

11 APRIL 2022

VOCALZONE V-TRAP SOUND INSULATION BOOTH



Kıvanç Kitapçı

PH.D.

This report summarizes the acoustic analysis and properties of the VocalZone V-Trap. All acoustic measurements and analyses in this report were carried out in accordance with *ISO 16283-1:2014 Acoustics — Field measurement of sound insulation in buildings and of building elements — Part 1: Airborne sound insulation* (ISO 16283-1:2014).

ISO 16283-1:2014 specifies procedures for determining the airborne sound insulation between two rooms in a building using sound pressure measurements. The test results are used to measure, assess and compare the airborne sound insulation of unfurnished or furnished rooms, whether or not a diffuse sound field is present. The measured airborne sound insulation is frequency-dependent and can be expressed as a single-number rating of acoustic performance using the procedures in ISO 717-1.

Given the intended function of the product tested, the apparent sound reduction index was taken as the key acoustic indicator.

What is the apparent sound reduction index?

To calculate the apparent sound reduction index, the sound pressure level difference between the two spaces must first be defined. It is calculated with the following equation:

$$D = L_{p1} - L_{p2}$$

In this equation, L_{p1} is the sound pressure level in the source room and L_{p2} is the sound pressure level in the receiving room.

Once the sound pressure level differences between the inside and outside of the booth had been determined, the apparent sound reduction index (D_n) was calculated for each one-third-octave band from the normalized level differences, using the following equation:

$$D_n = D - 10 \log \frac{A}{A_0}$$

In the equation for the normalized level difference D_n , D is the level difference, A is the equivalent sound absorption area of the receiving room (m^2), and A_0 is the reference absorption area, taken as 10 m^2 .

Because of the product's shape, sound also travels between the inside and outside of the booth by flanking paths. Flanking transmission was therefore taken into account in the laboratory measurements (ISO 16283-1:2014).

In addition, to verify the calculations, the measurement method of ASTM E2249 was adapted to the product setup. White noise was played into the reverberation chamber in each relevant one-third-octave band. Because the product is small enough, the sound pressure level was measured at a single microphone position for the pre-test stage. On the receiving side (inside the booth), the sound pressure level was measured over a measurement surface made up of five receiver positions and monitored with a p-p sound pressure probe. As recommended by the standard, one scanning path was used for the edges and two vertical scanning paths for the front face. When the difference between the average levels from the two scanning paths was compared with the D_n calculations, it was found to be below the +1 dB recommended by ASTM E2249, and the calculated values were thus **validated**.

ANALYSIS RESULTS AND SOUND INSULATION VALUES

The results of the acoustic analysis of the booth are summarized under two headings: (1) sound insulation and (2) room modes.

The sound insulation values of the booth are given in Table 1 and Figure 1.

Sound level difference	
Frequency (Hz)	D_n (dB)
50	22
63	20
80	20
125	26
160	22
200	32
250	32
315	33
400	38
500	39
630	41
800	45
1000	45
1250	46
1600	47
2000	47
2500	49
3150	52
4000	53
5000	54

Table 1. Sound level difference of a single panel (D_n)

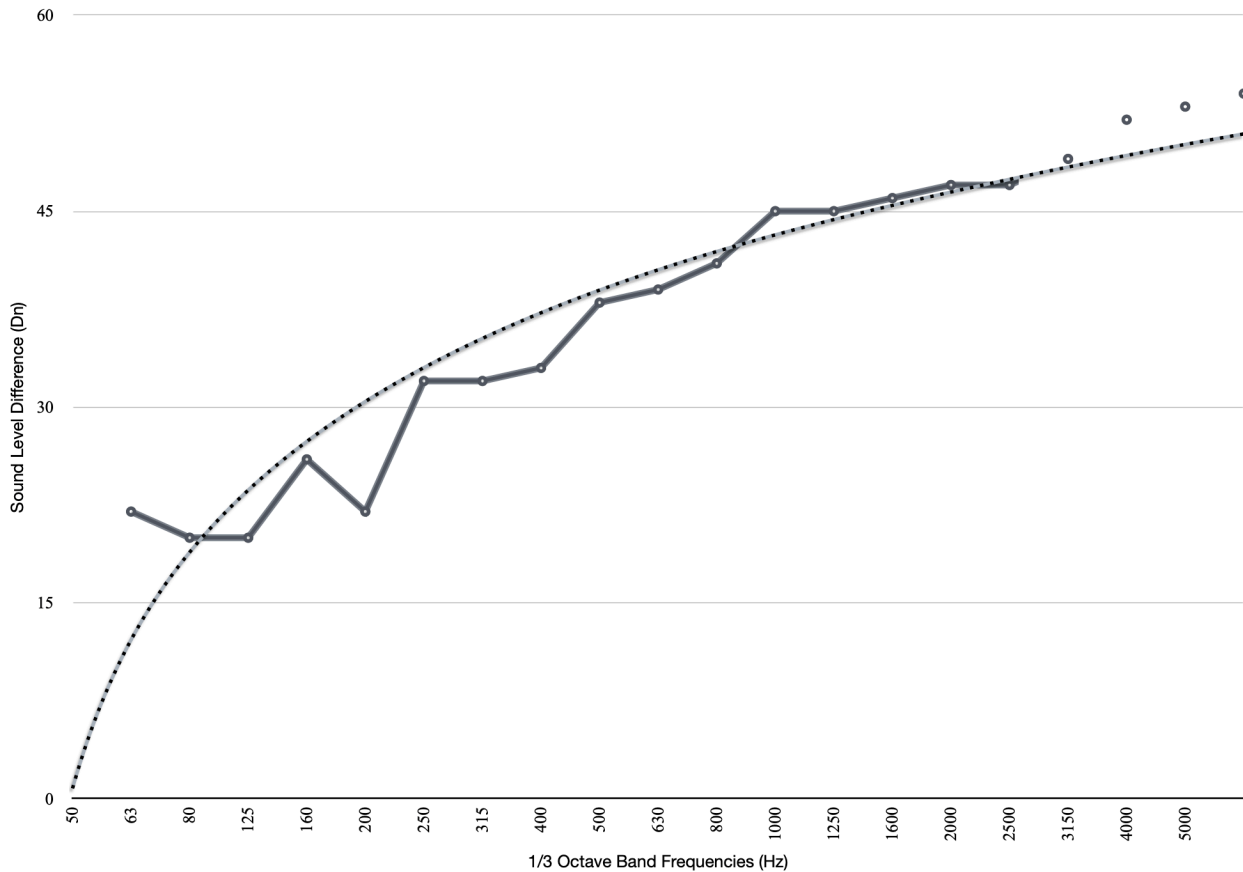


Figure 1. Weighted sound level differences for a single panel

Given the technical properties of the material used in the booth walls, Table 1 and Figure 1 show that the sound insulation performance of the booth increases with frequency. Sound insulation, as low as 20 dB at low frequencies, rises to 54 dB in the 5000 Hz one-third-octave band. The logarithmic trend shows that performance is evenly distributed across the frequency range.

Because the booth has a semi-open structure and its floor surface changes with where it is used (on a desk, suspended, and so on), a single fixed reverberation time (T_{60}) cannot be given. However, even assuming there is no floor covering and no surface behind the speaker, and taking the absorption coefficient as 0 (zero), the reverberation time was found to be below the 0.5 seconds recommended for speech in the relevant standards.

For the test setup to be treated as a transmission package with a reverberant source side (outside the booth) and an anechoic receiving side, and for the equations to be valid, the source sound field (outside the booth) must be diffuse. In a diffuse sound field the sound level does not depend on the source position, so measurements taken at different positions can all represent the sound pressure level on the test specimen. Achieving a diffuse sound field depends entirely on the damping properties of the room in which the source is placed.

To obtain a more uniform pressure distribution in a room, several room modes must be excited at the same time. Modal density increases with frequency and causes the modes to overlap, which is what makes a diffuse sound field possible. The most widely used way to find the cut-off frequency between modal and diffuse behavior is the Schroeder frequency:

$$f_{sch} = 2000 \sqrt{\frac{T_{60}}{V}} = 2000 \sqrt{\frac{0.163}{S\bar{\alpha}}}$$

In this equation, V is the room volume, T is the reverberation time, S is the total area of the wall surfaces, and $\bar{\alpha}$ is the mean sound absorption coefficient of the wall surfaces. As the equation shows, the dimensions of a room have a strong effect on its cut-off frequency.

CONCLUSION

In terms of sound insulation, the product analyzed was found to be **suitable** for speech.

In terms of reverberation time, the product analyzed was found to be **suitable** for speech.

Given the volume of the booth analyzed, the varying lining materials and the spherical geometry of the surface behind the speaker, the sound field was found to be **not diffuse**, and **multiple room modes** were observed, particularly at 2000 Hz and above.

Room modes have a greater effect in small rooms than in large ones. In small rooms the frequency range below the Schroeder frequency is wide, and optimizing the spectrum in this range is critical. Modal frequencies should be spaced as evenly as possible to avoid gaps and overlaps between modes. To obtain a diffuse field and minimize energy loss, absorption at the walls should be as low as possible; however, this design choice raises the Schroeder frequency of the room.

For the reasons above, it is recommended that the inner lining not only absorb sound but also scatter it, acting as a diffuser. In addition, adding a modular, removable floor option to the package to prevent early floor reflections would both lower the reverberation time and help suppress multiple room modes.

The spherical surface behind the speaker may focus sound at points close to the microphone position. Although this surface absorbs sound at high frequencies, potential focusing at low frequencies may, in rare cases, cause resonance at the microphone position.

The recommendations in this report were tested first with mathematical models and then with the Odeon and Insul software. At the client's request, they can be developed into a project through further discussion.

Note: During the acoustic tests and demonstration use, it was observed that, subject to the relevant revisions, the product could be brought up to semi-anechoic standards, giving it applications in scientific research, standards-compliant noise measurement of products and technical equipment, and many other sectors. A modular, portable semi-anechoic booth that could replace the laboratories currently required for such services has a potential market among accredited laboratories, measurement bodies, universities and many other institutions.