AEROSPACE STANDARD

AS6228™	REV. A
Issued 2017-09 Revised 2023-07 Superseding AS6228	

(R) Safety Requirements for Procurement, Maintenance, and Use of Handheld Powered Tools

RATIONALE

The SAE Aerospace Standard (AS) has been updated to coincide with publication of a layman's guide and reordered to enhance ease of use. Specific changes include

1. Updated Table A1 notional guidance on weighting factors for tool evaluation to include physical safety factors (factors which can create an acute injury such as electrical safety or physical disintegration). (Note that the table in the original version of AS6228 had 90 possible points versus 100 possible points.)

2. Include basic guidance for safety in purchase of appendages (consumables/removable tools).

3. Provide guidance for dust control by adding an appendix which was not included in initial version of AS6228.

4. Developed a supporting SAE Aerospace Information Report (AIR6916) to serve as a layman's guide for application of the standard. This standard and AIR6916 are being published concurrently.

5. Update references and links to websites, as appropriate.

6. Deleted some material deemed too basic for users of this standard.

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For more information on this standard, visit
https://www.sae.org/standards/content/AS6228A

TABLE OF CONTENTS

1. SCOPE

This SAE Aerospace Standard (AS) covers the requirements and technical guidance for evaluation of life-cycle cost, productivity, and safety/health factors related to power hand tool selection. It applies approaches to selection of quieter and lower vibration handheld powered tools, with optimal ergonomic features, for the prevention of hand-arm vibration syndrome (HAVS), hearing loss, and repetitive motion injuries. Equipment selection for control of physical safety and electrical safety hazards are essential components of a tool safety program. It suggests use of noise and vibration data provided by vendors to be verified and supplemented by information available through the National Institute for Occupational Safety and Health (NIOSH) and European Union (EU) databases.

This AS has been updated to better address physical safety hazards. An appendix (APPENDIX D) on dust control has been included. A supporting SAE Aerospace Information Report (AIR6916) has been developed to facilitate use of the standard's approach by industrial users who require a terse guide, but may not need the level of technical detail required by the SAE standard process.

Inclusion/exclusion of data in this document is not intended to imply that all the products described herein are the only production models that meet this standard. Consumers are requested to consult with manufacturers concerning lists of stock production models that meet this standard.

Guidance for selection, procurement, and maintenance of power hand tools should be one component of management processes supporting productivity, reliability, and product quality while safeguarding the safety and health of employees. Workplace design, procurement of safest available products, and periodic evaluation is integral to risk/cost management and promotion of personnel morale and efficient operations. An ergonomics program should be an integral part of occupational health and management systems, such as those outlined in ANSI Z10.0-2019.

1.1 Classifications

Handheld power tools covered by this AS shall be classified as follows:

1.1.1 Type I Pneumatic Tools

Class 1: Grinders/polishers
- Style A - Straight
- Style B - Angle
- Style C - Die grinders including straight and angled categories
- Style D - Vertical grinders

Class 2: Drills

Class 3: Percussive tools (chipping and riveting hammer, needle scalers, rammers, and road breakers (jackhammers, etc.)

Class 4: Nailers/staplers

Class 5: Impact wrenches (impulse tools)

Class 6: Nut runners/screwdrivers

Class 7: Saws

1.1.2 Type II Electric Tools, Including Corded Electric and Battery Powered

Class 1: Grinders/polishers
Style A - Straight
Style B - Angle
Style C - Die

Class 2: Drills

Class 3: Percussive tools (chipping and riveting hammers and needle scalers, etc.)

Class 4: Nailers/staplers

Class 5: Impact wrenches (impulse tools)

Class 6: Nut runners/screwdrivers

Class 7: Saws

1.1.3 Type III Liquid Fuel Tools

Class 1: Chain saws

Class 2: Yard equipment (mowers/leaf blowers/string trimmers)

Class 3: Concrete saws/cutting saws (handheld)

Class 4: Drills (including post hole diggers)

Class 5: Rammers and road breakers (jackhammers)

1.1.4 Type IV Hydraulic Tools

Class 1: Prying tools

Class 2: Hammers

Class 3: Cutters

Class 4: Rams

Class 5: Impact wrenches (impulse tools)

Class 6: Torque tools (including nutsetters)

2. REFERENCES

2.1 Applicable Documents

The following publications form a part of this document to the extent specified herein. The latest issue of SAE publications shall apply. The applicable issue of other publications shall be the issue in effect on the date of the purchase order. In the event of conflict between the text of this document and references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

2.1.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or +1 724-776-4970 (outside USA), www.sae.org.

AIR6916	Guide for Safety, Efficiency, and Productivity in Buying Power Hand Tools
AS478	Identification Marking Methods
AS4786	Driver Drills, Battery Powered

Gotman, A. and Guerrero, R., “Torque Reactionless Differential Hand Held Rotary Power Tools,” SAE Technical Paper 931774, 1993, https://doi.org/10.4271/931774.

2.1.2 ASME Publications

Available from ASME, P.O. Box 2900, 22 Law Drive, Fairfield, NJ 07007-2900, Tel: 800-843-2763 (U.S./Canada), 001-800-843-2763 (Mexico), 973-882-1170 (outside North America), www.asme.org.

ASME B107.4-2005	Driving and Spindle Ends for Portable Hand, Impact, Air, and Electric Tools (Percussion Tools Excluded)

2.1.3 ISO Publications

Copies of these documents are available online at https://webstore.ansi.org/.

ISO 5349-1:2001	Mechanical Vibration - Measurement and Evaluation of Human Exposure to Hand-Transmitted Vibration - Part 1: General Requirements
ISO 5349-2:2001	Mechanical Vibration - Measurement and Evaluation of Human Exposure to Hand-Transmitted Vibration - Part 2: Practical Guidance for Measurement at the Workplace
ISO 5391:2003	Pneumatic Tools and Machines - Vocabulary
ISO 8662-11:1999	Handheld Portable Power Tools - Measurement of Vibrations at the Handle - Part 11: Fastener Driving Tools
ISO 11148-1:2011	Handheld Non-Electric Power Tools - Safety Requirements - Part 1: Assembly Power Tools for Non-Threaded Mechanical Fasteners
ISO 11148-10:2011	Handheld Non-Electric Power Tools - Safety Requirements - Part 10: Compression Power Tools
ISO 11148-11:2011	Handheld Non-Electric Power Tools - Safety Requirements - Part 11: Nibblers and Shears
ISO 11148-12:2012	Handheld Non-Electric Power Tools - Safety Requirements - Part 12: Circular, Oscillating, and Reciprocating Saws

ISO 11148-2:2011 Handheld Non-Electric Power Tools - Safety Requirements - Part 2: Cutting-off and Crimping Power Tools

ISO 11148-3:2012 Handheld Non-Electric Power Tools - Safety Requirements - Part 3: Drills and Tappers

ISO 11148-4:2012 Handheld Non-Electric Power Tools - Safety Requirements - Part 4: Non-Rotary Percussive Power Tools

ISO 11148-5:2011 Handheld Non-Electric Power Tools - Safety Requirements - Part 5: Rotary Percussive Drills

ISO 11148-6:2012 Handheld Non-Electric Power Tools - Safety Requirements - Part 6: Assembly Power Tools for Threaded Fasteners

ISO 11148-7:2012 Handheld Non-Electric Power Tools - Safety Requirements - Part 7: Grinders

ISO 11148-8:2011 Handheld Non-Electric Power Tools - Safety Requirements - Part 8: Sanders and Polishers

ISO 11148-9:2011 Handheld non-Electric Power Tools - Safety Requirements - Part 9: Die Grinders

ISO 15744:2008 Handheld Non-Electric Power Tools - Noise Measurement Code - Engineering Method (Grade 2)

ISO 18570:2017 Mechanical Vibration - Measurement and Evaluation of Human Exposure to Hand Transmitted Vibration - Supplementary Method for Assessing Risk of Vascular Disorders

ISO 28927-1:2019 Handheld Portable Power Tools - Test Methods for Evaluation of Vibration Emission - Part 1: Angle and Vertical Grinders

ISO 28927-10:2011 Handheld Portable Power Tools - Test Methods for Evaluation of Vibration Emission - Part 10: Percussive drills, Hammers, and Breakers

ISO 28927-11:2011 Handheld Portable Power Tools - Test Methods for Evaluation of Vibration Emission - Part 11: Stone Hammers

ISO 28927-12:2012 Handheld Portable Power Tools - Test Methods for Evaluation of Vibration Emission - Part 12: Die Grinders

ISO 28927-2:2009 Handheld Portable Power Tools - Test Methods for Evaluation of Vibration Emission - Part 2: Wrenches, Nutrunners and Screwdrivers

ISO 28927-3:2009 Handheld Portable Power Tools - Test Methods for Evaluation of Vibration Emission - Part 3: Polishers and Rotary, Orbital, and Random Orbital Sanders

ISO 28927-4:2010 Handheld Portable Power Tools - Test Methods for Evaluation of Vibration Emission - Part 4: Straight Grinders

ISO 28927-5:2009 Handheld Portable Power Tools - Test Methods for Evaluation of Vibration Emission - Part 5: Drills and Impact Drills

ISO 28927-6:2009 Handheld Portable Power Tools - Test Methods for Evaluation of Vibration Emission - Part 6: Rammers

ISO 28927-7:2009 Handheld Portable Power Tools - Test Methods for Evaluation of Vibration Emission - Part 7: Nibblers and Shears

ISO 28927-8:2009	Handheld Portable Power Tools - Test Methods for Evaluation of Vibration Emission - Part 8: Saws, Polishing and Filing Machines with Reciprocating Action and Small Saws with Oscillating or Rotating Action
ISO 28927-9:2009	Handheld Portable Power Tools - Test Methods for Evaluation of Vibration Emission - Part 9: Scaling Hammers and Needle Scalers
ISO/TR 22521:2005	Portable Handheld Forestry Machines - Vibration Emission Values at the Handles
ISO/TR 27609:2007	Vibration in Handheld Tools - Vibration Measurement Methods for Grinders - Evaluation of Round-Robin Test
ISO/TS 15694:2004	Mechanical Vibration and Shock - Measurement and Evaluation of Single Shocks Transmitted from Handheld and Hand-Guided Machines to the Hand-Arm System
ISO/TS 21108:2005	Handheld Power Tools - Impulse Wrenches - Dimensions and Tolerances of Interface to Power Socket

2.1.4 U.S. Military and Federal Standards

Copies of these documents are available online at https://quicksearch.dla.mil.

FED-STD-123	Marking for Shipment and Storage (Civil Agencies)
MIL-STD-129	Department of Defense Standard Practice; Military Marking
MIL-STD-882	Department of Defense Standard Practice for System Safety
MIL-STD-1472	Design Criteria Standard - Human Engineering

2.1.5 Code of Federal Regulations (CFR) Publications

Available from the United States Government Printing Office, 732 North Capitol Street, NW, Washington, DC 20401, Tel: 202-512-1800, www.gpo.gov.

29 CFR 1926.302	Federal Safety and Health Regulations for Construction Power-Operated Hand Tools

2.1.6 ANSI Accredited Publications

Copies of these documents are available online at https://webstore.ansi.org/.

ANSI S1.4-1983 (R-2006)	American National Standard Specification for Sound Level Meters
ANSI S2.73-2013/ ISO 10819:2013 (R-2019)	Mechanical Vibration and Shock - Hand-Arm Vibration - Method for the Measurement and Evaluation of the Vibration Transmissibility of Gloves at the Palm of the Hand
ANSI Z10.0-2019	Safety Management Systems
ANSI/ASA S2.1-2009/ ISO 2041:2009	Mechanical Vibration, Shock, and Condition Monitoring - Vocabulary
ANSI/ASA S2.70-2006 (R-2020)	American National Standard Guide for the Measurement and Evaluation of Human Exposure to Vibration Transmitted to the Hand
ANSI/ASSP Z590.3-2021	Prevention through Design Guidelines for Addressing Occupational Hazards and Risks in Design and Redesign Process
ANSI SNT-101-2015	American National Standard for Power Tools: Safety Requiremetns for Portable Compressed-Air-Actuated Fastener Driving Tools

2.1.7 NFPA Publications

Available from National Fluid Power Association, 3333 North Mayfair Road, Suite 211, Milwaukee, WI 53222-3219, Tel: 414-778-3344, www.nfpa.com.

NFPA 70B, Chapter 29	Portable Electric Tools and Equipment, Training, Tool Maintenance, Cord and Attachment Plug Care, Extension Cords, Major Overhauls, Leakage Current Testing
NFPA 70, Article 250.114	Equipment Connected by Cord and Plug
NFPA 70, Article 400	Flexible Cords and Cables
NFPA 70, Article 406	Receptacles, Cord Connectors and Attachment Plugs (Caps)

2.1.8 UL Publications

Available from UL, 333 Pfingsten Road, Northbrook, IL 60062-2096, Tel: 847-272-8800, www.ul.com.

UL 1097	Double Insulation System for Use in Electrical Equipment
UL 2054	Standard for Household and Commercial Batteries
UL 60745	Handheld Motor-Operated Electric Tools - Safety (part of IEC 60745)

2.1.9 International Electrotechnical Commission (IEC) Publications

Available from IEC Central Office, 3, rue de Varembe, P.O. Box 131, CH-1211 Geneva 20, Switzerland, Tel: +41 22 919 02 11, www.iec.ch.

IEC 60745-1	Handheld Motor-Operated Electric Tools - Safety - Part 1: General Requirements
IEC 62133	Standard Certification for Lithium Polymer Battery

2.1.10 Other Publications

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2.2 Definitions

ANTI-VIBRATION SOCKET: A specific type of power tool socket having dimensional characteristics for maintaining axial alignment with the power tool spindle which can reduce the vibration caused by misalignment.

ANTI-VIBRATION SLEEVE: Sleeve fitting a device for aligning the drive adapter with the axis of rotation of the power tool spindle for the purpose of reducing the vibration caused by misalignment. The sleeve outside of the socket is used to maintain axial alignment and maintain concentricity. The effect is to reduce vibration and wear by minimizing extraneous motion and decoupling the source from the tool. Technical guidance for design is provided in ISO/TS 21108.

ATTACHMENT: A device attached to a tool to convert energy into work through contact with a work piece. Attachments may wear in the process of use, such as grinding wheels, or may be intended for permanent energy transfer, such as a socket used to tighten a nut.

DEAD MAN'S SWITCH. A dead man's switch is a switch that is designed to be activated or deactivated if the human operator becomes incapacitated, such as through death, loss of consciousness, or being bodily removed from control. These switches are usually used as a form of fail-safe where they stop a machine with no operator from a potentially dangerous action or incapacitate a device as a result of accident, malfunction, or misuse. They are common in such applications in locomotives, aircraft refueling, freight elevators, lawn mowers, tractors, personal watercraft, outboard motors, chainsaws, snowblowers, tread machines, snowmobiles, amusement rides, and many medical imaging devices. On some machines, these switches merely bring the machines back to a safe state, such as reducing the throttle to idle or applying brakes, while leaving the machines still running and ready to resume normal operation once control is reestablished.

DECIBEL (dB): The decibel (dB) is a logarithmic unit used to express the ratio between two values of a physical quantity (usually measured in units of sound pressure, power, or intensity). One of these quantities is often a reference value, and in this case the dB can be used to express the relative scale of the physical quantity.

A change in sound power by a factor of 10 is a 10 dB change in level. A change in sound power by a factor of two is approximately a 3 dB change. A change in voltage by a factor of 10 is equivalent to a change in power by a factor of 100 and is thus a 20 dB change (given the resistance unchanged). A change in voltage ratio by a factor of two is approximately a 6 dB change.

dB: Un-weighted level of noise measured in decibels.

dBA: The A in dBA represents the A-weighting factor for noise measured in decibels reflecting the human ear’s response from 55 to 85 dB. Occupational noise exposure is typically reported using the dBA weighting scale.

GROUND FAULT CIRCUIT INTERRUPTER (GFCI): See residual current device (RCD).

HAND-ARM VIBRATION SYNDROME (HAVS): A disabling, preventable occupational disease formerly called “vibration white finger” or Reynaud’s disease. HAVS is reversible, assuming no continuation of exposure; however, continued exposure causing later stage disease leads to a permanent, potentially disabling condition. Consists of both a neurological (sensorineural) and vascular component. (Refer to guidance of ANSI S2.70/ISO 5349-1.)

HIGH EFFICIENCY PARTICULATE AIR (HEPA) FILTER: High-efficiency particulate air (HEPA), also known as high-efficiency particulate absorbing and high-efficiency particulate arrestance, is an efficiency standard of air filter. Filters meeting the HEPA standard must satisfy certain levels of efficiency. Common standards require that a HEPA air filter must remove—from the air that passes through—at least 99.95% (European Standard) or 99.97% (ASME, U.S. DOE) of particles whose diameter is greater than or equal to 0.3 µm.

KICKBACK: The sudden and interrupted movement of the tool or workpiece, which is typically caused by binding or pinching of the workpiece. Kickback is a significant source of potential injuries and requires design and work practice controls to prevent its occurrence.

MACHINE: A device for applying mechanical power to accomplish work through an attachment that interfaces directly with the work piece. Also see tool.

MAINTAINABILITY: Maintainability is the ease with which a product can be maintained in order to correct defects or their cause; repair or replace faulty or worn-out components without having to replace still-working parts; prevent unexpected working conditions; maximize a product’s useful life; maximize efficiency, reliability, and safety; meet new requirements; make future maintenance easier; or cope with a changed environment. In some cases, maintainability involves a system of continuous improvement—learning from the past, to improve the ability to maintain systems, or improve reliability of systems based on maintenance experience.

OBJECTIVE: Optimally achievable performance characteristics which may be established and communicated to prospective vendors as performance objectives. Communication of performance objectives provides an incentive for product improvement within the scope of available technology or practical improvements. In cases where competing performance characteristics are desired, the establishment of lowest acceptable performance thresholds and objectives may create a “trade space” for balancing alternative characteristics.

OCCUPATIONAL HEALTH AND SAFETY MANAGEMENT SYSTEMS (OHSMS): A set of interrelated elements that establish and/or support occupational health and safety policy and objectives and mechanism to achieve those objectives to continuously improve health and safety.

RELIABILITY: Reliability, in engineering, is defined by or concerned with the ability of a system or component to perform its required functions under stated conditions for a specified time.

REACTIVE/REACTION FORCE: A force that acts in the opposite direction to an action force. It can better be described as when one fires a bullet from a gun, they feel being pushed backward. The action force in this case is the gun pushing out the bullet and the reaction is the bullet pushing back on the gun and its holder.

RESIDUAL CURRENT DEVICE (RCD): A device that shuts off an electric circuit when it detects that current is flowing along an unintended path, possibly through a person. This equipment is used to reduce the risk of electric shock. It works by measuring the current leaving the hot side of the power source and comparing it to the current returning to the neutral side. If they are not equal, some of the current is flowing along an unintended path, and the RCD shuts the power off. Also see ground fault interrupter.

SLEEVE: See anti-vibration sleeve.

SOUND PRESSURE/SOUND PRESSURE LEVEL: Sound level is often defined in terms of sound pressure level (SPL or Lp). SPL is the logarithm of the ratio of the absolute (measured) sound pressure and a reference level (20 μPa) and can be calculated using this formula: SPL or Lp = 20*log$^{f()}$ (P/P_0), where P_0 = 20 μPa. The unit of SPL is decibels. Sound pressure level at the threshold of human hearing is 0 dB, which has the same pressure as the reference pressure, 2 x 10^{-5} Pa. SPL can be measured with a sound pressure level meter.

SOUND POWER/SOUND POWER LEVEL: Sound power is the total acoustic power radiated by a sound source per unit of time. The sound source can have different directional characteristics, and if without any reflections and obstructions it can radiate in all directions—that is, covering all 360 degrees. The directivity of sound is also affected by the location of sound source in relation to the reflection surface. Therefore, the sound directivity will affect the radiation distribution of sound power and hence change the intensity of sound received by receivers (e.g., a person or sound meter). The SI unit of sound power is the watt. Sound power can be converted into dB by using this formula: sound power level or Lw = 10*log$^{f()}$ (W/W_0), where W_0 = 10^{-12} W. The reference value 10^{-12} W is the minimal sound power that majority of people can hear (the threshold of human hearing).

SOUND INTENSITY/SOUND INTENSITY LEVEL: Sound intensity is defined as the ratio of sound power and its sphere area radiated at a given point. If sound source is radiated in all directions, sound intensity can be calculated using this formula: sound intensity or I = W/(4πr^2), where r is the distance from sound source to the receiver. The SI unit of sound intensity is the watts/meter^2 (W/m^2). Sound intensity can be converted into dB by using this formula: sound intensity level or L_I= 10*log$^{f()}$ (I/I_0). For a sound source, sound intensity and sound intensity level is distance dependent.

THRESHOLD: Minimum acceptable criteria for a given parameter. A threshold, or minimum acceptable value, may be assigned to parameters such as tool weight, level of productivity, cost, or noise levels. Products not meeting these minimum criteria would be excluded from further evaluation or ultimate purchase. (Note that a threshold might be a higher number than the desired performance object for parameters such as weight or cost.)

SOUND PRESSURE/SOUND PRESSURE LEVEL: Sound level, the intensity of sound at a given point, is defined in terms of sound pressure level (SPL). SPL is the ratio of the absolute (measured), sound pressure, and a reference level (usually the threshold of hearing, or the lowest intensity sound that can be heard by most people).

SPL can be measured with a sound pressure level meter. Sound pressure level uses a logarithmic scale to represent the sound pressure of a sound relative to a reference pressure, and it is measured in units of decibels. The sound pressure level at the threshold of human hearing is actually 0 dB, which has the same pressure as the reference pressure, 2 x 10^{-5} Pa. SPL is measured in decibels, a logarithmic scale, because of the incredibly broad range of intensities humans can hear, in the range of ten million to one between the threshold of normal hearing and noise levels creating acute discomfort and risk of hearing loss. Sound pressure level uses a logarithmic scale to represent the sound pressure of a sound relative to a reference pressure and is measured in units of decibels.

SOUND POWER: Sound power, or acoustic power, is the rate at which sound energy is emitted, reflected, transmitted, or received per unit time. The SI unit of sound power is the watt (W). It is the power of the sound force on a surface of the medium of propagation of the sound wave. The SI unit of sound power is the watt. It relates to the power of the sound force on a surface enclosing a sound source in air. For a sound source, unlike sound pressure, sound power is neither room-dependent nor distance-dependent. Sound pressure is a property of the field at a point in space, while sound power is a property of a sound source, equal to the total power emitted by that source in all directions. Sound power passing through an area is sometimes called sound flux or acoustic flux through that area. Measurements of sound pressure in the area surrounding a noise source are used to calculate total sound power. Sound power levels can be used to compare noise sources independent of their location and predict noise levels in a given setting.

SUSTAINABILITY: A measure of the resources and the impacts/costs of those uses during the life cycle of a product. Factors involved in assessment of sustainability include energy costs for use (e.g., costs of providing compressed air for a pneumatic tool during its estimated life cycle); fiscal costs for maintenance and parts; evaluation of reliability as a determinant of the effectiveness of resource use; and relative freedom from safety and health risk factors that may impair the health and productivity of product users such as noise, vibration, or ergonomic considerations that cause discomfort and inefficiency.

TOOL: A device applying power to a work piece through an attachment. Note that ISO/European standards may define a tool in the same manner as ANSI standards define an attachment to a machine.

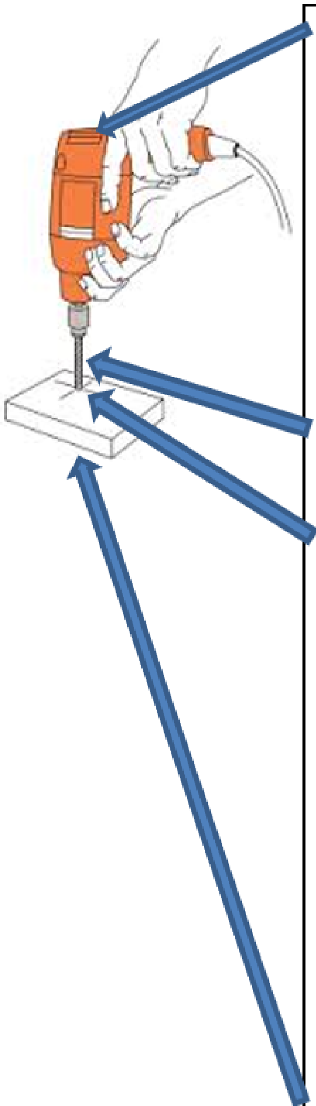
TOOL VIBRATION EMISSION LEVEL: Refers to the level of vibration, measured in accordance with ANSI S2.70, which describes the intensity of vibration during tool operation at the operator's hand without regard to duration of exposure, trigger time, or other normal mitigating factors. Evaluation of user daily vibration exposure depends upon a range of factors such as duty cycle and length of time spent in tool use.

Relationships between tool, attachment, and work piece are illustrated in Figure 1. Terminology commonly used in the U.S. and Canada, reflected in ANSI standards, may differ from common terms employed in Europe and defined in ISO standards.

TOOL POWER SOURCE: Describes the source of mechanical power supplied to the tool to augment or replace human-supplied force required to accomplish work.

Pneumatic tools are powered by compressed air, while electric tools are powered by electricity. Common types of these electric and air-powered hand tools that are used in industry include buffers, nailing and stapling guns, grinders, drills, jack hammers, chipping hammers, riveting guns, sanders, and impact wrenches. Certain tools (typically those intended for outside use in locations remote from power access) are powered by liquid-fueled internal combustion (typically gasoline) engines. Common categories of liquid-fueled tools include chain saws, yard equipment (mowers/leaf blowers/string trimmers), concrete saws, and drills (including post hole diggers). Certain tools, typically designed to yield maximum levels of torque at relatively low operating speed, are operated hydraulically. These may include prying tools, hammers, cutters and rams, and impact wrenches.

TOTAL COST OF OWNERSHIP: Total cost of product procurement, use, maintenance, support, and potential costs associated with hazards intrinsic to the operation. Safety and health risks should be considered in total costs of ownership. In general, tool procurement is a small fraction of the total life-cycle cost for a power hand tool.



Tool (ANSI) [**machine -** ISO] ISO 11148-1:2011(en)

ISO defines a **handheld power tool** as a machine operated by one or two hands and driven by rotary or linear motors powered by compressed air, hydraulic fluid, gaseous or liquid fuel, electricity, or stored energy (e.g., by a spring) to do mechanical work and so designed that the motor and the mechanism form an assembly that can easily be brought to its place of operation.

Note 1 to entry: Handheld power tools driven by compressed air or gas are called pneumatic tools (or air tools). Handheld power tools driven by hydraulic liquid are called hydraulic tools.

ISO defines a **machine interface** (between tool and attachment) drill bit for this type of tool.

ISO defines **inserted tool** as a tool inserted in the assembly power tool for non-threaded mechanical fasteners to perform the intended work (may also be described as a tool inserted into the power tool to perform the intended work).

ISO defines **drive adapter** (specifically for power tools for driving threaded fasteners) as an implement fitted to the power tool to drive the threaded fastener.

Attachment (ANSI) or **implement** [**tool** - ISO] bit

ISO defines **sleeve fitting** (specifically for power tools for driving threaded fasteners) as a device for aligning the inserted tool or drive adapter with the axis of rotation of the power tool spindle which can reduce the vibration caused by misalignment.

ANSI B186.1 defines **implement** as an accessory or attachment, intended by its manufacturer for use with a power tool, specifically designed for transmitting the output power of the tool to the work piece.

ANSI defines **work piece** as the object being modified by action of the tool. In the case of an extremely large surface being machined, the work piece may be the entire substrate, such a section of ship hull being welded in a shipyard.

Figure 1 - Relationship between tool (machine), interface, and attachment (comparison of ANSI and ISO 11148-1:2011(EN) terminology)

WORK PIECE: For the purposes of this standard, an item which is modified by application of directed force exerted by a tool. A finished product or repaired work piece is developed as the product of this process.

UNBALANCED FORCE: Unbalanced forces are forces that produce a non-zero net force, which changes an object’s motion. The result of an unbalanced force is acceleration of an object. It can better be described as a book at rest on a tabletop. There are two forces acting upon the book. One force—the Earth’s gravitational pull—exerts a downward force. The other force—the push of the table on the book—pushes upward on the book. The book is at equilibrium and is balanced, but if it is shoved across the table and is moving without being touched, then the book is no longer at equilibrium and falls to the floor.

USER TOTAL DAILY VIBRATION EXPOSURE: User’s total daily vibration dose evaluated in accordance with guidance of ANSI S2.70, which considers intensity of vibration exposure, frequency-related weighting, duration of exposures, and combined exposures related to use of multiple tools, if relevant.

VIBRATING TOOLS: All power hand tools are subject to some degree of vibration related to unbalanced forces and, in some types of tools, to impact and percussive operation. The level of potential risk to users is associated with the intensity of vibration and length of use. Factors such as impulse vibration exposures, and concurrent exposures to cold/damp and other ergonomic stressors such as unbalanced forces, static and/or awkward postures, and wrist deviation may potentially compound the effects of vibration or lead to other ergonomic stresses and potential health problems and limits on productivity and comfort.

For the purposes of this standard, vibrating tools are defined as those which may plausibly expose their users to potentially harmful levels of hand-arm vibration. In general, vibration exposures to the hands below a time-weighted value of 2.5 m/s^2, or half the daily exposure limit value specified in the European Directive 2002/44/EC for physical agents (vibration) and ANSI S2.70/ISO5349-1, is considered safe for prolonged daily exposure of up to 8 hours/day for a majority of worker populations.

Significance of vibration exposures: Hand-arm vibration exposure levels with time-weighted value of between 2.5 m/s^2 and 5.0 m/s^2 the European Union Occupational Exposure Standard for an 8 hour time-weighted average (TWA) should be evaluated with caution, but are considered safe for most users.

Vibration levels above 5.0 m/s^2 are considered high and need to be limited by reduction of exposure time or selection of lower vibration tools and processes. Concurrent stress factors such as cold exposure to the hands and other ergonomic stressors should also be carefully monitored and minimized.

VIBRATION EMISSION: For the purposes of this standard, the level of vibration created by the powered tool at the site of exposure—typically the worker's hand. Vibration emission may be strongly influenced by test method and evaluation during application of actual or simulated work and interaction with the work surface.

VIBRATION TOTAL VALUE: Total dose of vibration value made with three axis vibration measurement in accordance with ANSI S2.70.

If the vibration total value, $a_{hv(rms)}$, associated with the hand-transmitted vibration exposure of a worker is made up of several operations, each with different vibration magnitudes, then the vibration total value shall be obtained from Equation 5 in ANSI S2.70 as shown below:

$$a_{hv(rms)} = \sqrt{\frac{1}{T_v} \cdot \sum_{i=1}^{n} \left(a_{hv(rms)i}^2 \cdot T_i\right)} \quad \text{(Eq. 1)}$$

where:

T_v = the total daily duration in hours associated with the n operations

$a_{hv(rms)i}$ = the vibration total value of weighted root-mean-squared (rms) acceleration of the i^{th} operation

T_i = time duration in hours of the i^{th} operation

n = the total number of operations

2.3 Symbols, Acronyms, and Terminology

$a_{tv(rms)}$: Total vibration value, root-mean-squared value derived from the sum of three axis measurement, as shown in Equation 2.

ahy: Total vibration value (ISO 5349-1 terminology).

T_i: Time in duration of the i^{th} operation (of number being evaluated).

n: Number of operations evaluated.

T_O: Total time of exposure (ISO 5349-1).

T_v: Total time in hours associated with n operations.

Equation 2 is the total daily vibration exposure, as defined in ANSI S2.70.

The vibration total value, $a_{hv(rms)}$, for a single operation that involves hand-transmitted vibration exposure shall be obtained from the root-sum-squares of the measured rms. ISO frequency-weighted acceleration values in the x, y, and z directions, as shown in Equation 2. The vibration total value, $a_{hv(rms)}$:

$$a_{hv(rms)} = \sqrt{a_{hwx}^2 + a_{hwy}^2 + a_{hwz}^2} \quad \text{(Eq. 2)}$$

where:

$ahwx_{(rms)}$, $ahwy_{(rms)}$, and $ahwz_{(rms)}$ = the measured rms

ISO frequency-weighted acceleration magnitudes in the x, y, and z directions, respectively.

If the vibration total values, $a_{hv(rms)}$, associated with the hand-transmitted vibration exposure of a worker is made up of several operations, each with different vibration magnitudes, then the vibration total value shall be obtained from Equation 3:

$$a_{hv(rms)} = \sqrt{\frac{1}{T_v}\sum_{i=1}^{n}\left(a_{hv(rms)i}^2 T_i\right)} \quad \text{(Eq. 3)}$$

where:

$a_{hv(rms)i}$ = the vibration total value of the i^{th} operation

T_i = time duration in hours of the i^{th} operation

n = the total number of operations

T_v = total time in hours associated with the n operations

3. NOTIONAL GUIDANCE FOR PROCUREMENT EVALUATION OF POWERED HAND TOOLS FOR PRODUCTIVITY, SUSTAINABILITY, LIFE-CYCLE COST, AND SAFETY/HEALTH FACTORS

3.1 Process Evaluation and Selection for Safety and Efficiency

The process of evaluation for power tools should include a broader process assessment to ensure the appropriate and most efficient/safest process is being employed and that technology employed considers quality and efficiency. Concurrently, the tool manufacture's guidance should be consulted to ensure that the proposed tool and process is appropriate for the operation(s) being considered.

Examples of process selection, provided for purposes of illustration, include:

- Use of an automated grinding assembly to finish the flange edges of large diameter metal pipes, as an alternative to manual grinding. The operation saves significant labor costs for any pipelaying operation and minimizes personnel exposures to noise, hand-arm vibration, metal dusts and ergonomic stresses.

- Use of a vehicle-mounted pavement braker rather than individual use of jackhammers to break pavement prior to replacement. A typical project for a demolition of a small parking lot saved a week's worth of manual labor and concurrently avoided severe exposures to hand arm vibration, while minimizing concrete dust (chromium and silica) exposures.

- Quality management should be an integral element of process design.

Examples of quality management which minimize occupational exposures and reduce work time, provided for purpose of illustration, include:

- Improved casting quality in a foundry reducing the amount of flashing requiring subsequent removal by hand grinding.
- Proactive tool maintenance, literally sharpening of saws, to improve speed and precision of cutting while also reducing vibration and noise.
- Tool balancing as a part of maintenance to reduce vibration and improve precision during fabrication or machining of parts.

3.2 Notional Guidance for Weighting of Evaluation Factors

This section provides guidance for applying the rating factors described in the body of the standard using Table 1 to develop a notional system that can be used for semi-quantitative comparative evaluation of similar tools. This section is intended only as a guide. Minor differences in scoring between alternative products should not be considered an absolute measurement of their relative effectiveness or suitability. In APPENDIX A, Sections A.2 and A.3 provide guidance for evaluation of factors specific to particular uses and categories of tools.

3.3 Steps in the Evaluation Process

The recommended process is described in five steps, detailed below.

Step 1: Review/determination of relative weighting of key product selection factors from Tables 1 and 2. This may require identification of threshold criteria essential to safety, productivity, and quality. Products failing to meet such requirements would be excluded from further consideration. (Also see APPENDIX B.)

Step 2: Develop a summary table applying relative weighting factors for each major element and linking to evaluation of a particular vendor's product.

Step 3: Identify the tool or tools to be evaluated.

Step 4: Assign specific evaluation criteria for each sub-element.

Step 5: Compile data comparing alternative products and select alternatives.

User evaluation and field experience provide the ultimate measurements of quality and effectiveness. Use of APPENDIX A may provide suitable preliminary evaluation and a possible pre-selection ("screening") tool for selection of products for detailed on-site user evaluation.

APPENDIX A provides detailed guidance for user evaluation of alternative power hand tools under workplace conditions. Noise and vibration measurements should accompany worker evaluation. Both noise and vibration levels are likely to differ significantly between laboratory evaluations and workplace operations. Work practices of individual operators also introduce significant variability. APPENDIX A also provides detailed alternative formats for worker evaluation of alternative powered hand tools. Atlas Copco (2014) summarizes approaches to laboratory and workplace evaluation of vibration and noise and describes the variability of workplace vibration levels relative to laboratory test environments.

Table 1 - Notional guidance on weighting factors for tool evaluation

Factor	Relative Weighting	Notes
Productivity	20% (20 of 100 possible points)	Sub-factors may include cycle time, amount of material removed, and time to accomplish a specific amount of work. In general, tasks used for evaluation should be common to the industry and representative of the type of application projected for the tool(s) being procured. Where feasible, they should be the same as work tasks used to evaluate noise and vibration in the NIOSH and/or European Union databases. Units of work need to be identified but must be task/job specific. Productivity requires a definition common to a specific type of task and should be described in the test report.
Ergonomic factors other than shock and vibration	20% (20 of 100 possible points)	CCOHS (2015), Hedge (2013), NIOSH (2004), and Lindqvist and Skogsberg (2022) should be considered as initial basis for criteria. Considerations may include deviation of wrist from neutral position; balance of tool; area of trigger (and force necessary to activate tool). Where risk criteria cannot be measured independent of a specific work process, evaluation criteria should be associated with assessment of prospective stresses that would be experienced in a setting representative of the category of work to be accomplished, but reproducible in a laboratory environment. Specific factors may include factors shown in Table A1.
Noise	10% (10 of 100 possible points)	Report sound levels obtained in a representative setting in decibels un-weighted (dB) and weighted dBA. Octave band data are preferred. Where feasible, sound power data should be obtained and reported. Guidance of ISO 15744 or other accepted testing standard should be used and described in the report. Vendor's declared values might be used as initial estimate but should be subject to verification. (Suitable penalties for significant misstatement would need to be applied, potentially including product disqualification.) Noise exposure evaluation may also be linked to the noise dose experienced during performance of a given amount of work. For example, one tool may create noise levels of 94 dBA, but allow completion of a set task in 30 minutes; another might create noise levels of 91 dBA but require 60 minutes to accomplish the same task. A valid comparison would consider the total fraction of allowable daily noise experienced during the required time period. Using an 8 hour allowable time-weighted average of 85 dBA, the quieter tool would create 50% of the allowable dose (1 hour or 2 hours exposure allowable at 91 dBA), while the noisier tool would also create a 50% of the allowable daily dose while accomplishing the same task (1.0 hour/1 hour allowable at 94 dBA).
Hand-arm vibration	20% (10 of 100 possible points)	Depend on relative contribution as a risk factor. For example, tools typically operating below 2.5 m/s^2 might have 5% of the evaluation based on vibration levels. Tools operating in the range of >5.0 m/s^2 would have 10% of the evaluation based on vibration levels. Information from EU and NIOSH databases may be used. (See Section 2.) Vendor's declared values might be used as initial estimate but should be subject to verification. (Suitable penalties for significant misstatement would need to be applied, potentially including product disqualification.) Correction factors for different tool types and work tasks should be considered where the vibration test code provides an evaluation under conditions significantly different than the intended applications. Shock reaction (reactive torque) at end of tool cycle is minimized. Measured in accordance with ISO 28927 and evaluated by criteria of Lindqvist (1993) (ideally less than 10 Newton-seconds). Vibration exposure evaluation may also be linked to the hand arm vibration dose experienced during performance of a given amount of work. This dose depends both on the absolute (uncorrected) intensity of vibration exposure created during performance of a selected task as well as the effective "trigger" time. The so-called duty cycle—fraction of time in which the tool is operating—should be considered to evaluate the fraction of time exposed to vibration (and/or noise) during the work period. Total vibration dose might be computed in allowable "points" on a maximum scale of 400/day in accordance with European Union guidance.

Factor	Relative Weighting	Notes
Initial procurement cost	5% (5 of possible 100 points)	May depend on anticipated lifespan of tool and intensity of use (for example, occasional, periodic, daily).
Five-year operational cost	10% (10 of possible 100 points)	Factors to consider include: ▪ Initial procurement cost ▪ Cost of manpower to produce a given level of output ▪ Reliability, and maintainability of the tools ▪ Parts required for recommended maintenance (note that maintenance costs may be initially estimated on the basis of manufacture recommendations, but where feasible should be supplemented by field experience) ▪ Costs of storage of spare parts and back up tools ▪ Cost of scrapping or decommissioning of tools ▪ Potential "hidden costs" associated with unplanned production stoppage when a tool fails in production
Cost to produce given quantity of work including utility costs	5% (5 of possible 100 points)	Clearly defined representative tasks would need to be identified. In general, these should be the same tasks and processes described in the NIOSH and European Union databases for noise and vibration. Typically, there is a cost for compressed air or other utilities. General formulas for calculation of compressed air cost: (Tool air consumption in M^3/hour) x (work time in hours/day/tool) x power required in kWh for compressor to produce 1 M^3 air at 7.5 bar (110 psi) 1 M^3 = 28.3 ft^3 Rule of thumb: 1 M^3 requires approximately 0.105 kWh. Refer to Atlas Copco (n.d.).
Physical safety factors	10% (10 of possible 100 points)	Certain physical safety factors are likely to be a minimum condition (threshold) for procurement. Tools without essential safety features shall not be purchased. As such, minimum essential safety factors do not contribute to this numerical scale. Such safety factors may include suitable interlocks to prevent operation when guards are not present, ground fault interruption or dual isolation, machine guarding, and other design considerations that are required by regulation, industry standards, and/or the needs of a specific type of work. A dead man control (automatic shut off) is often needed to ensure automatic shut off when the operator is disabled or inattentive. Other factors to consider include: ▪ Factors that minimize the potential for accidental activation ▪ Designs to prevent electrical failure and/or short to ground ▪ Factors to prevent contact with moving parts
Possible Supplemental Factors (User's hands-on evaluation is not always available for small quantity purchase or for preliminary screening of alternative products)		
User preference	15% (above baseline score)	While user preference is notionally assigned a point value of 15% additional to the scoring factors above, in practice, user preference is likely to be an essential component of purchasing decisions. APPENDIX B provides guidance for formal user evaluation and feedback related to tool use. NIOSH evaluation provides good prototype for worker review of product including comfort and perceived productivity considerations. Note that basic user acceptance may also be a requirement for procurement of numbers of products above a key threshold of cost/quantity.

3.4 Ergonomic Factors

Table 2 provides guidance for identification of ergonomic factors within the framework of tool evaluation. Because ergonomic factors are process-dependent, their selection and relative weighting should be adapted to the situation being evaluated. A notional weighting of ergonomic factors related is provided to facilitate consideration in tool procurement and use. The selection and relative weighting of these and potentially other factors may depend upon the application and user needs and preferences. For example, the relative importance of tool weight is greatly increased if a tool is relatively heavy and the process requires that it be held above the head.

Users are also advised to refer to checklists or other guidance for presence of ergonomic stress or risk factors. Potential prevalence of risk factors for a particular task suggests that the relative weight assigned to that parameter should be increased.

Table 2 - Notional weighting of ergonomic factors

Ergonomic Factors for Consideration		
Sub-Factor	**Criteria**	**Relative Weighting (Notional figures are provided. Factors used may depend upon the application.)**
Power to weight ratio		
Weight	Weight in pounds or kilograms.	May be reduced in importance if provision can be made for suspending tool.
Handle design and support surface	Minimize wrist deviation, non-heat conductive material, grip size consistent with user population. Material is relatively soft within user criteria for comfort. Vibration attenuation may be a factor in selection.	MIL-STD-1472 criteria for anthropomorphic data.
Trigger design and activation	Maximum feasible area (for example, use of multiple fingers versus single finger), trigger minimum necessary to provide user feedback while avoiding fatigue. Provision of automatic or fixed trigger activation where it is safe to do so.	Safe trigger activation is likely to be threshold (basic necessary) criteria for certain tools, such as nail guns and specific operations where one hand is used to secure the work while the tool is operated with the other hand.
Contact temperature—low thermal conductivity (handle is neither hot nor cold)	Thermal conductivity typically in the range of 0.5 W/mK (similar to wood or human skin). Pneumatic blow off is directed away from the hands. Key consideration in prevention of hand-arm vibration syndrome.	
Tool balance	Tool is neutrally balanced when suspended from point of grip. Where pneumatic hoses or other utilities are required, these may be counterbalanced.	The tool may be suspended mechanically at the hand grip point of grip without becoming unbalanced. Subjective evaluation of “balance” by users holding the tool in a position consistent with typical use. Where pneumatic hoses or other power sources are required for operation, their contribution to balance/unbalancing of a neutral position shall be considered.
Optimal feed force required to safely conduct tool operations	As low as reasonably feasible consistent with need to ensure safety and quality (minimize potential for user injury or damage to work).	Feed force may be estimated by use of tool and work piece on a scale. The difference between weight when user is operating (for example, drilling) and the tool is not operating. Feed force may be best evaluated as a comparative measure to estimate the force required to operate two or more similar tools.

Ergonomic Factors for Consideration		
Sub-Factor	**Criteria**	**Relative Weighting (Notional figures are provided. Factors used may depend upon the application.)**
Dust and oil release created by tool operation (This is distinct from dust released from grinding or other interaction with the surface being machined, cut, or otherwise modified by the tool operation. Dust control is likely to be a separate evaluation criterion when hazardous particulate is released during a particular operation and/or process.)	Depends upon application.	Criteria for dust and oil release depend on application, source of compressed air and provision for tool lubrication, such as graphite rotating components allowing for "oil less" operation.

3.5 Noise and Vibration

Step 1: Review the notional guidance for relative weighting of key product selection factors in Tables 1 and 3 to ensure suitability to the operation/application and products being considered. Note that some tools with higher levels of productivity, as measured by the time required to accomplish a given task, may have higher levels of noise and vibration measured during the work cycle. However, a significantly shorter work period may result in lower total exposures. Tables 5 and 6 provide a comparative example. Whenever available, European data sources should be consulted including the noise and vibration required by European Union regulations.

Table 3 - Tool evaluation weighting factor calculation[(1)]

Tool Type	**Manufacturer**	**Model**	**Accessories/Tool (example: 4 inch disc)**		**Notes on Tool**
Factor	**Weighting Factor**	**Score (1-10) (1 lowest/ worst, 10 best possible score)[(3)]**	**Weighted Score (Weighting factor x score)**	**Factor Score[(2)]**	**Notes** **-**
Productivity	2 (20% of total possible score)				
Ergonomics	2 (20% of possible score)				
Noise	1 (10% of possible score)				
Hand-arm vibration	20 (20% of possible score)				
Initial procurement cost	0.5 (5% of possible score)				
Five-year operating cost	1 (10% of possible score)				
Utility cost	0.5 (5% of possible score)				
Physical safety factors	1 (10% of possible score)				
Total (sum of factor scores):					
Optional: User acceptance (additional factor above initial rating)	1.5 (additional 15% of possible score)		1.5		
Total (with user acceptance):					

(1) All ratings are subject to verification. If vendor's products differ markedly from advertised values, then contact should be made to ask for explanation of the difference. If response and/or data are not satisfactory, then reconsideration should be given to procurement, potentially including temporary or permanent disqualification.

(2) Highlighted area may be incorporated into an imbedded Excel table providing "automatic" calculation at a later date or in separate software.

(3) Give the highest observed or reported value a score from 1 to 10. If you are not fully satisfied with the best evaluated product, you may give it a score below 10. When alternative products are compared, each should receive a rating for each factor. For example, if rating productivity of a grinder you may monitor the time required to remove a certain amount of material or conduct a specific job. Describe details of how the measurements made so that a consistent comparison can be made with other products at a later time.

Step 2: Develop a summary table applying relative weighting factors for each major element and linking to evaluation of a particular vendor's product. Tables 5 and 6 provide a notional example.

Each element will receive a semi-quantitative score ranging from 1 (worst or lowest) to 10 (highest or best possible). The weighted score will reflect the relative weighting of each factor times the score for each element. For example, a product that received a score of 5 (out of a possible 10) for productivity would receive a score for that factor of 5 x 4 or 20 points (out of a possible 40 points).

Table 4 provides a notional example in which rating of each characteristic were applied to give a total rating for a particular product.

Table 4 - Notional example of tool evaluation applying weighting factor calculation[(1)]

Tool Type	**Manufacturer**	**Model**	**Accessories/Tool**	**Notes on Tool**	
Sander	**XYZ Mfr**	**Sand Fast**	**4 inch disc**	**Notional Example Only**	
Factor	**Weighting Factor**	**Score (1-10) (1 lowest/worst, 10 best possible score)[(3)]**	**Weighted Score (Weighting factor x score)**	**Factor Score[(2)]**	**Notes[(1)]**
Productivity	2 (20% of possible score)	5	2 * 5	10	(2)
Ergonomics	2 (20% of possible score)	6	2 * 6	12	(3)
Noise	1 (10% of possible score)	7	1 * 7	7	
Hand-arm vibration	2 (20% of possible score)	8	2 * 8	16	(4)
Initial Procurement cost	0.5 (5% of possible score)	6	0.5 * 6	3	
Five-year operating cost	1 (10% of possible score)	5	1 * 5	5	
Utility cost	0.5 (5% of possible score)	6	0.5 * 8	3	
Total (sum of factor scores): 58 (of potential 100 points)					
Optional: User acceptance (additional factor above initial rating)	1.5 (additional 15% of possible score)				
Total (with user acceptance):					

(1) The basis of productivity measurement or other evaluation factors are not shown in this example. The numbers provided are used entirely for purposes of illustration. More detailed examples are provided in step 4 below.

(2) In the example above, a score of 5 points (of a possible 10) is assigned to a specific tool on the basis of its performance in the area of productivity). Since productivity is rated as 20% of the total score, a "multiplier" factor of 4 is used to calculate the contribution of productivity to the rating of this product. 5 x 2 = 10 points (of a total possible 20 in the category of productivity).

(3) In the example above, a score of 6 points (of a possible 10) is assigned to a specific tool on the basis of its evaluation in the area of ergonomics). Since ergonomics is rated as 20% of the total score, a "multiplier" factor of 2 is used to calculate the contribution of productivity to the rating of this product. 6 x 2 = 12 points (of a total possible 20 in the category of productivity).

(4) Correction factors for different tool types and work tasks should be considered where the vibration test code provides an evaluation under conditions significantly different than the intended applications.

Step 3: Identify the tool to be evaluated.

This is likely to require identifying the operation and/or process(es) most relevant to your procurement effort.

A nominal example of a 6 inch pneumatic grinder used for finish grinding of welding beads chosen for purposes of illustration. The case used should be relevant to the production setting, but sufficiently reproducible for comparative evaluation. Manufacturer's data should be obtained but may require verification/validation.

Where field testing of noise and vibration is not practical, standard data obtained from European Union or NIOSH sound and vibration databases should be considered.

Description of operation: Finish grinding to remove welding bead from SMAW (arc) welding using 3/8 inch 6010 electrode on mild steel base metal. Butt weld jointing two plates of 1 inch thick low carbon mild steel. The material to be removed is approximately 1/2 inch high and 3/4 inch wide. Optimal time for finish grinding to flat surface is estimated to be 15 minutes/linear foot using a 6 inch circular grinder. For purposes of consistency, a working level of 36 inches—approximately waist height—may be chosen.

Step 4: Assign specific evaluation criteria for each sub-element.

Semi-quantitative rating factors: Evaluation criteria will provide a semi-quantitative rating scheme for each factor. Since these are relative and semi-quantitative, their suitability should be considered on a “common sense” basis and potentially adjusted, if appropriate. The process of describing fair and realistic evaluation criteria is apt to be iterative.

Thresholds and objectives: A decision may be made to exclude products not meeting minimum criteria in given areas. A “threshold” or minimum acceptable value may be assigned to parameters such as tool weight, level of productivity, or noise levels. Products not meeting these minimum criteria would not be considered for further evaluation or ultimate purchase. For purposes of illustration relevant to this example, grinders weighing more than 15 pounds generating more than 110 dBA under standard conditions or creating more than 12 m/s^2 vibration would not meet a procurement threshold and would not be considered for purchase.

A design characteristic excluding a product from purchase consideration might be air exhaust (blow-off) from a pneumatic tool directed at the hands of the operator. The absence of Undewrighters Laboratory (UL) or comparable third-party safety testing for specific electric tools should disqualify a product from consideration.

Desired optimal achievable performance characteristics may be established and communicated to prospective vendors as performance “objectives.” Communication of performance objectives provides an incentive for product improvement within the scope of available technology or practical improvements. For purposes of illustration relevant to this example, performance objectives might be communicated to vendors such as grinders weighing less than 8 pounds generating less than 88 dBA under standard conditions or removing 20 ounces of welding bead within a 15-minute work period.

In cases where competing performance characteristics are desired, the establishment of thresholds and objectives may create a “trade space” for balancing alternative characteristics. For purposes of illustration relevant to this example, thresholds and objective for a 6 inch diameter pneumatic grinder are illustrated in Table 5.

Table 5 - Notional example of performance criteria for portable 6 inch pneumatic grinder

Performance/ Section Criteria	Threshold	Objective	Remarks
Productivity	Removal of 12 ounces of mild steel in 15 minutes	Removal of 20 ounces of mild steel in 15 minutes	Related criteria might include output in watts or time to complete a specified level of production. Power is often related to weight of motor and other components so that productivity may conflict with lower weight as optimal performance parameter.
Weight	14 pounds	8 pounds	Weight is a significant ergonomic stressor in this application. However, a certain mass is necessary to damp transient motion and vibration. Alternative approaches to minimizing weight while limiting transmitted inertial movement may include combined use of finer grit and faster rotational speed and use of certain tools with self-balancing features.
Noise	110 dBA	88 dBA	Certain noise controls depend on mass damping. Lowered desired weight would stimulate alternative control approaches such as mechanical isolation and better-balanced components. Transmitted vibration would also tend to be reduced by these control approaches.

Notional evaluation schemes are provided in Tables 6 through 12.

Step 5: Nominal example for productivity evaluation.

Operation: Finish grinding to remove welding bead from SMAW (arc) welding using 3/8 inch 6010 electrode on mild steel. Butt weld jointing two plates of 1 inch thick low carbon mild steel. Material to be removed is approximately 1/2 inch high and 3/4 inch wide. Optimal time for finish grinding to flat surface is 15 minutes/linear foot using a 6 inch circular grinder.

Table 6 - Notional example of productivity evaluation

Time to remove 12 inches (minutes)	20	18	17	16	15	14	13	12	11	10
Weight removed (ounce) in 15 minutes	10	11	12	13	14	14.5	15	16	18	20
Score	1	2	3	4	5	6	7	8	9	10
Multiplier 2 x score					10		14	16		
Products evaluated (in example)					Tool 2		Tool 3	Tool 1		

It is decided to base productivity on the time required to accomplish a standard task: removal of 12 inches of welding bead. A notional score ranging from 1 (lowest) to 10 (highest) is assigned to reflect the anticipated range of productivity. Because of the relative importance of productivity, a multiplier of 2 is assigned. This assumes an “ideal” product could potentially achieve a total score of 20 points for productivity and a total combined score of up to 100 points for all factors being considered.

Notional case study: In this case, three tools were tested under comparable conditions. Tool #1 took only 12 minutes to complete the task and rated 8 (of a possible 10) points. When multiplied by 2, the total productivity “score” of 16/20 was recorded for this product.

Tools 2 and 3 required 15 minutes and 13 minutes, respectively, to complete the same task and rated scores of 10 and 14, respectively, on a possible scale of 20 points.

Ergonomics (ergonomic factors other than shock and vibration): A wide range of factors might be considered. However, for purposes of this simplified example, weight of the tools is used as criteria to represent what users might consider the most important features supporting comfort and productivity. The range of weights for alternative products are identified and semi-quantitative “scores” are assigned with lower weight being ranked “better” or receiving a high rating on a scale of 1 to 10 than heavier tools.

Other alternatives which might be considered include semi-quantitative evaluation of ergonomic stresses and risk factors evaluated by on-site evaluations for hand arm stress such as the rapid upper limb assessment (RULA) or whole-body/postural stress such as the rapid entire body assessment (REBA).

Table 7 provides a notional example of application to ergonomic factors in tool evaluation. In this simplified case, only the weight is considered.

Table 7 - Notional example of ergonomic factors considered in tool evaluation

Tool weight (pounds)	15	14.5	14.0	13	13.5	12.0	11.5	11.0	10.5	10.0
Score assigned	1	2	3	4	5	6	7	8	9	10
Multiplier (2 x score) (20% of total)	2	4	6	8	10	12	14	16	18	20
Weight of tools evaluated			Tool 2 14.1 pounds				Tool 3 11.4 pounds	Tool 1 11.2 pounds		
Assigned score (20 points possible best rating)			6 points				14 points	15 points		

In this case, Tool 1 had the lowest weight (11 pounds) and was assigned a score of 15 points (of a possible 20). (The score of 15 fell between possible ratings of 14 for an 11.5-pound tool and 16 for an 11-pound tool.)

Tool 2 was the heaviest at 14.1 pounds and was accordingly ranked the lowest (6 points on a scale of 20).

Tool 3 weighed 11.4 pounds and was ranked second with a score corresponding to 14 points on a scale of 20.

3.5.1 Noise

The conditions of measurement should be described so that a comparison can be made of products performing the same job. A sample scoring system is provided for purposes of comparison. Where such data is not available and/or cannot be obtained readily, reported values in the NIOSH and/or European Union data bases should be considered. These databases may also be consulted for purposes of initial product screening. Table 8 provides an example of where alternative products were evaluated performing the same task.

Because noise rating is assigned a factor of 10% of the total product score, ratings of 1 (worst) through 10 (best) were assigned based on user knowledge regarding available products. Table 8 provides an illustrative example of the evaluation of alternative tools based on noise measured during a representative operation.

Table 8 - Notional evaluation of alternative noise levels in portable grinding operation

Sound level (dBA)[(1)]	≥115	112	108	105	102	99	96	93	90	87
Score (highest possible rating of 10)	1	2	3	4	5	6	7	8	9	10
Multiplier 1 (10% of total score)	1	2	3	4	5	6	7	8	9	10
Products evaluated and sound level					Tool 3 101 dBA		Tool 2 97 dBA			Tool 3 88 dBA

(1) Sound level measurements are obtained at the operator's position during the performance of a work task. They represent instantaneous, direct measurements rather than time-weighted average daily exposures. The potential attenuation of hearing protective equipment should not be considered in this evaluation because of the need to focus upon engineering control measures and the wide variability of the effective noise reduction rating provided by personal protective equipment.

In the simplified example above, only sound level measurements made at the operator's position during tool operation are considered. Alternatively, the fraction of daily allowable noise dose sustained while performing a particular task might be estimated on the basis of operator noise exposure and work time required to complete the relevant task.

3.5.2 Hand-Transmitted Vibration

For vibration, a lower measurement of acceleration in m/s^2 score is preferable. Tables 9 and 10 provide a higher (better) score for tools/processes that expose the operators to lower levels of vibration. A sample scoring system is provided for purposes of comparison.

Ensure that the conditions of measurement should be described so that you are comparing products that are performing the same job under similar conditions. NIOSH or European Union data for similar products may be used in the absence of on-site measurements or considered for initial product screening. The European Union requires a noise and vibration declaration which should be obtained and consulted whenever feasible. Vendor's reported data should be considered but needs to be subject to independent verification.

Tables 9 and 10 provide notional examples of vibration evaluation methodology used for power tool selection.

Table 9 - Evaluation approach for tool vibration based on transmitted vibration level

Vibration level m/s^2 [(1)]	16	14	12	10	8	6	5	4	3	2
Score (on possible scale of 10)	1	2	3	4	5	6	7	8	9	10

(1) Measurement must be made in a manner consistent with ISO standards and appropriately documented.

Alternatively, evaluators may choose to rate the tool by the length of time it may be operated without exceeding EU standards 5 m/s^2 (8 hour time-weighted average). In this case, a higher score could be preferred. Table 10 illustrates use of allowable operating time as the vibration evaluation criteria for alternative tools.

Table 10 - Notional rating criteria for power tool vibration based on allowable period of exposure

Vibration level m/s²	16	14	12	10	8	6	5	4	3	2
Allowable work time(1)	45 minutes	1 hour	1.5 hours	2 hours	3 hours	6 hours	8 hours	9 hours	>9 hours	>9 hours
Score	1	2	3	4	5	6	7	8	9	10

(1) Measurement must be made in a manner consistent with ISO standards and appropriately documented.

Use the formula $A(8) = a_{hv} = (T_{task}/T_0)$ (based on allowable daily exposure of 5 m/s^2 on an 8 hour average, using only the tool being evaluated).

Addressing the balance between productivity, time on task, and relative noise and vibration levels. Note that some tools with higher levels of productivity, as measured by the time required to accomplish a given task, may generate higher levels of noise and vibration measured during the work cycle. However, a significantly shorter work period may result in lower total exposures. Table 11 provides a comparative example of a case where a more productive tool may have higher measured levels of noise or vibration, but create a similar or lower total exposure because of reduced required time to perform a comparable task. Use of these types of comparative exposure estimates requires that the employer limit exposure time to ensure that total worker exposures remain at the lowest levels consistent with economic requirements, regulatory compliance, and accepted practice.

Table 11 - Balancing productivity, time on task, and relative noise and vibration levels

Tool	**Time Required for Given Task**(1)	**Labor Cost to Accomplish Task (Based on loaded labor of $75/ hour)**	**Noise Level During Task (dBA)**	**Noise Dose During Task (Using 85 dBA 8 hour TWA as 1.0)**(2)	**Vibration Level During Task**	**Total Vibration Dose (Using 5 m/s² averaged over 8 hours)**(3)
A	60 minutes	$75	98 dBA	2.0	8 m/s²	33% (Allowable work time is 3 hours/day)
B	120 minutes	$150	94 dBA	1.0	6 m/s²	33% (Allowable work time is 6 hours/day)

(1) A notional task of drilling ten holes, each 3/4 inch wide and 6 inches deep in concrete is used for comparative purposes. Silica exposures, and possibly chromium CrVI, would also be a critical parameter, though not described in this example.

(2) Allowable exposure limits using 85 dBA with 3 dB doubling 8 hour TWA as 1.0 dose. For detailed information, refer to Appendix B of Ontario (2021).

Sound Level dBA	**Exposure Time Permitted in Hours to Reach Equivalent of 8 hour Exposure of 85 dBA**
85	8
88	4
91	2
94	1
97	0.5
100	0.25

(3) For vibration exposure periods permitted under ANSI S2.70, see Table 10.

3.6 Initial Procurement Cost

A notional value of 5% of the weighting is shown for initial procurement costs for tools. In a production situation, the actual fraction of costs is apt to be less than this fraction. In one representative evaluation, 5-year costs for alternative rivet guns purchased for $400 and $1200, respectively, were in the range of $30000 for the lower initial cost product and approximately $16000 for the initially high-cost product. Initial tool purchase costs accounted for only 1% and 8% of total 5-year costs in this scenario. Purchasing these tools only on the basis of initial costs would have been false economy. Additionally, lower cost tools are apt to have fewer ergonomic refinements and are likely to operate at higher levels of noise and vibration and thus are apt to have higher "human" costs which are more difficult to capture through superficial economic assessment.

Table 12 illustrates a nominal scoring system for procurement of alternative tools on the basis of initial cost.

Table 12 - Nominal scoring system for initial product cost

Initial Procurement Cost	$1200	$1100	$1000	$900	$800	$700	$600	$500	$400	$300
Raw score (highest possible rating of 10)	1	2	3	4	5	6	7	8	9	10
Adjusted score (multiplier 0.5) (5% of total score)	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0
Cost of representative product (6 inch pneumatic grinder)		Tool 1 $1125				Tool 3 $695		Tool 2 $430		
Relative product ranking (purchase cost)		3				2		1		

3.7 Estimate of Life-Cycle Cost

Factors in estimating total life-cycle costs may include procurement cost; replacement parts and tools; time associated with maintenance; potential "hidden costs" of failed tools from unplanned production stoppage; costs of multiple spares and back up tools, storage space; administrative costs of extra inventory, etc.; utility costs based on tool power and energy consumption (unless factored in separately as below); and the total labor costs required to perform a specified level of production. Note: Tools not operated and maintained within manufacturer's recommendations for lubrication and cleaning have a different frequency of failure than ones that are maintained within specifications. A higher life-cycle cost can be expected when appropriate maintenance is not performed.

A notional value 10% is shown in this example for purposes of weighting selection factors. Higher fraction may be considered, particularly if data support such analysis.

Recordkeeping and tracking are more difficult to establish for life-cycle costs. The real costs tend to be significantly underestimated.

3.7.1 Cost for Consumables and Parts

Costs for consumables may constitute a high fraction of total costs for processes such as grinding where replacement of abrasive media is a persistent part of the process. Inadequate equipment maintenance and parts replacement may create inefficiencies and increase total effective costs and defect rates in processes such as drilling.

3.7.2 Utility Costs/Energy Consumption

Utility cost can be based on electrical power consumption or the cost of compressed air for pneumatic tools and anticipated rate of use. The intent is to provide realistic estimates, which can be used for comparative purposes, rather than exact figures.

Typical costs for electric tools, loaded during operation:

Power in watts x hours operation/per day x 250 workdays/year $__cost/kW (provide a typical figure) = ___ (Eq. 4)

NOTE: Usually the energy consumed is from the controller which consume a few hundred watts during load, depending on the tool size and load, manufacturer, etc.

Also note the speed or power of the tool in completing work and its impact on energy consumption costs. Suggest measuring power consumption in amps using a special multi-meter during the work process being performed.

Typical costs for pneumatic tools = __ rated air consumption (cfm) x
$__ cost of compressed air/cubic foot x __ hours operation/per day x 250 workdays/year (Eq. 5)

Leakage of about 20% of air consumption is common.

NOTE: 1 m^3 = 28.3 ft^3. As a rule of thumb, 1 m^3 requires approximately 0.105 kWh. Where exact data is not available, use $0.05 per kWh as ballpark cost for electricity in the United States.[1]

Effective utility costs may be higher in construction environments or other settings where temporary sources of power are less energy efficient than fixed utilities or have higher transmission losses in field conditions.

Compile data comparing alternative products and select alternatives.

Table 13 provides a notional example of a comparative review for alternative products.

Table 13 - Comparison of alternative products (nominal example for purposes of illustration)

			Tool 1	Tool 2	Tool 3	
Factor	**Weighting Factor**	**Possible Points**	**Weighted info Transferred from Tables in Section 4**	**Weighted info Transferred from Tables in Section 4**	**Weighted info Transferred from Tables in Section 4**	**Source of Representative (Notional) Information**
Productivity	40%	40	32	20	28	Tables 3 and 5
Ergonomic factors	20%	20	15	6	14	Tables 3 and 5
Noise	10%	10	10	7	5	Table 3
Hand-arm vibration	10%	10	8	5	5	Tables 1, 2, or 3
Initial procurement cost	5%	5	2	4	3	Tables 3 and 5
Five-year operating cost(1)	10%	10	6	4	6	Section 3.6
Utility cost(1)	5%	5	3	4	3	Section 3.7
Total score	100%	100	76	49	64	

(1) Sample calculations are shown for certain representative data. However, the comparative information provided in the above table is provided without demonstrating examples of calculated values.

In the notional example provided in Table 13, Tool 1 achieved the highest total rating (76/100). Review suggests that Tool 1 should be selected on the basis of productivity, lower weight (a key ergonomic factor), as well as reduced noise and vibration. Note that Tool 1 has a higher initial procurement cost than both alternative products. If initial price had been the only selection criteria, a product with less satisfactory levels of productivity and safety would have been purchased.

General constraints and limitations: Using the tool for a sole specialized task, or in a way which is not represented by the quoted standard (i.e., ISO 8662, ISO 28927, or EN 60745), or with accessories or consumables other than those which have been recommended or supplied by the manufacturer, may produce a different average emission; in such cases, it is strongly recommended that a specific evaluation of the vibration emission is performed according to ISO 5349. Such measurements may be supplemented, but not replaced, by evaluation using the weighting scale of ISO 18570 to evaluate risks of vascular effects of very low or very high frequency vibration.

3.8 Dust Control as a Weighting Factor

Control of hazardous dusts is often essential to mitigation of health hazards associated with powered hand tool use. Where exposure to highly toxic or carcinogenic dusts is involved, it is a critical purchase parameter (threshold for purchase) and relative scoring should not be necessary to justify dust control. In some cases, the effectiveness of dust control may be a weighting factor in purchase, particularly if it can reduce or eliminate the need for respiratory protective equipment and/or otherwise increase process efficiency.

1 Source: http://www.webmath.com/kwh.html. The figures cited are consistent with 2012 data. More recent information may be used, where available.

Where operations are intermittent, evaluation of dust control and related control of occupational exposures should be measured on a short-term basis to directly evaluate the level of control, rather than as a time-weighted average because the duration of operations and related exposures are likely to be both variable and unpredictable.

Where less toxic dusts are being captured, weighting dust control may be considered as a factor in equipment purchase, if additional mitigations such as respiratory protection are used effectively, and exposures can reliably be maintained below occupational exposure limits. Table 14 provides a notional guide for weighting of dust control.

Table 14 - Notional guide for weighting of dust control in procurement decisions

Factor	Relative Weighting (Points added to baseline “scoring” of possible 100)	Notes (The lowest recognized occupational exposure limit should be utilized)
Effective dust avoidance	0% where hazardous dust is not a consideration and nuisance dusts are not generated in visible quantity	Processes where dust is not typically released such as bolt tightening and where hazardous potentially friable (materials readily aerosolized) are not present
Effective dust control of low hazardous dusts	10%	Products considered nuisance dusts and/or without recognized exposure limit
Control of low to moderately hazardous dust	20%	Airborne concentration <50% TLV and TLV >1 mg/m^3 (for particulates)
Control of moderately hazardous dust	30%	Airborne concentration <50% TLV and TLV <1 mg/m^3 (for particulates)
Control of hazardous dust	40%	Airborne concentration >50% TLV and/or TLV <1 mg/m^3 (for particulates)
Control of very hazardous dust	50%	Airborne concentration >50% TLV and/or TLV >0.1 mg/m^3

INFORMATION SHEET – PN3-02/November 2013 (replaces January 2011)

Noise and vibration information published in tool instruction manuals as required by the EU Machinery Directive (2006/42/EC)

This Information Sheet provides guidance to PNEUROP members on adopting a common approach to publishing noise and vibration information in the instruction manuals of power tools and similar equipment.

1 Noise and vibration declaration

The recommended Noise and Vibration Declaration Statement comprises two parts:

- a data section;
- a statement about how that data should and should not be used, plus information about where to seek further advice.

The "Data section" sets out the noise and vibration data which, according to the EU Machinery Directive, has to be declared for each hand-held or hand-guided power tool and which must accompany it, when it is placed on the market in the European Economic Area.

The "Statement section" is optional, but is recommended, since it delineates the responsibilities of the tool manufacturer from those of the persons responsible for the safety of workplaces in which tools are used.

Noise & Vibration Declaration Statement

Data section

Sound pressure level	____ 1), 2) dB(A),	uncertainty ____ 3) dB(A)	in accordance with ____ 4)	
Sound power level	____ 5) dB(A),	uncertainty ____ 3) dB(A)	in accordance with ____ 4)	
Vibration value	____ 1) m/s^2,	uncertainty ____ 3) m/s^2	in accordance with ____ 6)	

Statement section

These declared values were obtained by laboratory type testing in accordance with the stated standards and are suitable for comparison with the declared values of other tools tested in accordance with the same standards. These declared values are not adequate for use in risk assessments and values measured in individual work places may be higher. The actual exposure values and risk of harm experienced by an individual user are unique and depend upon the way the user works, the workpiece and the workstation design, as well as upon the exposure time and the physical condition of the user.

We, 7), cannot be held liable for the consequences of using the declared values, instead of values reflecting the actual exposure, in an individual risk assessment in a work place situation over which we have no control.

This tool may cause hand-arm vibration syndrome if its use is not adequately managed. An EU guide to managing hand-arm vibration can be found by accessing http://www.pneurop.eu/index.php and selecting 'Tools' then 'Legislation'.

We recommend a programme of health surveillance to detect early symptoms which may relate to noise or vibration exposure, so that management procedures can be modified to help prevent future impairment.

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Figure 2 - Noise and vibration declaration statement

NOTE: This declaration is required by European Union regulations and should be obtained whenever feasible.

3.9 Physical and Electrical Safety Factors

Certain physical safety factors and electrical safety factors are likely to be a minimum condition (threshold) for procurement. Tools without essential safety features shall not be purchased. As such, minimum essential safety factors do not contribute to this numerical scale but are a requirement for purchase. Such safety factors may include suitable interlocks to prevent operation when guards are not present, ground fault interruption or dual isolation, machine guarding, and other design considerations that are required by regulation, industry standards, and/or the needs of a specific type of work. A dead man control (automatic shut off) is often needed to ensure automatic shut off when the operator is disabled or inattentive.

3.9.1 Electrical Safety Criteria and Independent Test/Certification

Tools selection purchase should require compliance with relevant design standards and, where available, be certified by an independent test organization, such as UL or equivalent.

3.9.2 Lithium-Ion Battery Powered Tools

The battery and charger must be considered a system to be used in combination. Purchase and use devices that are listed by a qualified testing laboratory. Ensure that batteries are listed as meeting standards such as AS4786, IEC 62133, or UL 2054. These standards should also be consulted for additional technical guidance. UL maintains a database of lithium batteries which have been approved through third-party testing (refer to https://www.ul.com/services/battery-safety-testing).

3.9.3 Other Factors to Consider

- Factors that minimize the potential for accidental activation.
- Designs to prevent electrical failure and/or short to ground.
- Machine guarding and designs which prevent contact with moving parts.

3.9.3.1 Prevention of Unintentional Activation

Safe trigger activation of the tool may be an essential purchase and operational selection criteria. Compliance with relevant standards should be a minimum product selection criteria. Where standards identify alternative measures of control, selection of the best (safest) alternative is advised. For example, the standard for nail guns allows alternative means of trigger control; automatic triggering on contact and activation only when the trigger is pressed. The second alternative is strongly preferred because it prevents accidental misfires, including those most likely to result in injury. (refer to ANSI SNT-101-2015)

3.9.3.2 Kickback

Kickback is a significant source of potential injury and requires design and work practice controls to prevent its occurrence. Certain power tool operations are associated with the potential for kickback or a sudden, forceful recoil. Technology features which will prevent this phenomenon should be an essential element in purchasing.

The Milwaukee Tool Company provides an overview of anti-kickback features relevant to drills and saws (refer to https://onekeyresources.milwaukeetool.com/en/how-to-stop-drill-kickback).

Relevant technology may include a sensor which detects and arrest motion in the improper direction. One patent—7552,781 B2 (June 2009) (Power Tool Anti-Kickback System with Rotational Rate Sensor)—uses a rotational rate detector to detect lateral displacement and interrupts power to the tool until motion ceases.

Certain operations should require selection of tools and processes which minimize or prevent the potential for kickback. Some operations require combined process and product selection. For example, cutting of underground pipe with a circular pipe cutter or chain saw is an intrinsically hazardous operation both because of the risk of using a saw in an enclosed space with limited room for maneuver and the potential for kickback if the saw encounters an obstacle or rotates in a way which “catches” the blade and diverts the energy in a way which creates a recoil. Kickback can occur more rapidly than the operator can perceive and react. Examples of tools equipped with anti-kickback devices include a pipe cutter with circular system which surrounds the pipe being cut. Associated control mechanisms include electronics controlling motor overload, adjustment mechanism to support straight cutting.

4. REQUIREMENTS AND RECOMMENDATIONS FOR IMPLEMENTATION

4.1 Requirements for Power Tools

4.2 Illustrations

The illustrations shown herein are descriptive, not restrictive, and are not intended to preclude other tools or tool assemblies.

4.3 Materials

Unless otherwise specified hereinafter, the materials used in the manufacture of the tools shall be described by the manufacturer's data sheets.

4.4 Safety Requirements

Non-electric tools should conform to safety requirements of the relevant section of ISO 11148 series or comparable standard. Electric tools shall conform to the safety requirements of the relevant part of UL 60745 (USA), IEC 60745 (international), or comparable international standard.

4.5 Marking, Labeling, and Technical Instructions

Sections 4.5 and 4.6 provide guidance for marking and labeling of tools and associated boxes and supporting technical instructions. Required and recommended information is summarized in Table 15.

Table 15 - Marking, labeling, and technical instructions

		Tool Information and Risk Factors Data/Information Location				To Whom is the Information Directed?			
	Category of Information	**Tool**	**Original Package/ Box**	**Manual**	**Symbol Used***	**Supervisor**	**Engineering**	**Procurement Officer**	**User**
General information	Country of origin[1]	R	R	(R)				x	
	Manufacturer's name or symbol	R	R	X				x	
	Part number	R	R	R		x	x	x	
	Vibration level (box or tool)[2]	X[3]	*	R declared value	No standard vibrating symbol	x	x	x	x
	Noise[2]	- [3]	*	R declared value and sound power level under test conditions where SPL ≥80 dBA	Use of hearing protection 	x	x	x	x
	Reference to manual	-		* Certifying authority	Open book symbol	x			x
	Use of eye protection	O	0	X	Goggles	X			X
	Power source safety (especially electrical)	X*	X*	X	UL, CSA, CE,	x	x	x	x
	General operational guidance			X		x	x	P[4]	X

	Category of Information	Tool Information and Risk Factors Data/Information Location			Symbol Used*	To Whom is the Information Directed?			
		Tool	Original Package/ Box	Manual		Supervisor	Engineering	Procurement Officer	User
From Balanced Score Card: Factor	Productivity			x needs to describe conditions of use, task to be accomplished and estimated time/task		x	X	P(4) (as procurement consideration)	
	Ergonomics			x conditions for optimal use		x	x	P(4)	X
	Noise			x		x	x	P(4)	x
	Hand-arm vibration			x		x	x	P(4)	x
	Initial procure-ment cost (potential ratio)			x		x	x	P(4)	
	Five-year operating cost			x			x	P(4)	
	Utility cost			x			x	P(4)	
	Factors to consider	Limited space requires use of symbols		Identify test standards and limits of evaluation (refer to guidance in PN3-02)					

References and symbols used:

X Relevance to category.(3)
* Use the symbol (such as a person wearing hearing protection to designate a product as potentially noisy and describe the need for users to wear hearing protection during use).
R Required by this standard and accepted good practice.
(R) Indicates may be required. Information is typically in manual.
GSA Requirement of the General Services Administration (GSA) or other federal government packaging (refer to MIL-STD-129)
EU Requirement of European Union.
* Symbol of certifying authority for power sources, typically electrical.

Conformity to accepted test for power sources, particularly related to electrical safety such as UL/CSA Canadian Standards Association or CE indicating conformance to European Union standards.

(1) Definition subject to the Federal Acquisition Regulations (FAR) and other interpretation with focus on location of manufacture of components and assembly of components into final product.
(2) The declared value described in the manual shall describe the measurement technique/standard and indicate if the measurement includes the tool alone and/or the attachment. It should be noted that noise created from interaction with the work piece may be a significant/and/or primary source of noise. (Also see APPENDIX A, section A.1.)
(3) In general, space limitations constrain the amount of information which can be communicated on the tool. Noise and vibration levels are often task dependent. However, for some large tools with high levels of noise and/or vibration, it may be appropriate to include vibration and/or noise warnings on the tool. The intent is to indicate the anticipated need for suitable precautions and protective equipment in many likely scenarios of operation. Possible examples of tools where noise and vibration warming may be required on the tool are jack hammers (pavement breakers) and chain saws. Both products are large tools which commonly create significant levels of noise and vibration.
(4) P (information to be used as factor procurement consideration).

4.5.1 Tool Marking

The tool shall be marked in a permanent manner with the minimum of the following: model number, the country of origin, and the manufacturer's name or with a trademark of known character that the source of manufacture may be determined. Marking requirement shall be in accordance with AS478.

More detailed information related to noise and vibration hazard should be in the operator's manual, which may address vibration and noise hazards with reference to type of work being conducted and type of attachments utilized and relevant work time limits, if appropriate. A manufacturer's declaration statement, summarized in Figure 2 and shown in APPENDIX A, Section A.2, may be used.

A noise hazard symbol (earmuff or other relevant symbol indicating need for use of hearing protection) should be recommended or required for products typically operating above 85 dBA.

The extent of marking is apt to be limited by available tool size and related space. The tool may have an indicator for additional information in operator's manual which is typically indicated by an icon showing an open book. Where the vendor's manual and related technical information is also provided by online sources, the relevant web link may be engraved on the tool.

Symbols indicating conformity to accepted test for power sources, particularly related to electrical safety such as UL/CE indicating conformance to European Union standards should be marked on the tool.

4.5.2 Packages Used to Contain the Individual Tools (Package Marking)

The package used to box the tool shall be marked in a permanent manner with the minimum of the following: manufacturer's name, address, country of origin, tool nomenclature, tool model number. Larger containers used for shipping multiple boxes of tools and/or other products generally will not require all of the above information but should be marked in accordance with relevant shipping regulations describing source of shipment, destination, and safety information relevant to the type of product(s) being shipped.

The package may also show noise hazard symbol (earmuff or other relevant symbol indicating requirement for use of hearing protection) for product typically operating above 85 dBA.

Marking requirement should be in accordance with AS478. More detailed information related to noise and vibration hazard shall be in the operator's manual which may address vibration and noise hazards with reference to type of work being conducted and type of attachments utilized and relevant work time limits, if appropriate.

Conformity to accepted test for power sources, particularly related to electrical safety such as UL, CSA Canadian Standards Association, or CE indicating conformance to European Union standards.

The box may have the vendor relevant web link as well as vendor location, phone, and address.

Additional standards such as U.S. MIL-STD-129 and U.S. FED-STD-123 may be applied to packing of multiple boxes of individual tools.

4.6 Interface Between Tool Drives and Attachments

Interface between tool drives, attachments and associated attachment devices should conform to requirements for industry standards for minimum acceptable tolerances to minimize wear, and limit noise and vibration. The length of drive extensions shall be minimized to reduce the potential for vibration and related wear and noise. The most stringent feasible tolerances and categories for tool connections should be used to reduce undesired energy waste transfer and thereby ensure production quality and tool life cycle while minimizing safety and health risks. ISO 21108 should be consulted for detailed guidance in product selection. ISO 1174-2 provides supplemental information.

An anti-vibration socket or related type of interface device may be required or recommended to limit vibration, noise, and wear, as well as to optimize quality.

ISO/TS 21108-2005 specifies dimensions and tolerances for the interface between impulse wrenches and their sockets, the output spindle of the power tool, and the female drive end of the socket. The scope includes air and electric impulse tools, but it could also be applied to other tool types.

The square drive dimensions are dimensioned according to ISO 1174-2. This technical specification gives preferred dimensions for the diameter of the power tool spindle shaft and the internal diameter of the socket.

Vibration and wobbling are reduced, energy loss is reduced, and torque accuracy is improved.

4.7 Square Drive Ends

4.7.1 Type and Classes of Tools with Square-End Drives

Interfaces between tools and attachments must meet relevant industry standards for interface between internal (drive end) and external drive (tool spindle or similar point of attachment). ISO 1174-2 provides guidance.

- Type I (pneumatic tools), Class 5 (impact wrenches/impulse tools).
- Type II (electric tools), Class 5 (impact wrenches/impulse tools).
- Type IV (hydraulic tools), Class 5 (impact wrenches/impulse tools).

4.7.1.1 Drive End Requirements

External drive tangs shall be in accordance with ASME B107.4 and shall be used to judge the following requirements:

- Dimensional tolerances for the external drive ends.
- Interchangeability of external drive ends with mating internal drive ends.
- External square drive tangs shall pass the gages defined in ASME B107.4.
- All external surfaces shall be free from pits, nodules, burrs, cracks, and other detrimental defects.

Use of anti-vibration drives is recommended, when appropriate, to minimize vibration and noise and improve quality and tool life.

4.8 Tool User's Manual and Instructions

Powered hand tools shall be provided with a user's/operator's instruction manual that includes guidance for safe and efficient operation of the tool. Typical contents may include:

- Cover page.
- A title page and copyright page.
- Manufacturer's name, location, and the product designation model and nomenclature, and a preface containing details of related documents and information on how to navigate the user guide, including guidance for any icons/pictographs used to mark the tool.
- A contents page (table of contents).
- Safety guidance to include selection of accessories, description of potential hazards to users and basic mitigation methods, and work practices to avoid.
- Noise and vibration hazards should be described and related protective equipment, range of potential exposures and for vibration, potential time limitations for use, described noise and vibration, declared value, and a summary of conditions under which these estimates were obtained.

- Maintenance guidance.
- Sources of replacement/repair parts and equipment.
- A troubleshooting section detailing possible errors or problems that may occur, along with how to fix them.
- Frequently asked questions (FAQ) page.
- Where to find further help and contact details, potentially including website information.
- A glossary and, for larger documents, an index.

Pictographic vibration hazard symbol consistent with European Union criteria for products with anticipated vibration levels above 5 m/s and hearing protection symbol for tools creating noise levels consistent with the need for use of hearing protection, typically >85 dBA.

Where noise and vibration data are provided, they should be accompanied by a statement describing the test conditions (or standard under which test data was obtained) and limitations of testing information with regard to conditions which may occur in the workplace. Guidance of PNEUROP (European Association of Manufacturers of Compressors, Vacuum Pumps, Pneumatic Tools and Air and Condensate Treatment Equipment) is provided for consideration.

Figure 2 summarizes information to be provided. APPENDIX A, Section A.2 provides detailed guidance from PNEUROP.

4.8.1 Supplemental Information Provided by Vendors

Vendors may choose to provide supplemental information and/or guidelines for users in the container or box, as well as through other technical support channels. This may include guidance such as standalone information pamphlets on topics such as noise and vibration. Use of common language and non-copyrighted fact sheets may be encouraged to make information widely available with minimal development cost. Key topics may include safety and health areas, noise, vibration control, general tool safety, productivity, and process management areas such as tool maintenance, effective use of air supply systems, and guidance for grinding operations. Representative examples and information sources are cited in Section 2.

4.8.2 Manufacturers' Technical Assistance

Manufacturers also provide extensive technical support upon user/customer request, both with technical materials noted above and guidance for specific issues and processes.

4.9 Workmanship

All items covered herein shall be free from fins, burrs, external sharp or rough edges, corners, or surfaces and other defects which may impair their serviceability or usability.

4.9.1 Foreign Object Damage (FOD)

It is important to avoid damage to aircraft due to foreign objects. Rips, tears, burrs, slivers, plating peel, screws, clips, fittings, retaining rings, and/or any material which could become loose and detached from the tool during gaging, testing, or normal use shall be unacceptable. Tools must be properly maintained according to manufacturer's guidelines to prevent FOD.

4.10 Mechanical Performance

Power tools shall meet the technical specifications given in the manufacturer's product manual. Verification testing for the performance parameters such as torque output, durability, and serviceability or failure modes of the tools is outside the scope of this standard.

4.11 Safe Operation of Power Tools

The end user shall operate the power tools within the operational limits defined in the manufacturer's manual. Any tool use outside the safe operational envelope is unsafe and should be avoided. Adequate safeguards for personnel and property shall be employed when using power tools. Appropriate personal protective equipment (PPE) shall always be worn and equipment safety shields shall be put in place when operating power tools, if needed. More detailed guidance is provided in 4.3 and APPENDIX E.

5. NOISE/VIBRATION TEST CONDITIONS

This standard only covers the test condition for evaluating noise and vibration transmitted from power tools. Adequate safeguards for personnel and property shall be employed in conducting all tests. Appropriate personal protective equipment (PPE) shall always be worn, and appropriate equipment safety shields shall be put in place when tests are in progress.

Appropriate international standards for the measurement of noise and vibration of specific types of tools during actual working conditions using ISO 5349 shall be used when they are feasible, or simulated work conditions, using ISO 28927 as guidance.

Test conditions should be consistent with ISO/ANSI standards cited above for the type of tools being evaluated. Where feasible, they should be consistent with test approaches used by NIOSH and/or the European Union to evaluate noise and vibration under conditions representative of typical industrial use, including operation under load rather than "free spinning" without load. Where feasible, ANSI S2.70 methodology should be utilized to provide assessment of vibrations most consistent with plausible conditions of use. When application of ANSI S2.70 is not feasible due limitations of laboratory reproducibility or data is not immediately available, application of ISO 28927 shall be utilized (providing three-axis vibration).

When ISO 15744:2002 (noise) methods used for laboratory evaluation and technical consistency are applied, they should be described and limitations or divergence of field conditions of typical industrial application identified in the test documentation. The sound power should also be given when the sound pressure level exceeds 80 dBA. Also, the uncertainty of both vibration and noise values shall be given.

Vibration data obtained from ISO 8662 methods (evaluation of vibration in the predominant axis of motion) may be considered for percussive and other types of tools with a primary motion in one direction where data from ISO 28927 methods are unavailable. However, the rationale for using this data should be explained.

Measurements should be consistent with the regulatory guidance of the nations in which products will be sold. Within the European Union, the Machinery Directive from 1998 was active until December 2009. The declared values were single-axis values measured according to ISO 8662. A new directive 2006/42/EC became active in 2010. Declared vibration values changed to three-axes values, measured according to ISO 28927 or EN 60745. These values are generally higher than the old declared values, because of the input from additional axis. The old and new values should not be mixed and cannot be compared. In case the machine tested is not covered in ISO 28927, the general standard ISO 20643 is used. The reference to ISO 20643 should preferably be followed by a note explaining how the test was performed. The noise values are declared using the same standard as before, ISO 15744. The only change is that the sound power should now be given when the sound pressure exceeds 80 dBA. Also, the uncertainty of both vibration and noise values shall be given.

6. TOOL SAFETY AND PRODUCTIVITY GUIDANCE FOR USERS

Safety guidance for users should be integrated into a process management system that supports workplace design, product selection, maintenance, and user and management education to maximize quality, safety, and productivity. AIR6916 provides supplemental details for implementing this standard and supporting an organization quality assurance program. Very often, the indicators of reliability and maintainability issues are subtle such as increased waiting time for repairs, storage of "extra" parts due to unpredictable failures in existing operations, and other patterns of behavior by maintenance staff which may not be reflected in existing statistics tracking reliability.

7. MANAGEMENT PROCESS

The safety and health program should be a component of management oversight, risk management, and support process efficiency. Key programmatic aspects include workplace design, procurement of safest available products, and periodic evaluation. These measures are integral to risk/cost management and promotion of personnel morale and efficient operations. An ergonomics program should be an integral part of occupational health and management systems, such as those outlined in ANSI Z10.0-2019. Prevention through design concepts consistent with ANSI Z590.3-2011 or comparable guidelines should be incorporated into the process for design, equipment selection, and related risk management. The hearing conservation program should include provisions for procurement of quietest feasible equipment and preventive maintenance to preserve operational efficiency and noise control, as well as regulatory required elements of exposure evaluation, protective equipment use, medical monitoring, and staff training.

The level of physical stress and related ergonomic risks to users depend both on the characteristics of the tool which for which preliminary assessment can be made in laboratory environment (noise, vibration, weight) and the design of the workplace and tasks involved in operations conducted in a specific setting. Assessment and control of workplace risks should be part of a management safety and health program with an ergonomic component.

Laboratory measurement of parameters such as noise and vibration can only provide a comparative guide to workplace exposures, which may be influenced by factors such as level of maintenance, work practices and the specific work task(s) being undertaken.

Factors to consider may include the hand-activity level based on hand exertions and duty (work/rest cycle) (ACGIH); deviation of the wrist; and position, weight, and balance of the tool.

8. GUIDANCE FOR SUSTAINABLE PRODUCT EVALUATION AND PROCUREMENT

Use of procurement criteria considering only first (purchase) cost have commonly been demonstrated to represent false economy and are highly likely to result in higher total costs and risks for the purchaser/user due to factors such as increased frequency of replacement; increased defects; lower reliability and productivity as well as higher likelihood of ergonomic injuries, and noise and vibration exposures to operators.

Developing guidance for sustainable procurement of products based on quality, productivity, safety, and life-cycle cost requires criteria for evaluation that can be communicated to prospective suppliers and implemented by the purchasing organization. The process requires a system supporting user input, identification of quantifiable and verifiable requirements and integration of user feedback in operations. The process also demands education of procurement staff and an organization policy favoring life-cycle cost and safety evaluation, rather than purchase primarily on the basis of initial cost. Guidelines of ANSI Z10.0, or similar process, should be systematically implemented to support the integration of safety and health into overall management systems. Concurrently, the procurement and fiscal management system must consider life-cycle cost and risk management.

The first step is to identify factors that are essential to product safety and performance and are requirements for procurement. Products not meeting these criteria would typically be eliminated from further consideration. Table 16 lists illustrative examples of characteristics that may be critical parameters for a particular tool. A more-detailed list is provided in APPENDIX A, Section A.4.

Table 16 - Illustrative examples of characteristics essential to procurement

Critical Selection Criteria	Description	Standards/Remarks/Examples
Product safety testing by approved certification laboratory organization for electric tools		UL approval
Supporting technical manual provides acceptable documentation and safety guidance	Minimum requirements for contents such as manufacturer's name, contact information, tool name, and part numbers	
Pneumatic exhaust (blow-off) directed away from user's hands		Prevention of risk factor for hand-arm vibration syndrome
Type of coupling device	Coupling device designed to limit loss of transmitted energy to control quality, noise, and vibration	Coupling device for tool attachments conforms to accepted standard for configuration and tolerances (refer to ISO 21108)

The next typical step is to describe performance characteristics supporting productivity and safety and develop a rating system for their relative evaluation.

This section provides detailed notional examples for applying these criteria in a typical procurement situation.

APPENDIX A provides alternative guidance for user evaluation of powered hand tools.

9. RECOMMENDED WEIGHTING FACTORS

Factors for tool evaluation outlined in Section 3 provide a suggested semi-quantitative approach to relative evaluation and scoring of alternative products using weighting factors.

These factors represent notional guidance and are intended to provide an approach that allows for effective comparative evaluation of alternative products. Minor differences in scoring should not be considered as definitive or absolute indicators of relative product quality, safety, or effectiveness. Actual worker exposures to noise and vibration are likely to differ from measurements obtained in laboratory settings because of test methodology, differences in work practices, process and equipment, and the acoustic environment of the workplace.

9.1 Thresholds and Objectives

A decision may be made to exclude products not meeting minimum criteria in given areas. A threshold, or minimum acceptable, value may be assigned to parameters such as tool weight, level of productivity, or noise levels. Products not meeting these minimum criteria would be excluded from further evaluation or ultimate purchase. Desired optimally achievable performance characteristics may be established and communicated to prospective vendors as performance objectives. Communication of performance objectives provides an incentive for product improvement within the scope of available technology or practical improvements. In cases where competing performance characteristics are desired, the establishment of thresholds and objectives may create a “trade space” for balancing alternative characteristics.

10. AUXILIARY EQUIPMENT AND EVALUATION OF OPERATING CONDITIONS

Guidance for operating conditions during user test should be obtained from the section of ISO 28927 relevant to the product evaluated, or other documented criteria, and described in test reports. A general summary is provided below.

The integration time shall be in accordance with ISO 20643:2005.

The following criteria and techniques shall be applied in evaluating operating conditions under which tools are tested and documenting relevant power input and output levels:

1. For pneumatic machines, the air pressure shall be measured using a pressure gauge with accuracy equal to or better than 0.1 bar (1.45 psi).

2. For hydraulic machines, the flow shall be measured using a flow meter with accuracy equal to or better than 0.25 L/min.

3. For electrical machines, the voltage shall be measured using a voltmeter with accuracy equal to or better than 3% of the actual value.

4. The rotational speed shall be measured and reported with accuracy better than 5% of the actual value, using either a tachometer or frequency analysis of the measured vibration signal. When a tachometer transducer is placed on the machine, it should be small enough not to influence the vibration of the machine. The feed force shall be measured with accuracy equal to or better than 5% of the actual value.

11. GUIDANCE FOR PROCUREMENT STAFF AND PROSPECTIVE VENDORS

Organizational policy should support procurement based on customer/user needs with reference to sustainability and avoidance of risk factors for injury. Implementation of an effective safety management system such as a process consistent with ANSI Z10.0, mandates higher management policy and support, user involvement and periodic process evaluation. It also requires adaptation of a hierarchy of controls for occupational health and safety hazards stressing elimination of hazards, where feasible, substitution/procurement of the safest feasible products and development of the safest feasible/cost effective materials and processes and use of protective equipment, and training as the least preferred approaches to risk mitigation.

Solicitation for vendor’s bids should describe this policy in the context of identifying criteria and rating evaluation processes for powered hand tools that require description of factors supporting productivity, lowest feasible life-cycle costs, and safety and health factors that will be considered in purchasing decisions.

The solicitation should also describe potential penalties for inaccurate information, including disqualification from future solicitations.

12. PROGRAM FOR ROUTINE MAINTENANCE OF EQUIPMENT AND REPLACEMENT/REPAIR OF DAMAGED OR OUTDATED TOOLS

Ensure that a program is in place for routine tool maintenance and replacement, as well as communication of procurement criteria to purchasing departments. All efforts should be made to identify life-cycle costs and the benefits of a preventive maintenance program in terms of quality, reliability, safety for users, and risk reduction.

Basic elements include:

- Inventory of tools and related equipment (bits, blades) and spare parts. Automation of the inventory and bar coding or RFID use may support efficiency and improve tracking for large operations.

- Compilation of vendor’s instructions for tool maintenance and related technical guidance. Tool vendors and, particularly, the manufacturer’s representatives are commonly experts in the products they sell and typically want to maintain effective customer relations based on good service and tool performance.

- Developing processes for periodic inspection, condition monitoring, maintenance, and post repair evaluation of tools. Inspection may include visual evaluation for excessive wear, distortion of parts, and condition of the cutting surfaces. More sophisticated evaluations may include tool balancing and noise and/or vibration testing (measurement of the range of vibration on a test apparatus rather than evaluation of user exposures). Routine inspection and replacement of lower cost parts will avoid more expensive tool failure and replacement. For example, early lubrication, replacement of bushing, and bearings will support efficient operation and avoid the need to replace the more expensive motor or even the entire tool.

- Tracking of tools performance, wear, and maintenance records.

- Inspection of how tools are used and supporting utilities. This often means getting out on the shop floor and discussing processes with tool users. For example, ensuring proper air pressure, hose sizes, and volume of supply air will allow pneumatic tools to operate at the correct speed. An under-powered tool will often operate less efficiently, create greater drag, and even transmit more vibration that a properly operated tool.

- Education and interaction with users. This often goes with observation of operations in the workplace and consultation with production managers, supervisors, and workers.

- Develop procurement criteria for future product purchase. In general, better-made tools are likely to have lower vibration and noise, last longer and operate more economically over their life cycle. Ensure that the safety and health department is involved as early as feasible to help support justification for safer and more efficient products. Early involvement of the comptroller and purchasing department is essential to enlist their understanding and support for the need to obtain safer products which provide better quality and more effective investments, while protecting the users.

Retrofit of tools is typically not effective in reducing vibration or other undesirable characteristics. A study of retrofitted anti-vibration devices for powered hand tools demonstrated the limitations of handles and other retrofit apparatus in most applications. (Refer to Shanks et al., 2013.) Exceptions were anti-vibration sleeves on chipping hammers and suspension of certain heavy tool which allowed for addition of additional weight to create mass damping and alleviate some of the stress associated with manually holding heavy tools.

13. GUIDANCE FOR COMPARATIVE WORKPLACE PRODUCT EVALUATION

Worker participation is an essential element of a safety management system and is vital to evaluation and user acceptance of new and updated products. A continuous improvement process should identify both production concerns and quality management issues such as safety and health problems and product quality assurance deficiencies. Where process inefficiencies and/or safety and health considerations are identified, worker engagement is vital to develop alternative approaches and ensure their effective incorporation into process improvement. APPENDIX A provides detailed alternative formats for worker evaluation of alternative powered hand tools. Atlas Copco (2014) summarizes approaches to laboratory and workplace evaluation of vibration and noise and describes the variability of workplace vibration levels relative to laboratory test environments.

User education is a vital part of any product trial and to long-term process improvement. In some cases, preconceptions may need to be understood and addressed to overcome resistance to change. Examples may include (1) inaccurate association of noise with power and productivity, and (2) association of tool vibration as a necessary component of feedback during the use process. Note that personnel affected with hand arm vibration may have impaired sensory feedback and rely on higher levels of vibration to assess tool operation.

Tables 16 and 17 and APPENDIX A and APPENDIX B outline evaluation factors to be considered.

Possible components of user evaluation may include summary elements described in Table 17. Additional subtle indicators of reliability and maintainability issues, which may not be reflected in commonly maintained statistics, include increased storage of spare parts, maintenance staff attention to particular operations in unrecorded knowledge of past reliability issues, and customer waiting time for certain products or project completion (in the case of construction work).

13.1 Components of User Feedback Related to Powered Tool Evaluation

- Productivity.
- Quality including feedback and ease of evaluating during work. (For example, can the user see the area being machined, or does the tool obstruct their view?)
- Comfort.
- Noise.
- Perceived vibration (measured, if feasible).
- Tool weight and balance.
- Fatigue (or relative lack thereof).*
- Duty cycle (work-rest cycle).*
- Discomfort index such as the Borg Scale.*
- Optimal feed force.*
- Safety in operation.

* This evaluation is likely to be employed as a comparative measure in evaluation of existing processes/tools and alternative products.

13.2 Purchaser and Supplier Roles in Product Testing and Evaluation

Vendors provide basic safety information and test general data, often obtained in a reproducible laboratory environment. Users/purchasers must describe the actual conditions of use and apply this information to their specific needs and applications. Workplace evaluation should be conducted in a representative environment, but with conditions described in a manner that can be duplicated for comparative purposes. Sufficient orientation and trial time should be allotted to ensure that users acquire a degree of comfort and familiarity with new products and processes. If factors such as fatigue may contribute to the productivity, safety, and/or quality, sufficient time should be given to allow prospective differences to become apparent. For example, differences in tool weight are more apt to create an apparent difference in user acceptance after a reasonably representative work period than during very short-term initial trials.

Input of tool maintainers should be considered in the procurement decision; see Table 16 and APPENDIX A.

Supplemental factors may include cost and difficulty of maintenance (i.e., does the product appear to be easy to fix?) and correction or improvement of problems identified in existing systems/equipment.

Feedback related to the evaluation(s) and actions resulting in improved workplace design and worker safety should be provided to those involved in workplace evaluations.

Representative survey questionnaires for evaluation of user input are provided in APPENDIX A.

14. SUMMARY OF TRAINING RECOMMENDATIONS

Education is vital to effective process management for power hand tools or any other vital component of work operations, productivity, quality, and worker safety and health. An overview of education suggested for varied staff members is provided in Table 17.

Table 17 - Recommended outreach and education for staff involved with powered hand tool procurement, maintenance, and use

Staff Category[(1)]	**Key Education Components**	**Possible Vehicle/Approaches**	**Cross Reference in this Standard and Regulations**
Senior management	▪ Fiscal and sustainability factors supporting productivity and safety. ▪ Safety and health risks associated with operations, including risk acceptance at the appropriate management level. Associated accountability and potential liability for occupational illness and injuries. ▪ Results of periodic program evaluations.	▪ Senior level policy documents. ▪ Periodic program reviews. ▪ Production and quality reports. ▪ Safety summary and mishap reports.	4.8 Summary of OSHA or other regulations in noise (29 CFR 1910.95), physical and chemical safety Organizational policy/overview of best practice in QA and ergonomics
Engineering and production management	▪ Safety and health risk factors inherent in processes. ▪ Basic ergonomic risk factors. ▪ Cos/benefit considerations associated with ergonomic programs. ▪ Lean six-sigma and other process/productivity evaluation approaches.	▪ Management policy and related training. ▪ Ergonomic working group involving engineering, production, and support personnel.	4.8 Summary of OSHA regulations in noise (29 CFR 1910.95) and other hazards relevant to the workplace
Procurement/logistics department	▪ Risk factors inherent in processes and role of purchasing in modulating risks of productivity impairment and injury risk. ▪ Life-cycle cost/benefit accounting considerations supporting best value procurement.	▪ Management policy and related training. ▪ User feedback related to product procurement. ▪ Rating systems based on customer/user feedback, including satisfaction with procurement support.	4.9 Guidance on integrated process/product team

Staff Category[1]	Key Education Components	Possible Vehicle/Approaches	Cross Reference in this Standard and Regulations
Maintenance and tool room	▪ Productivity evaluation. ▪ Purchasing process and approaches to justify procurement. ▪ Safety and health considerations associated with work and maintenance operations.	▪ Collaboration and routine meetings between procurement and production.	4.10
Production and maintenance staff using power hand tools	▪ Safety and health requirements and rationale for their adaption including risks relevant to their work and appropriate control measures. ▪ Link between safety and productivity. ▪ Protective equipment requirements, limitations, and evaluation of effectiveness. ▪ Overview of the organizations safety and health program including feedback/risk reporting.	▪ Safety and health training required/recommended by organizational policy and by regulations such as the European Union and related national regulations or U.S. OSHA regulations. ▪ New employee orientation.[2] ▪ Routine training and training related to updated processes.[2]	4.3 APPENDIX E
Safety and health personnel	▪ Productivity evaluation. ▪ Purchasing process and approaches to justify procurement. ▪ Lean six-sigma and other process/productivity evaluation approaches.	▪ Collaboration and routine meetings between procurement and production.	4.8 4.9 4.10

(1) Descriptions are intended to be generic.
(2) Safety and health considerations should be integrated into such education.

15. SAFETY AND PROGRAMMATIC OVERSIGHT

Oversight and program feedback consistent with ANSI Z10.0 or equivalent and best practices is necessary to ensure that lessons-learned are incorporated into practice. Factors to consider include:

- Periodic program review and feedback to management.
- Cost/benefit evaluation to describe productivity issues and their relationship with maintenance support.
- Ergonomic program evaluation and communication of process improvements and lessons-learned.
- Integration of tool support and replacement.
- Conduct of required and recommended safety and health training.
- Mishap and workers' compensation information relevant to processes involving tool use.
- Hearing conservation program evaluation including product selection ("buy-quiet" programs), exposure evaluation, audiometric testing results with a focus on hearing loss trends, and effectiveness of training and management communication.

16. TESTING

Vibration and noise testing shall be conducted in accordance with guidance of consensus standards cited in the references to this standard (Section 2) and guidance of the APPENDIX C and APPENDIX D. Testing conditions and standards employed shall be described in reports.

Where techniques not fully described by such standards are needed to meet unique characteristics of the products being tested and/or provide reproducible conditions—ideally representative of the work setting—this methodology must be described in the test report, along with the rationale for their application.

Physical safety criteria such as machine guarding, and compliance with power supply safety considerations such as UL approval, shall be documented in accordance with a published standard industry standards and good practices. Where applicable, third party testing should be documented.

17. NOTES

17.1 Revision Indicator

A change bar (l) located in the left margin is for the convenience of the user in locating areas where technical revisions, not editorial changes, have been made to the previous issue of this document. An (R) symbol to the left of the document title indicates a complete revision of the document, including technical revisions. Change bars and (R) are not used in original publications, nor in documents that contain editorial changes only.

PREPARED BY SAE EG-1B1 POWER TOOLS - PRODUCTIVITY, ERGONOMICS AND SAFETY COMMITTEE

APPENDIX A - GUIDANCE FOR USER EVALUATION OF POWERED HAND TOOLS

Representative survey questionnaires for evaluation of user input are provided in Sections A.1 and A.2. Section A.3 identifies factors which may be considered in evaluation of specific types of tools.

A.1 SAMPLE USER EVALUATION FORM FOR POWERED HAND TOOL(S)

Table A1

User Evaluation of Power Hand Tools Date:				
Company/Organization	**Shop/Work Unit**	**Supervisor**	**Contact Information**	**Notes**
Sparky Electrical, Inc.	Custom installation division	DC Volta	Don.Volta@sparky.com (xxx) yyy-1234	Example
Evaluation Coordinator	**Organization**	**Contact**	**Contact Information**	**Notes**
Sparky Electrical, Inc.	Safety dept	B.E. Secure	Barry.Secure@sparky.com (xxx) yyy-1234	Example
Tool Description				
Tool Type(s)	**Manufacturer**	**Model**	**Accessory**	**Notes**
Drill	XYZ Tool Company	EZ Drill	3/4 inch bit	Example
Company/Organization	**Shop/Work Unit**	**Worker Conducting Evaluation**	**Contact Information**	**Notes**
Worker Information (Voluntary)				
Height	**Weight**	**Age**	**Experience in Task (Years)**	**Dominant Hand**
Operation Being Evaluated	Drilling to install electrical fixtures			
Locations Normally Conducted	Home construction			
Areas of Concern	Overhead work, potential electrical contacts	A caution zone checklist may be completed for each work task to identify areas of concern. Refer to OSHA (n.d.).		
Substrate (What material are you working on?)	Wood (3 x 5 inches) often under sheet rock			
Notes	Example			

Table A2 - Worker's evaluation of tool

Worker Conducting Evaluation	Company/Organization	Shop/Work Unit Being Evaluated	Contact Information Phone/Email	Date
Worker's name	**Shop**	**Phone**	**Email**	**Notes**

Evaluation Factor	1 Disagree/ Poor/ Lowest	2 Slightly Disagree/ Below Average	3 Average/ Neutral	4 Slightly Agree/ Above Average	5 Agree/ Highest	Remarks (Check if you have further comments)
Check one box per row						
1. Rate the **quality** of work this tool will produce.						
2. Rate the **quantity**/rate of production.						
3. Rate the tool **weight** relative to comfort.						
4. Rate the **comfort** of the tool grip/handle.						
5. Rate the **balance** of the tool.						
6. Rate the **force** needed to operate relative to tools you typically use for this operation .						
7. Evaluate the "kickback" or reaction force experienced at the end of a cycle.						
8. Would you recommend this tool to co-workers? Why or why not?						
Remarks (notes related to evaluation factors or other inputs):						

Table A3 - Surveyor's note to supplement task description above

Rate of production	Units (e.g., number of rivets)	Time of evaluation	Factors that might improve or limit productivity	Potential safety and health considerations
Surveyor's name	**Organization**	**Phone**	**Email**	**Notes**

Other factors that may be considered by the evaluator and workers using on a trial basis:

- Sound level.
- Measured vibration m/s^2.
- Cycle time (or trigger time).
- Comfort/discomfort using a tool such as the Borg rating of perceived exertion scale (refer to CDC, 2022).
- Semi-quantitative evaluation of ergonomic stresses and risk factors evaluated by on-site evaluations for hand arm stress such as the rapid upper limb assessment (RULA) or whole-body/postural stress such as the rapid entire body assessment (REBA) (refer to both publications of Middlesworth, n.d.).

A.2 NOTIONAL FORM FOR EVALUATION OF TOOL[2]

Table A4

Name or description of tool:					Review date:				
Reviewer:					Location/col. number:				
Tool number (see PW procedure):					Estimated hours/day using tool:				
#	**Question**	**Yes**	**No**	**N/A**	**#**	**Question**	**Yes**	**No**	**N/A**
	Basics					**Handles and Grips (cont.)**			
1	Does the tool perform the desired function effectively?				3	Is the precision grip triangular in shape with the base on top?			
2	Can the tool be used without undue fatigue?				4	Is there a thumb locator or depression to aid in positioning accuracy?			
3	Does the tool match the size and strength of the operator?				5	Is the grip surface finely textured?			
4	Does the tool provide sensory feedback?				6	Is the grip soft, high friction surface to reduce the risk of slipping?			
5	Are the tool and maintenance costs reasonable?				7	Large gripping surfaces to distribute pressures and reduce pressure on hand?			
6	Will the tool require periodic calibration?				8	No unnecessary sharp edges.			
7	What is the required interval?				9	Does it use non-conductive grip materials to minimize heat transmission to or from the hand?			
	Anatomical Concerns				10	Is there no metal to hand contact?			
1	If force is required, can the tool be grasped in a power grip? (i.e., handshake)				11	Is the surface able to tolerate grease and oil and remain non-staining?			
2	Can the tool be used without shoulder abduction?				12	Is the grip length at least 4.5 inches (115 mm) and 5 inches (125 mm) if gloves are worn?			
3	Can the tool be used within an 80 to 120-degree elbow angle? (i.e., forearms horizontal, ideally at 90 degrees)				13	Is the handle diameter change less than 1/4 inch (6 mm) for the length of the grip area?			
4	Can the tool be used with the wrist straight?				14	For power uses, is the tool grip 1.8 to 2.00 inches (30 to 50 mm) in diameter?			
5	Does the tool handle have large contact surfaces to distribute forces?				15	Can the handle be grasped with the thumb and fingers slightly overlapped?			
6	Can the tool be used comfortably by a 5th percentile female operator?				16	Does the tool have a hilt, flange, or finger stop to transmit push forces?			
7	Can the user see work clearly with the tool in use?				17	Does the tool have a flared butt end to reduce slippage and pull forces?			
8	Can the tool be used in either hand?				18	Will the hand tool be used to transmit torque?			
9	Can the tool be used with and without gloves?				a	Is the handle of a non-circular, oval shape?			
	Handles and Grips				b	Is the tool handle triangular shaped?			
1	Does the tool have a precision grip? If not, skip to #5.				19	Does the tool have at least one flat side to prevent rolling?			
2	For precision tasks, is the tool grip cross-section circular 0.3 to 0.63 inch (8 to 16 mm) in diameter?				20	Does the tool have a hex or square bolster to allow a wrench for added torque?			

[2] Used with permission of United Technology/Pratt and Whitney.

Name or description of tool:					Review date:				
Reviewer:					Location/col. number:				
Tool number (see PW procedure):					Estimated hours/day using tool:				
#	**Question**	**Yes**	**No**	**N/A**	**#**	**Question**	**Yes**	**No**	**N/A**
	Handles and Grips (cont.)					**Power Tool Considerations (cont.)**			
21	Is the span of the tool handles between 70 mm and 80 mm?				11	Will the tool require a balanced or articulated arm?			
22	Are handles for two-handed tools located 120 degrees apart and suitable for both left and right-handed users?				12	For repetitive use is a finger strip trigger present?			
23	Can a two-handed tool be operated with less than 90 N grip force?				13	Are less than 10000 trigger actions required per shift?			
24	Is the tool balanced? (i.e., center of gravity on the grip axis)				14	Are trigger activation forces less than 2.2 lbf (10 N)?			
25	Can the tool be used without gloves?				15	Is the handle nonconductive?			
26	Does the tool have stops to limit closure and pinching?				16	Are the user's fingers or hands exposed to cool (<77 °F) tool surface or exhaust air?			
a	Do the stops maintain a minimum of 1 inch opening to avoid pinching?				17	Does the tool expose user to shock forces? (i.e., pounding or vibration)			
27	Does the tool have a return spring to automatically open the tool to reduce fatigue?				18	Is the tool prone to vibration?			
28	Does the tool have a locking device to prevent inadvertent spring opening?				19	Are third party independent vibration tests available?			
	Power Tool Considerations				20	Does the tool have three plane vibration exposure levels less than permitted by ANSI?			
1	What are the electrical requirements? VAC _____ amps ___ VDC _____ Estimated battery life after full charge and continuous use is _____ minutes Replacement battery number is ____.				a	Total daily exposure m/s^2 g^{Δ} Daily exposure action 2.5 four value Daily exposure limit 5.0 See tables for all other Time exposure ANSI S270-2006			
2	What are air pressure requirements? Min _____ Max ______ Consumption ______SCFM				21	Is the tool supplied with an anti-activation switch? (Prevents continuous run if dropped.)			
3	Does the tool require lubrication?				22	Is the tool electrically operated effectively grounded or feature approved double insulation?			
4	What are the lubrication frequency and amount requirements?					**Miscellaneous and General**			
5	Are the lubricants or compatible equivalents on an approved list and MSDS available?				1	What is the weight of the tool? _______________			
6	What is the rated dBA? ________				2	For general use, is the weight of the tool less than 2.3 kg?			
7	Is there available written data for sound measurements?				3	For precision tasks, is the weight of the tool less than 0.4 kg?			
8	Does the tool produce dust or debris?				4	For extended use, is the tool suspended?			
9	Is there adequate means to exhaust dust or debris away from the operator in a safe manner?				5	Are additional keys and wrenches suitable for use with the tool?			
10	Does the tool exhaust air away from hands arms and body parts?				6	Is a tool holder or bench mounting available to allow easy storage and retrieval of constant use tooling?			

Name or description of tool:					Review date:				
Reviewer:					Location/col. number:				
Tool number (see PW procedure):					Estimated hours/day using tool:				
#	**Question**	**Yes**	**No**	**N/A**	**#**	**Question**	**Yes**	**No**	**N/A**
	Miscellaneous and General (cont.)				11	Does the tool require an articulating air swivel to orientate the tool?			
7	For power users, does the tool have a pistol grip at 78 degrees?				12	Are cutting surfaces coated to reduce friction levels?			
8	Does the tool have low gloss or non-reflective polished surfaces?				13	Is a reaction bar provided for torque exceeding:			
9	Is the torque limited to:				a	6 N-m for in-line tools?			
a	14 inch-pound (1.6 N-m) for in-line tools?				b	12 N-m for pistol-grip tools?			
b	24 inch-pound (3.2 N-m) for pistol-grip tools?				c	50 N-m for right-angled tools?			
c	177 inch-pound (20 N-m) for right-angled tools?								
10	Is the tool effectively covered with a correct shield, guard, or other attachment as recommended by consensus standard or code?				14	Is handle axis aligned with the operator to allow tool control and application of force?			

A.3 NOTIONAL GUIDANCE FOR USER EVALUATION OF POWERED HAND TOOLS—FACTORS FOR CONSIDERATION IN EVALUATION OF SPECIFIC TOOLS

Certain categories of tools and related work tasks are likely to require emphasis of particular factors relevant to the safety and evaluation of their operations. A partial list of such considerations is provided below. Such aspects may also be considered in procurement evaluation and often constitute necessary basic (threshold) criteria for purchase. When multiple tools are available for trial, a direct comparison of alternative products should be considered. Users may be asked to provide a semi-quantitative assessment of each product for direct comparison.

1. Trigger mechanism and safety of operation: Safe trigger activation is likely to be threshold (basic necessary) criteria for certain tools such as nail guns and specific operations where one hand is used to secure the work while the tool is operated with the other hand. Evaluators should be asked to consider the risk of injury and its control by specific interlock mechanisms.

2. Control of reactive counter-torque at the end of a fastening cycle: Nut runners and other fastening tools may create significant impulse (reaction) which can be modulated by the mechanism for control of torque and the speed of reaction.

3. Control of counter-reaction to impulsive tools: The reaction force after impulse and ability to direct this force away from the user by mechanisms such as diversion of pneumatic blow-off should be considered.

4. Role of supported/stabilized tools versus unsupported/handheld tools: A comparison of stresses, productivity, and comfort, as well as effect on long-term fatigue should be made. Stresses created by holding the tool both during operation and during rest periods, when picking up the tool need to be considered.

A.4 ADDITIONAL SELECTION CRITERIA BASED ON TOOL TYPE

Table A5

Type of Tool	Additional Selection Criteria						Other Key Issues for Tool
	Exhaust Air Directed Away from Hands	**Maximum Allowable Torque**	**Rate of Torque Buildup and Release (Including kick-back after cycle completion)**	**Isolation from Reaction Force During Impact**	**Double Wall Isolation or Use with Ground Fault Interrupter**	**Muffler or Other Noise Mitigation for Exhaust**	
Type I Pneumatic Tools	G*	G	S	S	N/A	G	
Class 1: Grinders/Polishers Style A - Straight Style B - Angle Style C - Die	G			NA	N/A		Safety of grinding tool lock and ease of change
Class 2: Drills	G	G	S*	NA	N/A		
Class 3: Percussive Tools (Air Hammers, Needle Scalers, Rammers and Road Breakers (Jackhammers)	G		S	G	N/A	G	
Class 4: Nailers/Staplers	G	NA	S	G	N/A		
Class 5: Impact Wrenches	G	G	G*	G	N/A		
Class 6: Nut Runners/Screwdrivers	G	G	S	S	N/A		
Type II Electric Tools	N/A	G	G	S	G		
Class 1: Grinders/Polishers Style A - Straight Style B - Angle Style C - Die	N/A	G	N/A	N/A	G		
Class 2: Drills	S		G*		G		
Class 3: Air Hammers	G	N/A	N/A	G*	G	G*	
Class 4: Nailers/Staplers	N/A			G*	G		
Class 5: Impact Wrenches	N/A	G	S*	G*	G		
Class 6: Nut Runners/Screwdrivers	N/A	G	S*	G*	G		
Type III Liquid Fuel Tools	G (and breathing zone of user)	S (engine stall or damage)?	S (engine stall or damage)?	S	N/A		
Class 1: Chain Saws	G (and breathing zone of user)					G	
Class 2: Yard Equipment (Mowers/Leaf Blowers/Weed Eaters)	G (and breathing zone of user)					G	
Class 3: Concrete Saws/Cutting Saws (Handheld)	G (and breathing zone of user)					G	

Type of Tool	Additional Selection Criteria						Other Key Issues for Tool
	Exhaust Air Directed Away from Hands	Maximum Allowable Torque	Rate of Torque Buildup and Release (Including kick-back after cycle completion)	Isolation from Reaction Force During Impact	Double Wall Isolation or Use with Ground Fault Interrupter	Muffler or Other Noise Mitigation for Exhaust	
Class 4: Drills (Post Hole Diggers)	G (and breathing zone of user)						
Type IV Hydraulic Tools	N/A						Protection of hydraulic line and protection of operator from failure
Class 1: Prying Tools	N/A	G	S		N/A	N/A	G
Class 2: Hammers	N/A			G	N/A	N/A	G
Class 3: Cutters	N/A	G	S		N/A	N/A	G
Class 4: Rams	N/A			G	N/A	N/A	G

N/A Not typically applicable.
G Generally applicable.
G* Generally applicable and particularly important.
S Sometimes applicable, particularly for specialty applications.

APPENDIX B - MEASUREMENT REPORTS

The following information shall be given in the test report:

1. Criteria use for physical agents evaluation:

   a. Vibration: Refer to the part of ISO 28927 (i.e., ISO 28927-1) and ANSI S2.70 when workplace evaluation is conducted. Measurements should be consistent with the regulatory guidance of the nations in which products will be sold. Within the European Union, the Machinery Directive from 1998 was active until December 2009. The declared values were single-axis values measured according to ISO 8662. A new directive—2006/42/EC—became active in 2010. Declared vibration values changed to three-axes values, measured according to ISO 28927 or EN 60745. These values are generally higher than the old declared values because of the input from additional axis. The old and new values should not be mixed and cannot be compared. In case the machine tested is not covered in ISO 28927, the general standard ISO 20643 is used. The reference to ISO 20643 should preferably be followed by a note explaining how the test was performed. The noise values are declared using the same standard as before, ISO 15744. The only change is that the sound power should now be given when the sound pressure exceeds 80 dBA. The uncertainty of both vibration and noise values shall be described.

   b. Noise: Refer to the test method used and underlying ANSI/ISO standard, such as ANSI A1.4 through S1.4. If sound power levels are obtained, cite the relevant test protocol and standard, such as ISO 3746:2010.

2. Name of the measuring laboratory.

3. Date of measurement and name of the persons responsible for the test.

4. Specification of the handheld machines (manufacturer, type, serial number, etc.) and related correction factors and support equipment:

   a. Declared vibration emission value a, hd and uncertainty K, as well as information on any correction applied.

   b. Attached or inserted tools and method of attachment. It may be necessary to specify the type and related tolerance of the attachment (refer to ISO 21108 for guidance).

   c. Energy supply (air pressure/input voltage, etc., as applicable).

5. Instrumentation (accelerometer, recording system, hardware, software, etc.) and calibration traceability:

   a. Position and fastening of transducers, measuring directions and individual vibration value.

   b. Other factors related to equipment use, as needed.

6. Operating conditions and other quantities to be specified, including environmental conditions such as location of measurements (indoors/outdoors), temperature, humidity, and any other factors reasonably likely to influence measurements. Where noise is measured, the acoustical conditions (reflectivity of the area) should be described.

7. Detailed results of the test (see APPENDIX C and APPENDIX D).

8. Additional information to be considered: If transducer positions or measurements other than those specified in the relevant part of ISO 29827 are used, they shall be clearly defined and an explanation of the reason for the change in the position of the transducer shall be inserted in the test report.

Factors relevant to workplace versus laboratory evaluation and additional parameters to be considered.

APPENDIX A provides detailed alternative formats for worker evaluation of alternative powered hand tools. Information collected on this or a comparable format should be included in report of test results.

Atlas Copco (2014) summarizes approaches to laboratory and workplace evaluation of vibration and noise and describes the variability of workplace vibration levels relative to laboratory test environments.

If at all feasible, measurements should be made on at least three operators, each making five test runs on three different tools (or number of products being evaluated).

Personal characteristics of personnel performing field tests to include age, sex, handedness (predominant hand used), height, and experience in the work being evaluated.

Process description including duty cycle and trigger time (required to estimate daily vibration exposure dose), materials (substrate), and process conducted.

Consider photographic records and/or drawings to describe the operation.

Data comparing declared and recorded vibration and noise measurements and description of factors that might account for differences.

B.1 SAMPLE MEASUREMENT REPORT

Laboratory (Letterhead)
Address

Tool Evaluated	Model	Serial Number	Attachment

<table>
<tr><th>Physical Agent Evaluation (Summary Data) Parameter</th><th>Reference Criteria</th><th>Measured Value</th><th>Parameter or Units</th><th>Notes/ References</th></tr>
<tr><td>Hand-transmitted vibration</td><td>ISO 28927-__
ANSI S2.70</td><td></td><td>m/s²</td><td></td></tr>
<tr><td>Peak acceleration</td><td>ISO 28927-__
ANSI S2.70</td><td></td><td>m/s²</td><td>Describe conditions creating acceleration</td></tr>
<tr><td>Steady state noise</td><td>ANSI S4.1</td><td></td><td>dBA</td><td></td></tr>
<tr><td>Steady state noise</td><td>ANSI S4.1</td><td><table><tr><td>62</td><td>125</td><td>250</td><td>0.5K</td><td>1K</td><td>2K</td><td>4K</td><td>8K</td><td>16K</td><td>dB (total un-weighted)</td><td>dBA (A-weighted)</td></tr><tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr></table></td><td>dB</td><td>Octave band analysis</td></tr>
</table>

Test Equipment Used

Measuring Equipment		Calibration Equipment		Verification	Additional Sensor/Attachment	Remarks
Model	Serial	Model	Serial			

Description of Test Conditions/Laboratory Setup

Process description including duty cycle and trigger time (required to estimate daily vibration exposure dose); materials (substrate) and process conducted.

Consider photographic records and/or drawings to describe the operation.

Data comparing declared and recorded vibration and noise measurements and description of factors that might account for differences.

Person Performing Test	Contact Information	Notes	Date
Laboratory Director	**Contact Information**	**Notes**	**Date**

APPENDIX C - TESTING

Information should be consistent with the method specified and relevant ISO/ANSI or another consensus standard. APPENDIX A lists commonly used testing methods and standards. When feasible, testing of noise and vibration should be done under conditions of load, representative of the type of work typically done with the tool(s) being evaluated. Where third-party testing is required, certificates of laboratory certification and test results should be provided.

C.1 VIBRATION TESTING

All vibration testing shall be done using ISO 29827 and consist of the following parts, under the general title "Handheld Portable Power Tools - Test Methods for Evaluation of Vibration Emission."

Part 1: Angle and vertical grinders (ISO 29827-1)

Part 2: Wrenches, nutrunners and screwdrivers (ISO 29827-2)

Part 3: Polishers and rotary, orbital and random orbital sanders (ISO 29827-3)

Part 4: Straight grinders (ISO 29827-4)

Part 5: Drills and impact hammers (ISO 29827-5)

Part 6: Rammers (ISO 29827-6)

Part 7: Nibblers and shears (ISO 29827-7)

Part 8: Saws, polishing and filing machines with reciprocating action and small saws with oscillating or rotating action (ISO 29827-8)

Part 9: Scaling hammers and needle scalers (ISO 29827-9)

Part 10: Percussive drills, hammers, and breakers (includes rivet guns) (ISO 29827-10)

Part 11: Stone hammers (ISO 29827-11)

C.2 GENERAL TESTING

Where ISO/ANSI methods do not provide guidance for test methods for a particular tool category or process, a standard approach should be developed and documented. The approaches described in European Union and/or NIOSH noise and vibration databases should be considered, and referenced, if they are used. Notational guidance for such situations is provided below for testing methods where existing guidance is incomplete.

All tools of the same type will be tested in the same manner. Where feasible, use a standardized test block solid steel testing block that is 1 ft^3, bolted to a non-movable surface. A 3/8 inch grade 8 bolt head for 1/4 inch drive, 1/2 inch grade 8 bolt head for 1/2 inch drive, 1 inch grade 8 bolt head for 3/4 inch and 1 inch drives will be secured into the block. A six-point impact socket of the same size as the grade 8 bolt head will be used. An extension of 2 inches will be used between the socket and the tool. For pneumatic tools, the air input to the tool will be set at the max usable input.

The vibration data will be collected from the grip of the tool. Noise data may also be taken from this test. Sound testing equipment will be stationed no more than 3 feet from the working radius of the tool.

Alternative testing set-ups shall be developed where tool operations and/or access during use does not permit use of the mounting arrangement described above.

Levels of illumination should be sufficient to clearly illuminate the work area. Glare should be minimized to provide levels of contrast suitable to provide clear vision of the work location.