Research/Study

Hand/Arm Vibration Syndrome (HAVS)

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Hand-Arm Vibration Standards: The New ANSI S2.70 Standard

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INTRODUCTION: The Problem

There are some 1.5-2 million U.S. workers, and millions more worldwide, who are regularly exposed to Hand-Arm Vibration (HAV) (1,2). For the most part, these workers regularly use pneumatic, hydraulic, electrical, or gasoline-powered hand tools as part of their jobs. First described in the U.S. in 1918 (3,4), regular HAV exposures have been shown to be inextricably, medically linked to an irreversible, non-curable medical condition of the hands originally called Raynaud's Phenomenon, later called Vibration White Finger, and now known as Hand-Arm Vibration Syndrome (HAVS) (1,2,5).

HAVS is characterized initially by tingling and/or numbness in one or more fingers in either or both hands. With increasing and prolonged HAV exposure, usually in the presence of cold temperatures, blanching (whitening) attacks of one or more or the HAV exposed finger(s) begins. These discrete attacks usually last five to fifteen minutes. As the HAV exposures continue, the number and frequency of HAVS attacks both progressively increase: the exposed worker next becomes progressively debilitated and can no longer work. The prognosis can even worsen in some instances, since one or more fingers may become gangrenous, and amputation may be required (2).

As a rule, even if a worker is removed from a vibration related job, the HAVS problem does not go away, remaining even in the absence of vibration exposure. HAVS attacks continue, now triggered solely by cold temperatures.

In the U.S. alone, typical prevalence of HAVS can be as high as 50% of a HAV exposed work force, with white-finger attacks beginning as early as one to two years after the start of HAV exposures (called "blanching latency period") (1,6). Medical professionals dealing with HAVS usually use an internationally recognized evaluation criterion called "The Stockholm Scale" to evaluate the severity of HAVS in one or both hands. Current HAVS medical treatment is palliative and does not cure the disease (2). Note that HAVS is not Carpal Tunnel Syndrome

(CTS). Prevention is the keyword if we are to minimize the risk of workers acquiring HAVS. Prevention is multifaceted and includes the following basic elements including the need for and use of appropriate HAV workplace standard(s) (1,2).

Use only anti-vibration/ergonomically designed power tools (whenever and wherever possible) that meet or exceed appropriate HAV standard(s). A description follows.

Use only certified full-finger protection anti-vibration gloves which meet or exceed A/V glove standard ISO 10819 (7).

Use HAV-prevention work practices which include the following: Keep fingers and hands warm and dry at all times; do not smoke, because nicotine, cold temperatures, and vibration are all blood vessel vasoconstrictors; let the tool do the work: grasp the tool as lightly as possible consistent with safe work practices; take vibration rest breaks, nominally ten minutes per continuous vibration work hour; keep the tools properly maintained; operate tools at reduced speed if possible.

Be aware that ergonomically designed power tools alone or certified A/V gloves alone will not necessarily reduce exposure to mandated levels. A combination of all prevention methods will yield the best results.

Immediately seek medical help if signs and symptoms of HAVS occur.

HAND-ARM VIBRATION MEASUREMENT BASICS (2,8,9,10)

A Must Know: Virtually all HAV health/safety standards require vibration measurements to be performed. During the late 1970's, the International Standards Organization (ISO, Geneva) produced one of the first accepted HAV standards, ISO 5349 (11). ISO 5349 provided a measurement template for all other standards to follow, thus there has been great uniformity and international acceptance as to how HAV measurements are to be performed. Here are some important basics followed by a brief discussion of the HAV health/safety standards used in the U.S:

By definition, vibration is called a "vector quantity", which simply means vibration motion has both a direction and a magnitude or intensity.

In all Hand-Arm (and Whole-Body) vibration work the universally accepted vibration magnitude (or intensity) quantity measured and/or evaluated is "acceleration," in particular, root-mean-squared [rms] acceleration. Acceleration is measured in gravitation 'g' units in the U.S. Elsewhere, it is expressed as 'meters/sec/sec', where 1g = 9.81 m/sec/sec. The HAV frequency bandwith range for most power tools is nominally 5 Hz - 1400 Hz.

To classically define vibration at any one point normally takes an astounding six mutually perpendicular simultaneous vibration acceleration measurements. These measurements consist of three motions which move up-down, side-to-side, and front-to-back (called "linear motions" because they move in a line) and three twisting or "rotational movements" called pitch, yaw, and roll. To simplify human vibration measurements, the three rotational motions are not made, thus, only the three linear acceleration measurements are simultaneously obtained and each motion direction is evaluated.

Universally, each of the three simultaneous (triaxal) HAV measurement directions has a specific designation: acceleration motion parallel to the long bones of the forearm is designated as the z axis acceleration direction; motion moving back and forth across the knuckles of the hand is designated the y axis acceleration direction; and motion moving into and out of the palm is designated the x axis acceleration direction.

HAV measurements are simultaneously made using three lightweight transducers called accelerometers. Each accelerometer is mounted mutually perpendicular on a single lightweight metal cube. This cube is then mounted to a device such as an adjustable diameter auto hose clamp. Finally, this combination of clamp, cube and three accelerometers is tightly clamped to the power tool handle being tested, with the mounting position of the test device located very close to where the tool is grasped by the tool operator.

If two hands are used to grasp and operate the tool, then (optimally) two test devices are needed, and will be positioned close to where each hand grasps and operated the tool. Each accelerometer must be individually and appropriately calibrated. Cables leading from each accelerometer/transducer/axis are plugged into portable electronic equipment, which simultaneously enables each accelerometer to capture each acceleration signal (providing an ISO-HAV weighting function) and process, store and analyze each vibration axis signal separately. Finally, the vibration axis results can be individually displayed, or mathematically combined into a single, total ISO weighted rms acceleration "sum value," to determine if a given HAV standard has or has not been exceeded.

In certain instances, control engineers trying to eliminate specific workplace vibration hazards may employ a "1/3 Octave Band Fourier vibration spectrum analysis" using these HAV measurements, to enhance the understanding of vibration data. Usually the total ISO weighted rms sum value is easily derived from the spectrum analysis.

U.S. HAND-ARM VIBRATION HEALTH AND SAFETY STANDARDS

ISO 5349 provides an excellent measurement template, but since ISO 5349 does not prescribe daily acceptable HAV dose values, virtually all other standards (including all U.S. standards) use this same HAV data collection/analysis method, but differ as to the interpretation of the analyzed HAV data.

The First HAV Standard was published and promulgated in 1984 (to the present) by the American Conference of Government Industrial Hygienists (ACGIH, Cincinnati, OH)(12). AACGIH requires the weighted HAV measurement process described above and separate evaluation of each x, y, and z vibration axis measured. If one or more vibration axes rms weighted acceleration values exceed the ACGIH recommended standard, then the standard has been exceeded for that number of daily vibration does hours worked. In particular, the ACGIH standard states that for each vibration axis: For 4<8 hrs/day, 4 meters/sec/sec should not be exceeded. For 2<4 hrs/day, 6 meters/sec/sec should not be exceeded. For 1<2 hrs/day, 8 meters/sec/sec should not be exceeded. For exposures less than 1 hr/day, 12 meters/sec/sec should not be exceeded.

The Second HAV Standard was published and promulgated in 1986 (through April, 2006) by the American National Standards Institute (ANSI, New York, NY)(13) and was designated ANSI S3.34-1986. This standard, too, required the weighted HAV process described above and also a Fourier vibration spectrum analysis for each tested vibration axis. Each axis results are graphically compared/overlaid onto a family of weighted, exposure time-dependent curves. This system allowed precise determination of which (if any) of the weighted curves' daily exposure time curves had been exceeded, and determination of which vibration frequencies within the measured tool were the culprits. The standard was very precise and accurate, and was used for many years. Unfortunately, it became too cumbersome for many, since a Fourier spectrum analyzer was needed to evaluate the HAV data.

In May 2006, ANSI replaced S3.34 with an easier to use, easier to understand HAV standard called ANSI S2.70-2006, which will be described later in this paper.

The Third HAV "criteria for a recommended standard" was published by the National Institute for Occupational Safety and Health (NIOSH) in 1989 and is designated #89-106. It is rarely if ever used, because it is an interim document that does not establish hand-arm vibration numerical limits, although NIOSH fully recognized the need for a HAV standard, and the gravity of the HAVS problem in the U.S. NIOSH 89-106 has become an HAV/HAVS information document (15).

The Fourth HAV Standard used in the U.S. is not a health and safety standard per se, but is a test certification standard for full-finger protected anti-vibration gloves. Known as ISO 10819-1996, the standard was later adopted by ANSI as ANSI S3.40-2002: ISO 10819. The procedures under this standard are unique to A/V glove testing and are accepted worldwide (7).

Finally, at this writing, the U.S. Occupational Safety and Health Administration (OSHA) has adopted no HAV standard, but does recognize the HAVS problem.

THE NEW ANSI S2.70-2006 HAV STANDARD (14, 16)

Background, EU: In 1989, the European Union (EU) in Brussels issued a Directive (89/391/EEC) informing its member nations that it planned to take measures to protect its member nation workers from various occupational "physical agents" found in the workplace. These included Hand-Arm Vibration and Whole-Body Vibration. In a later 2002 Directive (2002/44/EEC) (17) to its member nations, the EU further declared its intention to begin establishing firm health and safety criteria for these physical agents by developing criteria "on the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents-vibration."

Finally, in July 2005, these HAV and WBV criteria were actually enacted into law by the EU, thus affecting millions of vibration-exposed workers and their employers in all EU nations.

The legislative action of the EU represents the most profound and far-reaching protective standards activities ever undertaken in the area of occupational vibration. The effects of the EU Directive are being felt worldwide not only by EU workers and employers, but also by international manufacturers whose products vibrate, including all types of power tools and chain saws (HAVS) and all types of heavy construction equipment, farm vehicles, trucks and buses (WBV).

Background, ANSI Working Group 39 and S2.70-2006: Some four decades ago the American National Standards Institute formed a working group committee (ANSI S2/Working Group (WG) 39) under the administrative auspices of the Acoustical Society of America. This group of human vibration scientists, engineers, and physicians tackled the task of developing ANSI human vibration consensus standard documents, and this same committee also functions as the ANSI United States Delegation to the International Standards Organization (ISO) in Geneva, Switzerland. The WG 39 committee (numbering approximately 15 members) is currently chaired by D. Reynolds, and this author DW has been an active member of WG39 for the past 35 years.

WG 39 has been responsible for virtually every ANSI and ISO human vibration standard (and revision) since its inception, including HAVs related standards ISO 5349 and ANSI S.3.34-1986. Fully cognizant of international human vibration standards activity and the need to revise the 20 year-old ANSI S3.34 standard, the committee began developing ANSI S2.70, to replace S3.34. After much work, drafting and consensus voting/resolution, in May 2006, ANSI S2.70 was finally approved.

Both the EU HAV Directive and ANSI S2.70 are, to a significant extent, in harmony with one another, and provide a single global HAV standard.

IMPORTANT NOTES:

I. Please recognize that although similar, the EU Vibration Directive is a legal binding document being implemented by the EU member nations. The same is NOT true in the U.S. for ANSI S2.70-2006, which is a voluntary, legally nonbinding, consensus HAV standard.

II. The reader is strongly advised to obtain a complete copy of ANSI S2.70-2006* and thoroughly read and understand the standard before attempting to implement it in the workplace. The brief discussion provided below is intentionally simplified and informative, not an attempt to replace the complete version of the HAV standard.

Here is a brief summary of the important, common, and harmonized parts of both ANSI S2.70-2006 and the EU Directive. Both require the following:

The employer is the designated party responsible for the health and safety of its workers; thus the employer must provide a safe workplace for its employees. Thus the employer needs to purchase reduced vibration tools and ISO 10819 compliant/certified anti-vibration gloves; institute safe work practices; and provide workplace prevention programs, etc. to keep their workers safe.

If Hand-Arm Vibration workplace acceleration values (ISO frequency weighted rms acceleration sum value) for a given tool or product exceed 2.5 meters/sec/sec for 8 hrs/day (this is called the "Daily Exposure Action Value" or DEAV), employers must begin implementing HAV safety and health measures to protect exposed workers.

In the extreme case, for 8 hrs/day, workers shall not be exposed above 5.0 meters/sec/sec. This is the "Daily Exposure Limit Value" or DELV for HAV (ISO frequency weighted rms acceleration sum.)

Note that "ISO frequency weighted sum value" simply means the following:

I. Triaxial vibration acceleration measurements are simultaneously made on the tool or product being tested in accordance with ISO 5349, Parts 1 and 2;

II. The ISO frequency weighted rms acceleration values are next separately calculated for the x, y, and z axes, respectively;

III. The resulting "x axis ISO frequency weighted rms acceleration value" is squared, the resulting "y axis ISO frequency weighted rms acceleration value" is squared, and the resulting "z axis ISO frequency weighted rms acceleration value" is squared.

IV. Next, sum each of these three squared ISO frequency weighted rms acceleration values obtained in the previous step, and finally, calculate the square root of this ISO summed value.

This final numerical answer is what is needed: the "total daily ISO frequency weighted rms acceleration sum."

a. For an 8 hr/day work shift, if this final value is less than 2.5 meters/sec/sec, the tool can be operated over the work shift.

b. If this final value is greater than 2.5 meters/sec/sec, then the "action value" has been exceeded, and the HAV protective measures must be instituted by the employer.

c. If this final value exceeds 5.0 meters/sec/sec, workers may not use the tested tool until this ISO frequency weighted rms acceleration sum value can be reduced to below 5.0 meters/sec/sec for an 8-hour day.

ANSI S2.70-2006 TERMINOLOGY

The following will be helpful to potential users of ANSI S2.70. Again, the user is urged to obtain a complete copy of this document* before attempting HAV work.

ANSI S2.70 is a 17-page document consisting of three "normative" annexes. The term normative means these annexes are considered an actual part of this standard, as opposed to an "informative annex," which is not.

Daily Exposure Action Value (DEAV) is defined by this standard as the "health risk threshold," or the HAV dose sufficient to produce abnormal signs, symptoms, etc. in the hands and arms of some exposed persons. DEAV = 2.5 meters/sec/sec for 8 hrs/day HAV exposures. A graph is provided in this document if DEAV exposures are other than 8 hrs/day.

Daily Exposure Limit Value (DELV) is defined by this standard as the "high health risk threshold." or the HAV dose sufficient to product abnormal signs, symptoms, etc. in the hand and arms of a high proportion of exposed persons. DELV = 5.0 meters/sec/sec for 8 hrs/day HAV exposures. A graph is provided in this document if DELV exposures are other than 8 hrs/day.

Once triaxial HAV measurements have been made, processed, ISO weighted, etc. for a tested tool, and the final "total ISO weighted rms acceleration values" have been determined, it is possible to roughly statistically predict when in time a percent of the HAV exposed population using that tested tool might expect to enter into the vascular or early finger blanching stage. This time duration is called the "latent period". This standard provides a graph that can help predict the latent period for 10% of the HAV exposed population.

The ANSI S2.70 HAV standard recommends that only certified anti-vibration gloves that have passed or exceeded the ANSI S3.40/ISO 10819, EU compliance anti-vibration glove testing standard(s) be used in the workplace. Note: ANSI S2.70 does not change or modify testing procedures and other criteria now required by S3.40/ISO 10819.

*The ANSI S2.70-2006, HAV Standard is available from the Acoustical Society of America, Standards Secretariat,

35 Pinelawn Rd., Suite 114E, Melville, NY 11747; phone (631) 390-0215; FAX (631) 390-0217;

email asastds@aip.org.

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