



AEROSPACE INFORMATION REPORT

AIR6916™

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Guide for Safety, Efficiency, and Productivity
in Buying Power Hand Tools

RATIONALE

This SAE Aerospace Information Report (AIR) provides a non-technical overview of SAE Aerospace Standard (AS) AS6228A. Several appendices describe potential health and safety hazards associated with power hand tools and describe approaches to minimizing safety risks through procurement of best available equipment. Both the AS6228A standard and this AIR support the recognition and control of health and safety hazards while optimizing productivity, quality, and value for resources used to procure and operate power tools.

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Documents

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1. SCOPE

Power tools are essential in most modern industries. However, poorly selected and managed tools can contribute to safety risks, including physical injuries, noise-associated hearing loss, and repetitive motion injuries. Outdated or poorly maintained tools also cost far more to operate than better quality products and often create quality and productivity issues. This SAE Aerospace Information Report (AIR) guides buyers and users of power tools in the evaluation, selection, and use of power tools for economy, efficiency, and safety. It intended to be a "layman's guide" and supports the application of the SAE Aerospace Standard AS6228, which provides guidance for a scientific and engineering audience focusing upon manufacturers and engineering developers.

2. 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 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.

AS6228 Safety Requirements for Procurement, Maintenance, and Use of Held-Held Power Tools

2.2 Related Publications

The following publications are provided for information purposes only and are not a required part of this SAE Technical Report.

Users of this report should select from these and other resources, as appropriate, to support safety and quality.

2.2.1 Noise and Vibration Publications

Occupational Safety and Health Administration (OSHA). (1980). Noise control: A guide for workers and employers. Available at <https://www.nonoise.org/hearing/noisecon/noisecon.htm>.

U.S. Army Public Health Command. (2014). Vibration pocket guide: A guide for prioritizing hand-arm vibration exposure. Available at https://phc.amedd.army.mil/PHC%20Resource%20Library/TG356_VibrationPocketGuide.pdf.

2.2.2 Power Hand Tool Noise and Vibration Publications

Industrial Noise and Vibration Centre. (n.d.). Hand-arm vibration - HAV - assessment. Available at <https://invc.com/vibration/hand-arm-vibration-hav-assessment/>.

Italian Physical Agents Portal (PAF). (n.d.). Hand-arm vibration database. Available at https://www.portaleagentifisici.it/fo_hav_list_macchinari_avanzata.php?lg=EN&page=0.

National Institute for Occupational Safety and Health (NIOSH). (n.d.). Database for power hand tool noise and vibration. Available at https://www.cdc.gov/niosh/topics/noise/solutions/downloads/ALL_TOOLS_SWLA.pdf.

National Institute for Working Life. (n.d.). Centralised European hand-arm database on the internet. Available at http://resource.isvr.soton.ac.uk/HRV/VINET/pdf_files/Appendix_H4B.pdf.

NOTE: The database cited in this guide has been relocated to another site. The hand-arm vibration database is available at <https://www.vibration.db.umu.se/app/>.

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

2.2.3 Ergonomics Publications

Albers, J.T. and Estill, C.F. (2007). Ergonomics for construction workers. *National Institute for Occupational Safety and Health*. Available at <https://blogs.cdc.gov/niosh-science-blog/2007/12/17/erg/>.

Atlas Copco. (2015). The art of ergonomics. Available at https://www.atlascopco.com/content/dam/atlas-copco/industrial-technique/ergonomics/documents/Pocket%20Guide%20Ergonomics%209833858701_L.pdf.

Defense Centers for Public Health - Aberdeen. (2022). Ergonomics. Available at <https://phc.amedd.army.mil/topics/workplacehealth/ergo/Pages/default.aspx>

Lindqvist, B., Skogsberg, L., Graf, F., Haettel, R., and Mazaheri, A. (2022). Power tool ergonomics: Evaluation of power tools. *Atlas Copco*, ISBN 978-91-527-0284-0. Available at <https://www.atlascopco.com/content/dam/atlas-copco/industrial-technique/ergonomics/documents/PowerToolErgonomics.pdf>.

National Institute for Occupational Safety and Health (NIOSH). (2006). Simple solutions ergonomics for construction workers. Available at <https://www.cdc.gov/niosh/docs/2007-122/>.

National Safety Council. (1993). Ergonomics: A practical guide. Second edition. Available at <https://www.nsc.org/shop/workplace-safety/ergonomics/ergonomics-practical-guide-2ed-cd-kit>.

Washington State Department of Labor and Industries. (n.d.). Caution zone checklist. Available at <https://lni.wa.gov/safety-health/docs/CautionZoneJobsChecklist.pdf>.

2.2.4 Health Hazard Publications

American Conference of Governmental Industrial Hygienist (ACGIH). (2023). Threshold Limit Values® for chemical substances and physical agents in the work environment. Available at <https://www.acgih.org/publications/>.

NOTE: This link is updated annually. Relevant criteria include hand activity level, vibration guidelines, noise standards, and recommended standards for varied chemical substances.

2.2.5 Web-Based Information Sources

Hand Tools Institute. Address: 25 North Broadway, Tarrytown, NY 10591. Phone: 914-332-0040. Email: info@hti.org. Website: <http://www.hti.org>.

Power Tool Institute. 1300 Sumner Avenue, Cleveland, OH 44115-2851. Phone: 216-241-7333. Fax: 216-241-0105. Email: pti@powertoolinstitute.com. Website: <http://www.powertoolinstitute.com/>.

3. FORMAT

The format is intended to be flexible and provide an outline and text which can be modified for an organization's internal use. Appendices A through C provide standalone guidance for specific health and safety program areas—noise, ergonomics, hand-arm vibration. Appendix D provides guidelines for control of hazardous dusts from power tools. A suggested format for worker evaluation of tools during use is provided as Appendix E. An outline for quality assurance and safety programs is provided as Appendix F. The educational needs for varied personnel, including manager, supervisors, engineering, logistics, and production workers are summarized in Appendix G. A safety or quality program cannot work if it only focuses upon training of tradesmen without the informed engagement of management and technical personnel. The format accounts for some redundancy in citation of supporting resources in each stand-alone enclosure.

4. BACKGROUND

Powered hand tools are vital to the production, maintenance, and/or construction activities conducted in most industrial organizations. This AIR was developed because of the need to better inform both power tool users and those providing purchasing, engineering and safety support in the recognition, evaluation, and control of safety risk factors and barriers to productivity and quality. Educating users and procurement/logistics staff, engineering and managers in product selection and maintenance will improve productivity, cost-efficiencies, safety, and health.

5. HOW AND WHY THIS SAE AEROSPACE INFORMATION REPORT WAS DEVELOPED

The EG1-B1 committee of SAE International, a well-known standards and quality assurance organization, developed technical guidance for management of powered hand tools for productivity, life cycle cost management, and safety and health risk management (AS6228). AS6228 has been used by the U.S. government's main purchasing agency, The General Services Administration, since 2014. The committee includes U.S. and international members from the Department of Defense, industry including tool manufacturers and large-scale users, the General Services Administration (the U.S. government's purchasing group), the National Institute for Occupational Safety and Health, and the Mine Safety and Health Administration. However, it was felt that the AS6228 standard required a layman's guide to make it more usable and accessible to a wider audience. Several groups of representative industrial power tool users were consulted and contributed greatly to the readability of this report. AIR6916 explains the AS6228 standard in layman's terms. It is intended for all industrial users of powered hand tools in production, maintenance, and construction applications, including some that may not be able to purchase the primary standard. It contains several appendices which are meant to provide non-technical standalone guides on topics such as noise hazards and their control. AS6228 has also been updated and is being released as AS6228 at the same time as this report.

6. PRODUCTIVITY AND LIFE-CYCLE COST EVALUATION OF POWER HAND TOOLS

The process for managing hand-held power tools have some similarities to maintaining larger unit cost equipment and facilities. Important differences include (a) it is often amenable to more rapid improvement because of the typically shorter lifespan of many powered tools, and (b) the involvement of multiple groups is needed for a successful quality and safety program. The guidance in this report can be applied to address the following areas:

- Cost-benefit analysis for power hand tool procurement and maintenance.
- Productivity evaluations.
- Role of early and predictive maintenance in reducing costs of parts replaced and avoiding breakdowns.
- Link between maintenance and sustained productivity.
- Hidden costs of deferred maintenance in inferior quality, reduced productivity, and increased risk to users.
- The process of interdisciplinary collaboration needed to develop and implement effective safety, health quality, and productivity.

7. HEALTH AND SAFETY RISK FACTORS POTENTIALLY ASSOCIATED WITH POWER HAND TOOL USE

Informed product selection and performance of scheduled maintenance quality of initial product selection can maximize productivity, efficiency and support quality while reducing the risk to tool users. Table 1 provides an overview of potential risk factors and their prospective impact on productivity and quality.

Table 1 - Process management and equipment selection factors for hand-held power tools

Factor or Risk	Health Impacts	Productivity and Quality Impact	Potential Controls
Noise	Hearing loss and impaired communication. Non-auditory (hearing) effects including general stress and related impacts as elevated blood pressure, sleep interruption and fatigue.	Communication issues affecting safety and quality.	Low vibration/low noise tools (purchase); tool balancing and maintenance. Isolation of vibrating equipment. Advanced communication systems (for noise).
Vibration	Hand-arm vibration disease risk (see Appendix D).	Decrease in precision/quality; increased rejection rate; impacts on skilled work forces.	Protective equipment-and related training including hearing protection and potentially third-party certified anti-vibration gloves.
Ergonomic design of workplace and tools	Long-term disease potential such as carpal tunnel syndrome; most long-term disease and potential disability is preceded by discomfort and reduced productivity.	Direct link between comfort and productivity.	Equipment selection and process design. Need to consider both the tool, its attachments and supporting work stands and related workplace design. Evaluation and monitoring of current workplaces.
Physical safety hazards and related controls	Potential injuries.	Productivity impacts of workarounds.	Equipment selection and maintenance to avoid potential physical injuries.
Life-cycle costs (including replacement/repair)	Low-cost tools are likely to be noisier, have higher vibration, and be less ergonomic.	Informed product selection and performance of scheduled maintenance will minimize the costs and delays of unplanned failures and optimize efficiency. Decreased productivity and quality (inexpensive or consumer-grade tools are expensive due to maintenance costs and quality issues.	Note that consumables and labor are the highest costs. (Up to 80 or 90% for common activities such as grinding.)

8. BALANCED SCORE CARD

Selection and safe user of power tools can be difficult because many factors are involved. Over-reliance on one purchase factor such as initial purchase cost frequently leads to selection of equipment which is less safe to operate and actually creates much higher long-term costs than selection of tools which better suited to the work operation(s). An approach balancing selection factors through use of a semi-quantitative scoring system can improve the process outline in Table 2. This scoring system does not provide a fine line between safe and unsafe, but a method for comparing tools which are meant to perform a similar job. It allows for preliminary selection (screening) among alternative products and may remove tools which may be unsafe or do not meet basic user needs from further consideration. If possible, a final selection should be made by having users compare the best available products through trial use in the workplace.

Risk factors are listed in Table 2. Review for varied risk factors may be provided with a summary sheet as an attachment to the internal operating procedure.

- Noise (see Appendix A, a guide for this noise hazards and summary for developing a hearing conservation program).
- Physical injuries.
- Electrical safety hazards.
- Ergonomics and repetitive motion. Appendix B helps identify potential risk factors and suggests general approaches for their evaluation and control. Consider use of a website for identification of ergonomic risk factors and related form. Washington State Department of Labor and Industries developed an ergonomic caution checklist, which has been used by the Department of Defense, available at https://lni.wa.gov/safety-health/_docs/CautionZoneJobsChecklist.pdf.
- Hand-arm vibration. Appendix C provides summary guidance. Consider use of the United Kingdom's Health and Safety Executive guidelines, available at <http://www.hse.gov.uk/VIBRATION/hav/advicetoemployers/assessrisks.htm>.
- Dispersion of contaminants, such as grinding dusts, related to the rate of production and availability of control measures.

8.1 Physical 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.

8.2 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.

8.3 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>).

8.4 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.

8.5 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.)

8.6 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.

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

Table 2 - Representative guidance on weighting factors for tool evaluation

Factor	Relative Weighting	How to Evaluate ⁽¹⁾
Productivity	20% (20 of 100 possible points)	Criteria may include cycle time, amount of material removed, or time to accomplish a specific amount of work. 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 reporting on the noise and vibration levels created by varied tools. Units of work need to be identified but must be task/job specific (e.g., number of holes drilled in sheet metal during a specific time period).
Ergonomic factors other than shock and vibration	20% (20 of 100 possible points)	Ergonomics describes how well the tool is suited to the user and the job. A good fit will increase productivity and comfort while avoiding risks of long-term injury. See Appendix B. Some resources including illustration of risk factors: - Guidance from the Canadian Center for Occupational Health: https://www.ccohs.ca/oshanswers/ergonomics/handtools/tooldesign.html - Cornell University: http://ergo.human.cornell.edu/studentdownloads/DEA3250pdfs/Hand%20Tools.pdf - The U.S. Center for Disease Control (CDC)/OSHA: https://www.cdc.gov/niosh/docs/2004-164/pdfs/2004-164.pdf?id=10.26616/NIOSH-PUB2004164 Considerations may include deviation (bending) of the wrist from neutral (un-bent) position; balance of tool; area of trigger (and force necessary to activate tool); awkward positions of the head, neck, arm, and shoulders. Additional factors are shown in Table 1 of AS6228

Factor	Relative Weighting	How to Evaluate ⁽¹⁾
Noise	10% (10 of 100 possible points)	Report sound levels obtained in a representative setting in decibels un-weighted (dB) and weighted dBA. Vendor's declared values might be used as initial estimate but should be subject to verification. Noise exposure evaluation may also be linked to the total noise amount or "dose" of noise 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; while another might create noise levels of 91 dBA but require 60 minutes to accomplish the same task. 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 hour allowable at 94 dBA).
Hand-arm vibration	20% (10 of 100 possible points)	Depends 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 20% of the evaluation based on vibration levels. Information from the European Union and NIOSH databases may be used. See Appendix B. Vendor's declared values might be used as initial estimate but should be subject to verification. 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. PNEUEOP Pamphlet PN3-01 provides guidance for conversion of varied test setting for specific tool categories to real work tasks commonly considered. The CEN document 15350 spells out using a correction factor of between 1.0 and 1.7, depending on type of tool, condition, etc. For mechanical vibration, guidelines for the assessment of exposure to hand-transmitted vibration using available information, including that provided by manufacturers of machinery PD CEN/TR 15350:2020, http://store.uni.com/catalogo/norme/root-categorie-ics/13/13-160/uni-cen-tr-15350-2020 Euro 55 and https://store.uni.com/en/uni-cen-tr-15350-2020. 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.
Initial purchase cost	5% (5 of possible 100 points)	May depend on anticipated lifespan of tool and intensity of use (e.g., occasional, periodic, daily).

Factor	Relative Weighting	How to Evaluate ⁽¹⁾
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 work. - Reliability, and maintainability of the tools. - Parts required for recommended maintenance.⁽²⁾ - 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)	Most costs are related to labor and consumables. These data can be used if other information is not available. Clearly defined representative tasks 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.
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. 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⁽³⁾		
User preference	15% (above baseline score)	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 of AS6228 provides guidance for formal user evaluation and feedback related to tool use.

⁽¹⁾ Also see the appendices of this document and more detailed guidelines in AS6228.

⁽²⁾ Maintenance costs may be initially estimated on the basis of manufacture recommendations but, where feasible, should be supplemented by (your) field experience.

⁽³⁾ User's hands-on evaluation is not always available for small quantity purchase or for preliminary screening of alternative products.

9. COMPARISON OF TOOLS—USING THE BALANCED SCORECARD

When a comparative scoring system has been developed, it can be used to compare alternative tools. The appendices on noise, vibration and ergonomics provide examples of how a semi-quantitative scoring system can be developed to compare multiple tools. Table 3 provides an example of how multiple tools may be compared using the balanced scorecard approach. The scoring system provides suggested guidelines for comparing similar products. It is a screening tool—not a measure of absolute value. The scoring factors should be adjusted on the basis of experience and common sense. It should not be a rigid, inflexible ruler.

Most tools being compared will be more similar in performance and cost. However, if purchase cost had been the only criteria, Model B costing \$350 would have been chosen over Model A, which cost \$525. If other factors related to safety and productivity were fully considered, the alternative choice would be made.

10. WORKER EVALUATION OF TOOLS

When an initial identification of best available tools has been made, workplace evaluation should be done. The productivity, efficiency, and safety of varied power tools is best evaluated by workers using these products. A suggested guideline for worker evaluation is provided as Appendix E. Trial use of a few representative products should be considered before large volume purchases are made. Many companies may be willing to allow the trial use of their products if they are reasonably confident of sales.

Measurements of productivity, quality, noise, and—if possible—vibration should be made during trial use of alternative power tools.

Why spend the time and money? The time and cost of evaluating alternative products, making low volume trial purchases, and conducting workplace evaluations should be considered a long-term investment in productivity and safety. The technology of hand-held power tools continues to evolve rapidly. Not investing in the evaluation and potential use of best available technology is likely to represent a false economy.

Table 3 - Example comparing two tools using a balanced scorecard approach

Factor	Relative Weighting	Range for Available Products	Possible Score (Partial Example)	Tool A Performance/ Score	Tool B Performance/ Score
Productivity	20% (20 of 100 possible points)	60 to 98 holes drilled/hour	20 points → 100 holes 10 points → 75 holes 0 points below 50 holes	98 holes/hour 20 points.	75 holes/hour 10 points.
Ergonomic factors (other than shock and vibration)	20% (20 of 100 possible points)	Tool weight (3 to 6 pounds)	3 pounds → 20 points 4 pounds → 15 points 5 pounds → 10 points 6 pounds → 0 points	3.5 pounds 17 points	5 pounds 10 points
Noise	10% (10 of 100 possible points)	88 to 96 dbA	88 dBA → 10 points 90 dBA → 8 points 92 dBA → 6 points 94 dBA → 4 points 96 dBA → 0 points	90 dBA 8 points	96 dBA 0 points
Hand-arm vibration	20% (10 of 100 possible points)	3 to 5.8 m/s ²	2.5 m/s ² → 20 points 3.0 m/s ² → 15 points 4 m/s ² → 10 points 5 m/s ² → 5 points 6 m/s ² → 0 points	3.0 m/s ² 15 points	4 m/s ² 10 points
Initial procurement cost	5% (5 of 100 possible points)	\$275 to \$450	\$275 → 5 points \$450 → 0 points	\$525 2 points	\$350 4 points

Factor	Relative Weighting	Range for Available Products	Possible Score (Partial Example)	Tool A Performance/ Score	Tool B Performance/ Score
Five-year operational cost	10% (10 of 100 possible points)	\$350 to \$700 Based on 300 hours/use per year, maintenance, and replacement parts.	\$300 → 10 points \$400 → 8 points \$500 → 6 points \$600 → 4 points \$700 → 2 points	\$500 6 points	\$630 4 points
Cost to produce given quantity of work (including utility costs)	5% (5 of 100 possible points)	Time cost to drill 100 holes with \$60/hour labor cost \$37 to \$60 labor cost/100 holes	100 holes/hour → 5 points 75 holes/hour → 3 points 50 holes/hour → 1 point Below 50 holes/hour → do not buy the tool!	98 holes/hour 5 points	65 holes/hour 2 points
Physical safety factors	10% (10 of 100 possible points)			Best grip and electrical safety 10 points	Fair grip, barely acceptable electrical safety 3 points
Total	100 possible			83	49

Table 4 provides a table for comparison of alternative tools.

Table 4 - Comparative evaluation of tools using a balanced scorecard approach

Factor	Relative Weighting	Range for Available Products	Possible Score (Partial Example)	Tool A Performance/ Score	Tool B Performance/ Score	Tool C Performance/ Score
Productivity	20% (20 of 100 possible points)					
Ergonomic factors (other than shock and vibration)	20% (20 of 100 possible points)					
Noise	10% (10 of 100 possible points)					
Hand-arm vibration	20% (10 of 100 possible points)					
Initial procurement cost	5% (5 of 100 possible points)					
Five-year operational cost	10% (10 of 100 possible points)					
Cost to produce given quantity of work (including utility costs)	5% (5 of 100 possible points)					
Physical safety factors	10% (10 of 100 possible points)					
Total	100 possible					

11. ROLE OF HIERARCHY

Role of hierarchy of controls in optimizing productivity and minimizing risk to users. The “hierarchy of controls” refers to the process of eliminating the hazard where possible and using alternative methods where a hazard cannot be eliminated. It is the accepted, and most cost-effective, system used in industry to minimize or eliminate exposure to hazards. The following hazard controls are listed in order of greatest effectiveness:

- Elimination (of a hazardous material or process). An example might be elimination of electric shock hazard in a wet environment through use of pneumatic tools.
- Substitution of less hazardous materials or process. Examples might include reduction of noise by use of quieter tools or reduction of dust hazard by chemical removal of paint (rather than driving or chipping) or use of paint not containing toxic heavy metals such as lead.

- Engineering controls. Where a hazard cannot be eliminated, it may need to be contained/controlled through engineering technologies such as ventilation for dust control.
- Administrative controls and training. For instance, limiting the exposure time of workers for a job.
- Personal protective equipment- This is often the least effective “control” measure because it does not eliminate exposures, requires significant training, supervision, and oversight, may be uncomfortable, and often provides incomplete protection.

In practice, some combination of control measures may be required. A common example is selection of quietest available power tools to reduce noise generated, but still requiring some hearing protection use to further limit noise exposures. Selection of controls may also involve some trade-offs. For example, use of pneumatic rather than electric tools in a wet environment eliminates the hazard of electric shock but is likely to increase the level of noise.

An example is use of vinyl paint not containing toxic metals for lead paint. This reduces exposure risks to workers and, also reduces necessary control for lead containment, environmental and medical surveillance. It may also reduce future product liability for the finished product.

12. TEAM APPROACH—ENGINEERING AND PURCHASING IN EVALUATION, SELECTION, AND PROCUREMENT

The best approach to improvement of productivity, safety, and quality is preliminary consultation between users, engineers, and logistics/supply to best outline the job needs, relative costs, and requirements for product purchase. Each group may shape their expectations based on feedback from their peers. For example, logistics/supply may be surprised to learn that the costs of consumables and manpower greatly exceed the life-cycle cost of “expensive” power tools on a long-term—and, often, immediate—basis. Even minor differences in productivity are apt to justify better, safer, and/or more efficient products.

12.1 Suggested Approach

1. Outline product and process needs in a way that is fiscally defensible. It must consider both direct cost and relative efficiency prospectively gained by better products, most often through enhanced labor productivity. Reduction of error/defects and the related lost time and material waste should also be considered if this information is available.
2. Develop a preliminary weighting scale. Refer to procurement selection criteria matrix (from Appendix A of AS6228) and see Table A3 in this report.
3. Compare alternative products using the preliminary procurement selection criteria.
4. Obtain a representative number of best-available products and arrange for user trial. Consider use of work feedback forms in Appendix B of AS6228.
5. Adjust procurement to meet inputs obtained from steps 1 through 4 above.

Key points to consider:

- Include the need to engage user’s inputs and feedback.
- Application of cross-functional education and engagement of all affected groups (Appendix E). Appendix C of AS6228 outlines the background and training suggested for varied members of management, logistics, production, and other groups.
- Higher total procurement costs for sub-standard products including more frequent replacement and the collateral costs of injuries, lost productivity, and poor quality.
- Process management and feedback systems in procurement.

Long-term sustainability requires attention to maintenance and feedback from both logistics and the tool room or other product maintainers. Future procurement criteria should be adjusted on the basis on experience gained during use.

12.2 Team Effort and Suggested Approach

The best approach to control is preliminary discussion between users, engineers, and logistics/supply to best outline the job needs, relative costs, and requirements for product purchase.

Each group may shape their expectations based on feedback from their peers. For example, logistics/supply may be surprised to learn that the costs of consumables and manpower greatly exceed the life-cycle cost of “expensive” power tools on a long-term and often on an immediate basis. Even minor differences in productivity are apt to justify better, safer, and/or more efficient products.

1. Money talks. Outline product and process needs in a way that is fiscally defensible. Consider both direct cost and relative efficiency prospectively gained by better products, often through enhanced labor productivity. Cost savings should be calculated, including the money saved by reducing defects. Cost savings calculators are available online, such as Atlas Copco’s Return on Investment (ROI) calculator, available at <https://www.atlascopco.com/en-us/itba/local/roi-calculator.html?iesrc=ctr>.
2. Find alternatives. Identify approaches to comparing different products. This will typically involve identifying “needs” minimum acceptable criteria (thresholds) for purchase and “wants” desired levels of performance (objectives). This is similar to the process you use to make other complicated purchase decisions such as buying a new car or evaluating home improvements.

If necessary, develop a preliminary weighting (comparison) scale. For example, available grinders used for a given operation may create noise exposures between 90 and 112 dBA. Purchasers may decide that anything above 105 dBA is unacceptable and set 105 dBA as the threshold for purchase. No products creating noise levels above 105 dBA will be purchased. The remaining products operating between 90 and 104 dB may be receive ratings of 10 points (best) to 0 points (minimum acceptable product). See the example in Appendix A.

3. Compare. Compare alternative products from the preliminary procurement selection criteria.
4. Workplace trials. Obtain a representative number of best-available products and arrange for user trial. Noise, productivity, and—if possible—vibration, measurements should be made during these evaluations. Appendix E provides a format for collecting user feedback. (For more information, refer to Appendix B of AS6228.)

13. EDUCATION, TRAINING, AND ACCOUNTABILITY

An organization’s policy should include:

- Role of management in leadership, policy, and oversight. A safety or quality program cannot work if it only focuses upon training of tradesmen without the informed engagement of management and technical personnel.
- Education and orientation of varied organizational groups. (See Appendix G in this report and refer to Table 5 of AS6228.)
- Personal and professional accountability including management, engineering, procurement, and users.
- Discussion of supervisory training and leadership.
- Link to existing policies and procedures.
- Process management and feedback systems.
- Quality assurance overview.
- Tool maintenance and inventory control.
- Evaluation/procurement of tool appendages (bits, drills, etc.) and consumables due to effect on quality and vibration. (Note prevalence of low quality “knock-off” products and the need to ensure suitable screening.)

- Integrated product team approaches to feedback and process improvement.
- Maintaining profitability and productivity.
- Role of safety and health in feedback systems.
- Risk management factors for process and employees.

14. NOTES

14.1 Revision Indicator

A change bar (I) 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 - NOISE HAZARD EVALUATION/CONTROL GUIDANCE IN POWERED HAND TOOL SELECTION

A.1 BACKGROUND

This appendix is an attachment to AIR6916, which describes a process for evaluation and procurement of power tools for safety and productivity. Additional information is provided in AS6228, also available from SAE International.

A.2 NOISE EXPOSURES ARE A COMMON HEALTH HAZARD

Noise is among the most common industrial health hazards throughout the world. In the U.S alone, about 22 million are exposed to hazardous levels of noise at work. Additional millions are exposed to substances such as certain solvents and metals which are potentially ototoxic (chemicals which can create hearing loss alone and/or increase the risk of hearing loss from noise exposure) that could put them at increased risk for hearing loss. (Refer to <https://www.safework.nsw.gov.au/resource-library/hazardous-manual-tasks/hazardous-noise-and-hearing-loss-at-work-the-facts/ototoxins/exposure-to-ototoxic-substances-can-also-cause-hearing-loss>). Power tools are often a significant source of noise exposures. A high fraction of power tools create noise levels during operation which can create long-term hearing loss if protective measures including use of hearing protection, selection of the quietest feasible tools, and equipment maintenance are not applied. Prolonged and intense noise exposures (85 dBA and above—the sound level in which one shout can be heard at arms-length) are associated with hearing loss. Initially, temporary recovery occurs within hours or days. After months and years of noise exposure, the hearing loss slowly becomes permanent. Typically, hearing loss is a complex process that happens over a long period of time but also affects the person on a daily basis. This appendix addresses two areas: (1) how to address noise exposure through exposure measurement and protective equipment use, and (2) measures to reduce noise exposure through equipment selection and maintenance. It provides supporting information on (1) methods of comparing tools by using a noise scoring system, and (2) addressing common misunderstanding which often hinder noise control efforts.

A.3 HEARING LOSS RISK FACTORS AND EFFECTS OF NOISE EXPOSURE

- Almost all work-related hearing loss is permanent, and it can have a profound impact on quality of life. The quality (fidelity) of hearing typically declines more rapidly than the ability to hear sound of a given volume.
- As hearing loss worsens, hearing and understanding others becomes increasingly difficult, which can lead to isolation.
- Hearing loss is associated with cognitive (mental) decline and heart problems, such as high blood pressure and heart disease.
- Hearing loss is also strongly associated with depression.
- Hearing loss can lead to loss of enjoyment, when all the sounds we want to hear (e.g., music, voice of loved one) become muted and lack quality.
- Ringing in the ears (tinnitus), which often occurs along with hearing loss, can disrupt sleep and concentration, and is associated with both depression and anxiety.
- Hearing loss can impact safety at home and on the job.
- Income is typically lower among workers with hearing loss than among workers with normal hearing.

A.4 HEARING LOSS USUALLY COMES FROM NERVE DAMAGE

The specialized nerve cells, known as hair cells, within the inner ear (cochlea) receive sound and translate mechanical energy into nerve signals sent to the brain. The hair cells recover from initial noise exposures, but can they gradually degrade and lose their function with prolonged, uncontrolled noise exposures. In Figure A1, a photo micrograph of intact and damaged cochlea (inner ear nerve cells) conveys the image which can be created by severe, uncontrolled noise exposure sustained over a long period of time.

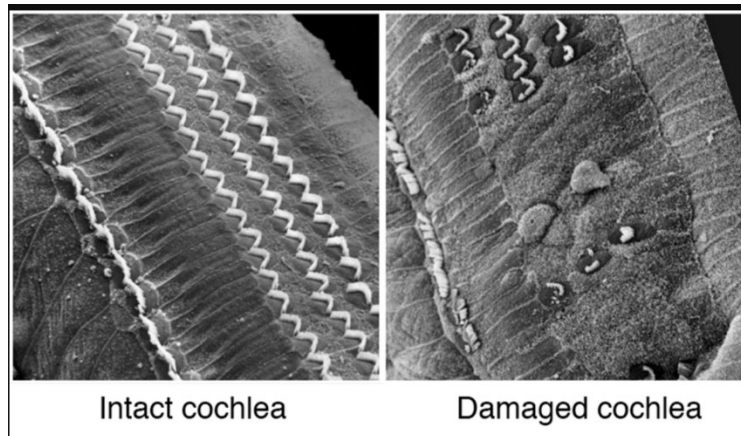


Figure A1 - Intact and damaged cochlea—the part of the inner ear which converts sound to nerve impulses

A.5 SENSING YOUR NOISE EXPOSURE

Sound levels requiring very elevated voice levels (shouting) at arm's length are typically consistent with noise levels in the range of, or above, recommended occupational exposure limits. The threshold of hearing (the lowest sound level you can hear) may be shifted temporarily immediately after acute noise exposure. Either you or friends/family may notice that you are speaking more loudly than necessary. You might notice that the car radio is louder than normal the morning after day of significant noise exposure. Other indications of acute overexposure may include fuzziness or "ringing in the ears" (tinnitus) after exposure ceases. None of these indicators can substitute for measurement of sound levels and associated exposures to noise, but they do provide an indicator of potential risk.

A.6 MEASUREMENT AND EVALUATION OF EXPOSURE

When noise is present at levels potentially dangerous to workers, OSHA requires that employers establish a hearing conservation program. The main elements of a hearing conservation program include (from <https://www.osha.gov/sites/default/files/publications/osha3074.pdf>):

1. Monitoring of employee noise exposures.
2. The institution of engineering, work practice, and administrative controls for excessive noise.
3. The provision of each overexposed employee with an individually fitted hearing protector with an adequate noise reduction rating (See the section on protective equipment).
4. Employee training and education regarding noise hazards and protection measures.
5. Baseline and annual audiometry (Hearing tests and their evaluation by medical professionals).
6. Procedures for preventing further occupational hearing loss by an employee whenever such an event has been identified.
7. Recording keeping.