



AEROSPACE STANDARD	AS6228™	REV. A
	Issued	2017-09
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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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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 Scalars
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
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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 Requirements 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

ACGIH. (2019). Industrial ventilation: A manual of recommended practice for design. 30th Edition. American Conference of Governmental Industrial Hygienists.

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University of Bristol. (n.d.). Controlling the risks from vibration at work. Safety and Health Services. Retrieved from <http://www.bris.ac.uk/safety/media/gn/vibration-gn.pdf>.

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 L_p). 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: $\text{SPL or } L_p = 20 \cdot \log^{f()}(P/P_0)$, where $P_0 = 20 \mu\text{Pa}$. 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, 2×10^{-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 $L_w = 10 \cdot \log^{f()}(W/W_0)$, 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 $I = W/(4\pi r^2)$, where r is the distance from sound source to the receiver. The SI unit of sound intensity is the watts/meter² (W/m^2). Sound intensity can be converted into dB by using this formula: sound intensity level or $L_I = 10 \cdot \log^{f()}(I/I_0)$. 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, 2×10^{-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.

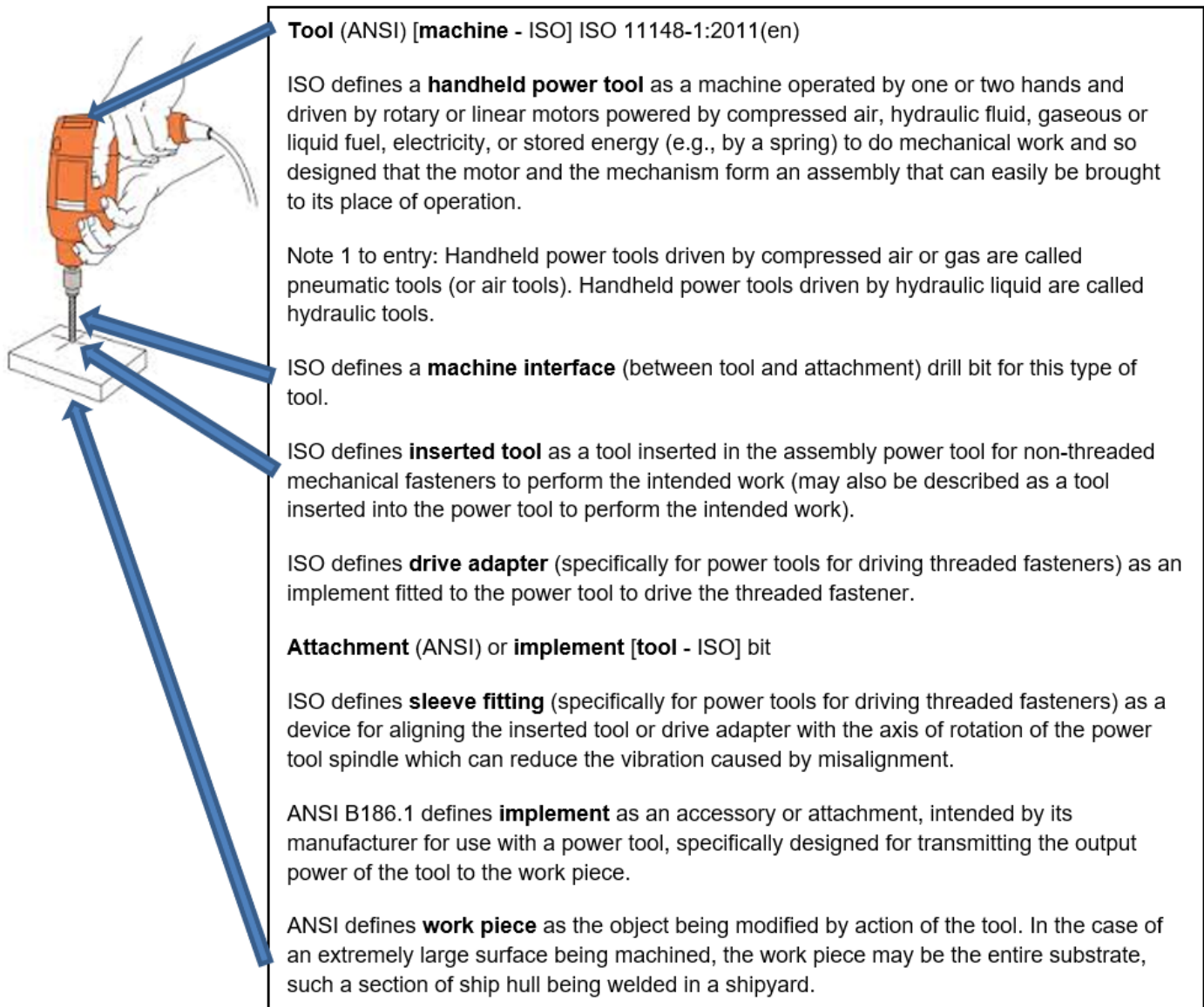


Figure 1 - Relationship between tool (machine), interface, and attachment (comparison of ANSI and ISO 11148-1:2011(EN) terminology)

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:

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

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.

a_{hy} : 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:

$a_{hwx(rms)}$, $a_{hwy(rms)}$, and $a_{hwz(rms)}$ = 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:

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

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/s² might have 5% of the evaluation based on vibration levels. Tools operating in the range of >5.0 m/s² 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 M³/hour) x (work time in hours/day/tool) x power required in kWh for compressor to produce 1 M³ air at 7.5 bar (110 psi) 1 M³ = 28.3 ft³ Rule of thumb: 1 M³ 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.