DOI: 10.61782/fa.2023.0391

Comparison of ASTM E596-96 and ISO 23351-1 methods for sound reduction measurements of working booths

Jukka Keränen[1*] **Jarkko Hakala**[1] **Valtteri Hongisto**[1]
[1] Acoustics Laboratory, Turku University of Applied Sciences, Finland

ABSTRACT

The number of laboratory tests of phone booths has increased rapidly after publishing ISO 23351-1 standard in 2020. The speech level reduction, $D_{S,A}$, is the single-number value of ISO 23351-1. ISO method is used internationally among manufacturers to declare the acoustic properties of booths. There have been questions about the differences between ISO 23351-1 and ASTM E596-96. The latter yields NIC as a single-number value. This study compares measurement results obtained with ASTM E596-96 and ISO 23351-1:2020 for four phone booths. The discussion analyzes the similarities and differences in the methods, and the application of the quantitative results. It is obvious that ISO 23351-1 method is more suitable for assessing the acoustic properties of phone booths used in offices, schools, and similar workplaces where speech is the main sound source since $D_{S,A}$ describes directly the reduction of A-weighted sound pressure level of speech produced by the product. ASTM E596-96 provides more generic data of enclosures giving no special limitations for the sound source. NIC has no relationship to speech. Therefore, $D_{S,A}$ of ISO 23351-1 is more suitable for booths used in above-mentioned environments.

Keywords: *room acoustics, sound insulation, measurement*

1. INTRODUCTION

This study investigates two different methods that are used for measurements of sound reduction of enclosures, e.g., furniture that are partially or completely closed. ASTM E596-96 method describes laboratory measurement of noise reduction of sound-isolating enclosures [1]. ASTM E413-87 is standard method of classification for rating sound insulation [2]. The noise isolation class (NIC) is usually applied as a single-number quantity of ASTM method. ISO 23351-1 method describes laboratory measurement of level reduction of furniture ensembles and enclosures [3]. The outcoming single-number quantity is speech level reduction, $D_{S,A}$. The method applies sound power level (SWL) measurements according to ISO 3741 [4]. This study compares measurement methods ASTM E596-96 and ISO 23351-1:2020 in determination of sound reduction of four phone booths.

2. MATERIALS AND METHODS

2.1 Enclosures

Four one-person-booths were tested. Their dimensions were rather similar, and the volumes varied between 2.0 and 2.6 m^3. The ceilings were made of several layers of boards and sound absorbers. The walls and the door were either glass, laminated glass or made of several layers of boards and sound absorbers. There were different ventilation solutions in the booths.

2.2 Reverberation room

The acoustics laboratory has FINAS accreditation for measurements of sound absorption, sound insulation, and speech level reduction (ISO 23351-1).

The measurements were conducted in a reverberation room: 9.90 m x 5.68 m x 3.57 m and volume, V=201 m^3. The room boundaries were painted reinforced concrete so that the total absorption area, A, in the room was very small.

The temperature, relative humidity, and ambient atmospheric pressure were controlled and measured during the measurements.

[*]***Corresponding author***: jukka.keranen@turkuamk.fi.

2.3 ASTM -method

ASTM E596-96 method describes laboratory measurement of noise reduction of sound-isolating enclosures in a reverberation room (V > 200 m^3) [1]. The booth was placed in the reverberation room and an omnidirectional sound source (OSS) was used to produce test sound (pink noise). The OSS was placed in the room so that the enclosure was not in the direct sound field of the OSS. The sound pressure level (SPL) of the test sound was measured in six positions in the reverberation room outside the booth. The SPL was also measured in four positions inside the booth.
The SWL of the OSS was set so high that background noise correction was not needed.
Noise reduction was calculated in one-third octave bands by:

$$NR_j = \overline{L_{1,j}} - \overline{L_{2,j}} \tag{1}$$

where L_1 was space averaged SPL measured in the reverberation room outside the booth and L_2 space averaged SPL measured inside the booth. The one-third octave bands j were 100–5000 Hz. The space averaged SPL for Eq. (1) was determined by:

$$\overline{L_X} = 10\log_{10}\left(\frac{1}{n}\sum_{i=1}^{n} 10^{0.1L_i}\right) \tag{2}$$

where X=1 denoted outside the booth, and X=2 inside the booth, and i denoted measurement position (n=6 outside the booth and n=4 inside the booth).
The NR_j–values were used to determine NIC according to ASTM E413-87 [2]. The procedure applied reference contour for calculating a single-number rating (Fig. 1). The reference contour's shape corresponds to A-weighting. Values of NR_j were rounded to the nearest integer and the reference contour was fitted to the values according to ASTM E413-87. NIC was the value of the shifted reference contour at 500 Hz one-third octave band.

2.4 ISO -method

ISO 23351-2020 method describes laboratory measurement of speech level reduction of furniture ensembles and enclosures in a reverberation room (V > 200 m^3) [3]. The booth was placed in the reverberation room and the OSS was used to produce test sound (pink noise). The OSS was placed inside the booth at the height of 1.55 m representing standing occupant.

The booths were tested in two locations in the reverberation room. The SWL of the OSS enclosed with the booth was determined according to ISO 3741-2010 [4] as ISO 23351-1 required. The SWL of the OSS was also determined without the enclosure, i.e., in the empty reverberation room.

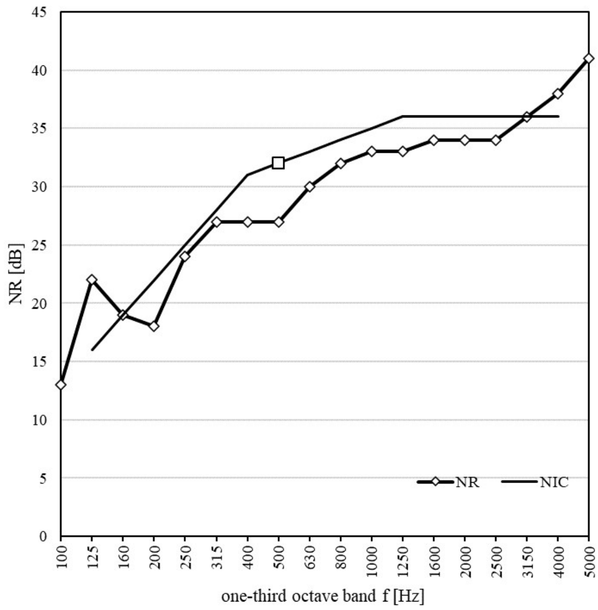

Figure 1. Determination of NIC by fitting the reference contour to measured noise reduction NR_j.

According to ISO 3741-2010, the SPL, L_S, of the test sound was measured using a continuously traversing microphone in the reverberation room outside the booth. The SWL of the OSS was set so high that background noise correction was not needed.
Reverberation time, T, was measured right after the SPL measurements using 3 sound source positions and 2 microphone positions outside the booth according to ISO 3382-2 [5]. The mean reverberation time was used to determine the equivalent sound absorption area, A [m^2], by:

$$A = \frac{55.6}{c}\left(\frac{V}{T}\right) \tag{3}$$

The SWL was determined by:

$$L_W = \bar{L}_s + \left\{ \begin{array}{c} 10\log_{10}\frac{A}{A_0} + \\ 4.34\frac{A}{S} + \\ 10\log_{10}\left(1+\frac{S\cdot c}{8Vf}\right) + \\ C_1 + C_2 - 6 \end{array} \right\} \quad (4)$$

where A_0=1 m^2, S [m^2] was the total surface area of the reverberation room, f [Hz] was the mid-band frequency, and the speed of sound in air was c=344 m/s. The dB-corrections C_1 and C_2 were negligible since the environmental conditions did not change during the measurements.

The SWL of the OSS without the booth was $L_{W,P,1}$ and the SWL of the OSS inside the booth was $L_{W,P,2}$. Measurements were conducted within octave bands 125–8000 Hz.

The frequency-dependent level reduction, D_j, of the booth was calculated in octave bands by:

$$D_j = L_{W,P,1,j} - L_{W,P,2,j} \quad (5)$$

Standardized SWL of speech $L_{W,S,1,j}$ and A-weighting A_j were used in determination of speech level reduction (Table 1) [3].

Table 1. Unweighted SWL of genderless speech, $L_{W,S,1,j}$, and A-weighting in octave bands 125–8000 Hz [3].

f	$L_{W,S,1,j}$	A_j
[Hz]	[dB]	[dB]
125	60.9	-16.1
250	65.3	-8.6
500	69.0	-3.2
1000	63.0	0.0
2000	55.8	1.2
4000	49.8	1.0
8000	44.5	-1.1

The values of D_j were used to determine the SWL of speech radiated by the booth in octave bands:

$$L_{W,S,2,j} = L_{W,S,1,j} - D_j \quad (6)$$

The A-weighted SWL of speech radiated by the booth was calculated by:

$$L_{W,S,A,2} = 10\log_{10}\left(\sum_{j=1}^{7} 10^{0.1(L_{W,S,2,j}+A_j)}\right) \quad (7)$$

and rounded to the nearest 0.1 dB. The speech level reduction, $D_{S,A}$ [dB], was determined by:

$$D_{S,A} = L_{W,S,A,1} - L_{W,S,A,2} \quad (8)$$

where $L_{W,S,A,1}$=68.4 dB was the A-weighted standardized SWL of speech. The calculation of $D_{S,A}$ is depicted in Fig. 2.

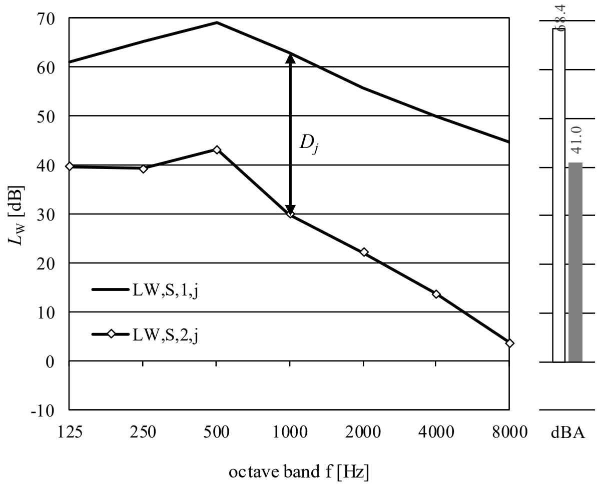

Figure 2. Determination of $D_{S,A}$ using the standardized speech power level $L_{W,S,1,j}$ and the measured reduction D_j. In this case $D_{S,A}$=27.4 dB.

3. RESULTS

ISO 23351-1 results of level reduction, D_j, and ASTM E596-96 results of noise reduction, NR_j and NR_{oct}, are presented for the booths in Figs. 3 and 4, respectively. The values of D_j and NR_{oct} are compared in Fig. 5. The single-number values are presented in Fig. 6.

4. DISCUSSION

The principal difference between the ASTM E596-96 and ISO 23351-1 methods was the measurement direction. The sound reduction was measured from outside to the inside of the booth according to ASTM E596-96, but according to ISO 23351-1, the sound reduction was measured from inside to outside.

The SWL measurements (ISO 3741) incorporate corrections for sound absorption in the reverberation room both with and without the booth. ASTM E596-96 applies no corrections for sound absorption. Comparison of D_j and NR_{oct} suggests that ASTM E596-96 produced lower sound reduction values in 125–250 Hz and higher sound reduction values in 500–4000 Hz than ISO 23351-1 (Fig. 5). Too high values may have occurred due to lack of absorption correction.

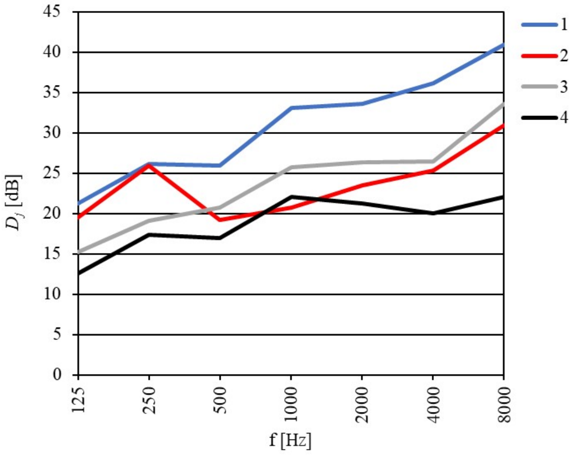

Figure 3. Level reduction, D_j, of the booths according to ISO 23351-1. D_j.

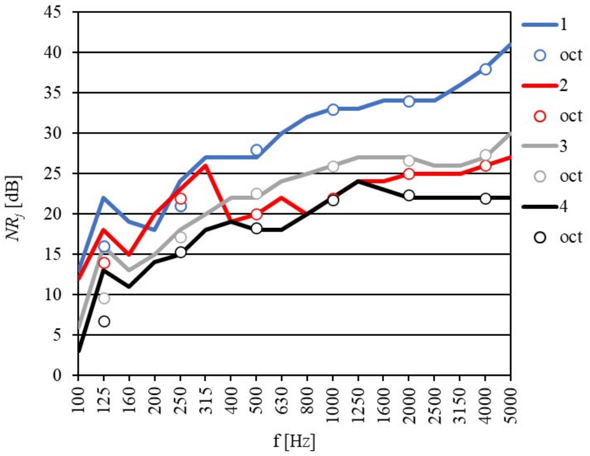

Figure 4. Noise reduction, NR_j, of the booths according to ASTM E596-96. Octave band values, NR_{oct}, are presented with circles.

The measurements according to ASTM E596-96 were conducted in 1/3-octave bands 100–5000 Hz, and NIC was determined according to ASTM E413-87 within 125–4000 Hz. The frequency range according to ISO 23351-1 was the octave bands 125–8000 Hz, i.e., 1/3-octave bands 100–10000 Hz. The choice of ISO 23351-1 is more favorable since intelligibility of speech is also affected by 5000–10000 Hz [6]. In booths, sound leaks via door seams and ventilation ducts, and related decline in sound reduction may often occur in this very high frequency range. ASTM E596-96 ignores this and may lead to misleading NIC values.

It was interesting to note that NR_{oct} -values (Fig. 5) could be used to estimate the $D_{S,A}$ value quite well, although, 8000 Hz was not available from ASTM E596-96. These values are compared in Fig. 7. The $D_{S,A}$ estimated by NR_{oct}-values was on average 0.5 dB higher than $D_{S,A}$ obtained with ISO method. However, this constant cannot be generalized since we studied only four booths.

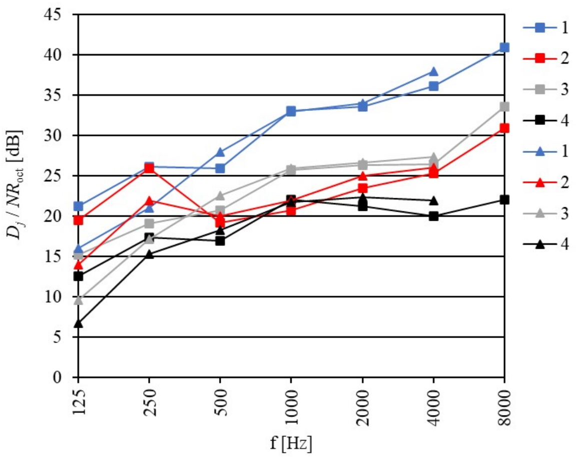

Figure 5. Comparison of D_j (square) and NR_{oct} (triangle) of the booths.

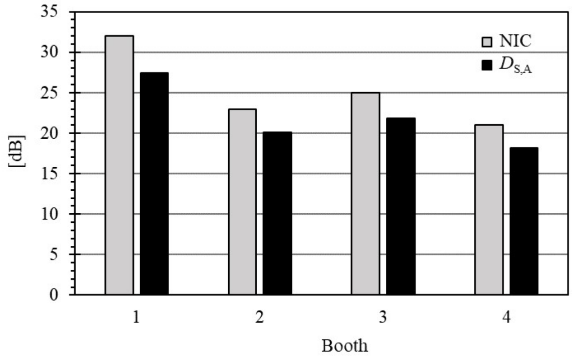

Figure 6. The single-number results of the booths according to ISO 23351-1 and ASTM E413-87.

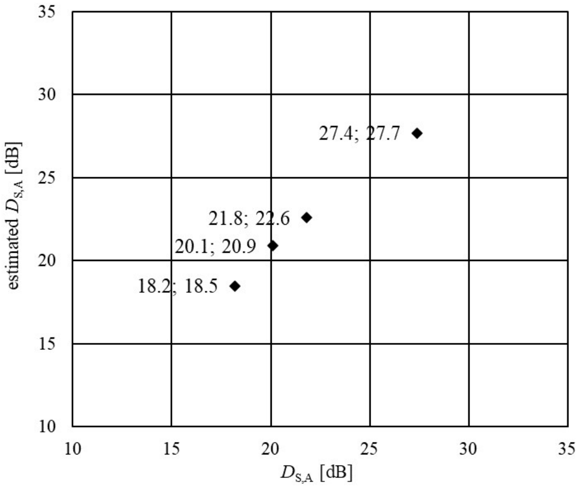

Figure 7. The measured $D_{S,A}$ according to ISO 23351-1 (1st number) and the estimated $D_{S,A}$ based on NR_{oct} values of ASTM E413-87 (2nd number).

5. CONCLUSIONS

ISO 23351-1 method seemed to be more suitable for assessing the booths used in offices, schools, and similar workplaces where speech is the main sound source because the single-number value, $D_{S,A}$, is directly the reduction of the A-weighted SPL of speech produced by the booth. NIC defined by ASTM E596-96 does not give any requirements for the spectrum of sound source.

6. ACKNOWLEDGMENTS

This study was part of a project "Motti – Indoor environment and wellbeing in offices (2020–2023)" conducted by Turku University of Applied Sciences. The project was funded by Business Finland.

7. REFERENCES

[1] ASTM E596-96 Standard test method for laboratory measurement of noise reduction of sound isolating enclosures, ASTM International, West Conshohocken, PA, USA

[2] ASTM E413-87 Classification for rating sound insulation, ASTM International, West Conshohocken, PA, USA

[3] ISO 23351-1:2020 Acoustics – Measurement of speech level reduction of furniture ensembles and enclosures – Part 1: Laboratory method, International Organization for Standardization, Geneve, Switzerland

[4] ISO 3741:2010 Acoustics – Determination of sound power levels and sound energy levels of noise sources using sound pressure. Precision methods for reverberation test rooms, International Organization for Standardization, Geneve, Switzerland

[5] ISO 3382-2:2008 Acoustics – Measurement of room acoustic parameters – Part 2: Reverberation time in ordinary rooms, International Organization for Standardization, Geneve, Switzerland

[6] Larm P., Hongisto V., "Experimental comparison between speech transmission index, rapid speech transmission index, and speech intelligibility index," *J. Acoust. Soc. Am.* 119 (2), pp. 1106–1117, 2006