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2023-10-31
B141038/19 Version 1 MSG/STEG

Curtain fabric type Saint of the company AB Ludvig Svensson

Measurement of sound absorption in a reverberation room according to DIN EN ISO 354

Test Report No. B141038/19

Client:	AB Ludvig Svensson Bangatan 8 51182 Kinna SWEDEN
Consultant:	M. Eng. Philipp Meistring Jan-Lieven Moll
Report date:	2023-10-31
Delivery date of test object:	2023-10-26
Date of test:	2023-10-27 / 2023-10-30
Total number of pages:	In total 17 pages, thereof 6 pages text 4 pages Appendix A 2 pages Appendix B 5 pages Appendix C

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1 Task

On behalf of the company AB Ludvig Svensson, 51182 Kinna, Sweden, the sound absorption of the curtain fabric type “Saint” was to be measured according to DIN EN ISO 354 [1] in the reverberation room.

The fabric was tested as a curtain both in a flat arrangement and as a pleated hanging curtain with 100 % fullness, each with a distance of 100 mm and 150 mm to the reflective wall.

The results are to be evaluated according to DIN EN ISO 11654 [2] and ASTM C 423-22 [3].

2 Basis

This test report is based on the following documents:

[1] DIN EN ISO 354: Acoustics - Measurement of sound absorption in a reverberation room (ISO 354:2003); German version EN ISO 354:2003. 2003-12

[2] DIN EN ISO 11654: Acoustics - Sound absorbers for use in buildings - Rating of sound absorption (ISO 11654:1997); German version EN ISO 11654:1997. 1997-07

[3] ASTM C 423-22: Standard Test Method for Sound Absorption and Sound Absorption Coefficients by the Reverberation Room Method. Revision: 22. 2022-03

[4] ISO 9613-1: Acoustics; Attenuation of sound during propagation outdoors; part 1: calculation of the absorption of sound by the atmosphere. 1993-06

[5] DIN EN ISO 12999-2: Acoustics – Determination and application of measurement uncertainties in building acoustics – Part 2: Sound absorption (ISO 12999-2:2020); German version EN ISO 12999-2:2020. 2020-11

[6] DIN EN ISO 9053-1: Acoustics –Determination of airflow resistance – Part 1: Static airflow method (ISO 9053-1:2018); German version EN ISO 9053-1:2018. March 2019

[7] DIN EN ISO 5084: Textiles - Determination of thickness of textiles and textile products (ISO 5084:1996); German version EN ISO 5084:1996. 1996-10

3 Test object and test assembly

3.1 Test object

The tested material is described by the client as follows:

- manufacturer AB Ludvig Svensson
- type “Saint”
- material 100 % Trevira CS
- area specific mass: m'' = 265 g/m²

The testing laboratory has measured as follows at one sample 210 mm x 297 mm from testing material:

- thickness acc. DIN EN ISO 5084 [7] (3 positions, pressure 1.00 kPa, pressure-foot 2,000 mm²): t = 0.66 mm
- specific air flow resistance acc. to DIN EN ISO 9053-1 [6]: R_s = 753 Pa·s/m

3.2 Test assembly

The installation of the test object was carried out at the reverberation room by employees of the test laboratory.

The test assemblies were made following mounting type G according to DIN EN ISO 354 [1], annex B.5. The mounting details of the test set-ups are as follows:

- curtain web fixed to a metal rail that was placed directly at the ceiling of the reverberation room, the height of the rail was 90 mm, the fabric was fixed at the rail with 60 mm overlap
- test set-up with free curtain edges at sides and at bottom (no enclosing frame)

Testing was done in the test-assemblies as listed in Table 1.

Table 1. Overview of the tested curtain assemblies.

Test certificate Appendix A, page	**Clear distance to the reflective wall (at fixing rail)**	**Drapery**	**Fabric dimensions *W* x *H***	**Dimensions of test surface (from lower border of the rail) *W* x *H* = *S***
1	100 mm	Flat hanging curtain	1 web 3.50 m x 2.97 m	3.50 m x 2.91 m = 10.19 m²
2	150 mm			
3	100 mm	Pleated curtain, 100 % fullness	1 web 7.06 m x 2.97 m	3.53 m x 2.91 m = 10.27 m²
4	150 mm			

The test certificates in Appendix A and the photographs in Appendix B show further details of the test assemblies.

4 Execution of the measurements

The measurements were executed according to DIN EN ISO 354 [1].

The test procedure, the test stand and the test equipment used for the measurements are described in Appendix C.

5 Evaluation

The sound absorption coefficient α_S was determined in one-third octave bands between 100 Hz and 5000 Hz according to DIN EN ISO 354 [1].

In addition, the following characteristic values were determined according to DIN EN ISO 11654 [2].

- Practical sound absorption coefficient α_p in octave bands
- Weighted sound absorption coefficient α_w as single value

  The weighted sound absorption coefficient α_w is determined from the practical sound absorption coefficients α_p in the octave bands of 250 Hz to 4000 Hz.

According to ASTM C 423 [3] the following characteristic values were determined:

- Noise reduction coefficient *NRC* as single value

  Arithmetical mean value of the sound absorption coefficients in the four one-third octave bands 250 Hz, 500 Hz, 1000 Hz and 2000 Hz; mean value rounded to 0.05.

- Sound absorption average *SAA* as single value

  Arithmetical mean value of the sound absorption coefficients in the twelve one-third octave bands between 250 Hz and 2500 Hz; mean value rounded to 0.01.

6 Measurement results

The sound absorption coefficients α_S in one-third octave bands, the practical sound absorption coefficients α_p in octave bands and the single values (α_w, *NRC* und *SAA*) are indicated in the test certificate in Appendix A.

Information on the uncertainty of measurement is given in Appendix C. When assigning the absorption group, the measurement uncertainty was not taken into account in accordance with DIN EN ISO 11654 [2].

7 Remarks

The test results exclusively relate to the investigated subjects and conditions described.

M.Eng. Philipp Meistring
(Project manager)

Sound absorption coefficient ISO 354

Measurement of sound absorption in reverberation rooms

Client: AB Ludvig Svensson
51182 Kinna, Sweden

Test specimen: Fabric Saint,
flat curtain, 100 mm wall distance

Curtain fabric:
Information provided by the client
- designation Saint
- material 100 % Trevira CS
- area specific mass m'' = 265 g/m²

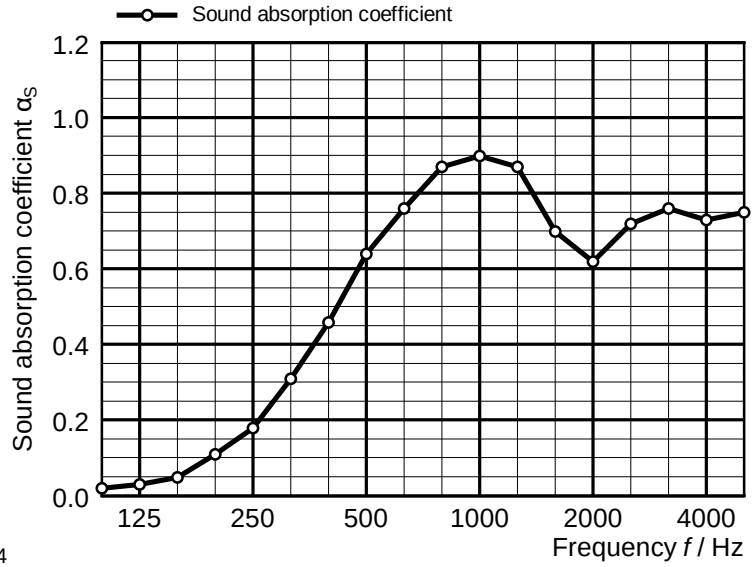
Properties determined by the testing laboratory
(determined at one sample from test material dim. 210 mm x 297 mm)
- airflow resistance R_S = 753 Pa s/m
- thickness t = 0.66 mm

Test arrangement:
- type G-100 mounting acc. to DIN EN ISO 354
- arranged as a flat curtain hanging in front of a reflecting wall
- fixed directly underneath the ceiling of the reverberation room, suspended from a metal rail (height 90 mm, overlap 60 mm), distance to the back wall 100 mm
- test arrangement without enclosing frame
- factory-made ready-for-use curtain splice width x height = 3500 mm x 2970 mm, 6 cm curtain tape at the upper edge
- test surface width x height = 3.50 m x 2.91 m (starting at the lower edge of the metal rail)

Room: E
Volume: 199.60 m³
Size: 10.19 m²
Date of test: 2023-10-30

	θ [°C]	*r. h.* [%]	*B* [kPa]
without specimen	20.5	47.2	94.1
with specimen	20.5	47.2	94.1

Frequency [Hz]	α_S 1/3 octave	α_p octave
100	° 0.02	
125	° 0.03	0.05
160	° 0.05	
200	0.11	
250	0.18	0.20
315	0.31	
400	0.46	
500	0.64	0.60
630	0.76	
800	0.87	
1000	0.90	0.90
1250	0.87	
1600	0.70	
2000	0.62	0.70
2500	0.72	
3150	0.76	
4000	0.73	0.75
5000	0.75	



° Equivalent sound absorption area less than 1.0 m²
α_S Sound absorption coefficient according to ISO 354
α_p Practical sound absorption coefficient according to ISO 11654

Rating according to ISO 11654:	Rating according to ASTM C423:
Weighted sound absorption coefficient α_w = 0.50 (*MH*)	**Noise Reduction Coefficient *NRC* = 0.60**
Sound absorption class: D	**Sound Absorption Average *SAA* = 0.59**

Sound absorption coefficient ISO 354

Measurement of sound absorption in reverberation rooms

Client: AB Ludvig Svensson
51182 Kinna, Sweden

Test specimen: Fabric Saint,
flat curtain, 150 mm wall distance

Curtain fabric:
Information provided by the client
- designation Saint
- material 100 % Trevira CS
- area specific mass *m*'' = 265 g/m²

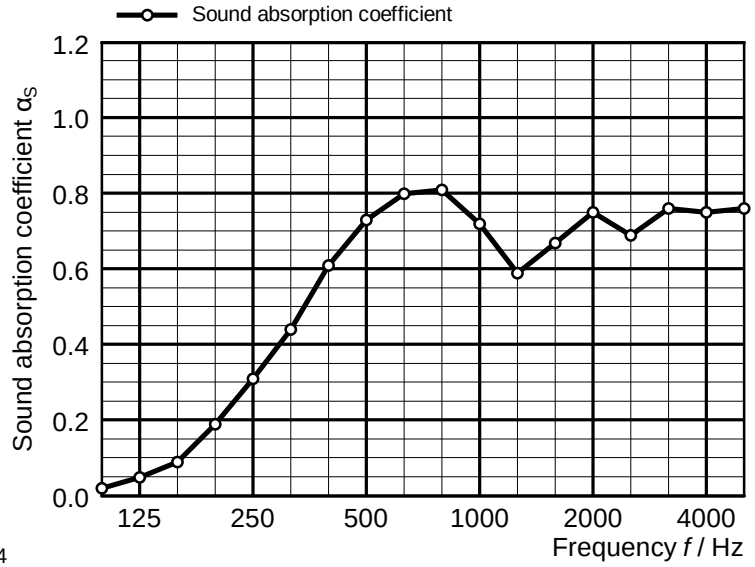
Properties determined by the testing laboratory
(determined at one sample from test material dim. 210 mm x 297 mm)
- airflow resistance R_S = 753 Pa s/m
- thickness *t* = 0.66 mm

Test arrangement:
- type G-150 mounting acc. to DIN EN ISO 354
- arranged as a flat curtain hanging in front of a reflecting wall
- fixed directly underneath the ceiling of the reverberation room, suspended from a metal rail (height 90 mm, overlap 60 mm), distance to the back wall 150 mm
- test arrangement without enclosing frame
- factory-made ready-for-use curtain splice width x height = 3500 mm x 2970 mm, 6 cm curtain tape at the upper edge
- test surface width x height = 3.50 m x 2.91 m (starting at the lower edge of the metal rail)

Room: E
Volume: 199.60 m³
Size: 10.19 m²
Date of test: 2023-10-30

	θ [°C]	*r. h.* [%]	*B* [kPa]
without specimen	20.5	47.2	94.1
with specimen	20.5	47.3	94.1

Frequency [Hz]	α_S 1/3 octave	α_p octave
100	° 0.02	
125	° 0.05	0.05
160	° 0.09	
200	0.19	
250	0.31	0.30
315	0.44	
400	0.61	
500	0.73	0.70
630	0.80	
800	0.81	
1000	0.72	0.70
1250	0.59	
1600	0.67	
2000	0.75	0.70
2500	0.69	
3150	0.76	
4000	0.75	0.75
5000	0.76	



° Equivalent sound absorption area less than 1.0 m²
α_S Sound absorption coefficient according to ISO 354
α_p Practical sound absorption coefficient according to ISO 11654

Rating according to ISO 11654:	Rating according to ASTM C423:
Weighted sound absorption coefficient α_w = 0.60 (*H*)	**Noise Reduction Coefficient *NRC* = 0.65**
Sound absorption class: C	**Sound Absorption Average *SAA* = 0.61**

Sound absorption coefficient ISO 354

Measurement of sound absorption in reverberation rooms

Client: AB Ludvig Svensson
51182 Kinna, Sweden

Test specimen: Fabric Saint,
pleated curtain with 100 % fullness, 100 mm wall distance

Curtain fabric:
Information provided by the client
- designation Saint
- material 100 % Trevira CS
- area specific mass m'' = 265 g/m²

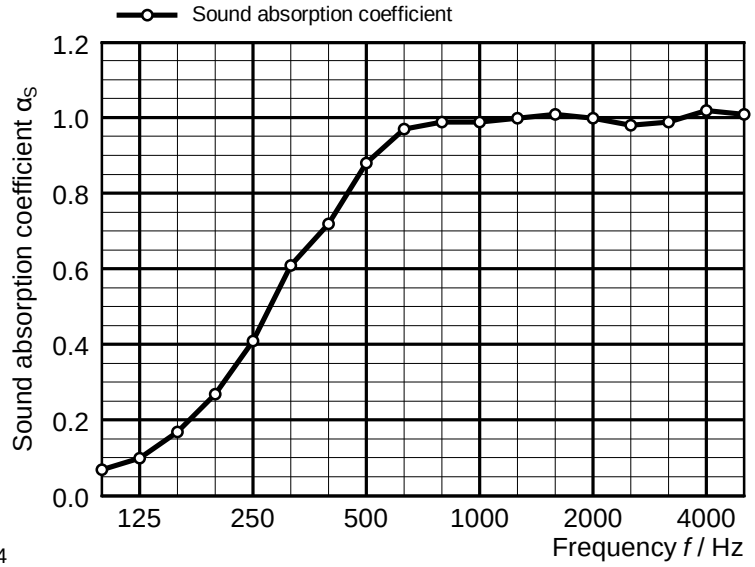
Properties determined by the testing laboratory
(determined at one sample from test material dim. 210 mm x 297 mm)
- airflow resistance R_S = 753 Pa s/m
- thickness t = 0.66 mm

Test arrangement:
- style of type G-100 mounting acc. to DIN EN ISO 354
- arranged as a pleated curtain with 100 % fullness hanging in front of a reflecting wall
- fixed directly underneath the ceiling of the reverberation room, suspended from a metal rail (height 90 mm, overlap 60 mm), distance to the back wall 100 mm
- test arrangement without enclosing frame
- factory-made ready-for-use curtain splice width x height = 7060 mm x 2970 mm, 6 cm curtain tape at the upper edge
- test surface width x height = 3.53 m x 2.91 m (starting at the lower edge of the metal rail)

Room: E
Volume: 199.60 m³
Size: 10.27 m²
Date of test: 2023-10-27

	θ [°C]	*r. h.* [%]	*B* [kPa]
without specimen	20.9	51.3	93.4
with specimen	20.8	51.6	93.4

Frequency [Hz]	α_S 1/3 octave	α_p octave
100	° 0.07	
125	0.10	0.10
160	0.17	
200	0.27	
250	0.41	0.45
315	0.61	
400	0.72	
500	0.88	0.85
630	0.97	
800	0.99	
1000	0.99	1.00
1250	1.00	
1600	1.01	
2000	1.00	1.00
2500	0.98	
3150	0.99	
4000	1.02	1.00
5000	1.01	



° Equivalent sound absorption area less than 1.0 m²
α_S Sound absorption coefficient according to ISO 354
α_p Practical sound absorption coefficient according to ISO 11654

Rating according to ISO 11654:	Rating according to ASTM C423:
Weighted sound absorption coefficient α_w = 0.75 (*MH*)	**Noise Reduction Coefficient *NRC* = 0.80**
Sound absorption class: C	**Sound Absorption Average *SAA* = 0.82**

Sound absorption coefficient ISO 354

Measurement of sound absorption in reverberation rooms

Client: AB Ludvig Svensson
51182 Kinna, Sweden

Test specimen: Fabric Saint,
pleated curtain with 100 % fullness, 150 mm wall distance

Curtain fabric:
Information provided by the client
- designation Saint
- material 100 % Trevira CS
- area specific mass m'' = 265 g/m²

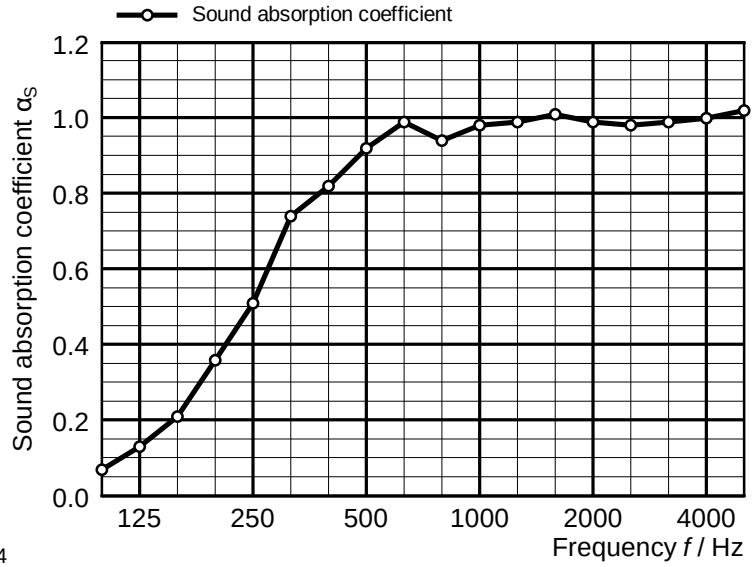
Properties determined by the testing laboratory
(determined at one sample from test material dim. 210 mm x 297 mm)
- airflow resistance R_S = 753 Pa s/m
- thickness t = 0.66 mm

Test arrangement:
- style of type G-150 mounting acc. to DIN EN ISO 354
- arranged as a pleated curtain with 100 % fullness hanging in front of a reflecting wall
- fixed directly underneath the ceiling of the reverberation room, suspended from a metal rail (height 90 mm, overlap 60 mm), distance to the back wall 150 mm
- test arrangement without enclosing frame
- factory-made ready-for-use curtain splice width x height = 7060 mm x 2970 mm, 6 cm curtain tape at the upper edge
- test surface width x height = 3.53 m x 2.91 m (starting at the lower edge of the metal rail)

Room: E
Volume: 199.60 m³
Size: 10.27 m²
Date of test: 2023-10-27

	θ [°C]	*r. h.* [%]	*B* [kPa]
without specimen	20.9	51.3	93.4
with specimen	20.9	51.4	93.4

Frequency [Hz]	α_S 1/3 octave	α_p octave
100	° 0.07	
125	0.13	0.15
160	0.21	
200	0.36	
250	0.51	0.55
315	0.74	
400	0.82	
500	0.92	0.90
630	0.99	
800	0.94	
1000	0.98	0.95
1250	0.99	
1600	1.01	
2000	0.99	1.00
2500	0.98	
3150	0.99	
4000	1.00	1.00
5000	1.02	



° Equivalent sound absorption area less than 1.0 m²
α_S Sound absorption coefficient according to ISO 354
α_p Practical sound absorption coefficient according to ISO 11654

Rating according to ISO 11654:	Rating according to ASTM C423:
Weighted sound absorption coefficient α_w = 0.85 (*H*)	**Noise Reduction Coefficient *NRC* = 0.85**
Sound absorption class: B	**Sound Absorption Average *SAA* = 0.85**

Curtain fabric type Saint, Manufacturer AB Ludvig Svensson

Figure B.1. Flat hanging curtain in the reverberation room: frontal view.

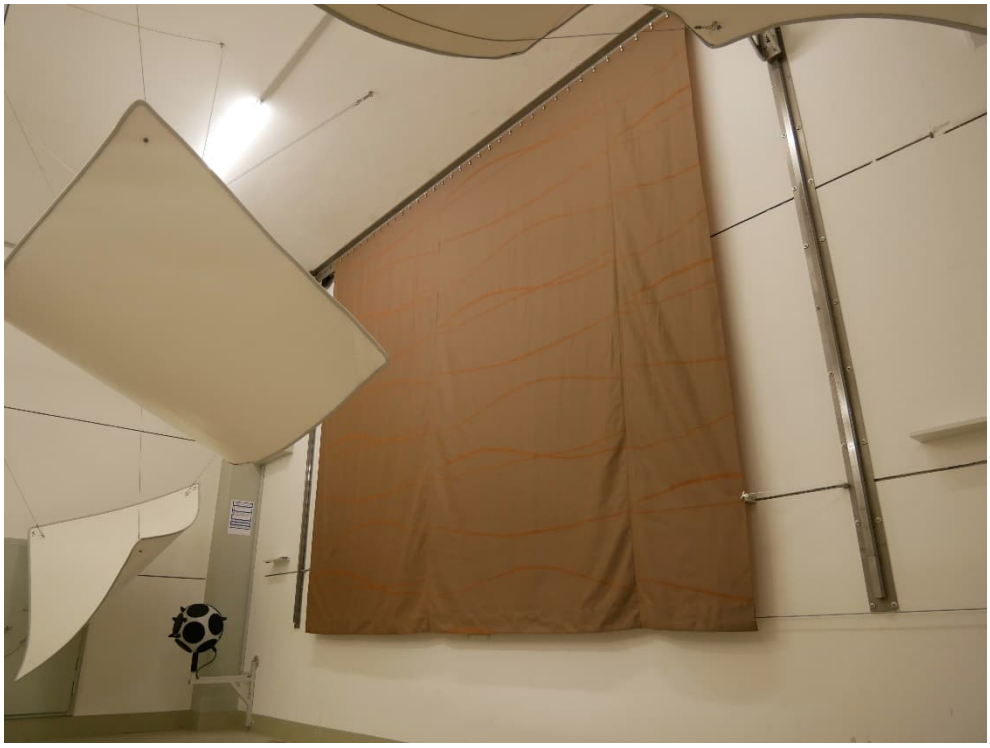


Figure B.2. Flat hanging curtain in the reverberation room: diagonal view.

Curtain fabric type Saint, Manufacturer AB Ludvig Svensson

Figure B.3. Pleated hanging curtain, 100 % fullness in the reverberation room: frontal view.

Figure B.4. Pleated hanging curtain, 100 % fullness in the reverberation room: diagonal view.

Description of the test procedure for the determination of the sound absorption in a reverberation room

1 Measurand

The sound absorption coefficient α of the test object was determined. For this purpose the mean value of the reverberation time in the reverberation room with and without the test object was measured. The sound absorption coefficient was calculated using the following equation:

$$\alpha_S = \frac{A_T}{S}$$

$$A_T = 55{,}3\,V\left(\frac{1}{c_2 T_2} - \frac{1}{c_1 T_1}\right) - 4\,V\,(m_2 - m_1)$$

With:

α_S sound absorption coefficient

A_T equivalent sound absorption area of the test object in m²

S area covered by the test object in m²

V volume of the reverberation room in m³

c_1 propagation speed of sound in air in the reverberation room without test object in m/s

c_2 propagation speed of sound in air in the reverberation room with test object in m/s

T_1 reverberation time in the reverberation room without test object in s

T_2 reverberation time in the reverberation room with test object in s

m_1 power attenuation coefficient in the reverberation room without test object in m^{-1}

m_2 power attenuation coefficient in the reverberation room with test object in m^{-1}

The area covered by the test object was used as testing area.

The different dissipation during the sound propagation in the air was taken into account according to paragraph 8.1.2 of DIN EN ISO 354 [1]. The power attenuation coefficient was calculated according to ISO 9613-1 [4]. The climatic conditions during the measurements are indicated in the test certificates.

Information on the repeatability and reproducibility of the test procedure are given in DIN EN ISO 354 [1] and DIN EN ISO 12999-2 [5]. In [5] for the single-number α_w a standard deviation of reproducibility of $\sigma_R = 0.035$ is indicated. This value was determined from reproducibility data of the test method based on round robin tests and describes the reproducibility of test results that was determined in test laboratories for similar constructions. An aspired confidence level of 95 % results in a coverage factor of $k = 2.0$ and an expanded uncertainty of $U = \pm 0.07$ for the weighted sound absorption coefficient α_w.

2 Test procedure

2.1 Description of the reverberation room

The reverberation room complies with the requirements according to DIN EN ISO 354 [1].

The reverberation room has a volume of V = 199.6 m^3 and a surface of S = 216 m^2.

Six omni-directional microphones and four loudspeakers were installed in the reverberation room. In order to improve the diffusivity, six composite sheet metal boards dimensioned 1.2 m x 2.4 m and six composite sheet metal boards dimensioned 1.2 m x 1.2 m were suspended curved and irregularly.

Figure C.1 shows the drawings of the reverberation room.

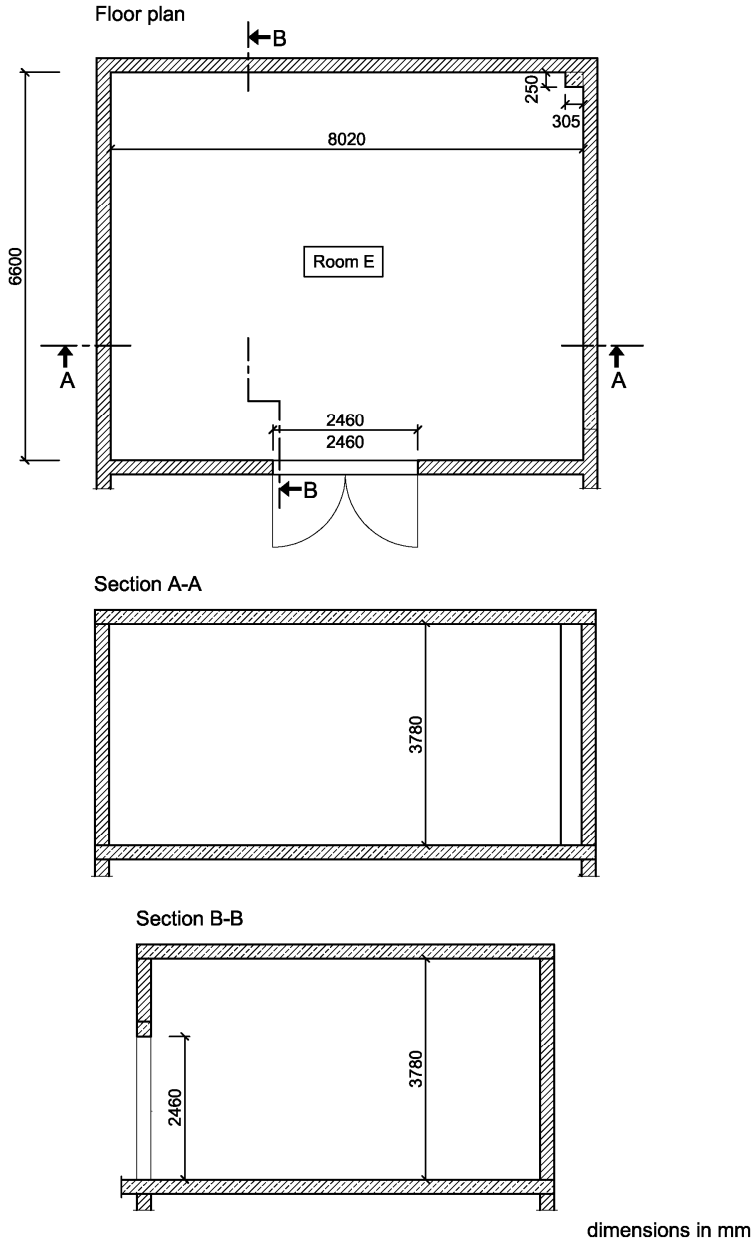


Figure C.1. Plan view and sections of the reverberation room.

2.2 Measurement of reverberation time

The determination of the impulse responses were carried out according to the indirect method. In all tests, a sinusoidal sweep with pink noise spectrum was used as test signal. In the reverberation room with and without test objects each 24 independent combinations of loudspeakers and microphones were measured. The reverberation time was evaluated according to DIN EN ISO 354 [1], using a linear regression for the calculation of the reverberation time T_{20} from the level of the backward integrated impulse response.

The determined reverberation times are indicated in Tables C.1 and C.2.

Table C.1. Reverberation times without and with test objects (Appendix A, pages 1 - 2).

Frequency *f* in Hz	**Reverberation time *T* in s**		
	T_1 (without test object)	**T_2 (with test object)**	
	Appendix A pages 1 to 2	**Appendix A page 1**	**Appendix A page 2**
100	5.56	5.39	5.37
125	6.11	5.76	5.60
160	6.15	5.58	5.24
200	5.29	4.48	4.01
250	5.68	4.30	3.64
315	5.49	3.58	3.12
400	5.58	3.07	2.67
500	5.57	2.61	2.44
630	5.37	2.34	2.27
800	5.07	2.12	2.20
1000	5.18	2.10	2.37
1250	5.21	2.14	2.64
1600	5.12	2.40	2.44
2000	4.86	2.49	2.26
2500	4.12	2.12	2.17
3150	3.40	1.86	1.87
4000	2.68	1.65	1.63
5000	2.15	1.42	1.42

Table C.2. Reverberation times without and with test objects (Appendix A, pages 3 - 4).

Frequency *f* in Hz	Reverberation time *T* in s		
	T_1 (without test object)	T_2 (with test object)	
	Appendix A pages 3 to 4	Appendix A page 3	Appendix A page 4
100	5.74	5.11	5.08
125	6.10	5.12	4.88
160	6.10	4.57	4.30
200	5.26	3.63	3.28
250	5.68	3.27	2.95
315	5.48	2.64	2.39
400	5.55	2.43	2.26
500	5.50	2.16	2.11
630	5.30	2.00	1.98
800	5.06	1.95	2.01
1000	5.11	1.95	1.97
1250	5.15	1.95	1.96
1600	5.14	1.94	1.93
2000	4.87	1.91	1.91
2500	4.14	1.80	1.80
3150	3.44	1.65	1.65
4000	2.75	1.45	1.46
5000	2.24	1.30	1.30

2.3 List of test equipment

The test equipment used is listed in Table C.3.

Table C.3. List of test equipment.

Name	Manufacturer	Type	Serial-No.
AD-/DA-converter	RME	Fireface 802	23811470
Amplifier	APart	Champ 2	17120171
Dodecahedron	Müller-BBM	DOD360A	372828
Dodecahedron	Müller-BBM	DOD360A	372829
Dodecahedron	Müller-BBM	DOD360A	372830
Dodecahedron	Müller-BBM	DOD360A	372831
Microphone	Microtech Gefell	M370	1355
Microphone	Microtech Gefell	M370	1356
Microphone	Microtech Gefell	M360	1786
Microphone	Microtech Gefell	M360	1787
Microphone	Microtech Gefell	M360	1788
Microphone	Microtech Gefell	M360	1789
Microphone power supply	MFA	IV80F	330364
Hygro-/Thermometer	Testo	Saveris H1E	01554624
Barometer	Lufft	Opus 10	057.0410.0003.9.4.1.30
Software for measurement and evaluation	Müller-BBM	Bau 4	Version 1.11
Measurement system airflow resistance	Müller-BBM	M89319-00	315003
Software for measurement and evaluation	Müller-BBM Acoustic Solutions	m|ars	Version 1.23.8256.29682
Thickness gauge	Hans Schmidt & Co GmbH	D-2000-C0913	2985
Electronic balance	Kern	KB1200-2N	W1402353