone [108-94-1] —<br>Skin                      | 25                        | 100                  | (100)                      | (400)                |
| Cyclohexene [110-83-8]                                   | 300                       | 1,015                | —                          | —                    |
| Cyclohexylamine<br>[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-<br>trichloroethane)<br>[50-29-3] | —                         | 1                    | —                          | (3)                  |
| Decaborane [17702-41-9] —<br>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<br>[102-81-8] — Skin            | 2                         | 14                   | (4)                        | (28)                 |
| Dibutyl phosphate [107-66-4]                             | 1                         | 5                    | 2                          | 10                   |
| †Dibutyl phthalate [84-74-2]                             | —                         | 5                    | —                          | (10)                 |
| Dichloroacetylene<br>[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<br>[91-94-1] — Skin               | —                         | A2                   | —                          | —                    |
| †Dichlorodifluoromethane<br>[75-71-8]                    | 1,000                     | 4,950                | (1,250)                    | (6,200)              |
| 1,3-Dichloro-5,5-dimethyl<br>hydantoin [118-52-5]        | —                         | 0.2                  | —                          | 0.4                  |

Capital letters A, B, C & E refer to Appendices; C denotes ceiling limit.  
† See Notice of Intended Changes.  
\* 1985-1986 Addition.  
(d) Lint-free dust as measured by the vertical elutriator cotton-dust sampler described in the *Transactions of the National Conference on Cotton Dust*, p. 33, by J.R. Lynch (May 2, 1970).

| Substance                                             | ADOPTED<br>VALUES  |                      | ADOPTED<br>VALUES  |                      |
|-------------------------------------------------------|--------------------|----------------------|--------------------|----------------------|
|                                                       | TWA                |                      | STEL               |                      |
|                                                       | ppm <sup>(a)</sup> | mg/m <sup>3(b)</sup> | ppm <sup>(a)</sup> | mg/m <sup>3(b)</sup> |
| 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<br>[540-59-0] .....              | 200                | 790                  | 250                | 1,000                |
| Dichloroethyl ether<br>[111-44-4] — Skin .....        | 5                  | 30                   | 10                 | 60                   |
| Dichlorofluoromethane<br>[75-43-4] .....              | 10                 | 40                   | —                  | —                    |
| Dichloromethane, see Methylene chloride               |                    |                      |                    |                      |
| †1,1-Dichloro-1-nitroethane<br>[594-72-9] .....       | 2                  | 10                   | (10)               | (60)                 |
| 1,2-Dichloropropane, see Propylene dichloride         |                    |                      |                    |                      |
| †Dichloropropene<br>[542-75-6] — Skin .....           | 1                  | 5                    | (10)               | (50)                 |
| 2,2-Dichloropropionic acid<br>[75-99-0] .....         | 1                  | 6                    | —                  | —                    |
| †Dichlorotetrafluoroethane<br>[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] —<br>Skin .....                | —                  | 0.25                 | —                  | —                    |
| Dicyclopentadiene [77-73-6]                           | 5                  | 30                   | —                  | —                    |
| †Dicyclopentadienyl iron<br>[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<br>[100-37-8] — Skin .....        | 10                 | 50                   | —                  | —                    |
| Diethylene triamine<br>[111-40-0] — Skin .....        | 1                  | 4                    | —                  | —                    |
| Diethyl ether, see Ethyl ether                        |                    |                      |                    |                      |
| Di-2-ethylhexylphthalate, see Di-sec, octyl phthalate |                    |                      |                    |                      |
| Diethyl ketone [96-22-0] ..                           | 200                | 705                  | —                  | —                    |
| †Diethyl phthalate [84-66-2]                          | —                  | 5                    | —                  | (10)                 |
| †Difluorodibromomethane<br>[75-61-6] .....            | 100                | 860                  | (150)              | (1,290)              |
| Diglycidyl ether (DGE)<br>[2238-07-5] .....           | 0.1                | 0.5                  | —                  | —                    |
| Dihydroxybenzene, see Hydroquinone                    |                    |                      |                    |                      |
| Diisobutyl ketone [108-83-8]                          | 25                 | 250                  | —                  | —                    |
| Diisopropylamine<br>[108-18-9] — Skin .....           | 5                  | 20                   | —                  | —                    |

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| Substance                                                                     | ADOPTED<br>VALUES  |                      | ADOPTED<br>VALUES  |                      |
|-------------------------------------------------------------------------------|--------------------|----------------------|--------------------|----------------------|
|                                                                               | TWA                |                      | STEL               |                      |
|                                                                               | ppm <sup>(a)</sup> | mg/m <sup>3(b)</sup> | ppm <sup>(a)</sup> | mg/m <sup>3(b)</sup> |
| Dimethoxymethane, see Methylal                                                |                    |                      |                    |                      |
| †Dimethyl acetamide<br>[127-19-5] — Skin .....                                | 10                 | 35                   | (15)               | (50)                 |
| Dimethylamine [124-40-3] ..                                                   | 10                 | 18                   | —                  | —                    |
| Dimethylaminobenzene, see Xylidene                                            |                    |                      |                    |                      |
| Dimethylaniline [121-69-7]<br>(N,N-Dimethylaniline) —<br>Skin .....           | 5                  | 25                   | 10                 | 50                   |
| Dimethylbenzene, see Xylene                                                   |                    |                      |                    |                      |
| Dimethyl carbamoyl chloride<br>[79-44-7] .....                                | A2                 | A2                   | —                  | —                    |
| Dimethyl-1,2-dibromo-2-dichloroethyl phosphate, see Naled                     |                    |                      |                    |                      |
| Dimethylformamide<br>[68-12-2] — Skin .....                                   | 10                 | 30                   | (20)               | (60)                 |
| 2,6-Dimethyl-4-heptanone, see Diisobutyl ketone                               |                    |                      |                    |                      |
| †1,1-Dimethylhydrazine<br>[57-14-7] — Skin .....                              | 0.5,A2             | 1,A2                 | (1,A2)             | (2,A2)               |
| Dimethylnitrosoamine, see N-Nitrosodimethylamine                              |                    |                      |                    |                      |
| Dimethylphthalate<br>[131-11-3] .....                                         | —                  | 5                    | —                  | (10)                 |
| Dimethyl sulfate<br>[77-78-1] — Skin .....                                    | 0.1,A2             | 0.5,A2               | —                  | —                    |
| Dinitolmide [148-01-6] .....                                                  | —                  | 5                    | —                  | 10                   |
| Dinitrobenzene [528-29-0;<br>99-65-0; 100-25-4] (all<br>isomers) — Skin ..... | 0.15               | 1                    | (0.5)              | (3)                  |
| Dinitro-o-cresol<br>[534-52-1] — Skin .....                                   | —                  | 0.2                  | —                  | (0.6)                |
| 3,5-Dinitro-o-toluamide, see Dinitolmide                                      |                    |                      |                    |                      |
| Dinitrotoluene<br>[121-14-2] — Skin .....                                     | —                  | 1.5                  | —                  | (5)                  |
| Dioxane, tech. grade<br>[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<br>ether [34590-94-8] .....                         | 100                | 600                  | 150                | 900                  |
| †Propyl ketone [123-19-3]                                                     | 50                 | 235                  | —                  | —                    |
| †Quat [85-00-7] .....                                                         | —                  | 0.5                  | —                  | (1)                  |

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

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LAM009304

| Substance                                        | ADOPTED<br>VALUES       |                                | ADOPTED<br>VALUES        |                                | Substance                                                        | ADOPTED<br>VALUES       |                                | ADOPTED<br>VALUES        |                                |
|--------------------------------------------------|-------------------------|--------------------------------|--------------------------|--------------------------------|------------------------------------------------------------------|-------------------------|--------------------------------|--------------------------|--------------------------------|
|                                                  | TWA<br>ppm <sup>a</sup> | mg/m <sup>3</sup> <sup>b</sup> | STEL<br>ppm <sup>a</sup> | mg/m <sup>3</sup> <sup>b</sup> |                                                                  | TWA<br>ppm <sup>a</sup> | mg/m <sup>3</sup> <sup>b</sup> | STEL<br>ppm <sup>a</sup> | mg/m <sup>3</sup> <sup>b</sup> |
| Di-sec. octyl phthalate<br>[117-81-7] .....      | —                       | 5                              | —                        | 10                             | Ethylene dichloride<br>[107-06-2] .....                          | 10                      | 40                             | (15)                     | (60)                           |
| †Disulfiram [97-77-8] .....                      | —                       | 2                              | —                        | (5)                            | Ethylene glycol [107-21-1]<br>Vapor .....                        | C 50                    | C 125                          | —                        | —                              |
| †Disulfoton [298-04-4] .....                     | —                       | 0.1                            | —                        | (0.3)                          | Ethylene glycol dinitrate<br>[628-96-6] — Skin .....             | 0.05                    | 0.3                            | —                        | —                              |
| ‡2,6-Ditert. butyl-p-cresol<br>[128-37-0] .....  | —                       | 10                             | —                        | (20)                           | Ethylene glycol methyl ether acetate, see 2-Methoxyethyl acetate | 1,A2                    | 2,A2                           | —                        | —                              |
| Diuron [330-54-1] .....                          | —                       | 10                             | —                        | —                              | Ethylene oxide [75-21-8] ..                                      | 1,A2                    | 2,A2                           | —                        | —                              |
| Divinyl benzene [108-57-6] ..                    | 10                      | 50                             | —                        | —                              | Ethylenimine [151-56-4] —<br>Skin .....                          | 0.5                     | 1                              | —                        | —                              |
| †Emery [112-62-9] .....                          | —                       | D                              | —                        | (20)                           | Ethyl ether [60-29-7] .....                                      | 400                     | 1,200                          | 500                      | 1,500                          |
| †Endosulfan [115-29-7] —<br>Skin .....           | —                       | 0.1                            | —                        | (0.3)                          | Ethyl formate [109-94-4] ..                                      | 100                     | 300                            | (150)                    | (450)                          |
| †Endrin [72-20-8] — Skin ..                      | —                       | 0.1                            | —                        | (0.3)                          | Ethylidene chloride, see 1,1-Dichloroethane                      | —                       | —                              | —                        | —                              |
| †Epichlorohydrin<br>[106-89-8] — Skin .....      | 2                       | 10                             | (5)                      | (20)                           | Ethylidene norbornene<br>[16219-75-3] .....                      | C 5                     | C 25                           | —                        | —                              |
| †EPN [2104-64-5] — Skin ..                       | —                       | 0.5                            | —                        | (2)                            | Ethyl mercaptan [75-08-1] ..                                     | 0.5                     | 1                              | (2)                      | (3)                            |
| 1,2-Epoxypropane, see Propylene oxide            | —                       | —                              | —                        | —                              | N-Ethylmorpholine<br>[100-74-3] — Skin .....                     | 5                       | 23                             | (20)                     | (95)                           |
| 2,3-Epoxy-1-propanol, see Glycidol               | —                       | —                              | —                        | —                              | Ethyl silicate [78-10-4] ..                                      | 10                      | 85                             | (30)                     | (255)                          |
| Ethane [74-84-0] .....                           | —                       | E                              | —                        | —                              | fenamiphos<br>[22224-92-6] — Skin .....                          | —                       | 0.1                            | —                        | —                              |
| Ethanthiol, see Ethyl mercaptan                  | —                       | —                              | —                        | —                              | Fensulfothion [115-90-2] ..                                      | —                       | 0.1                            | —                        | —                              |
| Ethanol, see Ethyl alcohol                       | —                       | —                              | —                        | —                              | Fenthion [55-38-9] — Skin ..                                     | —                       | 0.2                            | —                        | —                              |
| Ethanolamine [141-43-5] ..                       | 3                       | 8                              | 6                        | 15                             | Ferbam [14484-64-1] .....                                        | —                       | 10                             | —                        | (20)                           |
| Ethion [563-12-2] — Skin ..                      | —                       | 0.4                            | —                        | —                              | Ferrovanadium dust<br>[12604-58-9] .....                         | —                       | 1                              | —                        | 3                              |
| 2-Ethoxyethanol<br>[110-80-5] — Skin .....       | 5                       | 19                             | —                        | —                              | Fibrous glass dust .....                                         | —                       | 10                             | —                        | —                              |
| 2-Ethoxyethyl acetate<br>[111-15-9] — Skin ..... | 5                       | 27                             | —                        | —                              | Fluorides, as F .....                                            | —                       | 2.5                            | —                        | —                              |
| Ethyl acetate [141-78-6] ..                      | 400                     | 1,400                          | —                        | —                              | Fluorine [7782-41-4] .....                                       | 1                       | 2                              | 2                        | 4                              |
| †Ethyl acrylate [140-88-5] —<br>Skin .....       | 5                       | 20                             | (25)                     | (100)                          | Fluorotrichloromethane, see Trichlorofluoromethane               | —                       | —                              | —                        | —                              |
| Ethyl alcohol [64-17-5] ..                       | 1,000                   | 1,900                          | —                        | —                              | Fonofos [944-22-9] — Skin ..                                     | —                       | 0.1                            | —                        | —                              |
| Ethylamine [75-04-7] .....                       | 10                      | 18                             | —                        | —                              | Formaldehyde [50-00-0] ..                                        | 1,A2                    | 1.5,A2                         | 2,A2                     | 3,A2                           |
| Ethyl amyl ketone [541-85-5] ..                  | 25                      | 130                            | —                        | —                              | Formamide [75-12-7] .....                                        | 20                      | 30                             | (30)                     | (45)                           |
| Ethyl benzene [100-41-4] ..                      | 100                     | 435                            | 125                      | 545                            | Formic acid [64-18-6] .....                                      | 5                       | 9                              | —                        | —                              |
| Ethyl bromide [74-96-4] ..                       | 200                     | 890                            | 250                      | 1,110                          | Furfural [98-01-1] — Skin ..                                     | 2                       | 8                              | (10)                     | (40)                           |
| †Ethyl butyl ketone<br>[106-35-4] .....          | 50                      | 230                            | (75)                     | (345)                          | Furfuryl alcohol [98-00-0] —<br>Skin .....                       | 10                      | 40                             | 15                       | 60                             |
| †Ethyl chloride [75-00-3] ..                     | 1,000                   | 2,600                          | (1,250)                  | (3,250)                        | Gasoline [8006-61-9] .....                                       | 300                     | 900                            | 500                      | 1,500                          |
| Ethylene [74-85-1] .....                         | E                       | —                              | —                        | —                              | Germanium tetrahydride<br>[7782-65-2] .....                      | 0.2                     | 0.6                            | (0.6)                    | (1.8)                          |
| Ethylene chlorohydrin<br>[107-07-3] — Skin ..... | C 1                     | C 3                            | —                        | —                              | —                                                                | —                       | —                              | —                        | —                              |
| Ethylenediamine [107-15-3] ..                    | 10                      | 25                             | —                        | —                              | —                                                                | —                       | —                              | —                        | —                              |
| Ethylene dibromide<br>[106-93-4] — Skin ..       | A2                      | A2                             | —                        | —                              | —                                                                | —                       | —                              | —                        | —                              |

<sup>a</sup>Capital letters A, B, C & E refer to Appendices; C denotes ceiling limit  
<sup>b</sup>See Notice of Intended Changes.  
 1985-1986 Addition.

| Substance                                      | ADOPTED<br>VALUES                                      |                                                         | ADOPTED<br>VALUES                                      |                                                         |
|------------------------------------------------|--------------------------------------------------------|---------------------------------------------------------|--------------------------------------------------------|---------------------------------------------------------|
|                                                | TWA<br>ppm <sup>1</sup> mg/m <sup>3</sup> <sup>2</sup> | STEL<br>ppm <sup>1</sup> mg/m <sup>3</sup> <sup>2</sup> | TWA<br>ppm <sup>1</sup> mg/m <sup>3</sup> <sup>2</sup> | STEL<br>ppm <sup>1</sup> mg/m <sup>3</sup> <sup>2</sup> |
| 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 DUSTS     |                                                        |                                                         |                                                        |                                                         |
| ‡Graphite (Synthetic) . . . . .                | —                                                      | (D)                                                     | —                                                      | —                                                       |
| ‡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                            |                                                        |                                                         |                                                        |                                                         |
| [87-68-3] — Skin . . . . .                     | 0.02, A2                                               | 0.24, A2                                                | —                                                      | —                                                       |
| ‡Hexachlorocyclopentadiene                     |                                                        |                                                         |                                                        |                                                         |
| [77-47-4] . . . . .                            | 0.01                                                   | 0.1                                                     | (0.03)                                                 | (0.3)                                                   |
| Hexachloroethane [67-72-1]                     |                                                        |                                                         |                                                        |                                                         |
| [1335-87-1] — Skin . . . . .                   | —                                                      | 0.2                                                     | —                                                      | (0.6)                                                   |
| ‡Hexafluoroacetone                             |                                                        |                                                         |                                                        |                                                         |
| [684-16-2] — Skin . . . . .                    | 0.1                                                    | 0.7                                                     | (0.3)                                                  | (2)                                                     |
| Hexamethyl phosphoramide                       |                                                        |                                                         |                                                        |                                                         |
| [680-31-9] — Skin . . . . .                    | A2                                                     | A2                                                      | —                                                      | —                                                       |
| Hexane (n-Hexane)                              |                                                        |                                                         |                                                        |                                                         |
| [100-54-3] . . . . .                           | 50                                                     | 180                                                     | —                                                      | —                                                       |
| Other isomers . . . . .                        | 500                                                    | 1,800                                                   | 1,000                                                  | 3,600                                                   |
| 2-Hexanone, see Methyl n-butyl ketone          |                                                        |                                                         |                                                        |                                                         |
| Hexone, see Methyl isobutyl ketone             |                                                        |                                                         |                                                        |                                                         |
| sec-Hexyl acetate [108-84-9]                   |                                                        |                                                         |                                                        |                                                         |
| [107-41-5] . . . . .                           | 50                                                     | 300                                                     | —                                                      | —                                                       |
| Hexylene glycol [107-41-5]                     |                                                        |                                                         |                                                        |                                                         |
| [302-01-2] — Skin . . . . .                    | C 25                                                   | C 125                                                   | —                                                      | —                                                       |
| Hydrazine [302-01-2] — Skin                    |                                                        |                                                         |                                                        |                                                         |
| [1333-74-0] . . . . .                          | 0.1, A2                                                | 0.1, A2                                                 | —                                                      | —                                                       |
| Hydrogen [1333-74-0] . . . . .                 | E                                                      | —                                                       | —                                                      | —                                                       |
| Hydrogenated terphenyls                        |                                                        |                                                         |                                                        |                                                         |
| [61788-32-7] . . . . .                         | 0.5                                                    | 5                                                       | —                                                      | —                                                       |
| ‡Hydrogen bromide                              |                                                        |                                                         |                                                        |                                                         |
| [10035-10-6] . . . . .                         | (3)                                                    | (10)                                                    | —                                                      | —                                                       |
| Hydrogen chloride                              |                                                        |                                                         |                                                        |                                                         |
| [7647-01-0] . . . . .                          | C 5                                                    | C 7                                                     | —                                                      | —                                                       |
| Hydrogen cyanide                               |                                                        |                                                         |                                                        |                                                         |
| [74-90-8] — Skin . . . . .                     | C 10                                                   | C 10                                                    | —                                                      | —                                                       |

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

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

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SC

008096

LAM009306

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

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

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

| Substance                                                   | ADOPTED<br>VALUES         |                                  | ADOPTED<br>VALUES          |                                  |
|-------------------------------------------------------------|---------------------------|----------------------------------|----------------------------|----------------------------------|
|                                                             | TWA<br>ppm <sup>(a)</sup> | mg/m <sup>3</sup> <sup>(b)</sup> | STEL<br>ppm <sup>(a)</sup> | mg/m <sup>3</sup> <sup>(b)</sup> |
| ‡Methyl demeton<br>[8022-00-2] — Skin                       | —                         | 0.5                              | —                          | (1.5)                            |
| Methylene bisphenyl<br>isocyanate (MDI)<br>[101-68-8]       | C 0.02                    | C 0.2                            | —                          | —                                |
| ‡Methylene chloride [75-09-2]                               | 100                       | 350                              | (500)                      | (1,740)                          |
| 4,4'-Methylene<br>bis(2-chloroaniline)<br>[101-14-4] — Skin | 0.02,A2                   | 0.22,A2                          | —                          | —                                |
| Methylene bis(4-cyclo-<br>hexylisocyanate)<br>[5124-30-1]   | C 0.01                    | C 0.11                           | —                          | —                                |
| ‡4,4'-Methylene dianiline<br>[107-77-9] — Skin              | (0.1)                     | (0.8)                            | (0.5)                      | (4)                              |
| Methyl ethyl ketone (MEK)<br>[78-93-3]                      | 200                       | 590                              | 300                        | 885                              |
| Methyl ethyl ketone<br>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<br>[60-34-4] — Skin                        | C 0.2,A2                  | C 0.35,A2                        | —                          | —                                |
| ‡Methyl iodide [74-88-4] —<br>Skin                          | 2,A2                      | 10,A2                            | (5,A2)                     | (30,A2)                          |
| Methyl isoamyl ketone<br>[110-12-3]                         | 50                        | 240                              | —                          | —                                |
| Methyl isobutyl carbinol<br>[108-11-2] — Skin               | 25                        | 100                              | 40                         | 165                              |
| Methyl isobutyl ketone<br>[108-10-1]                        | 50                        | 205                              | 75                         | 300                              |
| Methyl isocyanate<br>[624-83-9] — Skin                      | 0.02                      | 0.05                             | —                          | —                                |
| Methyl isopropyl ketone<br>[563-80-4]                       | 200                       | 705                              | —                          | —                                |
| Methyl mercaptan [74-93-1]                                  | 0.5                       | 1                                | —                          | —                                |
| ‡Methyl methacrylate<br>[80-62-6]                           | 100                       | 410                              | (125)                      | (510)                            |
| ‡Methyl parathion<br>[298-00-0] — Skin                      | —                         | 0.2                              | —                          | (0.6)                            |
| Methyl propyl ketone<br>[107-87-9]                          | 200                       | 700                              | 250                        | 875                              |
| ‡Methyl silicate [681-84-5]                                 | 1                         | 6                                | (5)                        | (30)                             |
| α-Methyl styrene [98-83-9]                                  | 50                        | 240                              | 100                        | 485                              |
| Metribuzin [21087-64-9]                                     | —                         | 5                                | —                          | —                                |

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

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‡ See Notice of Intended Changes

\* 1985-1986 Addition.

| Substance                                                                            | ADOPTED<br>VALUES  |                      | ADOPTED<br>VALUES  |                      |
|--------------------------------------------------------------------------------------|--------------------|----------------------|--------------------|----------------------|
|                                                                                      | TWA                |                      | STEL               |                      |
|                                                                                      | ppm <sup>(a)</sup> | mg/m <sup>3(b)</sup> | ppm <sup>(a)</sup> | mg/m <sup>3(b)</sup> |
| ‡Nitromethane [75-52-5] ..                                                           | 100                | 250                  | (150)              | (375)                |
| ‡1-Nitropropane [108-03-2]                                                           | 25                 | 90                   | (35)               | (135)                |
| ‡2-Nitropropane [79-46-9] .                                                          | (C 25,<br>A2)      | (C 90<br>A2)         | —                  | —                    |
| N-Nitrosodimethylamine<br>[62-75-9] — Skin .....                                     | —                  | A2                   | —                  | —                    |
| Nitrotoluene [99-08-1] —<br>Skin .....                                               | 2                  | 11                   | —                  | —                    |
| Nitrotrichloromethane, see Chloropicrin                                              |                    |                      |                    |                      |
| ‡Nonane [111-84-2] .....                                                             | 200                | 1,050                | (250)              | (1,300)              |
| Octachloronaphthalene<br>[2234-13-1] — Skin .....                                    | —                  | 0.1                  | —                  | 0.3                  |
| Octane [111-65-9] .....                                                              | 300                | 1,450                | 375                | 1,800                |
| Oil mist, mineral<br>[8012-95-1] .....                                               | —                  | 5 <sup>(e)</sup>     | —                  | 10                   |
| Osmium tetroxide<br>[20816-12-0], as Os ....                                         | 0.0002             | 0.002                | 0.0006             | 0.006                |
| Oxalic acid [144-62-7] ..                                                            | —                  | 1                    | —                  | 2                    |
| ‡Oxygen difluoride<br>[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<br>[8002-74-2] .....                                              | —                  | 2                    | —                  | (6)                  |
| Paraquat [1910-42-5],<br>respirable sizes .....                                      | —                  | 0.1                  | —                  | —                    |
| ‡Parathion [56-38-2] — Skin                                                          | —                  | 0.1                  | —                  | (0.3)                |
| Particulate polycyclic aromatic hydrocarbons (PPAH), see Coal<br>tar pitch volatiles |                    |                      |                    |                      |
| Pentaborane [19624-22-7]                                                             | 0.005              | 0.01                 | 0.015              | 0.03                 |
| ‡Pentachloronaphthalene<br>[1321-64-8] .....                                         | —                  | 0.5                  | —                  | (2)                  |
| ‡Pentachlorophenol,<br>[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                                                |                    |                      |                    |                      |
| Perchloromethylene<br>[127-13-4] .....                                               | 50                 | 335                  | 200                | 1,340                |
| Perchloromethyl mercaptan<br>[594-42-3] .....                                        | 0.1                | 0.8                  | —                  | —                    |
| Perchloryl fluoride<br>[7616-94-6] .....                                             | 3                  | 14                   | 6                  | 28                   |
| Phenacyl chloride, see $\alpha$ -Chloroacetophenone                                  |                    |                      |                    |                      |
| ‡Phenol [108-95-2] — Skin                                                            | 5                  | 19                   | (10)               | (38)                 |

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

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‡ See Notice of Intended Changes.

\* 1985-1986 Addition.

(e) As Sampled by method that does not collect vapor.

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SC

008099

LAM009309



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

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| Substance                                            | ADOPTED<br>VALUES  |                      | ADOPTED<br>VALUES  |                      |
|------------------------------------------------------|--------------------|----------------------|--------------------|----------------------|
|                                                      | TWA                |                      | STEL               |                      |
|                                                      | ppm <sup>***</sup> | mg/m <sup>3***</sup> | ppm <sup>***</sup> | mg/m <sup>3***</sup> |
| 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 <sup>*</sup>      | —                  | (20)                 |
| Silane, see Silicon tetrahydride                     | —                  | —                    | —                  | —                    |
| ‡Silicon [7440-21-3]                                 | —                  | D                    | —                  | (20)                 |
| ‡Silicon carbide [409-21-2]                          | —                  | D                    | —                  | (20)                 |
| Silicon tetrahydride                                 | —                  | —                    | —                  | —                    |
| [7803-62-5]                                          | 5                  | 7                    | —                  | —                    |
| Silver [7440-22-4]                                   | —                  | —                    | —                  | —                    |
| Metal                                                | —                  | 0.1                  | —                  | —                    |
| Soluble compounds,                                   | —                  | —                    | —                  | —                    |
| as Ag                                                | —                  | 0.01                 | —                  | —                    |
| Sodium azide [26628-22-8]                            | C 0.1              | C 0.3                | —                  | —                    |
| Sodium bisulfite [7631-90-5]                         | —                  | 5                    | —                  | —                    |
| Sodium 2,4-dichloro-phenoxyethyl sulfate, see Sesone | —                  | —                    | —                  | —                    |
| Sodium fluoroacetate                                 | —                  | —                    | —                  | —                    |
| [62-74-8] — Skin                                     | —                  | 0.05                 | —                  | 0.15                 |
| Sodium hydroxide                                     | —                  | —                    | —                  | —                    |
| [1310-73-2]                                          | —                  | C 2                  | —                  | —                    |
| Sodium metabisulfite                                 | —                  | —                    | —                  | —                    |
| [7681-57-4]                                          | —                  | 5                    | —                  | —                    |
| ‡Starch [9005-25-8]                                  | —                  | D                    | —                  | (20)                 |
| ‡Stibine [7803-52-3]                                 | 0.1                | 0.5                  | (0.3)              | (1.5)                |
| ‡Stoddard solvent                                    | —                  | —                    | —                  | —                    |
| [8052-41-3]                                          | 100                | 525                  | (200)              | (1,050)              |
| ‡Strychnine [57-24-9]                                | —                  | 0.15                 | —                  | (0.45)               |
| Styrene, monomer                                     | —                  | —                    | —                  | —                    |
| [100-42-5]                                           | 50                 | 215                  | 100                | 425                  |

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

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SC

008100

LAM009310

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

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

Capital letters A, B, C &amp; E refer to Appendices: C denotes ceiling limit

‡ See Notice of Intended Changes.

\* 1985-1986 Addition.

(f) Based on "high Volume" sampling.

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

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

| Substance                                     | ADOPTED<br>VALUES       |                                 | ADOPTED<br>VALUES        |                                 |
|-----------------------------------------------|-------------------------|---------------------------------|--------------------------|---------------------------------|
|                                               | TWA<br>ppm <sup>1</sup> | mg/m <sup>3</sup> <sup>1a</sup> | STEL<br>ppm <sup>1</sup> | mg/m <sup>3</sup> <sup>1a</sup> |
| Vanadium, as V <sub>2</sub> O <sub>5</sub>    |                         |                                 |                          |                                 |
| [1314-62-1]                                   |                         |                                 |                          |                                 |
| Respirable dust & fume                        | —                       | 0.05                            | —                        | —                               |
| Vegetable oil mists                           | —                       | 0                               | —                        | —                               |
| Vinyl acetate [108-05-4]                      | 10                      | 30                              | 20                       | 60                              |
| Vinyl benzene, see Styrene                    |                         |                                 |                          |                                 |
| Vinyl bromide [593-60-2]                      | 5,A2                    | 20,A2                           | —                        | —                               |
| Vinyl chloride [75-01-4]                      | 5,A1a                   | 10,A1a                          | —                        | —                               |
| Vinyl cyanide, see Acrylonitrile              |                         |                                 |                          |                                 |
| Vinyl cyclohexene dioxide                     |                         |                                 |                          |                                 |
| [106-87-6]                                    | 10,A2                   | 60,A2                           | —                        | —                               |
| Vinylidene chloride [75-35-4]                 | 5                       | 20                              | 20                       | 80                              |
| Vinyl toluene [25013-15-4]                    | 50                      | 240                             | 100                      | 485                             |
| †VM & P Naphtha                               |                         |                                 |                          |                                 |
| [8032-32-4]                                   | 300                     | 1,350                           | (400)                    | (1,800)                         |
| †Warfarin [81-81-2]                           | —                       | 0.1                             | —                        | (0.3)                           |
| Welding fumes (NOC†)                          | —                       | 5,B2                            | —                        | —                               |
| Wood dust (certain hard woods as beech & oak) | —                       | 1                               | —                        | —                               |
| Soft wood                                     | —                       | 5                               | —                        | 10                              |
| Xylene [1330-20-7] (o-, m-, p-isomers)        | 100                     | 435                             | 150                      | 655                             |
| m-Xylene α,α'-diamine [1477-55-0] — Skin      | —                       | C 0.1                           | —                        | —                               |
| Xylidine [1300-73-8] — Skin                   | 2                       | 10                              | —                        | —                               |
| Yttrium [7440-65-5]                           | —                       | 1                               | —                        | 3                               |
| Zinc chloride fume                            | —                       | 1                               | —                        | 2                               |
| [7646-86-7]                                   | —                       | 1                               | —                        | 2                               |
| Zinc chromate                                 | —                       | 0.5,A2                          | —                        | —                               |
| [13530-65-9], as Cr                           | —                       | 0.5,A2                          | —                        | —                               |
| Zinc oxide [1314-13-2]                        | —                       | 5                               | —                        | 10                              |
| Fume                                          | —                       | D                               | —                        | —                               |
| Dust                                          | —                       | D                               | —                        | —                               |
| †Zinc stearate [557-05-1]                     | —                       | 0                               | —                        | (10)                            |
| Zirconium compounds                           |                         |                                 |                          |                                 |
| [7440-67-2], as Zr                            | —                       | 5                               | —                        | 10                              |

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

† See Notice of Intended Changes.

\* 1985-1986 Addition.

† NOC = Not otherwise classified.

Radioactivity: See Physical Agents section on Ionizing Radiation.

## DUSTS

| Substance                                          | TLV-TWA                                                                                                                                                                                                                                                                                        |
|----------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <u>SILICA, SiO<sub>2</sub></u>                     |                                                                                                                                                                                                                                                                                                |
| <i>Crystalline</i>                                 |                                                                                                                                                                                                                                                                                                |
| ‡ Quartz [14808-60-7]                              | In mppcf: <sup>(h)</sup><br>$\frac{300^{(m)}}{\% \text{ quartz} + 10}$ For respirable dust in mg/m <sup>3</sup> :<br>$\frac{10 \text{ mg/m}^{(m)}}{\% \text{ Respirable quartz} + 2}$ For "total dust," respirable and nonrespirable:<br>$\frac{30 \text{ mg/m}^{(m)}}{\% \text{ quartz} + 3}$ |
| ‡ Cristobolite [14464-46-1]                        | Use one-half value calculated from the count or mass formulae for quartz.                                                                                                                                                                                                                      |
| * Silica, fused [60676-86-0]                       | 0.1 mg/m <sup>3</sup> , Respirable dust                                                                                                                                                                                                                                                        |
| ‡ Tridymite [15468-32-3]                           | Use one-half the value calculated from formulae for quartz.                                                                                                                                                                                                                                    |
| * Tripoli [1317-95-9]                              | 0.1 mg/m <sup>3</sup> of contained respirable quartz dust.                                                                                                                                                                                                                                     |
| ‡ Amorphous [7631-86-9]                            | (20 mppcf <sup>(h)</sup> )                                                                                                                                                                                                                                                                     |
| * ‡ Precipitated silica                            | ‡ (5 mg/m <sup>3</sup> , Respirable dust)<br>* 10 mg/m <sup>3</sup> , Total dust                                                                                                                                                                                                               |
| * ‡ Silica gel                                     | ‡ (5 mg/m <sup>3</sup> , Respirable dust)<br>* 10 mg/m <sup>3</sup> , Total dust                                                                                                                                                                                                               |
| <u>‡ SILCATES and OTHER DUSTS (&lt; 1% quartz)</u> |                                                                                                                                                                                                                                                                                                |
| <i>Asbestos<sup>(k)</sup></i>                      |                                                                                                                                                                                                                                                                                                |
| Amosite [12172-73-5]                               | 0.5 fiber/cc, A1a                                                                                                                                                                                                                                                                              |
| Chrysotile [12001-29-5]                            | 2 fibers/cc, A1a                                                                                                                                                                                                                                                                               |
| Crocidolite [12001-28-4]                           | 0.2 fiber/cc, A1a                                                                                                                                                                                                                                                                              |
| Other forms                                        | 2 fibers/cc, A1a                                                                                                                                                                                                                                                                               |
| * ‡ Graphite (natural) [7782-42-5]                 | * 2.5 mg/m <sup>3</sup> , Respirable dust<br>‡ (5 mg/m <sup>3</sup> , Total dust)                                                                                                                                                                                                              |
| ‡ Mica [12001-25-2]                                | (20 mppcf)                                                                                                                                                                                                                                                                                     |
| Mineral wool fiber                                 | 10 mg/m <sup>3</sup>                                                                                                                                                                                                                                                                           |
| ‡ Perlite                                          | (30 mppcf)                                                                                                                                                                                                                                                                                     |
| ‡ Portland cement                                  | (30 mppcf)                                                                                                                                                                                                                                                                                     |

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- \* Soapstone ..... 3 mg/m<sup>3</sup>, Respirable dust  
6 mg/m<sup>3</sup>, Total dust
- Talc (containing no asbestos fibers) [14807-96-6] ..... 2 mg/m<sup>3</sup>, Respirable dust
- \* Talc (containing asbestos fibers) ..... Use asbestos TLV. However, should not exceed 2 mg/m<sup>3</sup> respirable dust.
- Nuisance particulates (see Appendix D):  
‡ (30 mppcf) or 10 mg/m<sup>3</sup> of total dust < 1% quartz, or, ‡ (5 mg/m<sup>3</sup> respirable dust.)
- Conversion factors:  
mppcf × 35.3 = Million particles per cubic meter  
= Particles per cc
- \* ‡ COAL DUST
- ‡ (2 mg/m<sup>3</sup> (respirable dust fraction < 5% quartz).  
\* If > 5% quartz, use respirable quartz value.

## FOOTNOTES FOR DUSTS

- (h) Millions of particles per cubic foot of air, based on impinger samples counted by light-field technics.
- (i) The percentage of quartz in the formula is the amount determined from airborne samples, except in those instances in which other methods have been shown to be applicable.
- (j) Both concentration and percent quartz for the application of this limit are to be determined from the fraction passing a size-selector with the following characteristics:

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

- (k) As determined by the membrane filter method at 400-450 × magnification (4 mm objective) phase contrast illumination.
- (l) Fibers longer than 5 μm and with an aspect ratio equal to or greater than 3:1.
- ‡ (m) (Containing less than 1% quartz; if quartz content > 1%, use formulae for quartz.)

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# NOTICE OF INTENDED CHANGES (for 1985-86)

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

| Substance                                                                       | [CAS #] | TWA               |                                 | STEL              |                                 |
|---------------------------------------------------------------------------------|---------|-------------------|---------------------------------|-------------------|---------------------------------|
|                                                                                 |         | ppm <sup>a)</sup> | mg/m <sup>3</sup> <sup>b)</sup> | ppm <sup>a)</sup> | mg/m <sup>3</sup> <sup>b)</sup> |
| †Acrylamide [79-06-1] — Skin                                                    | —       | 0.03,A2           | —                               | —                 | —                               |
| Amitrole [61-82-5] . . . . .                                                    | —       | 0.2               | —                               | —                 | —                               |
| Ammonium persulfate<br>[7727-54-1], as S <sub>2</sub> O <sub>8</sub> . . . . .  | —       | 5                 | —                               | —                 | —                               |
| Boron tribromide<br>[10294-33-4] . . . . .                                      | C 1     | C 10              | —                               | —                 | —                               |
| 1,3-Butadiene [106-99-9] . . . . .                                              | 10,A2   | 22,A2             | —                               | —                 | —                               |
| Carbon dioxide [124-38-9] . . . . .                                             | 5,000   | 9,000             | 30,000                          | 54,000            | —                               |
| Cobalt metal, dust & fume<br>[7440-48-4], as Co . . . . .                       | —       | 0.05              | —                               | 0.1               | —                               |
| Enflurane [13838-16-9] . . . . .                                                | 75      | 575               | —                               | —                 | —                               |
| Grain dust . . . . .                                                            | —       | 4                 | —                               | —                 | —                               |
| Halothane [151-67-7] . . . . .                                                  | 50      | 400               | —                               | —                 | —                               |
| Hydrogen bromide<br>[10035-10-6] . . . . .                                      | C 3     | C 10              | —                               | —                 | —                               |
| Hydrogen fluoride<br>[7664-39-3], as F . . . . .                                | C 3     | C 2.5             | —                               | —                 | —                               |
| 4,4-Methylene dianiline<br>[101-77-9] . . . . .                                 | 0.1,A2  | 0.8,A2            | —                               | —                 | —                               |
| †2-Nitropropane [79-46-9] . . . . .                                             | 10,A2   | 35,A2             | (20,A2)                         | (70,A2)           | —                               |
| Oxygen difluoride<br>[7783-41-7] . . . . .                                      | C 0.05  | C 0.1             | —                               | —                 | —                               |
| Persulfates, alkali metal, as<br>S <sub>2</sub> O <sub>8</sub> . . . . .        | —       | 5                 | —                               | —                 | —                               |
| Potassium persulfate<br>[7727-21-1], as S <sub>2</sub> O <sub>8</sub> . . . . . | —       | 5                 | —                               | —                 | —                               |
| Sodium persulfate<br>[7775-27-1], as S <sub>2</sub> O <sub>8</sub> . . . . .    | —       | 5                 | —                               | —                 | —                               |
| Sulfur monochloride<br>[10025-67-9] . . . . .                                   | C 1     | C 6               | —                               | —                 | —                               |
| Sulfur pentafluoride<br>[5714-22-7] . . . . .                                   | C 0.01  | C 0.1             | —                               | —                 | —                               |
| Sulfur tetrafluoride<br>[7783-60-0] . . . . .                                   | C 0.1   | C 0.4             | —                               | —                 | —                               |
| Thionyl chloride [7719-09-7] . . . . .                                          | C 1     | C 5               | —                               | —                 | —                               |

| Substance                                             | [CAS #] | TWA               |                                 | STEL              |                                 |
|-------------------------------------------------------|---------|-------------------|---------------------------------|-------------------|---------------------------------|
|                                                       |         | ppm <sup>a)</sup> | mg/m <sup>3</sup> <sup>b)</sup> | ppm <sup>a)</sup> | mg/m <sup>3</sup> <sup>b)</sup> |
| m-Toluidine [108-44-1] —<br>Skin . . . . .            | —       | 2                 | 9                               | —                 | —                               |
| p-Toluidine [108-49-0] —<br>Skin . . . . .            | —       | 2,A2              | 9,A2                            | —                 | —                               |
| †1,2,3-Trichloropropane<br>[96-18-4] — Skin . . . . . | —       | 10                | 60                              | —                 | —                               |

## DELETE THE TLV-STELs FOR THE FOLLOWING SUBSTANCES:

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

(a) Parts of vapor or gas per million parts of contaminated air by volume at 25°C and 1 torr.

(b) Approximate milligrams of substance per cubic meter of air.

† 1985-1986 Revision or Addition.

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

Dinitro-o-cresol  
 Dinitrotoluene  
 Dioxane, tech. grade.  
 Diphenylamine  
 Diquat  
 Disulfiram  
 Disulfoton  
 †2,6-Ditert. butyl-p-cresol  
 Emery  
 Endosulfan  
 Endrin  
 Epichlorohydrin  
 EPN  
 †Ethyl acrylate  
 †Ethylbutyl ketone  
 Ethyl chloride  
 Ethylene dichloride  
 †Ethyl formate  
 Ethyl mercaptan  
 N-Ethylmorpholine  
 Ethyl silicate  
 Febram  
 Formamide  
 †Furfural  
 Germanium tetrahydride  
 †Glycidol  
 Gypsum  
 Hafnium  
 Heptachlor  
 Hexachlorocyclopentadiene  
 Hexachloronaphthalene  
 Hexafluoroacetone  
 Hydrogen peroxide  
 †Hydroquinone  
 †Indene  
 Indium & compounds  
 Iodoform  
 Iron oxide fume  
 Iron salts, soluble  
 †Isoamyl acetate  
 †Isobutyl alcohol  
 †Isopropoxyethanol  
 N-Isopropylaniline  
 Kaolin  
 Lead, inorganic dust & fumes  
 Limestone  
 Lindane  
 †L.P.G. (liquified petroleum gas)  
 Magnesite  
 Manganese cyclopentadienyl  
 tricarbonyl

Marble/calcium carbonate  
 Methylacrylonitrile  
 †Methylal  
 †Methyl n-aryl ketone  
 N-Methyl aniline  
 Methyl bromide  
 †Methylcyclohexane  
 †Methylcyclohexanol  
 Methylcyclopentadienyl  
 manganese tricarbonyl  
 Methyl demeton  
 Methylene chloride  
 Methyl iodide  
 †Methyl methacrylate  
 Methyl parathion  
 Methyl silicate  
 Molybdenum, soluble &  
 insoluble compounds  
 Naled  
 Nickel soluble compounds  
 Nicotine  
 Nitric oxide  
 Nitrobenzene  
 Nitroethane  
 Nitrogen trifluoride  
 Nitromethane  
 1-Nitropropane  
 †Nonane  
 †Paraffin wax fume  
 Parathion  
 Pentachloronaphthalene  
 Pentachlorophenol  
 Pentaerythritol  
 †Phenol  
 Phenothiazine  
 Phosphorus (yellow)  
 †Phthalic anhydride  
 †Pindone  
 Plaster of Paris  
 †Propargyl alcohol  
 †β-Propiolactone  
 †Propionic acid  
 †Propoxur  
 †Pyrethrum  
 †Pyridine  
 †Quinone  
 †Rosin core solder pyrolysis  
 products  
 †Rotenone (commercial)  
 Rouge  
 Sesone

Silicon  
 Silicon carbide  
 Starch  
 Stibine  
 †Stoddard solvent  
 Strychnine  
 Sucrose  
 Sulfotep  
 Sulfur dioxide  
 Sulfur hexafluoride  
 2,4,5-T  
 Tantalum  
 Temephos  
 TEPP  
 1,1,1,2-Tetrachloro-2,2-difluoroethane  
 1,1,2,2-Tetrachloro-1,2-difluoroethane  
 1,1,2,2-Tetrachloroethane  
 Tetrachloronaphthalene  
 Tetraethyl lead  
 Tetramethyl lead  
 Tetramethyl succinonitrile

Tetryl  
 4,4'-Thiobis  
 (6-tert. butyl-m-cresol)  
 Thiram  
 Tin, metal, oxide & insoluble  
 compounds  
 Tin, organic compounds  
 Titanium dioxide  
 Tributyl phosphate  
 1,1,2-Trichloroethane  
 Trichloronaphthalene  
 Trifluorobromomethane  
 †Trimethyl benzene  
 Trimethyl phosphite  
 2,4,6-Trinitrotoluene (TNT)  
 Triorthocresyl phosphate  
 Triphenyl phosphate  
 †Turpentine  
 †VM & P naphtha  
 †Wartarin  
 Zinc stearate

## NOTICE OF INTENDED CHANGES DUSTS

| Substance                                      | TLV-TWA                                                  |
|------------------------------------------------|----------------------------------------------------------|
| <b>SILICA, SiO<sub>2</sub></b>                 |                                                          |
| <i>Crystalline</i>                             |                                                          |
| Quartz . . . . .                               | 0.1 mg/m <sup>3</sup> , Respirable dust<br>[14808-60-7]  |
| Cristobalite . . . . .                         | 0.05 mg/m <sup>3</sup> , Respirable dust<br>[14464-46-1] |
| Tridymite . . . . .                            | 0.05 mg/m <sup>3</sup> , Respirable dust<br>[15468-32-3] |
| <i>Amorphous</i>                               |                                                          |
| Diatomaceous earth<br>(uncalcined) . . . . .   | 10 mg/m <sup>3</sup> , Total dust<br>[68855-54-9]        |
| † Precipitated silica <sup>(m)</sup> . . . . . | 10 mg/m <sup>3</sup> , Total dust                        |
| † Silica gel <sup>(m)</sup> . . . . .          | 10 mg/m <sup>3</sup> , Total dust                        |

† 1985-1986 Revision or Addition.

### †SILICATES and OTHER DUSTS<sup>(m)</sup>

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

### GENERIC LISTING

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

### FOOTNOTE(s)

(m) For silicates and other dusts, the values are for dust containing <1% quartz in the total dust. For coal dust, the value is for coal dust containing < 5% quartz in the respirable fraction. For materials containing more than these percentages of quartz, the environment should be evaluated against the TLV of 0.1 mg/m<sup>3</sup> for respirable quartz. Even where the respirable quartz concentration is less than 0.1 mg/m<sup>3</sup>, the level of the major component should not exceed its TLV.

## NOTICE OF INTENT TO CHANGE

### APPENDIX A Carcinogens

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

The Chemical Substances TLV Committee considers information from the following kinds of studies to be indicators of a substance's potential to be a carcinogen in humans: epidemiology studies, toxicology studies and, to a lesser extent, case histories. Because of the long latent period for many carcinogens,

and for ethical reasons, it is often timely and prudent to base risk-management decisions on results from human toxicological studies. In order to recognize the qualitative differences in research results, two categories of carcinogens are designated in this booklet: A1—Confirmed Human Carcinogens; and A2—Suspected Human Carcinogens. All steps must be taken to keep exposures to any carcinogens to a minimum. Workers exposed to A1 carcinogens without a TLV should be properly equipped to insure virtually no contact with the carcinogen. Please see the section covering this Notice of Intent to Change in the *Documentation of the Threshold Limit Values* for a more complete description of these designations.

## ADOPTED APPENDICES

### APPENDIX A Carcinogens

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

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

| Substance                                                      | TLV                                            |
|----------------------------------------------------------------|------------------------------------------------|
| Asbestos                                                       |                                                |
| Amosite . . . . .                                              | 0.5 fiber <sup>(m)</sup>                       |
| Chrysotile . . . . .                                           | 2 fibers <sup>(m)</sup>                        |
| Crocidolite . . . . .                                          | 0.2 fiber <sup>(m)</sup>                       |
| Other forms . . . . .                                          | 2 fibers <sup>(m)</sup>                        |
| bis-(Chloromethyl) ether . . . . .                             | 0.001 ppm                                      |
| Chromite ore processing<br>(chromate) . . . . .                | 0.05 mg/m <sup>3</sup> , as Cr                 |
| Chromium (VI), certain<br>water soluble<br>compounds . . . . . | 0.05 mg/m <sup>3</sup> , as Cr                 |
| Coal tar pitch volatiles . . . . .                             | 0.2 mg/m <sup>3</sup> , as benzene<br>solubles |
| Nickel sulfide roasting,<br>fume and dust . . . . .            | 1 mg/m <sup>3</sup> , as Ni                    |
| Vinyl chloride . . . . .                                       | 5 ppm                                          |

† 1985-1986 Revision or Addition.

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

4-Aminodiphenyl — Skin  
Benzidine — Skin  
 $\beta$ -Naphthylamine  
4-Nitrodiphenyl

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

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

|                                            |                          |
|--------------------------------------------|--------------------------|
| †Acrylamide — Skin                         | 0.03 ppm                 |
| Acrylonitrile — Skin                       | 2 ppm                    |
| **Amitrole                                 | —                        |
| Antimony trioxide production*              | —                        |
| Arsenic trioxide production                | —                        |
| Benzene                                    | 10 ppm                   |
| Benzo(a)pyrene                             | —                        |
| Beryllium                                  | 2 $\mu$ g/m <sup>3</sup> |
| 1,3-Butadiene                              | 10 ppm                   |
| Carbon tetrachloride — Skin                | 5 ppm                    |
| Chloroform                                 | 10 ppm                   |
| Chlormethyl methyl ether                   | —                        |
| Chromates of lead and zinc, as Cr          | 0.05 mg/m <sup>3</sup>   |
| Chrysene                                   | —                        |
| 3,3'-Dichlorobenzidine — Skin              | —                        |
| Dimethyl carbamoyl 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                 |
| 4,4-Methylene dianiline                    | 0.1 ppm                  |
| Methyl hydrazine — Skin                    | C 0.2 ppm                |
| Methyl iodide — Skin                       | 2 ppm                    |

|                               |         |
|-------------------------------|---------|
| 2-Nitropropane                | 10 ppm  |
| N-Nitrosodimethylamine — Skin | —       |
| N-Phenyl-beta-naphthylamine   | —       |
| †Phenylhydrazine — Skin       | 5 ppm   |
| Propane sulfone               | —       |
| $\beta$ -Propiolactone        | 0.5 ppm |
| Propylene imine — Skin        | 2 ppm   |
| o-Tolidine — Skin             | —       |
| o-Toluidine — Skin            | 2 ppm   |
| p-Toluidine — Skin            | 2 ppm   |
| Vinyl bromide                 | 5 ppm   |
| Vinyl cyclohexene dioxide     | 10 ppm  |

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

.....

#### The Committee Guidelines for Classification of Experimental Animal Carcinogens

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

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

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

\*\* See Notice of Intended Changes.

† 1985-1986 Addition.

‡ 1985-1986 Adoption.



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

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

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

**EXCEPTIONS:** No substance is to be considered an occupational carcinogen of any practical significance which reacts by the respiratory route at or above 1000 mg/m<sup>3</sup> for the mouse, 2000 mg/m<sup>3</sup> 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 trichloroethylene from consideration as carcinogens.

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

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

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

a. **Respiratory.** Elicit cancer from 1) dosages below 1 mg/m<sup>3</sup> (or equivalent ppm) via the respiratory tract in 6- to 7-hour daily repeated inhalation exposures throughout lifetime; or 2) from a single intratracheally administered dose not exceeding 1 mg of particulate, or liquid, per 100 ml or less of animal minute respiratory volume.

**Examples:** 1) bis-Chloromethyl ether — malignant tumors, rats, at 0.47 mg/m<sup>3</sup> (0.1 ppm) in 2 years; 2) Hexamethyl phosphoramide — nasal squamous cell carcinoma, rats at 0.05 ppm, in 13 months.

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

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

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

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

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

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

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

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

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

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

1. **Respiratory.** Elicit cancer from a) dosages greater than 10 mg/m<sup>3</sup> (or equivalent ppm) via the respiratory tract in 6- to 7-hour, daily repeated inhalation exposures, for 12 months' observation period; or b) from intratracheally administered dosages totaling more than 10 mg of particulate or liquid per 100 ml or more of animal minute respiratory volume.

**Examples:** 1) Beryl (beryllium aluminum silicate) — malignant lung tumors, rats, at 15 mg/m<sup>3</sup> at 17 months; 2) Benzidine — various tumors, rats, 10-20 mg/m<sup>3</sup> at > 13 months.

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

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

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

## APPENDIX B

### Substances of Variable Composition

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

**B2. Welding Fumes — Total Particulate (NOC)†**  
TLV-TWA, 5 mg/m<sup>3</sup>

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 TLVs are exceeded. Conclusions based on total fume concentration are generally adequate if no toxic elements are present in welding rod, metal, or metal coating and conditions are not conducive to the formation of toxic gases.

Most welding, even with primitive ventilation, does not produce exposures inside the welding helmet above 5 mg/m<sup>3</sup>. That which does, should be controlled.

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

† Not otherwise classified (NOC).

## APPENDIX C

### Threshold Limit Values for Mixtures

When two or more hazardous substances, which act upon the same organ system, are present, their combined effect, rather than that of either individually, should be given primary consideration. In the absence of information to the contrary, the effects of the different hazards should be considered as additive. That is, if the sum of the following fractions,

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

exceeds unity, then the threshold limit of the mixture should be considered as being exceeded.  $C_i$  indicates the observed atmospheric concentration, and  $T_i$  the corresponding threshold limit (see Example A.1 and B.1).

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

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

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

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

#### Examples of TLVs for Mixtures

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

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

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

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

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

2. Special case when the source of contaminant is a liquid mixture and the atmospheric composition is assumed to be similar to that of the original material, e.g., on a time-weighted average exposure basis, all of the liquid (solvent) mixture eventually evaporates. When the percent composition (by weight) of the liquid mixture is known, the TLVs of the constituents must be listed in mg/m<sup>3</sup>. TLV of mixture =

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

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 x the TLV; 10 x the TLV; etc.)

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

50% heptane: TLV = 400 ppm or 1600 mg/m<sup>3</sup>

$$1 \text{ mg/m}^3 \equiv 0.25 \text{ ppm}$$

30% methyl chloroform: TLV = 350 ppm or 1900 mg/m<sup>3</sup>

$$1 \text{ mg/m}^3 \equiv 0.18 \text{ ppm}$$

20% perchloroethylene: TLV = 50 ppm or 335 mg/m<sup>3</sup>

$$1 \text{ mg/m}^3 \equiv 0.15 \text{ ppm}$$

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

48

$$= \frac{1}{0.00031 + 0.00016 + 0.0006} = \frac{1}{0.00107} = 935 \text{ mg/m}^3$$

of this mixture

50% or (935)(0.5) = 468 mg/m<sup>3</sup> is heptane

30% or (935)(0.3) = 281 mg/m<sup>3</sup> is methyl chloroform

20% or (935)(0.2) = 187 mg/m<sup>3</sup> is perchloroethylene

These values can be converted to ppm as follows:

heptane: 468 mg/m<sup>3</sup> × 0.25 = 117 ppm

methyl chloroform: 281 mg/m<sup>3</sup> × 0.18 = 51 ppm

perchloroethylene: 187 mg/m<sup>3</sup> × 0.15 = 29 ppm

TLV of mixture = 117 + 51 + 29 = 197 ppm, or 935 mg/m<sup>3</sup>

**B. Independent effects.** TLV for mixture =

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

**Example B.1:** Air contains 0.15 mg/m<sup>3</sup> of lead (TLV, 0.15) and 0.7 mg/m<sup>3</sup> of sulfuric acid (TLV, 1).

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

Threshold limit is not exceeded.

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

## APPENDIX D

### Some Nuisance Particulates<sup>(m)</sup>

‡TLV-TWA, (30 mppcf) or

10 mg/m<sup>3</sup> of total dust<sup>(m)</sup> or, (5 mg/m<sup>3</sup> respirable dust)

α-Alumina (Al<sub>2</sub>O<sub>3</sub>)

Calcium carbonate

Calcium silicate

Cellulose (paper fiber)

Emery

Glycerin mist

‡Graphite (synthetic)

Gypsum

Kaolin

Limestone

Magnesite

Marble

Mineral wool fiber

Pentaerythritol

Plaster of Paris

Portland cement

Rouge

Silicon

Silicon carbide

Starch

Sucrose

Titanium dioxide

49

SC

008110

LAM009320

Vegetable oil mists  
(except castor oil,  
cashew nut or similar  
irritant oils)

Zinc stearate  
Zinc oxide dust

## APPENDIX E Some Simple Asphyxiants<sup>(a)</sup>

Acetylene  
Argon  
Ethane  
Ethylene  
Helium

Hydrogen  
Methane  
Neon  
Propane  
Propylene

## APPENDIX F Conversion of mppcf to Mass Concentration

Calculations for Conversion of Particle Count Concentration (by Standard Light Field — Midget Impinger Techniques), in mppcf, to Respirable Mass Concentration (by Respirable Sampler) in mg/m<sup>3</sup>.<sup>(1)</sup>

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

The following calculations result in an equivalence of 6.37 mppcf to 1 mg/m<sup>3</sup> of respirable dust. Thus, an approximate ratio of 6 mppcf to 1 mg/m<sup>3</sup> of respirable dust is suggested for conversion of TLVs from a count to a mass basis when the density and mass median diameter have not been determined.

2. Basic assumptions:

- a. Average density for silica containing dusts  $\approx 2.5$  g/cm<sup>3</sup> (2500 mg/cm<sup>3</sup>). Pulmonary significant dust densities may vary from 1.2 g/cm<sup>3</sup> for coal dust to 3.1 g/cm<sup>3</sup> for Portland cement. Silica densities vary from 2.2 (amorphous) to 2.3 (cristobalite and tridymite) to 2.5 ( $\alpha$ -quartz) g/cm<sup>3</sup>.
- 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  $\mu$ m or  $1.5 \times 10^{-4}$  cm. This assumption is, of course, quite arbitrary since the mmd of all dust clouds is quite variable, depending on many independent parameters, such as source of dust, age of dust cloud, meteorological conditions, processes and equipment changes, etc. If the density and the mass median diameter of the dust particles are known, the nomograph in Figure 1 can be used to convert dust count concentrations (mppcf) to respirable mass concentrations (mg/m<sup>3</sup>).

3. Calculation:

- a. Vol. per particle:  $\frac{4}{3} \pi r^3$ ;  $r = 0.75 \times 10^{-4}$  cm  
 $= \frac{4}{3} \cdot \pi \cdot (0.75 \times 10^{-4})^3$   
 $= 1.77 \times 10^{-12}$  cm<sup>3</sup>
- b. Wt. per particle = vol.  $\times$  density  
 $= 1.77 \times 10^{-12}$  cm<sup>3</sup>  $\times 2.5 \times 10^3$  mg/cm<sup>3</sup>  
 $= 4.425 \times 10^{-9}$  mg/particle
- c. 1 particle/ft<sup>3</sup> = 35.5 part./m<sup>3</sup> (since 35.5 ft<sup>3</sup> = 1 m<sup>3</sup>)  
 $10^6$  part./ft<sup>3</sup> = mppcf =  $35.5 \times 10^6$  part./m<sup>3</sup>  
 wt. of 1 mppcf =  $35.5 \times 10^6$  part./m<sup>3</sup>  $\times 4.425 \times 10^{-9}$  mg/part.  
 $1$  mppcf  $\approx 0.157$  mg/m<sup>3</sup>, or  
 $6.37$  mppcf  $\approx 1$  mg/m<sup>3</sup>, or  
 $\approx 6$  mppcf  $\approx 1$  mg/m<sup>3</sup>

### Reference

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

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

(o) As defined in the Introduction.

‡ See Notice of Intended Changes.

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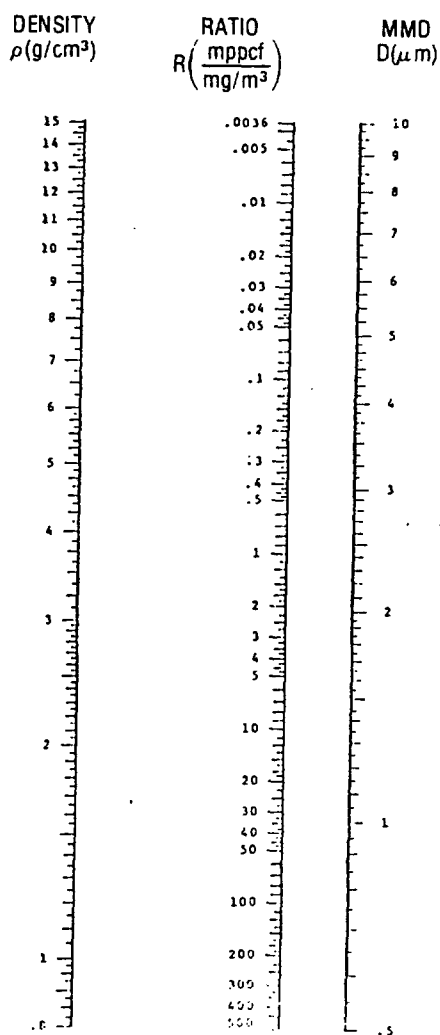


Figure 1—Ratio of Particle Count—mppcf to Respirable Mass Concentration—mg/m<sup>3</sup> (as function of density and mmd). (Prepared by P.E. Caplan and R.J. Smith.)

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TABLE 1  
Equivalent TLVs in mppcf and mg/m<sup>3</sup> (Respirable Mass) for Mineral Dusts†

| Substance                       | Threshold Limit Value |                                 |                                  |
|---------------------------------|-----------------------|---------------------------------|----------------------------------|
|                                 | Count<br>mppcf        | Resp. Mass<br>mg/m <sup>3</sup> | Total Mass*<br>mg/m <sup>3</sup> |
| <i>Silica (SiO<sub>2</sub>)</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,<br>natural  | —                     | 1.5                             | —                                |
| Mica                            | 20                    | (3)                             | (6)                              |
| Mineral wool fiber              | —                     | (5)                             | 10                               |
| Nuisance particulates           | 30                    | (5)                             | 10                               |
| Perlite                         | 30                    | (5)                             | (10)                             |
| Portland cement                 | 30                    | (5)                             | (10)                             |
| Soapstone                       | 20                    | (3)                             | (6)                              |
| Tripoli                         | (3)                   | 0.1                             | (0.3)                            |

†Assuming that the mass median diameter is 1.5 μm and density is 2.5 g/cm<sup>3</sup>.

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

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

#### APPENDIX G

##### Chemical Substances and Other Issues Under Study\*

###### Chemical Substances

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

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

#### Other Issues

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

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

#### APPENDIX H Registered Trade Names

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

# **Biological Exposure Indices**

**Proposed by  
ACGIH  
for 1985-86**



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### 1984-85 BIOLOGICAL EXPOSURE INDICES COMMITTEE

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

### CONSULTANTS

Mitchell R. Zvon, M.D.

### INTRODUCTION BIOLOGICAL EXPOSURE INDICES

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

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

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

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



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

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

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

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

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

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

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

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

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

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

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

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

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

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# NOTICE OF INTENT TO ESTABLISH BIOLOGICAL EXPOSURE INDICES

| Airborne Chemical [CAS #]           | Indices               | Timing                              | BEI                                                     | Additional<br>Notation |
|-------------------------------------|-----------------------|-------------------------------------|---------------------------------------------------------|------------------------|
| †BENZENE [71-43-2]                  | Total phenol in urine | End of shift                        | 50 mg/L                                                 | † G                    |
| •• Benzene in exhaled air           |                       | Prior to next shift                 |                                                         |                        |
| • mixed-exhaled:                    |                       |                                     | 0.08 ppm                                                |                        |
| • end-exhaled:                      |                       |                                     | 0.12 ppm                                                |                        |
| CARBON MONOXIDE [630-08-0]          |                       |                                     |                                                         |                        |
| • Carboxyhemoglobin in blood        |                       | End of shift                        | less than 8%                                            | R                      |
| • CO in end-exhaled air             |                       | End of shift                        | less than 40 ppm                                        | †                      |
| ETHYL BENZENE [100-41-4]            |                       |                                     |                                                         |                        |
| • Mandelic acid in urine            |                       | End of shift and<br>end of workweek | 2 g/L                                                   | G                      |
| •• Ethyl benzene in end-exhaled air |                       | Prior to shift                      | 1.5 g/g creat.                                          | G                      |
| †n-HEXANE [110-54-3]                |                       |                                     | 2 ppm                                                   |                        |
| • 2,5-Hexanedione in urine          |                       | End of shift                        | 5 mg/L                                                  | G                      |
| •• n-Hexane in end-exhaled air      |                       | During shift                        | 40 ppm                                                  |                        |
| †LEAD [7439-92-1]                   |                       |                                     |                                                         |                        |
| Lead in blood                       |                       | Not critical                        | 50 µg/100 ml                                            | R                      |
| Lead in urine                       |                       | Not critical                        | 150 µg/g creat.                                         | † G                    |
| Zinc protoporphyrin in blood        |                       | After 1 month of exposure           | 250 µg/100 ml<br>erythrocytes or<br>100 µg/100 ml blood | † G                    |
| †PHENOL [108-95-2]                  |                       |                                     |                                                         |                        |
| • Total phenol in urine             |                       | End of shift                        | 250 mg/g creat.                                         | † G                    |
| STYRENE [100-42-5]                  |                       | Last 2 hrs of shift                 | 15 mg/hr                                                | † G                    |
| • Mandelic acid in urine            |                       |                                     |                                                         |                        |
| Styrene in mixed-exhaled air        |                       | End of shift                        | 1 g/L                                                   | G                      |
| • Phenylglyoxylic acid in<br>urine  |                       | Prior to shift                      | 40 ppb                                                  |                        |
| •• Styrene in mixed-exhaled air     |                       | End of shift                        | 250 mg/L                                                | † G                    |
| •• Styrene in blood                 |                       | During shift                        | 240 mg/g creat.                                         | G                      |
|                                     |                       | End of shift                        | 18 ppm                                                  |                        |
|                                     |                       | Prior to shift                      | 0.55 mg/L                                               |                        |
|                                     |                       |                                     | 0.02 mg/L                                               |                        |
| TOLUENE [108-88-3]                  |                       |                                     |                                                         |                        |
| • Hippuric acid in urine            |                       | End of shift                        | 2.5 g/g creat.                                          | † G                    |
|                                     |                       | Last 4 hrs of shift                 | 3 mg/min.                                               | G                      |

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**Additional  
Notation**

**BEI**

**Timing**

**Indices**

- \*\* Toluene in venous blood
- \*\* Toluene in end-exhaled air

**TRICHLOROETHYLENE [79-01-6]**

- \* Trichloroacetic acid in urine
- \* Trichloroacetic acid and trichloroethanol in urine
- \* Free trichloroethanol in blood

- \*\* Trichloroethylene in end-exhaled air

**XYLENES [1330-20-7]**  
Methylhippuric acids in urine

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†1985-86 Addition or Revision.

100 mg/L  
300 mg/L  
320 mg/g creat.  
4 mg/L  
0.5 ppm

End of workweek  
End of workweek and end of shift  
End of shift and end of workweek  
Prior to shift and end of workweek

End of shift  
Last 4 hrs of shift  
1.5 g/g creat.  
2 mg/min

**TLVs®**

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



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**1984-85 PHYSICAL AGENTS TLV COMMITTEE**

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

**CONSULTANTS**

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

**PREFACE****PHYSICAL AGENTS**

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

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

These limits are intended for use in the practice of industrial hygiene and should be interpreted and applied only by a person trained in this discipline. They are not intended for use, or for modification for use, 1) in the evaluation or control of the levels of 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 revision or additions, as further information becomes available.

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

**ADOPTED  
THRESHOLD LIMIT VALUES  
HEAT STRESS**

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

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

where:

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

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

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

**Evaluation and Control**

**1. Measurement of the Environment**

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

**TABLE 1  
Permissible Heat Exposure Threshold Limit Values  
(Values are given in °C WBGT)**

| Work — Rest Regimen               | Work Load |          |       |
|-----------------------------------|-----------|----------|-------|
|                                   | Light     | Moderate | Heavy |
| Continuous work                   | 30.0      | 26.7     | 25.0  |
| 75% Work —<br>25% Rest, each hour | 30.6      | 28.0     | 25.9  |
| 50% Work —<br>50% Rest, each hour | 31.4      | 29.4     | 27.9  |
| 25% Work —<br>75% Rest, each hour | 32.2      | 31.1     | 30.0  |

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

B. A globe thermometer, consisting of a 15 cm (6-inch) diameter hollow copper sphere painted on the outside with a matte black finish or equivalent, shall be used. The bulb or sensor of a thermometer (range -5° to +100°C with an accuracy of  $\pm 0.5^\circ\text{C}$ ) 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.<sup>(3,4)</sup>

## II. Work Load Categories

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

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

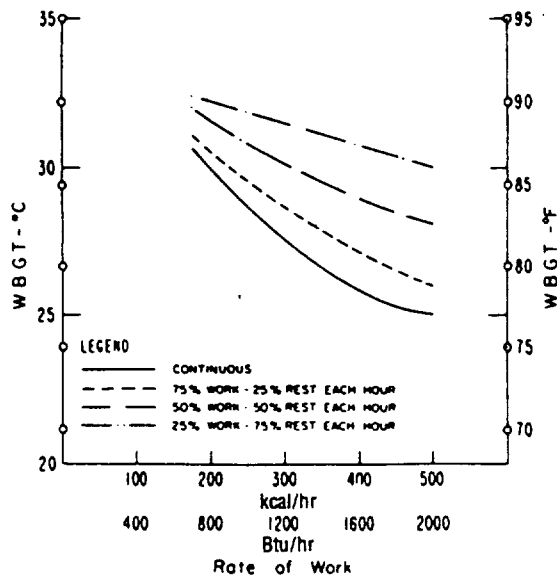


Figure 1—Permissible Heat Exposure Threshold Limit Values.

TABLE 2  
Assessment of Work Load<sup>(9)</sup>

Average values of metabolic rate during different activities.

| A. Body position and movement |  | kcal/min              |
|-------------------------------|--|-----------------------|
| Sitting                       |  | 0.3                   |
| Standing                      |  | 0.                    |
| Walking                       |  | 2.0-3.0               |
| Walking up hill               |  | add 0.8               |
|                               |  | per meter (yard) rise |

| B. Type of Work     |            | Average kcal/min | Range kcal/min |
|---------------------|------------|------------------|----------------|
| Hand work           | light      | 0.4              | 0.2-1.2        |
|                     | heavy      | 0.9              |                |
| Work with one arm   | light      | 1.0              | 0.7-2.5        |
|                     | heavy      | 1.7              |                |
| Work with both arms | light      | 1.5              | 1.0-3.5        |
|                     | heavy      | 2.5              |                |
| Work with body      | light      | 3.5              | 2.5-15.0       |
|                     | moderate   | 5.0              |                |
|                     | heavy      | 7.0              |                |
|                     | very heavy | 9.0              |                |

- (1) light work (up to 200 kcal/hr or 800 Btu/hr): e.g., sitting or standing to control machines, performing light hand or arm work,
- (2) moderate work (200-350 kcal/hr or 800-1400 Btu/hr): e.g., walking about with moderate lifting and pushing, or
- (3) heavy work (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<sup>(5-8)</sup> may be utilized also. When this method is used the permissible heat exposure limit can be determined by Figure 1.

**TABLE 3**  
**Activity Examples<sup>a)</sup>**

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

#### Simple Calculation

Assembly line work using a heavy hand tool.

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

#### III. Work-Rest Regimen

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

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

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

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:

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

where  $\text{WBGT}_1$ ,  $\text{WBGT}_2$  ... and  $\text{WBGT}_n$  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% (1 g NaCl to 1.0 liter or 1 level tablespoon of salt to 15 quarts of water). The added salt shall be completely dissolved before the water is distributed, and the water shall be kept reasonably cool.

#### V. Other Considerations

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

under hot environmental conditions. If special clothing is required for performing a particular job and this clothing is heavier or it impedes sweat evaporation or has higher insulation value, the worker's heat tolerance is reduced, and the permissible heat exposure limits indicated in Table 1 and Figure 1 are not applicable. For each job category where special clothing is required, the permissible heat exposure limit shall be established by an expert.

**B. Acclimatization and Fitness:** Acclimatization to heat involves a series of physiological and psychological adjustments that occur in an individual during this first week of exposure to hot environmental conditions. The recommended heat stress TLVs are valid for acclimated workers who are physically fit. Extra caution must be employed when unacclimated or physically unfit workers must be exposed to heat stress conditions.

#### References

1. *Health Factors Involved in Working Under Conditions of Heat Stress.* WHO Technical Report Series No. 412 (1969).
2. *Dukes-Dobos, F.N. and A. Henschel:* Development of Permissible Heat Exposure Limits for Occupational Work. *ASHRAE Journal* 15(9):57-62 (Sept. 1973).
3. *Minard, D.:* Prevention of Heat 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 the 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.<sup>(1)</sup> 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 exposure to ionizing radiation be kept as low as reasonably achievable within the stated guidance.

#### References

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

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

## LASERS

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

#### Limiting Apertures

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

The TLVs for "extended sources" apply to sources which subtend an angle greater than  $\alpha$  (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 IV, V or VII or a single pulse of the same duration as the entire pulse group.
- (3) When the Instantaneous Pulse Repetition Frequency (PRF) of any pulses within a train exceeds one, the protection standard applicable to each pulse is reduced, as shown in Figure 6, for pulse durations less than  $10^{-5}$  second. For pulses of greater duration, the following formula should be followed:

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

where:

$n$  = number of pulses in train

$\tau$  = duration of a single pulse in the train

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

‡ See Notice of Intended Changes.

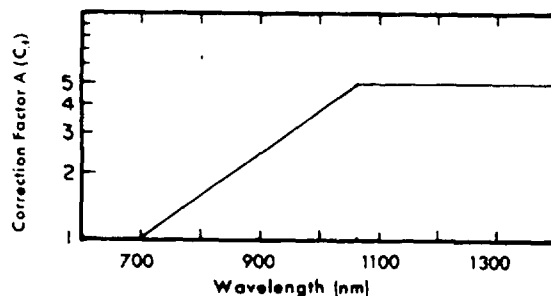


Figure 2—TLV correction factor for  $\lambda = 700$ –1400 nm.\* (\* For  $\lambda = 700$ –1049 nm,  $C_A = 10^{(0.002(\lambda-700))}$ ; For  $\lambda = 1050$ –1400 nm,  $C_A = 5$ .)

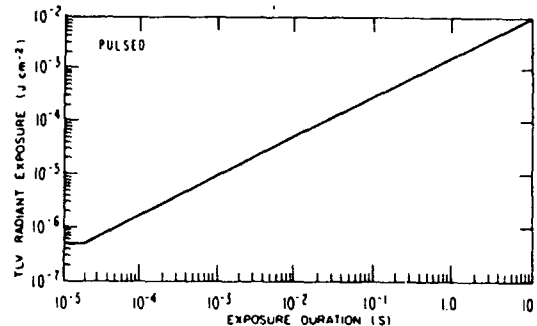


Figure 3a—TLV for intrabeam (direct) viewing of laser beam (400-700 nm).

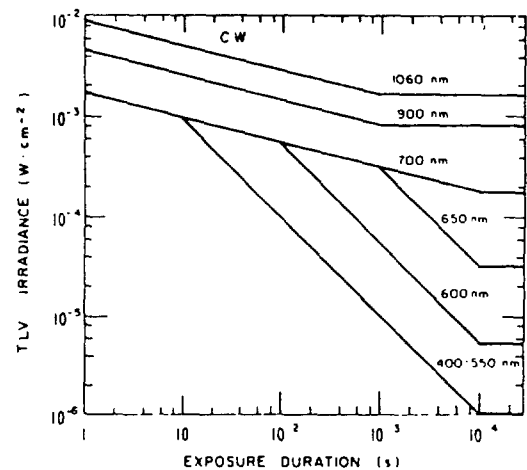


Figure 3b—TLV for intrabeam (direct) viewing of CW laser beam (400-1400 nm).

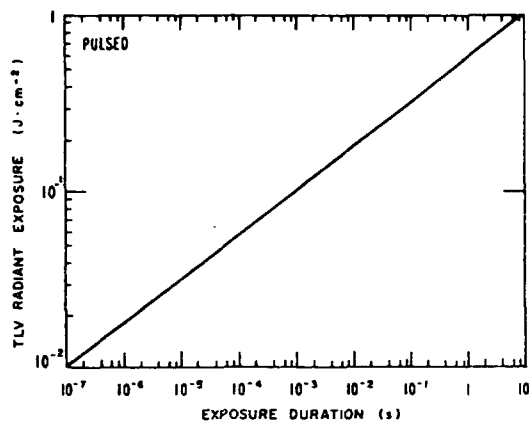


Figure 4a—TLV for laser exposure of skin and eyes for far-infrared radiation (wave-lengths greater than 1.4  $\mu\text{m}$ ).

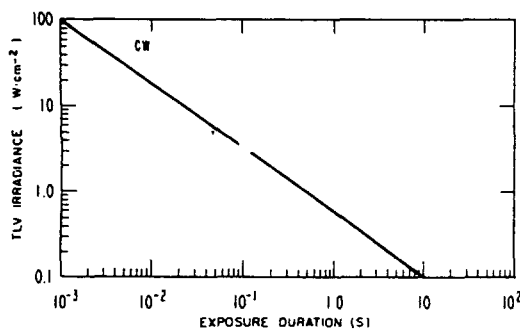


Figure 4b—TLV for CW laser exposure of skin and eyes for far-infrared radiation (wave-lengths greater than 1.4  $\mu\text{m}$ ).

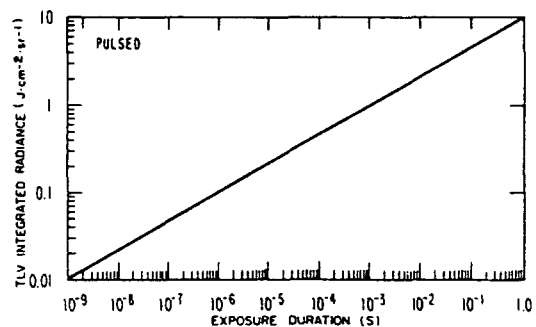


Figure 5a—TLV for extended sources or diffuse reflections of laser radiation (400-700 nm).

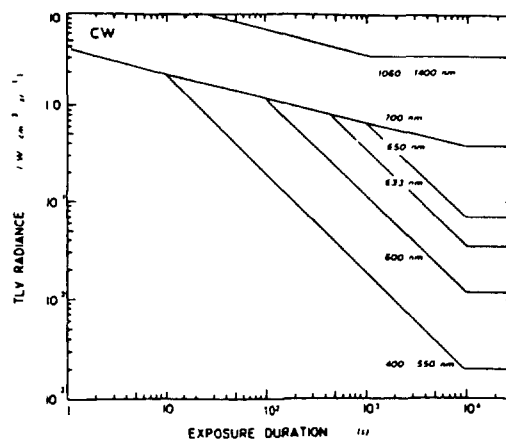


Figure 5b—TLV for extended sources or diffuse reflections of laser radiations (400-1400 nm).

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

| Spectral Region | Wave Length      | Exposure Time, (t) Seconds   | TLV                                 |
|-----------------|------------------|------------------------------|-------------------------------------|
| UVC             | 200 nm to 280 nm | $10^{-9}$ to $3 \times 10^4$ | $3 \text{ mJ} \cdot \text{cm}^{-2}$ |
| 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  $0.56 \text{ t}^{1/4} \text{ J} \cdot \text{cm}^{-2}$   
for  $t \leq 10 \text{ s}$ .

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

$C_A$  - See Fig. 2  
 $C_B = 1$  for  $\lambda = 400$  to  $549 \text{ nm}$ ;  $C_B = 10^{10.015 (\lambda - 550)/\lambda}$  for  $\lambda = 550$  to  $700 \text{ nm}$ .  
 $T_1 = 10 \text{ s}$  for  $\lambda = 400$  to  $549 \text{ nm}$ ;  $T_1 = 10 \times 10^{0.02 (\lambda - 550)/\lambda}$  for  $\lambda = 550$  to  $700 \text{ nm}$ .

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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              | 200 nm to 400 nm                        | $10^{-9}$ to $3 \times 10^4$ | Same as Table 4                                                                |
| Light           | 400 nm to 700 nm                        | $10^{-9}$ to 10              | $10 \sqrt{t} \text{ J} \cdot \text{cm}^{-2} \cdot \text{sr}^{-1}$              |
|                 | 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 $10^4$              | $21 C_A \text{ J} \cdot \text{cm}^{-2} \cdot \text{sr}^{-1}$                   |
|                 | 400 nm to 700 nm                        | $10^4$ to $3 \times 10^4$    | $2.1 C_A t \times 10^{-3} \text{ W} \cdot \text{cm}^{-2} \cdot \text{sr}^{-1}$ |
| IR-A            | 700 nm to 1400 nm                       | $10^{-9}$ to 10              | $10 C_A \sqrt{t} \text{ J} \cdot \text{cm}^{-2} \cdot \text{sr}^{-1}$          |
|                 | 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 $3 \times 10^4$    | $0.64 C_A \text{ W} \cdot \text{cm}^{-2} \cdot \text{sr}^{-1}$                 |
| IR-B & C        | $1.4 \mu\text{m}$ to $10^3 \mu\text{m}$ | $10^{-9}$ to $3 \times 10^4$ | 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 $3 \times 10^4$ | 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 $3 \times 10^4$        | $0.2 C_A \text{ W} \cdot \text{cm}^{-2}$              |
| IR-B & C        | $1.4 \mu\text{m}$ to $10^3 \mu\text{m}$ | $10^{-9}$ to $3 \times 10^4$ | Same as Table 4                                       |

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

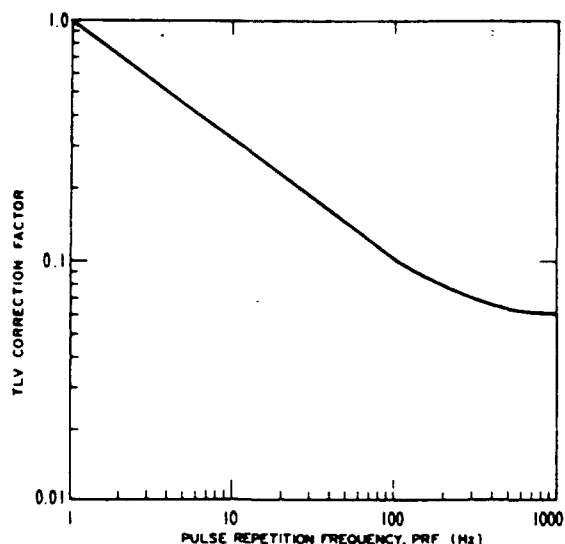


Figure 6 — Multiplicative correction factor for repetitively pulsed lasers having pulse durations less than  $10^{-5}$  second. TLV for a single pulse of the pulse train is multiplied by the above correction factor. Correction factor for PRF greater than 1000 Hz is 0.06.

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

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

## NOISE

These Threshold Limit Values (TLVs) refer to sound pressure levels and durations of exposure that represent conditions under which it is believed that nearly all workers may be repeatedly exposed without adverse effect on their ability to hear and understand normal speech. Prior to 1979, the medical profession had defined hearing impairment as an average hearing threshold level in excess of 25 decibels (ANSI-S3.6-1969) at 500, 1000, and 2000 Hz, and the limits which are given have been established to prevent a hearing loss in excess of this level.<sup>(a)</sup> 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.  $C_i$  indicates the total duration of exposure at a specific noise level, and  $T_i$  indicates the total duration of exposure permitted at that level. All on-the-job noise exposures of 80 dBA or greater shall be used in the above calculations.

<sup>a</sup> In 1979 the American Academy of Ophthalmology and Otolaryngology (AAO) included 3000 Hz in their hearing impairment formula.

**TABLE 8**  
Threshold Limit Values for Noise

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

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

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

### IMPULSIVE OR IMPACT NOISE

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

**TABLE 9**  
Threshold Limit Values Impulsive or Impact Noise

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

\* Decibels peak sound pressure level; re 20  $\mu$ Pa.

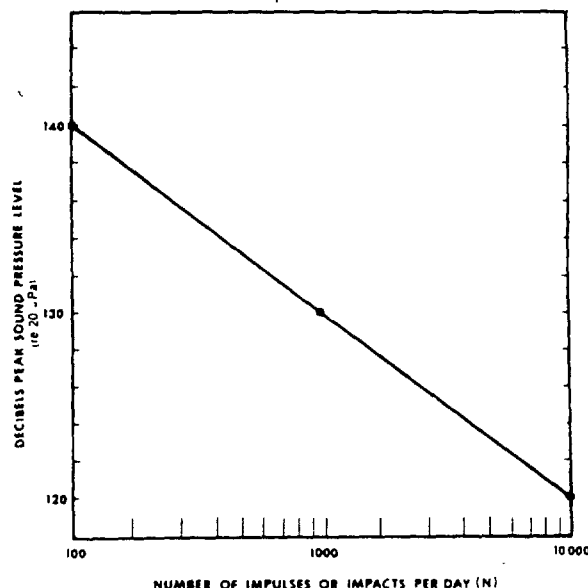


Figure 7 — Threshold Limit Values for Impulse/Impact Noise.

### 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-minute (0.1 hr) period for 3 MHz to 300 GHz, see Figure 8. Between 10 kHz and 3 MHz the average whole body SAR is still limited to 0.4 W/kg, but the plateau at 100 mW/cm<sup>2</sup> was set to protect against shock and burn hazards.

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

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

where:

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

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

where:

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

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

#### Notes:

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

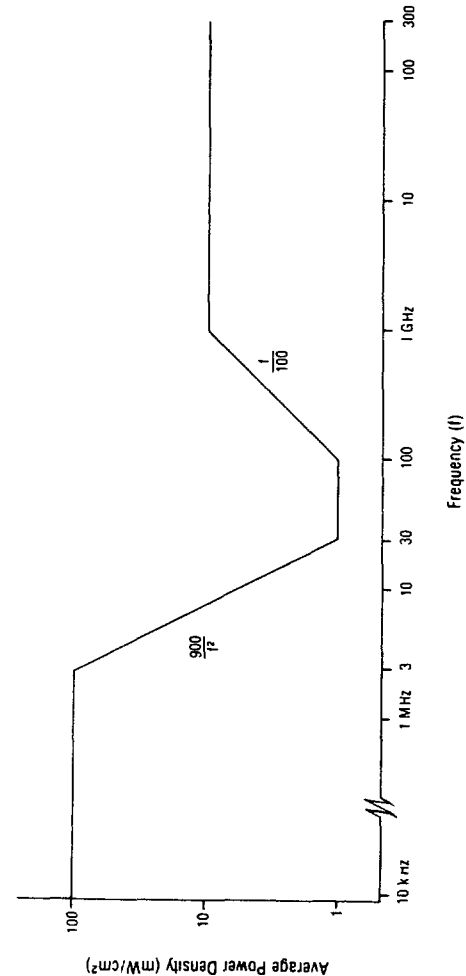


Figure 8 — Threshold Limit Values (TLV) for Radiofrequency/Microwave Radiation in the workplace (whole body SAR less than 0.4 W/kg).

TABLE 10  
Radiofrequency/Microwave Threshold Limit Values

| Frequency           | Power Density<br>(mW/cm <sup>2</sup> ) | Electric Field<br>Strength Squared<br>(V <sup>2</sup> /m <sup>2</sup> ) | Magnetic Field<br>Strength Squared<br>(A <sup>2</sup> /m <sup>2</sup> ) |
|---------------------|----------------------------------------|-------------------------------------------------------------------------|-------------------------------------------------------------------------|
| 10 KHz to 3 MHz     | 100                                    | 377,000                                                                 | 2.65                                                                    |
| 3 MHz to 30 MHz     | 900/f*                                 | 3770 × 900/f <sup>2</sup>                                               | 900/(37.7 × f)                                                          |
| 30 MHz to 100 MHz   | 1                                      | 3770                                                                    | 0.027                                                                   |
| 100 MHz to 1000 MHz | f/100                                  | 3770 × f/100                                                            | f/37.7 × 100                                                            |
| 1 GHz to 300 GHz    | 10                                     | 37,700                                                                  | 0.265                                                                   |

\*f = frequency in MHz.

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## ULTRAVIOLET RADIATION\*

These Threshold Limit Values (TLVs) refer to ultraviolet radiation in the spectral region between 200 and 400 nm and represent conditions under which it is believed that nearly all workers may be repeatedly exposed without adverse effect. These values for exposure of the eye or the skin apply to ultraviolet radiation from arcs, gas and vapor 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.<sup>(1)</sup> These values should be used as guides in the control of exposure to continuous sources where the exposure duration shall not be less than 0.1 sec.

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

### Recommended Values:

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

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

$$E_{\text{eff}} = \sum E_i S_i \Delta\lambda$$

where:

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

$E_i$  = spectral irradiance in W/cm<sup>2</sup>/nm

$S_i$  = relative spectral effectiveness (unitless)

$\Delta\lambda$  = band width in nanometers

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

\* See Laser TLVs.

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**TABLE 11**  
Relative Spectral Effectiveness by Wavelength\*

| Wavelength<br>(nm) | TLV<br>(mJ/cm <sup>2</sup> ) | Relative<br>Spectral<br>Effectiveness<br>$S_{\lambda}$ |
|--------------------|------------------------------|--------------------------------------------------------|
| 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<br>Per Day | Effective Irradiance,<br>$E_{\text{eff}}$ ( $\mu\text{W}/\text{cm}^2$ ) |
|---------------------------------|-------------------------------------------------------------------------|
| 8 hrs                           | 0.1                                                                     |
| 4 hr                            | 0.2                                                                     |
| 2 hrs                           | 0.4                                                                     |
| 1 hr                            | 0.8                                                                     |
| 30 min                          | 1.7                                                                     |
| 15 min                          | 3.3                                                                     |
| 10 min                          | 5                                                                       |
| 5 min                           | 10                                                                      |
| 1 min                           | 50                                                                      |
| 30 sec                          | 100                                                                     |
| 10 sec                          | 300                                                                     |
| 1 sec                           | 3,000                                                                   |
| 0.5 sec                         | 6,000                                                                   |
| 0.1 sec                         | 30,000                                                                  |

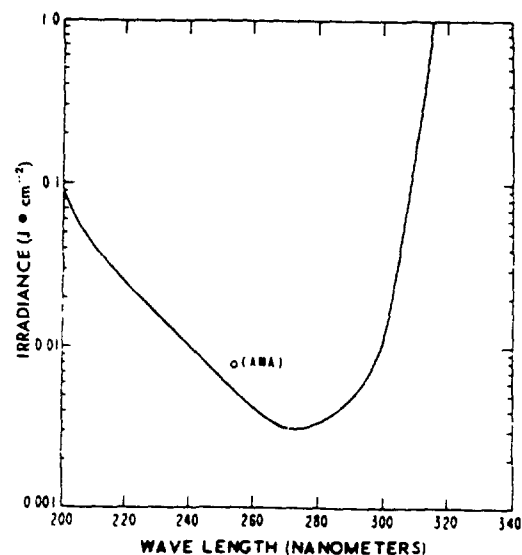


Figure 9—Threshold Limit Values for Ultraviolet Radiation.

The exposure time may also be determined using Table 12 which provides exposure times corresponding to effective irradiances in  $\mu\text{W}/\text{cm}^2$ .

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

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

#### Reference

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

## NOTICE OF INTENDED CHANGES (for 1985-86)

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 the "Adopted" list.

### LASERS

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

#### *Repetitively Pulsed Exposures*

Scanned CW lasers or repetitively pulsed lasers can both produce repetitively pulsed exposure conditions. The TLV for intrabeam viewing which is applicable to a single-pulse exposure (of pulse duration  $t$ ) is modified in this instance by a correction factor determined by the number of pulses in the exposure. First, calculate the number of pulses ( $n$ ) in an expected exposure situation; this is the pulse repetition frequency (PRF in Hz) multiplied by the duration of exposure. The corrected TLV on a per-pulse basis is:

$$TLV = (n^{-4}) \text{ (TLV for single-pulse)} \quad (1)$$

This approach applies only to thermal-injury conditions, i.e., all exposures at wavelengths greater than 700 nm, and for many exposures at shorter wavelengths. For wavelengths less than or equal to 700 nm, the corrected TLV from equation 1 above applies if the average irradiance does not exceed the TLV for continuous exposure. The average irradiance (i.e., the total accumulated exposure for  $nt$  seconds) shall not exceed the radiant exposure given in Table 4 for exposure durations of 10 seconds to  $T_1$ .

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

At wavelengths greater than 1400 nm, for beam cross-sectional areas exceeding 100 cm<sup>2</sup> the TLV for exposure durations exceeding 10 seconds is:

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

where  $A_s$  is the irradiated skin area for 100 to 1000 cm<sup>2</sup>, and the TLV for irradiated skin areas exceeding 1000 cm<sup>2</sup> is 10 mW/cm<sup>2</sup> and for irradiated skin areas less than 100 cm<sup>2</sup> is 100 mW/cm<sup>2</sup>.

## NOTICE OF INTENT TO ESTABLISH THRESHOLD LIMIT VALUES

### LIGHT AND NEAR-INFRARED RADIATION

These Threshold Limit Values (TLVs) 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 ( $L_\lambda$ ) and total irradiance ( $E$ ) of the source as measured at the position(s) of the eye of the worker. Such detailed spectral data of a white light source is generally only required if the luminance of the source exceeds 1 cd cm<sup>-2</sup>. At luminances less than this value the TLV would not be exceeded.

The TLVs are:

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

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

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

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

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  $B_\lambda$  (Table 13) should not exceed:

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

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

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

| Wavelength<br>(nm) | Blue-Light<br>Hazard-Function<br>$B_1$ | Burn Hazard<br>Function<br>$R_1$ |
|--------------------|----------------------------------------|----------------------------------|
| 400                | 0.10                                   | 1.0                              |
| 405                | 0.20                                   | 2.0                              |
| 410                | 0.40                                   | 4.0                              |
| 415                | 0.80                                   | 8.0                              |
| 420                | 0.90                                   | 9.0                              |
| 425                | 0.95                                   | 9.5                              |
| 430                | 0.98                                   | 9.8                              |
| 435                | 1.0                                    | 10.0                             |
| 440                | 1.0                                    | 10.0                             |
| 445                | 0.97                                   | 9.7                              |
| 450                | 0.94                                   | 9.4                              |
| 455                | 0.90                                   | 9.0                              |
| 460                | 0.80                                   | 8.0                              |
| 465                | 0.70                                   | 7.0                              |
| 470                | 0.62                                   | 6.2                              |
| 475                | 0.55                                   | 5.5                              |
| 480                | 0.45                                   | 4.5                              |
| 485                | 0.40                                   | 4.0                              |
| 490                | 0.22                                   | 2.2                              |
| 495                | 0.16                                   | 1.6                              |
| 500-600            | $10^{[(450-\lambda)/50]}$              | 1.0                              |
| 600-700            | 0.001                                  | 1.0                              |
| 700-1049           | 0.001                                  | $10^{[(700-\lambda)/505]}$       |
| 1050-1400          | 0.001                                  | 0.2                              |

The weighted product of  $L_1$  and  $B_1$  is termed  $L$  (blue). For a source radiance  $L$  weighted against the blue-light hazard function ( $L$  (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:

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

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

for the Laser TLV. For a light source subtending an angle  $\alpha$  less than 11 mrd (0.011 radian) the above limits are relaxed such that the spectral irradiance weighted against the blue-light hazard function  $B_1$  should not exceed  $E$  (blue).

$$\sum_{400}^{1400} E_1 \cdot t \cdot B_1 \cdot \Delta\lambda \leq 10 \text{ mJ} \cdot \text{cm}^{-2} \quad (t \leq 10^4 \text{ s}) \quad (5a)$$

$$\sum_{400}^{1400} E_1 \cdot B_1 \cdot \Delta\lambda \leq 1 \text{ } \mu\text{W} \cdot \text{cm}^{-2} \quad (t \geq 10^4 \text{ s}) \quad (5b)$$

For a source where the blue light weighted irradiance  $E$  (blue) exceeds  $1 \text{ } \mu\text{W} \cdot \text{cm}^{-2}$  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  $10 \text{ mW cm}^{-2}$ . For an infrared heat lamp or any near-infrared source where a strong visual stimulus is absent, the near infrared (770-1400 nm) radiance as viewed by the eye should be limited to:

$$\sum_{770}^{1400} L_1 \cdot \Delta\lambda \leq 0.6/\alpha \quad (7)^*$$

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

### AIRBORNE UPPER SONIC AND ULTRASONIC ACOUSTIC RADIATION

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

\* Formulae (1) and (7) are empirical and are not, strictly speaking, dimensionally correct. To make the formulae dimensionally correct, one would have to insert a dimensional correction factor  $k$  in the right hand numerator in each formula. For formula (1) this would be  $k_1 = 1 \text{ W} \cdot \text{rad} \cdot \text{s}^{1/2}/(\text{cm}^2 \cdot \text{sr})$ , 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<br>Third-Octave Band<br>kHz | One-Third Octave — Band Level<br>in dB re 20 $\mu$ Pa |
|----------------------------------------------|-------------------------------------------------------|
| 10                                           | 80                                                    |
| 12.5                                         | 80                                                    |
| 16                                           | 80                                                    |
| 20                                           | 105                                                   |
| 25                                           | 110                                                   |
| 31.5                                         | 115                                                   |
| 40                                           | 115                                                   |
| 50                                           | 115                                                   |

### COLD STRESS

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

#### Introduction

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

TABLE 15  
Progressive Clinical Presentations of Hypothermia\*

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

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

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

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

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

#### Evaluation and Control

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

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

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

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

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

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

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

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

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Notes for Table 17:

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

2. The following is suggested as a guide for estimating wind velocity. If accurate information is not available:

5 mph: light flag moves; 10 mph: light flag fully extended; 15 mph: raises newspaper sheet; 20 mph: blowing and drifting snow.

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

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

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

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

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

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

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

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

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

quency of change shall be determined empirically and will vary individually and according to the type of shoe worn and how much the individual's feet sweat.

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

#### Work-Warming Regimen

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

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

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

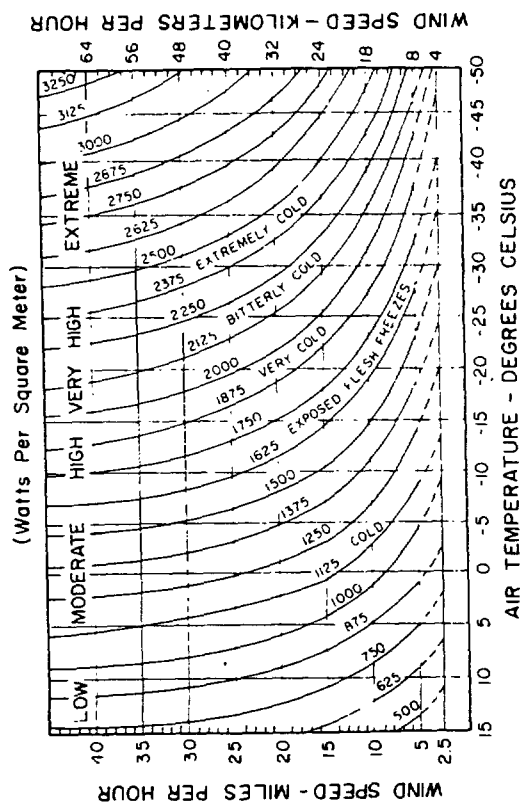


Figure 10 — Wind chill cooling rates. Adapted from Canadian Department of the Environment, Atmospheric Environment Service.

TABLE 18  
Wind Chill Cooling Rate Effects\*

| Wind Chill Rates<br>(Watts/m <sup>2</sup> /hr) | Comments/Effects                                                                                                                               |
|------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------|
| 700                                            | Conditions considered comfortable when dressed for skiing.                                                                                     |
| 1200                                           | Conditions no longer pleasant for outdoor activities on overcast days.                                                                         |
| 1400                                           | Conditions no longer pleasant for outdoor activities on sunny days.                                                                            |
| 1600                                           | Freezing of exposed skin begins for most people depending on the degree of activity and the amount of sunshine.                                |
| 2300                                           | Conditions for outdoor travel such as walking become dangerous. Exposed areas of the face freeze in less than 1 minute for the average person. |
| 2700                                           | Exposed flesh will freeze within half a minute for the average person.                                                                         |

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

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



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

#### *Special Workplace Recommendations*

Special design requirements for refrigerator rooms include the following:

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

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

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

Workplace monitoring is required as follows:

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

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

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

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

### **HAND-ARM (SEGMENTAL) VIBRATION**

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

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

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

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

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

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

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

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

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

$$= \sqrt{(a_{k_1})^2 \frac{T_1}{T} + (a_{k_2})^2 \frac{T_2}{T} + \dots + (a_{k_n})^2 \frac{T_n}{T}}$$

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

$T$  = total daily exposure duration

$a_{k_i}$  =  $i$ th frequency-weighted, rms acceleration component with duration  $T_i$

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

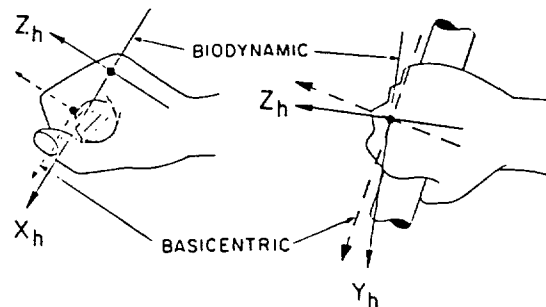


Figure 11—Biodynamic and basicentric coordinate systems for the hand, showing the directions of the acceleration components (ISO 5349).

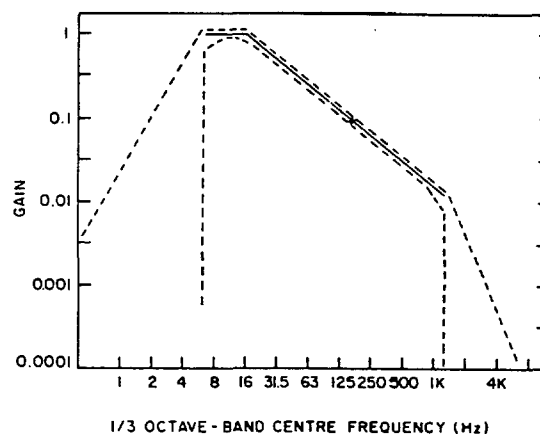


Figure 12—Gain characteristics of the filter network used to frequency-weight acceleration components (continuous line). The filter tolerances (dashed lines) are provisional, and are those contained in ISO 5349.

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

| Total Daily Exposure<br>Duration <sup>a</sup> | Values of the Dominant, <sup>b</sup><br>Frequency-Weighted, rms,<br>Component Acceleration<br>Which Shall not be Exceeded <sup>c</sup> |      |
|-----------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------|------|
|                                               | $a_k, (a_{k_{eq}})$                                                                                                                    |      |
|                                               | m/s <sup>2</sup>                                                                                                                       | g    |
| 4 hours and less than 8                       | 4                                                                                                                                      | 0.40 |
| 2 hours and less than 4                       | 6                                                                                                                                      | 0.61 |
| 1 hour and less than 2                        | 8                                                                                                                                      | 0.81 |
| less than 1 hour                              | 12                                                                                                                                     | 1.22 |

<sup>a</sup> The total time vibration enters the hand per day, whether continuously or intermittently.

<sup>b</sup> Usually one axis of vibration is dominant over the remaining two axes. If one or more vibration axis exceeds the Total Daily Exposure then the TLV has been exceeded.

<sup>c</sup>  $g = 9.81 \text{ m/s}^2$ .

**Notes: Table 19:**

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

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

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**PHYSICAL AGENTS UNDER STUDY**

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

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

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

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

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

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