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Sound Measurement - Off-Road Work Machines – Operator - Singular Type				

RATIONALE

The test method defined within SAE J919 has been developed and used for nearly 40 years. Updates to this standard have been to align with updated references and no additional changes are required.

STABILIZED NOTICE

This document has been declared "Stabilized" by the SAE OPTC3, Lighting and Sound Committee and will no longer be subjected to periodic reviews for currency. Users are responsible for verifying references and continued suitability of technical requirements. Newer technology may exist.

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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.

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1. SCOPE

This SAE Standard sets forth the instrumentation and procedure to be used in measuring sound pressure levels at the operator position for self-propelled off-road work machines as defined in SAE J1116. This document does not address the operation of safety devices such as backup alarms, horns, or accessories. This SAE document is applicable to machines that have operator stations where the operator can either stand or sit and will be either transported by, or walk with the machine during its operation. The sound levels obtained using this procedure are repeatable and representative of the higher range of sound levels generated by machines under actual field operating conditions. Due to variability of field operating conditions, this data is not intended to be used for operator noise exposure evaluations.

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—Loaders
SAE J1116	Categories of Off-Road Self-Propelled Work Machines
SAE J1166	Sound Measurement—Off-Road Self-Propelled Work Machines Operator-Work Cycle

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
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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 6394:1998 Acoustics—Measurement of airborne noise emitted by earthmoving machinery—Operator's position—Stationary test condition.

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

3. TERMS AND DEFINITIONS

3.1 Free Field

A free field, for the purposes of this document, is defined as a space with no reflecting surface within 30 m of the sound source or microphone in any direction except for the horizontal reflecting plane on which the test machine is located.

3.2 Horizontal Reflecting Plane

A horizontal reflecting plane is defined as flat ground with a surface no rougher than an asphalt road. A paved parking lot with no reflecting surfaces within 15 m would be an acceptable horizontal reflecting plane for the tests outlined in this document.

3.3 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.

3.4 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,

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

3.5 Sound Pressure Level (SPL)

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

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

3.6 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

4.1 ANSI

American National Standards Institute (<http://www.ansi.org/>)

4.2 IEC

International Electrotechnical Commission (<http://www.iec.ch/>)

4.3 ISO

International Organization for Standardization (<http://www.iso.org/>)

5. INSTRUMENTATION

Persons technically trained and experienced in current techniques of sound measurements should select and operate the equipment. Sound engineering judgment, including an assessment of the "state-of-the-art" with respect to test equipment, facilities, and test personnel, should be used when establishing specific test procedures used to verify compliance with the requirements of this standard. When single-sided test parameters are specified, such as "minimum", "maximum", and "at least", it is intended that the required specific parameter be met, with the constraint that deviations from the nominal parameter value (on the open-ended side) be minimized. When non-specific parameter tolerances are used, such as "approximately", it is intended that deviations from the nominal parameter be minimized.

5.1 Sound Level Meter

A sound level meter that meets the Type 1 requirements of ANSI S1.4 shall be used. Alternatively an integrating sound level meter may be used if it meets IEC 61672-1 requirements. If an integrating sound level meter is used for dynamic measurements, it must have a slow dynamic and max hold capability.

5.2 Alternatives to Sound Level Meter

As an alternative to making direct measurements using a sound level meter, a microphone or sound level meter may be used with a sound data acquisition system or digital tape recorder provided the instrumentation meets the requirements for SAE J184 for the frequency range that is of primary concern. The deviations in the sound data acquisition system frequency response from flat response, especially at lower frequencies, must not affect the overall reading by more than ± 0.5 dB(A).

5.3 Acoustical Calibrator

An acoustical calibrator (accuracy within ± 0.3 dB – see 7.2.4) shall be used to ensure correct calibration of the sound level meter(s) or data acquisition system as specified in sections 5.1 and 5.2.

5.4 Windscreens

The use of a windscreen may be required under some test conditions. Refer to 6.1.3, 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. (Also refer to 7.2.2.)

5.5 Anemometer

An anemometer or other device for measurement of ambient wind speed and direction shall be used. The accuracy is $\pm 10\%$ at the highest recommended wind speed. (See 7.2.2.)

5.6 Engine Speed Indicator

A speed indicator shall be used for determination of machine power source(s) rpm (accuracy within $\pm 2\%$ of the indicated reading).

5.7 Thermometer

A thermometer for measurement of ambient temperature (accuracy within $\pm 1^\circ\text{C}$) shall be used.

5.8 Barometer

A barometer shall be used to measure atmospheric pressure (accuracy within $\pm 0.1\text{ kPa}$ of the indicated reading).

6. PROCEDURE

6.1 Test Site

The test area shall consist of a smooth, uniform plane that has open space free of uncompacted snow, tall grass, and large reflecting surfaces such as a signboard, building, or vertical earth and rock embankment within 15 meters of the machine being measured (see 7.2.5).

6.1.1 Steel wheel and crawler machines shall be tested with the machines on a level surface of compacted earth or gravel. The moisture content should be low enough to prevent the material from sticking to the wheels or tracks. Other types of machinery may be tested with the machinery on a level surface of either hard-packed earth, gravel, concrete, or asphalt. The level surface should not have over a $\pm 1\%$ grade in the direction of travel.

6.1.2 The test site may also be the same site as per SAE J88 (Recommended). Such a test site area shall consist of a flat horizontal reflecting plane in a free-field environment within 30 m of either the microphone or the machinery being measured (see Figure 1).

6.1.3 The minimum measurement area (Figure 1) shall consist of the triangle formed by the microphone location, points A and B, and the rectangle formed by points A, B, C, and D. Both designated areas shall be smooth concrete or smooth and sealed asphalt or a similar hard and smooth surface. The rectangle formed by points C, D, E, and F shall consist of hard-packed earth. The planes between the microphone location and line AB and planes encompassed by points A, B, C, F, E, and D shall form a continuous, uniform plane. A minimum measurement area test site will require reorientation of the machine for each major surface measurement during the stationary tests, and the moving tests will have to be run in opposite directions. The other option is to have a larger measurement area test site and relocate the microphone for the series of prescribed test conditions with the machine in one position for stationary tests and driving by in only one direction for moving tests.

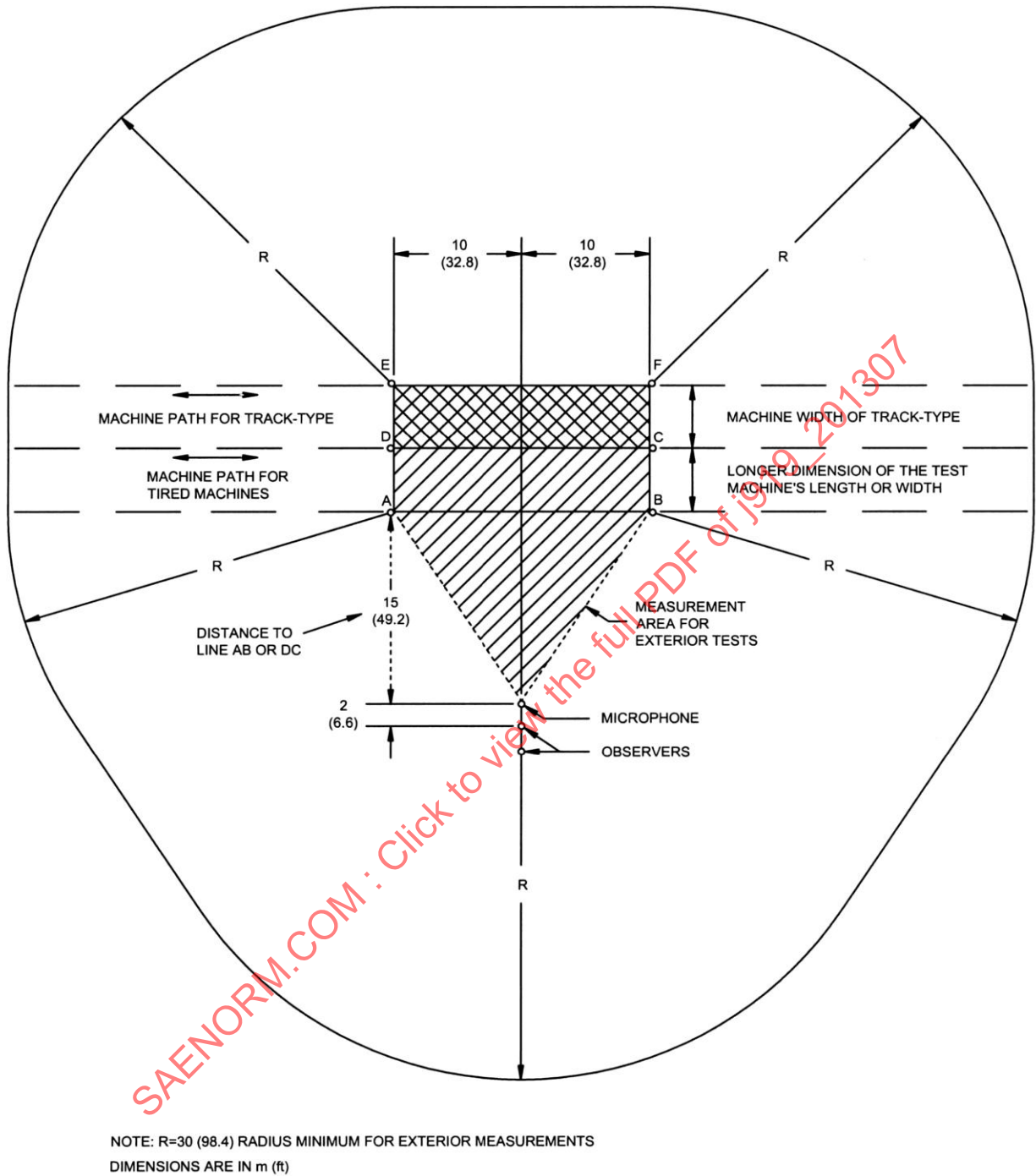


FIGURE 1 - TYPICAL TEST SITE CONFIGURATION

6.2 Environmental, Operator, and Machine Guidelines

- 6.2.1 No person other than the operator shall be in the operator's station area of the machine.
- 6.2.2 The ambient sound level measured at the microphone location (including wind effects), due to sources other than machinery being measured, shall be at least 10 dB(A) lower than the level of the machine being tested.

6.2.3 An operator shall be selected whose physical dimensions are as close as possible to an averaged operator as defined in ISO 3411:

- a. Standing Height – With shoes 1715 mm (percentile, 5th - 1550 mm and 95th - 1880 mm)
- b. Sitting Height – 880 mm (percentile, 5th - 800 mm and 95th - 960 mm)
- c. Head Width – 145 to 165 mm (percentile, 5th - 145 mm and 95th - 165 mm)

An operator with physical dimensions that fall outside the 5th percentile to the 95th percentile range should not be permitted to operate the machine during this sound evaluation test.

6.2.4 The microphone shall be located 200 mm $\pm$ 20 mm from the median plane of the head and in line with the eyes and to the side of the head where the equivalent continuous a-weighted sound pressure level is highest. The microphone should either point in the direction of the operator's vision (head mounted) or upward (shoulder mounted). It is envisioned that a head-mounted or shoulder-mounted microphone will be remote mounted via a cable. Microphones mounted on the machinery should point in the forward direction of travel. Care shall be taken to isolate the microphone from vibrations or movements which could affect the measurements.

If more than one operating position is located on the machine, sound levels at all positions will be measured and the highest value reported. A 13 mm nominal diameter microphone is recommended.

6.2.5 When the test machine has a fully enclosed operator's station, measurements are to be taken with windows, doors, and vents in a fully closed position and the appropriate climate control accessories in operation. For air circulation fan(s) with two positions, the high speed shall be used. If more than two operating speeds are available, the air conditioning and/or pressurizing ventilating system(s) shall be operated at the midrange speed. If the air conditioning and/or pressure ventilating system(s) has(have) a recirculation position and outside air position, then the outside air position shall be used. The test machine shall also be tested under a fully open configuration with all doors, windows, and vents open that are designed to be open during machine operation. Climate control accessory fans shall be off for the fully open configuration tests.

6.2.6 All machine components shall be at a stabilized operating temperature during the test and must be operated in a manner such that the break-in procedure specified by the manufacturer is not violated.

6.3 Tests Required

Machines that are used primarily in a mobile mode shall be tested per 6.3.1.1, 6.3.1.2, 6.3.1.3, 6.3.1.4, 6.3.1.5 and 6.3.2. Combined machines (such as loaders with a backhoe), shall be tested per 6.3.1.1, 6.3.1.2, 6.3.1.3, 6.3.1.4, 6.3.1.5 and 6.3.2 when in the loader mode and tested per 6.3.1.1, 6.3.1.2, 6.3.1.3, 6.3.1.4, 6.3.1.5 when in the backhoe mode.

Rubber-tired and tracked excavators shall be tested in a stationary test mode only per 6.3.1.1, 6.3.1.2, 6.3.1.3, 6.3.1.4

6.3.1 Stationary Tests with Ground Propulsion Transmission Shift Selector in Neutral Position

- 6.3.1.1 Operate mobile machine power source(s) at no-load with all component drive systems in neutral position and maximum governed speed (high idle at no load) at a stabilized condition. All cooling system fans shall be operated at the maximum speed.
- 6.3.1.2 Operate machine power source(s) at no-load and at manufacturer's specified rated speed with all component drive systems in neutral position. All cooling system fans shall be operated at the maximum speed.
- 6.3.1.3 Operate machine power source(s) at no-load and at manufacturer's specified low-idle speed with all component drive systems in neutral position. All cooling system fans shall be operated at the allowable speed for low-idle operation.

- 6.3.1.4 Operate mobile machine power source(s) at no-load with all major component drive systems in neutral position through the cycle low idle to the maximum governed speed (high idle) and back to the low idle as rapidly as possible, but allow the engine to stabilize for at least 10 s at the maximum governed speed (high idle) and the and cooling system(s) fan(s) to stabilize at the maximum operating speed before it is permitted to return to low idle. It is recommended that care be taken to ensure stabilized combustion chamber surface temperatures prior to this test sequence. For some types of engines, such as engines with pre-combustion chambers, repeatability of sound levels may be affected. Between cycles, a cool-down period of one minute is recommended.
- 6.3.1.5 With the power source(s) at the maximum governed speed (high idle) or manufacturer's recommended operating speed at no-load in a stabilized condition and the cooling system(s) fan(s) operating at the maximum speed, activate the appropriate hydraulic circuits, mechanical, electrical, hydrostatic, or torque converter drive systems to cycle the major components or component from the most retracted and/or lowered position to $\frac{3}{4}$ or 75 percent of the fully extended and/or maximum height position, and then back to original position. The component cycled must have controls at the operator's station. This cycling should be done as fast as practical, taking into consideration all the pertinent safety factors, and be accomplished without exceeding relief valve settings. For short cycle hydraulic operation, the system may be feathered. For safety reasons and undesirability of change of location of major noise source(s) in relation to other major components of the machine, a major portion of the mobile machine, such as the tractor of a scraper unit, or the upper rotational structure of an excavator shall not be moved, or scraper elevator placed in operation during this stationary machine test. For units such as non-riding trenching machines without power steering or hydraulic controls, this section shall be omitted. In no case shall the digging chain (wheel) or vibratory plow drives be engaged for this test or other tests in this document. For self-propelled street sweepers, the brooms should be operated in the raised position without contacting the measurement surface.

6.3.2 Constant Speed Moving Test

Machines shall be operated in a forward intermediate gear ratio at no load. The power source(s) shall be operated at maximum governed speed (high idle). All cooling system fans shall be operated at the maximum speed. A separate test may also be run with the cooling system(s) fan(s) at the minimum speed for comparison.

Intermediate is intended to mean second gear ratio for machines with three or four gear ratios, third gear ratio for machines with five or six gear ratios, fourth gear ratio for machines with seven or eight gear ratios, etc. (Gear ratio refers to overall gear reductions.) If there is a problem with a transmission shifting up or down in this phase of the test, one gear lower or higher may be used to eliminate the problem. Machines with hydrostatic, electric drive, or other type drives shall be operated at approximately one-half maximum ground speed with the governor control set in maximum (high idle) position at no load. If this operating condition cannot be attained because of the interaction of the power source(s) and drive controls, then the ground speed may be increased or decreased so as to still permit the power source(s) governor control to be set in maximum (high idle) position. Machines that have major noise-generating components that are normally in use at this ground speed shall have these major components in operation during this test. For self-propelled street sweepers, these components include water systems, brooms, and blower or conveying systems.

- 6.3.3 Sweepers, dozer blades on either wheel or track-type tractors, and backfill blades, digging booms (wheel), direct burial plows, or backhoes on trenchers. For all tests, except component cycling, these attachments shall be in a minimum transport position of 160 to 320 mm for dozers, scrapers, etc. For loaders and trenchers with loaders, use bucket carry position as specified by SAE J732. For machinery equipped with a ripper, such as on a wheel or track-type tractor, or a backhoe, such as on a front end loader, these attachments shall be in the transport position. For trenching machines and self-propelled sweepers these attachments shall be in their normal transport position, for example, backfill blade or brooms fully raised; plow, boom, or wheel fully raised and restrained.

6.4 Measurements

- 6.4.1 The microphone shall be located next to the operator's right or left ear as stated in 6.2.4 for all operating conditions. Spatial averaging of the sound measurements for the left and right microphone positions can be used to identify potential standing wave effects.

- 6.4.2 All sound pressure level measurements shall be filtered using the a-weighting network. For dynamic power source(s) cycling, component cycling, and constant speed moving test conditions, the sound level meter or data acquisition system shall be set for slow dynamic characteristic (see 3.1). For the stabilized test condition of maximum governed speed (high idle) or rated engine speed, the time weighted average sound level (L_{eq}) may be reported in place of the slow dynamic characteristic.
- 6.4.3 The ambient temperature, atmospheric pressure, and a-weighted sound pressure level shall be measured and recorded at the operator's station with the machine shut down. If the machine has a fully enclosed operator's station, these measurements shall be taken with the operator station configured per the test requirements (see 4.2.5). The ambient wind speed and direction shall be measured for all applicable tests.
- 6.4.4 The stabilized maximum governed power source(s) speed (high idle) at no load shall be measured and recorded.
- 6.4.5 The power source(s) speed shall be monitored during the rated speed test.
- 6.4.6 The gear ratio and approximate ground speed during the moving tests shall be recorded.
- 6.4.7 The sound level meter or data acquisition system digital readout shall be observed during each test sequence. The highest value observed for all tests disregarding sounds of short duration that are out of character with the test on the machine (example – impact noise such as bucket rap against stops) shall be recorded for each test sequence. The sound level meter or data acquisition system must be frequently reset so the out-of-character sound levels for the test sequence are not included if the maximum hold mode is being used.
- 6.4.8 Sound data to be recorded for the stabilized test condition and data reporting: for the stabilized test condition of maximum governed speed (high idle) or rated speed, a single reading shall be recorded at each measuring point. The final recorded sound level for this test mode shall be the highest reading for the stabilized test condition at each measuring point.
- 6.4.9 For power source(s) cycling, component cycling, and constant speed moving test conditions, a minimum of three valid readings shall be taken for each measuring point.
- 6.4.10 Number of Simulated Work Cycles

Three simulated work cycles shall be carried out resulting in three measurements to be taken at the microphone position.

It is necessary to have two of the measurements at the microphone within a 1 dB range of each other. If these results are not obtained, additional simulated work cycles shall be taken to meet this requirement. Operational procedures may require correction to achieve this.

6.4.11 Determination of Measurement Result

Report, as the value of the equivalent continuous a-weighted sound pressure level, the arithmetic average of the two highest measurements within a 1 dB range of each other.