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Comparison of sound power levels of portable powered hand tools in the loaded and unloaded conditions

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ABSTRACT

Most electrically powered hand tools are specified in ANSI Standard S12.15 to have sound power levels measured while the power tool is in the unloaded condition (full-speed, no load or just simply idling). In an effort to properly define noise sources and levels on construction sites, sound power level data was gathered in both the loaded and unloaded condition from a variety of electrically powered hand tools. This paper compares the differences in the magnitude of the sound power level data and discusses whether existing test standards are in harmony with the reasons that we measure and subsequently use that data. On average for all tools tested, there is a 4.1 dBA increase in sound power level when the power tool is tested in the loaded condition compared to testing in the unloaded condition. In order to provide relevant data, specific recommendations are made to revise existing ANSI Standard S12.15. The recommendations include specifying loaded conditions for testing, standardization of test jig setup and work piece material size and type.

1 INTRODUCTION

The purpose of measuring sound power levels (L_{WA}) of powered hand tools is to establish the magnitude of noise emissions from the tool and subsequently assess the tool's noise-induced hearing loss potential. Currently, construction workers are exposed to hazardous noise levels from powered hand tools and there is a nearly universal failure to wear adequate hearing protection.[1-8] A recent research article relates the measured L_{WA} of powered hand tools to the sound pressure level (L_{PA}) estimate at the operator's ear.[9] The loading conditions of the tools can significantly change the L_{WA} and consequently effect the estimate of L_{PA}. The current testing standard, ANSI S12.15 for measuring L_{WA} of powered hand tools, stipulates loading conditions which may underestimate L_{WA} by as much as 15 dB.[9,10] The purpose of this paper is to compare the L_{WA} radiated in both the loaded and unloaded conditions for powered hand tools commonly used in the construction industry. This effort is accomplished to further the long term goal of reducing noise induced hearing loss among construction and workers in other industries who use powered hand tools.

Aside from individual tool characteristics, L_{WA} varies with loading condition, feed rate, work-piece material, power consumption, and speed. There are two conditions used in L_{WA} testing; (1) unloaded (idling or free-running) and (2) loaded with the tool engaging a work-piece

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such as a wood board or metal block. ANSI S12.15 assigns loading, mounting, and operating conditions according to tool type. Unfortunately, ANSI S12.15 stipulates that L_{WA} be measured in the unloaded condition for many tool types such as circular hand saws, drills, grinders, reciprocating saws, and screwdrivers.

L_{WA} magnitude should be used as part of a "buy quiet" program and to select appropriate hearing protection or to estimate worker's noise exposure. In response to these needs, NIOSH developed a database of L_{WA} from powered hand tools used in the construction industry.[11,12] Using the data gathered in developing the NIOSH database, this paper shows that within each tool type there is considerable variation in the L_{WA} between the loaded and unloaded conditions for different models of tools within the same type.

2 PREVIOUS WORK

L_{WA} data can be found in research papers, internet databases, and on L_{WA} labels and declarations. While several papers on powered hand tools report L_{WA}, many do not specify the loading conditions.[13-20]

European Union and Swedish internet databases report sound pressure and L_{WA} for thousands of machines, equipment, and powered hand tools. Unfortunately, applicable test codes, mounting, loading, operating conditions, and origin of the data may not be readily available.[21,22] While NIOSH has a relatively small database, with only 120 tools of different tool types, all of the tools have been tested in both the loaded and unloaded conditions.[12]

Another source of L_{WA} data are noise labeling on various products. The European Union and Australia currently require noise labels on selected powered hand tools.[24-26] In the United States (US), there is an unfunded and consequently unenforced requirement that noise emitting power tools sold in the US have a L_{WA} label permanently attached to them.[27]

3 METHODS

In previous INCE conference proceedings, testing methods for various types of power tools and a discussion of the applicable standards were presented (ANSI S12.15 and ISO 3744).[11,28] This paper expands on that work to include additional loaded testing for several tool types. For these tools, ANSI S12.15 either does not specify a loaded setup or stipulates testing in the unloaded condition only. Without any specific guidance from ANSI S12.15, loaded test jigs were designed to provide a realistic noise assessment for the real-world use of the powered hand tool. This section details the loading and mounting conditions used for circular saws, drills, grinders, jig saws, reciprocating saws, and screw drivers. For the tests, the manufacturer's standard blades and tool bits that came with the tools were used. Steel blocks were used for the grinder and both an aluminum block and a steel block were used for metal cutting tests. The wood material used was oak or ash hardwood. The use of a hardwood provided the most limiting case with regard to noise emissions. A softer wood, such as pine, could be expected to provide L_{WA} and L_{PA} more closely in magnitude to those measured in the unloaded condition. However, when gathering sound emissions data to be used to estimate an operator or worker's exposure to noise, the most limiting method, or method emitting the greatest sound level should be the test method of choice.

3.1 Circular Saws

As shown in Figure 1, a portable work bench was used as the mounting structure for measuring the L_{WA} of circular saws. Two 1-inch thick oak boards were resiliently mounted to the top of a work bench (Black and Decker Workmate 550 Portable Project Center and Vise). Rubber strips were then laid out on the workbench top and oak boards were then placed on the strips and clamped into position using C-clamps having rubber feet. During cutting, nominal pressure was applied to the saw by the tool operator to keep the saw moving through the wood at a continuous rate.

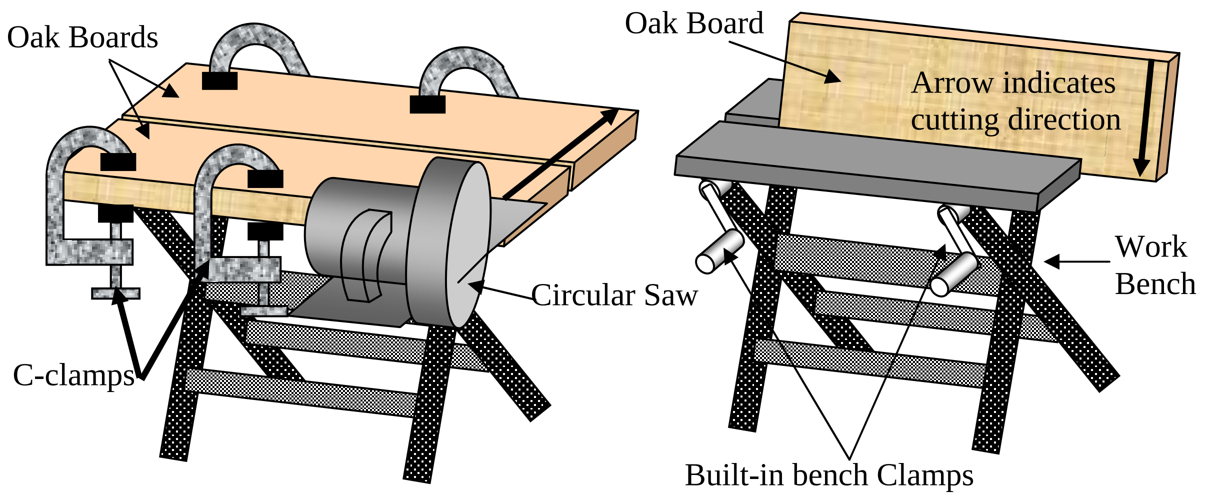

Figure 1: On the left, the circular saw cuts through two oak boards of nominal dimensions of 1 x 12 x 36 inch. The boards were placed side by side to increase the duration of the cutting time and subsequently, the data acquisition time. On the right, a reciprocating saw held horizontally, cuts through a single oak board from top to bottom. The dark black arrows indicate the direction of the cuts.

3.2 Reciprocating Saws

A 1 x 12 x 36 inch oak board was resiliently mounted to the work bench using rubber straps and the built-in bench clamps as shown on the right in Figure 1. The reciprocating saw was held horizontally with vertical cuts being made starting at the top of board as indicated by the arrow.

3.3 Jig Saws

Jig saws were tested with the same test setup as the circular saws.

3.4 Grinders

A 7/8 x 2 x 8 inch steel block was resiliently mounted to the portable work bench using rubber strips, 2 x 4 inch wooden blocks, and C-clamps. The grinder was held horizontally by a tool operator, with the grinding wheel flat against the 7/8 inch wide side of the steel block. The grinder was pressed against the steel and operated in 10-second data acquisition increments. The number of increments or test runs was determined by the uncertainty analysis described previously.[28] After each set of incremental test runs, the steel block was cooled in a water bath to retain hardness.

3.5 Drills

A 4 x 9 x 48 inch ash wood block was resiliently mounted on the work bench. Each drill was tested with a drill bit of the maximum rated size. The drill bits were standard two flute twist design, straight shank, high speed steel, polished bright finish, jobber length. Drilling started at an unaltered surface of the block at full speed. The hole depth was chosen so that there was sufficient measurement time without clogging or burnishing the drill. After drilling each hole, the drill bit was cooled with water and cleared of debris.

3.6 Screw Drivers

L_{WA} was measured by driving a test screw (#12 wood screw, 3½ inch long, #3 flat head, Phillips drive, galvanized steel) into a wood block until the screw head was flush with the block surface. Any clutch slip noise was not included in the L_{WA} measurement as not all screw drivers produce a clutch slip noise. The wood block with dimensions 4 x 10 x 11 inch was assembled by connecting four 1-inch oak boards together with large wood screws. The oak block was resiliently mounted on a short table placed on top of the work bench. The short table setup is detailed in the previous INCE proceedings.[28] Pilot holes 5/32 inch diameter were drilled and counter bored for all test screws. Before testing, each test screw was hand tightened (approximately ½ to ¾ inch deep) to hold the nominal force from the tool operator pushing down on the screw without the screw pivoting sideways. While holding the screw driver tightly, the tool operator pushed down with nominal force against the screw and when ready, pulled the variable speed trigger to full speed for data acquisition.

4 RESULTS

The data presented here is available on the NIOSH power tools searchable database website. The website provides L_{WA} in both the loaded and unloaded conditions.[12]

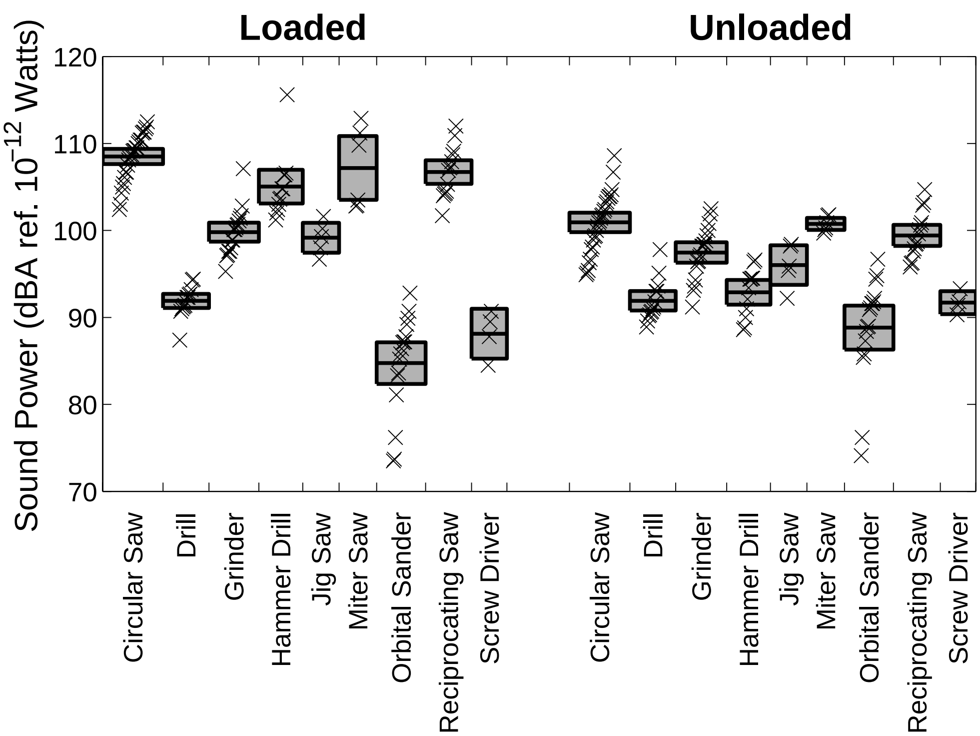

Figure 2: The sound power level of each model of powered hand tool is indicated for the loaded and unloaded conditions.

Table 1: Comparison of tool types with mean sound power level and 95 percent confidence interval (CI).

Tool Type (# of tools tested)	Loaded		Unloaded
	Mean (95% CI) dBA		Mean (95% CI) dBA
Circular Saw (28)	108.5 (0.9)		100.9 (1.1)
Drill (14)	91.9 (0.8)		91.9 (1.1)
Grinder (18)	99.8 (1.1)		97.5 (1.1)
Hammer Drill (12)	105.0 (2.0)		92.9 (1.4)
Jig Saw (5)	99.2 (1.7)		96.0 (2.3)
Miter Saw (6)	107.2 (3.7)		100.8 (0.6)
Orbital Sander (17)	84.7 (2.4)		88.8 (2.6)
Reciprocating Saw (14)	106.7 (1.4)		99.4 (1.2)
Screw Driver (4)	88.1 (2.9)		91.7 (1.3)

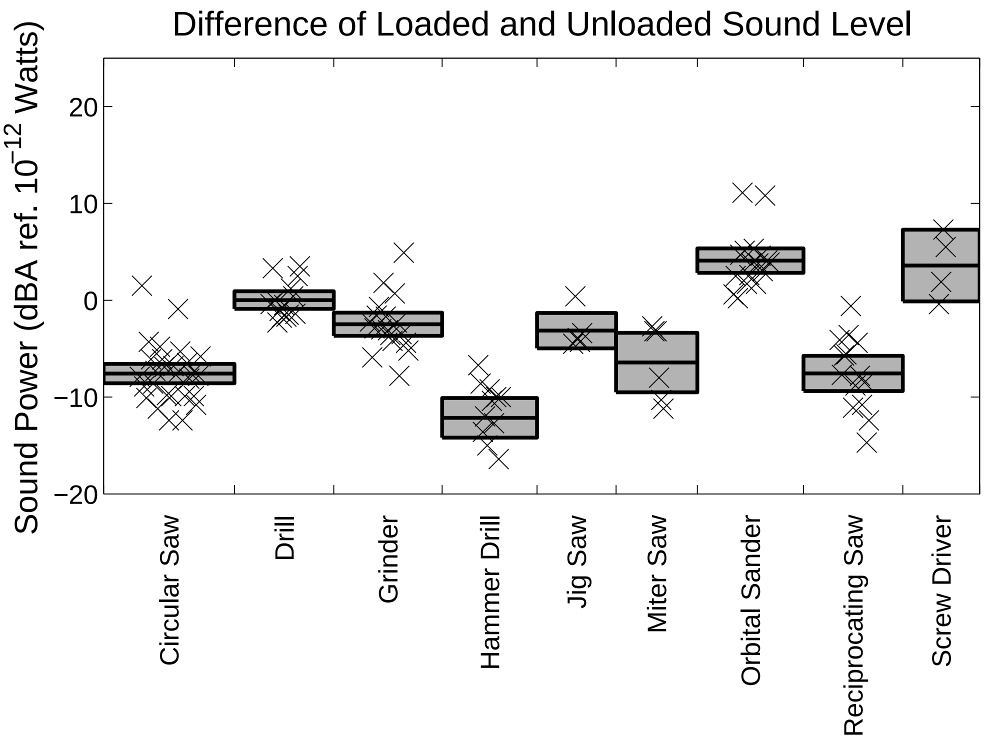

Figure 3: Difference between loaded and unloaded sound power levels. A greater sound pressure level in the loaded condition is indicated for data points above zero dBA on the y-axis.

Table 2: Loaded minus unloaded sound power level (dBA) statistics determine which loading condition radiates the greatest sound power level. 95% confidence interval (CI) and range are listed.

Tool Type (# models tested)	Mean (95% CI) (Range)
Circular Saw (28)	7.6 (1.0) (-1.5, 12.4)
Drill (14)	0.0 (0.9) (-3.5, 2.3)
Grinder (18)	2.5 (1.2) (-4.9, 7.8)
Hammer Drill (12)	12.2 (2.1) (6.7, 21.2)
Jig Saw (5)	3.1 (1.9) (-0.4,4.5)
Miter Saw (6)	6.4 (3.0) (2.7, 11.2)
Orbital Sander (17)	-4.1 (1.2) (-11.1, -0.2)
Reciprocating Saw (14)	7.6 (1.8) (0.6, 14.7)
Screw Driver (4)	-3.6 (3.7) (-7.3, 0.4)

5 DISCUSSION

The L_{WA} of various powered hand tools is shown in Figure 2 as tested in the loaded and unloaded condition. Within a particular tool type, the 95 percent confidence interval (CI) is often much smaller than the range of data. The smaller CI is indicative of having tested a sufficient number of tools for that tool type, while the large range indicates having testing a wide variety of tool models within that particular tool type. Comparison of data within a particular tool type must take into consideration important factors such as tool bit (or blade) size, power and speed ratings. Other considerations when comparing models of particular tool types to one another are the various applications such as metal cutting versus wood cutting. Only one metal cutting circular saw was tested and it was the only circular saw of the 28 tested that was louder in the unloaded condition. Table 1 provides the mean and 95 percent CI for L_{WA} tested in both the loaded and unloaded conditions. Circular saws, hammer drills, jig saws, miter saws, and reciprocating saws showed an increase in L_{WA} in the loaded condition over tests done in the unloaded condition. Overall, the 95 percent CI was slightly higher for the loaded tests. This would be expected as the distance between the tool and the microphone changes slightly throughout most loaded tool tests. Circular saws show a 7.6 dBA greater mean L_{WA} in the loaded condition than in the unloaded condition and have the greatest mean L_{WA} of all the tool types tested. Orbital sanders have a 4 dBA lower mean L_{WA} in the loaded condition and had the lowest L_{WA} of all the tool types tested. ANSI S12.15 specifies that circular saws be tested in the unloaded condition, which turns out to be the quieter loading condition. Further, ANSI S12.15 specifies that orbital sanders be tested in the loaded condition which again, turns out to be the quieter loading condition.

The difference between loaded and unloaded L_{WA} is illustrated in Figure 3. Data points above zero on the y-axis indicate that L_{WA} was greater in the loaded condition for that tool. If the mean and 95 percent CI are all above zero, then the L_{WA} is significantly greater in the loaded condition. If the mean and 95 percent CI are all below zero, then the L_{WA} is significantly greater in the unloaded condition. If the 95 percent CI captures zero on the y-axis, there is not a significant difference in mean L_{WA} in either loading condition. More specifically, the values given in Table 2 show no significant difference between loaded and unloaded L_{WA} tests for drills, grinders, and screw drivers (albeit screw drivers only minimally fall into this category and more typically test with a higher sound power level in the unloaded condition). Orbital sanders tested at a L_{WA} significantly higher when tested in the unloaded condition. All other tool types tested had a significantly higher L_{WA} when tested in the loaded condition versus the unloaded condition.

Categorizing tool types by the testing condition (loaded or unloaded) having the greater L_{WA} can sometimes be done by considering the tool bit/work-piece contact point. Tool types that almost always had a greater L_{WA} in the loaded condition included tools with toothed blades or impulsive contact such as circular saws, jig saws, miter saws, reciprocating saws, and hammer drills.

In general, electric powered hand tools have different dominate noise sources in the loaded and unloaded conditions. In the unloaded condition, the tool runs freely at full-speed or idle-speed. Motor, bearings, cooling fan, and flow noise from the cooling air usually dominate as the primary source of noise emissions.[12] In the loaded condition, the tool bit contacting the work-piece reduces the motor speed and hence the cooling fan speed, thereby reducing the cooling air flow velocity and the resulting turbulent flow noise. However this same tool/work-piece interaction tends to generate impacts and vibrations. Thus, while the loaded condition generates less flow noise, there is usually an overall noise increase resulting from impulsive structural dynamics generated at the tool/work-piece interface. Note that in laboratory L_{WA} measurements, the work-piece is resiliently mounted, in the field however, the work-piece will typically not be resiliently mounted and this could result in increased noise emissions.

6 CONCLUSIONS

For the loaded condition there are numerous possibilities of work-piece material, feed rate, and blade speed depending on the desired quality and use of the final product and the design of the powered hand tool. There are countless methods for loading, mounting, and operating conditions. It is not feasible to test all powered hand tools in all the permutations of the loaded condition, therefore a limited set of standardized tests must be developed and used. Current test standards such as ANSI S12.15 have limited value for measuring relevant noise emissions of powered hand tools. If sound level tests are being conducted as part of a sound quality or squeak and rattle noise analysis, then choosing to test an item in either the loaded or unloaded condition would be the choice of the test engineer. However, when noise emissions from a product are approaching or above stated sound pressure levels determined to be hazardous to hearing health, then that product must be tested in the condition emitting the greatest L_{WA} and more importantly, that level must be reported to the consumer or end user through noise labeling of that product. Standards such as ANSI S12.15 should be revised to reflect appropriate loading conditions and test methods of powered hand tools.

Manufacturers of powered hand tools should provide relevant L_{WA} testing, product labeling of the test results, and increase efforts to reduce noise emissions from those products. At the purchasing end, organizational buyers of powered hand tools should demand quieter products from the manufacturers, establish more stringent purchasing guidelines and specifications with regard to lowered noise emissions, and request noise labeling on the products they purchase so that the organization’s end users of powered hand tools will be better informed with the essential information to protect themselves against the hazardous noise they are being exposed to.

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