

Design of a Self-Contained Acoustical Testing Facility

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ABSTRACT

This paper presents an overview of the acoustical design of a small volume self-contained acoustical testing facility (SCATF). The design focuses on a small volume (25m³) reverberation room for testing the random incidence sound absorption performance of small samples of acoustical materials and automotive parts. This reverberation room also couples to a small volume hemi-anechoic room and serves as the random incidence source room for sound transmission loss testing. These testing approaches respectively target the SAE J2883 (pending) and J1400 test standards.

INTRODUCTION

Traditional measurements of random incidence sound absorption coefficient ($R\alpha$), sound transmission loss (STL), and sound power levels (PWL) require the use of a full size reverberation room. The recommended room volume in this case is 200m³ [1, 2, 3, 4] which has the potential to be diffuse at and above the 100 Hz 1/3rd octave band. The size of the room recommended in the standards is primarily dictated by the application of the products that are being tested and/or the primary industry for which the standard is being developed. Most of these standards were developed for evaluating the performance of architectural materials that would be used for industrial, commercial, residential, and performance halls. The samples that are used in these applications are generally large size samples and therefore evaluating large size samples in the test facility is beneficial. For example, the recommended sample size for the random incidence sound absorption test per the ASTM C 423 is 6.69m² and per the ISO 354 is 10m². For sound transmission loss tests the typical sample size in the ASTM E 90 test method is 1.22m × 2.44m. In order to evaluate these large size samples properly one

needs a large room and hence large reverberation rooms are necessary.

However, in automotive applications (including automobiles, light and heavy trucks, commercial vehicles, farm tractors, and construction vehicles) most samples are much smaller in size than that required for testing according to the ASTM or ISO standards. Also due to the size and surface density of acoustical materials that could be used in these applications, the acoustic performance for reducing airborne noise tends to be most beneficial in the range of 250 Hz to 8,000 Hz. Therefore, a small reverberation room has the potential to be very useful in evaluating the acoustics of sound package materials for automotive applications for both absorption and sound transmission loss measurements. Currently a test methodology for evaluating the absorption performance of small size acoustical materials using a small reverberation room is being developed by the SAE Acoustical Materials Committee [5]. Also, the original impetus for devising the SAE J1400 [6] standard was to develop an STL test for samples which are much smaller than that required by ASTM E 90 [7].

The purpose of this paper is to discuss the development and verification of a small volume self-contained acoustical testing facility (SCATF) for these studies. The SCATF combines a small volume (25m³) reverberation chamber with an equally small volume free-field chamber for conducting sound absorption and sound transmission loss tests (Figure 1). Previous work has shown that reverberation chambers designed specifically for sound absorption tests on small samples can have interior volumes significantly smaller than 200m³ and yet yield valid test results in the frequency range of interest. [8]



Figure 1. Exterior View of the SCATF

POTENTIAL USES

The SCATF has numerous potential uses beyond testing sound absorption and sound transmission loss. These include insertion loss (IL) measurements of automotive body cavity filler (BCF) materials [9] and sound power measurements on physically small acoustic sources such as electric motors, alternators and compressors.

CONCEPTUAL DESIGN

The conceptual design of the SCATF is based upon a 25m³ rectangular parallelepiped reverberation room. The SCATF is constructed of painted steel-faced acoustical panels specially built to prevent panel vibration and minimize adverse influence on the decaying sound field in the room. This small scale reverb room is coupled to an adjacent free-field chamber through a 0.25m² opening designed to hold:

- Flat panel barrier materials for sound transmission loss tests in accordance with SAE J1400 (An exception is that the 25m³ reverberation room is smaller than the 50m³ minimum room volume source room called for in that standard. However, as discussed below, the SCATF reverberation room has sufficient Eigenmode density to potentially achieve diffusion starting in the 250 Hz 1/3rd octave band frequency, and thereby satisfies the intent of that standard).
- Body cavity filler materials for insertion loss tests in accordance with SAE J2846.
- Automotive sheet metal with dash pass-throughs.

The design of this facility was based on the following three basic criteria for designing a reverberation room:

- Cut-off frequency
- Schroeder frequency
- Eigenmodes

However, these criteria alone do not assure a diffuse sound field in the reverberation room for the tests that are

mentioned above. Therefore upon the completion of the design and construction the SCATF was qualified as discussed later in this paper.

The **cut-off frequency** identifies the frequency above which the reverberation room **has the potential to be diffuse**. For the 25m³ reverberation room, the cut-off frequency is 185 Hz which falls below the lower end of the 250 Hz 1/3rd octave frequency band.

The **Schroeder frequency** in a space identifies the frequency above which the room modes become sufficiently close in frequency, such that the Eigenmodes are no longer seen as resonant peaks, i.e., the room is diffuse. This frequency is based on the volume, the total surface area of the room, and on the total acoustic absorption in the room. For the 25m³ reverberation room of the SCATF the Schroeder frequency is 800 Hz.

One of the key features of a reverberation room is that the sound field in the room is diffuse, i.e., there is a sufficient number of well spaced **Eigenmodes** per frequency band especially at low frequencies. This distribution is mostly critical between the cut off frequency and the Schroeder frequency. For the SCATF this was achieved by selecting a ratio of room dimensions for length, width, and height that conform to the recommended room proportions mentioned in the ASTM, ISO, ANSI, and SAE standards [3, 4, 6] and by incorporating stationary diffusers. According to SAE J1400 [6], the minimum requirement for achieving diffusion within the reverberant source room for sound transmission loss tests is satisfied by the volume of the room and a minimum of 20 Eigenmodes within the lowest 1/3rd octave band of interest. To satisfy ASTM E 90 [3], the minimum preferred room volume at the lowest one-third octave band of interest is derived by assuming approximately 18 Eigenmodes in that frequency band will ensure a satisfactorily diffuse sound field in the room. Room mode analysis shows that the SCATF exceeds this requirement with 38 Eigenmodes in the 250 Hz. third octave band. Achieving diffusion also becomes a bigger challenge when the test signal is transient (as is the case for sound absorption measurements) than when the test signal is steady state (as is the case for sound transmission loss and sound power tests).

For the SCATF, stationary acoustical diffusers have been introduced at strategic locations. For small reverb rooms in particular, stationary diffusers are preferred over rotating diffusers, since the latter consume useable interior volume of the reverb room. Rotating diffusers in small volume rooms also make it more difficult for testing personnel to gain access into the room and move about (for installing and removing test samples, for example). The diffusers for the SCATF consist of two massive, glass-fiber-reinforced plaster domes (approximately 1.2m in diameter), secured and sealed