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Development of a small reverberation cabin for sound absorption tests according to SAE J2883

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ABSTRACT

Small reverberation cabins (R-Cabins) are widely used in automotive industry for determining random-incidence sound absorption properties of flat materials and finished parts. SAE J2883 standard gives the guideline and verification methods for design and testing of the R-Cabins. A nine cube-meter R-Cabin was designed and manufactured according to SAE J2883. The performances of the cabin were tested and compared with the standard requirements. The sound absorption results of standard materials were compared with the 6.4 cube-meter cabins and 200 cube-meter reverberation rooms. The standard deviations of the results were analysis. The advantages of using nine cube-meter cabin were discussed.

Keywords: Sound Package, Absorption, Reverberation, R-Cabin. I-INCE Classification of Subjects Number(s): 35

1. INTRODUCTION

Due to various needs in the development of a vehicle sound package, one conducts random incidence sound absorption coefficient tests on flat samples as well as on molded parts or components. Typical vehicle molded parts of interest are hoodliners, headliners, seats, trunk trim, shelf panels and floor carpet systems. The sizes of these parts are, in most cases, significantly smaller than 6.69 m². In some cases, it is even difficult to procure flat material samples with the 6.69 m² area recommended by the ASTM standard (1) or 10 m^2 recommended by ISO 345(2).

Typical materials used in the automotive industry, based on the available packaging space, mass and cost criteria, generally have poor sound absorption performance at frequencies less than 250 Hz 1/3 octave band frequency. In addition, vehicles generally have low sensitivity to changes in absorption below 400 Hz 1/3 octave band frequency.

Currently there are at least two types of small volume reverberation rooms that are serving the automotive industry based on specific needs (4-6). Both of these rooms are based on some scale model of large volume “full size” reverberation rooms. One of the small volume rooms, the Alpha Cabin - a 6.4 m^3 room (5), was designed and developed originally in Europe. There are many OEM specifications that are based on Alpha Cabin tests. The other room type was developed in the US for an acoustics material supplier (6). This room (25.8 m^3) is a dimensionally scaled version of a 206 m^3 rectangular parallelepiped reverberation room.

SAE J2883-2015 (3) is the only standard available to specify the requirements of small reverberation cabin. The standard specifies the volume, sample size and testing procedures for measuring sound absorption coefficients in the small cabin.

2. DESIGN OF SMALL REVERBERBERTION CABIN

2.1 Standard Requirements

The SAE J2883 provides the requirements for design a small reverberation cabins. The

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requirements with comparison to ISO and ASTM standards are summarized in Table 1.

Table 1 – Comparison of standard requirements

Requirements	SAE J2883	ISO 354	ASTM C423
Volume (m^3)	6 - 25	200	200
Sample size (m^2)	1.2	10	6.69
Measure positions	10	12	8
Surface absorption	<0.06		

The volume of the cabin is recommended to be within 6-25 m^3. The surface sound absorption of empty cabin is recommended to be less than 0.06. The test sample size is 1.2m^2 for the cabins with recommended volumes.

2.2 Design Considerations

The volume of the cabin is most important parameter in design considerations. A 9 m^3 is chosen for the new cabin. The 9 m^3 volume of the R-cabin will provide large floor space and better diffuse field comparing with 6.4 m^3 cabins. The cabin dimensions are designed according to J2883 recommended ratios of 2.62x1.65x2.08 m^3. The floor area of 4.3 m^2. The standard requires the sample size for the flat panel is 1.2 m^2 and for the irregular components the size should be smaller than 30% of the floor area. The interior wall were design as non-paralleled surfaces using curved structures. The structures of the wall are made from steel panel with sound insulations. The transmission loss of the wall is designed to be Rw 45 (or STC 45).

The cabin equipped with two omni-directional sound sources and five microphones. The source and microphone positions complies with the standard requirements. Figure 1 shows the final product of R-Cabin.

Figure 1- R-Cabin designed and built according to SAE J2883.

3. CERTIFICATION TESTS OF R-CABIN

3.1 Reverberation Time

To obtain a diffuse sound field in the small cabin, it is important to have high reverberation time of the empty cabin. The standard requires the sound absorption coefficient of the surface below 0.06 which corresponds to the reverberation time of the empty cabin greater than 0.91s for the frequency range of 315–8000 Hz. Figure 2 shows that the results of reverberation time of the R-cabin. It can be seen that the low frequency has higher reverberation time and it decreases with the frequencies. At

8000 and 10000Hz, the reverberation time is strong influence by air absorption.

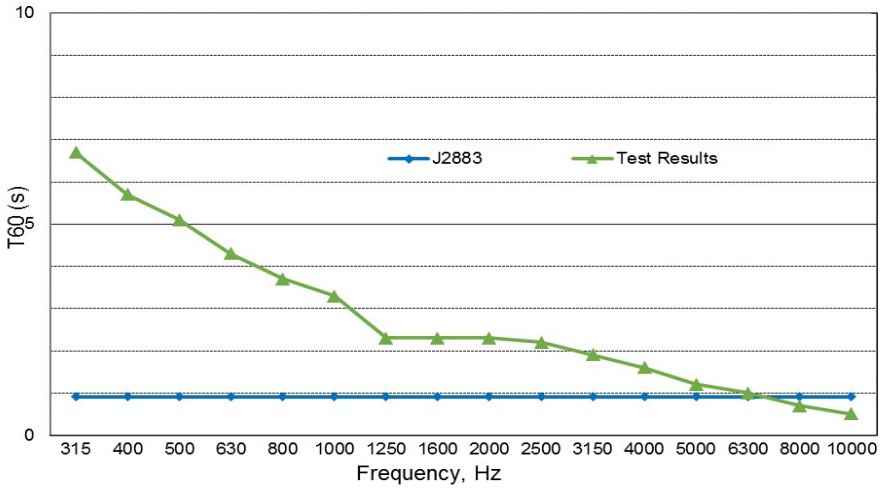

Figure 1 – Reverberation time of R-Cabin

3.2 Variation of Decay Rate

The diffusion issue is more critical for small rooms due to the physical size of the diffusers. In order to ensure that a reverberation room is adequately diffuse for a transient signal, the variation of decay rate need to be determined with fixed microphone positions for empty cabin. The variation of decay rate with microphone position is the ratio of the standard deviation of decay rates for all microphone positions and the average decay rate for all microphone positions. This is given by SD_M/D_M. The variation of decay rate is similar to the variation of reverberation time measured at different positions.

The variation of decay rates of R-Cabin were measured according to the standard. The reverberation time measured at 12 microphone positions and the decay rates and standard deviations were calculated. The results are shown in Figure 3.

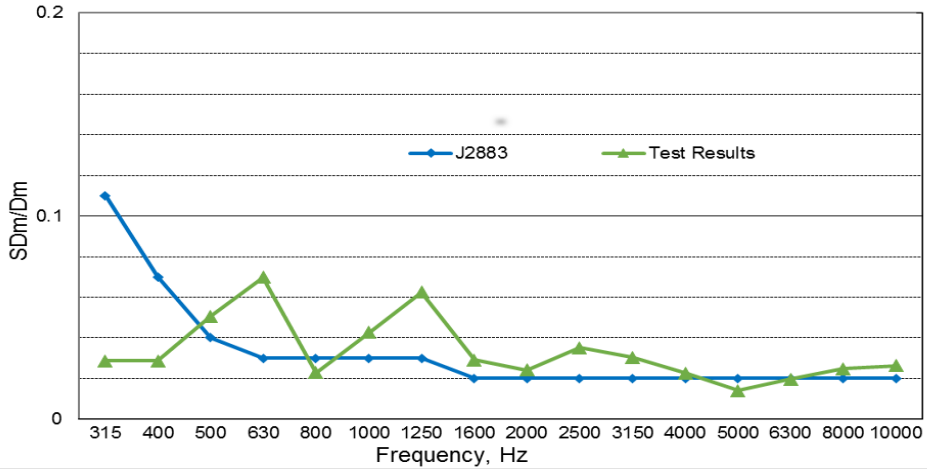

Figure 3 - Measured Variation of decay rate comparing with J2883 requirements

The blue line shows the J2883 requirements for the variation of decay rate and the green line is the measurement results. It can be seen that variation of decay rate of R-cabin does not meet the requirements of the standard. The variation of decay rate is controlled by the variation of the reverberation time. To meet the standard requirements, the variation of reverberation time at different positions has to be small. Further studies are required to investigate the variation due to the measurement accuracy and variation due to the sound fields (7-8).

3.3 Noise Reduction by Enclosure

The R-Cabin is designed to be used in factories where environmental noise is normally high. The

enclosure on the R-Cabin is specially designed to reduce the external noise. The noise reduction of the enclosure was tested by operating two internal sound sources. The sound pressure levels were measured inside and outside of the R-Cabin. Four outside measurement positions are 1 meter from cabin walls. The noise reductions are calculated from the averaged sound pressure level inside and outside. The results are shown in Figure 4.

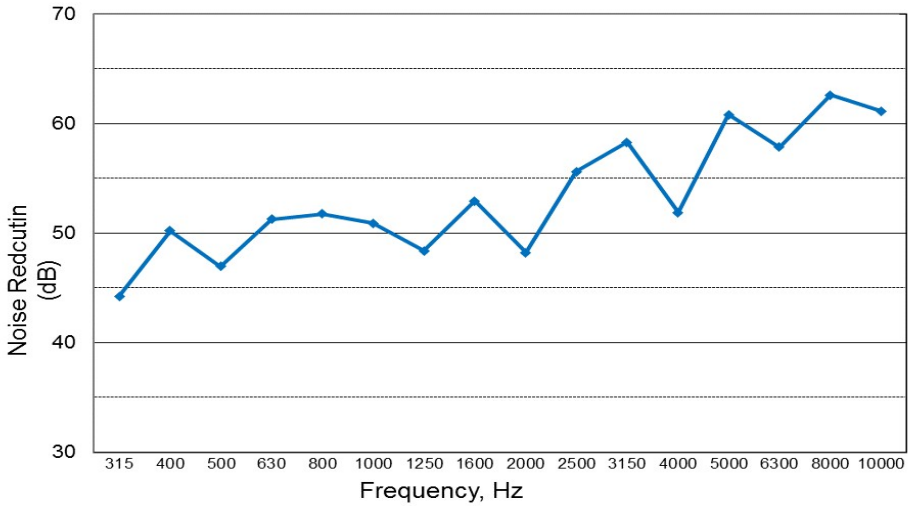

Figure 4 – Noise reduction by R-Cabin enclosure.

It can be seen that the R-Cabin provides 43 – 63 dB noise reductions. It is also required that the sound sources provide 90 dB or above for all 1/3 octave bands for the measurements.

3.4 Variation of Sound Pressure Levels

For the diffuse sound field, the sound pressure level inside of cabin is uniformed. The variation of sound pressure level was measured using four microphone positions. The standard deviations (SDs) were calculated for each 1/3 octave bands. The results are shown in Figure 5. It can be seen that the SDs in the cabin are within 1.0 dB in each 1/3 octave bands.

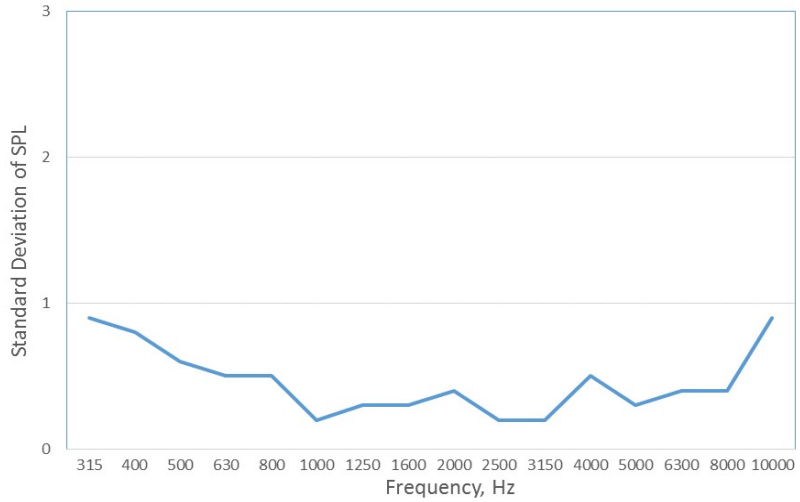

Figure 5 - Standard Deviation of SPL in the cabin

4. MEASUREMENT RESULTS

4.1 Comparison with Large Reverberation Room

The comparison tests of R-Cabin with large reverberation room were conducted in China Automotive Technology and Research Center in Tianjin. The center has ISO standard 280 m^3 reverberation room and 9 m^3 R-Cabin manufactured by BSWA. Two samples were tested in both rooms. One sample was 40 mm thick open cell foam and the other sample was 35 mm thick fiber material. The sample size of 11 m^2 was tested in large reverberation room, and 1.2 m^2 was tested in

R-Cabin. The sound absorption coefficient results are compared in Figure 6-7.

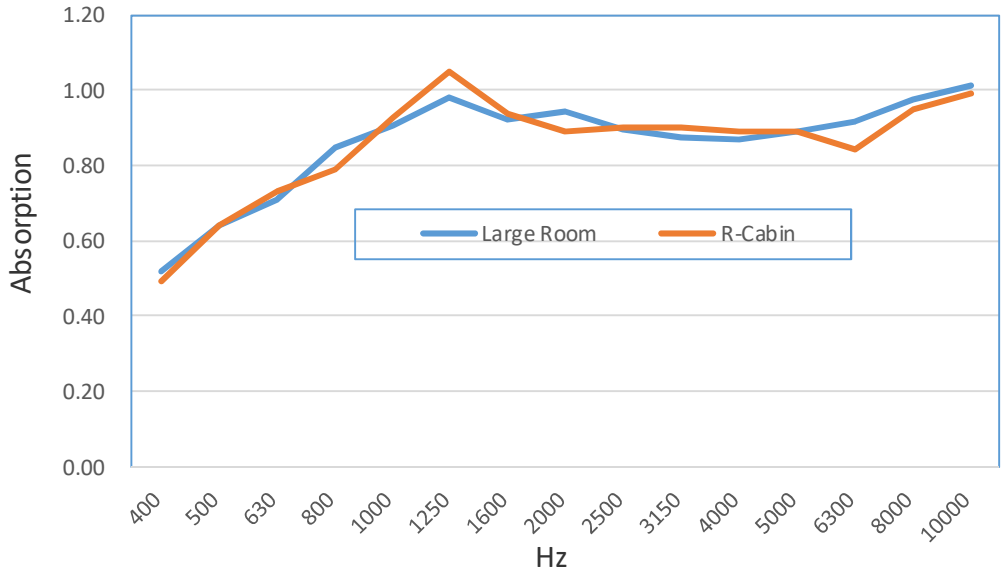

Figure 6 – Sound absorption of fiberglass wood tested in standard room and R-Cabin.

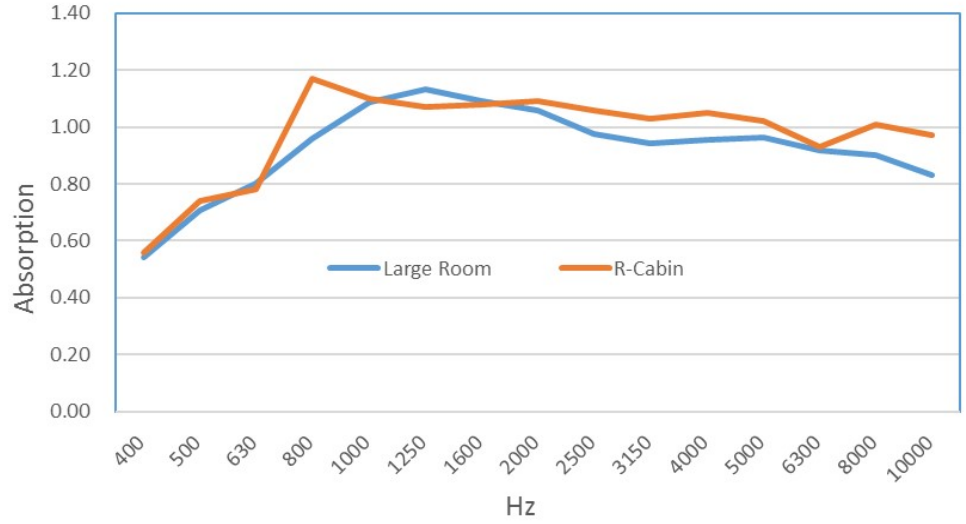

Figure 7 - Sound absorption of foam tested in standard room and R-Cabin.

Two results in Figure 6-7 show that the agreements between large reverberation room and R-Cabin are good at low frequencies. Figure 7 also shows that difference between two results could be 20% at 800 Hz band.

5. CONCLUSIONS

The new 9 m^3 small reverberation cabin was designed and constructed according to SAE J2883. The measurement results are compared with the standard large room. It is found that the results are agreed well with large room for fiberglass and foam materials.

The certification tests of R-Cabin were performed in the empty cabin. The test parameters include reverberation time, noise reduction of enclosure; sound pressure variation and the variation of the decay rate. The results show that the variation of decay rate does not meet the standard requirements. Further studies may be required to reduce the variation of decay rate.

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