V. BASIS FOR THE RECOMMENDED STANDARD

The NIOSH recommendations for control of hand-arm vibration are based on review and analysis of (1) epidemiologic data derived from field investigations, (2) data from clinical examinations of workers who have used vibrating tools, and (3) data derived from laboratory studies. Chapters III and IV contain reviews of the published data on which this recommended standard is based. HAVS is a chronic, progressive disorder that normally requires months or years of vibration exposure to manifest itself. The quantitative relationship between the magnitude of the vibration exposure and the latency and severity of the disorder is not precisely known.

A. PREVALENCE OF HAVS

Several hundred published epidemiologic and clinical studies have reported the development of HAVS in workers who used vibrating tools. In the epidemiologic studies summarized in Table IV-8, the prevalence of the vascular symptoms of HAVS ranged from 6% to 100%, with more than half of the studies showing a prevalence rate greater than 40%.

Vascular symptoms were reported in 0% to 14% of control workers who did not use vibration-producing tools, with a median prevalence of 4%. In all studies that compared workers who did with those who did not use vibrating tools, the prevalence of vascular symptoms was always higher in the vibration-exposed group.

The epidemiologic and clinical data support the conclusion that healthy workers who use vibrating tools can be protected from developing the disabling effects of HAVS. Protection can be provided by medical monitoring of the workers, engineering controls to reduce the vibration levels produced by the tools, work practices such as limited daily use time of vibrating tools and ergonomic design of tools and work methods, protective clothing and equipment, and worker training programs in the proper handling and maintenance of vibrating tools and in recognition of the early symptoms of HAVS.

B. RATIONALE FOR FREQUENCY-UNWEIGHTED ACCELERATION MEASUREMENTS

The 1/3-octave-band center-frequency weighting of the acceleration has been used previously to express the magnitude of the vibration exposure. However, on the basis of recently published data cited in this section, NIOSH proposes the use of the frequency-unweighted acceleration. The frequency-weighted acceleration concept assumes that the harmful effects of 1/3-octave-band center-frequency accelerations are independent of frequency between 6.3 and 16 Hz but progressively decrease with higher frequencies between 16 and 1,500 Hz. The frequency-unweighted concept assumes that the magnitude of pathophysiologic effects from exposure to vibration are proportional to the acceleration and are frequency independent at all frequencies.

The rationale for frequency weighting is based primarily on the data reported by Miwa [1967, 1968a, 1968b]. From these studies, data were obtained on the levels of acceleration that subjects identified as "tolerance limit" or "unpleasant" sensations when they pressed a hand on a plate that was vibrating at a frequency of 10, 20, 30, 60, 100, or 300 Hz. The acceleration level required for the subjective sensation of "tolerance" and "unpleasant" limits increased progressively with vibration frequency above 16 Hz. These psychophysically derived test data were not analyzed to determine the correlation between frequency and acceleration and the development of clinical or pathophysiologic signs and symptoms of HAVS. The investigators assumed that the subjective degree of "intolerance" would be related to injury.

Data from some epidemiologic and laboratory studies support the concept that the pathophysiologic effects of vibration are mainly frequency independent. Engstrom and Dandanell [1986] and Dandanell and Engstrom [1986] reported vibration acceleration levels and frequencies produced by riveting hammers, bucking bars, rivet shavers, and drills used in the aircraft industry. Most of the acceleration occurred at frequencies above 400 Hz (up to 10,000 Hz). If the ISO [1986] frequency-weighting criteria were applied, most of the higher frequency acceleration would be excluded from the exposure assessment. At frequencies below 400 Hz, the frequency-weighted acceleration was only about 10 m/sec^2 for the riveting hammer and bucking bar. At frequencies between 400 and 10,000 Hz, the frequency-weighted acceleration was 2 m/sec^2 for drills, 5 m/sec^2 for rivet shavers, and 6 to 10 m/sec^2 for riveting hammers and bucking bars. In the absence of frequency weighting, the acceleration was about 100 m/sec^2 at frequencies between 100 and 10,000 Hz.

Riveting hammers and bucking bars were used not more than 15 minutes per working day, with a total daily exposure to vibrating tools of not more than 30 minutes. Of the 288 workers studied, the authors reported that 59 showed finger blanching; of those with more than 10 years of exposure, 50% had HAVS. This prevalence of HAVS far exceeded that expected from exposures at 10 m/sec^2 (frequency weighted) for similar years of exposure and 30 minutes of daily use time. The authors suggested that frequency weighting would have grossly underestimated the health impact of the high-frequency vibration acceleration produced by these vibrating tools.

The data from experimental studies of Nohara et al. [1986] also call into question the assumption that pathophysiologic effects of vibration acceleration are frequency-independent at 16 Hz or below and frequency-dependent above 16 Hz. The test group consisted of five healthy, 25- to 31-year-old males who were nonsmokers and had never used vibrating tools. For the 1-hr test periods at 1- to 4-day intervals, subjects grasped with the left hand a 40-mm- (1.6-in.-) diameter handle that was fixed to a vibrating plate. A constant acceleration of 50 m/sec^2 at randomized frequencies of 30, 60, 120, 240, and 960 Hz was applied to the plate during the test period. For control values, the subjects grasped the handle for 1 hr without vibration.

Physiologic parameters measured were finger blood flow, finger skin temperature, and peripheral motor nerve conduction velocity of the ulnar and median nerves. The data were analyzed by NIOSH and are summarized in Table V-1.

Table V-1.—Changes in physiologic functions after 1-hr exposures to hand-arm vibration at 50 m/sec^2 and frequencies of 30 to 960 Hz*

	Average change in physiologic function				
Frequency (Hz)	Skin temperature °C	Skin temperature °F	Blood flow (ml/100 per min)	MCV† ulnar nerve (m/sec)	MCV median nerve (m/sec)
0§	0.8	1.4	2.0	4.0	3.0
30	0.0	0.0	14.0	3.0**	2.5
60	0.50	0.9	5.0	4.5	1.5**
120	0.60	1.1	5.5	5.5	5.5
240	1.0	1.8	5.0	2.0	1.0
480	1.0	1.8	6.5	1.0	2.5
960	0.20	0.4	2.5**	.0**	1.0

*Based on data from Nohara et al. [1986].
†Motor nerve conduction velocity.
§Without vibration (control).
**After-vibration exposure value is higher than before-vibration value.

The following generalizations can be made based on the data summarized in Table V-1 at a fixed vibration acceleration of 50 m/sec^2:

- None of the physiologic functions measured showed a consistent change in function with vibration frequency.

- Each physiologic function had one or more vibration frequencies at which the physiologic effects were greatest.
- The frequencies at which the maximum effects occurred were different for the various physiologic functions.
- The maximum effects occurred at the lowest exposure frequency (30 Hz) for only one function (peripheral blood flow).
- Maximum change occurred in skin temperature at 240 and 480 Hz, in blood flow at 30 Hz, and in MCV at 120 Hz.
- Grasping the handle for 1 hr without vibration (control) also resulted in changes in the physiologic functions measured.

Nohara et al. [1986] concluded that the peripheral nervous system was affected most at the lower frequencies and the circulatory system was affected significantly at both the lower and the higher frequencies. The data from the study do not support the assumption that frequencies above 16 Hz have progressively less harmful effects than the lower frequencies.

The Nohara study has the following obvious shortcomings: only a small number of subjects were tested, exposures were not repeated at any of the frequencies, and each exposure was limited to 1 hr per test session.

Starck and Pekkarinen [1988] compared the observed and predicted prevalence and latency periods of HAVS among workers using different types of vibrating tools. For operators of chain saws that produce relatively low-frequency and low-impulse vibrations, the predicted and observed values were in good agreement when acceleration was calculated according to the ISO 5349 frequency weighting [ISO 1986]. However, for pedestal grinders, stone workers, shipyard workers, and platers whose tools produced higher impulses and frequencies, the comparisons were less consistent. Frequency weighting of the acceleration in accordance with ISO 5349 did not appear to adequately reflect the harmful effects of tools that produced higher-frequency and higher-impulse vibrations.

The data reported by Hyvarinen et al. [1973] suggest no constant frequency relationships on the threshold acceleration levels required for the production of finger vasospasms in lumberjacks who had a "history of traumatic vasospastic disease." The frequency of 125 Hz was more effective in producing finger vasospasms than higher or lower frequencies. These data suggest that acceleration frequency weightings throughout the entire vibration-frequency spectrum produced by vibrating tools may underestimate the potential risk to workers exposed at higher vibration frequencies. The degree of intimal thickening observed

Table V-2.—Minimum acceleration levels required to produce vibration sensation and vasospasm at various frequencies (rms m/sec^2)*

Frequency (Hz)	Minimum acceleration levels (rms m/sec^2)	
	Sensation	Vasospasms
16.0	0.4	—
31.5	0.8	35
63	0.7	65
125	0.6	70
250	0.9	70
500	1.8	71
2,000	25	80

*Adapted from Brammer [1982a].

in experimental animals subjected to either 30 or 480 Hz at 50 m/sec^2 was comparable [Inaba et al. 1988].

Literature surveys by Brammer [1982a, 1982b] suggest that the minimal vibration acceleration level required to produce a sensation of vibration and a pulseless vasospasm does not consistently increase as the vibration frequency is increased. For the production of vasospasm, the minimum vibration acceleration required did not vary with vibration frequencies between 31.5 and 2,000 Hz, and the minimum vibration acceleration required to produce vibration sensation was independent of frequency between 31.5 and 500 Hz. The minimum vibration acceleration levels required to produce vasospasm and sensation at frequencies of 31.5 to 2,000 Hz are given in Table V-2.

Because of the lack of objective, experimentally derived data, it is not possible to quantitatively convert the health impact of frequency-weighted accelerations to frequency-unweighted accelerations. However, some semiquantitative conversions are possible. Frequency weighting that is done by reducing the input of the higher frequencies (especially above 400 Hz) decreases the total acceleration energy calculated for the vibrating tool. The frequency-weighted acceleration will therefore underestimate the total energy produced by the vibrating system. Frequency-unweighted acceleration calculated over the entire frequency range of the tool will be higher than the frequency-weighted acceleration, but it is a more complete representation of the energy actually produced.

The rationale for recommending the use of frequency-unweighted acceleration is supported by the following information:

1. Data from epidemiologic, clinical, and laboratory studies suggest that the hazardous effects of vibration exposure are frequency independent.

2. Exposure measurements based on frequency-unweighted acceleration have the advantage of simplifying the measurement of vibration acceleration levels of vibrating tools used in industry.

3. The prevalence of HAVS among users of high-frequency (up to 10,000 Hz) vibrating tools was 50% with 10 years of exposure at a frequency-weighted acceleration of about 10 m/sec^2 for about 30 minutes per day of actual tool use [Dandanell and Engstrom 1986]. The frequency-weighted acceleration level grossly underestimated the HAVS-producing effect of the high-frequency vibration exposure.

C. 4-HR-PER-DAY USE TIME

All of the guidelines, standards, and published studies of the harmful effects of vibration exposure accept a time-dose relationship between total vibration exposure and the development of HAVS. The exposure dose can be expressed as m/sec^2 normalized for 4 hr, 8 hr, or any other amount of tool use time per day. If the acceleration level is expressed by all researchers as a time-corrected, 4-hr/day equivalent, comparisons of data from different studies would be easier. The ISO [1986] and ANSI [1986] guidelines recommend using a 4-hr energy equivalent acceleration expressed in m/sec^2. The time (hr/day) and dose (acceleration in m/sec^2) energy equivalents are plotted as a log-log function. In these relationships it is assumed that the daily exposure time required to produce symptoms is inversely proportional to the square of the acceleration and is independent of the vibration characteristics of the tool. Thus if the vibration level is reduced by one-half, the exposure time may be doubled. The total daily time of actual tool use has not usually been reported, but in most industries it does not exceed 4/hr day.

D. DOSE-RESPONSE RELATIONSHIP

HAVS is a chronic disorder with a latency period between the first exposures and the appearance of the first signs and symptoms. The latency period may vary from a few months to several years, depending on many interacting factors. Among the more important factors that determine the clinical profile of HAVS are

1. Vibration acceleration level of the tool

2. Total hours of tool use
3. Pattern of daily tool use
4. Type of tool
5. Vibration profile produced by the tool
6. Ergonomics of tool use
7. Vibration tolerance of the individual
8. Antivibration devices used
9. Tobacco and drug use

As a result of the complexity of the confounding interactions between these factors and the lack of experimentally derived objective data, dose-response relationships cannot be established with precision. Establishing a reliable, valid, minimal dose-risk level would require quantitative data not presently available.

In 1982, Brammer [1982a, 1982b] analyzed the epidemiologic data derived from several reports that contained data on the vibration level produced by the tool used (frequency-weighted m/sec^2), daily tool use (hr/day), and the latency period (years of tool use) preceding the first appearance of vascular symptoms. The analysis was presented as percentiles of population that would be expected to have Stage 1 HAVS as a function of acceleration (frequency-weighted) and years of tool use. Based on extrapolations of these analyses, predictions are that 5% of the workers who use vibrating tools will develop early Stage 1 HAVS in <2 years at 10 m/sec^2, in 5 years at 4 m/sec^2, in 10 years at 2 m/sec^2, and in >20 years at 1 m/sec^2 [Brammer 1982a]. The predicted minimum (frequency-weighted) acceleration (m/sec^2) required to produce Stage 1 HAVS (finger blanching) has been reported to be 1 to 2.9 by Brammer [1982a], 1 to 2.1 by Miura et al. [1959], and <4.7 by Taylor et al. [1977].

The data on the pathogenesis of HAVS are not sufficient to establish an REL that would ensure that healthy workers who use vibrating tools would not develop signs and symptoms of HAVS. Because such an REL cannot be justified on the basis of present dose-response data, the prevention and control of HAVS as an occupationally-induced disorder must be based on other considerations. The approach to controlling HAVS must be through (1) medical monitoring to recognize the first signs and symptoms of developing HAVS, (2) medical removal of workers who exhibit signs and symptoms of Stage 2 HAVS, (3) engineering controls to minimize the level of vibration produced by tools, (4) establishment of a work regimen to reduce exposure to a feasible minimum, (5) ergonomic design of tools and workplaces, (6) training of workers to recognize and report early signs of HAVS, and (7) supervision to ensure optimal tool maintenance and use.

E. CONCLUSIONS

1. Setting a Standard

HAVS is a chronic disorder with a latency period varying from a few months to several years. The latency is believed to depend on many interacting factors, including vibration level produced by the tool, hours of tool use per day, environmental conditions, type and design of the tool, manner in which the tool is held, vibration spectrum produced by the tool, vibration "tolerance" of the worker, and tobacco and drug use by the worker. Because of the complex interactions among these and other factors and the general lack of objective data, it is not currently possible to establish meaningful dose-response relationships. Thus it is not possible to establish a specific REL that will protect all workers against the development of HAVS in all occupational situations. However, the problem of HAVS is too serious and pervasive to delay measures for correcting it. NIOSH has therefore recommended a standard for exposure to hand-arm vibration that includes no specific exposure limit but does include medical monitoring and surveillance, engineering controls, good work practices, use of protective clothing and equipment, worker training programs, and administrative controls such as limited daily use time. If this standard is implemented, it will protect workers who use vibrating tools from the debilitating effects of HAVS. NIOSH also anticipates that this criteria document will stimulate research and development in all areas relating to hand-arm vibration.

2. Use of Frequency-Unweighted Acceleration Measurements

The 1/3-octave-band, center-frequency-weighted acceleration historically has been used to express the magnitude of vibration acceleration levels. The frequency-weighted acceleration concept assumes that the harmful effects of vibration are independent of frequencies between 6.3 and 16 Hz but that the effects progressively decrease with higher frequencies between 16 and 1,500 Hz. On the basis of data published in recent studies, however, NIOSH has concluded that the use of the frequency-unweighted acceleration is a more appropriate means of assessing the health risk to exposed workers. Although the major consensus standards-setting organizations currently recommend the frequency-weighted acceleration levels, NIOSH believes that this measurement grossly underestimates the HAVS-producing effects from tools that vibrate at high frequencies. Exposure measurements based on frequency-unweighted acceleration provide the additional benefit of simplifying the measurements because the acceleration data produced by the accelerometer is frequency unweighted.

3. Medical Monitoring

Medical monitoring of workers who use vibrating hand tools is a vital component of any standard for preventing or controlling HAVS. The medical monitoring program must include (1) a preplacement medical examination with special emphasis on peripheral vascular and neural factors, (2) yearly or more frequent exams designed to detect HAVS in its early and reversible stages, and (3) an open channel of communication with the workers to ensure that the early symptoms are promptly reported.

4. Medical Removal

NIOSH recommends that workers who develop Stage 2 HAVS be removed from further exposure to vibration until they are free of signs and symptoms of HAVS. If HAVS is permitted to progress beyond Stage 2 by the continued use of vibrating tools, the effects can become irreversible. A provision for medical removal could be controversial, but it would provide a powerful incentive for the employer to implement the engineering and administrative controls necessary to reduce the worker's risk of developing HAVS.

VI. OTHER STANDARDS AND RECOMMENDATIONS

Recommendations and guidelines for permissible worker exposure to hand-arm vibration have been formulated or are in the process of being formulated in several countries, including the USSR, Czechoslovakia, Finland, Sweden, Australia, United Kingdom, Japan, Poland, and the United States. Even though the problems of objectively diagnosing HAVS, measuring the input parameters of vibration energy transmitted to the hand and arm, and establishing reliable dose-response relations are formidable, some agreement has been reached in establishing vibration exposure criteria [Griffin 1980]. The major national and international guidelines, standards, and recommendations reviewed in this chapter suggest that vibration exposure be expressed as acceleration in m/sec^2 over the vibration spectrum of 1/3-octave-band center frequencies of 6.3 to 1,250 Hz. The acceleration limit is standardized to 4 hr of actual tool use time per day.

A. DOMESTIC

1. American Conference of Governmental Industrial Hygienists (ACGIH)

The American Conference of Governmental Industrial Hygienists (ACGIH) has established threshold limit values (TLVs®) for physical agents in the work environment, including a TLV for hand-arm (segmental) vibration [ACGIH 1988]. The TLVs "refer to component acceleration levels and duration of exposure . . . that most workers may be exposed [to] repeatedly without progressing to Stage 3 of the Taylor-Pelmear classification for Vibration-induced White Finger (VWF)." Because of the relative lack of controlled, experimentally derived dose-response data, the values are designed to be used as guides in the control of hand-arm vibration exposure and not as absolute tolerance levels. The measurement and calculation of the vibration levels produced by vibrating tools conform to the procedures and instrumentation set forth in the ISO Guideline 5349 [ISO 1986].

The TLV presents, in tabular form, acceleration values that should not be exceeded for various total daily exposure times. The accelerations are frequency-weighted and are expressed in m/sec^2 or g (acceleration due to gravity; 1 g = 9.81 m/sec^2) based on the weighting factors given in the ISO Guideline 5349. The use of the table is relatively straightforward.

Suggestions are provided on how to prevent and control excessive vibration exposure through engineering controls, work practices, administrative procedures, and medical supervision. However, the TLV does not provide guidance for estimating the risk that any group of workers has for developing HAVS within a given period when exposed to various frequency-weighted, component acceleration levels. The only reference to risk estimates is the statement that acute exposure to a frequency-weighted component acceleration three times the TLV will produce an equal level of biologic health effects in 5 to 6 years of exposure (presumably equivalent to Stage 2 on the Taylor-Pelmear classification). The TLV states the following:

> *"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 . . . , and (4) a conscientiously applied medical surveillance program are ALL necessary to rid VWF from the workplace." [ACGIH 1988]*

However, objective and subjective tests that are required for the diagnosis of HAVS, its stage of progression, and medical removal of affected workers are not stressed.

2. American National Standards Institute (ANSI)

The American National Standards Institute's *Guide for the Measurement and Evaluation of Human Exposure to Vibration Transmitted to the Hand* (S3.34-1986) was prepared by a working group of the Acoustical Society of America [ANSI 1986]. This guide is more comprehensive than either the ISO Guideline 5349 or the ACGIH TLV. The major features of the ANSI guide include (1) methods for the measurement of vibration and analysis of the data, and (2) procedures for reporting worker exposure. The goal of this document is to reduce worker exposure to hand-arm vibration and thereby reduce the probability of incurring HAVS. Special features include (1) a discussion of the factors that may influence the probability of occurrence or the severity of the pathophysiologic effects of vibration, (2) a figure (Figure A-1 of Appendix A) that presents daily vibration "exposure zones" (0.5-1 hr/day to 4-8 hr/day) for frequency-weighted rms acceleration (m/sec^2) of 1/3-octave-band center frequencies (6.3 to 1,250 Hz), and (3) a figure (Figure B-1 of Appendix B) that presents total exposure time in years before the first appearance of Taylor-Pelmear Stage 1 symptoms in the 30th, 40th, and 50th percentiles of vibration-exposed worker groups for frequency-weighted acceleration (m/sec^2) and actual exposures of 4 hr/day. The latent periods (Figure B-1 of Appendix B) of the ANSI standard and Figure 2 of ISO Guideline 5349 are identical except for the percentiles of worker groups included (10th to 50th percentile and 30th to 50th percentile, respectively). Both figures base exposure time on number of years until the first appearance of finger blanching (Stage 1 in the Taylor-Pelmear classification). Appendices A and B are stated not to be part of the official standard. Thus the ANSI guide does not include a recommended numerical limit for vibration exposure.

B. INTERNATIONAL

1. International Organization for Standardization (ISO)

The ISO *Guidelines for the Measurement and the Assessment of Human Exposure to Hand-Transmitted Vibration* [ISO 1986] emphasizes standardized procedures for measuring and assessing the levels of hand-arm vibration to which the worker may be exposed when using various vibrating tools. It does not specify the limits for safe exposure in terms of acceleration and daily exposure, nor does it specify the risk of health impairment for different operations and tools. The document presents guidance "to protect the majority of workers against serious health impairment and to assist in the development of hand-operated tools the use of which will reduce the risk of disorders in workers caused by vibration."

The ISO guidelines lack a description of (1) the clinical features of hand-arm vibration syndrome and (2) objective tests and procedures for diagnosing HAVS. Appendix A of the ISO guidelines presents exposure time in years for different percentiles of population groups exposed to various levels of frequency-weighted acceleration (m/sec^2) before finger blanching occurs. However, finger blanching is only one aspect of HAVS and usually is not the first to occur.

The ISO document points out its shortcomings and gives precautions about the use of their guidelines. The procedures and techniques for measurement, assessment, and expression of the vibration intensity are similar to the approaches used in other vibration guidelines. Of special interest is Appendix B, which contains recommendations for medical preventive measures, engineering control methods, administrative approaches, and worker training. Appendices A and B are not part of the official standard; thus the ISO guide does not include a recommended numerical exposure limit.

2. Australian Council of Trade Unions—Victorian Trades Hall Council (ACTU-VTHC)

In 1982, the Australian Council of Trade Unions--Victorian Trades Hall Council (ACTU-VTHC) published the *Health and Safety Bulletin Guidelines on Hazards of Vibration* [ACTU-VTHC 1982]. This publication presents guidelines for whole-body, hand-arm, and low-frequency vibration exposures and is not an official standard. These guidelines take into consideration vibration characteristics, health effects, sources, control methods, medical monitoring, measurements, and prevention. The presentation reviews the state of the art and does not introduce new data or new concepts. Specific details are not given for measuring the vibration of hand-held tools. The acceptable weighted acceleration levels cited (in m/sec^2) are based on the draft version of ISO Guideline 5349 [ISO 1986]. A frequency-weighted, 4-hr exposure limit of 1 m/sec^2 is suggested.

The document provides an informative summary of the measurement of vibration, the effects of vibration on the body, and useful procedures for controlling or preventing the effects. However, the guidelines are directed more to trade union personnel than to those responsible for the measurement, assessment, and control of HAVS.

3. USSR

The 1972 USSR State Standard (Gost Standard 17770-72) is a revision of earlier state standards and sanitary standards [Griffin 1980]. Some of the pertinent features of the standard are as follows:

- Limits are for octave bands of 8 to 2,000 Hz.
- Procedures are given for measuring the vibration levels of tools.
- Hand-held vibrating tools should not weigh more than 22 pounds (10 kg).
- Force exerted on the tool should not exceed 44 pounds (20 kg).
- Preemployment and yearly medical examinations should be given for those working at vibration levels exceeding 20% of the limit.
- Actual maximum daily use time for vibrating tools should be 5 to 6 hr.
- Working environment temperatures should be above 16°C (60°F); rewarming facilities should be required when they are below 16°C.
- Gloves are required to prevent hand cooling.
- If HAVS symptoms occur, the worker should be transferred to work that does not involve vibration exposure.
- Prophylactic measures are suggested (e.g., massage, exercise, vitamins, and ultraviolet radiation).

The limits for vibration exposure for vibrating tools were 2 m/sec^2 at 10 Hz to 50 m/sec^2 at 2,000 Hz. Vibration disease from the use of vibrating tools covered by this standard includes whole-body complaints, as well as peripheral neural, vascular, and muscular symptoms.

4. United Kingdom

The 1987 *British Standard Guide to the Measurement and Evaluation of Human Exposure to Vibration Transmitted to the Hand* [BSI 1987] "provides guidance on measuring and evaluation of hand-transmitted vibration exposure . . . [and] a uniform method for measuring and reporting hand-transmitted vibration." The sections on characterization of hand-transmitted vibration, measurement of hand-transmitted vibration, and characterization of vibration exposure cover the same areas as ANSI 53.34 [ANSI 1986] and ISO Guideline 5349 [ISO 1986] (frequency-weighted acceleration and frequency cutoff at 1,250 Hz 1/3-octave-band center frequencies). Of special interest and value are Appendices A and B, which contain discussions of the dose-effect relationship for hand-transmitted vibration and the guideline for preventive procedures. However, those discussions are included as appendices and are not considered to be part of the standard. No numerical recommended exposure limits are given. A particularly important guideline presented in Appendix A indicates that with "a tool having a frequency weighted vibration magnitude of about 4 m/sec^2 rms, used regularly for 4 hours a day, there may be an occurrence of symptoms of (finger) blanching in about 10% of the vibration-exposed population after about 8 years."

5. Japan

Early Japanese guidelines for permissible vibration exposure levels are derived from both field and laboratory data and are based on the concept of "no complaint" and "complaints by 50%" of the subjects [Miwa 1967, 1968a, 1968b]. The Miwa curves for "tolerance limits" and "unpleasant limits" were frequency dependent with acceleration levels of 17.8 m/sec^2 for "tolerance limit" and 3.2 m/sec^2 for "unpleasant limit" at 20 Hz. In 1970, the Japanese Association of Industrial Health (JAIH) proposed limits for exposure to hand-held vibrating tools. The limits were for "intolerable levels" of vibration for 10 to 400 minutes daily at octave bands of 8 to 250 Hz. Permissible acceleration levels for 400 minutes of exposure ranged from about 1.5 m/sec^2 below 16 Hz to 35 m/sec^2 at 250 Hz; and for 30 minutes of daily exposure, permissible acceleration levels were about 6.5 m/sec^2 below 16 Hz and 100 m/sec^2 at 250 Hz. The limits based on "intolerable levels," although not strictly comparable with ISO guidelines, appear to be higher than the levels recommended in ISO Guideline 5349, which are based on the development of HAVS in vibrating tool users.

6. Czechoslovakia

The official 1977 *Czechoslovakian Guide* evolved through a series of revisions, including the 1967 Hygiene Regulation #33 of the Czechoslovakian Ministry of Health [Griffin 1980]. The 1967 regulation is for vibration octave bands ranging from 8 to 500 Hz, and it is based on 2-hr daily exposures. If daily exposures are less than 2 hr for either uninterrupted or regularly interrupted exposure patterns, correction factors in permissible acceleration levels are provided. The guide states that when exposures exceed these limits, protective measures are required. At frequencies below 20 Hz, permissible acceleration levels are constant but are exposure-time dependent.

The exposure limits in the 1977 Guide are similar to but not exactly the same as those in ISO Guideline 5349. The frequency range and the frequency weighting are similar; however, for exposure time above 1 hr, the vibration limits are lower than those in ISO Guideline 5349.

7. Sweden

Efforts in Sweden to establish guidelines for vibration exposure control have been directed mainly to chain saws and their use [Griffin 1980]. The earlier studies led to the conclusion that vibrations in the frequency range of 50 to 500 Hz were important in producing hand-arm injuries. Two vibration exposure limits were suggested—the "injury risk limit" and the "occupational injury limit." Below the injury risk limit, there was no danger of vibration-induced injury, whereas above the occupational injury limit, there was a definite risk of injury. Between the two limits, the risk of injury depended on exposure duration. Short exposures above the occupational injury limit were considered to have minimal risk [Axelsson 1977]. The SFS 1977: 1166 Labor Safety Board Ordinance concerning the use of vibrating tools has revised directions that became valid January 1, 1987, as Ordinance AFS1986:7, "Vibration from Hand-Held Tools" [Danielson 1986]. The manufacturers, suppliers, and purchasers of Swedish equipment are all held responsible for ensuring that the equipment is constructed to produce the least possible amount of vibration. The worker must be informed of the risks of using vibrating tools, and medical examinations must be furnished at no cost to the workers.

In 1973, the Swedish Board of Occupational Safety and Health set a limit of 50 N as the maximum permissible vibration force. Studies by Axelsson [1977] indicated that a 50-N force measured in a laboratory would correspond to 90 to 100 m/sec^2 rms measured on chain saws held by an operator (this equivalent may change with the grip force applied by the operator); 90 m/sec^2 is the 1- to 2-hr exposure at 500 Hz given in ISO Guideline 5349.

8. Poland

In 1986, Poland published proposed maximum permissible intensity values for hand-arm vibration exposures [Biuletyn Zeszyt 1986]. In general, the document followed the draft version of ISO Guideline 5349 [ISO 1986]. The measurement of vibration and the analysis procedure follow the ISO guidelines. The Polish guidelines are based on 8 hr of daily use of the vibrating tools.

The maximum permissible acceleration levels at various vibration frequencies for an 8-hr day of tool use are presented. For 1/3-octave-band center frequencies, the permissible acceleration levels in m/sec^2 are listed as 1 m/sec^2 at 20 Hz, 2 m/sec^2 at 40 Hz, 4 m/sec^2 at 80 Hz, 8 m/sec^2 at 160 Hz, 16 m/sec^2 at 320 Hz, 32 m/sec^2 at 640 Hz, and 50 m/sec^2 at 1,000 Hz. This represents another method of vibration frequency weighting of acceleration level. For the frequency range of 5.6 to 1,400 Hz, the frequency-weighted maximum permissible acceleration level for an 8-hr daily tool use is 1.4 m/sec^2. For a 4-hr tool use, it would be 2.8 m/sec^2. In Table 2 of the Polish document, correction factors are listed for the actual use time in each hr that is less than 60 minutes.

The document does not include a discussion of health effects, diagnosis, treatment, or control procedures.