

# Hand-Arm Vibration Syndrome

## Protecting Powered Hand Tool Operators

By Mark B. Geiger, Donald Wasserman, Steven G. Chervak, Craig M. Henderson, Elizabeth Rodriquez-Johnson and Aimee Ritchey

**U**se of powered hand tools is essential to a range of U.S. Department of Defense (DOD) mission-critical equipment and facilities maintenance, corrosion control processes and operations. A high percentage of nondefense-related industrial production, fabrication and maintenance operations also depend on powered hand tools. Many of these operations are associated with hand-arm vibration (HAV) levels of sufficient intensity and duration to create risk of a preventable, but irreversible occupational disease described as hand-arm vibration syndrome (HAVS). The syndrome may affect up to 50% of workers in particular operations and has been reported in the U.S. since the early 1900s (NIOSH, 1983; Pelmeur & Wasserman, 1994; Taylor, Wasserman, Behrens, et al., 1994; Wasserman, 1998) as well as in other countries (Mirbod, Yoshida, Komura, et al., 1994; Yoo, Lee, Lee, et al., 2005).

In 2005, EU adopted legal workplace vibration standards, but the U.S. is lagging to develop similar

legally binding criteria (EU, 2002; EU-OSHA, 2008; Geiger, Borcicky, Burdge, et al., 2010). Rather, the U.S. has alternatively adopted voluntary consensus standards that closely follow EU standards (ANSI, 2006) and are generally considered to supersede previous consensus criteria (ACGIH, 2001, 2014).

In a proactive effort to minimize the risk of HAVS occurrence in the federal workforce of power-tool users, a Defense Safety Oversight Council (DSOC) project was initiated to improve low-vibration power hand tools and suitable certified protective equipment available in the federal supply system, provide educational outreach, and process management guidance necessary to minimize the risk of disease and disability among DOD personnel and other federal power-tool users (Geiger, 2006; Geiger, et al., 2010). Collaborators in this effort include, but are not limited to, General Services Administration (GSA) product managers for power hand tools; NIOSH; the Defense Logistics Agency (DLA); Office of the Secretary of Defense

**Mark B. Geiger, CSP, CIH**, works for the Naval Safety Center's Pentagon Liaison Office supporting the integration of occupational safety and health into systems acquisition and sustainment. He has 30 years' safety and health experience in a range of industrial, laboratory and policy management positions. Geiger holds an M.S. in Environmental Engineering from the Civil Engineering Department of Catholic University; an M.S. in Environmental Health Sciences from the University of Cincinnati; and a B.S. in Biology from Earlham College.

**Donald Wasserman, M.S.E.E., M.B.A.**, is an occupational vibration consultant in Frederick, MD. He is a biomedical engineer and a recognized expert in the area of occupational vibration. From 1971 to 1984, he served as the first chief of the NIOSH Occupational Vibration Group where he developed and implemented the nation's first program in occupational vibration. These studies formed the basis for much of the vibration research and control implementation in use today throughout the U.S. He

holds a B.A. in Biophysics and Physics from the University of Connecticut, an M.S.E.E. in Biomedical & Electrical Engineering from New York University and a M.B.A. from Xavier University.

**Steven G. Chervak, M.S., CPE**, is a human factors engineer at Aberdeen Proving Ground, MD. He is an active member of ANSI's Committee on Human Vibration and has several publications on human factors and ergonomics research. Chervak holds a B.S. in Engineering and Management from Clarkson University and an M.S. in Industrial Engineering from the University at Buffalo.

**Craig M. Henderson, M.S., CIH**, recently retired from Puget Sound Naval Shipyard and Intermediate Maintenance Facility, Bremerton, WA, where he was the technical lead for both ergonomics and hearing conservation programs, after 23 years of work for the U.S. Navy. He worked for OSHA between 1977 and 1989. Henderson has an M.S. in Chemical Engineering from the

University of Illinois and a B.S. in Chemistry from Ripon College.

**Elizabeth Rodriquez-Johnson, Ph.D.**, is retired after 30 years of civil service, the past 8 years of which she was a senior analyst specializing in system safety within the Office of Secretary of Defense Systems Engineering Office. She is a principal safety and acquisition specialist with Concurrent Technologies Corp., Johnstown, PA.

**Aimee Ritchey, B.S.**, is a project manager with Concurrent Technologies Corp. for various Department of Defense projects, managing a wide array of technical areas including safety, alternative energy, systems engineering and production type programs. She is a manager and task lead for several projects under the OSD Defense Safety Oversight Council. Ritchey holds a B.S. in Computer Systems Management from St. Francis University and is currently pursuing an M.B.A.



Acquisition and Technology; occupational health representatives of the U.S. Army, Navy and Air Force; and industry partners in shipyard and aircraft manufacturing.

Power-tool users in general industry and government are generally similar, with the exception of some categories of manufacturing work. One objective of this project was to facilitate improved access to state-of-the-art tools within the federal supply system. These collaborators are currently working through the Society of Automotive Engineers (SAE) EG-1B Aerospace Committee to develop a standard for comparative evaluation, product selection and support for powered hand tools, and with GSA to promote several lower vibration powered tools recently made available through the federal supply system to DOD customers.

### **Hand-Arm Vibration Syndrome: An Underrecognized Occupational Health Risk**

Underreporting of HAVS is common in the U.S. and other countries (ACGIH, 2001; Henderson, 2008; NIOSH, 1983; Pelmeur, 1998). This makes determining the scope of the problem more difficult to ascertain.

Many processes critical to corrosion control and industrial maintenance may create high HAV exposures and related injury risks during maintenance of defense systems and equipment. Operations such as grinding, polishing and chipping to remove corrosion or finish surfaces are conducted by DOD personnel and contractors, both domestically and abroad. Prolonged exposure can permanently injure the worker, resulting in extensive medical treatment costs, retraining costs and disability payments for the life of the injured party (EU-OSHA, 2008; NIOSH, 1983; Pelmeur & Wasserman, 1998; Taylor, et al., 1994; Wasserman, 1998; Yoo, et al., 2005). Numerous categories of power hand tools exist, many of which are vital to maintenance and corrosion control operations (ISO, 2003, 2011). Table 1 (p. 36) provides a general overview of types of power hand tools that have a high potential to create high levels of HAVS exposures [ $> 5 \text{ m/s}^2$  for an 8-hour time weighted average (TWA)] and most common in DOD use compiled by the authors.

Figure 1 (p. 37), from the EU Guide to Good Practice on Hand-Arm Vibration, illustrates the range of vibration exposures associated with common types of power hand tools, including many used in DOD operations.

DSOC provided NIOSH with funding to complete the tests and assessments and funded the work of a support contractor Concurrent Technologies Corp. (CTC) to coordinate efforts. Service occupational health representatives, NIOSH scientists, GSA product managers and a consultant specializing in defense logistics were part of the team. However, most of the work and organizational efforts were done without formal agreements. Industry partners were engaged and made an informal part of the team, and also participated in developing the SAE standard.

Early recognition and control of HAVS is critical because it has been shown to be irreversible after symptoms progress past initial stages, which are potentially developed over prolonged, daily exposure (NIOSH, 1983; Pelmeur & Wasserman, 1994; Taylor, et al., 1984; Wasserman, 1998). Common signs and symptoms of HAVS affecting the fingers and hands of exposed power tool operators are typical. These include a tingling sensation initially, often described by workers as a pins and needles feeling; tingling, numbness, loss of finger sensation and dexterity; nightly awakening with painful fingers and hands. Advanced symptoms (typically during cold weather) include painful finger attacks lasting 5 to 15 minutes during which one or more fingers turn white or blanch due to a loss of blood supply to these fingers (Photo 1, p. 38). These blanching attacks typically increase in number, severity and duration with continued vibration exposure. Cold temperatures and/or smoking can worsen HAVS because vibration, cold and nicotine all constrict blood vessels. In a few cases, one or

#### **IN BRIEF**

- Hand-arm vibration is a potentially irreversible neurovascular disease associated with intense and prolonged exposures to vibration, most commonly from powered hand tools.
- EU regulations have created an increased awareness of hand-arm vibration disease and demand for low-vibration powered hand tools, while the U.S. has lagged in this regard.
- A collaborative project was initiated to influence procurement criteria for powered tools, improve the availability of low-vibration tools for the federal workforce and increase general awareness through outreach and education.
- Current collaboration has been extended to industry partners and is focused on development of a standard that will consider productivity, hand-arm vibration, other safety and health factors' and life-cycle costs in procurement criteria for powered hand tools.



Since HAVS is irreversible and without a cure, current medical treatment can only attempt to reduce pain and suffering associated with the disease.

Table 1

## Common Process Involving Use of Powered Hand Tools

Tool type	Primary processes involved (indicates operations common in DOD maintenance)					
	Maritime/shipyard	Construction	Aircraft and vehicles maintenance	Ground/road and facility maintenance	Forestry	Mining/milling/quarry
Grinders	X	X	X			
Polishing	Limited	Limited	XX			
Welding, pre- and postgrinding	XX	X	X		Limited to support ops	X
Mechanical metal cutting	X Submarine recycling	XX	X	X Concrete work		XX
Wood cutting/finishing	X (Support structures)	XX		X	XX Chainsaws	X (Support structures)
Concrete work, finishing and set up, cutting				XX Mixers, jackhammers		
Impact wrenches	X	X	XX Tires and wheel	X		XX Assembly
Riveting		X Limited	XX Airframes			
Demolition—Pavement breakers	X			XX Jackhammers	X (Tree stump and rock removal)	XX
Foundry operations and "finishing" cast work	X		Limited			Support areas
Drilling	X	XX	XX	XX	X	XX
Stone cutting		XX		XX	X	XX Quarry work

**Note.** X shows common use; XX shows common operations that may be of particular concern due to potential vibration exposures.

more fingers can progress to gangrene and require amputation.

Since HAVS is irreversible and without a cure, current medical treatment can only attempt to reduce pain and suffering associated with the disease. Thus, the watchwords are *vigilance* and *prevention*. Documented workplace prevalence of HAVS ranges from 20% to 50% in the U.S. for power-tool users depending on the tools used, daily HAV exposure levels and work practices. An estimated 2.5 million total power-tool users in the U.S. are exposed to daily HAV (NIOSH, 1983; Wasserman 1998).

A common term, *latent period*, describes HAVS prevalence, which measures how long it takes for the first white-finger blanching attack to occur starting from when the tool operator first begins using the power tool(s) to the appearance of the first white fingertip(s). The latent period can range from a few years to 10 or more years (NIOSH, 1983; Pelmeur & Wasserman, 1994; Taylor, et al., 1984; Wasserman, 1998). In addition, HAVS always starts/appears at the fingertips moving downward toward the palm (distal to proximal), not the reverse.

### Understanding & Measuring Vibration

*Vibration* is motion described as a vector (directional) quantity, defined as vibration intensity with a corresponding direction. Theoretically, vibra-

tion measurement at any one point requires six simultaneous mutually perpendicular measurements, three linear directions moving along a line (i.e., up-down, side to side, front to back) and three rotations or twisting motions (i.e., pitch, yaw, roll). However, for human occupational vibration, rotations are not measured; only three linear measurements are used, which are obtained from power tool handle measurements, because of the paucity of medical data for rotational vibration (ANSI, 2006; NIOSH, 1982, 1983; Pelmeur & Wasserman, 1998; Wasserman, 2006, 2014).

The measure of vibration intensity is (root-mean-squared, rms) acceleration, which is mathematically adjusted (i.e., weighted) to account for the human's response to the impinging vibration. Intensity is measured in gravitational units where  $g = 9.81 \text{ m/s}^2$ . In practice, all three perpendicular linear acceleration measurements are weighted and vector summed (square root of the sum of the squares) producing a total weighted vector sum value. Knowing how long a tool operator uses a given tool, this weighted vector sum value is compared to health exposure HAV standards worldwide.

Both ANSI S2.70-2006-R2011 in the U.S. and the EU standard (EU-OSHA, 2008) set a maximum daily exposure of  $5 \text{ m/s}^2$  for an 8-hour TWA and an action level at which monitoring and controls are required above  $2.5 \text{ m/s}^2$  for an 8-hour TWA. No regulatory U.S. standard exists, but the ANSI S2.70/ISO and EU standard include a risk matrix that links exposure severity to potential HAVS medical outcomes (NIOSH, 1982; Wasserman, 1987, 2006, 2008, 2014).

Fortunately for OSH professionals assessing personnel exposures, technology for vibration measurement has advanced in recent years. Affordable handheld measuring equipment usable by personnel with a basic science background is increasingly available. (See "Additional Resources" sidebar, p. 39.)

### Reduced-Vibration Protective Gloves

It is essential to ensure that protective equipment performs as necessary to reduce transmitted vibration and HAVS exposures. In 1996, ISO pro-

mulgated a single comprehensive HAV glove testing standard, ISO 10819. It is currently adopted in the U.S. as ANSI/ASA S2.73, and a recent update was released.

Testing is performed under strict and uniform laboratory conditions by a third party, and the results determine a pass or fail condition. If a glove passes the testing criteria, it is deemed ISO 10819-certified as antivibration. Only full-finger gloves are tested and can be certified to ISO 10819 criteria; fingertip cutoff gloves do not protect the fingers and hands from HAVS, because HAVS begins at the finger tips and moves downward toward the palm.

Numerous products marketed as anti-vibration fail to meet relevant ANSI/ISO criteria for vibration reduction. Informal telephone interviews with representatives of several organizations that market these products showed that several vendors were unaware of the relevant standards (M.B. Geiger, personal communication, 2012). Purchasers of antivibration gloves must verify that products have third-party certification to demonstrate that they meet the performance standards of ISO 10819/ANSI S2.73.

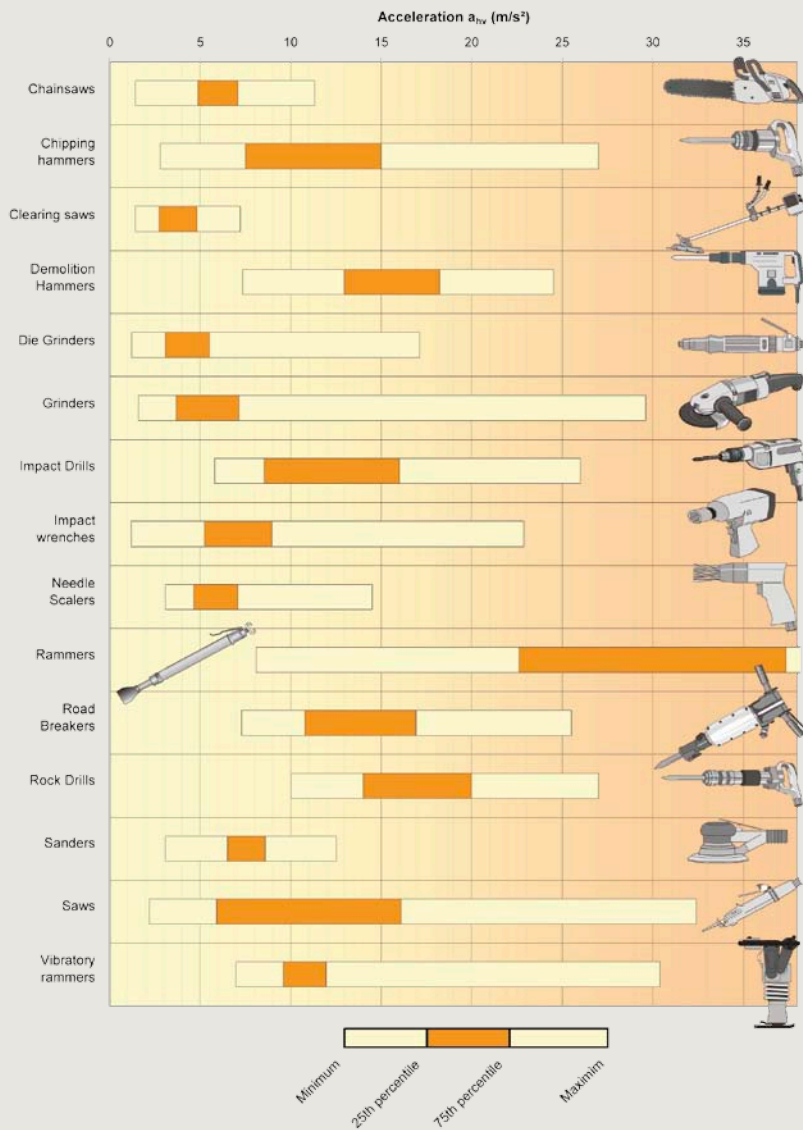
### Project Background

This project originated from outreach at the Puget Sound Naval Shipyard and Intermediate Maintenance Facility when the Safety and Health Department's ergonomics program manager approached the GSA for assistance in obtaining low-vibration power hand tools. A representative of GSA's tools section communicated the issue to the DOD Ergonomics Working Group (Moran, 2005). This presentation provided the basis for a project sponsored by DSOC and its Acquisition and Technology Task Force (working group) to improve education and awareness of HAVS and affect procurement specifications for power hand tools and certified antivibration gloves (Geiger, 2006). DOD also requested GSA collaboration in procurement of low-vibration power hand tools (OSD, 2007). Prior to this project, low-vibration characteristics had not been routinely applied to selection criteria for tool procurement. Also, no suitable (certified) antivibration gloves available in the federal supply system met relevant ISO/ANSI standards.

This project began in 2008 and is a part of a larger DOD/Navy effort to better integrate safety and health requirements and technology into manage-

ment of defense acquisition, sustainment and procurement processes. Technical outreach includes education of OSH professionals; application of the system safety process to HAV management; and influencing process requirements for maintenance and support operations. Initial efforts included publication of a website describing common safety and health hazards associated with operation and maintenance of Navy ships, which included

**Figure 1**  
Examples of Vibration Magnitudes for Common Tools



**Note.** Adapted from EU Guide to Good Practice on Hand-Arm Vibration, by EU, 2006, retrieved from <http://resource.isvr.soton.ac.uk/HRV/VIBGUIDE/HAV%20Good%20practice%20Guide%20V7.7%20English%20260506.pdf>.

Photo 1: Hands of a vibrating pneumatic hand-tool operator in the later stages of irreversible hand-arm vibration syndrome.



a section on whole body and segmental vibration (Bucher & Geiger, 2003; Wasserman, 2003). (See [www.public.navy.mil/navsafecen/Pages/acquisition/acquisition.aspx](http://www.public.navy.mil/navsafecen/Pages/acquisition/acquisition.aspx) or [www.safetycenter.navy.mil](http://www.safetycenter.navy.mil), select the section on acquisition.)

The need to view HAV as a system safety consideration necessitating recognition and management involvement at an organizational level was communicated to ensure minimized risk/exposure (Estrada, Newell, Harrer, et al., 2005; Geiger, 2009). Requirements for risk management through a defense systems life cycle, using Military Standard 882, the standard practice for system safety (DOD, 2012) are outlined in DOD (2013) and service acquisition regulations.

### Project Methods & Results

The project focused on minimizing HAVS risks through application of existing management processes, and the related education of both safety and health professionals and managers of maintenance and logistics processes, including maintenance training centers. Concurrently, it provides a selective update of available power hand tools and provision of certified antivibration gloves to minimize the risk of HAV injury (Geiger, 2006; 2009). The approach is also consistent with NIOSH's National Occupational Research Agenda (NORA) to provide guidance to the entire OSH community for moving research to practice ([www.cdc.gov/niosh/nora](http://www.cdc.gov/niosh/nora)).

An extension on the initial project focused on the incorporation of improved products within critical maintenance processes and providing related guidance/training materials. The emphasis is on management of several key processes including riveting/air frames maintenance; use of lower vibration needle scalers (needle guns) for surface preparation and another noncorrosion-related operation; and use of lower vibration power hand saws for certain shipyard operations. Participation of industry partners has been encouraged to broaden the project's reach.

Process improvements and alternative operations are also identified where appropriate. For ex-

ample, an operation that required removal of paint and corrosion from small aircraft parts by use of grinding tools required 3 to 4 hours, exposing users to significant vibration and other ergonomic stressors, has been modified by using a glove box operation to accomplish the same task within about 20 minutes (Estrada, et al., 2005). Noise and vibration exposures are also markedly reduced when the glove box is used.

NIOSH is collaborating with the U.S. Air Force to evaluate riveting operations, identify riveting hammers and bucking bars, which are currently most favored by workers and create the lowest levels of hand-arm vibration (Crowley, 2010). NIOSH is also collaborating with the U.S. Navy Clothing and Textile Research Facility to evaluate antivibration gloves and develop alternative test methods (Welcome, Dong, Xu, et al., 2010). GSA has incorporated low-vibration and other ergonomic parameters into criteria for tool selection and evaluation.

Extensive outreach has been a key aspect of the DSOC-sponsored project, as well as publications and website information developed for the Naval Safety Center. The Naval Safety Center collaborated with the DSOC group, NIOSH and the DOD Ergonomics Working Group to update a HAVS video made by NIOSH in the late 1980s. The new version consists of 10 menu-driven segments designed for diverse audiences (e.g., medical, engineers, industrial hygienists, personnel, management, tool operators, purchasing agents). It is available at no cost to DOD entities and publically for sale through the National Audiovisual Center. (See "Additional Resources" sidebar.)

### Reducing HAV Exposure During Corrosion Control & Industrial Maintenance Operations

A vibration management program should be integrated with existing measures to evaluate and improve process management and productivity, as well as other aspects of safety and health. Awareness is the first step to address any issue. While HAV exposures are often not fully considered, significant information is available. Lack of regulatory requirements does not exclude HAV exposures from OSHA review under the General Duty Clause. Additionally, numerous lawsuits have prompted varied private employers to control exposures (Wasserman, 2008).

Even more critical, acute vibration exposures are associated with increased fatigue while prolonged occupational exposures may jeopardize worker health and productivity. Productivity typically increases with the use of more ergonomic and lower vibration tools. Numerous anecdotal reports describe a strong correlation between reduced vibration tools and improved work quality. A vibration management program should include medical screening as well as periodic medical surveillance. Early detection at Puget Sound Naval Shipyard



was instrumental in minimizing long-term disabilities (Henderson, 2008).

### **Availability & Use of Low-Vibration Tools & Alternative Processes**

The advent of EU regulations has greatly increased the availability of lower-vibration power hand tools. NIOSH maintains a website listing noise and vibration levels for varied power tools ([wwwn.cdc.gov/niosh-sound-vibration](http://wwwn.cdc.gov/niosh-sound-vibration)), as does the Hand Arm Vibration Test Center ([www.operc.com/havtec/havinfo.asp](http://www.operc.com/havtec/havinfo.asp)). Because techniques for laboratory and field (workplace) vibration measurement differ, vendor data or even independent test data may serve as a basis for comparison of tools, but cannot fully replace on-site evaluations. Collaboration with GSA and several industry partners was initiated to influence procurement criteria and improve the availability of quieter tools that produce less vibration.

The Fleet Readiness Center, East, in Cherry Point, NC, is investigating use of mechanical assist to facilitate manual grinding, including applications that currently require the operator to hold a vibrating tool overhead at arm's length while lying on a creeper (Borcicky, 2011) (see [www.equipoisinc.com](http://www.equipoisinc.com)). A similar evaluation is being conducted for certain grinding operations at the Norfolk Naval Shipyard in Portsmouth, VA.

Puget Sound Naval Shipyard and Intermediate Maintenance Facility, in Bremerton, WA, have been evaluating overhead grinding the past 3 years. Work primarily was with a 7-in. (15.8-cm diameter) pneumatic grinder and a stabilized arm (Zero G Equipois System). Several static operations with limited or no vibration, such as use of a 20-lb heat gun to remove ceramic tile are also being evaluated. Use of the stabilized arm increased in production rates, improved work quality and significantly decreased vibration. The vibration decrease is primarily attributed to the reduced force needed to hold the tool (i.e., less mechanical coupling of the hand and tool).

NIOSH was asked to validate Puget's findings. This project was transferred to Norfolk Naval Shipyard in Portsmouth, VA, because of its proximity to NIOSH support in Morgantown, WV. Preliminary results from an evaluation conducted in October 2013 indicated lower ergonomic stresses and strong worker preference of the stabilized arm. A more detailed follow-up evaluation occurred in the summer of 2014.

In some applications, alternative processes may reduce or avoid HAV exposures. As noted, hand grinding to remove paint from small parts was replaced with use of a glove box for one aviation maintenance process. In addition to reducing vibration exposures, noise and airborne environmental levels of chromium-containing paint were also minimized because the dust was contained within an abrasive blast cabinet. The cabinet also

provided some acoustic shielding for the operation's noise (Estrada, et al., 2005).

The Naval Air Systems Command is investigating use of an e-drill electronic device to remove damaged rivets; this device employs an electronic current to breakdown fasteners such as rivets and reduces bonding between substrate with greatly reduced need for mechanical impacts. (See [www.ppedm.com](http://www.ppedm.com) and [www.youtube.com/watch?v=1LZT6dktnDo](http://www.youtube.com/watch?v=1LZT6dktnDo)).

## **Additional Resources**

### **Acquisition Safety—Vibration**

[www.public.navy.mil/navsafecen/Pages/acquisition/vibration\\_acquisition.aspx#introduction](http://www.public.navy.mil/navsafecen/Pages/acquisition/vibration_acquisition.aspx#introduction)

### **Burdge, G. & Geiger, M.B.**

Hand-arm vibration: Addressing the hazards. *The Monitor*, a publication of ASSE's Industrial Hygiene Practice Speciality, Vol. 9, No. 1. (available to ASSE members at <http://members.asse.org>).

### **Burdick, M.**

Stop pickin' up bad vibrations. *The Fabricator*. Retrieved from [www.thefabricator.com/article/safety/stop-pickin-up-bad-vibrations](http://www.thefabricator.com/article/safety/stop-pickin-up-bad-vibrations)

### **DOD Medical Surveillance Procedures Manual & Medical Matrix**

[www.med.navy.mil/sites/nmcpbc/Documents/oem/medical-matrix-11.pdf](http://www.med.navy.mil/sites/nmcpbc/Documents/oem/medical-matrix-11.pdf)

### **Geiger, M.B.**

Protecting our people from bad vibrations. (2009, Dec.), *Sea & Shore*.

### **Guidance for Users of Antivibration Gloves**

[www.denix.osd.mil/ergoworkinggroup/upload/98DODEWGNNews.pdf](http://www.denix.osd.mil/ergoworkinggroup/upload/98DODEWGNNews.pdf)

### **Hand-Arm Vibration Syndrome (HAVS)**

- [www.patient.co.uk/health/Hand-Arm-Vibration-Syndrome.htm](http://www.patient.co.uk/health/Hand-Arm-Vibration-Syndrome.htm)
- [www.hse.gov.uk/vibration/index.htm](http://www.hse.gov.uk/vibration/index.htm)
- [www.hse.gov.uk/vibration/hav/advicetoemployers/index.htm](http://www.hse.gov.uk/vibration/hav/advicetoemployers/index.htm)
- [www.public.navy.mil/navsafecen/Documents/acquisition/HAVS\\_Fact\\_Sheet.pdf](http://www.public.navy.mil/navsafecen/Documents/acquisition/HAVS_Fact_Sheet.pdf)

### **Hand-Arm Vibration Test Center**

[www.operc.com/havtec/havinfo.asp](http://www.operc.com/havtec/havinfo.asp)

### **HAVS Revisited [CD]**

[www.Defenselmagery.mil](http://www.Defenselmagery.mil), search for PIN 807012, or [www.ntis.gov/products](http://www.ntis.gov/products)

### **Lindqvist, B. & Skogsberg, L.**

*Power tool ergonomics: Evaluation of power tools*, [www.atlascopco.se](http://www.atlascopco.se)

### **NIOSH Power Tools Database**

[wwwn.cdc.gov/niosh-sound-vibration](http://wwwn.cdc.gov/niosh-sound-vibration)

### **Vibration Exposure Assessment of Industrial Power Tools Pocket Guide**

[www.atlascopco.se](http://www.atlascopco.se)

Discussion of the link between productivity, life cycle and improved ergonomics included numerous examples and case studies.

**Table 2**

## Comparison of Projected Life-Cycle Costs for Two Rivet Hammers

	Tool type	
	RRH 04-12 TS, Rivet hammer	Brand C, Rivet hammer
Purchase price estimate	\$1,179.35	\$312.02
Operator labor costs (rivet time only)	\$23.23	\$59.14
Energy consumption cost	\$91.48	\$92.13
Maintenance labor costs	\$1,394.45	\$3,051.22
Maintenance repair parts costs	\$1,340.97	\$3,479.60
Total maintenance costs (reflects warranty costs savings for new tools)	\$2,557.40	\$6,006.78
Expected number of failures per year (based on simulation)	9.68	21.28
Total life cycle costs 5 years	\$15,749.93	\$32,312.26
Yearly costs	\$3,149.99	\$6,462.45
Average part repair cost yearly	\$138.60	\$163.49

*Note.* Adapted from *Tool Comparison for the U.S. Government Presentation provided to the DOD DSOC Hand-Arm Vibration Working Group*, by M. Persson and D. Gibson, 2011; and from *EG-1B Hand Tool Committee meeting*, by Society for Automotive Engineers, January 2012.

### Education & Work Practice Guidelines

Procurement of suitable tools is only part of the risk-reduction process. Communication of work practice guidelines and best maintenance practices is essential. Educational materials, including a fact sheet, "Occupational Exposure to Hand-Arm Vibration: Just the Facts," were developed and are available for wider dissemination.

Tools and equipment should be maintained in accordance with manufacturer guidelines. Aspects such as maintaining suitable air pressure, proper cutting tool conditions, and systematic evaluation and replacement of lower-cost parts reduce operating costs and often also reduce equipment noise and vibration.

Worker and supervisory education includes awareness of ergonomic, vibration and issues. Workers should also be engaged in evaluating alternative tools and work processes. Good work practices include:

- Keep fingers, hands and body warm.
- Do not smoke or chew tobacco.
- Let the tool do the work; grasp it as lightly as

possible, consistent with established safe work practices.

- Do not use the tool unnecessarily and keep it well maintained.

- For pneumatic tools, keep the cold exhaust air away from fingers and hands.

- Take breaks from tool use for at least 10 minutes per hour to allow circulation recovery.

- Use ISO 10819-certified full-finger gloves for high-vibration operations. (Some constraints on dexterity and increased grip force needed to overcome the physical thickness and compressibility are may limit certain uses of antivibration gloves.)

- If signs and symptoms of HAVS appear, seek medical help.

### Guidance for Healthcare Professionals

Provide physicians with background information related to work operations that have a potential for HAV, as well as other ergonomic stressors. Sources such as medical references (Pelmeur & Wasserman, 1998) and DOD medical surveillance guidance such as the U.S. Navy's Medical Surveillance Manual may be considered (Navy Marine Corps Public Health Center, 2011). (See [www.med.navy.mil/sites/nmcphc/Documents/oem/medical-matrix-11.pdf](http://www.med.navy.mil/sites/nmcphc/Documents/oem/medical-matrix-11.pdf) and refer to the section on "Vibration, Hand-arm 508.")

### Development of Process Guidelines

Through the course of the project, it became increasingly apparent that it was necessary to address HAV in the context of an overall process management approach, particularly in the absence of binding regulatory criteria (ACGIH, 2001; Crowley, 2010; Yoo, et al., 2005). Collaboration with GSA stimulated affiliation with the SAE EG-1B committee on hand tools in January 2011 (SAE, 2012).

Discussion of the link between productivity, life cycle and improved ergonomics included numerous examples and case studies. The most salient was a reliability-based comparison of the 5-year costs for two rivet guns used in an aircraft production facility based on projected costs related to preventive maintenance and tool repair, productivity and estimated direct costs of tool failure. Comparative data are shown in Table 2. Total 5-year projected costs for a \$312 tool were in the range of \$31,000 while the initially more expensive tool (\$1,200) had 5-year costs in the range of \$16,000 (Persson & Gibson, 2011).

A major tool manufacturer conducted this evaluation in an aircraft production facility. It compared

estimated costs and productivity based on experience with a different vendor's rivet gun used in large aircraft production facility with that product maintained according to manufacturer's guidelines. The tool originally in use was commonly run to failure prior to repair or disposal. However, the comparison estimated costs for both tools maintained according to optimal preventive maintenance criteria. Significantly higher maintenance costs were estimated on this basis (\$2,557 per year for the higher cost product versus \$6,007 per year for the lower cost tool). A lower maintenance and/or replacement cost might have been achieved by continuing the practice of running the lower-cost tool to failure due to its lower purchase cost. However, as noted in Table 2 (column 3), the estimated rate of productivity was lower for the lower-cost product: \$59.14 versus \$23.23 to produce a similar level of output.

The comparison was accepted as plausible by the expert audience, which was composed primarily of competing tool manufactures and vendor representatives (SAE, 2012). Most important, the data also convinced the aircraft manufacturer to switch to the higher-cost product. The study focused on reliability and maintainability. Additional hidden fiscal and human costs might be created on the basis of potentially higher levels of vibration and longer periods of exposure, but were not directly evaluated in this study.

Further evaluations conducted by independent third parties comparing life-cycle costs, productivity and safety and health costs, and risks are needed. However, the general principle of linking product quality, reliability and maintainability with reduced life-cycle costs is well accepted.

The outcome of the January 2012 EG-1B committee meeting was a commitment to develop a standard for power tool procurement that would consider life-cycle costs, productivity, and safety and health factors. Information was shared with the safety and health community at the Third American Conference on Human Vibration (Borcicky, Chervak, Dong, et al., 2012). Development of a standard (SAE, 2014) was initiated through the EG1-B1 Hand Tools Committee, but eventually resulted in the formation of a separate working group, the SAE Technical Committee EG1-B1, Powered Hand Tools—Productivity, Ergonomics and Safety, which developed a process standard for comparative evaluation and selection of alternative products. GSA anticipates adapting the SAE AS 6288 standard for evaluation/selection of powered hand tools after its publication.

Puget Sound Naval Shipyard and Intermediate Maintenance Facility applied the general approaches of the draft standard to a recent major procurement initiative to update powered hand tools in advance of a major project (Henderson, 2014). Concurrently, GSA has identified and is marketing

approximately 140 low-vibration powered tools. DOD and GSA contacts are collaborating to develop materials and outreach to communicate the availability of these products as well.

## Conclusion

Safe and efficient maintenance and fabrication often depends on effective use of powered hand tools. Optimal equipment selection, user training and process management to improve quality and efficiency while protecting the safety and productivity of users must consider ergonomic criteria, including vibration. HAVS is irreversible and only a proactive approach of vigilance and the use of both antivibration power tools and certified antivibration gloves combined with proven effective work practices will help prevent the disease. A process management approach, including development of procurement criteria, considering all aspects of tool selection and use, is recommended. **PS**

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