



SURFACE VEHICLE STANDARD

J1166™

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(R) Sound Measurement - Off-Road Self-Propelled Work Machines
Operator-Work Cycle

RATIONALE

SAE J1166 has been reaffirmed to comply with the SAE Five-Year Review policy.

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Documents

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FOREWORD

This document has changed to incorporate the latest applicable and related publications, test equipment and machine technology. Some technical aspects have been clarified. Engine cooling fan speed requirements have been updated to coincide with global sound test standards.

1. SCOPE

This SAE Standard sets forth the procedures to be used in measuring sound levels and determining the time weighted sound level at the operator's station(s) of specified off-road self-propelled work machines. This document applies to the following work machines which have operator stations as specified in SAE J1116:

- Crawler Loader
- Wheel Loader
- Dumper
- Tractor Scraper
- Roller/Compactor
- Pad Foot Wheel Compactor with Dozer
- Excavator and Wheel Feller-Buncher
- Grader
- Crawler Tractor with Dozer
- Wheel Tractor with Dozer
- Backhoe
- Hydraulic Excavator
- Log Skidder
- Pipelayer
- Trencher
- Sweeper

The instrumentation requirements and specific work cycles for these machines are described. The method used to calculate the time weighted average sound level at the operator station(s) is specified for $L_{eq(5)}$, or optional exchange rates, during continuous operation in a work cycle representing continuous medium to heavy work. The work cycles provide a repeatable reproduceable means to uniformly measure working machines against a "yard stick. A method to relate the time weighted average sound level at the operator station(s) to estimate operator sound exposure with part load work, supervision, and rest breaks is also provided.

2. REFERENCES

2.1 Applicable Publications

The following publications form a part of the specification to the extent specified herein. For undated references, the latest edition of the referenced document (including any amendments) applies.

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 724-776-4970 (outside USA), www.sae.org.

- | | |
|-----------|--|
| SAE J184 | Qualifying a Sound Data Acquisition System |
| SAE J732 | Specification Definitions—Loader |
| SAE J919 | Sound Measurement—Off-Road Work Machines— Operator—Singular Type |
| SAE J1116 | Categories of Off-Road Self-Propelled Work Machines |

2.1.2 ANSI Publications

Available from ANSI, 25 West 43rd Street, New York, NY 10036-8002, Tel: 212-642-4900, www.ansi.org. Also see www.nssn.org.

- | | |
|------------|--|
| ANSI S1.4 | Specification for Sound Level Meters |
| ANSI S1.40 | Specification for Acoustical Calibrators |

2.1.3 IEC Publication

Available from International Electrotechnical Commission, 3, rue de Verambe, P.O. Box 131, 1211 Geneva 20, Switzerland, Tel: +41-22-919-02-11, www.iec.ch.

IEC 61672-1 Electroacoustics—Sound Level Meters—Part 1: Specifications

2.2 Related Publications

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

2.2.1 ISO Publications

Available from ANSI, 25 West 43rd Street, New York, NY 10036-8002, Tel: 212-642-4900, www.ansi.org. Also see www.nssn.org.

ISO 3411 Earth moving machinery—Human physical dimensions of operators and minimum operator space envelopes

ISO 6165 Earth-moving machinery—Basic types—Vocabulary

ISO 1999 Acoustics—Determination of occupational noise exposure and estimation of noise-induced hearing impairment

ISO 9612 Acoustics—Measurement and calculation of occupational noise exposure—Engineering method

3. TERMS AND DEFINITIONS

3.1 A-Weighting (dB(A))

A-Weighting is the frequency filter that simulates the 40 phone curve on the equal loudness scale for human hearing response.

3.2 Equivalent-Continuous Sound Level (L_{eq})

The equivalent-continuous sound level is the level of the sound pressure squared averaged over a period of time as defined by,

$$L_{eq} = 10 \log_{10} \left\{ \left[\frac{1}{T} \int_0^T p^2(t) dt \right] / p_{ref}^2 \right\}$$

3.3 Sound Pressure Level (SPL)

The sound pressure level is the sound pressure squared as defined by:

$$L_p = 10 \log_{10} \left(\frac{P^2}{P_{ref}^2} \right), \quad P_{ref} = 20 \times 10^{-6} \text{ Pa}$$

3.4 Logarithmic Average

The logarithmic average is the power based average of two or more sound pressure levels as defined by:

$$\bar{L} = 10 \log_{10} \left\{ \frac{1}{N} \left[\sum_{i=1}^N 10^{0.1L_i} \right] \right\}$$

3.5 Ambient Sound Level

The ambient sound level is the maximum equivalent-continuous level measured for the surrounding test area when the machine is not in operation.

4. SYMBOLS AND ABBREVIATIONS

ANSI American National Standards Institute (<http://www.ansi.org/>)
IEC International Electrotechnical Commission (<http://www.iec.ch/>)
ISO International Organization for Standardization (<http://www.iso.org/>)

5. DATA ACQUISITION AND REDUCTION SYSTEM

5.1 The dynamic range of the system shall include +20 dB to –10 dB of the $L_{eq(5)}$ value that is determined.

NOTE: To determine if the appropriate instrumentation is available for the initial test, the highest value from SAE J919 can be substituted for $L_{eq(5)}$.

5.2 An exchange of 5 dB increase in sound level for halving of the time period shall be applied to the sound level data, unless otherwise noted.

5.3 The A-weighting network (reference IEC 61672-1) shall be applied to the input signal by the system.

5.4 The system shall meet the requirements of IEC 804-(1985) (except use a 5 dB exchange rate instead of an equal energy 3 dB exchange rate), or include a sound level meter meeting requirements of IEC 61672-1 plus a direct integrating exposure accumulating system. If made up of separate instrument components, the system shall comply with SAE J184 for a frequency range of interest.

5.5 Examples of sound data acquisition and reduction systems are:

5.5.1 Extended range audio-dosimeter (cutoff level at least 15 dB below measured value).

5.5.2 Sound level meter, tape recorder, signal converter, and direct integrating exposure accumulating system.

5.5.3 Integrating-averaging sound level meter (reference IEC 804-(1985)).

5.5.4 Sound level meter, signal converter, and direct integrating exposure accumulating system.

5.5.5 Microphone, power supply signal, converter, and direct integrating exposure accumulating system.

5.6 The acoustical calibrator shall have an accuracy of ± 0.5 dB.

5.7 The use of a windscreen may be desired under some test conditions (refer to 5.2.2); otherwise its use is optional, providing that it does not affect the A-weighted sound level of the source being measured by more than ± 0.5 dB(A) under zero wind speed conditions.

5.8 Alternate exchange rates can be used by using the appropriate instrumentation and referencing the formula in Appendix A.

6. MEASUREMENT OF OTHER PHYSICAL PARAMETERS

- 6.1 The wind speed shall be determined with an accuracy of $\pm 10\%$ at the highest wind speed encountered. (See 7.2.4).
- 6.2 The engine rotational speed shall be determined with an accuracy of $\pm 2\%$ of the indicated reading.
- 6.3 The temperature shall be determined with an accuracy of $\pm 1^\circ\text{C}$ of the indicated reading.
- 6.4 The barometric pressure shall be determined with an accuracy of $\pm 1.1\text{ kPa}$ of the indicated reading.

7. TEST PROCEDURE

7.1 General Test Site Requirements

The recommended test site should be a uniform plane of earth or other appropriate surface as noted in test cycle Section 8 with a grade not exceeding 3% in any direction, free of surface undulations that would restrict machinery operation. All earthen material in the test area should have a density of approximately 1800 kg/m^3 . The test surface shall be free of snow, tall grass, or large rocks. For machines with an operator station that will be tested in an open configuration, the test area within 10 m of the test machine shall be free of reflecting surfaces such as signboards, buildings, or earth embankments. Haul roads must be in a condition to allow the machinery to operate at the specified speeds. Where machinery configurations or location is such that it is impractical to use a test site as described, sites with other conditions such as field job sites may be used. In such cases, a description of the test site conditions must be included in the data report to qualify the sound level data.

7.2 Environment, Operator, and Machine Guidelines

- 7.2.1 Testing shall only be performed within ambient temperatures of -10°C to 40°C , wind speeds below 8 m/s and with no precipitation i.e. rain or snow falling.
- 7.2.2 No person other than the operator shall be in the operator station area on machines with or without a cab.
- 7.2.3 The ambient sound level (including wind noise) due to sources other than the machinery being measured, shall be at least 10 dB(A) below the lowest sound level generated by the machine under test on the work cycle.
- 7.2.4 The environmental conditions such as humidity, temperature, vibration, stray electromagnetic fields, etc., shall also be within the limits specified by the manufacturer of the test instrumentation.
- 7.2.5 The operator shall be positioned at the machines normal operating location as recommended by the manufacturer during the primary work function of the machine. The operator shall have a height physical dimension that falls within the 5th to 95th percentile as described by ISO 3411 (800 mm to 960 mm for a sitting operator; 1550 mm to 1880 mm for a standing operator.)
- 7.2.6 The microphone shall be located $200\text{ mm} \pm 20\text{ mm}$ to the right of the centerline of the operator's head unless the engine of the machinery is located on the left side of the operator. For machinery with the engine on the left side of the operator, the microphone shall be located on the left side. The face of the microphone should be in line with the ear canal. The microphone should either point in the direction of the operator's vision (head mounted) or upwards (shoulder mounted). It is envisioned that for a head mounted or shoulder mounted microphone, it will be remote mounted via a cable.
- 7.2.7 The machine shall be at a stabilized operating temperature during the test and must be operated in a manner such that the operating procedures specified by the manufacturer are not violated. Audible warning devices shall be functional and operated as consistent with machine operation in the field.
- 7.2.8 Tire pressures, track tension adjustment, fluid levels, governor setting, pressure valve relief settings, etc., must be within the manufacturer's specifications.

- 7.3 Sound exposure work cycles for the machinery defined in this document are described in Section 10. For machinery categories not listed, elements of common field uses may be used for determining the time weighted average sound level at the operator's station(s). The test conditions shall meet criteria similar to that implied by the defined work cycles. Work cycles not specifically included in this document shall be fully described in the test report.
- 7.4 Test machines that have a major attachment which is normally used for the main operating function shall be equipped with this attachment. Examples of this are the standard capacity buckets on loaders and excavators and dozers on crawler and wheel tractors and on compactors.
- 7.5 Measurements and Reported Data
- 7.5.1 The ambient temperature and atmospheric pressure for the test site shall be determined.
- 7.5.2 The stabilized maximum governed engine speed (high idle) at no load shall be determined.
- 7.5.3 When the test machine is equipped with a fully enclosed and climatized operator's station(s), the test shall only be conducted under the closed condition and with the climatizing air circulation fan(s) in operation. For air circulation fan(s) with two speed positions, the high speed shall be used. On fan(s) with three or more speed positions, the intermediate speed shall be used. Intermediate is defined as the third highest of a four or five speed position arrangement. If the operator's station is equipped with air circulation controls that will permit either recirculated or outside air, the position for outside air should be used. When the machine is not equipped with climatization, a closed test and a fully open test (all doors, windows, and vents open if they are designed to be open during machine operation) shall be conducted.
- 7.5.4 The ambient sound level should be measured at the start and end of the test.
- 7.5.5 The ambient wind speed should be measured prior to starting the test at the test site.
- 7.5.6 The machine operation on the work cycle shall be repeated until the number of cycles or time requirements given in Table 1 are met before data is processed.

TABLE 1 - TEST INTEGRATION TIME

Instrumentation	Minimum Required Test Time for ± 0.25 dB(A) Accuracy in Calculation
Any system meeting IEC 804 (1985) or IEC 61672-1-Type 1	3 cycles or 10 min
Any system meeting IEC 61672-1-Type 2 with a resolution to 0.1% dosage	15 min
Any system meeting IEC 61672-1-Type 2 with a resolution to 1% dosage	2 h

Work cycles used in the calculations for the first two systems must not vary in time more than $\pm 10\%$ of the average time of the cycles used for calculation of $L_{eq(5)}$.

NOTE: The machine operator should be allowed to run a number of practice work cycles before the test period begins to develop proficiency to repeat the cycles in less than $\pm 10\%$ elapsed time difference. The cycle time shall be monitored during the test so that incorrect work cycles can either be eliminated or the test restarted.

- 7.5.7 The reported result for this document shall be the time weighted average sound level at the operator's work station(s), $L_{eq(5)}$ (unless a different exchange is noted).

8. CALCULATION OF AN OPERATOR'S SOUND EXPOSURE

An operator's sound exposure is the value determined from the result reported in 7.5.7 which has been corrected by the actual work time of the operator, the output duty cycle of the machinery, and the effect of other noise sources. To determine the sound exposure, data on the actual duty cycle of the operator is required. If the machinery is run at reduced output for portions of the work shift and break time, the time ratio, and equivalent sound level for the periods of reduced output must be determined. For other noise sources, the time duration as a ratio of the work shift and their equivalent sound level must be determined. See Appendix A for the method to calculate the sound exposure.

9. GENERAL COMMENTS

9.1 It is recommended that persons technically trained and experienced in the current techniques of sound measurement select the instrumentation and evaluate the results.

9.1.1 The test engineer must be familiar with the required operation of the machine during the work cycle. Proper instructions must be given to the machine operator. Grade stakes or cone markers may be helpful in indicating travel distances or turn angles. Dry runs may be desirable to familiarize the machine operator with the required technique. Avoid running sound work cycles that is extreme material conditions such as very wet or in large rock.

9.1.2 The machine operator must be familiar with the machine and proficient enough to work the machine as intended.

9.1.3 The test engineer must judge if the machine operator complies with the requirements of the work cycles.

9.2 Proper use of all test instrumentation is essential to obtain valid measurements.

9.2.1 The effects of ambient weather conditions on the performance of all instruments (temperature, humidity, and barometric pressure) should be known. Instrumentation can be influenced by temperature extremes or significant changes in temperature.

9.2.2 Vibration isolation of the microphone is essential particularly when the microphone is mounted on the machine. Care must be taken to ensure that spurious signals are not induced on the microphone output by vibration, electromagnetic pickup, or other sources. Nonacoustically generated signals shall be at least 10 dB below the acoustic signal. The microphone can be capped, (use of a dummy microphone or use of the calibrator in the off mode) to check for nonacoustical signals.

9.2.3 The wind speed at the microphone location shall not exceed 8 m/s prior to the start of the test.

9.2.4 When multi-instrument measurement systems are used, caution shall be exercised. The effect of cable length and terminating impedances on the signal levels shall be considered. They shall not affect the data.

9.2.5 Calibration shall be made immediately before and at the end of the test. The calibration shall include the effects of cable length.

9.3 The calibration of a dosimeter must produce a count 20 times $\pm 8\%$ of the lowest increment of the readout.

10. SOUND EXPOSURE WORK CYCLES

10.1 Crawler Loader

See Figure 1.

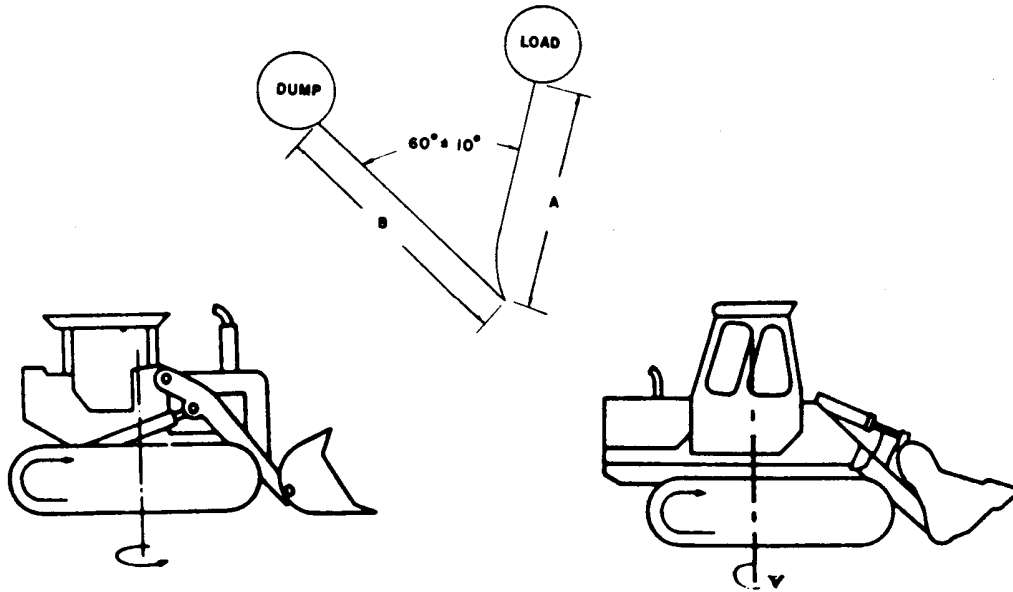


FIGURE 1 - CRAWLER LOADER OPERATOR SOUND EXPOSURE WORK CYCLE

10.1.1 Material

The material should be earth that is slightly moist. The moisture content must be low enough so that the material does not stick to or pack in the track system. It should be free of large stones greater than 80 mm in diameter and not exceed 1/2 sand, gravel, or crushed rock. The soil can be clay or loam. The compaction of the material should not exceed that which allows grouser penetration. The material to be loaded shall be in a loose stockpile of height appropriate for the size of the machine.

10.1.2 Machine Operation

The cycle is simulated truck loading from a stockpile. The machinery shall be operated at maximum governor setting considering all the safety requirements that are necessary on the test site. For machines with manual transmissions, changing the gear ratio during the cycle is not typically done. For machines where it is practical to change gear ratios, the machinery shall be operated in the speeds specified. See Appendix B for definition of travel speeds.

- Load at low travel speed.
- In reverse, back straight and start to raise the bucket, then commence turning until an angle of 60 degrees $\pm$ 10 degrees is made. Then move forward at intermediate speed while continuing to raise the bucket. The bucket should reach kickout height or the typical bucket dump height at the same time that the machine reaches the point for dumping into the phantom truck body.
- Bring machine to a stop, then dump bucket.
- Lower bucket while reversing from the dump point and move forward to the stockpile to complete the cycle.

The total travel distance for each type of machinery will be determined by the time required to raise the bucket from the position it has when loaded to the dumping height. The reverse travel distance shall be such that the bucket has been raised to 1/2 of its height. The remaining lifting should then be done while moving forward. The lengths A and B in the drawing shall be approximately equal.

10.2 Wheel Type Loader

See Figure 2.

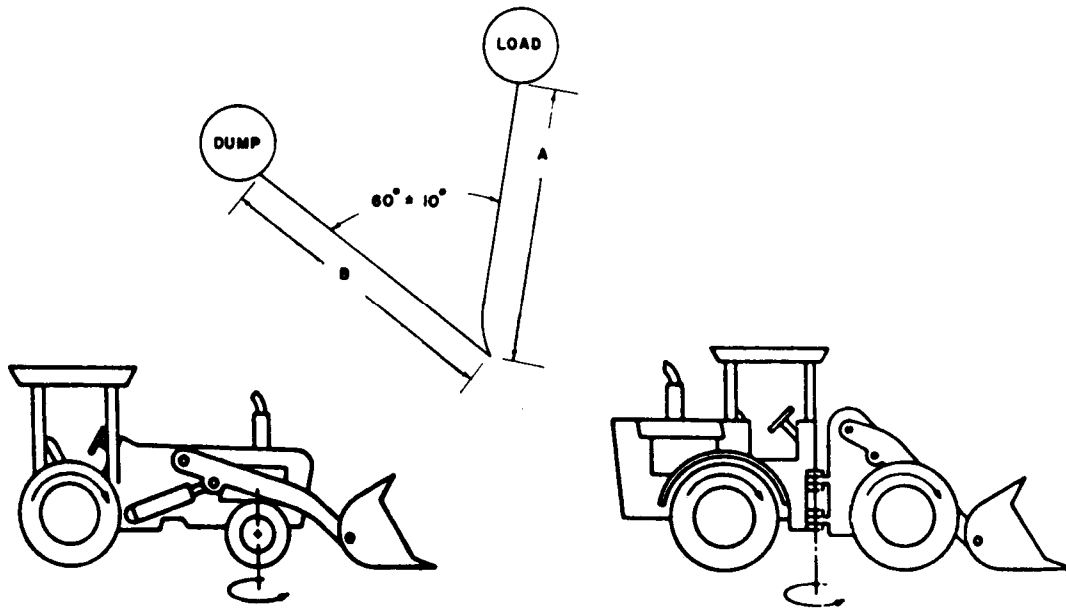


FIGURE 2 - WHEEL TYPE LOADER OPERATOR SOUND EXPOSURE WORK CYCLE

10.2.1 Material

The material should be earth that is slightly moist. The moisture content should be low enough so that the material does not stick in the bucket. It should be free of large stones greater than 80 mm in diameter. It can contain varying proportions of sand, small stones, crushed rock, clay, and loam. The material to be loaded shall be in a loose stockpile of height appropriate for the size of the machine.

10.2.2 Machine Operation

The cycle is simulated truck loading from a stockpile. The machinery shall be operated at maximum governor setting considering all of the safety requirements that are necessary on the test site. The work cycle is structured for articulated frame automatic transmission machinery. Skid steer, rear wheel steer, front axle steer, and machinery with manual transmissions will require slight alteration of the work cycle in that the bucket lifting operation commences at a different point in the cycle, and that transmission gear ratio changes may not be made. See Appendix B for definition of travel speeds.

- a. Load at low travel speed.
- b. In reverse, back straight and start to raise the bucket, then commence turning until an angle of 60 degrees $\pm$ 10 degrees is made. Then move forward at intermediate speed while continuing to raise the bucket. The bucket shall reach kickout height or the typical bucket dump height at the same time that the machine reaches the point for dumping into the phantom truck body.
- c. Bring the machine to a stop, then dump bucket.
- d. Lower the bucket while reversing from the dump point and move forward to the stockpile to complete the cycle.