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VIBRATION EXPOSURE AND PREVENTION IN THE UNITED STATES

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ABSTRACT

There are over one million workers exposed to hand-arm vibration in the United States. Cases of hand-arm vibration syndrome have been reported in the U.S. since 1918. Typical hand-arm vibration exposure conditions are given in this presentation. Vibration control methods are discussed; these include vibration damping and isolation, use of antivibration (A/V) tool and gloves, and the application work practices and hand-arm vibration standards in the workplace.

Key Words: Hand-Arm vibration, Antivibration tools and gloves, Acceleration, Vibration hazard, Vibration control

INTRODUCTION

In 1918 Dr. Alice Hamilton was one of the first to describe and attribute idiopathic Raynaud's Phenomenon to vibrating pneumatic hand-tool use in the U.S.[1] In 1946, E.E. Dart described hand pain, swelling, tenosynovitis, and increased vascular tone in 112 U.S. aircraft workers using vibrating hand-tools.[2] In the 1960's Ashe et al. at Ohio State University clinically diagnosed several Canadian miners with Raynaud's Phenomenon.[3] During the 1960's, vibration white fingers (VWF) was well on its way to being established in many industrialized countries. Yet despite this ever increasing evidence that use of vibrating hand-tools led to essentially irreversible VWF, Pecora in the 1960's (incorrectly) claimed that VWF "may have become an uncommon occupational disease approaching extinction in this country (U.S.)".[4] The effects of the Pecora study was to retard virtually all VWF studies in the U.S. for several years.

In the early 1970's our NIOSH vibration team determined that some eight million U.S. workers were exposed to occupational vibration, 6.8 million of which were exposed to whole-body vibration, 1.2 million of which were exposed to hand-arm vibration and thus potential candidates for VWF.[5] In the late 1970's our NIOSH team, together with Drs. W. Taylor and P.L. Pelmear, conducted a series of VWF studies and determined VWF prevalences in the order of 20–50% with latencies to blanching as short as 1–2.4 years in U.S. foundry chipper and grinder workers.[6–8] These findings thus completely rebuked Pecora's incorrect claim. In 1978, we repeated the famous Hamilton study and found virtually the same 80% prevalence of VWF[9] which she had found in 1918; nothing had changed in the workplace for 60 years, only the newly afflicted workers! Because of the discovery of these high VWF prevalences with relatively short blanching latencies, NIOSH issued a Current Intelligence Bulletin #38 "Vibration Syndrome"[10] to warn and inform the U.S. occupational medical community of the VWF problem.

Although guidance for the minimizing of VWF had been ongoing internationally for many

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Table 1. ACGIH threshold limit values for exposure of the hand to vibration in either X, Y, Z directions.

Total Daily Exposure Duration*	Values of the Dominant,† Frequency-Weighted, rms, Component Acceleration Which Shall Not Be Exceeded a_K, ($a_{K_{eq}}$)	
	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.
(Courtesy of ACGIH)

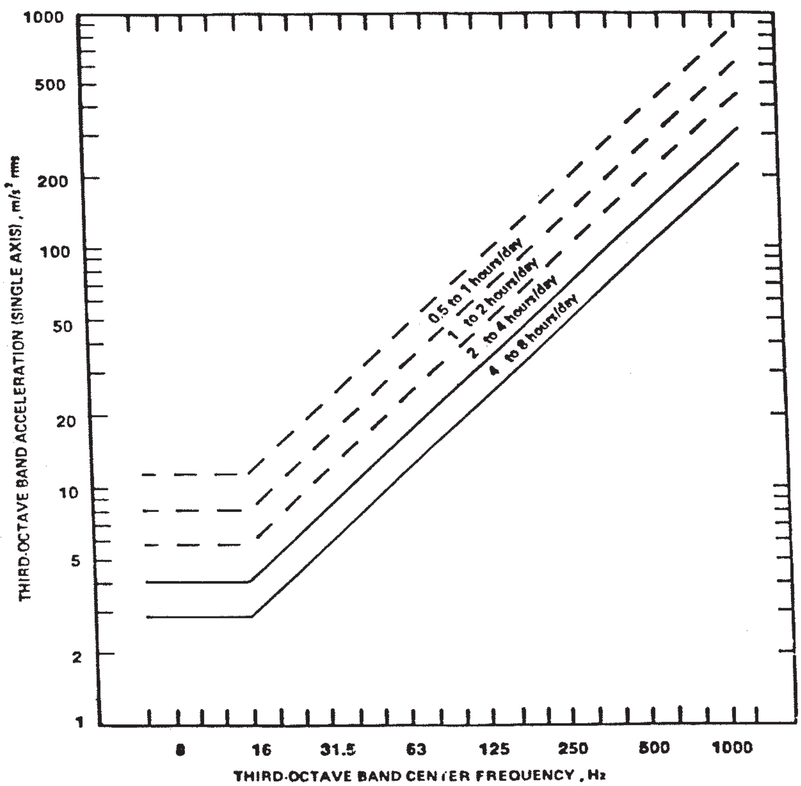

Fig. 1. ANSI S3.34: Single axis, hand-arm vibration daily exposure zones are analyzed as third octave bands of rms acceleration of discrete frequency vibration and for narrow-band or broadband vibration.

years. In 1984, the American Conference of Gov't Industrial Hygienists (ACGIH), were the first to officially issue a Hand-Arm Vibration Threshold Limit Value (TLV) standard in the U.S.[11] Their TLV is a numerical standard using weighted triaxial measurements (5—1, 500 Hz), with each axis separately evaluated and compared to the daily exposure values given in Table 1. The attempt in this TLV is to insure that most workers rarely progress beyond Stage 1 in the Taylor-Pelmear classification system.

ISO TC108/SC4 chose not to declare permissible (triaxial) acceleration levels in their ISO 5349 standard, deferring instead to each nation to establish their own limits.

In 1986, the American National Standards Institute responded by issuing their S3.34 Hand-Arm Vibration Standard,[12] shown in Fig. 1. Once again, weighted triaxial acceleration measurements are obtained and separately compared to the S3.34 standard to determine the maximum permissible daily exposure time for the worker. In order to statistically predict the latent time interval to blanching (Stage 1) for various percentages of the exposed population with unchanged exposure conditions, the dominant axis acceleration value is next determined and mathematically normalized to a four hour/day equivalent exposure. This normalized value is finally compared to the Brammer curves to determine the latent interval to blanching. ANSI S3.34 was the second U.S. HAV standard.

The third U.S. HAV standard was issued by NIOSH in 1989 as document #89—106.[13] In view of the current weighted vs. unweighted dose response controvery at the higher vibration frequencies, NIOSH administratively chose to issue it as an interim standard not specifying an acceptable acceleration level. NIOSH also requires both ISO weighted (to 1,4000 Hz) and unweighted measurements (to 5,000 Hz) together with medical monitoring of workers and engineering vibration control.

HAND-ARM VIBRATION EXPOSURE CONDITIONS

Despite the fact that the 1918 Hamilton study of U.S. stonecutters and carvers was one of the first to be reported on VWF, most of the technical advances continued elsewhere in Europe, Scandinavia, and Japan. In 1975, NIOSH held an international hand-arm vibration conference[14] in Cincinnati, Ohio an effort to elucidate the VWF problem. One of NIOSH's major conclusions was, with very limited financial resources, it would not be advisable to pursue the area of gasoline powered tools since many antivibration (A/V) saws were already being introduced world-wide for workers. Rather, we would focus our limited resources mainly on the myriad of vibrating pneumatic tools where so much work needed to be done.[14]

We then went forward and conducted several comprehensive vibrating pneumatic tool studies which included not only clinical and epidemiological components, but also triaxial (unweighted) linear acceleration measurements too. These studies included workers using a variety of pneumatic chipping and grinding hand-tools, jackhammers, and mining tools such as jack-leg type drills.[6,15—17] These unweighted measurements results are summarized in Table 2 where it can be seen that for #2 type chipping hammers the hand holding the chisel is experiencing nearly 2,400 g(rms) with the opposite hand squeezing the trigger handle exposed to two orders of magnitude less acceleration, nearly 31 g(rms). Our experience with grinders shows a large variation in acceleration levels, due in part to the tool maintenance and condition. Not unsurprisingly, the small stone chipping hammers tested exhibited high vibration levels, in part due to their small mass and little damping. The acceleration levels on jack-leg type mining drills were modest; higher in the large drills, lower in the smaller drills; recognizing that there is some vibration

Table 2. Typical unweighted acceleration levels measured in various NIOSH studies of pneumatic vibrating hand-tools

Tool Type	Acceleration Range: g(rms), Frequency Range 6.3–1kHz
Large jack-leg type drills	16.86–19.04
Small jack–leg type drills	5.16– 6.90
Jack hammers	10.20–16.52
(Limestone) chipping hammers	
[Chisel]	494.28
[Handle]	205.32
Metal chipping hammers	
[Chisel]	2,390.00
[Handle]	30.51
Horizontal grinders	1.71–44.56
Vertical grinders	0.56–49.75

damping due to the telescoping "leg" mechanism expanding on an air cushion as the drill bites deeper into the mine face.

CONTROLLING AND MINIMIZING HAND-ARM VIBRATION[18–20]

Controlling hand-arm vibration usually is multifaceted for maximum effectiveness. First, and most importantly, is reducing hand-tool vibration at the tool source; workers are therefore advised to use ergonomically designed antivibration (A/V) tools.

In the U.S. there are several patented viscoelastic vibration damping materials available. Some tool users have chosen to wrap conventional tool handles with these materials in the hope of possibly reducing vibration exposure levels. Unless there is no other choice, we do not advise doing this, since merely wrapping a tool handle with an arbitrary damping material cannot possibly produce the same vibration reduction as a well-engineered A/V tool. Other problems encountered when using these tool wraps, indicate that they increase the tool handle diameter making it more difficult to use and control the tool; this causes the worker to grip the tool with a more forceful grip strength for better tactile feedback; thus reducing the effectiveness of the damping material, due to the increased compression of the material.

Second, with regard to personal glove protection, use only full finger covered A/V gloves when and where possible. The use of A/V gloves where the finger tips are exposed and only the palm is protected is self defeating and should not be used because HAVS begins at the finger tip and moves towards the finger root. Further, an effective A/V glove must not only damp vibration but it also must fit well and be comfortable and maximize tactile feedback; it must keep the fingers and hands warm and dry; the glove must prevent lacerations and cuts; and finally it must be strong and durable. Unfortunately, at this writing, most A/V gloves do not as yet meet many of these requirements.

Third, with regard to work practices, workers are advised to: keep their fingers, hands, and body warm and dry; let the tool do the work by gripping it as lightly as possible thus reducing the vibration coupling into the hand, consistent with safe work practices; do not smoke, because of the vasoconstrictive effects of nicotine; where possible operate tools at reduced speeds; vibration warning labels should be placed on tools; work schedules should have a 10 minute rest break for each hour of continuous vibration exposure; keep tools properly maintained and/or replaced as necessary to keep vibration levels to a minimum; if possible, prescreen workers to minimize the risk to those already with Primary Raynaud's Disease; and workers should seek medical attention if signs and symptoms of HAVS appear.

Fourth, with regard to HAVS standards, in the U.S. we primarily use the ACGIH-TLV for hand-arm vibration and ANSI S3.34. We also obtain both weighted and unweighted measurements to conform with the NIOSH #89–106 HAV interim[21–23] standard. We rarely use ISO 5349 because as previously stated this standard does not specify a HAV protective acceleration level.

HAND-ARM VIBRATION CONTROL[20,24]

Vibration damping and isolation are two different engineering methods commonly used to minimize vibration.

Damping refers to the response of certain viscoelastic materials to deform when vibration impinges the material and to then convert and dissipate this vibration into heat. This results in some of the vibration being blocked from emerging through the viscoelastic material, thus reducing the input vibration. How much vibration reduction is achieved depends on: 1) The physical geometry of the vibrating surface. 2) The matching (or tuning) of the damping material's spectral characteristics, operating temperature, and material loss factor characteristics to the vibrating (hand-tool) source spectral and operating temperature characteristics. 3) The vibration coupling between the vibrating surface and the so-called "damping treatment" used. 4) The thickness of the damping material as well as other physical and operational constraints.

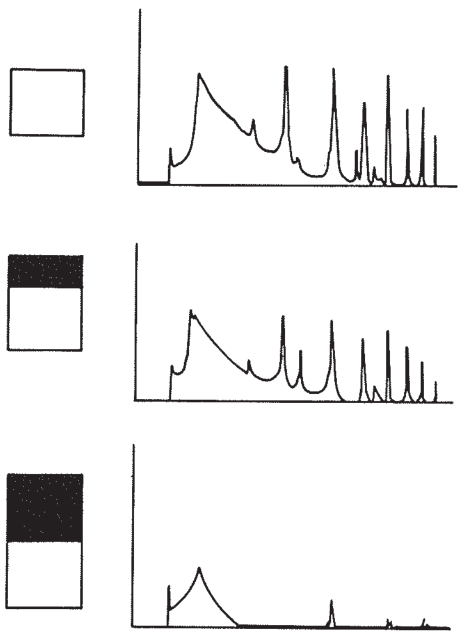

Fig. 2. The significant effects of tuned damping. A vibrating structure (left) and corresponding vibration spectra (right) with added tuned damping material applied to the structure.

A well designed vibration damping system properly matched or tuned to at the vibrating source (e.g. tool or other structure) can result in significantly reduced vibration impinging on workers as demonstrated in Fig. 2. As a properly matched damping treatment is applied to the vibrating structure the corresponding spectral amplitude is reduced to a point where additional damping does not reduce the amplitude and longer.

Isolation refers to the intentional "mismatching" of the pathway(s) between the vibrating hand-tool and the hand receiving the vibration (Fig. 3). This technique is likened to placing small vibration shock absorbers between a vibrating tool and its handle where the worker grasps the tool. The result of mismatching the vibration pathways, reduces or attenuates the vibration transmissibility to the hand and helps reduce exposure.

A antivibration tool which is also ergonomically designed not only reduces vibration impinging on the worker but also significantly reduces the likelihood of CTD occurring[20] such as Carpal Tunnel Syndrome. Referring to Fig. 4, it can be seen that various types of tool-handle configurations can be optimized for specific tasks. When the objective is to minimize wrist tor-

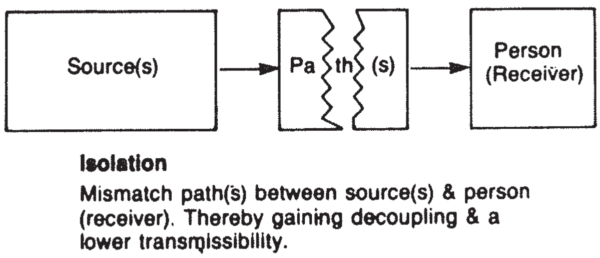

Fig. 3. Vibration isolation is the mismatching of the pathway between the source and the receiver, resulting in lower vibration trasmissibility through increased decoupling.

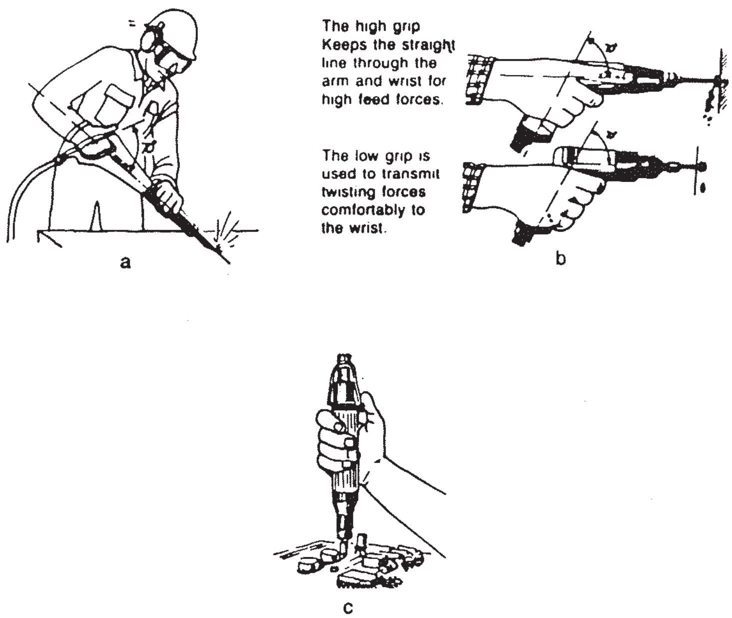

Fig. 4. Various types of tool handles: (a) Bow handle, (b) Pistol handle, (c) Straight handle. (Courtesy Atlas-Copco Co.)

que and simultaneously transmit high feed forces, bow handles are used on tools at a 70 degree angle to the center line of the wrist and arm as the tool is gripped (Fig. 4-a). For precision tasks, a pistol handle is used with a short tool length and minimizing the bending forces on the wrist by keeping the tool's center of mass on the handle top (Fig. 4-b). Straight handles (Fig. 4-c) are used for screwdrivers, drills, nut runners, and some grinders. A 38mm diameter for men and a 34mm diameter for women has been found to optimize grip strength at minimum hand strain. The center of mass of the tool should be located where the tool is gripped with the distance between the work piece and hand kept at a minimum distance. Using tool balancers is also desirable to minimize tool weight on workers hands.

A CONCLUDING LESSON FROM THE PAST[25]

Dr. Alice Hamilton[1] in 1918 reported: "Among men who use the air hammer for cutting stone there appears very commonly a disturbance in the circulation of the hands which consists in spasmodic contraction of the blood vessels of certain fingers, making them blanched, shrunken, and numb. These attacks come on under the influence of cold, and are most marked, not while the man is at work with the hammer, but usually in the morning or after work...The fingers affected are numb and clumsy when the vascular spasm persists. As it passes over there may be decided discomfort and even pain, but the hands soon become normal in appearance and as a usual thing the men do not complain of discomfort between the attacks...The condition is undoubtedly caused by the use of the air hammer; it is most marked in those branches of stonework where the air hammer is most continuously used and it is absent only where the air hammer is little or not at all. Stonecutters who do not use the air hammer do not have this condition of the fingers...Men who have given up the use of the air hammer for many years may still have their fingers turn white and numb in the cold weather...The trouble seems to be caused by three factors — long continued muscular contraction of the fingers in holding the tool, the vibration of the tool, and cold. It is increased by too continuous use of the air hammer, by grasping the tool too tightly, by using a worn, loose air hammer, and by cold in the working place. If these factors can be eliminated the trouble can probably be decidedly lessened".

This message of the past remains with us today, despite the fact that the technology to rid the workplace of VWF is here. Let us hope that future generations of workers need not be afflicted with VWF....

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