Process Management Approaches to Power Hand Tool Selection and Use

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Naval Safety Center Liaison Office
30 October 2014
Disclaimer

Material and views presented are the responsibility of the authors and do not necessarily represent official Navy/DOD policy.

Members of Society of Automotive Engineers standards activities participate on their own behalf as technical experts and do not necessarily represent the views of their employing organizations.
Objectives

• Describe safety and influence of power tools with particular reference to vibration, noise and ergonomics improving quality of tools available to Federal workers and the construction industry in general

• Provide background of Defense Safety Oversight Council Project addressing hand-arm vibration, minimize direct cost associated with personnel downtime and medical.

• Describe EG-1B1 Committee of the Society of Automotive development standard approaches for power tool evaluation and procurement
Human body resonance frequencies

- Eyeball, intraocular structures (20 - 90 Hz)
- Head (axial mode) (20 - 30 Hz)
- Shoulder girdle (4 - 5 Hz)
- Lower arm (16 - 30 Hz)
- Spinal column (axial mode) 10 - 12 Hz
- Chest wall (50 - 100 Hz)
- Arm (5 - 10 Hz)
- Hand (30 - 50 Hz)
- Abdominal mass (4 - 8 Hz)
- Seated person
- Legs (Variable from ca. 2 Hz with knees flexing to over 20 Hz with rigid posture)

Mechanical model of the human body showing resonance frequency-ranges of the various body sections
Hand Vibration Injuries

Hand Arm Vibration Syndrome (HAVS) is an illness caused by vibration when working with tools or holding a vibrating work piece. 

The common "White Finger" effect termed Reynaud’s Disease
An Ignored Disease?

• In 1918, Alice Hamilton, MD, identified and documented HAVS in Indiana limestone quarry workers

• Sixty years later in 1978, the National Institute for Occupational Safety and Health, NIOSH (Don Wasserman) completed a study at the same quarry and the incidence of disease was the same, about 80% of the exposed workers had symptoms of HAVS.
  – Up to 1978, there were no changes in pneumatic rock-breaking tools
  – “attack rate “ was about 50% for “at risk” exposed workers
Hand-Arm-Vibration (HAV)

• Long Term vibration causes resonance in the affected body part, i.e., the hands
  – Causes damage to neurovascular structures in fingers
  – Carpal Tunnel, Vibration White Finger (VWF)
  – Incidence rate in the US is under-reported due to limitations on recognition as a compensable disease and lack of specific exposure regulation.
  – Dr. Ron House, Canadian Physician- A problem common undiagnosed
  – About 198/claims year in Canada) Should be 75,000 –144,000 based on UK and US data
New cases of Prescribed Vibration White Finger (VWF) and Carpal Tunnel Syndrome (CTS) in Great Britain 1995-2007


Population of Britain = 62 million
Population of the USA = 307 million
Population of Canada = 31 million
Occupational exposure limits for hand-arm vibration demonstrate a good correlation between exposures to vibration (measured as acceleration) and the incidence & prevention of disease.

An example from the forestry industry in Finland (Koskimies et. al. 1992):

<table>
<thead>
<tr>
<th>Equipment Type (Chain Saw)</th>
<th>Vibration</th>
<th>Prevalence of HAV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Existing equipment (unimproved)</td>
<td>14 m/s²</td>
<td>40% (1972)</td>
</tr>
<tr>
<td>Anti-vibration design</td>
<td>2 m/s²</td>
<td>5% (1990)</td>
</tr>
</tbody>
</table>

Project outcomes include:

Defense Safety Oversight Council Projects

- Influenced GSA procurement criteria for power hand tools
- Provided certified (third-party) anti-vibration gloves in the Federal supply system via DLA.
  - Berry Amendment compliant (US Mfr) made in the U.S.
- Increased awareness throughout DOD and industry partners of hand-arm vibration issues
- Supported several NIOSH research projects
- Guidelines on how to justify and purchase AV tools and gloves
- But- still limited/unfocused influence on everyday-purchase decisions for powered hand tools
- Guidelines have not been accepted as policy requirements
Meeting at National Institute for Occupational Safety and Health, Morgantown, West VA
February 2008
Population at risk

- Health and Safety Executive (HSE) in Britain estimates 2 million persons are at risk in the U.K.
- NIOSH estimated 1.5 million at risk in the U.S.
  - Seems to underestimate the affected population based on the number of working persons in Britain compared to the number of worker persons in the U.S.
- Using HSE estimates, more than 3 million U.S. workers are at risk.
- The European Agency for Safety and Health at Work data shows between 5 and 10% of workers in the EU are exposed to a potential HAVS risk from the use of powered hand tools.
- No one knows for sure the number of U.S. workers at risk because of disease under-reporting
Pneumatic Tools in History

Samuel Ingersoll invented the pneumatic drill in 1871. Charles Brady King of Detroit invented the pneumatic hammer (a hammer which is driven by compressed air) in 1890, and patented on January 28, 1894. Charles King exhibited two of his inventions at the 1893 Worlds Columbia Exposition; a pneumatic hammer for riveting and caulking and a steel brake beam for railroad road cars.

Pneumatic Hammer

Men use pneumatic hammers to tamp Denver and Rio Grande Western Railroad track base, in Garfield County, Colorado.

http://inventors.about.com/od/weirdmuseums/ig/The-Films-of-Thomas-Edison/Pneumatic-Hammer-.htm
Powered Hand Tools $10.9 Billion Annual US Market

## Hand Power Tool Use in the Department of Defense

<table>
<thead>
<tr>
<th>Tool Type</th>
<th>Industry Area</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Maritime /Shipyard</td>
</tr>
<tr>
<td>Grinders</td>
<td>X</td>
</tr>
<tr>
<td>Polishers</td>
<td>X</td>
</tr>
<tr>
<td>Welding/pre-post grinding</td>
<td>XX</td>
</tr>
<tr>
<td>Metal cutting</td>
<td>Submarine recycling</td>
</tr>
<tr>
<td>Woodwork</td>
<td>Support structures</td>
</tr>
<tr>
<td>Concrete work</td>
<td></td>
</tr>
<tr>
<td>Impact wrenches</td>
<td>X</td>
</tr>
<tr>
<td>Demolition</td>
<td>X</td>
</tr>
<tr>
<td>Foundry (finishing cast work)</td>
<td>X</td>
</tr>
<tr>
<td>Drilling</td>
<td>X</td>
</tr>
</tbody>
</table>
Product Selection is Vital for Vibration (and Noise) Control
Effect of Tools

Resource: NIOSH Buy-Quiet Programs
http://www.cdc.gov/niosh/topics/buyquiet/component.html
• Ergonomic injuries and illnesses*
  – Represent the single largest source of claims and costs to the Navy
  – Roughly $90 million annually or one-third of all recent claims
• If left unchecked, the Navy’s annual cost is
  – Projected to increase to $111 million by FY 2009.

* Analyzing the Navy’s Safety Data by CNA, December 2001
## Powered Hand Tools

**Process management and equipment selection factors**

<table>
<thead>
<tr>
<th>Factor or Risk</th>
<th>Health Impacts</th>
<th>Productivity Impacts</th>
<th>Potential controls</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vibration</td>
<td>Hand-arm vibration disease risk</td>
<td>Long-term impact on skilled workforce</td>
<td>Equipment selection and maintenance, Process selection</td>
</tr>
<tr>
<td>Noise</td>
<td>Hearing loss</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ergonomic design of workplace and tools</td>
<td>Long-term disease potential</td>
<td>Direct link between comfort and productivity</td>
<td>Equipment selection and process design</td>
</tr>
<tr>
<td>Physical safety hazards/ controls</td>
<td>Potential injuries</td>
<td>Productivity impacts of work-arounds</td>
<td>Equipment selection and maintenance</td>
</tr>
<tr>
<td>Life-cycle costs (replacement/repair)</td>
<td>Low-cost tools are likely to be noisier, and less “ergonomic”</td>
<td>Decreased productivity and quality (cheap tools are expensive)</td>
<td>Note that labor and consumables are highest costs (up to 80% for grinding)</td>
</tr>
</tbody>
</table>
Regulatory Challenges

- OSHA Permissible Exposure Limits (PELs) stuck in the 1970s
- Proposed Ergonomics Standard derailed in 1999
- Recent Budget, signed into law Dec. 23, 2011 prohibits OSHA from developing a rule that would add a musculoskeletal disorder column to the OSHA 300 form.
Overcoming Tunnel Vision?

- Perspective on all aspects of usability (not just vibration)
- Focused application of relevant standards
- Application of “safety for use” approach
- Reviewer with diverse backgrounds and perspectives
- Improved user feedback
Challenges

• Educating industrial hygienists and safety professionals to understand and engage in existing processes for feedback
• Integrating information for change as opposed to traditional surveys and reports
• Streamlining and clarifying current processes and policies
• Establishing new policies and procedures, if needed
Need New Approach
Systems Engineering!

• Tried the moral approach – failed due to perceived budgetary constraints
• Only looked at initial tool cost and ignored Total Cost of Ownership (TCO)
  – DOD term is TOC (total ownership cost)
• Need to make a “business case” to show total cost to shop
4. TCO (Total Cost of Ownership)

Brand "X" Rivet Hammer
- Purchase Price Estimate
- Operator labour Costs (rivet time only)
- Energy Consumption Cost
- Maintenance Labor Costs
- Maintenance Repair Parts Costs

Initial tool cost $1,200
5 year cost $15,750

Brand "Y" Rivet Hammer
Initial tool cost $312
5 year cost $32,312

Low price ≠ Low TCO
• Addresses evaluation, procurement, use and support of powered hand tools
  • Integrating safety, health and productivity into procurement and process management.
• Complements the SAE EG-1B Aerospace Hand Tool Committee which addresses all facets of aerospace hand tools and tool kits.
• Focus on development of aerospace standard AS6228, which provides programmatic guidance for sustainable tool evaluation and procurement
  • Will educate tool users and program managers
  • Promote economic effectiveness and efficiency.
• Members include government, original equipment manufacturers, and users
Need for “Balanced Scorecard”
Society of Automotive Engineers (SAE)
E1B Committee Project
Meeting in Kansas City, Mo Jan 18-19, 2012

• GSA Power tool leads, Tool manufactures, DOD Safety and Health and NIOSH represented

• Mutual interest in obtaining and selling better tools
  – Better products can (and will) be undercut if initial cost is the only criteria
  – Safety/ Ergonomics/Productivity and Quality coincide

• Developing rating criteria to consider all aspects of life-cycle
  – Productivity
  – Safety and health – Noise -Vibration - Ergonomics
  – Life-cycle costs
    • Maintenance/parts * Energy-Utilities (especially air) * Injuries/Illness
“Balanced Scorecard”

- Develop a COMPLETE evaluation and procurement process for portable power tools
- Use a WEIGHTED approach to key parameters
- Produce input for ISO/SAE/ASME standards
## AS 6228 Safety Requirements for Procurement, Maintenance and Use of Hand-held Powered Tools

<table>
<thead>
<tr>
<th>Factor</th>
<th>Relative Weighting</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Productivity</td>
<td>20%</td>
<td>May include cycle time; amount of material removed, time to accomplish a particular amount of work.</td>
</tr>
<tr>
<td>Noise</td>
<td>10%</td>
<td>Depend on relative contribution as a risk factor. For example:</td>
</tr>
<tr>
<td>Hand-arm vibration</td>
<td>20%</td>
<td>Depend on relative contribution as a risk factor. For example: 5% of the evaluation based on vibration levels if &lt; 2.5%. 10% if tools operate in the range of &gt; 5.0 m/s². 15% if tools &gt; 10 m/s² and used &gt; 2 hours/day</td>
</tr>
<tr>
<td>Ergonomic factors other than shock and vibration</td>
<td>20%</td>
<td>Guidance from Atlas Copco Guide to Power Hand tool Ergonomics and associated references.</td>
</tr>
<tr>
<td>Initial procurement cost</td>
<td>5%</td>
<td>May depend on anticipated life-span of tool and intensity of use (for example, occasional; periodic; daily).</td>
</tr>
<tr>
<td>Life cycle cost</td>
<td>15%</td>
<td>Includes maintenance - parts and labor</td>
</tr>
</tbody>
</table>
Scorecard Presentation

![Graph showing productivity, ergonomics, TCO, and noise & vibration/exposure scores for Models A, B, and C.]

- Model "A" has a higher productivity score.
- Model "B" has a good balance of ergonomics and TCO.
- Model "C" excels in noise & vibration/exposure but has lower productivity and TCO.

![Images of the three models with accompanying icons for ergonomics, TCO, and noise & vibration/exposure.]
Can a Department of Defense (DOD) effort provide leadership and suitable equipment that will influence others within this organization and the larger marketplace?

- Role of DOD occupational health establishment
  - Role of DOD in many health and safety areas including noise, heat/cold stress, ergonomics
  - Recent initiatives to reduce mishaps

- Market influence
  - DOD and allied defense industry size
  - International role (Europe, Asia)
  - Corps of Engineers safety and health guidance for Federal contracts
Alternative Views of Federal Procurement
The 800 pound Gorilla and/or hopeless maze

Amazing complexity
- Each organization has their own maze
- Progress is slow and inconsistent- even if the process can be understood

The 800 pound gorilla with widespread market influence
Approaches to Tool and Process Management

• Getting the best (versus best marketing) vendors
• What aspects of European and other approaches might be considered?
• It’s not just the tools – it’s the process management!
• Cultural issues and organizational impediments to progress
• How integrate safety and health as an indicator of process quality and effectiveness
The Department of Defense/Industry Working Group and the General Services Administration Heartland Acquisition Center (HAC) have been working together to ensure a wide variety of ergonomic, low-vibration tools are offered to the DoD community. We have chosen to focus on lower vibration because of the risks of hand-arm vibration, producing Hand-Arm Vibration Syndrome (HAVS), a potentially irreversible disease associated with prolonged and intense exposure to this vibration. Tools developed to reduce vibration often also have other desirable performance properties such as longer life-spans, improved ergonomics and lower noise levels. This brochure outlines program details.

General Ergonomic Program Details can be found at the following sites, or at your unit safety officer office. [https://www.gsaglobalsupply.gsa.gov/](https://www.gsaglobalsupply.gsa.gov/)
Power Tools: The Approach

• Evaluate power hand tools where vibration, noise or other safety concerns are a hazard
• Identify and communicate with GSA product manager regarding procurement criteria
  – Identify the same need at local and process management level
• Establish procedures for the Qualified Products List (QPL)
  – Evaluate possible approaches to facilitate and document labs which can provide testing and evaluation
• Crosslink GSA, DLA and NIOSH websites
• Make improved products available via GSA schedule both to Federal and Federal contractor buyers
  – Contractors can buy through GSA for certain government projects
  – Product marketed by GSA have open description of specifications (usable to any prospective purchaser)
Introduction

- The Navy cares deeply about protecting the safety and health of its greatest resource - its people. In today's workplaces, there exist many potentially serious occupational hazards. Some hazards, like noise-induced hearing loss and heat stress, are well known, heavily reported, and well documented. Much less is known about other workplace perils, which can produce serious, irreversible, and unsuspected diseases. Occupational Vibration, affecting eight to ten million people in the U.S. alone, is one of these less obvious workplace hazards. Because Navy Leadership is concerned about the safety and health of its military and civilian workers, they are working hard to address this under-recognized occupational health problem through acquisition of safe, cost-effective, and performance-improving designs and equipment. This section of the Acquisition Safety website addresses the vibration issue uniquely and in depth. Included are the potential health effects of uncontrolled vibration and ongoing efforts to control this risk to Navy personnel. Also provided are best business practices and technical assistance for acquisition (research, development, design and procurement) of designs and equipment that will maximize productivity and operational effectiveness while protecting operators and maintainers of this equipment.

* Copyright 1990, D.E. Wasserman, Inc.; Image of hands (not U.S. Navy worker) used with permission.
Wrap-up – Systems Engineering Approach is Needed!

- HAVS and other safety/health risk factors will be addressed through a tool evaluation process employing a Balanced Scorecard approach.
- Society of Automotive Engineers EG1-B1 Committee Subcommittee developing evaluation guidance
  - Members include DOD Health and Safety, General Services Administration and industry representatives
  - Standard would allow common approach to procurement without needing to justify each purchase individually
- DOD and allied defense industry size = market influence
  - International role (Europe, Asia)
  - Corps of Engineers safety and health guidance for Federal contracts a possible consideration
- Regulatory challenges will need to be addressed.
- Link with NIOSH is vital to this effort
  - Health Effects Research Laboratory (Vibration evaluation)
  - Construction Safety and Health
  - Prevention through Design
- Support for outreach to industry and Federal agencies
Thank you

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703 695-4703

SAE EG-1B1 Committee Powered Hand Tools – Productivity, ergonomics and safety (www.sae.org)
Back-up Materials
Publications

- Society of Automotive Engineers Standard AS 6228 Safety Requirements for Procurement, Maintenance and Use of Hand-held Powered Tools September 2014 (available www.sae.org)


DEVELOPMENT OF A BALANCED SCORECARD FOR EVALUATION AND PROCUREMENT OF POWERED HAND TOOLS

Richard Borcicky, NAVAIR Fleet Readiness Center, East, Cherry Point, NC
Steve Chervak, Army Public Health Command, Aberdeen Proving Ground, MD
Ren Dong, National Institute for Occupational Safety and Health, Morgantown, WV
Mark Geiger, Naval Safety Center Liaison Office, Pentagon, Arlington, VA
Craig Henderson, retired, previous Puget Sound Naval Shipyard
Keith Herbster, Atlas Copco, Auburn Hills, Michigan
Roy Jardin, M.S., Dynamics Research Corp DRC, Robbins AFB, Robbins, Georgia
Craig Kuznia, General Services Administration, Kansas City, MO
Mark Lehnert, Stanley Black and Decker, New Britain, CT
Thomas McDowell, National Institute for Occupational Safety and Health, Morgantown, WV
Magnus Persson, Atlas Copco, Stockholm, Sweden
John Ster, JMS Aerospace Engineering and Consulting (previously Engineering Director GSA Kansas City)
Don Wasserman, Consultant, Frederick, MD
Andrew Wells, USAF Health Risk Assessment Division, Wright Pat AFB, Dayton, OH
NIOSH Data Base for Powered Hand Tools
Includes noise and vibration

NIOSH provides a power-tool data base on their website with information on belt sanders, circular saws, drills, grinders, hammer drills, impact wrenches, jigsaw, miter saw, orbital saw, reciprocating saw and powered screw drivers


European Union Database
Provides for search of tools and manufactures products for sound and vibration levels

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http://www.vibration.db.umu.se/HavSok.aspx?lang=en
Hand-Arm Vibration as a Risk Factor in Systems Design, Development, and Support

Paper/Presentation at International System Safety Conference
San Diego August 2005

Carol Lavery, MPH, CIH*  
Alec Wong, MS*  
LT Kristen Harrer, MS*

Nancy Estrada, MPH*  
Jane Nowell, MS, CIH*  
Mark Geiger, MS, CIH, CSP**

* Naval Medical Center, San Diego

**OPNAV Safety Liaison Office
Evaluation of Three Pavement Breakers

• Construction Battalion 405 (CBU) cement pad removal (40X80 ft)

• Comparison
  – standard pavement breaker
  – 2 anti-vibration pavement breakers
## Before and After Pavement Breaker Substitution

Work done by Naval Medical Center, San Diego

<table>
<thead>
<tr>
<th>Work method</th>
<th>Initial</th>
<th>Alternative</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pavement breaker (jack hammer)</td>
<td>Bobcat equipped with pavement breaker</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Tool type/brand</th>
<th>Hand-arm Vibration exposure (re 5 m/s² criteria)</th>
<th>Hand-arm Vibration exposure (re 5 m/s² criteria)</th>
<th>5 m/s² criteria applied</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chicago (standard)</td>
<td>382 (m/s²)</td>
<td>--</td>
<td>Initial efforts to select better tools</td>
</tr>
<tr>
<td>Chicago (anti-vibration)</td>
<td>277 (m/s²)</td>
<td>--</td>
<td>Slightly better</td>
</tr>
<tr>
<td>Atlas Copco (anti-vibration)</td>
<td>18.9 (m/s²)</td>
<td>--</td>
<td>Much better but &gt;&gt; 5 m/s²</td>
</tr>
<tr>
<td>Bobcat – with pavement breaker</td>
<td>--Nil-</td>
<td></td>
<td>Final control by process change</td>
</tr>
</tbody>
</table>

| Man-hours | 80 | 8 |
| Labor cost | $2000 | $200 |
Sanding Aircraft

• Paint Shop prepares surfaces for painting

• All aircraft require some sanding prior to painting

• Thickness of previous layers of paint dictates how much sanding
Effects of Process Substitution

Sanding versus Blasting Parts

F/A-18 Wing Corrosion Shop
Small parts have paint removed to look for corrosion

• Dirty, corroded small parts
• Hand sanding with power tools
• Because the parts are small and have corners and tight areas to get into it took 3-4 hours to remove paint and corrosion from the parts.
• High hand-arm vibration exposures

• Clean, un-corroded parts
• Whereas, in the blasting cabinet (glove box) it takes about 20 minutes.
• Other advantages include: Less stress to hands and arms due to vibration and repetitive motion, dust control (chromates), less damage to part.
### Frequency-weighted rms Acceleration of a Random Orbital Sanders for the Dominant Axis (Z-Axis)

<table>
<thead>
<tr>
<th>Sander</th>
<th>Average Acceleration Dominant Handle Axis (m/s²)</th>
<th>Allowable Vibration Exposure Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>National Detroit</td>
<td>14.4</td>
<td>&lt;1 hour</td>
</tr>
<tr>
<td>George Renault</td>
<td>6.0</td>
<td>&lt;4 hours</td>
</tr>
<tr>
<td>Dynabrade</td>
<td>7.0</td>
<td>2 hours</td>
</tr>
<tr>
<td>Clayton</td>
<td>6.3*</td>
<td>Less than 1 hour</td>
</tr>
</tbody>
</table>

*The HVM 100 registered an overload while taking measurements generated by the Clayton sander. Therefore, this value is not accurate and the actual value could not be determined.*

This study used the ACGIH TLVs (dominant axis) to evaluate exposures.
### Mishap Risk Assessment Matrix Before and After Process Change

**Using Military Standard 882 System Safety per DOD Acquisition Regulations**

<table>
<thead>
<tr>
<th>Probability (Frequency)</th>
<th>Severity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>I Catastrophic</td>
</tr>
<tr>
<td>A Frequent</td>
<td>IA – 1</td>
</tr>
<tr>
<td>B Probable</td>
<td>IB – 2</td>
</tr>
<tr>
<td>C Occasional</td>
<td>IC – 4</td>
</tr>
<tr>
<td>D Remote</td>
<td>ID – 8</td>
</tr>
<tr>
<td>E Improbable</td>
<td>IE – 12</td>
</tr>
</tbody>
</table>

Initial Exposures – SERIOUS- PEO Initial risk level IIIB to IIC, depending upon length of exposure

Modified risk level IIID or IVC, Medium to Low (somewhat dependent on length of exposure) PM or local risk acceptance.
Comparison of Bucking Bars
Richard Borcicky, Ergonomist
Fleet Readiness Center, East, Cherry Point, NC
February 2008

Bucking Bars Vibration Testing
May 4th, 2007

With Grip Wrap
Without Grip Wrap
New Design Tool Bar
Straight Bar
L Bar

4.5 Times
4.1 Times
23.53 Times
7.53

.41
1.85
.41
1.72
.32

May 4th, 2007