



SURFACE VEHICLE STANDARD

J1400™

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Superseding J1400 JUL2017

Laboratory Measurement of the Airborne Sound Barrier Performance of Flat Materials and Assemblies

RATIONALE

The SAE J1400 technical report has transitioned from being an SAE Recommended Practice and is now classified as an SAE Standard. This updated version expands the measurement frequency range from 8000 to 10000 Hz and extends the control sample sound transmission loss values in Table 3 to 10000 Hz. Furthermore, the tolerance levels for pressure transducers measuring ambient conditions, as outlined in 3.6, have been tightened. Additionally, the legend in Figure C1 has been modified, and 4.3 has been paraphrased to enhance readability.

FOREWORD

This SAE Standard has been modified in response to user comments and to clarify some of the theoretical basis for the testing. The fundamental methodology of this procedure has not been changed from previous revisions.

INTRODUCTION

This document is intended to provide a means of measuring the sound transmission loss (STL) of materials. At each test frequency, the STL is determined based on the measured noise reduction (MNR) of the test specimen using a correlation factor (CF). The respective CF for the test condition is determined as the difference between the MNR of a homogeneous limp panel, such as mass loaded vinyl, and its theoretically calculated field-incidence STL. Note that the calculated STL is for a theoretical panel of infinite dimensions, and the intent is to remove the effect of different size test windows found in different labs, with consideration of low frequency limitations imposed by smaller openings. This SAE Standard then recognizes that many laboratories have measurement variances that can be corrected to a certain extent using this methodology.

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1. SCOPE

This SAE Standard presents a test procedure for determining the airborne sound insulation performance of materials and composite layers of materials commonly found in mobility, industrial, and commercial products under conditions of representative size and sound incidence so as to allow better correlation with in-use sound insulator performance. The frequency range of interest is typically 100 to 10000 Hz 1/3-octave band center frequencies.

This test method is designed for testing flat samples with uniform cross section, although in some applications the methodology can be extended to evaluate formed parts, pass-throughs, or other assemblies to determine their acoustical properties. For non-flat parts or assemblies where transmitted sound varies strongly across the test sample surface, a more appropriate methodology would be ASTM E90 (with a reverberant receiving chamber) or ASTM E2249 (intensity method with an anechoic or hemi-anechoic receiving chamber).

2. REFERENCES

2.1 Applicable Documents

The following publications form a part of this specification to the extent specified herein. Unless otherwise indicated, the latest issue of SAE 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 J184 Qualifying a Sound Data Acquisition System

Ebbitt, G. and Hansen, M. (2007). *Mass law—Calculations and measurements* (Paper no. 2007-01-2201. SAE International. <https://doi.org/10.4271/2007-01-2201>.

2.1.2 ANSI Accredited Publications

Copies of these documents are available online at <https://webstore.ansi.org/>.

ANSI S1.1 Acoustical Terminology

ANSI S1.4a Specification for Sound Level Meters

ANSI S1.40 Specification for Acoustical Calibrators

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 C423 Standard Test Method for Sound Absorption and Sound Absorption Coefficients by the Reverberation Room Method

ASTM E90 Laboratory Measurement of Airborne Sound Transmission Loss of Building Partitions

ASTM E2249 Standard Test Method for Laboratory Measurement of Airborne Transmission Loss of Building Partitions and Elements Using Sound Intensity

2.1.4 Other Publications

Beranek, L.L. (1988). *Noise and vibration control* (Revised edition). Institute of Noise Control Engineering.

Beranek, L.L. and Vér, I.L. (2005). *Noise and vibration control engineering: Principles and applications* (Second edition). John Wiley & Sons.

Bohn, D.A. (1988). Environmental effects on the speed of sound. *Journal of the Audio Engineering Society*, 36(4), 223-231.

Moritz, C., Shaw, J., and Carrera, A. (2015). The influence of test fixture damping on the measurement of sound transmission loss. *The Journal of the Acoustical Society of America*, 137, 2215. <https://doi.org/10.1121/1.4920070>.

3. INSTRUMENTATION

Instrumentation to be used is as follows:

3.1 Sound Level Meter

A sound level meter that meets the Type 1 requirements of ANSI S1.4a is required. As an alternative to making direct measurements using a qualified sound level meter, a microphone, measuring amplifier, and a sound data acquisition system may be used, provided the system meets the requirements of SAE J184.

3.2 Filter Requirements

A third-octave filter set covering the range of center frequencies of interest. The filters shall meet the Class III requirements of ANSI S1.11.

3.3 Microphone Calibrator

A sound level calibrator that meets the Class 1 requirements of ANSI S1.40.

3.4 Source Room Speakers

An acoustical sound generating system shall be selected to generate random noise containing a continuous distribution of frequencies over each test band.

3.5 Instrumentation

A schematic diagram of the instrumentation is shown in Figure 1.

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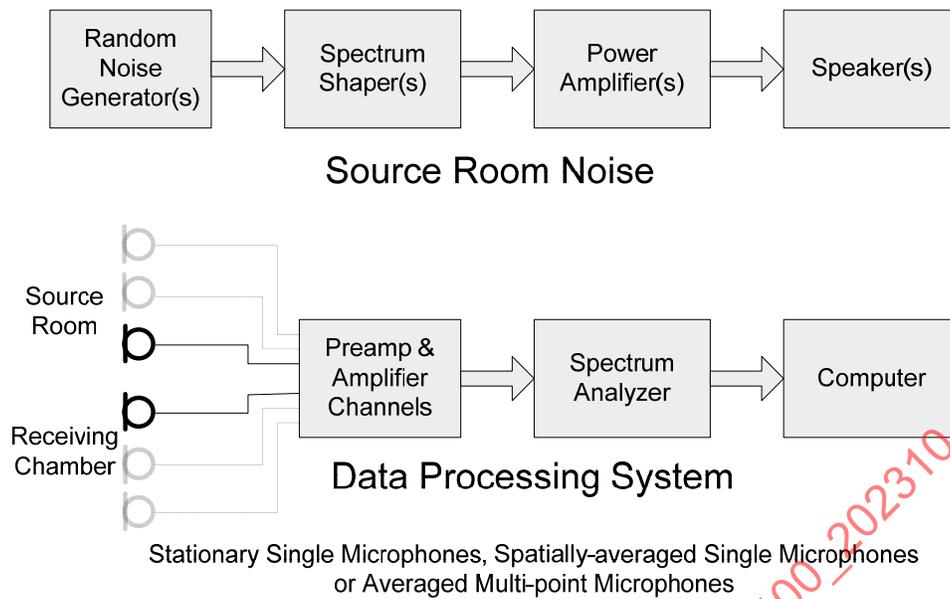


Figure 1 - Typical measurement system

3.6 Ambient Sensors

Temperature and humidity sensors should be used to monitor and record ambient test conditions in the source and receiving chambers, preferably in the vicinity of the sample mounting location.

Recommended accuracy of the sensors:

- ± 1 °C for temperature
- $\pm 3\%$ for relative humidity
- ± 5 kPa for barometric pressure

4. FACILITIES

A schematic diagram of a typical measurement facility is shown in Figure 2.

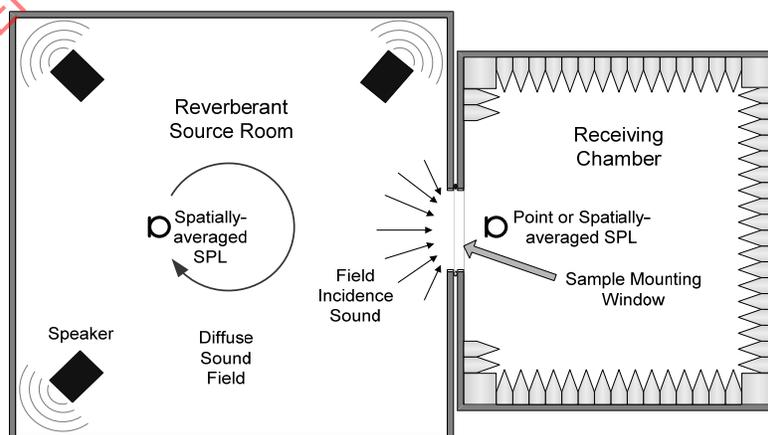


Figure 2 - Typical measurement facility

4.1 Layout of Chambers

Two adjacent chambers are located such that they share a common test window, into which test samples are mounted. The two chambers must be isolated from each other so that the only significant transmission path is through the sample window. Test windows are normally oriented in the vertical plane, but may also be oriented horizontally or even non-orthogonally to the vertical or horizontal planes.

4.2 Receiving Chamber

It is recommended that the receiving chamber be fully anechoic in order to minimize the influence of flanking paths and modal coupling between the chambers. However, good results can also be achieved with semi-anechoic or even reverberant receiving chamber designs if proper care is taken for isolation between the chambers, modal decoupling through the test window and spatial averaging of receiving chamber microphone(s).

4.3 Chamber Sizes

Source room volume is required to be at least 50 m³ (1765 ft³), with approximately 200 m³ (7100 ft³) being the recommended volume. Table 1 shows low frequency cutoff for various room sizes. However, rooms smaller than those specified in Table 1 may be usable if measured diffusion criteria are met. In order to meet the criteria, ideally, room/chamber sizes should be established based on the presence of at least 20 natural frequency modes within the lowest 1/3-octave frequency band of interest for good diffusion of sound. For rectilinear design, room proportions of 1:2^{1/3}:4^{1/3}, or 1:1.26:1.59, are also recommended for good diffusion and modal separation.. Appendix X1 of ASTM E90 suggests some alternate volume criteria based on a smaller number of resonant modes in each 1/3-octave band. Reverberant receiving chamber proportions should be the same; but sized at least 10% smaller or larger in interior volume to avoid natural frequencies which coincide with the source room. It is also advisable to keep reverberant receiving chamber boundaries and sound absorber elements at least 1/4-wavelength from the sample test window. It is possible to do a test using the methodology of SAE J1400 using a small reverberation chamber as a source room, but this will increase the low frequency cutoff for valid test results.

4.4 Source Room Lower Cutoff Frequency and Diffusion

To qualify a test chamber once it has been built or whenever changes are made to the chamber which may affect diffusion, it is recommended that the population standard deviation of twenty randomly located sound pressure measurements in the source room be no more than 2 dB at the 1/3-octave center frequency which is one octave higher than the low frequency cutoff and above (for example, 200 Hz and above for a room with 100 Hz low frequency cutoff), with a representative test sample mounted in the test window. Microphones should be spaced at least 1/4-wavelength from each other, from diffusers and from any room boundaries at the lowest measurement frequency. Diffusion in the reverberation source room can be enhanced by the use of rotating or stationary diffusers. Note that excessively large reverberant source rooms may not exhibit diffuse field characteristics at high frequencies due to air absorption. Refer to Section 7 of ASTM C423 for guidance on reverberation room design. Refer to Annex A3 and Appendix X1 of ASTM C423 regarding room qualification and the use of diffusers to reduce the variability of sound pressure levels within the source room. See 4.9 regarding proper location and orientation of source room speaker(s).

NOTE: ASTM C423 and ASTM E90 procedures specify 5000 Hz as the highest 1/3-octave band. In order to measure accurately at higher frequencies, diffusion at these higher frequencies must be adequate. It is reasonable to extend the 5000 Hz values in Table A3.1 of ASTM C423 to higher frequencies for the purposes of room qualification. Ambient conditions (temperature and relative humidity) in the source room must be controlled to minimize air absorption—refer to Section 6 of ASTM C423 and ANSI S1.26.

Table 1 - Suggested minimum source room volume at lowest measurement frequency

Lowest 1/3-Octave Band Measurement Frequency Hz	Minimum Room Volume m ³ (ft ³)	
80	410	(14479)
100	205	(7240)
125	105	(3708)
160	52	(1836)

NOTES:

1. Minimum room volume figures are based on a minimum of 20 resonant modes in the lowest 1/3-octave band of interest using recommended dimensions of 1:1.26:1.59. The low frequency limit for a given size room may be extended even lower by good design of low frequency absorption/diffusion.
2. Calculations use sound speed of 343 m/s (1125 ft/s) corresponding with an air temperature of 20 °C (68 °F).

4.5 Ambient Conditions

Source and receiving chamber temperatures should be controlled to 22 °C ± 5 °C. Relative humidity should be controlled for both chambers at 40 to 70%. Temperature and humidity should not vary by more than ±3 °C and ±5% RH between measurements of the reference sample(s) and the test sample(s).

4.6 Facility Design

The source and receiver chambers should have wall constructions of a sufficient STL to minimize flanking paths into the receiving chamber. If the existing isolation between test chambers is adequate, supplemental insulation added to potential flanking noise surfaces should have little or no effect on measured STL of maximum transmission loss samples. If supplemental insulation is beneficial, it should be left in place where feasible.

4.1 Maximum Measurement Capability

When the STL of the wall(s) separating the receiving chamber from the source room is not sufficiently greater than the sample under test, the measurements may be compromised by sound transmitted from source to receiving chamber via paths other than through the specimen under test. The maximum STL measurement capability of the system should be determined by measuring the STL of an insulator assembly composed of a 10 to 50 mm foam or fiber decoupler layer in combination with a 2 to 10 kg/m² septum or barrier layer. Continue to add successive insulator assemblies and measure STL after adding each insulator assembly until no further changes in STL are noted (less than 1.0 dB change at all frequencies). Note that a second set of measurements may be required using an insulator assembly composed strictly of mass layers to determine the maximum STL at lower frequencies. The maximum STL capability is limited by flanking paths or residual noise in the overall measurement system. Measured sample STL values should fall at least 10 dB below maximum STL capability levels at all frequencies. Maximum STL levels can be improved by increasing the STL of the common wall between the rooms, by improving the sample sealing system, increasing the structure-borne vibration isolation between rooms or by decreasing the residual noise of the measurement system. Maximum STL measurement capability does not need to be run with every sample, but it should be measured periodically (recommended annually) or whenever changes may have been made affecting the measurement facility and/or data acquisition system.

4.2 Test Sample Fixture

A test sample fixture should hold the test sample securely between the source and receiving chambers. The fixture should be well sealed to prevent leakage between the source and receiving chambers through the fixture (see recommended sample mounting system in Appendix A). The fixture should provide means to maintain typical in-use contact between the various layers of the test assembly. Unless intended, care must be taken to assure that no air gaps are induced in a multilayer assembly or within sample layers during sample mounting or sealing. Although it is common practice to use a vertical test window orientation, horizontal test windows may provide a means of using gravity to naturally hold test layers properly together or to represent the in-use compression of layers.

For materials with low inherent damping, the sample fixture may impart significant damping into the assembly, influencing the measured STL, especially near coincidence. This effect is more significant as the sample size decreases. The STL of a measured substrate should be compared with the theoretical or large sample value to insure that the test fixture does not adversely affect the results.

4.3 Loudspeakers

One or more broadband loudspeakers of sufficient sound power capability should be used to produce sound pressure levels in the receiving chamber at least 10 dB above the noise floor of the measurement system and chamber at all frequencies with the test sample in place. It is recommended that sound spectrum shaping in the source room be utilized in order to reduce the span between the lowest and highest levels versus frequency of the measured sound spectrum in the receiving chamber to within the dynamic range capability of the measurement system. Typically, a source room sound pressure spectrum rising at 6 dB/octave will significantly reduce the dynamic range requirements in the receiving chamber. Selection, exact placement and orientation of the loudspeaker(s) within the source room are often trial-and-error processes to achieve desired source levels and diffusion. Should multiple loudspeakers be used, it is recommended that uncorrelated signals be fed to the broadband loudspeaker sources for best low frequency diffusion. To help define proper loudspeaker placement and orientation, the population standard deviation of the randomly located or spatially averaged sound pressure measurements in the source room should follow the population standard deviation guideline as previously defined in 4.4.

Once placed and qualified, loudspeaker position(s) and orientations must be maintained for all tests.

4.4 Microphones

One or more random incidence microphones (reverberant chambers) or free field microphones (hemi-anechoic or anechoic chambers) shall be positioned within the source and receiving chambers. The number and spacing of microphone positions required in each room depends on the statistical precision desired in the time and space average band sound pressure levels.

4.4.1 Microphone Placement in Reverberant Source Room and Reverberant Receiving Room

Randomly placed microphones or the traverse of a spatially averaged microphone should maintain at least 1/4-wavelength distances from room boundaries, room diffusers, noise sources, and the test sample window at the lowest test frequency consistent with the microphone placement for source room qualification specified in 4.4. For more specifics, please refer to Section 10.1 of ASTM C423.

4.4.2 Microphone Placement in Anechoic or Hemi-Anechoic Receiving Room

The exact number and placement of receiving chamber microphones for best results is often a trial-and-error process. A recommended starting point is to place microphones 10 to 100 mm from the receiving room surface of the test sample. The population standard deviation of the randomly located or spatially averaged sound pressure measurements in the source room should still follow the population standard deviation guideline as previously defined in 4.4—i.e., be no more than 2 dB at 200 Hz 1/3-octave center frequency and above, with a representative test sample mounted in the test window. The distance of the microphone from the surface of the sample facing the receiving room should remain constant. For example, if 20 mm from the face of the sample is selected for a test of an initial sample, and the next sample in the test is substantially thicker or thinner than the previous sample, the microphones should still be placed 20 mm from the face of the new sample.

Note that the construction of a control sample is defined in 6.3, with target STL values that are defined in 6.4. These can be used to aid in the above trial-and-error process.

Once placed, microphone positions must be maintained throughout the test sequence and ideally for all tests.

4.5 Test Window Opening

For finite size panels, random incidence or field-incidence transmission loss in the mass-controlled region will be higher for smaller panels, and this effect will be more pronounced at lower frequencies. The CF calculated using the reference limp barrier essentially converts the MNR to field-incidence STL for an infinite panel.

There is not a specific limit to window size. However, in order to meet the CF requirements in 5.4.3 (in terms of difference between MNR and calculated limp barrier STL) the user should be aware of the low frequency effect of finite window size. Appendix E contains a brief discussion of the theory behind this. Table 2 shows the minimum window size necessary for 5 dB or 10 dB deviation of ideal MNR from calculated limp barrier STL. The actual CF for a given window may be somewhat higher or lower, depending on microphone placement and other factors. As long as CF requirements are met as specified in 5.4.3 the window opening sizes in Table 2 do not need to be strictly observed. However, the smaller the test window is, the more the CF will approach the specified limits. Although Table 2 is specific to square test samples, the theory is generally applicable to non-square openings and these figures are useful as a guideline. A useful empirical rule of thumb is to consider the low frequency limit to be that for which the diagonal opening of the test window is 1/4 of the wavelength (in air).

Table 2 - Effect of diagonal dimension of a square test window at lowest measurement frequency and comparison with 1/4-wavelength of lowest 1/3-octave band frequency

Lowest 1/3-Octave Band Measurement Frequency Hz	Minimum Diagonal of Square Test Window Opening for 5 dB Deviation m (feet)	Minimum Diagonal of Square Test Window Opening for 10 dB Deviation m (feet)	1/4-Wavelength of Lowest Frequency in 1/3-Octave Band m (feet)
80	2.42 (8.0)	1.21 (4.0)	1.21 (4.0)
100	1.93 (6.4)	0.96 (3.2)	0.96 (3.2)
125	1.52 (5.0)	0.76 (2.5)	0.76 (2.5)
160	1.22 (4.0)	0.61 (2.0)	0.61 (2.0)
200	0.96 (3.2)	0.48 (1.6)	0.48 (1.6)
250	0.78 (2.6)	0.38 (1.3)	0.38 (1.3)
315	0.60 (1.0)	0.30 (1.0)	0.30 (1.0)
400	0.48 (1.6)	0.24 (0.8)	0.24 (0.8)
500	0.38 (1.2)	0.19 (0.6)	0.19 (0.6)

NOTES:

- Calculations use sound speed of 343 m/s (1125 ft/s) corresponding with an air temperature of 20 °C (68 °F).
- Diagonal dimensions are based on maximum deviation of either 5 dB or 10 dB from infinite panel field-incidence STL to finite panel STL calculated per Equation E.2 at the lowest frequency of interest

5. PROCEDURE

5.1 Sample Mounting

Test samples must be mounted and sealed completely within the test fixture so as to ensure a minimum of sound flanking the test sample. The recommended sample mounting system is shown in Appendix A.

5.2 Sample Conditioning

Test samples should be conditioned to the same temperature and humidity as the test chambers for at least 12 hours prior to testing.

5.3 Measurements

5.3.1 Background Noise

Background noise levels within both the source and receiving chambers shall be measured and noted in all measurement bands and averaged over all measurement positions for each measurement series. Background noise levels in the receiving chamber must be measured at the same gain settings as during normal measurements in order to include the noise floor of the measurement system. Ultra-low noise microphones and preamps are available for laboratory use and can be effective in lowering the noise floor of the measurement system.

5.3.2 Reference Sample

Install and seal the reference sample, a homogeneous limp material such as lead, PVC sheet, EVA sheet, or another monolithic limp material that does not show a critical frequency phenomenon in the frequency range of interest, into the test opening so that its field-incidence STL can be calculated from the relation:

$$\text{STL}(\text{reference sample}) = -0.192 + 10 \log(\beta^2) - 10 \log \left[\ln \frac{\beta^2 + 1}{0.043227\beta^2 + 1} \right] \quad (\text{Eq. 1})$$

where:

$$\beta = \rho_s \omega / 2\rho_0 c$$

$$\omega = 2\pi f$$

f = center frequency of the 1/3-octave measurement band

ρ_s = surface density of the reference sample (kg/m²)

ρ_0 = volumetric density of air (kg/m³) at measurement barometric pressure, temperature, and humidity

c = speed of sound (m/s) at measurement barometric pressure, temperature, and humidity

The procedure for calculating the speed of sound accounting for temperature, humidity, and barometric pressure is found in Appendix D.

5.3.3 Reference Sample Surface Density

The surface density of the reference sample should be selected to be within 50 to 200% of the surface density of each test panel or multi-layer test assembly as long as the requirements of 5.3.1 are met and the reference sample surface density does not exceed 10.0 kg/m². Reference samples of different surface densities may be required to cover various test sample materials

5.3.4 Signal-to-Noise Ratios

The source signals may be amplified or filtered versus frequency so that, with the test sample sealed in place, the source room and receiving chamber signal levels are each at least 10 dB, and preferably more than 15 dB, higher than the background noise levels within the respective chambers and within the dynamic range capability of the measurement system at all frequencies of interest.

5.3.5 Measurement Conditions

The time and spatially averaged third-octave band levels in both the source and receiving chambers shall be measured and recorded over the desired measurement bands with the reference sample sealed into the fixture in the test opening. Optionally, time averaged, single point measurements may be used on the receiving side of the sample mounting window if they can be shown to give STL results within ± 2.0 dB at all measurement frequencies to time and spatially averaged measurements. Averaging times shall be long enough to provide an estimate of the time-averaged level to within ± 0.5 dB for 95% confidence limits at all measurement frequencies. See 5.5.4 and Appendix B. Measurement distance to the sample mounting plane and number of measurement positions in the receiving chamber which give best results will vary from lab to lab and are usually determined through trial and error. See 4.10 for microphone placement guidelines.

Note that the construction of a control sample is defined in 6.3, with target STL values defined in 6.4. These can be used to aid in the above trial-and-error process.

5.3.6 Test Samples

After removing the reference sample, the test sample is installed and sealed into the same opening and in the same manner as the reference sample. The measurements are then repeated as in 5.3.5. The test sample may be a homogeneous single layer material, a multi-layer material, a combination of multilayer materials with a sheet metal backing, a porous material without an impervious layer, or any of the previous materials with a pass-through, opening or intentional leakage path. The results for each of these systems are compared to the results for the reference sample tested in 5.3.5. If microphones are moved during test sample mounting, they must be accurately replaced (within 3 mm) to the same positions as in prior measurements, including reference sample measurements. In a hemi-anechoic or anechoic receiving room, distance from the surface of the sample facing the receiving room shall remain the same.

5.3.6.1 Test Sample Sealing

Some studies have found that the method of sealing the edges of a lightly damped test sample (e.g., a steel or aluminum panel) can affect the STL measured according to SAE J1400, particularly in the vicinity of the coincidence frequency of the test panel. To minimize this artifact it is strongly recommended that the minimum necessary amount of material be used to seal the edges of the sample to the test fixture. A convenient tool to use to check for sealing gaps is an ultrasonic leak detector.

5.4 Data Analysis

The following procedures are used to calculate the field incidence STL of the test sample.

5.4.1 Background Noise Correction

If the difference between background noise level and signal plus background noise level is between 10 dB and 15 dB, correct for background noise levels at each measured third octave frequency band of interest and at each microphone for both the source and receiving chambers using the following equation:

$$L_S = 10 \log_{10} (10^{L_C/10} - 10^{L_B/10}) \quad (\text{Eq. 2})$$

where:

L_S = corrected sound pressure level of the signal (dB)

L_C = sound pressure level of the signal and background noise combined (dB)

L_B = sound pressure level of the background noise alone (dB)

NOTE: Correction is not necessary if $L_C - L_B$ is greater than or equal to 15 dB.

5.4.2 Measured Noise Reduction

For both the reference sample and the test sample, compute the measured noise reduction (MNR) at each 1/3-octave band of interest. Using the corrected band pressure levels, if required, for each measurement band, subtract the receiving chamber band pressure level from the source room band pressure level to obtain the MNR for both samples. Where applicable, use spatially averaged values for source and/or receiving room/chamber.

$$\text{MNR}_f = \text{SPL}_f(\text{source room}) - \text{SPL}_f(\text{receiving chamber}) \quad (\text{Eq. 3})$$

NOTE: Subscript “f” indicates frequency-dependent variables.

5.4.3 Correlation Factors

Determine the correlation factor applicable to the test opening and source/receiving chamber pair at each test frequency (CF_f) as the difference between the measured noise reduction of the reference sample, MNR_f (reference) and its calculated STL_f (reference).

$$CF_f = MNR_f(\text{reference}) - STL_f(\text{reference}) \quad (\text{Eq. 4})$$

NOTE 1: Correlation factors at all frequencies should fall within +10/-0 dB for a well-implemented test system, +15/-0 dB for a typical system and should not exceed the range of +15/-5 dB. Methods to reduce the correlation factor without major facility changes would include changing the position of the receiving microphone(s), increasing the absorption in the receiving chamber, improving the sealing and/or sample mounting system, increasing the number of receiving room microphones, averages or spatial averaging in the receiving room.

NOTE 2: The correlation factors (CF_f) determined using this methodology are subsequently used for computing the STL of multi-wall samples as well as single wall samples.

5.4.4 Sound Transmission Loss

Compute the sound transmission loss (STL_f) of the test sample at each test frequency by subtracting the CF_f from the MNR_f of the test sample:

$$STL_f(\text{sample}) = MNR_f(\text{sample}) - CF_f \quad (\text{Eq. 5})$$

STL_f (sample) at each frequency band of interest should be rounded to the nearest whole dB.

5.4.5 Insertion Loss

Sometimes an insertion loss (IL) is desired. In the context of SAE J1400, IL is defined as the difference between the STL of a substrate (e.g., a metal panel) and the STL of the substrate plus insulator. This can be easily calculated at each frequency band as:

$$IL_f(\text{insulator}) = STL_f(\text{substrate} + \text{insulator}) - STL_f(\text{substrate}) \quad (\text{Eq. 6})$$

Similarly, if the CF meets the requirements of 5.4.3, then the IL may be calculated directly from the MNR as:

$$IL_f(\text{insulator}) = MNR_f(\text{substrate} + \text{insulator}) - MNR_f(\text{substrate}) \quad (\text{Eq. 7})$$

5.5 Reporting

The following shall be included when reporting results of these test procedures.

5.5.1 Basic Information

Measurement date, test location, person performing tests, sample description(s), and reference sample(s) used. It is also required to specifically state any deviations to the SAE J1400 procedure requirements, if any. Sample description shall include dimensions, weight, overall composition/number of layers, which surface faces the source room, and sample orientation (horizontal, vertical, or other). Photos of each sample as installed should be included. Microphone positions within source/receiving rooms and number of microphones used (or a single microphone on a rotating boom), Microphone/preamp model numbers, other measurement instrumentation model and serial numbers, and frequency range should be recorded.

5.5.2 Ambient Conditions

Ambient temperature, local barometric pressure, and humidity conditions in each test chamber at time of measurements.

5.5.3 Sound Transmission Loss

Sound transmission loss rounded to the nearest whole dB versus 1/3-octave center frequencies in Hz. Measurements which have been corrected for background noise should be marked with an asterisk and a note explaining such. See 5.4.1. If the user does not have specific data presentation requirements (e.g., internal company standards), the SAE J2629 document and spreadsheets provide data presentation formats for SAE J1400 and other acoustical tests.

5.5.4 Confidence Limits

95% confidence limits in dB versus 1/3-octave center frequencies in Hz are defined in Appendix B. Calculations for confidence limits do not have to be made for each test, but should be done annually or following any changes made to the chamber and/or measurement system which may affect confidence limits. Confidence limits may be shown graphically as upper and lower bounds for STL at each frequency (i.e., "error bars").

5.5.5 Maximum Measurement Capability

Maximum STL capability rounded to the nearest whole dB versus 1/3-octave center frequencies in Hz. See 4.7.

6. GENERAL COMMENTS

6.1 Qualified Personnel

It is essential that technically qualified personnel trained in the current techniques of sound measurements select equipment and perform the tests.

6.2 Routine Calibration

Instrumentation manufacturers' or quality standard recommended calibration practices should be followed before each test.

6.3 Control Sample Construction

A control sample has been developed to aid in the assessment and minimization of intra-laboratory variability and/or bias. See Appendix C for construction details. Specific sources of construction materials are mentioned as guidelines. Alternative sources may work as well.

6.4 Control Sample Target Results

The following table is based on a weighted average of multiple control samples produced independently and tested in a number of independent test laboratories. All qualified laboratories should be able to reproduce these results within 3 dB at all frequencies. Laboratories having trouble with reproducibility particularly below 1000 Hz should seek improvements as suggested in 4.3 and 4.8. If measured STL is too low relative to target levels above 2500 Hz, improvements as suggested in 4.6 and 4.9 are recommended. Note that stiffness effects of finite size panels may affect low frequency STL. Every lab may not be able to reproduce the table shown below in its full frequency and STL ranges. A good understanding of lab limitations (flanking paths, source room diffuse field cutoff, effects of window size, etc.) should provide understanding of how much of Table 3 is valid.

Table 3 - Target sound transmission loss values - control sample

1/3-Octave Center Frequency Hz	Sound Transmission Loss dB
125	10
160	9
200	10
250	16
315	25
400	33
500	40
630	45
800	50
1000	54
1250	59
1600	63
2000	66
2500	69
3150	72
4000	74
5000	77
6300	79
8000	82
10000	85

7. NOTES

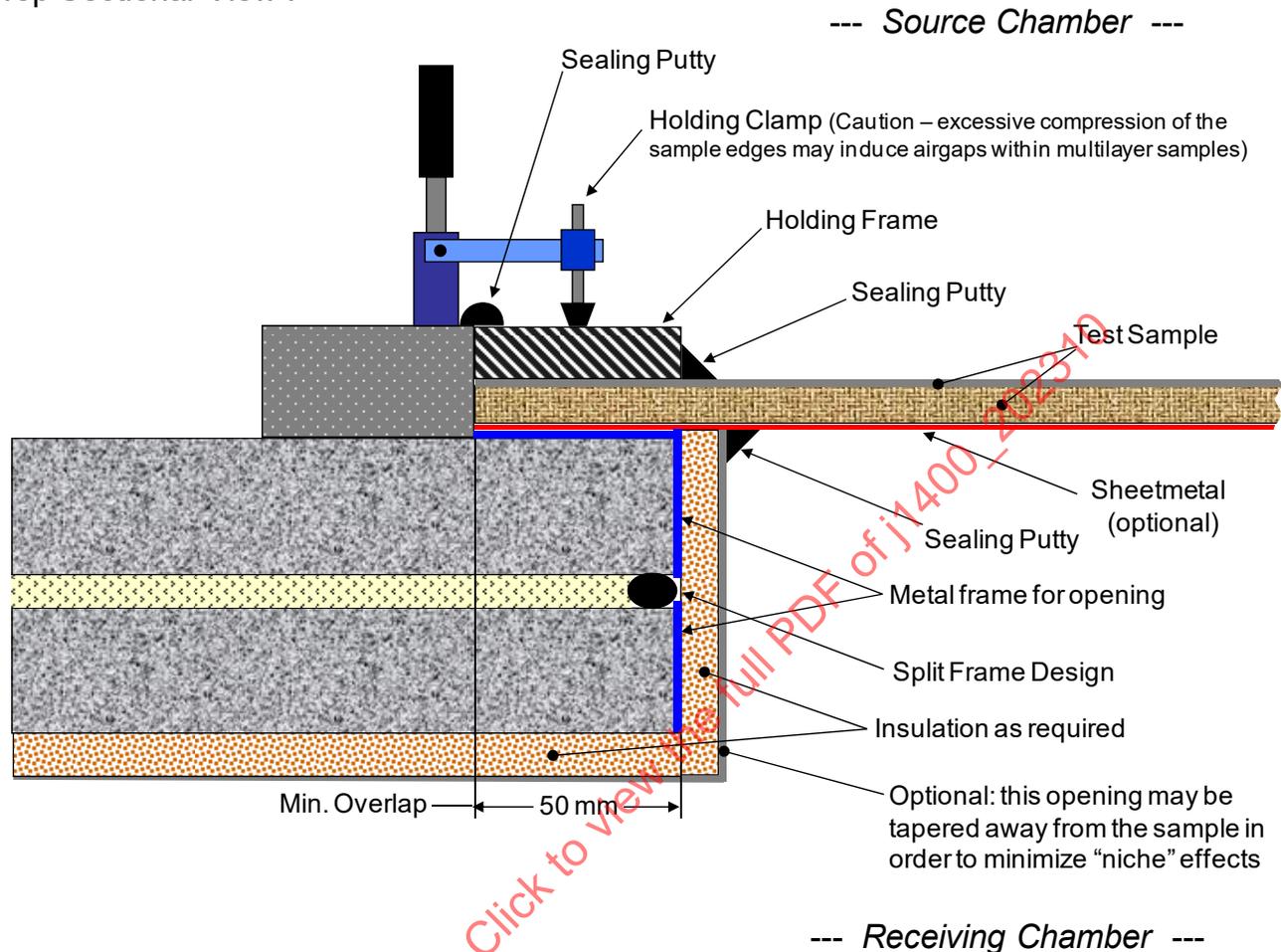
7.1 Revision Indicator

A change bar (|) located in the left margin is for the convenience of the user in locating areas where technical revisions, not editorial changes, have been made to the previous issue of this document. An (R) symbol to the left of the document title indicates a complete revision of the document, including technical revisions. Change bars and (R) are not used in original publications, nor in documents that contain editorial changes only.

PREPARED BY SAE ACOUSTICAL MATERIALS COMMITTEE

APPENDIX A - RECOMMENDED SAMPLE MOUNTING SYSTEM

Top Sectional View :

**Figure A1 - Recommended sample mounting and sealing system**

The test sample shown here is installed from the source room, which is recommended for convenience of sample mounting. In some cases, test samples may not have a sheet metal base panel or it may be a different material/composite. Test window orientation may be horizontal or non-orthogonal in order to duplicate end-use orientation, particularly if gravity holds test samples in place. The sheet metal-to-sample orientation may be reversed (sheet metal facing source room) in order to have the sound field incident on the same face as the intended application.

APPENDIX B - ACCURACY, PRECISION, AND REPEATABILITY

B.1 ACCURACY

Accuracy determines how well the test data measures the STL properties of the test specimen. Since this test protocol is defined, the accuracy of a test conducted by this method is governed by the design of the test facility and by the sample mounting and microphone placement procedures.

B.2 PRECISION

Precision determines the variation of the average measurement for a certain confidence level. The precision of this test is determined by the variation in each measured data set and is calculated from the confidence intervals for each data set.

B.2.1 Confidence Intervals

The overall confidence interval for the resulting data is derived from the confidence intervals for the individual measured quantities. The following paragraphs describe the steps to be taken to collect and calculate confidence intervals.

B.2.2 Standard Deviations

Calculate the standard deviation, s_f , for the mean of each time and space averaged 1/3-octave band sound pressure level for L_{SRf} , L_{RRf} , L_{STf} , and L_{RTf}

where:

L_{SRf} = source room sound pressure level for the reference sample

L_{RRf} = receiving chamber sound pressure level for the reference sample

L_{STf} = source room sound pressure level for the test sample

L_{RTf} = receiving chamber sound pressure level for the test sample

Using this expression:

$$s_f = \text{SQRT} \left\{ \left(\frac{1}{(n-1)} \right) * \text{SUM} (X_{if} - X_{\text{MEANf}})^2 \right\} \quad (\text{Eq. B1})$$

where:

s_f = standard deviation at each frequency band of interest

X_{if} = individual measurement of sound pressure level at each frequency band of interest

X_{MEANf} = arithmetic mean of the set of sound pressure levels at each frequency band of interest

n = number of measurements of sound pressure level in each set; a minimum of six is recommended

B.2.3 95% Confidence Interval

Calculate the 95% confidence interval for the individual measurement frequency bands from:

$$\Delta X_f = a \cdot s_f \quad (\text{Eq. B2})$$

where:

ΔX_f = confidence interval at each frequency band of interest

s_f = standard deviation at each frequency band of interest

a = factor which depends on the number of measurements and is given in Table C1

Table B1 - Factors for 95% confidence limits for averages

Number of Measurements n	Factor a for Confidence Limits
4	1.591
5	1.241
6	1.050
7	0.925
8	0.836
9	0.769
10	0.715
11	0.672
12	0.635
13	0.604
14	0.577
15	0.544
16	0.533
17	0.514
18	0.497
19	0.482
20	0.468
21	0.455
22	0.443
23	0.432
24	0.422
25	0.413
n greater than 25	$a = n^{0.5}/(0.512n-0.71)$

B.2.4 Overall Confidence Intervals

Calculate the confidence interval for each frequency band of interest from:

$$\Delta \text{STL}_f = \text{SQRT} \{ (\Delta L_{\text{SRF}})^2 + (\Delta L_{\text{RRF}})^2 + (\Delta L_{\text{STF}})^2 + (\Delta L_{\text{RTF}})^2 \} \quad (\text{Eq. B3})$$

B.3 REPEATABILITY

Repeatability determines the success in obtaining identical test results on the same sample. Within the limits for precision defined in B.2.4, the repeatability of a test on any sample is influenced by the mounting and microphone placement/replacement procedures. If mounting and microphone placement practices are closely replicated, then repeatable results should be expected within the limits of precision.