Designing and Building an Innovative Sound Transmission Loss Facility

Richard A. Kolano, Kolano & Saha Engineers, Inc., Waterford Michigan

This article presents the design, construction, and implementation of a novel sound transmission loss testing fixture that is unique to the automotive industry. This fixture was built within a large opening in the wall between a reverberation room and an adjacent anechoic chamber. The fixture was designed and built to accommodate interchangeable plugs that allow STL measurements on an automotive "buck" as well as on flat sample materials.

Testing the sound transmission loss (STL) of flat sample materials per standard SAE J1400[1] traditionally requires a sample holding fixture built within a dedicated opening in the wall between the reverberant source room and an anechoic termination. Testing STL of large automotive sections, such as front-of-dash assemblies, normally requires a larger, separate opening between the reverberant source room and anechoic receiving room. These arrangements usually require two separate anechoic terminations built outside openings often on different walls of the reverberant source room.

As part of a turn-key project for upgrading and improving an old, existing but seldom-used reverberation room test suite, Ford Motor Company sought to resurrect the use of a sound transmission loss testing opening between the existing reverberation room and adjacent anechoic chamber.[2]

Figure 1 shows the original opening between test rooms, massive hinged doors that close and seal the opening when it's not in use, and the original flat-sample holding fixture. This fixture was intended to fill half of the STL opening, while one of the massive doors filled the remaining half of that opening. Figure 2 provides a close-up view of a previous attempt at building a removable STL sample holding fixture.

Due to the limited available building space surrounding the original reverberation room, it was not practical to introduce a second opening in one of the room walls and couple that opening to a second anechoic termination. As a result, a novel sound transmission loss testing fixture that readily allows testing of both automotive bucks as well as flat sample material tests was designed, built, installed, and qualified.

Original STL Test Fixture

The original 1.14 m high × 2.28 m wide (3 ft 9 in × 7 ft 6 in) opening in the wall between the reverberation room and adjacent full anechoic room was seemingly intended to serve STL testing of both large automotive sections (so-called bucks) and flat sample materials. This opening was covered by a pair of massive hinged doors that blocked sound passage between the two rooms when the rooms were not being used for STL tests. These doors and perimeter frame of the opening impeded installation and acoustic sealing of both automotive bucks and a flat sample holding frame placed in the opening for STL measurements.

The STL sample holding fixture was a simple wood frame with a square center hole in which samples could be clamped and manually sealed in place for each test. This fixture created not only a tedious process to install, seal, and test each sample, but also tied up both the reverberation room and anechoic room while sample installation/removal was being conducted. Furthermore, the sample holding frame was built of plywood and wood framing, which alone was not a very massive construction. This lightweight construction likely created severe flanking limitations in any STL measurements conducted on samples held in this holding frame.

New STL Test Fixture

The new replacement fixture used the original opening in the double brick and concrete block walls between the existing reverberation room and anechoic room. However, that original opening was judged to be too small to accommodate typical automotive bucks, such as a vehicle front-of-dash assembly. As a result, the opening was subsequently enlarged to approximately 1.68 m high × 2.74 wide (5 ft 6 in × 9 ft).

Figure 1. Original STL opening between the reverberation room and anechoic room.

Figure 2. Previous flat sample STL holding fixture.

Both the reverberation room and anechoic room sides of the opening were then framed with matching heavy plate steel perimeter frames that are separated to maintain acoustical isolation between the two frames and walls. These frames were covered with absorption material and a perforated metal protective facing as a means of increasing the effectiveness of passive acoustical seals on both sides of the opening (see Figure 3).

Figure 3. Reverberation room side of the matching plate steel perimeter frames showing perforated protective facing that covers center sound absorption and clamps that secure interchangeable inserts.

These matching perimeter-framed openings with seals allowed interchangeable inner frames or plugs to be quickly inserted and acoustically sealed for STL testing and then removed from the opening. Two types of interchange inserts were provided. One is an inner frame for installing an automotive section (buck) for testing molded parts.

Figure 4 shows the inner frame for installing automotive bucks inserted and clamped into the perimeter frames of the wall opening. This frame had its inner surfaces lined with thick hardwood for attaching an automotive buck. In this photo, the opening formed by the hardwood frame had been temporarily filled with a sheet of Melamine-faced particleboard to serve as a dust barrier between the reverberation and anechoic rooms during construction.

The second interchangeable insert was a massive plug with a square, center opening for receiving custom, flat sample holding frames for STL measurements. The framed center opening was specifically designed as a receiver for removable frames that hold, clamp, and seal the flat sample materials. These removable frames

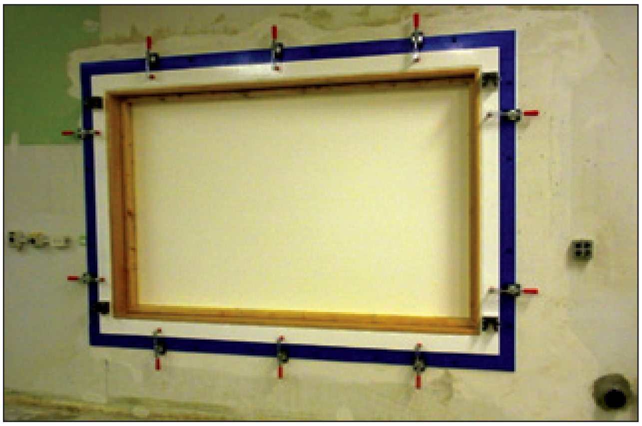

Figure 4. Reverberation room side of inner frame insert for installing an automotive buck.

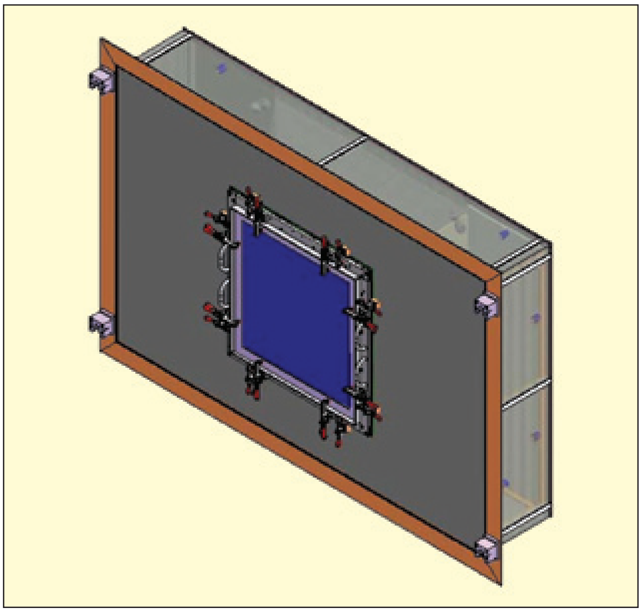

Figure 5. Isometric view of STL plug from reverberation room side showing STL sample holding frame inserted into square center receiver opening.

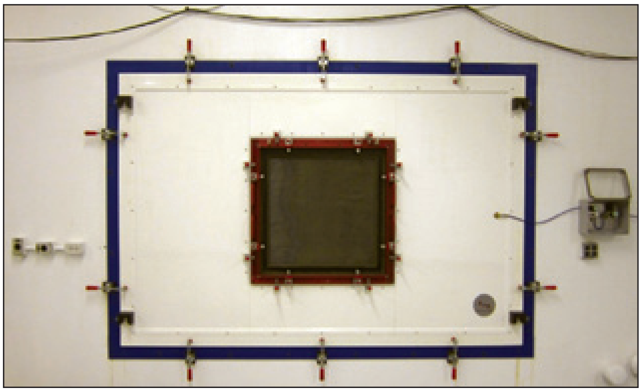

Figure 6. Photo of reverberation room side of completed STL opening with STL fixture installed and maroon-colored sample holding frame complete with lead sheet homogeneous sample inserted in fixture.

were sealed in place using pneumatically inflated seals that are quickly inflated for the test and then deflated for quick removal of the frame and replacement with the next sample holding frame.

Figure 5 shows a CAD drawing of the STL plug. Also shown is the removable sample holding frame inserted and clamped into the square center opening that serves as a receiver for the sample holding frames. Figure 6 shows a photo of the reverberation room side of the completed STL plug with the STL fixture installed.

The massive plug was built using a heavy-gage tubular steel space frame with sheet steel backed by high-density specialty

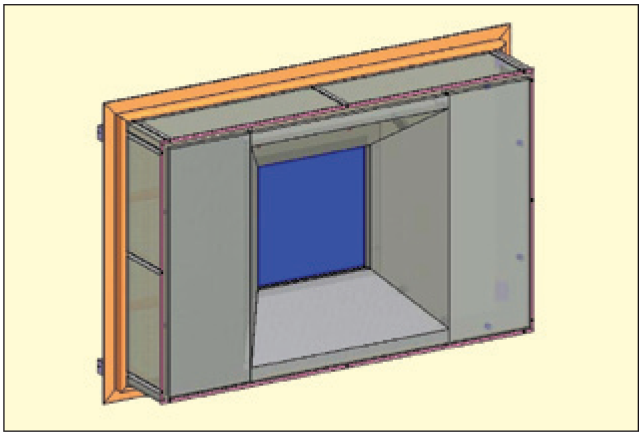

Figure 7. Isometric view of anechoic room side of STL plug showing flared absorptive facings.

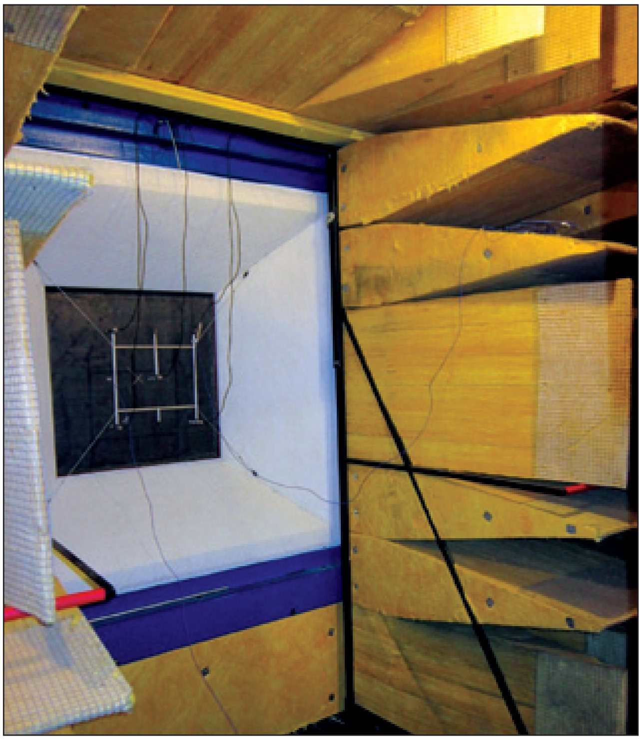

Figure 8. Anechoic side of completed STL opening with STL fixture installed.

drywall composites, liberal applications of a vibration damping adhesive, and polymeric vibration isolating mounts. These mounts isolate the reverberation room face of the plug from the anechoic room side face.

All surfaces on the anechoic room side of the plug were angled (flared) and covered with an acoustically absorptive porous glass fiber faced with a perforated metal protective cover. The purpose of the flaring and absorptive facing was to prevent sound radiating from the anechoic side of the STL test sample from reflecting off of these surfaces toward the receiving room microphone and influencing the sound pressure level it measures. This preserves the free-field sound propagation away from the receiving room side of the test specimen. (See Figure 7, which is a CAD drawing of the anechoic room side of the STL plug.)

Figure 8 shows the anechoic side of the completed STL opening with the STL plug installed in that opening. This view also shows the removable anechoic wedges that allow access to the receiving side of the fixture and a nine-microphone holding array developed by Ford for STL measurements.

STL Sample Holding Frames

Two different types of sample holding frames were designed and built. The first was a nonisolated frame built of milled aluminum bars and flats with integral clamps and a picture-frame-like steel

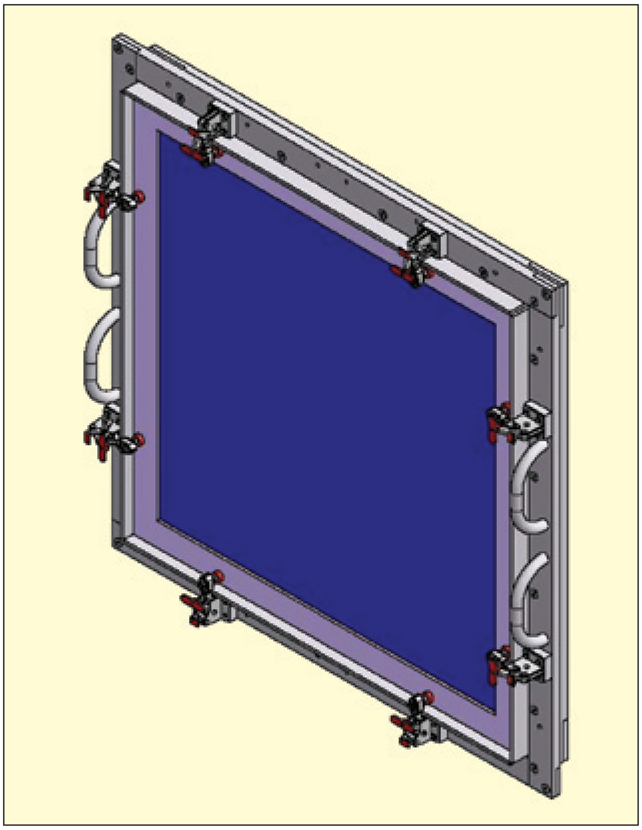

Figure 9. Isometric view of STL sample holding frame showing perimeter edge clamps and "picture frame" that secure test sample in place.

frame for clamping the perimeter edge of the test sample into the frame. The intent of the noninsulated frames was for holding and testing the homogeneous limp mass and materials that were expected to provide STL performance no greater than mass law. (See Figure 9 for a CAD drawing of the STL sample holding frame.)

The size of these frames were chosen to allow 1 m × 1 m samples to be held in the sample holding frames. The design of this entire fixture was conceived to allow the insertion and use of more than one plug. Other plugs can be built with a different size of sample holding frame that allow testing of samples that are smaller than 1 m × 1 m. For example, one common size sample that is often employed in acoustical material tests is 0.6 m × 0.6 m.

In addition, the sample holding fixture was designed so that the thickness of the sample projects out toward the reverberation room. This keeps the sample-to-receiving-microphone distance constant for any given test sample as well as the homogenous reference (lead sheet) for which the correlation factor is measured. This approach further helped minimize the amount of time required to set up and conduct tests with the removable sample holding frames.

The second type of sample holding frame was an isolated frame that included an isolation layer of a low durometer polymeric material that separates the front and rear halves of the frame. This isolation material introduced an impedance break into the frame for reducing structure-borne sound transmission through the frame. The isolated frames are intended for testing STL samples such as double-wall assemblies that are expected to exhibit high STL performance. An example of this is the SAE double-wall STL reference sample. To allow the test operator to keep track of frames that are isolated from those that are not, all frames were anodized using color coding. In addition, the frames intended to be reserved for holding the homogeneous reference mass (lead sheet) and the SAE reference STL sample were also color coded in separate colors to indicate their reserve status.

A pneumatically inflatable seal was built into the STL square center opening in the STL plug. The pneumatic seal allowed the STL sample holding frame to be quickly and easily sealed in place acoustically with minimal leakage.

The interchangeable inserts are relatively large and too heavy to

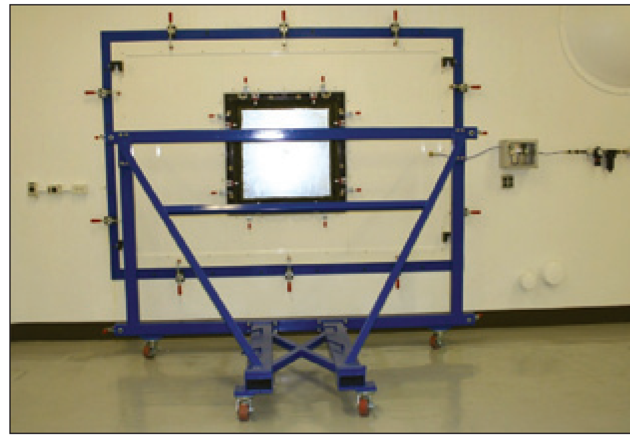

Figure 10. Frame built for installing and removing interchangeable inserts, shown with its attachment to forks of a standard forklift, in front of completed STL fixture.

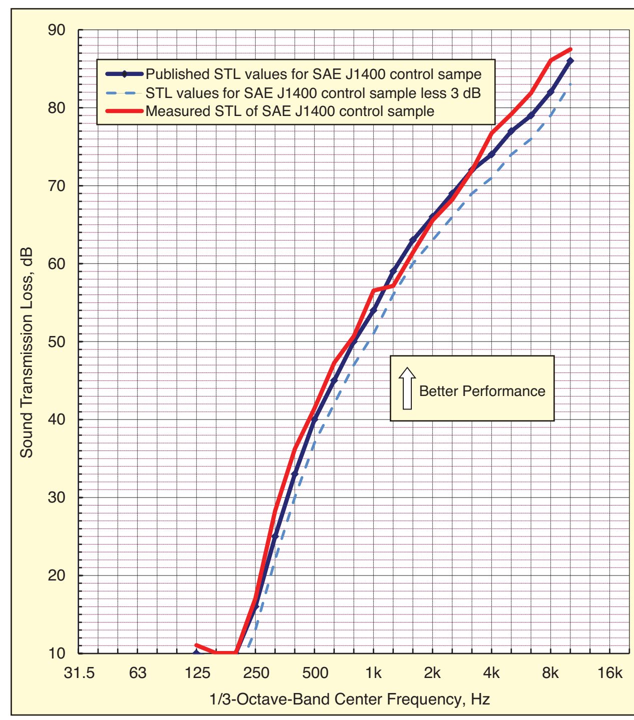

Figure 11. Sound transmission loss versus third-octave bands measured in upgraded laboratory facility compared to published STL values for SAE J1400 double-wall control sample.

be manually lifted and inserted into/or removed from the framed STL opening between the two rooms. Instead, the fixture was designed and built to allow the installation and removal of the inserts to be done using a forklift. Installation and removal was done by using a custom built frame that attaches to the forks of a standard forklift, as shown on Figure 10. This frame aligned with and engaged four inverted U-shaped lift points on the upper and lower corners of both the STL plug and the buck holding frame, as shown on Figures 4, 5, and 6.

Validation of New STL Test Fixture

The performance of the new STL test fixture for conducting sound transmission loss measurements of flat sample test materials was evaluated by conducting STL measurements on a reference sample built in accordance with the recommendations provided in Appendix C of SAE J1400. The testing consisted of first determining the correlation factor by measuring the noise reduction produced by a homogeneous limp mass. The limp mass (a nominal 5 kg/m^2 (1 lb/ft^2) lead sheet) was installed in a nonisolated sample holding frame and then inserted into and sealed in the STL opening.

The results of measurements conducted on the SAE J1400 double-wall control sample are compared graphically in Figure 11.

These data are provided in 1/3-octave-band frequencies from 125 Hz to 10,000 Hz. The comparison shows very good agreement exists between test results obtained in the upgraded test facility and the STL data published by SAE for the double-wall control sample. Per SAE J1400 standard, STL data measured for the SAE control sample in any facility should be at least within 3 dB of the values published in SAE J1400. The results here show that the measured STL of the control sample at frequencies above 2500 Hz 1/3-octave band was even higher than the published values. This indicates that the flanking paths are better controlled in this test facility than on average values obtained in the round robin testing.

Note that the sound transmission loss test suite exhibits valid room diffusion, a reverberation room cut-off frequency, and flat sample opening size (cut-off frequency) that support sound transmission loss measurements as low as 80 Hz. However, neither the SAE J1400 standard nor the control sample defined in that standard are intended to extend below 125 Hz. As a result, it is recommended that caution be exercised in using data below 125 Hz generated in this facility.

Conclusions

This article presents the design, construction, and implementation of a novel sound transmission loss testing fixture that is unique to the automotive industry. Validation measurements conducted on an SAE control sample demonstrate that the STL performance values obtained in this facility agree with the published SAE data for the control sample.

References

1. *SAE International Surface Vehicle Recommended Practice*, "Laboratory Measurement of the Airborne Sound Barrier Performance of Flat Materials and Assemblies," SAE Standard J1400, Rev. Aug. 2010.
2. Kolano, R. A., Abhyankar, S., and Martin, T., "Restoring and Upgrading of a Ford Motor Co. Reverberation Room Test Suite," SAE Technical Paper 2013-01-1960.

The author can be reached at: rakolanope@kandse.com.