



SURFACE VEHICLE RECOMMENDED PRACTICE

J2883™

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Laboratory Measurement of Random Incidence Sound Absorption Tests Using a Small Reverberation Room

RATIONALE

SAE J2883 has been reaffirmed to comply with the SAE Five-Year Review policy.

1. SCOPE

This SAE Recommended Practice describes a laboratory test procedure for measuring the random incidence sound absorption performance of a material or a part in a small size reverberation room by measuring decay rates. The absorption performance may include sound absorption coefficient of the test sample and or the amount of energy absorbed by the test sample. Materials for absorption treatments may include homogeneous materials, nonhomogeneous materials, or a combination of homogeneous, nonhomogeneous, and/or inelastic impervious materials. These materials are commonly installed in the mobility products and in the transportation systems such as ground vehicles, marine products, aircraft, and commercial industry (in industrial and consumer products) to reduce reverberant sound build-up and thus reduce the noise level in the environment by minimizing reflections off of hard surfaces. The test method described herein was developed also to describe a way to measure the absorption performance of a part or a sound package system that will relate to an application. It can be used to rank order materials for application on panels using general automotive steel but also may be applicable to other situations or conditions. This test procedure has been developed for measurements made in rooms between 6m³ to 25m³ in volume.

The absorption performance for most materials and systems varies as a function of frequency. Accordingly, this test procedure includes provisions for measuring absorption over a frequency range found applicable to many transportation systems. Samples that are used typically in the transportation industry are not thick enough to provide any significant absorptive properties below 250 Hz and in many cases below 400 Hz 1/3rd octave band frequency. Combining the size of the sample and the frequency range of interest for automotive and related applications, this test method has been developed for conducting measurements using a small reverberation room where the frequency range of interest would be from as low as 250 Hz to 8000 Hz 1/3rd octave band frequency, depending on the volume of the room. The recommended volume of the room for this test method is from 6m³ to 25m³.

The test method described here differs from the ASTM C423 and the ISO 354 methods in that the SAE method is based on using a significantly smaller size reverberation room than the recommended size room in the ASTM C423 or ISO 354 methods. This aids not only to testing a small size sample, but also allows testing a typical component, part, or a subsystem (that approximates closely to a small size sample as mentioned above) of a vehicle and other transportation systems, or products for other applications more conveniently and easily than the ASTM C423 or the ISO 354 test method. This test is appropriate to rank order a specific size material and/or part sound absorption properties and not intended to duplicate the results of other size samples. The results obtained by the SAE method may be different from that of the ASTM C423 or the ISO 354 as the room volume and the sample size may significantly impact the measured absorption. This recommended practice is not intended to replace the ASTM C423 or the ISO 354 test standard.

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Documents

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2. REFERENCES

2.1 Applicable Publications

The following publications form a part of this specification to the extent specified herein. The latest issue of publications shall apply.

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 +1 724-776-4970 (outside USA), www.sae.org.

SAE TSB 003 Rules for SAE Use of SI (Metric) Units

SAE J1355 Test Method for Measuring Thickness of Resilient Insulating Pads

SAE J2629 Standard Formats for Presenting Acoustical Data

2.1.2 ANSI Publications

Available from American National Standards Institute, 25 West 43rd Street, New York, NY 10036-8002, Tel: 212-642-4900, www.ansi.org.

ANSI S1.1 Acoustical Terminology

ANSI S1.11 Specification for Octave Band and Fractional Octave Band Filter Sets

ANSI S1.26 Method for Calculation of the Absorption of Sound by the Atmosphere

2.1.3 ASTM Publications

Available from ASTM International, 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959, Tel: 610-832-9585, www.astm.org

ASTM E691 Conducting an Interlaboratory Study to Determine the Precision of a Test Method

ASTM C423 Sound Absorption and Sound Absorption Coefficients by the Reverberation Room Method

ASTM E795 Practices for Mounting Test Specimens During Sound Absorption Tests

2.1.4 ISO Publications

Available from American National Standards Institute, 25 West 43rd Street, New York, NY 10036-8002, Tel: 212-642-4900, www.ansi.org.

ISO 354 Acoustics - Measurement of Sound Absorption in a Reverberation Room

ISO 3382-2 Acoustics - Measurement of room acoustic parameters - Part 2: Reverberation time in ordinary rooms

ISO 18233 Acoustics - Application of new measurement methods in building and room acoustics

ISO 3741 American National Standard ANSI S12.51 – Acoustics - Determination of Sound Power Levels and Sound Energy Levels of Noise Sources Using Sound Pressure – Precision Method for Reverberation Rooms”, Appendix A Guidelines for the Design of Reverberation Test Rooms.

3. TEST METHOD

The test method for this measurement is based on determining the sound absorption of an empty reverberation room (with any accessories required to seal the perimeter sides of a test sample as discussed later) and the sound absorption of the same room but with a test sample in the room. The difference of these two sound absorption values provides the sound absorption provided by the sample alone. This is known as the amount of energy absorbed by the sample. This quantity divided by the area of the test sample provides the sound absorption coefficient of the test sample.

The absorption of the bare reverberation room is computed using the equation:

$$A_1 = 0.921 \cdot (V \cdot D_1 / c) \quad (\text{Eq. 1})$$

or,

$$A_1 = 55.3 \cdot V / (c \cdot T_1) \quad (\text{Eq. 2})$$

The absorption of the reverberation room with the test sample in place is computed using the equation:

$$A_2 = 0.921 \cdot (V \cdot D_2 / c) \quad (\text{Eq. 3})$$

or,

$$A_2 = 55.3 \cdot V / (c \cdot T_2) \quad (\text{Eq. 4})$$

Where,

A_1 = Sound absorption of the bare reverberation room, m^2

A_2 = Sound absorption of the reverberation room with the test sample in place, m^2

V = Volume of the reverberation room, m^3

T_1 = Reverberation time of the bare reverberation room, s

T_2 = Reverberation time of the reverberation room with the test sample in place, s

D_1 = Decay rate of the bare reverberation room, dB/s

D_2 = Decay rate of the reverberation room with the test sample in place, dB/s

$D_1 = 60 / T_1$

$D_2 = 60 / T_2$

c = speed of sound, m/sec, is a function of temperature, humidity, and barometric pressure, and can be expressed as¹

$$c = 4.5513 c_d \sqrt{\frac{\gamma_w}{M_w}}, \text{ m/s} \quad (\text{Eq. 5})$$

Where, c_d = the speed of sound in dry air
 γ_w = specific heat ratio for moist air
 M_w = Total average molecular weight

See Appendix A at the end for step by step calculation of the speed of sound as a function of temperature, humidity, and barometric pressure.

¹ Ref: Bohn, D., A., "Environmental Effects on the Speed of Sound" J. Audio Eng. Soc., Vol. 36, No. 4, 1988 April

Therefore, the amount of sound energy (A) absorbed by the sample alone is given by:

$$A = A_2 - A_1 = 0.921 \cdot (V \cdot D_2 / c) - 0.921 \cdot (V \cdot D_1 / c) \quad (\text{Eq. 6})$$

The sound absorption coefficient (α) of the sample is given by:

$$\alpha = A/S \quad (\text{Eq. 7})$$

Where, S is the surface area of the sample in m^2 .

- 3.1 Measurements shall be conducted in a humidity controlled room as the absorption measurements are very susceptible to humidity. Test samples shall be conditioned in the humidity controlled room for at least 12 hours prior to testing.
- 3.2 The sound absorption coefficient of a test sample may be affected significantly due to sound absorption by air (air absorption). Excessive absorption could take place at high frequencies and at low relative humidities due to the changes in temperature and relative humidity (changes in environmental factors) during the course of the measurement.
- 3.3 At and above 1000 Hz 1/3rd octave band frequency, the effects of temperature and relative humidity are adjusted by subtracting the decay rate of the air absorption from the decay rate of the measurements. The decay rate of the air absorption is calculated following equations provided in the ANSI S1.26 [see Appendix B at the end]. The correction due to air absorption is given by

$$d_{air} = (\alpha_{air} \cdot c) \quad (\text{Eq. 8})$$

where,

d_{air} = decay rate due to sound absorption by air, dB/s

α_{air} = Attenuation coefficient due to air absorption and obtained from ANSI S1.26

Therefore, at and above 1000 Hz, the decay rate to use in Equations 1 and 3 is: $D_1 - d_{air}$ and $D_2 - d_{air}$, respectively².

Here,

$D_1 - d_{air}$ = Adjusted decay rate of the bare reverberation room, dB/s

$D_2 - d_{air}$ = Adjusted decay rate of the reverberation room with the test sample in place, dB/s

- 3.4 During all measurements the average test temperature shall be no less than 15 °C, and the average relative humidity in the room shall be at least 50%. However, it is strongly recommended to have 60% relative humidity for consistent measurements above 6.3 kHz.

Although the effect of change in temperature and relative humidity on air absorption is addressed by the equations discussed in Section 3.3, it is best practice if:

- The temperature between tests of a bare room and the room with a test sample does not vary more than 5 °C
- The relative humidity between tests of a bare room and the room with a test sample does not vary more than 5%.

² Although the adjustment in environmental factors is necessary at and above 1000 Hz 1/3rd octave band, it is encouraged to using these adjustments for all frequencies.

If the temperature and the relative humidity exceed these variations, a new bare room decay rate measurement is recommended such that the environmental conditions of the measurements made with the bare room and the test sample are within these deviations.

It is encouraged that devices that are used to measure the temperature, relative humidity, and barometric pressure have the following accuracy:

- ± 1 °C for temperature
- $\pm 2\%$ for relative humidity
- ± 30 kPa for barometric pressure.

4. REVERBERATION ROOM – SHAPE, SIZE, AND DIFFUSION

4.1 The test method is based on the fact these measurements are made in a reverberation room. A reverberation room is defined as a room where the sound field is diffuse and uniform throughout the room. Diffuse means sound waves approach from any direction at any time with equal probability, and therefore the sound field is the same everywhere. For sound absorption measurements, the diffusion has one more challenge. This has to do with the fact the decay signal is transient and not steady state, where normally the diffusion is best understood. Therefore the reverberant sound field needs to closely approximate the diffuse sound field not only for steady state sound with the source on, but also for the decay of sound when the source is turned off.

4.2 Both the design and construction of a reverberation room are very critical to the success of obtaining reasonably good sound absorption data of a material. There are four parameters to the proper design of a reverberation room:

- Cut-off frequency
- Schroeder frequency
- Room dimensions
- Axial/normal modes

The details of the design of a reverberation room are provided in Appendix C.

4.3 A reverberation room may be constructed of a massive masonry, concrete materials, massive steel panels, as well as light weight building construction materials. Walls should be painted to seal any pores and to increase diffusion in the room.

In addition, external sound reflecting panels or objects (commonly called diffusers) are required to achieve adequate diffusion in the room for stationary and transient sound signals in the room. Attention needs to be paid so the absorption coefficient of the room surfaces is low enough to provide proper diffusion. These are discussed further in Appendix C.

4.4 The reverberation room volume has the potential to establish the cut-off frequency for acceptable diffusivity of the reverberation room and therefore to have some confidence on the data. Table 1 provides the cut-off frequencies for different size small reverberation rooms. Room sizes should be established based on the assurance that there are at least twenty (20) natural frequency modes within the lowest $1/3^{\text{rd}}$ octave band frequency of interest for good diffusion of sound.

TABLE 1 - TABLE FOR DETERMINING THE LOWEST (CUT-OFF) FREQUENCY OF MEASUREMENT FOR A GIVEN ROOM VOLUME

<u>Room volume, m³</u>	<u>1/3rd Octave Band Cut-off Frequency, Hz</u>
6	400
10	315
15	250
25	250

Calculations used air temperature of 20 °C to compute the speed of sound.

Ref: Saha, P., Pan, J., and Veen, J. R., "Thoughts behind Developing SAE Standard J2883 – Random Incidence Sound Absorption Tests Using a Small Reverberation Room," SAE Technical Paper 2009-01-2141, 2009.

4.5 Once the reverberation room is constructed per the guidelines provided above, it is highly recommended that the room is qualified to ensure the diffuseness of the room. Appendix D provides the criteria for the room qualification as it is currently available.

5. TEST SAMPLE SIZE, ORIENTATION, AND MOUNTING

The size and the aspect ratio of the test sample are very critical for getting accurate results.

FLAT SAMPLES

The sample should be a rectangular patch, of one piece. Should the sample be of multiple pieces, each piece should be cut straight and square, so that when the multiple pieces are put together there is no visible gap and/or crack between any two adjacent pieces.

5.1 The sample size for this test is 1 m x 1.2 m (1.2 m²) for rooms between 6 m³ and 25m³.

5.2 The orientation of the sample in the reverberation room is very critical. The sample shall be placed on the floor such that any symmetry with respect to the length and width of the floor is avoided, i.e., none of the sides of the sample shall be parallel to the walls of the rooms or be within ¼ of a wavelength of sound from the walls of the room for the lowest frequency range of interest for that room. It is strongly recommended that a designated sample placement position be used in the room that meets the above requirements (i.e., the distance between the sample and any surface of the room including the diffuser) plus the distance requirement between the sample and the microphone that is discussed in Section 6.2.

5.3 The sample shall be mounted such that it simulates the actual application as close as possible and it shall be documented in the report. More information on the mounting specific to this test method is provided in Appendix E. This test method is suitable for:

- Flat sample test with no air gap between the sample and a hard surface (Type A mounting³). This is generally simulated in the testing by placing the sample on the floor.
- Flat samples test with an air gap between the sample and a hard surface (Type E-xx mounting³, where xx is the thickness of the air gap in mm). This is generally simulated in the testing by placing the sample on the floor with an air gap between the sample and the floor. The air gap could be created by using either blocks (where the sample is placed on the blocks) or by placing the sample on reticulated foam. The thickness of the blocks or the foam or other such devices should be the same as what is intended to be the air gap.

³ The type A and type E-xx mountings are the same as described in ASTM E 795. In type "A" mounting the sample is directly against the hard surface. In type E mounting the sample is elevated from the hard surface.

The blocks could be metal or hard or compressed wood blocks. The reticulated foam must be very open, so it does not contribute to the absorption performance of the test sample. Also the reticulated foam should not get compressed by the placement of the sample on top. The blocks or the reticulated foam should not affect the absorption coefficient performance by more than 5%.

- 5.4 The edges of the samples shall be shielded from the impinging sound. The edge shields, used to seal the edges, are often called frames and could be made of steel or aluminum angles or wood frames. These must not be significantly sound absorbing themselves – i.e., including them in the bare room measurement should have no measureable effect. In addition, they must be of significant mass as to block sound energy within the measurement range. The frame must extend at least to the top surface of the test sample being measured; but not extend more than 3 mm above the absorber top surface⁴. The edge shields must lie flush to the floor of the test chamber within 0.5 mm or less. Any gap between the edge shields and the edges of the flat test samples when viewed from above must be 1.0 mm or less. However, gaps between the edge shields and the floor; and between the edge shields and the edges of the sample exceeding the above values, shall be sealed with tape, caulking compound, or a similar product.

COMPONENTS AND PARTS

The sample (i.e., a component or a part) is generally a non-rectangular and non-flat piece. The size of the sample is also likely to be different for different components and parts. However, the sample size should be close to the size of the flat samples and no greater than 30% of the floor surface area.

- 5.5 Sample Mounting Conditions: The sample shall be mounted such that it simulates the actual application as close as possible and it shall be documented in the report. More information on the mounting specific to this test method is provided in Appendix E. This test method is suitable for:
- When testing parts and/or objects that are used in an application (i.e., non flat and non rectangular test samples or molded parts), tests shall be conducted in the same manner as is used in the application. For example, when testing a hoodliner or a package tray, the body panel (the hood and the package tray panel) on which these parts rest on in the application shall be used in the study. The part shall be installed to the body panel similar to the way it is done in the application. The body panel shall be resting on the floor. Any openings or cutouts on the part shall be covered with parts that are intended to be there. The bare room test shall be done with the body panel in the room
 - Provided the body panel is not available for measuring the performance of the part, the perimeter of the part shall be sealed to the floor. However for parts like seats that are normally bolted to the floor and do not have a body panel otherwise, they shall be tested as is as it is shown in Appendix E-4.

6. INSTRUMENTATION AND MEASUREMENTS

- 6.1 Sound Source: The sound source shall be one or more loudspeakers, preferably with an omnidirectional radiation pattern, such that the reverberation room can be qualified to ensure the diffuseness of the room per the requirements of Appendix D. Should multiple sound sources be used they shall be at least $\frac{1}{4}$ of a wavelength of sound (of the cutoff frequency) apart and preferably should be at the trihedral corners of the room. The sound pressure levels measured in the room with the sound sources operating shall be at least 45 dB above the background noise in that room in each frequency band of measurement. The background noise includes both the ambient noise in the reverberation room and the electrical noise in the measurement system.

⁴ Ref: Bertolini, C. and Falk, T., "On some Important Practical Aspects Related to the Measurement of the Diffuse Field Absorption Coefficient in Small Reverberation Rooms," SAE Technical Paper 2013-01-1972, 2013.