TLVs®
Threshold Limit Values for Physical Agents in the Work Environment Adopted by ACGIH for 1984-85

AP00055758

1983-84 TLV PHYSICAL AGENTS COMMITTEE

Herbert H. Jones (Retired) —*Chair*
Peter A. Breysse, University of Washington
Thomas Cummings (Retired)
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*
LCDR Richard Johnson, USN
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
COL Robert T. Wangemann, USA
Thomas K. Wilkinson, National Institutes of Health

CONSULTANTS

Gerald V. Coles
Donald E. Wasserman

Any comments or questions regarding these limits, or requests to reprint should be addressed to:

Executive Secretary
American Conference of Governmental Industrial Hygienists
6500 Glenway Ave., Bldg. D-5
Cincinnati, OH 45211; (513) 661-7881

PREFACE

PHYSICAL AGENTS

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

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

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

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

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

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

THRESHOLD LIMIT VALUES

HEAT STRESS

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

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

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

where:

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

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

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

EVALUATION AND CONTROL

I. Measurement of the Environment

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

TABLE 1

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

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

measurement of the environmental factors shall be performed as follows:

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

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

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

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

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

The methodology outlined above is more fully explained by Minard.[3-4]

II. *Work Load Categories*

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

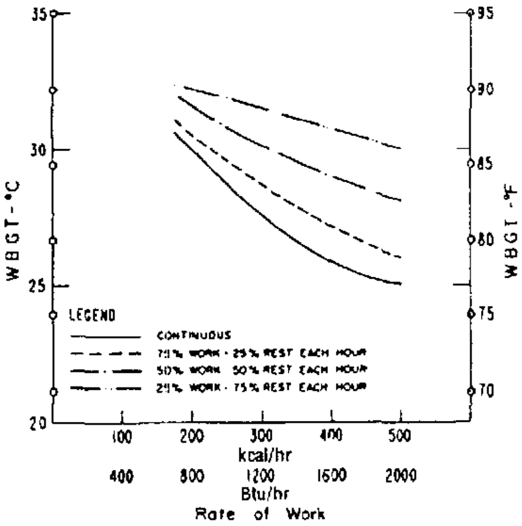

Figure 1 — Permissible Heat Exposure Threshold Limit Value

TABLE 2

Assessment of Work Load[9]

Average values of metabolic rate during different activities.

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

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

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

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

TABLE 3

Activity Examples[4]

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

Sample Calculation

Assembly line work using a heavy hand tool.

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

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

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

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

B. The ranking of the job may be performed either by measuring the worker's metabolic rate while performing his job or by estimating his metabolic rate with the use of Tables 2 and 3. Additional tables available in the literature[5-9] may be utilized also. When this method is used the permissible heat exposure limit can be determined by Figure 1.

III. *Work-Rest Regimen*

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

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

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

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

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

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

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

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

IV. *Water and Salt Supplementation*

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

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

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

V. *Other Considerations*

A. *Clothing:* The permissible heat exposure TLVs are valid for light summer clothing as customarily worn by workers when working under hot environmental conditions. If special cothing is required for performing a particular job and this clothing is heavier or it impedes sweat evaporation or has higher insulation value, the worker's heat tolerance is reduced, and the permissible heat exposure limits indicated in Table 1 and Figure 1 are not applicable. For each job category where special clothing is required, the permissible heat exposure limit shall be established by an expert.

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

References:

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

2. **Dukes-Dobos, F. N. and A. Henschel:** *Development of Permissible Heat Exposure Limits for Occupational Work. ASHRAE Journal 15(9)*:57–62 (Sept. 1973).
3. **Minard, D.:** *Prevention of Heat Casualties in Marine Corps Recruits. Period of 1955–60, with Comparative Incidence Rates and Climatic Heat Stresses in Other Training Categories.* Research Report No. 4, Contract No. MR 005.01-0001.01, Naval Medical Research Institute, Bethesda, MD (Feb. 21, 1961). Published in *Military Medicine 126(44)*:261–272 (April 1961).
4. **Minard, D. and R. L. O'Brien:** *Heat Casualties in the Navy and Marine Corps 1959–1962 with Appendices on the Field Use of the Wet Bulb-Globe Temperature Index.* Research Report No. 7, Contract No. MR 005.01-0001.01, Naval Medical Research Institute, Bethesda, MD (March 12, 1964).
5. **Astrand, Per-Olof and Kaare Rodahl:** *Textbook of Work Physiology.* McGraw-Hill Book Co., New York, San Francisco (1970).
6. Ergonomics Guide to Assessment of Metabolic and Cardiac Costs of Physical Work. *Am. Ind. Hyg. Assoc. J. 32*:560 (1971).
7. *Energy Requirements for Physical Work.* Research Progress Report No. 30, Purdue Farm Cardiac Project, Agricultural Experiment Station, West Lafayette, IN (1961).
8. **Durnin, J. V. G. A. and R. Passmore:** *Energy, Work and Leisure.* Heinemann Educational Books, Ltd., London (1967).
9. **Lehmann, G. E., A. Muller and H. Spitzer:** Der Kalorienbedarf bie Gewerblicher Arbeit. *Arbeitsphysiol. 14*:166 (1950).

IONIZING RADIATION

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

References:

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

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

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

LASERS

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

Limiting Apertures

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

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

Correction Factors A and B (C_A and C_B)

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

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

Repetitively Pulsed Lasers

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

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

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

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

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

where:

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

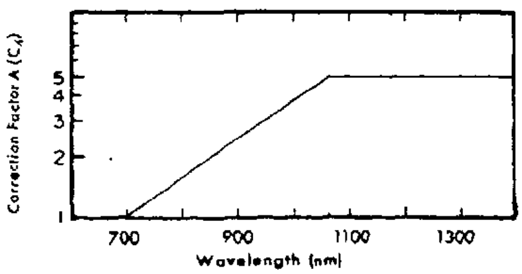

Figure 2 — TLV correction factor for λ = 700 − 1400 nm*

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

TABLE 4

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

Spectral Region	Wave Length	Exposure Time, (t) Seconds	TLV	
UVC	200 nm to 280 nm	10^{-9} to 3×10^{4}	3 mJ • cm^{-2}	*not to exceed $0.56\ t^{1/4}$ J • cm^{-2} for $t \leq 10$ s.
UVB	280 nm to 302 nm	"	3 "	
	303 nm	"	4 "	
	304 nm	"	6 "	
	305 nm	"	10 "	
	306 nm	"	16 "	
	307 nm	"	25 "	
	308 nm	"	40 "	
	309 nm	"	63 "	
	310 nm	"	100 "	
	311 nm	"	160 "	
	312 nm	"	250 "	
	313 nm	"	400 "	
	314 nm	"	630 "	

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

C_A See Fig 2.
$C_B = 1$ for $\lambda = 400$ to 549 nm; $C_B = 10^{[illegible]}$ for $\lambda = 550$ to 700 nm.
$T_1 = 10$ s for $\lambda = 400$ to 549 nm; $T_1 = 10 \times 10^{[illegible]}$ for $\lambda = 550$ to 700 n

TABLE 5

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

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

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

TABLE 6

Threshold Limit Value for Skin Exposure from a Laser Beam

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

$C_A = 1.0$ for $\lambda = 400$–700 nm; see Figure 2 for $\lambda = 700$ to 1400 nm.

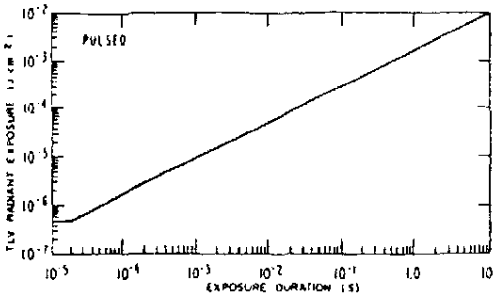

Figure 3a — TLV for intrabeam (direct) viewing of laser beam (400–700 nm).

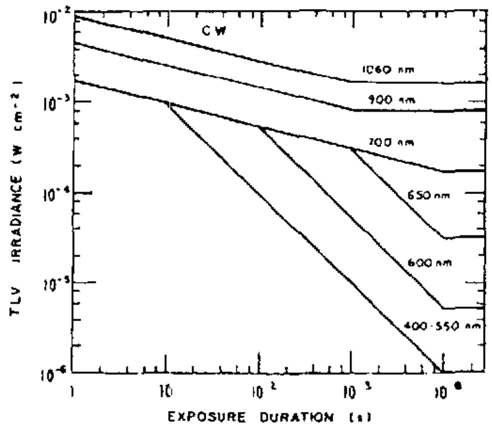

Figure 3b — TLV for intrabeam (direct) viewing of CW laser beam (400–1400 nm)

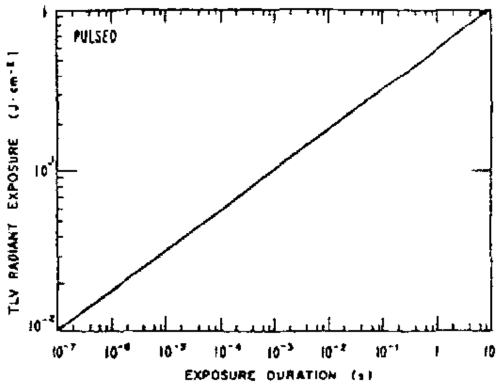

Figure 4a — TLV for laser exposure of skin and eyes for far-infrared radiation (wave-lengths greater than 1.4 μm).

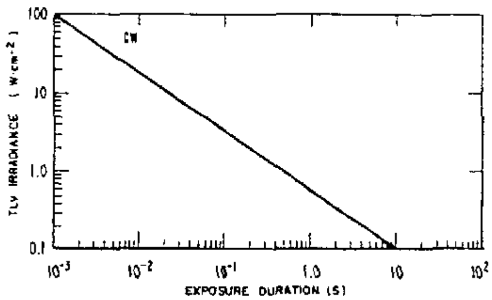

Figure 4b — TLV for CW laser exposure of skin and eyes for far-infrared radiation (wave-lengths greater than 1.4 μm).

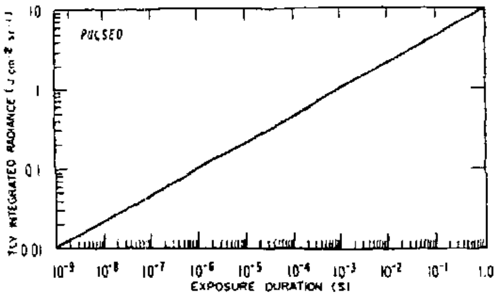

Figure 5a — TLV for extended sources or diffuse reflections of laser radiation (400–700 nm).

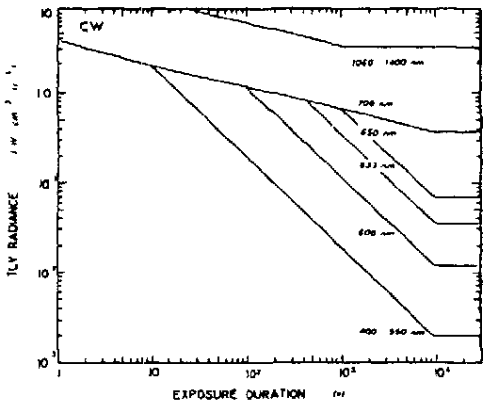

Figure 5b — TLV for extended sources or diffuse reflections of laser radiation (400–1400 nm).

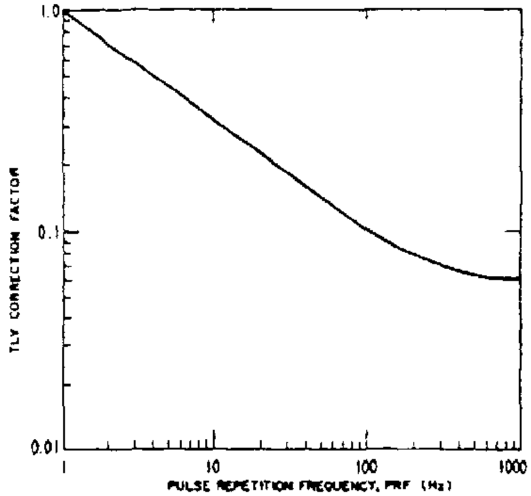

Figure 6 — Multiplicative correction factor for repetitively pulsed lasers having pulse durations less than 10^{-5} second. TLV for a single pulse of the pulse train is multiplied by the above correction factor. Correction factor for PRF greater than 1000 Hz is 0.06.

TABLE 7

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

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

AP00055768

NOISE

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

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

Continuous or Intermittent

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

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

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

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

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

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

Table 8
Threshold Limit Values

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

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

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

IMPULSIVE OR IMPACT NOISE

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

Table 9
Threshold Limit Values Impulsive or Impact Noise

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

**Decibels peak sound pressure level, re 20 μPa

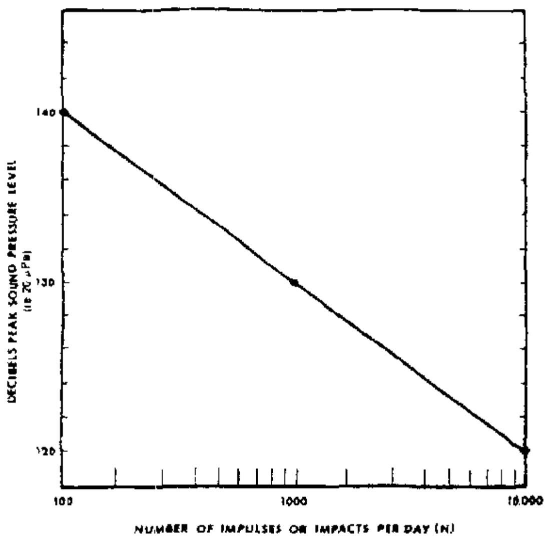

Figure 7 — Threshold Limit Values for Impulse/Impact Noise.

RADIOFREQUENCY/MICROWAVE RADIATION

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

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

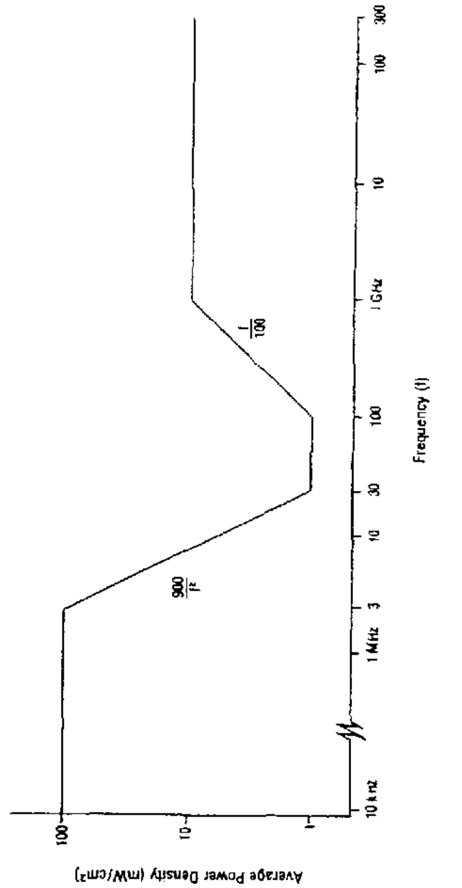

Figure 8 — Threshold Limit Values (TLV) for Radiofrequency/Microwave Radiation in Workplace (Whole Body SAR Less Than 0.4 W/kg).

TABLE 10

Radiofrequency/Microwave Threshold Limit Values

Frequency	Power Density (mW/cm²)	Electric Field Strength Squared (V²/m²)	Magnetic Field Strength Squared (A²/m²)
10 kHz to 3 MHz	100	377,000	2.65
3 MHz to 30 MHz	900/f²*	3770 × 900/f²*	900/(37.7 × f²*)
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

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/cm², if it can be assured that exposed individuals are not in contact with the ground plate.

6. At frequencies below 30 MHz, ungrounded objects such as vehicles, fences, etc., can strongly couple to RF fields. For field strengths near the TLV, shock and burn hazards can exist. Care should be taken to eliminate ungrounded objects, to ground such objects, or use insulated gloves when ungrounded objects must be handled.
7. No measurement should be made within 5 cm of any object.
8. All exposures should be limited to a maximum (peak) electric field intensity of 100 kV/m.

ULTRAVIOLET RADIATION*

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

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

Recommended Values:

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

1. For the near ultraviolet spectral region (320 to 400 nm) total irradiance incident upon the unprotected skin or eye should not exceed 1 mW/cm² for periods greater than 10^3 seconds (approximately 16 minutes) and for exposure times less than 10^3 seconds should not exceed one J/cm².
2. For the actinic ultraviolet spectral region (200—315 nm), radiant exposure incident upon the unprotected skin or eye should not exceed the values given in Table 11 within an 8-hour period.
3. To determine the effective irradiance of a broadband source weighted against the peak of the spectral effectiveness curve (270 nm), the following weighting formula should be used:

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

where:

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

E_λ = spectral irradiance in W/cm²/nm

S_λ = relative spectral effectiveness (unitless)

$\Delta\lambda$ = band width in nanometers

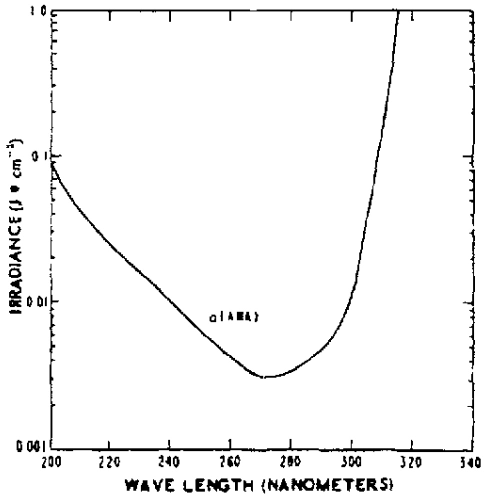

Figure 9 — Threshold Limit Values for Ultraviolet Radiation

*See Laser TLVs.

TABLE 11
Relative Spectral Effectiveness by Wavelength*

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

*See Laser TLVs.

TABLE 12
Permissible Ultraviolet Exposures

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

4. Permissible exposure time in seconds for exposure to actinic ultraviolet radiation incident upon the unprotected skin or eye may be computed by dividing 0.003 J/cm^2 by E_{eff} in W/cm^2. The exposure time may also be determined using Table 12 which provides exposure times corresponding to effective irradiances in $\mu W/cm^2$.
5. All the preceding TLVs for ultraviolet energy apply to sources which subtend an angle less than 80°. Sources which subtend a greater angle need to be measured only over an angle of 80°.

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

Reference:

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

NOTICE OF INTENDED CHANGES
(for 1984–85)

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

NOTICE OF INTENT TO ESTABLISH THRESHOLD LIMIT VALUES

LASERS

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

The IR-B and IR-C exposures to skin surface areas A(cm^2) exceeding 1000 cm^2, the TLV is

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

for areas greater than 10,000 cm^2, the TLV is 10 mW/cm^2.

LIGHT AND NEAR-INFRARED RADIATION

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

AP00055773

nm to 1400 nm and represent conditions under which it is believed that nearly all workers may be exposed without adverse effect. These values should be used as guides in the control of exposure to light and should not be regarded as a fine line between safe and dangerous levels.

Recommended Values:

The Threshold Limit Value for occupational exposure to broad-band light and near-infrared radiation for the eye apply to exposure in any eight-hour workday and require knowledge of the spectral radiance (L_λ) and total irradiance (E) of the source as mea-

TABLE 13

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

Wavelength (nm)	Blue-Light Hazard Function B_λ	Burn Hazard Function R_λ
400	0.10	1.0
405	0.20	2.0
410	0.40	4.0
415	0.80	8.0
420	0.90	9.0
425	0.95	9.5
430	0.98	9.8
435	1.0	10.0
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

sured at the position(s) of the eye of the worker. Such detailed spectral data of a white light source is generally only required if the luminance of the source exceeds 1 cd cm^{-2}. At luminances less than this value the TLV would not be exceeded.

The TLV's are:

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

$$\sum_{400}^{1400} L_\lambda R_\lambda \Delta\lambda \leqq 1/\alpha\, t^{1/4} \qquad (1)^*$$

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

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

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

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

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

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

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

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

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

$$\sum_{400}^{1400} E_\lambda \bullet B_\lambda \bullet \Delta\lambda \leqq 1 \mu\mathrm{W} \bullet \mathrm{cm}^2\ (t \geqq 10^4\ \mathrm{s}) \qquad (5b)$$

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

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

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

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

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

AIRBORNE UPPER SONIC AND ULTRASONIC ACOUSTIC RADIATION

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

*Formulae (1) and (7) are empirical and are not, strictly speaking, dimensionally correct. To make the formulae dimensionally correct, one would have to insert a dimensional correction factor k in the right hand numerator in each formula. For formula (1) this would be k_1 = 1 W • rad • s½/(cm² • sr), and for formula (7) k_2 = 1 W • rad/(cm² • sr).

TABLE 14

Permissible Ultrasound Exposure Levels

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

COLD STRESS

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

Introduction to Cold Stress

Fatal exposures to cold among workmen have almost always resulted from accidental exposures involving failure to escape from low environmental air temperatures or from immersion in low temperature water. The single most important aspect of life-threatening hypothermia is the fall in the deep core temperature of the body. The clinical presentations of victims of hypothermia are shown in Table 15 (taken from Dembert in AFP, January 1982). Workmen should be protected from expoure to cold so that the deep core temperature does not fall below 36°C

TABLE 15

Progressive Clinical Presentations of Hypothermia*

Core Temperature °C	°F	Clinical Signs
37.6	99.6	"Normal" rectal temperature
37	98.6	"Normal" oral temperature
36	96.8	Metabolic rate increases in an attempt to compensate for heat loss
35	95.0	Maximum shivering
34	93.2	Victim conscious and responsive, with normal blood pressure
33	91.4	Severe hypothermia below this temperature
32 } 31 }	89.6 } 87.8 }	Consciousness clouded; blood pressure becomes difficult to obtain; pupils dilated but react to light; shivering ceases
30 } 29 }	86.0 } 84.2 }	Progressive loss of consciousness; muscular rigidity increases; pulse and blood pressure difficult to obtain; respiratory rate decreases
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 } 21 }	71.6 } 69.8 }	Maximum risk of ventricular fibrilation
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.

(96.8°F); lower body temperatures will very likely result in reduced mental alertness, reduction in rational decision making or loss of consciousness with the threat of fatal consequences.

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

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

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

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

TABLE 16

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

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

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

stress factors and the medical condition of the worker.

Evaluation and Control

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

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

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

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

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

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

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

Provisions for additional total body protection is required if work is performed in an environment at or below 4°C (40°F). The workers shall wear cold protec-

TABLE 17

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

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

Notes for Table 17:

1. Schedule applies to moderate to heavy work activity with warm-up breaks of ten (10) minutes in a warm location. For Light-to-Moderate Work (limited physical movement): apply the schedule one step lower. For example, at −30°F with no noticeable wind (Step 4), a worker at a job with little physical movement should have a maximum work period of 40 minutes with 4 breaks in a 4-hour period (Step 5).
2. The following is suggested as a guide for estimating wind velocity. If accurate information is not available:

   5 mph: light flag moves; 10 mph: light flag fully extended; 15 mph: raises newspaper sheet; 20 mph: blowing and drifting snow.
3. If only the Wind Chill Factor is available, a rough rule of thumb for applying it rather than the temperature and wind velocity factors given above would be: 1) special warm-up breaks should be initiated at a wind chill of about 1750 W/m²/hr; 2) All non-emergency work should have ceased at or before a wind chill of 2250 W/m²/hr. In general the warm-up schedule provided above slightly under-compensates for the wind at the warmer temperatures, assuming acclimatization and clothing appropriate for winter work. On the other hand, the chart slightly over-compensates for the absolute temperatures in the colder ranges, since windy conditions rarely prevail at extremely low temperatures.

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

tive clothing appropriate for the level of cold and physical activity:

1. If the air velocity at the job site is increased by wind, draft, or artificial ventilating equipment, the cooling effect of the wind shall be reduced by shielding the work area, or by wearing an easily removable outer windbreak layer garment. Wind chill cooling rates are illustrated in Figure 10 and Table 18.
2. If only light work is involved and if the clothing on the worker may become wet on the job site, the outer layer of the clothing in use may be of a type impermeable to water. With more severe work under such conditions the outer layer should be water repellent, and the outerwear should be changed as it becomes wetted. The outer garments must include provisions for easy ventilation in order to prevent wetting of inner layers by sweat. If work is done at normal temperatures or in a hot environment before entering the cold area, the employee shall make sure that his clothing is not wet as a consequence of sweating. If his clothing is wet, the employee shall change into dry clothes before entering the cold area. The workers shall change socks and any removable felt insoles at regular daily intervals or use vapor barrier boots. The optimal frequency of change shall be determined empirically and will vary individually and according to the type of shoe worn and how much the individual's feet sweat.
3. If extremities, ears, toes and nose, cannot be protected sufficiently to prevent sensation of excessive cold or frostbite by handware, footwear and face masks, these protective items shall be supplied in auxiliary heated versions.
4. If the available clothing does not give adequate protection to prevent hypothermia or frostbite, work shall be modified or suspended until adequate clothing is made available or until weather conditions improve.
5. Workers handling evaporative liquid (gasoline, alcohol or cleaning fluids) at air temperatures below 40°F shall take special precautions to avoid soaking of clothing or gloves with the liquids because of the added danger of cold injury due to evaporative cooling. Special note should be taken of the particularly acute effects of splashes of "cryogenic fluids" or those liquids with a boiling point only just above ambient temperatures.

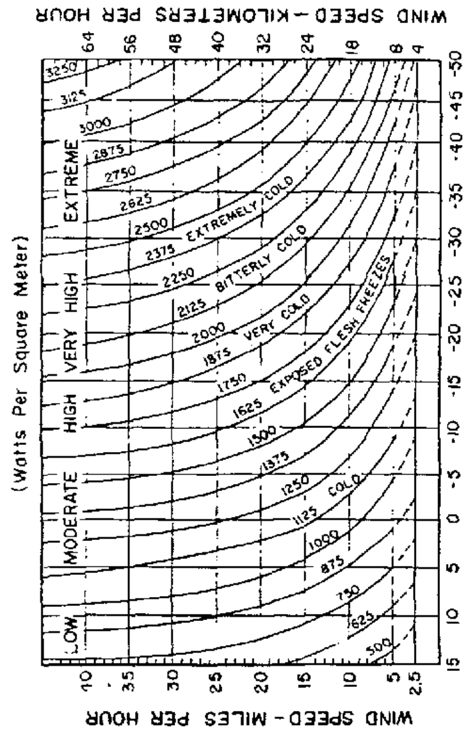

Figure 10 — Wind chill cooling rates. Adapted from Canadian Department of the Environment, Atmospheric Environment Service

TABLE 18

Wind Chill Cooling Rate Effects*

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

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

Work-Warming Regimen

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

the work site to provide caloric intake and fluid volume. The intake of coffee should be limited because of a diuretic and circulatory effect.

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

1. The worker shall be under constant protective observation (buddy system or supervision).
2. The work rate should not be so high as to cause heavy sweating that will result in wet clothing; if heavy work must be done, rest periods must be taken in heated shelters and opportunity for changing into dry clothing shall be provided.
3. New employees shall not be required to work full-time in cold in the first days until they become accustomed to the working conditions and required protective clothing.
4. The weight and bulkiness of clothing shall be included in estimating the required work performance and weights to be lifted by the worker.
5. The work shall be arranged in such a way that sitting still or standing still for long periods is minimized. Unprotected metal chair seats shall not be used. The worker should be protected from drafts to the greatest extent possible.
6. The workers shall be instructed in safety and health procedures. The training program shall include as a minimum instruction in:
   a. Proper rewarming procedures and appropriate first aid treatment.
   b. Proper clothing practices.
   c. Proper eating and drinking habits.
   d. Recognition of impending frostbite.
   e. Recognition signs and symptoms of impending hypothermia or excessive cooling of the body even when shivering does not occur.
   f. Safe work practices.

Special Workplace Recommendations

Special design requirements for refrigerator rooms include the following:

1. In refrigerator rooms, the air velocity should be minimized as much as possible and should not exceed 1 meter/sec (200 fpm) at the job site. This can be achieved by properly designed air distribution systems.

2. Special wind protective clothing shall be provided based upon existing air velocities to which workers are exposed.

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

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

Workplace monitoring is required as follows:

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

Employees shall be excluded from work in cold at −1°C (30°F) or below if they are suffering from diseases or taking medication which interferes with normal body temperature regulation or reduces tolerance to work in cold environments. Workers who are routinely exposed to temperatures below −24°C (−10°F) with wind speeds less than five miles per hour, or air temperatures below −18°C (0°F) with wind speeds above five miles per hour should be medically certified as suitable for such exposures.

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

HAND-ARM (SEGMENTAL) VIBRATION

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

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

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

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

The acceleration of a vibration handle or work piece should be determined in three mutually orthogonal directions at a point close to where vibration enters the hand. The directions shall preferably be those forming the ISO biodynamic coordinate system, but may be a closely related basicentric system with its origin at the interface between the hand and the vibrating surface (see Figure 11) to accommodate different handles or work piece configurations. A small and lightweight transducer shall be mounted so as to record accurately one or more orthogonal components of the source vibration in the frequency range from 5 to 1500 Hz. Each component should be frequency-weighted by a filter network with gain characteristics specified by the ISO for human-response vibration measuring instrumentation, to account for the change in vibration hazard with frequency (see Figure 12).

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

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

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

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

T = total daily exposure duration

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

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

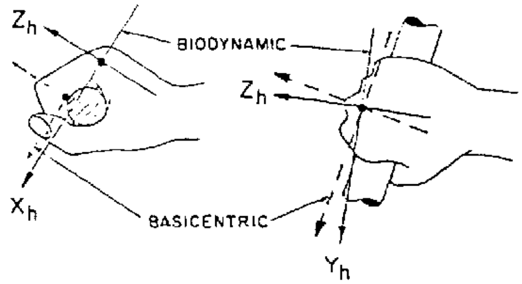

Figure 11 — Biodynamic and basicentric coordinate systems for the hand, showing the directions of the acceleration components (ISO 5349).

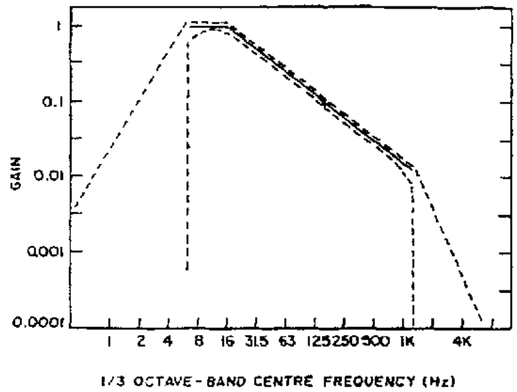

Figure 12 — Gain characteristics of the filter network used to frequency-weight acceleration components (continuous line). The filter tolerances (dashed lines) are provisional, and are those contained in ISO 5349.

AP00055782

TABLE 19

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

Total Daily Exposure Duration*	Values of the Dominant,† Frequency-Weighted, rms, Component Acceleration Which Shall not be exceeded** $a_K \cdot (a_{K_{eq}})$	
	m/s²	g
4 hours and less than 8	4	0.40
2 hours and less than 4	6	0.61
1 hour and less than 2	8	0.81
Less than 1 hour	12	1.22

*The total time vibration enters the hand per day, whether continuously or intermittently.

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

**1 g = 9.81 m/s²

Notes: Table 19:

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

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

References:

1. **Pyykko I.:** Vibration Syndrome, A Review. *Vibration and Work*, pp. 124. O. Dorhonen, Ed. Institute of Occupational Health, Helsinki (1976).
2. *Vibration White Finger in Industry*, W. Taylor and P. L. Pelmear, Eds. Academic Press, London (1975).
3. **NIOSH:** *Proceedings of the International Occupational Hand-Arm Vibration Conference*, D. E. Wasserman and W. Taylor, Eds. OHEW NIOSH Pub. No. 77–170 (1977).
4. **Brammer, J. J.:** Threshold Limit for Hand-Arm Vibration Exposure Throughout the Workday. *Vibration Effects on the Hand and Arm in Industry*, pp. 291–301. A. J. Brammer and W. Taylor, Eds. John Wiley & Sons, New York (1982).
5. **Wasserman, D. E. and W. Taylor:** *Environmental and Occupational Medicine*, Chap. 68, *Occupational Vibration*, pp. 743–749. W. N. Rom, Ed. Little, Brown and Co., Boston (1982).
6. **NIOSH:** *Current Intelligence Bulletin #38: Vibration Syndrome*. DHHS (NIOSH) Pub. No. 83-110 (1983).
7. **NIOSH:** *Vibration Syndrome*. NIOSH Videotape #177 (27 minutes). Cincinnati, OH.

8. **International Organization for Standardization:** *Guide for the Measurement and the Assessment of Human Exposure to Vibration Transmitted to the Hand*. Second DIS 5349. International Organization for Standardization, Geneva (in press, 1983).
9. **International Organization for Standardization:** *Human-Response Vibration Measuring Instrumentation*. Second Draft Proposal DP 8041 ISO/TC 108/SC 3 n 99. International Organization for Standardization, Geneva (unpublished, 1982).

PHYSICAL AGENTS UNDER STUDY

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

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

AP00055784

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

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

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

SILICATES and OTHER DUSTS(m)

Natural graphite [7782-42-5]	2.5 mg/m^3, Respirable dust 5 mg/m^3, Total dust
Soapstone	3 mg/m^3, Respirable dust 6 mg/m^3, Total dust
Talc (containing asbestos fibers)	Use asbestos TLV. However, should not exceed 2 mg/m^3 respirable dust.
Coal dust	If > than 5% quartz, use respirable quartz value.

BNA

Journal

MEETINGS SCHEDULED

June 12-14 — Governor's Safety and Health Conference, Louisville, Ky. (Doug Peek, Ky. Occupational Safety and Health Program, 127 Building, Frankfort, Ky. 40601; tel: (502) 564-6895).

June 13 — Behavioral Sciences in Accident Prevention, Burbank, Calif. (The Training Institute, 616 S. Westmoreland Ave., Los Angeles, Calif. 90005; tel: (213) 385-6461).

June 13 — Employee Right-to-Know Seminar, Toledo, Ohio (Regulatory Resources, Inc., 1946 N. 13th Street, Toledo, Ohio 43624; tel: (419) 255-0008).

June 17-19 — Toxicology Update '85, Baltimore, Md. (Johns Hopkins University School of Medicine, 720 Rutland Ave., Baltimore, Md. 21205; tel: (301) 955-6046).

June 17-21 — Particle Characterization in Technology, Iowa City, Iowa (J.K. Beddow, Center for Particulate Material Processing Sciences, Univ. of Iowa, Iowa City, Iowa 52242; tel: (319) 353-3842).

June 18 — Forklift Safety Training, Burbank, Calif. (The Training Institute, 616 S. Westmoreland Ave., Los Angeles, Calif. 90005; tel: (213) 385-6461).

June 18-19 — Safety/Management, a Behavioral Approach, Chicago, Ill. (National Hazards Control Institute, P.O. Box 667, Easton, Pa. 18044-0667; tel: (215) 258-7045).

June 19 — Worker's Right-to-Know, St. Paul, Minn. (Kathleen Anne, Midwest Center for Occupational Health and Safety, 640 Jackson St., St. Paul, Minn. 55101; tel: (612) 221-3992).

June 20 — Workers' Compensation 1985, Burbank, Calif. (The Training Institute, 616 S. Westmoreland Ave., Los Angeles, Calif. 90005; tel: (213) 385-6461).

June 24-26 — Meeting Your Responsibility for Worker Training and Right to Know, Los Angeles, Calif. (Institute of Safety and Systems Management, University of Southern California, Los Angeles, Calif. 90089-0021; tel: (213) 743-6523/6524).

June 24 — Right-to-Know and OSHA Hazard Communications Training for Trainers, Boston, Mass. (National Hazards Control Institute, P.O. Box 667, Easton, Pa. 18044-0667; tel: (215) 258-7045).

June 27-28 — Stress Management Seminar, Boston, Mass. (National Hazards Control Institute, P.O. Box 667, Easton, Pa. 18044-0667; tel: (215) 258-7045).

July 8-12 — Occupational Respiratory Protection No. 134, New Orleans, La. (Darell A. Bevis, Darell Bevis Associates, Inc., Rt. 2, Box 311, Sterling, Va. 22170; tel: (703) 430-7100).

July 15-18 — Advanced Occupational Respiratory Protection, New Orleans, La. (Darell A. Bevis, Darell Bevis Associates, Inc., Rt. 2, Box 311, Sterling, Va. 22170; tel: (703) 430-7100).

July 15-19 — Occupational Respiratory Protection, Los Angeles, Calif. (Institute of Safety and Systems Management, University of Southern California, Los Angeles, Calif. 90089-0021; tel: (213) 743-6523).

July 16-18 — Managing Safety: Techniques That Work for the Safety Pro, Mt. Pocono, Pa. (Du Pont Company, Professional Development Seminars, Barley Mill Plaza No. 19, Wilmington, Del. 19898; tel: (302) 992-3602).

July 22 — Right-to-Know and OSHA Hazard Communications Training for Trainers, Pittsburgh, Pa. (National Hazards Control Institute, P.O. Box 667, Easton, Pa. 18044-0667; tel: (215) 258-7045).

July 22-26 — Sampling and Evaluating Airborne Asbestos Dust, Los Angeles, Calif. (Institute of Safety and Systems Management, University of Southern California, Los Angeles, Calif. 90089-0021; tel: (213) 743-6523).

July 23-25 — National Fire Research Strategy Conference, Gaithersburg, Md. (National Bureau of Standards, Attn.: Bud Levin, A263 Polymers Bldg., Gaithersburg, Md. 20899; tel.: (301) 921-2721).

0095-3237/85/$0+.50

Coal dust	from:	2 mg/m^3 (respirable dust fraction < 5% quartz).
	TO:	2 mg/m^3 respirable dust fraction[m]

FOOTNOTE:

m) For silicates and other dusts, the values are for dust containing less than 1% quartz in the total dust. For coal dust, the value is for coal dust containing less than 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^3 for respirable quartz. Even where the respirable quartz concentration is less than 0.1 mg/m^3, the level of the major component should not exceed its TLV.

	TWA		STEL	
SUBSTANCE	ppm	mg/m^3	ppm	mg/m^3
Ethylene glycol dinitrate [628-96-6]-Skin	0.05	0.3	--	--
Formaldehyde [50-00-0]	1,A2	1.5,A2	2,A2	3,A2
Lead arsenate [10102-48-4], as $Pb_3(AsO_4)2$	--	0.15	--	--
p-Nitrochlorobenzene [100-00-5]	0.5	0.3	--	--
Nitroglycerin [55-63-0] - Skin	0.05	0.5	--	--
Phenylhydrazine [100-63-0]	5,A2	20,A2	10,A2	45,A2
Propylene glycol dinitrate [6423-43-4] - Skin	0.05	0.3	--	--

DUSTS

SUBSTANCE	TLV
SILICA, SiO2	
Crystalline	
Silica, fused [60676-86-0]	Use quartz value.
Tripoli [1317-95-9]	0.1 mg/m^3 of contained quartz, respirable dust
Amorphous	
Precipitated silica	5 mg/m^3, Respirable dust 10 $mg/m2$, Total dust
Silica gel	5 mg/m^3, Respirable dust 10 mg/m^3, Total dust

AP00055787

STEL VALUES DELETED FROM THE FOLLOWING CHEMICAL SUBSTANCES:

n-Amyl acetate
sec-Amyl acetate
Asphalt (petroleum) fumes
Benzene
Biphenyl
2-Butoxyethanol
sec-Butyl acetate
tert-Butyl acetate
Crotonaldehyde
Cumene
Cyclohexane
Cyclohexanone
Cyclopentadiene
Cyclopentane
Dibutyl phthalate
Diethyl phthalate
2,6-Ditert. butyl-p-cresol
Ethyl acrylate
Ethylbutyl ketone
Ethyl formate
Furfural
Glycidol
Hydroquinone
Indene
Isoamyl acetate
Isobutyl alcohol
Isopropoxyethanol
L.P.G. (Liquified petroleum gas)
Methylal
Methyl n-amyl ketone
Methylcyclohenane
Methylcyclohexanol
Methyl methacrylate
Nonane
Paraffin wax fume
Phenol
Phthalic anhydride
Pindone
Propargyl alcohol
-Propiolactone
Propionic acid
Propoxur
Pyrethrum
Pyridine
Quinone
Rosin core solder pyrolysis products
Rotenone (commercial)
Stoddard solvent
Sucrose
Trimethyl benzene
Turpentine
VM & P naphtha
Warfarin

REVISIONS (con't):

DUSTS

SUBSTANCE		TLV
SILICA, SiO_2		
Amorphous		
Precipitated silica	from:	5 mg/m3, Respirable dust 10 mg/m2, Total dust
	TO:	10 mg/m3, Total dust DELETE RESPIRABLE DUST VALUE
Silica gel	from:	5 mg/m3, Respirable dust 10 mg/m3, Total dust
	TO:	10 mg/m3, Total dust for material with < 1% quartz.(m) DELETE RESPIRABLE DUST VALUE
SILICATES and OTHER DUSTS[m]		
Graphite (natural) (7782-42-5)	from:	2.5 mg/m3, Respirable dust 5 mg/m3, Total dust
	TO:	2.5 mg/m3, Respirable dust DELETE TOTAL DUST VALUE

to prove that employer had knowledge of noise levels to which its employees were exposed (No. 83-921).

COURT CASES

Smith Steel Casting Company, appeal filed by employer, 5/21/85, 5th Cir., No. 85-4346 (RevComm: Nos. 80-2069 and 80-2322, 12 OSHC 1277).

NOTICES OF CONTEST

Abesco, Inc., Wheatridge, Colo., is contesting a serious citation and a $350 penalty for 1910.1001(c)(2)(iii) for failure to protect employees working with asbestos (No. 85-0516).

All Phase Electric & Maintenance, Inc., Tampa, Fla., is contesting a repeat citation and a $180 penalty for 1926.400(h)(1) for failure to equip temporary electrical circuits with approved grounding programs.

The company also is contesting a serious citation and a $360 penalty for 1926.303(c)(3) for failure to guard abrasive wheels (No. 85-0513).

Cargill, Inc., Carpentersville, Ill., is contesting a serious citation and a $630 penalty for Section 5(a)(1) for failure to protect employees from danger of fire and chemical explosion (No. 85-0493).

Larson Woodworking, Inc., Manchester, Conn., is contesting a serious citation and a $150 penalty for 1910.213(d)(1) for failure to guard table saws (No. 85-0495).

Monitor Construction, Portland, Maine, is contesting a serious citation and a $720 penalty for 1926.21(b)(2) for failure to instruct employees in safe installation of a personnel hoist (No. 85-0496).

Pymm Thermometer, Brooklyn, N.Y., is contesting a repeat citation and a $1,440 penalty for 1910.141(g)(2) for failure to prevent employees from consuming food and beverages in areas exposed to toxic materials (No. 85-0514).

Specialty Polymers, Inc., Leominster, Mass., is contesting a serious citation and a $2,250 penalty for 1910.106(h)(7)(i)(*a*) for failure to take precautions to prevent ignition of flammable vapors (No. 85-0497).

Tomahawk Power and Pulp Company, Tomahawk, Wis., is contesting a serious citation and a $720 penalty for 1910.212(a)(1) for failure to guard points of operation on feed rolls, and 1910.212(b)(1) for failure to guard machinery in conformance with standards (No. 85-0491).

Trackmobile, Inc., Lagrange, Ga., is contesting a serious citation and a $300 penalty for 1910.1025(c)(1) for failure to protect employees from exposure to lead (No. 85-0512).

BNA

Full Text

AMERICAN CONFERENCE OF GOVERNMENTAL INDUSTRIAL HYGIENISTS REPORT ON CHEMICAL SUBSTANCES TLV COMMITTEE, MAY 1985

Editor's note: The notation "A2" refers to a substance suspected of having a carcinogenic potential in humans on the basis of limited epidemiological data or on the basis of carcinogenicity in one or more animal species. "STEL" refers to short term exposure limits.

NOTICE OF INTENDED CHANGES FOR 1985-86

REVISIONS:

SUBSTANCE		TWA ppm	TWA mg/m^3	STEL ppm	STEL mg/m^3
Acrylamide [79-06-1]	from:	--	0.3	--	0.6
	TO:	--	0.03,A2	--	--
2-Nitropropane [79-46-9]	from:	10,A2	35,A2	20,A2	70,A2
	TO:	10,A2	35,A2	--	--
1,2,3-Trichloropropane [96-18-4]	from:	50	300	75	450
	TO:	10	60	--	--

AP00055789

REGULATORY TOXICOLOGY AND PHARMACOLOGY 7, 120–127 (1987)

A Scientific Basis for the Risk Assessment of Vinyl Chloride

Developed jointly by the Members of the Committee on the Evaluation of Carcinogenic Substances, National Health Council of The Netherlands[1]

Received October 28, 1986

In July 1984 the Minister of Welfare, Public Health and Culture, representing the Dutch government, sent a request to the Health Council of The Netherlands to advise on the health risks presented by environmental exposure to several carcinogenic substances. One of these substances was vinyl chloride (VC). On the basis of a working document prepared by the National Institute of Public Health and Environmental Hygiene, a committee of the Health Council of The Netherlands prepared a report concerning a health risk assessment of VC which was published in May 1986. A short review is presented of the available data and the considerations that formed the basis for the risk assessment of the carcinogenicity of VC to humans. The advice was based mainly on human data from epidemiological studies of workers occupationally exposed to VC. The committee concludes that continuous exposure to 0.001 mg/m^3 VC corresponds to an additional cancer mortality risk of 10^{-6} per lifetime. The Dutch government considers this additional risk to the general population to be acceptable.

0.4 ppb

Lived, dated, lifetime dose

INTRODUCTION

Man is continuously exposed to a multitude of substances that are present in the environment in which he lives. A number of these substances possess the capability to induce malignant tumors in animals, humans, or both. Some carcinogens are naturally occurring chemicals and exposure to these can hardly be prevented. Others are man-made, emitted into the environment as a consequence of human activities, and thus exposure can, at least in principle, be reduced to an acceptable level. Reduction of the emission of carcinogens can be achieved by governmental regulation. One of the instruments for such regulation is to set upper limits for pollutants in the environ-

[1] Committee on the Evaluation of Carcinogenic Substances, G. M. H. Swaen, Department of Occupational Medicine, University of Limburg, P.O. Box 616 6200 MD Maastricht, The Netherlands (to whom correspondence should be addressed); A. E. M. de Hollander, *Secretary*, Health Council of The Netherlands, The Hague, The Netherlands; R. Kroes, *Chairman of the Committee*, National Institute of Public Health, Bilthoven, The Netherlands; L. den Engelse, Dutch Cancer Institute, Amsterdam, The Netherlands; V. J. Feron, TNO-CIVO, Toxicology and Nutrition Institute, Zeist, The Netherlands; G. J. Mulder, Department of Toxicology, University of Leiden, Leiden, The Netherlands; A. L. M. Verbeek, Department of Social Medicine, University of Nijmegen, Nijmegen, The Netherlands; H. G. Verschuuren, Dow Chemical Europe, Horgen, Switzerland; E. W. Vogel, Department of Radiation Genetics, University of Leiden, Leiden, The Netherlands; A. W. van der Wielen, Ministry of Housing, Physical Planning and Environment, The Hague, The Netherlands.

0273-2300/87 $3.00

AP00055790

ment that may not be exceeded. These limits are in principle based on qualitative and quantitative information about the carcinogenicity of the specific substance. A particular health risk is then defined as an acceptable risk, which is frequently given as one additional cancer death per one million lives after a lifetime of continuous exposure. This risk will further be referred to as the 10^{-6} risk level. The actual low exposure levels that result in this risk cannot be directly determined and must therefore be estimated by extrapolation. The extrapolation of tumor incidence at high exposure levels to the incidence at low exposure levels is one of the principle problems connected with carcinogenic risk assessment. Several mathematical models have been developed to describe the relationship between the level of exposure to a carcinogen and the probability of developing cancer, none of which have been verified in real life circumstances. In principle two types of data can be used in an extrapolation model for carcinogenic risk assessment:

Data on the carcinogenic response in species other than man from experiments in which animals are exposed to high levels of a carcinogen.

Data on the carcinogenic response in humans circumstantially exposed to high levels of a carcinogen, e.g., industrial epidemiologic studies.

Animal studies should be performed in a rigorously controlled environment and thus ideally are not necessarily subject to bias or confounding by extraneous influences. However, the results must be extrapolated from the animal model to man, which introduces a considerable degree of uncertainty.

Epidemiology can only study the health effects of environmental or occupational exposures as they actually occur or have occurred. Moreover, epidemiological studies are more likely to be subject to bias or confounding due to uncontrolled differences between the exposed and nonexposed groups that have not been investigated. In addition epidemiological studies generally lack precision with respect to exposure data. However, they have the advantage of being actual health effects in humans and thus could provide more relevant information for human risk assessment.

Relatively high human exposures to carcinogens may occur in the occupational environment. Epidemiological studies that evaluate the carcinogenic effects of occupational exposure to particular substances may provide the most significant human data for carcinogenic risk assessment (Cook, 1982; Day, 1985). The purpose of this article is to compare two approaches for carcinogenic risk assessment, taking exposure to vinyl chloride (VC) as the exposure of interest. Long-term health effects of occupational exposure to VC have been entensively studied; thus VC is a chemical for which a good comparison can be made between the two approaches. An extensive review on the health hazards of VC has been compiled by the Dutch National Institute of Public Health and Environmental Hygiene (1984). We will first assess the carcinogenic risk of VC on the basis of animal data. Then we will conduct a risk assessment for VC using human data collected by means of epidemiological studies of workers occupationally exposed to VC. In both types of risk assessment a linear dose–response model has been applied. A linear dose–response relationship is supported by the one-hit stochastic model for carcinogenisis, recommended by the American Food and Drug Administration (1971) and by the Dutch National Health Council (1978). The application of a linear dose–response model was also supported by the occupational mortality study conducted by Weber *et al.* (1981). In this study a subanalysis was undertaken in which the VC exposed cohort was subdivided into

TABLE I

INCIDENCES OF ANGIOSARCOMAS IN THE EXPERIMENTS OF MALTONI *et al.* (1981) WITH SPRAGUE-DAWLEY RATS AFTER VARIOUS CONCENTRATIONS OF VC

Expt	VC concentration (ppm)	Incidence of angiosarcomas[a] (%)	Ratio of concentration to incidence
BT 1	250	8.5	29
BT 2	200	10.8	19
BT 2	150	5.0	30
BT 2	100	0.8	125
BT 1	50	3.4	15
BT 9	50	7.9	6
BT 15	25	4.2	6
BT 15	10	2.5	4

[a] Hepatic and extrahepatic angiosarcomas.

several dose groups, in terms of duration of exposure. The results of this subanalysis are indicative for the existence of a linear dose-response relationship between the duration of occupational exposure to VC and the subsequent risk of liver cancer mortality.

The pharmacokinetics of VC in animals and humans are still not understood well enough to incorporate an estimation of the "biologically effective dose," based on a pharmacokinetic model for saturable metabolism, in the dose-response extrapolation model, as was proposed by Gehring *et al.* (1978, 1979). Thus this model was not used in the risk assessment of VC.

RISK ASSESSMENT BASED ON ANIMAL DATA

VC is a procarcinogen which requires metabolic activation through the cytochrome *P*-450 system to exert genotoxic properties (Ivanetich *et al.*, 1977). Mutagenic activity of VC has been demonstrated in both *in vitro* and *in vivo* assays (Bartsch and Montesano, 1975; IARC, 1979). In several animal studies the animals exposed to VC by oral dosing developed more tumors than the control populations (Maltoni *et al.*, 1981; Feron *et al.*, 1981). There can be no doubt that VC is a carcinogen in animals. In several studies with mice and rats a clear dose-response relationship was noted between VC exposure and frequency of angiosarcomas of the liver. A series of studies with Sprague-Dawley rats, performed by Maltoni *et al.* (1981), was selected to form the scientific basis for the risk assessment based on animal data because in these studies VC was applied by means of inhalation and because the results suggested a clear dose-response relationship for angiosarcoma of the liver. The results of the experiments conducted by Maltoni with mice and rats are presented in Table I. A linear, nonthreshold model was applied for risk extrapolation to lower dose levels.

The results of each separate dose experiment were combined by taking the arithmetic mean of the incidence per mg/m^3 of VC applied in each experiment. The arithmetic mean of the ratios was 29, which indicates that in order to increase the incidence of angiosarcoma by 1% an additional concentration 29 ppm VC must be applied,

AP00055792

TABLE 2

RESULTS OF SEVEN OCCUPATIONAL MORTALITY OF WORKERS WITH PAST EXPOSURE TO VC

Reference	Number of exposed workers	Total mortality obs/exp	Total mortality SMR	Cancer mortality obs/exp	Cancer mortality SMR	Liver cancer mortality obs/exp	Liver cancer mortality SMR
Tabershaw and Gaffey, 1974 (United States)	8384	352/467	0.75	79/77	1.10	7/0.5[a]	14.0
Weber *et al.*, 1981 (West Germany)	7021	414/435.7	0.95	94/90.6	1.12	12/0.09	15.2
Fox and Collier, 1977 (United Kingdom)	7717	393/521	0.75	115/127	0.91	4/1.64	2.4
Waxweiler *et al.*, 1976 (United States)	1294	136/126	1.08	35/23.5	1.49	7/0.6	11.5
Ott *et al.*, 1975 (United States)	594	89/100	0.89	20/17.9	1.12	0/0	1.0
Theriault and Allard, 1981 (Canada)	451	59/55	1.07	20/13.5	1.48	8/0.14	57.1
Nicholson and Henneberger, 1984 (United States)	257	80/85.6	0.93	28/19.7	1.42	10/0.42	23.8

[a] Estimated.

which equals 74 mg/m^3 VC. Taking the inverse of this ratio, it can be concluded that an average increase of risk of 0.000135 of angiosarcoma per animal will be the result of an increase of 1 mg/m^3 VC. In order to adapt the experimental situation to human lifetime exposure, two conversion factors were introduced. The animals in the experiment were exposed to VC during 20 hr a week. Human exposure to environmental concentrations of VC occur during 168 hr per week, giving a conversion factor of $168/20 = 8.4$. A second conversion factor was necessary because the rats were not exposed for 143 weeks, the average life span of a rat, but only 52 weeks, giving a conversion factor of $143/52 = 2.75$.

The additional risk of angiosarcoma per mg/m^3 VC concentration for a continuous lifetime exposure for one individual was calculated to be $0.000135 \times 8.4 \times 2.75 = 0.0031$ per mg/m^3 VC. The proposed maximum level for environmental exposure to a particular carcinogen as formulated by the committee is one additional death of cancer per one million lives, giving a lifetime environmental exposure of 0.00032 mg/m^3 VC ($10^{-6}/0.0031$). Thus the committee would consider an environmental exposure to 0.00032 mg/m^3 VC to correspond to a 10^{-6} risk level on the basis of animal data.

RISK ASSESSMENT BASED ON HUMAN DATA

The risk for humans of occupational exposure to VC in industry has been investigated by epidemiologists for groups of workers. All studies used the design of a retrospective cohort study. A group of workers exposed to VC in the past was identified and followed through time to observe the occurrence of cancer in the exposed group.

Based on national statistics an expected number of deaths from a particular disease was calculated, taking into account the age distribution, length of follow-up, and calender period. By dividing the observed number by the expected number, the standardized mortality ratio (SMR) was calculated, which is a measure of the relative risk for a particular cause of death resulting from VC exposure.

Table 2 summarizes the results of the seven largest epidemiological studies on workers exposed to VC. All studies except one indicate an excess mortality from cancer of the liver and in particular of angiosarcoma of the liver (ASL). Other types of cancer also showed a tendency to be increased in incidence, but these increases are not consistent. Total cancer mortality, however, is higher in four out of the seven studies. In order to carry out a risk assessment the results of these epidemiological studies had to be combined to obtain an overall estimate of the relative risk. Prior to combining the results, the studies indicating the highest and the lowest relative risk were omitted, because these studies were considered to be extreme results due to random variation. Three studies were regarded as unbiased estimates of the true standardized mortality ratio. Although the cohort studied by Waxweiler *et al.* (1976) was probably completely included in the study conducted by Tabershaw and Gaffey (1974), both studies were regarded as being independent estimates of the risk of liver cancer after exposure to VC. An alternative analysis after omission of the study conducted by Waxweiler *et al.* revealed similar conclusions. Because the three studies were not of the same size, a weight was given to each study according to its size, based on the standard error of the observed SMR. This weight was the expected number squared divided by the observed number, being the inverse of the variance. The overall SMR was subsequently calculated by dividing the sum of the products of the individual weight and the SMR by the total sum of the weights. The overall SMR for liver cancer mortality obtained in this manner was 13.07, meaning that workers occupationally exposed to VC experienced a 13.07-fold risk of dying of liver cancer. The overall SMR for total cancer mortality is 1.14.

VC concentrations that have occurred at the workplace have varied greatly through time. Barnes (1980) retrospectively estimated these exposures to have been approximately 1000 ppm between 1945 and 1955, between 400 and 500 ppm, from 1955 to 1965; between 300 and 400 from 1966 to 1972; 150 ppm by 1973; and 5 ppm after 1975. Based on these numbers a time-weighted average of 500 ppm for the total exposure period was applied in the risk assessment.

An important aspect of the occupational exposure to VC and its long term health effects as described in the epidemiological studies, is the average duration of exposure. In the report of the large cohort study of VC exposed workers, conducted in the United States by Tabershaw and Gaffey (1974), it was stated that the average duration of VC exposure was 8.7 years. The committee decided that for the risk assessment for the duration of exposure of all three cohorts 8.7 years would be taken. In summary, epidemiological studies of workers occupationally exposed to an average concentration of 500 ppm for an average duration of 8.7 years indicated that these workers experienced a 13-fold risk of liver cancer as compared to the general population. Total cancer mortality was 1.14 times the cancer mortality in the general population.

Extrapolation to Lifetime, Continuous Exposure

A number of steps must be taken before the risks existing for workers exposed to 500 ppm VC for a period of 8.7 years can be converted into estimated risks of lifetime.

articular disease
' follow-up, and
umber, the stan-
'the relative risk

gical studies on
mortality from
SL). Other types
ese increases are
out of the seven
epidemiological
ive risk. Prior to
vest relative risk
e results due to
of the true stan-
et al. (1976) was
aw and Gaffey
'the risk of liver
of the study con-
he three studies
to its size, based
pected number
ance. The over-
ucts of the indi-
ll SMR for liver
vorkers occupa-
ver cancer. The

greatly through
e been approxi-
n, from 1955 to
and 5 ppm after
m for the total

ong term health
ion of exposure.
nducted in the
verage duration
assessment for
n. In summary,
rage concentra-
t these workers
ral population.
ral population.

kers exposed to
risks of lifetime,

continuous exposure to low concentrations. The first step is to convert the intermittent exposure occurring for 8 hr/workday to a continuous lifetime exposure. A workweek usually consists of 40 working hr, whereas a total week consists of 168 hr. Therefore a conversion factor of 168/40 = 4 must be applied. This means that an exposure encountered only at the workplace corresponds to one-fourth of the dose resulting from a continuous exposure to the same concentration.

The second step is the calculation of the conversion factor for the duration of the time-limited VC exposure experienced by the workers to lifetime exposure to ambient air concentrations of VC. The workers studied by epidemiological methods were exposed for an average duration of 8.7 years. Given an average lifetime of 70 years, lifetime exposure results in a 70/8.7 = 8-fold higher dose at equal concentrations. The conversion from 500 ppm during 40 hr per week, for 8.7 years ($500 \times \frac{1}{4} \times \frac{1}{8}$ ppm), leads to a lifetime exposure of 15.6 ppm. An estimated SMR of 13.07 will result from lifetime exposure to 15.6 ppm.

Extrapolation to the 10^{-6} Risk Level

Extrapolating the effects of high exposures to low concentrations can only be done if certain assumptions are made regarding the dose-response relationship. We will assume a linear dose-response relationship. This straight line is defined by two points. Having identified two points on the straight line, it is possible to express this line by means of a mathematical equation: SMR $= 1 + b \times c$ (in which c is the lifetime exposure concentration). Calculate b from the model: SMR $= 1 + b \times c$, if $c = 15.6$ and SMR $= 13.07$. Thus, $b = 0.774$. The dose-response relationship is SMR $= 1 + 0.774 \times c$. The next step is to express the 10^{-6} risk level in terms of an SMR. The accepted risk is expressed as one additional death by cancer per one million lives. In The Netherlands 1484 per million people die of liver cancer (CBS, 1980). One additional case would be 1485, giving an SMR of 1485/1484 = 1.00067.

By means of the above equation for the linear dose-response relationship, the concentration of VC for lifetime exposure can be calculated, resulting in this SMR of 1.00067: SMR $= 1 + b \times c$, $c = 0.0008$ ppm.

A lifetime exposure to a concentration of 0.0008 ppm = 0.002 mg/m^3 VC is expected to lead to an additional 10^{-6} risk. However, it can not be excluded that there are other cancer types related to VC exposure, or perhaps cancer unrelated to specific sites. In fact four of the seven epidemiological studies presented in Table 1 showed elevated cancer mortality.

The overall SMR of the three studies used earlier for cancer mortality is 1.14 for all types of cancer. The lifetime exposure concentration remains 15.6 ppm.

$$\text{SMR} = 1 + b \times c$$

if $c = 15.6$ and SMR $= 1.4$, then

$$b = 0.009, \text{ giving SMR} = 1 + 0.009 \times c.$$

In The Netherlands about 250,000 per one million deaths are due to cancer (CBS, 1980). One additional death will then result in an SMR of

$$250{,}001/250{,}000 = 1.000004$$

$$\text{SMR} = 1 + 0.009 + c$$

AP00055795

thus, $c = 0.000004/0.009 = 0.00044$ ppm $= 0.001$ mg/m^3 VC. It was concluded that a lifetime exposure to 0.001 mg/m^3 VC results in an additional risk to the general population of one death per million lives.

DISCUSSION

Epidemiological data have rarely been applied in environmental risk assessment. Extrapolation on the basis of experimental data as well as epidemiological data suffers from a number of shortcomings. The main uncertainty of a risk assessment based on animal experiments is extrapolation to humans. Differences in body size, metabolism, DNA-repair mechanisms, and immunological responses can lead to differences in response to exposures to carcinogens between animals and humans. As pointed out by many researchers on many occasions, the linear, nonthreshold dose–response model is likely to be an oversimplification of the complex process of carcinogenesis. However, no ideal model incorporating relevant biological mechanisms is yet available, or will be in the near future. Therefore a simple model of a conservative nature was considered to be most appropriate for environmental carcinogen risk assessment of VC.

The main uncertainty of a risk assessment based on human data is the lack of exact information with respect to the actual past exposures. Application of a linear extrapolation to these two different types of data resulted in two different environmental exposure limits, being 0.00032 mg/m^3 VC based on the experimental data and 0.001 mg/m^3 VC based on human data, which differ only by a factor of 3. Because of the existence of extensive human data the committee decided to base its risk assessment on human data. Conseqently, the Dutch Government was advised to take 0.001 mg/m^3 VC as an exposure corresponding to an additional risk of one death per million individals exposed for a lifetime as the scientific basis for the development of air quality standards.

REFERENCES

BARNES, A. W. (1976). Vinyl chloride and the production of PVC. *Proc. R Soc. Med.* **69**, 277–281.

BARTSCH, H., AND MONTESANO, R. (1975). Mutagenic and carciongenic effects of vinyl chloride. *Mutat. Res.* **32**, 93–114.

Centraal Bureau voor de Statistiek (CBS) (1980). *Atlas van de Kankersterfte in Nederland.* Staatsuitgeverij Den Haag.

COOK, R. R. (1982). The role of epidemiology in risk assessment. *Drug Metab. Rev.* **13**, 913–923.

DAY, N. E. (1985). Epidemiological methods for the assessment of human cancer risk. In *Toxicological Risk Assessment* (D. B. Clayson, D. Krewski, and I. Munro, Eds.), Vol. II. CRC Press, Boca Raton, FL.

Dutch National Health Council (Gezondheidsraad) (1978). *Advies Inzake de Beoordeling van Carcinogeniteit van Chemsiche Stoffen.* No. 19. Rijswijk.

FERON, V. J., HENDRIKSEN, C. F. M., SPEEK, A. J., TIL, H. P., AND SPIT, B. J. (1981). Life-span oral toxicity study of vinyl chloride in rats. *Food Cosmet. Toxicol.* **19**, 317–333.

Food and Drug Administration Advisory Committee on Protocols for Safety Evaluation (1971). Panel on carcinogenesis report on cancer testing in the safety evaluation of food additives and pesticides. *Toxicol. Appl. Pharmacol.* **20**, 419–438.

FOX, A. J., AND COLLIER, P. F. (1977). Mortality experience of workers exposed to vinyl chloride monomer in the manufacture of polyvinyl chloride in Great Britain. *Brit. J. Ind. Med.* **34**, 1–10.

GEHRING, P. J., WATANABE, P. G., AND PARK, C. N. (1978). Resolution of dose-response toxicity data for chemicals requiring metabolic activation: Example vinyl chloride. *Toxicol. Appl. Pharmacol.* **44**, 581–591.

GEHRING, P. J., WATANABE, P. G., AND PARK, C. N. (1979). Risk of angiosarcoma in workers exposed to vinyl chloride as predicted from studies in rats. *Toxicol. Appl. Pharmacol.* **49**, 15–21.

HOLMBERG, B., KRONEVI, T., AND WINELL, M. (1976). The pathology of vinyl chloride exposed mice. *Acta Vet Scand.* **17**, 328–342.

HONG, C. B., WINSTON, J. M., THORNBURG, L. P., AND LEE, C. C. (1981). Follow-up study on the carcinogenicity of vinyl chloride and vinylidene chloride in rats and mice. *J. Toxicol. Environ. Health* **7**, 909–924.

IARC (1979). *Monogr. Eval. Carcinogen. Risk Chem. Humans* **19**, 377–348.

IVANETICH, K. M., ARONSON, I., AND KATZ, I. D. (1977). The interaction of vinyl chloride with rat hepatic microsomal cytochrome *P-450 in vitro. Biochem. Biophys. Res. Commun.* **74**, 1411–1418.

MALTONI, C., LEFEMINE, G., CILIBERTI, A., COTTI, G., AND CARETTI, D. (1981). Carcinogenicity bioassays of vinyl chloride monomer: A model of risk assessment on an experimental basis. *Environ. Health Perspect.* **41**, 3–29.

NICHOLSON, W. J., AND HENNEBERGER, P. K. (1984). Trends in cancer mortality among workers in the synthetic polymers industry. *Prog. Clin. Biol. Res.* **141**, 65–78.

OTT, M. G., LANGENER, R. R., AND HOLDER, B. B. (1975). Vinyl chloride exposure in a controlled industrial environment. *Arch. Environ. Health* **30**, 333–339.

State Institute of Public Health and Environmental Hygiene (1984). *Criteriadocument over Vinyl Chloride, Lucht*, 34. Staatsdrukkerij Den Haag.

TABERSHAW, I. R., AND GAFFEY, W. R. (1974). Mortality study of workers in the manufacture of vinyl chloride and its polymers. *J. Occup. Med.* **16**, 509–518.

THERIAULT, G., AND ALLARD, P. (1981). Cancer mortality of a group of Canadian workers exposed to vinylchloride monomers. *J. Occup. Med.* **23**, 671–676.

WAXWEILER, R. J., STRINGER, W., WAGONER, J. K, JONERS, J., FALK, H., AND CARTER, C. (1976). Neoplastic risk among workers exposed to vinyl chloride. *Ann. NY Acad. Sci.* **271**, 40–48.

WEBER, H., REINL, W., AND GREISER, E. (1981). German investigation on morbidity and mortality of workers exposed to vinyl chloride. *Environ. Health Perspect.* **41**, 95–99.

...concluded that
... to the general

... risk assessment.
... suffers
... ased on
... metabo-
... ferences
... pointed
... -response
... nogenesis.
... yet avail-
... ative nature
... assessment

... is the lack of
... ion of a linear
... ferent environ-
... perimental data
... factor of 3. Be-
... ed to base its risk
... as advised to take
... of one death per
... development of

69, 277–281.
... inyl chloride. *Mutat.*
... rland. Staatsuitgeverij
13, 913–923.
... risk. In *Toxicological*
... ess, Boca Raton, FL.
... ling van Carcinogeni-
... 1981). Life-span oral
... ation (1971). Panel on
... nd pesticides. *Toxicol.*
... nyl chloride monomer
... 10.

NSF

National Sanitation Foundation

3475 Plymouth Road
P.O. Box 1468
Ann Arbor, Michigan 48106 U.S.A.
Telephone: 313-769-8010
Telex: 753215 NATSANFND UD

August 29, 1986

Mr. Bert Mason
Air Products
PO Box 538
Allentown, PA 18105

Dear Mr. Mason:

Per your request of Gordon Bellen, I am sending Beren's RVCM study: "Prediction of Vinyl Chloride Monomer Migration from Rigid PVC Pipe."

Also enclosed are the proposed changes of Standard 14 concerning RVCM as submitted to the Council of Public Health Consultants. These changes have since been adopted.

If there are any further questions, please do not hesitate to call me.

Sincerely,

Mae Lynn Thomas
Research Specialist

MLT:gh/8b/7

Enclosures

National Sanitation Foundation

3475 Plymouth Road
P.O. Box 1468
Ann Arbor, Michigan 48106 U.S.A.
Telephone: 313-769-8010
Telex: 753215 NATSANFND UD

MEMORANDUM

TO: Council of Public Health Consultants

FROM: William B. Middendorf, Chairperson

DATE: July 1, 1986

SUBJECT: Proposed Revisions to Standard 14: Plastics Piping Components and Related Materials

Enclosed are proposed revisions to Standard 14: Plastics Piping Components and Related Materials.

This review was conducted by the Joint Committee on Plastics for requirements affecting Item 3.3.2 Residual Vinyl Chloride Monomer (RVCM) and Table 1 Chemical and Physical Analyses.

In the review one Joint Committee member submitted a negative ballot. Staff review of the ballot (copy enclosed) determined it to be a policy issue relating to retesting of products not meeting requirements. This response has been provided to the manufacturer and is enclosed for your review.

The proposed revision involves a change of the Maximum Permissible Level for RVCM from 10 ppm to 2 ppm. Attached is the proposal along with supportive reasons.

This is an important issue. Our goal is to adopt it into Standard 14 as expeditiously as possible. Therefore, immediately following the Council ballot, the proposal will be forwarded to the Board of Trustees for review and adoption.

To help us achieve this goal we have shortened the normal ballot period by two weeks. Please carefully review the proposal and return the yellow copy of your ballot in the envelope provided by July 18, 1986.

mb/13/13

Enclosures: Proposed Revisions
Negative Ballot and Response
Joint Committee Roster
CPHC TC Compilation
Ballot Forms
Return Envelope

PROPOSED REVISIONS

TO

STANDARD 14

FOR

PLASTICS PIPING COMPONENTS AND RELATED MATERIALS

3.3.2 RESIDUAL VINYL CHLORIDE MONOMER: The maximum limit shall be 2 ~~10~~ ppm vinyl chloride monomer ~~Resin or compound used for conversion into~~ IN PVC AND CPVC potable water piping products ~~must produce finished products within the 2-10 ppm RVCM limit.~~ Evaluation of ~~PVC and CPVC~~ THESE piping products shall be conducted according to Appendix A.

psr/1/8

TABLE I

CHEMICAL AND PHYSICAL ANALYSES

Parameter	Maximum Permissible Level mg/L (ppm)
Antimony	0.05
Arsenic	0.05[3]
Barium	1.0[3]
Cadmium	0.01[3]
Chromium	0.05[3]
Lead	0.05[3]
Mercury	0.002[3]
pH	
Phenolic Substances	0.05
Selenium	0.01[3]
Total Dissolved Solids	70.0
Tin	0.05
TTHM	0.1
RVCM*	~~10.0~~ 2.0

*In the finished product ppm (mg/kg).

TASTE AND ODOR EVALUATIONS

Characteristic	Permissible Level
Odor	Cold application 40
	Hot application 60
Taste	Satisfactory

Reason for the Revision of NSF Standard 14 RVCM MPL from 10 to 2 ppm

Reason: Vinyl chloride monomer (VCM) is a known human carcinogen. The EPA has proposed a maximum contaminant level (MCL) for VCM in drinking water of 1.0 ug/L. In response to this proposed regulation NSF must be prepared to do one of two things:

- Test for VCM in extractant water exposed to PVC and CPVC pipe to assure that NSF Listed pipe does not impart VCM to water in excess of the MCL, or

- Determine that the NSF Standard 14 limit of 10 ppm residual vinyl chloride monomer (RVCM) in the product wall is adequate to assure that water in contact with NSF Listed product will not contain VCM at or above the MCL. If it is not, then revise the RVCM limit accordingly.

The preferred choice is to review the RVCM limit and change it if necessary. RVCM measurement procedures are less costly and more precise than VCM measurements. In addition, RVCM in product can be directly controlled in the manufacturing process, VCM in water cannot.

A study was conducted by NSF to reconfirm the RVCM-VCM relationship with PVC and CPVC pipe currently marketed. The data were plotted against a theoretical line (Figure 1). The correlation indicated that the model accurately describes VCM migration from PVC and CPVC products currently marketed.

The relationship between RVCM in the wall of plastics product and VCM in water in contact with the product has been established theoretically and experimentally[1]. This relationship is mathematically defined as:

$$M_{H_2O} = \frac{4}{r} \left(\frac{D}{\pi}\right)^{1/2} [(T + To)^{1/2} - To^{1/2}] M_P$$

Where:

M_{H_2O} = Diffused VCM into water, g/cm^3

r = Radius of product, cm

D = Diffusivity of VCM in PVC = 33×10^{-8} cm^2/day (@ 37° C)

T = Diffusion time period, days

To = Pipe age before start of diffusion time period, days

M_P = Average RVCM concentration in the PVC product wall, g/cm^3

Important assumptions in this model are: That the diffusivity constant (D) is independent of the concentration of RVCM in the pipe wall, and that in terms of relative concentration (RVCM to VCM) and diffusivity the RVCM concentration will remain constant. (In other words, the amount of VCM leaving the pipe is so small in comparison to the RVCM concentration that the depletion of RVCM is negligible). The experimental data show these to be valid assumptions for potable water PVC and CPVC pipe.

A majority of the NSF Listed product has aged 30 days or more from the time of manufacture until it is in service and in contact with drinking water. Figure 2 shows the relationship between RVCM and VCM

---

[1]A. R. Berens and C. A. Daniels, <u>Prediction of Vinyl Chloride Monomer Migrations from Rigid PVC Pipe</u>, Polymer Engineering and Science, Vol. 16, No. 8, August 1976.

for 30 day old product as predicted by the model. The model predicts that product with two ppm RVCM will impart less than one ppb of VCM to water which has been in contact with the product for three days.

Based on these data and its agreement with the model, it is recommended that the limit for RVCM in Standard 14 be changed to two ppm.

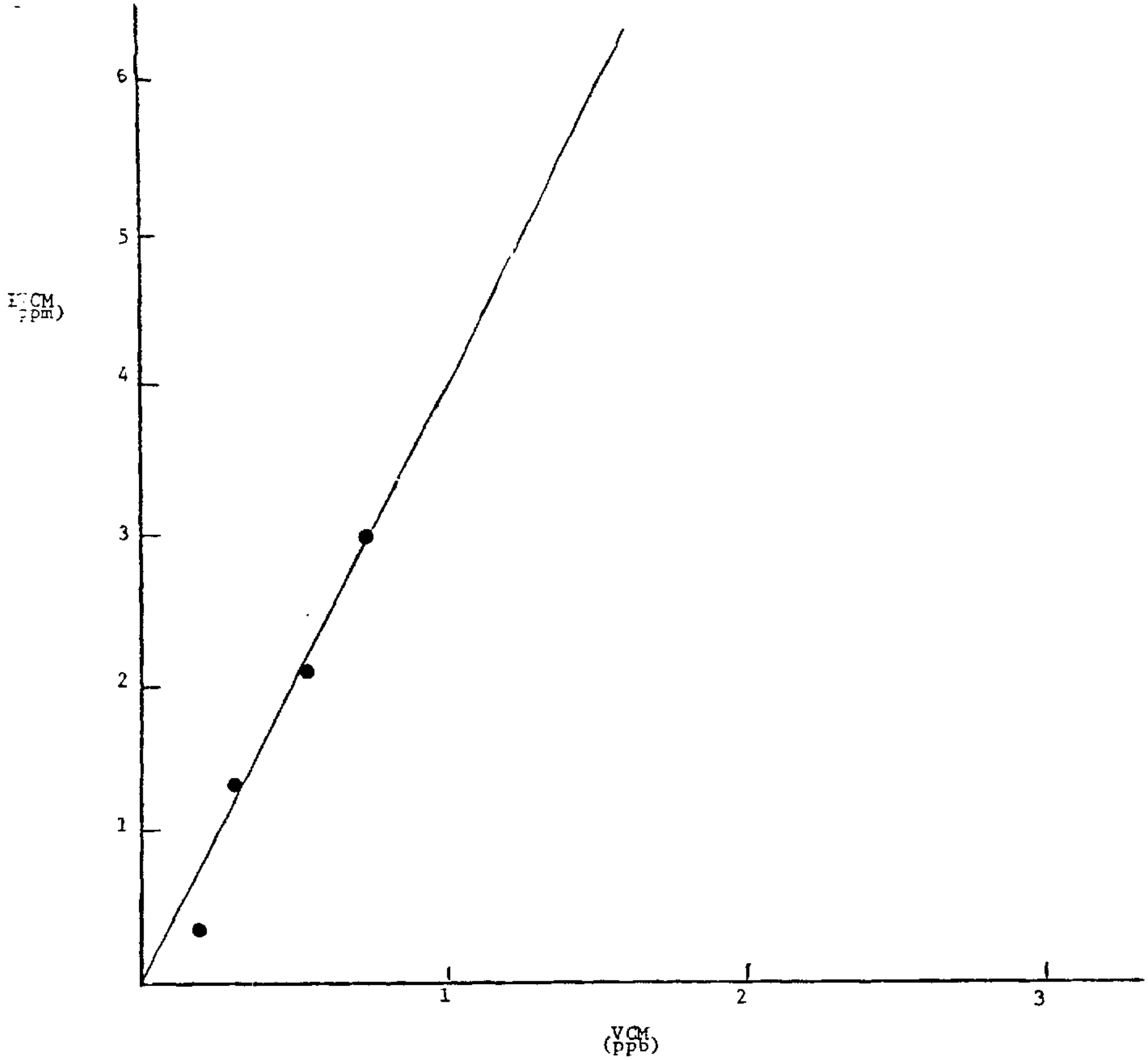

Figure 1

Theoretical line with actual NSF data at 37°C and 3 day exposure.

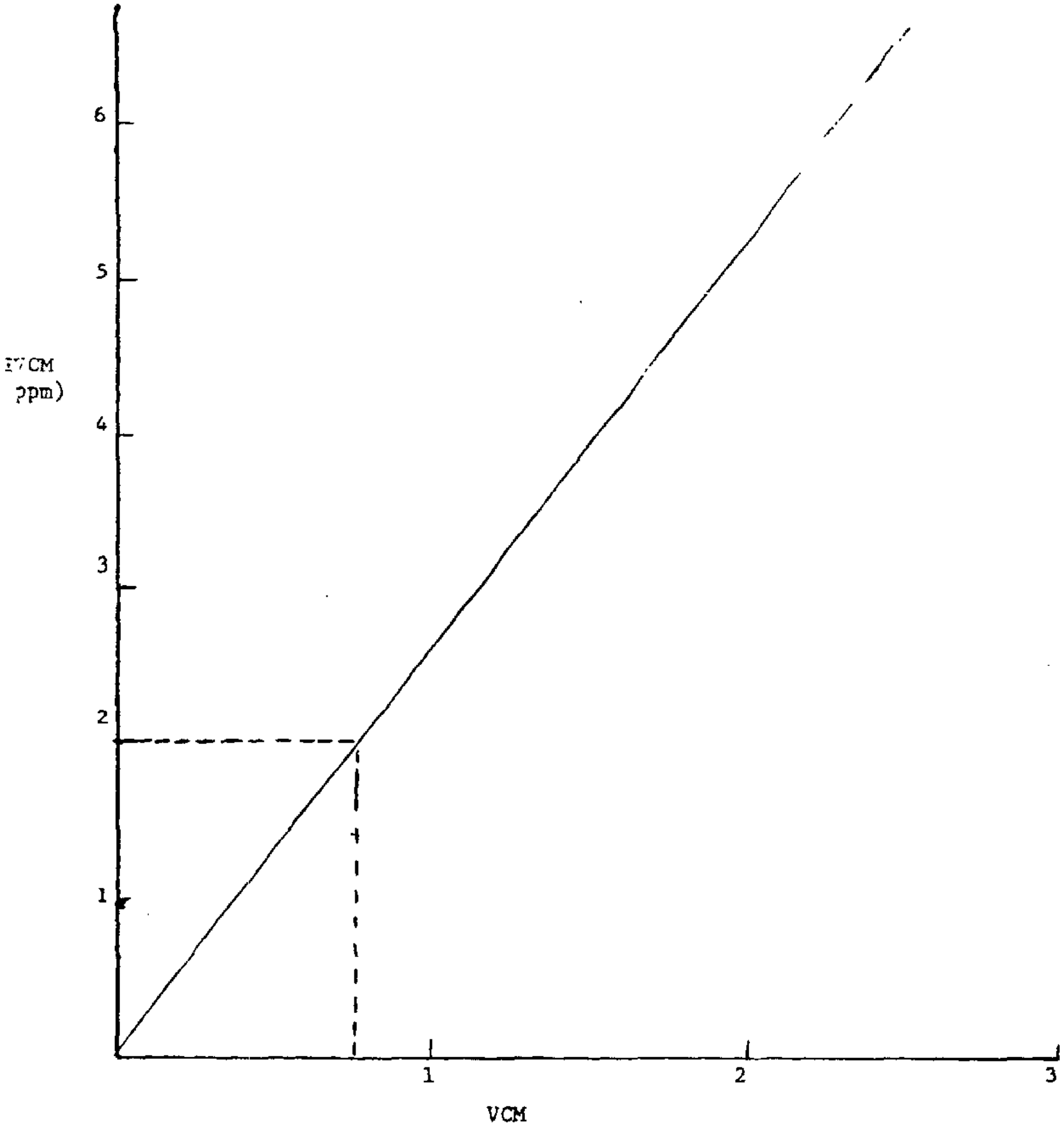

Figure 2

Theoretical relationship between RVCM and VCM at 37°C, an age of 30 days, and exposure of 3 days.