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M141038/09 Version 1 MSG/STEG

Curtain Fabric Type Sense, Manufacturer AB Ludvig Svensson

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

Test Report No. M141038/09

Client:	AB Ludvig Svensson Bangatan 8 51182 Kinna SWEDEN
Consultant:	M. Eng. Philipp Meistring Jan-Lieven Moll
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1 Task

On behalf of the company AB Ludvig Svensson, 51182 Kinna, Sweden, the sound absorption of the fabric type Sense had to be measured according to DIN EN ISO 354 [1] in the reverberation room. The fabric was tested as a curtain in a flat and a folded arrangement, 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 423-17 [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 423-17: Standard Test Method for Sound Absorption and Sound Absorption Coefficients by the Reverberation Room Method. Revision: 17. 2017-02
- [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] E DIN EN ISO 12999-2 (draft): Acoustics - Determination and application of measurement uncertainties in building acoustics - Part 2: Sound absorption. August 2019. German and English version prEN ISO 12999-2:2019
- [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

3 Test object and test assembly

3.1 Test object

The tested material is described by the manufacturer as follows:

- manufacturer AB Ludvig Svensson
- type Sense (sample indication 219135006HTH)
- material 100 % Trevira CS

The testing laboratory has measured as follows:

- area specific mass: $m'' = 345 \text{ g/m}^2$
- thickness: $t = 0.84 \text{ mm}$
- airflow resistance acc. to DIN EN ISO 9053-1 [6]: $R_s = 623 \text{ Pa s/m}$

3.2 Test assembly

The installation of the test objects was carried out by employees of the test laboratory at the reverberation room of Müller-BBM. The test object was installed in a flat and a folded arrangement, each with a distance to the reflective wall of 100 mm and 150 mm.

The mounting details for the tested arrangements are as follows:

- construction without enclosing frame
 - fixed directly underneath the ceiling, suspended from a metal rail, height 60 mm
- a) flat arrangement (100 mm distance to reflective wall)
- mounting type G-100 according to DIN EN ISO 354 [1] section 6.2.1 and appendix B.5 of DIN EN ISO 354 [1]
 - factory-made ready-for-use curtain 3.50 m x 2.98 m, with universal curtain tape (lateral hem 20 mm, bottom edge 75 mm)
 - total dimensions of the test surface (starting at the lower border of the metal rail): width x height = 3.50 m x 2.92 m
 - total test surface $S = 10.22 \text{ m}^2$
- b) flat arrangement (150 mm distance to reflective wall)
- mounting type G-150 according to DIN EN ISO 354 [1] section 6.2.1 and appendix B.5 of DIN EN ISO 354 [1]
 - factory-made ready-for-use curtain 3.50 m x 2.98 m, with universal curtain tape (lateral hem 20 mm, bottom edge 75 mm)
 - total dimensions of the test surface (starting at the lower border of the metal rail): width x height = 3.50 m x 2.92 m
 - total test surface $S = 10.22 \text{ m}^2$
- c) folded arrangement (100 mm distance to reflective wall)
- folded with 100 % fabric addition
 - factory-made ready-for-use curtain with universal curtain tape (lateral hem 20 mm, bottom edge 75 mm)
 - dimensions of the unfolded fabric 7.15 m x 2.98 m
 - total dimensions of the test surface (starting at the lower border of the metal rail): width x height = 3.58 m x 2.92 m
 - total test surface $S = 10.45 \text{ m}^2$

- d) folded arrangement (150 mm distance to reflective wall)
- folded with 100 % fabric addition
 - factory-made ready-for-use curtain with universal curtain tape (lateral hem 20 mm, bottom edge 75 mm)
 - dimensions of the unfolded fabric 7.15 m x 2.98 m
 - total dimensions of the test surface (starting at the lower border of the metal rail): width x height = 3.58 m x 2.92 m
 - total test surface $S = 10.45 \text{ m}^2$

The photographs in Appendix B show details of the test arrangements.

4 Execution of the measurements

The measurements of sound absorption in the reverberation room were executed and evaluated according to DIN EN ISO 354 [1].

The test method, the test facility 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 to the sound absorption coefficients 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 423-17 [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* and *SAA* are indicated in the test certificate in Appendix A.

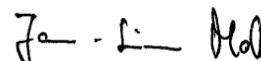
Information on the measurement uncertainties (repeatability and reproducibility) are given in Appendix C. Measurement uncertainties were not considered for attribution of the class of sound absorption according to DIN EN ISO 11654 [2].

7 Remarks

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



M. Eng. Philipp Meistring
(Project Manager)



Jan-Lieven Moll
(Responsible)

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Die Akkreditierung gilt für die in der Urkunde aufgeführten Prüfverfahren.

Sound absorption coefficient ISO 354

Measurement of sound absorption in reverberation rooms

Client: AB Ludvig Svensson
51182 Kinna, Sweden

Test specimen: Curtain fabric Sense,
Flat arrangement, 100 mm distance to reflective wall

Curtain fabric:

- manufacturer Svensson
- curtain fabric Sense
- area-related mass $m'' = 345 \text{ g/m}^2$
- airflow resistance $R_S = 623 \text{ Pa s/m}$
- thickness $t = 0.84 \text{ mm}$

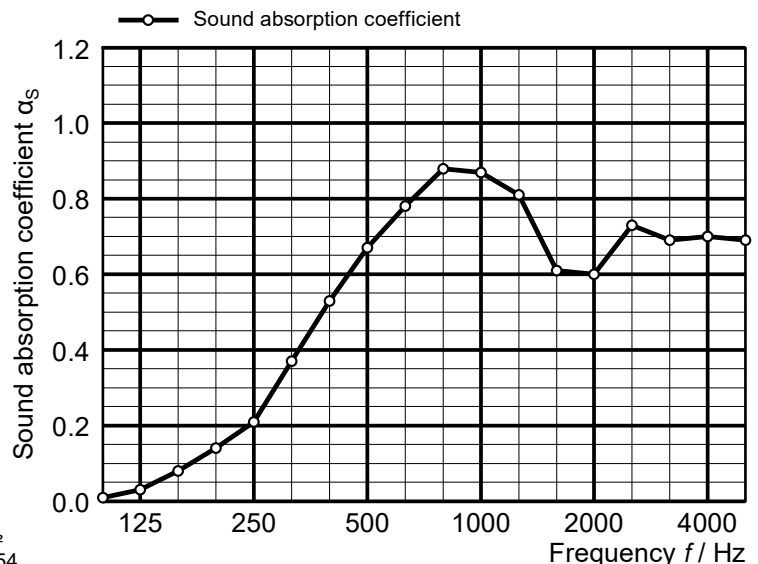
Test arrangement:

- hanging in front of a reflecting wall with 100 mm distance
- fixed on a metal rail (height 60 mm) at the ceiling of the reverberation room
- test arrangement without enclosing frame
- factory-made ready-for-use, gathered curtain 3.50 m x 2.98 m (dim. of fabric), with universal curtain tapes (lateral edges 20 mm, bottom edge 75 mm)
- test surface width x height = 3.50 m x 2.92 m, 100 % fabric addition (starting at the lower edge of the metalrail)

Room: E
Volume: 199.60 m³
Size: 10.22 m²
Date of test: 2019-06-05

	θ [°C]	$r. h.$ [%]	B [kPa]
without specimen	21.6	63.5	94.6
with specimen	21.7	61.6	94.6

Frequency [Hz]	α_s 1/3 octave	α_p octave
100	0.01	0.05
125	0.03	
160	0.08	
200	0.14	0.25
250	0.21	
315	0.37	
400	0.53	0.65
500	0.67	
630	0.78	
800	0.88	0.85
1000	0.87	
1250	0.81	
1600	0.61	0.65
2000	0.60	
2500	0.73	
3150	0.69	0.70
4000	0.70	
5000	0.69	



◦ 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

<p>Rating according to ISO 11654: Weighted sound absorption coefficient $\alpha_w = 0.55$ (MH) Sound absorption class: D</p>	<p>Rating according to ASTM C423: Noise Reduction Coefficient NRC = 0.60 Sound Absorption Average SAA = 0.60</p>
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Sound absorption coefficient ISO 354

Measurement of sound absorption in reverberation rooms

Client: AB Ludvig Svensson
51182 Kinna, Sweden

Test specimen: Curtain fabric Sense,
Flat arrangement, 150 mm distance to reflective wall

Curtain fabric:

- manufacturer Svensson
- curtain fabric Sense
- area-related mass $m'' = 345 \text{ g/m}^2$
- airflow resistance $R_S = 623 \text{ Pa s/m}$
- thickness $t = 0.84 \text{ mm}$

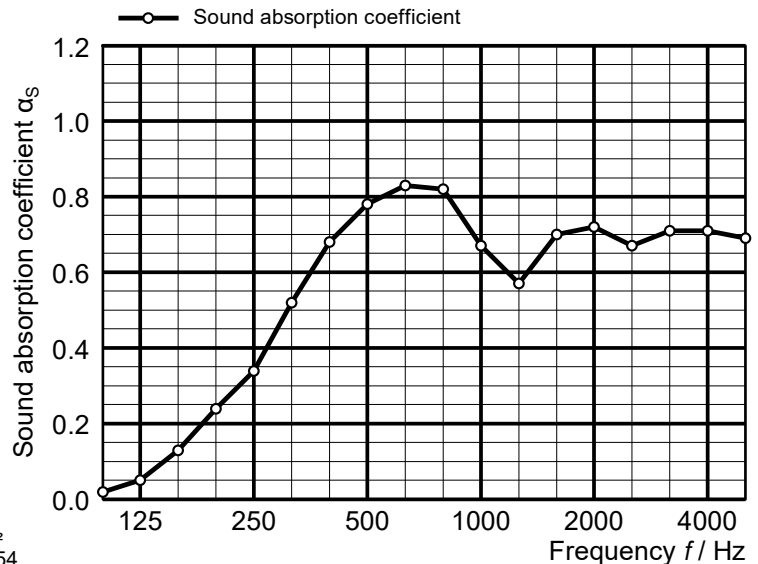
Test arrangement:

- hanging in front of a reflecting wall with 150 mm distance
- fixed on a metal rail (height 60 mm) at the ceiling of the reverberation room
- test arrangement without enclosing frame
- factory-made ready-for-use, gathered curtain 3.50 m x 2.98 m (dim. of fabric), with universal curtain tapes (lateral edges 20 mm, bottom edge 75 mm)
- test surface width x height = 3.50 m x 2.92 m, 100 % fabric addition (starting at the lower edge of the metalrail)

Room: E
Volume: 199.60 m³
Size: 10.22 m²
Date of test: 2019-06-05

	θ [°C]	<i>r. h.</i> [%]	<i>B</i> [kPa]
without specimen	21.6	63.5	94.6
with specimen	21.7	61.9	94.6

Frequency [Hz]	α_s 1/3 octave	α_p octave
100	0.02	0.05
125	0.05	
160	0.13	
200	0.24	0.35
250	0.34	
315	0.52	
400	0.68	0.75
500	0.78	
630	0.83	
800	0.82	0.70
1000	0.67	
1250	0.57	
1600	0.70	0.70
2000	0.72	
2500	0.67	
3150	0.71	0.70
4000	0.71	
5000	0.69	



◦ 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

<p>Rating according to ISO 11654: Weighted sound absorption coefficient $\alpha_w = 0.65$ Sound absorption class: C</p>	<p>Rating according to ASTM C423: Noise Reduction Coefficient <i>NRC</i> = 0.65 Sound Absorption Average <i>SAA</i> = 0.63</p>
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Appendix A
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Sound absorption coefficient ISO 354

Measurement of sound absorption in reverberation rooms

Client: AB Ludvig Svensson
51182 Kinna, Sweden

Test specimen: Curtain fabric Sense,
Folded arrangement (100 % fabric addition), 100 mm distance to reflective wall

Curtain fabric:

- manufacturer Svensson
- curtain fabric Sense
- area-related mass $m'' = 345 \text{ g/m}^2$
- airflow resistance $R_S = 623 \text{ Pa s/m}$
- thickness $t = 0.84 \text{ mm}$

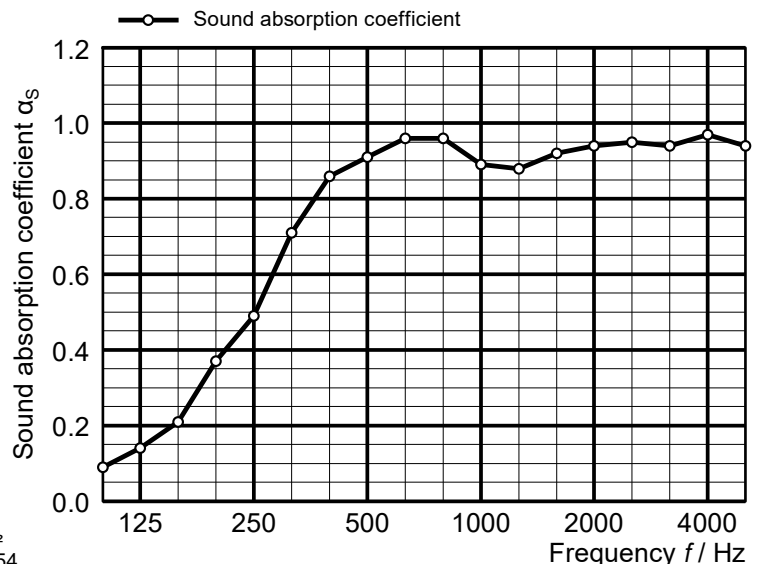
Test arrangement:

- hanging in front of a reflecting wall with 100 mm distance
- fixed on a metal rail (height 60 mm) at the ceiling of the reverberation room
- test arrangement without enclosing frame
- factory-made ready-for-use, gathered curtain 7.15 m x 2.98 m (dim. of fabric), with universal curtain tapes (lateral edges 20 mm, bottom edge 75 mm)
- test surface width x height = 3.58 m x 2.92 m, 100 % fabric addition (starting at the lower edge of the metalrail)

Room: E
Volume: 199.60 m³
Size: 10.45 m²
Date of test: 2019-06-05

	θ [°C]	$r. h.$ [%]	B [kPa]
without specimen	21.6	63.5	94.6
with specimen	21.6	63.4	94.6

Frequency [Hz]	α_s 1/3 octave	α_p octave
100	0.09	
125	0.14	0.15
160	0.21	
200	0.37	
250	0.49	0.50
315	0.71	
400	0.86	
500	0.91	0.90
630	0.96	
800	0.96	
1000	0.89	0.90
1250	0.88	
1600	0.92	
2000	0.94	0.95
2500	0.95	
3150	0.94	
4000	0.97	0.95
5000	0.94	



◦ 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

<p>Rating according to ISO 11654: Weighted sound absorption coefficient $\alpha_w = 0.80$ (H) Sound absorption class: B</p>	<p>Rating according to ASTM C423: Noise Reduction Coefficient NRC = 0.80 Sound Absorption Average SAA = 0.82</p>
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Sound absorption coefficient ISO 354

Measurement of sound absorption in reverberation rooms

Client: AB Ludvig Svensson
51182 Kinna, Sweden

Test specimen: Curtain fabric Sense,
Folded arrangement (100 % fabric addition), 150 mm distance to reflective wall

Curtain fabric:

- manufacturer Svensson
- curtain fabric Sense
- area-related mass $m'' = 345 \text{ g/m}^2$
- airflow resistance $R_S = 623 \text{ Pa s/m}$
- thickness $t = 0.84 \text{ mm}$

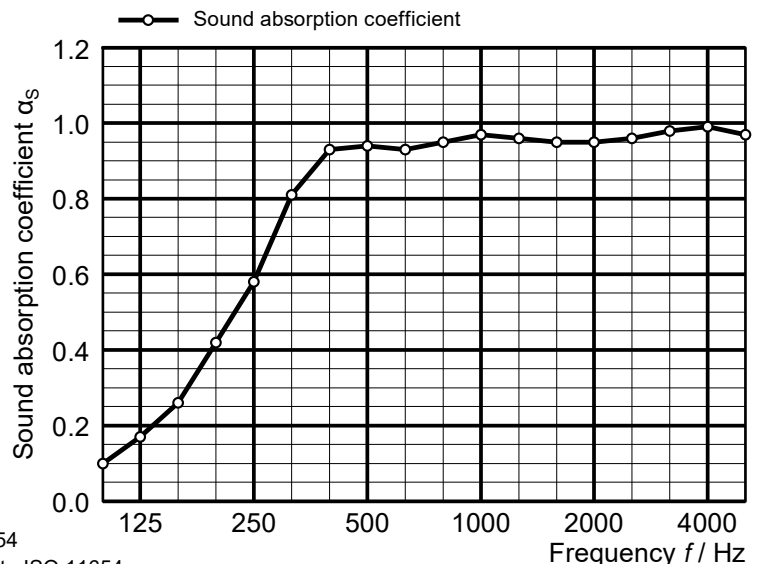
Test arrangement:

- hanging in front of a reflecting wall with 150 mm distance
- fixed on a metal rail (height 60 mm) at the ceiling of the reverberation room
- test arrangement without enclosing frame
- factory-made ready-for-use, gathered curtain 7.15 m x 2.98 m (dim. of fabric), with universal curtain tapes (lateral edges 20 mm, bottom edge 75 mm)
- test surface width x height = 3.58 m x 2.92 m, 100 % fabric addition (starting at the lower edge of the metalrail)

Room: E
Volume: 199.60 m³
Size: 10.45 m²
Date of test: 2019-05-27

	θ [°C]	$r. h.$ [%]	B [kPa]
without specimen	20.1	51.2	94.7
with specimen	20.1	50.8	94.7

Frequency [Hz]	α_s 1/3 octave	α_p octave
100	0.10	
125	0.17	0.20
160	0.26	
200	0.42	
250	0.58	0.60
315	0.81	
400	0.93	
500	0.94	0.95
630	0.93	
800	0.95	
1000	0.97	0.95
1250	0.96	
1600	0.95	
2000	0.95	0.95
2500	0.96	
3150	0.98	
4000	0.99	1.00
5000	0.97	



α_s Sound absorption coefficient according to ISO 354
 α_p Practical sound absorption coefficient according to ISO 11654

<p>Rating according to ISO 11654: Weighted sound absorption coefficient $\alpha_w = 0.90$ Sound absorption class: A</p>	<p>Rating according to ASTM C423: Noise Reduction Coefficient $NRC = 0.85$ Sound Absorption Average $SAA = 0.86$</p>
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Appendix A
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Fabric Type Sense, Manufacturer AB Ludvig Svensson



Figure B.1. Flat arrangement: test object mounted in the reverberation room, frontal view.



Figure B.2. Flat arrangement: test object mounted in the reverberation room, diagonal view.

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Fabric Type Sense, Manufacturer AB Ludvig Svensson



Figure B.3. Folded arrangement: test object mounted in the reverberation room, frontal view.



Figure B.4. Folded arrangement: test object mounted 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 m^2
- S area covered by the test object in m^2
- V volume of the reverberation room in m^3
- 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 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 [1]. 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 E DIN EN ISO 12999-2 [5].

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 $V = 199.6 \text{ m}^3$ and a surface of $S = 216 \text{ m}^2$.

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 $1.2 \text{ m} \times 2.4 \text{ m}$ and six composite sheet metal boards dimensioned $1.2 \text{ m} \times 1.2 \text{ m}$ were suspended curved and irregularly.

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

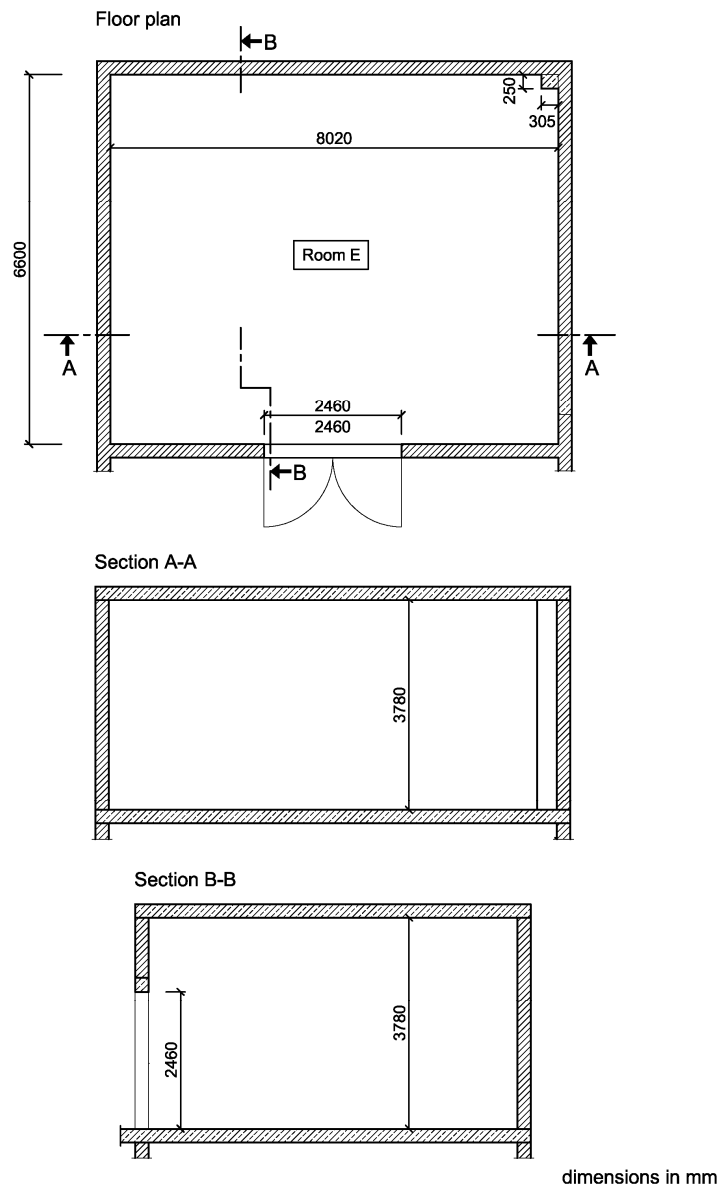


Figure C.1. Plan view and sections of the reverberation room.

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 a backward integrated impulse response.

The determined reverberation times in the reverberation room with and without test object are indicated in table C.1.

Table C.1. Reverberation times without and with test objects.

Frequency in Hz	Reverberation time T in s					
	T_1 (without test object)		T_2 (with test object)			
	Appx. A, page 1-3	Appx. A, page 4	Appx. A, page 1 G-100 flat (100 mm)	Appx. A, page 2, G-150 flat (150 mm)	Appx. A, page 3, folded 100 % (100 mm)	Appx. A, page 4, folded 100 % (150 mm)
100	5.32	5.24	5.19	5.12	4.62	4.50
125	4.97	4.98	4.74	4.61	4.07	3.90
160	5.29	5.26	4.68	4.35	3.87	3.64
200	5.17	5.13	4.20	3.70	3.17	3.02
250	5.26	5.26	3.90	3.35	2.85	2.65
315	4.96	5.00	3.14	2.71	2.31	2.15
400	5.30	5.41	2.80	2.47	2.14	2.06
500	5.38	5.32	2.51	2.30	2.07	2.03
630	5.18	5.22	2.27	2.18	1.98	2.02
800	4.85	4.91	2.05	2.14	1.92	1.95
1000	5.04	5.08	2.10	2.43	2.05	1.96
1250	5.21	5.16	2.23	2.68	2.08	1.98
1600	5.21	5.19	2.60	2.41	2.03	2.00
2000	4.96	4.88	2.55	2.33	1.98	1.95
2500	4.31	4.16	2.15	2.24	1.85	1.82
3150	3.62	3.42	2.01	1.98	1.71	1.64
4000	2.93	2.69	1.77	1.76	1.52	1.44
5000	2.48	2.20	1.59	1.60	1.41	1.30

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2.3 List of test equipment

The test equipment used is listed in Table C.2

Table C.2. List of test equipment.

Name	Manufacturer	Type	Serial-No.
AD-/DA-converter	RME	Fireface 802	23811470
Amplifier	APart	Champ 2	09050048
Dodecahedron	Müller-BBM	DOD360A	372828
Dodecahedron	Müller-BBM	DOD360A	372829
Dodecahedron	Müller-BBM	DOD360A	372830
Dodecahedron	Müller-BBM	DOD360A	372831
Microphone	Microtech	M370	1355
Microphone	Microtech	M370	1356
Microphone	Microtech	M360	1786
Microphone	Microtech	M360	1787
Microphone	Microtech	M360	1788
Microphone	Microtech	M360	1789
Microphone power supply	MFA	IV80F	330364
Hygro-/Thermometer	Testo	Saveris H1E	01554624
Barometer	Lufft	Opus 10	030.0910.0003.9. 4.1.30
Software for measurement and evaluation	Müller-BBM	Bau 4	Version 1.11