SAE International

SURFACE VEHICLE STANDARD

SAE J88 JUN2013

Issued 1972-11
Stabilized 2013-06

Superseding J88 FEB2006

Sound Measurement - Off-Road Work Machines - Exterior

RATIONALE

The test method defined within SAE J88 has been developed and used for nearly than 40 years. The last update to SAE J88 was in 2006 which updated references to align with modern standards. With no changes in the test method or references, SAE J88 should be stabilized.

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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TABLE OF CONTENTS

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 instrumentation and procedure to be used in measuring the exterior sound pressure levels for self-propelled off-road work machines as defined in sections 1, 3, 5 and 6 of SAE J1116.This document does not address the operation of safety devices such as backup alarms, horns, or accessories. The sound levels obtained by using the test procedures set forth in this document are repeatable and are representative of the higher range of sound levels generated by machines under actual field operating conditions. Due to the variability of field operating conditions, this data is not intended to be used for construction site boundary noise 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, 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—Front End Loader

SAE J1116 Categories of Off-Road Self-Propelled Work Machines

2.1.2 ANSI Publication

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

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:

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

3.6 Logarithmic Average

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

$$\overline{L} = 10\log_{10}\left\{\frac{1}{N}\left[\sum_{i=1}^{N} 10^{0.1L_i}\right]\right\} \quad \text{(Eq. 3)}$$

3.7 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 measurement 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 ±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 ±2% of the indicated reading).

5.7 Thermometer

A thermometer for measurement of ambient temperature (accuracy within ±1 °C) shall be used.

5.8 Barometer

A barometer shall be used to measure atmospheric pressure (accuracy within ±0.1 kPa of the indicated reading).

6. PROCEDURE

6.1 Test Site

The test 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).

6.1.1 The minimum measurement area (see 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. If a minimum measurement area test site is used, it 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.

6.1.2 Because bystanders may have an appreciable influence on the meter response when they are in the vicinity of the earthmoving machinery or microphone, not more than one person, other than the observer reading the meter, shall be within 17 m of the earthmoving machinery and 2 m of the measuring microphone, and that person shall be directly behind the observer who is reading the meter, on a line through the microphone and the observer (see Figure 1).

6.1.3 The ambient sound pressure levels due to background noise (in frequency bands or A-weighted) averaged over the microphone positions on the measurement surface shall be at least 6 dB and preferably more than 15 dB below the mean sound pressure level due to the noise source under test for a specific test condition (see 6.3.3). This includes the effects of wind.

6.1.4 The surface between and under the machinery and microphone shall be smooth and free of acoustically absorptive material, such as snow or grass.

6.1.5 For all stationary tests, the machine shall be located on the hard surface area formed by points A, B, C, and D in Figure 1.

6.1.6 Moving Tests

6.1.6.1 For moving tests of all rubber-tired machines, the path of travel shall be across the area defined by points A, B, C, and D in the directions shown in Figure 1.

6.1.6.2 For moving tests of all steel wheel or track type machines, the path of travel shall be across the area defined by C, D, E, and F in the directions shown in Figure 1.

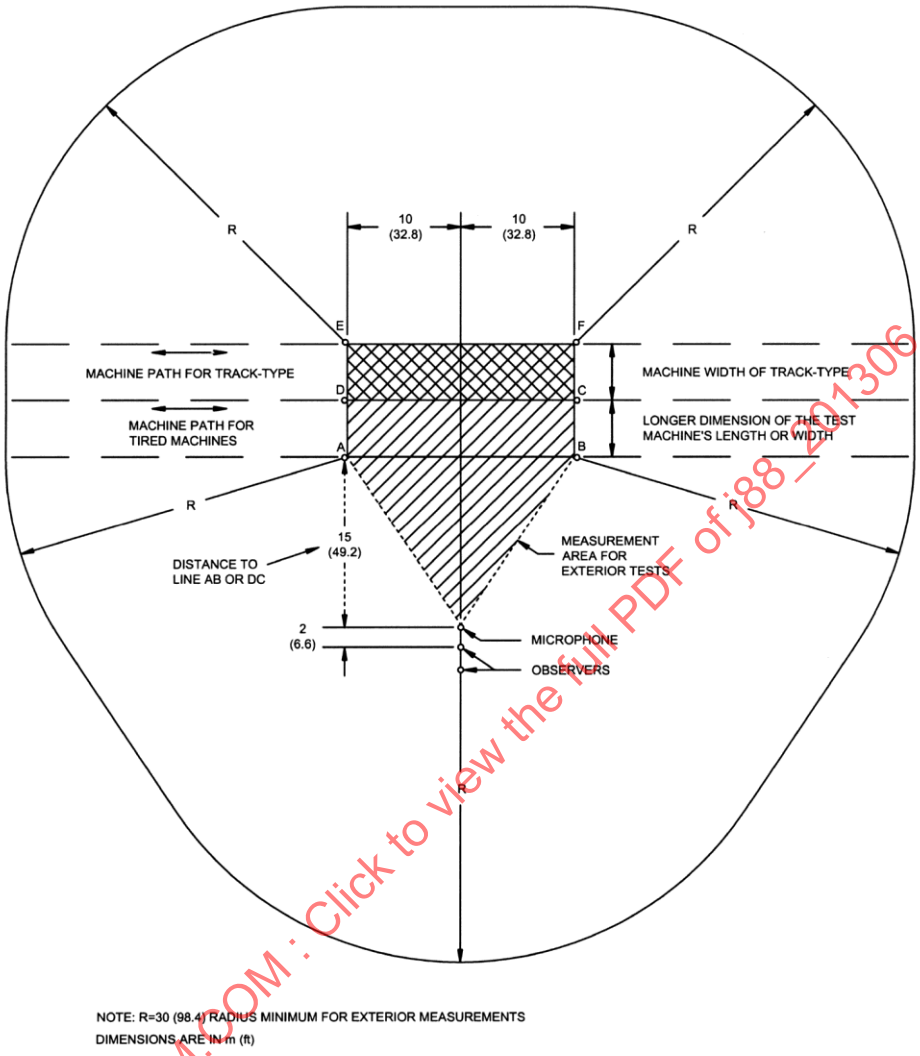

FIGURE 1 - TYPICAL TEST SITE CONFIGURATION

6.2 Tests Required

Machines that are used primarily in a mobile mode or combined machines (such as loaders with a backhoe) shall be tested per 6.2.1.1, 6.2.1.2, 6.2.1.3, 6.2.1.4, and 6.2.2.

Rubber-tired and tracked excavators shall be tested in a stationary test mode only per 6.2.1.1, 6.2.1.2, 6.2.1.3, and 6.2.1.4.

For all tests, all machine components shall be at a stabilized operating temperature during testing and must be operated in a manner such that the break-in procedure specified by the manufacturer is not violated.

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

6.2.1.1 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 set at the maximum operational speed.

6.2.1.2 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.

6.2.1.3 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. Between cycles, a cool-down period of 1 min is permitted as needed.

6.2.1.4 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 ¾ 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.

6.2.2 Constant Speed Moving Test

Machines shall be operated in a forward intermediate gear ratio at no-load at a location as specified in 6.1.6.1 or 6.1.6.2. The power source(s) shall be operated at maximum governed speed (high idle). All cooling system fans shall be operated at the maximum speed. Intermediate is intended to mean second gear ratio for machinery with three or four gear ratios, third gear ratio for machinery with five or six gear ratios, fourth gear ratio for machinery with seven or eight ratios, etc.

If there is a problem with the 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 its 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(s) to be set in the maximum (high idle) position. Machines that have major noise-generating components which 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.

6.2.3 Machines that have a major attachment that is normally used for the main operating function shall be equipped with this attachment. Examples of this are buckets on loaders, brooms on 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 implement 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 (if appropriate).

6.3 Measurements

6.3.1 The microphone shall be located at a height of 1.2 m above the ground plane.

6.3.2 All sound pressure level measurements shall be filtered using the A-weighting setting. 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 5.1). 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.

6.3.3 The nominal ambient wind speed and direction, ambient temperature and atmospheric pressure shall be measured and recorded at the height of 1.2 m and within at least 3 m of one specified location of the microphone as shown in Figure 1. The ambient A-weighted sound pressure levels shall be measured and recorded at each microphone as shown in Figure 1.

6.3.4 The stabilized maximum governed power source(s) speed shall be measured and recorded.

6.3.5 The power source(s) speed(s) shall be monitored during the rated speed test per 6.2.1.2.

6.3.6 The gear ratio and approximate ground speed during the moving test shall be recorded.

6.3.7 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.

6.3.8 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.

6.3.9 Sound Data to be Recorded for the Power Source Cycling, Component Cycling and Constant Speed Moving Test Conditions and Data Reporting

For power source(s) cycling, component cycling, and the constant speed moving test conditions a minimum of three valid readings shall be taken for each measuring point. If for each specific test mode none of the readings are within 1 dB of each other, then additional readings shall be taken until there are two that are within 1 dB of each other. If there are two pairs of readings that are within 1 dB of each other, record the higher pair. The final reported sound level for each test mode shall the arithmetic mean of the two highest values that are within a 1 dB range of each other.

6.3.10 Sound Data to be Recorded and Number of Simulated Work Cycles for the Work Cycle Test and Data Reporting

Three simulated work cycles shall be carried out resulting in three measurements to be taken at each microphone position. It is necessary to have two of the readings 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. Report, as the value of the equivalent continuous A-weighted sound pressure level, the arithmetic mean of the two highest values that are within a 1 dB range of each other.

6.3.11 Sound Data to be Recorded for the Stationary Test Conditions and Data Reporting

For stationary tests, record the sound level obtained at a distance of 15 m from each major surface, normal to the centers of the four major surfaces of the equipment at the microphone height. Generally, four major surfaces refer to front, rear, and sides of an imaginary box that would just fit over the machine but does not include attachment items such as buckets, dozers, backfill blades, backhoes, rippers, and booms (see Figure 2). These attachments should not be removed for the tests, but are not considered in defining major surfaces. In the case of an excavator, the upper (revolving superstructure) fore-and-aft centerline should be in line with the lower fore-and-aft centerline. Operate the machine in a manner as specified in 6.2.1.1, 6.2.1.2, 6.2.1.3, and 6.2.1.4. The reported sound level for each of the stationary test modes shall be the logarithmic average of the recorded sound levels at each of the four measuring points. The reported sound levels for a given machine shall be included in the report format as shown in Appendix A.