MÜLLER-BBM

**Vescom B.V.,
Curtain fabric Marmara**

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

Test Report No. B111250/33

Client:	Vescom B.V. Sint Jozefstraat 20 5753 AV Deurne Netherlands
Consultant:	M. Eng. Philipp Meistring Jan-Lieven Moll
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1 Task

On behalf of the company Vescom B.V., 5753 AV Deurne, Netherlands, the sound absorption of the curtain fabric type Marmara was to be determined by measurements in the reverberation room according to DIN EN ISO 354 [1].

The fabric was arranged at a distance of 150 mm from the reflecting wall. Testing was done for the curtain fabric arranged hanging flat and pleated with 100 % fullness.

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] 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. October 1996

3 Test object and test assembly

3.1 Test object

The tested material is described by the client as follows:

- designation: Marmara

- material composition: 100 % polyester FR

The testing laboratory has measured as follows
(values determined at one sample 210 mm x 297 mm from the test material):

- Thickness acc. DIN EN ISO 5084 [7]
  (3 positions, pressure 1.00 kPa, pressure-foot 2000 mm²): t = 0.31 mm

- area specific mass: m'' = 92 g/m²

- specific airflow resistance
  acc. to DIN EN ISO 9053-1 [1]: R_s = 114 Pa · s/m

3.2 Test assemblies

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 as a flat and a pleated hanging curtain, each with a distance to the reflective wall of 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 of the rail 90 mm, fabric with 60 mm overlap at the rail

- 150 mm distance to reflective wall

a) flat hanging curtain

- 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]

- one curtain web with fabric dimensions of W x H = 3550 mm x 3030 mm arranged flat hanging

- total dimensions of the test surface (starting at the lower border of the metal rail): width x height = 3.55 m x 2.97 m

- total test surface S = 10.54 m²

b) pleated curtain

- arranged in style of 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]

- two curtain webs, dimensions of the unfolded fabric: one web W x H = 3550 mm x 3030 mm and one web W x H = 3680 mm x 3030 mm, arranged pleated hanging with 100 % fullness and approx. 20 mm overlap at the vertical web joint

- total dimensions of the test surface (starting at the lower border of the metal rail): width x height = 3.61 m x 2.97 m

- total test surface S = 10.72 m^2

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

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 423-17 [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.
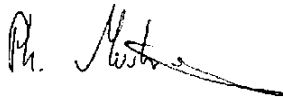
6 Measurement results

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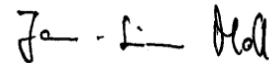
Information on the measurement uncertainties (repeatability and reproducibility) are given in Appendix C. Measurement uncertainties were not considered for attribution of the classes of sound absorption according to DIN EN ISO 11654 [2].

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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DAkkS
Deutsche
Akkreditierungsstelle
D-PL-14119-07-00

Testing laboratory accredited by DAkkS according to DIN EN ISO/IEC 17025:2018.
The accreditation is valid only for the scope listed in the annex of the accreditation certificate.

Sound absorption coefficient ISO 354
Measurement of sound absorption in reverberation rooms

Client: Vescom B.V., Sint Jozefstraat 20,
5753 AV Deurne, Netherlands

Test specimen: Curtain fabric Marmara,
arranged hanging flat, 150 mm wall distance

Curtain fabric:
Information provided by the client
- designation Marmara
- material: 100 % polyester FR

Properties determined by the testing laboratory at one A4-sized sample from test material:
- area specific mass $m'' = 92$ g/m²
- airflow resistance $R_S = 114$ Pa s/m
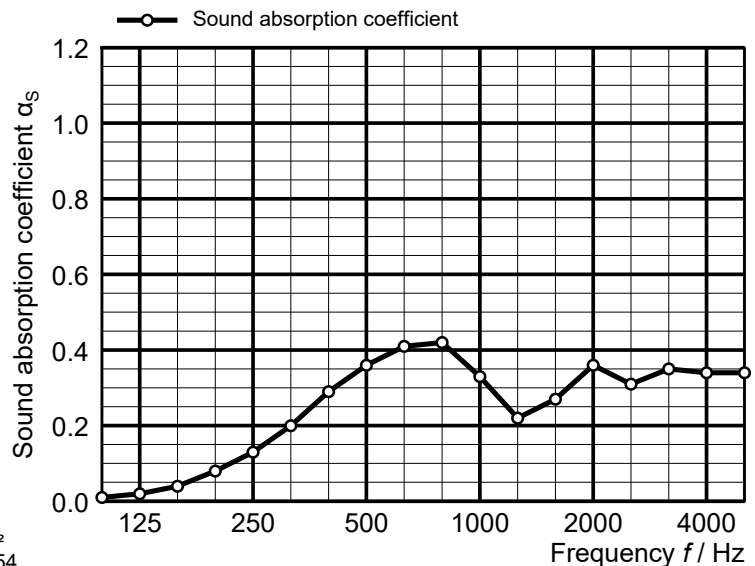- thickness $t = 0.31$ mm

Test arrangement:
- mounting type G-150 acc. to DIN EN ISO 354
- curtain fabric hanging flat 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
- fabric dimensions W x H = 3550 mm x 3030 mm
- test surface width x height = 3.55 m x 2.97 m (starting at the lower edge of the metal rail)

Room: E
Volume: 199.60 m³
Size: 10.54 m²
Date of test: 2022-07-27

	θ [°C]	r. h. [%]	B [kPa]
without specimen	24.7	54.5	95.1
with specimen	24.8	53.7	95.1

Frequency [Hz]	α_S 1/3 octave	α_p octave
100	∘ 0.01	
125	∘ 0.02	0.00
160	∘ 0.04	
200	∘ 0.08	
250	0.13	0.15
315	0.20	
400	0.29	
500	0.36	0.35
630	0.41	
800	0.42	
1000	0.33	0.30
1250	0.22	
1600	0.27	
2000	0.36	0.30
2500	0.31	
3150	0.35	
4000	0.34	0.35
5000	0.34	

∘ 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 $\alpha_w = 0.35$ Sound absorption class: D	**Noise Reduction Coefficient *NRC* = 0.30** **Sound Absorption Average *SAA* = 0.28**

MÜLLER-BBM

Sound absorption coefficient ISO 354
Measurement of sound absorption in reverberation rooms

Client: Vescom B.V., Sint Jozefstraat 20,
5753 AV Deurne, Netherlands

Test specimen: Curtain fabric Marmara,
arranged hanging pleated with 100 % fullness, 150 mm wall distance

Curtain fabric:
Information provided by the client
- designation Marmara
- material: 100 % polyester FR

Properties determined by the testing laboratory at one A4-sized sample from test material:
- area specific mass $m'' = 92$ g/m²
- airflow resistance $R_S = 114$ Pa s/m
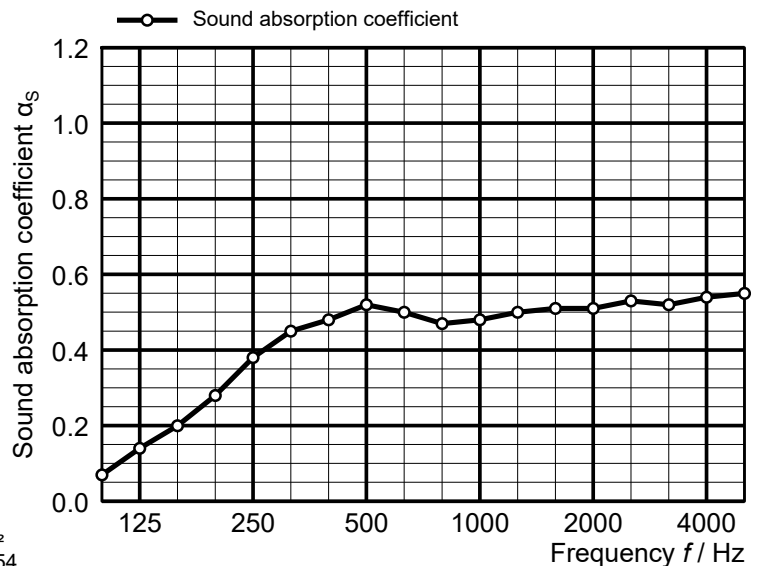- thickness $t = 0.31$ mm

Test arrangement:
- style of type G-150 mounting acc. to DIN EN ISO 354
- curtain fabric hanging pleated with 100 % fullness 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
- two curtain webs, fabric dimensions one web $W \times H$ = 3550 mm x 3030 mm and one web $W \times H$ = 3680 mm x 3030 mm, with 20 mm overlap at vertical web joint
- test surface width x height = 3.61 m x 2.97 m (starting at the lower edge of the metal rail)

Room: E
Volume: 199.60 m³
Size: 10.72 m²
Date of test: 2022-07-27

	θ [°C]	r. h. [%]	B [kPa]
without specimen	24.7	54.5	95.1
with specimen	24.8	53.7	95.1

Frequency [Hz]	α_S 1/3 octave	α_p octave
100	∘ 0.07	
125	0.14	0.15
160	0.20	
200	0.28	
250	0.38	0.35
315	0.45	
400	0.48	
500	0.52	0.50
630	0.50	
800	0.47	
1000	0.48	0.50
1250	0.50	
1600	0.51	
2000	0.51	0.50
2500	0.53	
3150	0.52	
4000	0.54	0.55
5000	0.55	

∘ 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

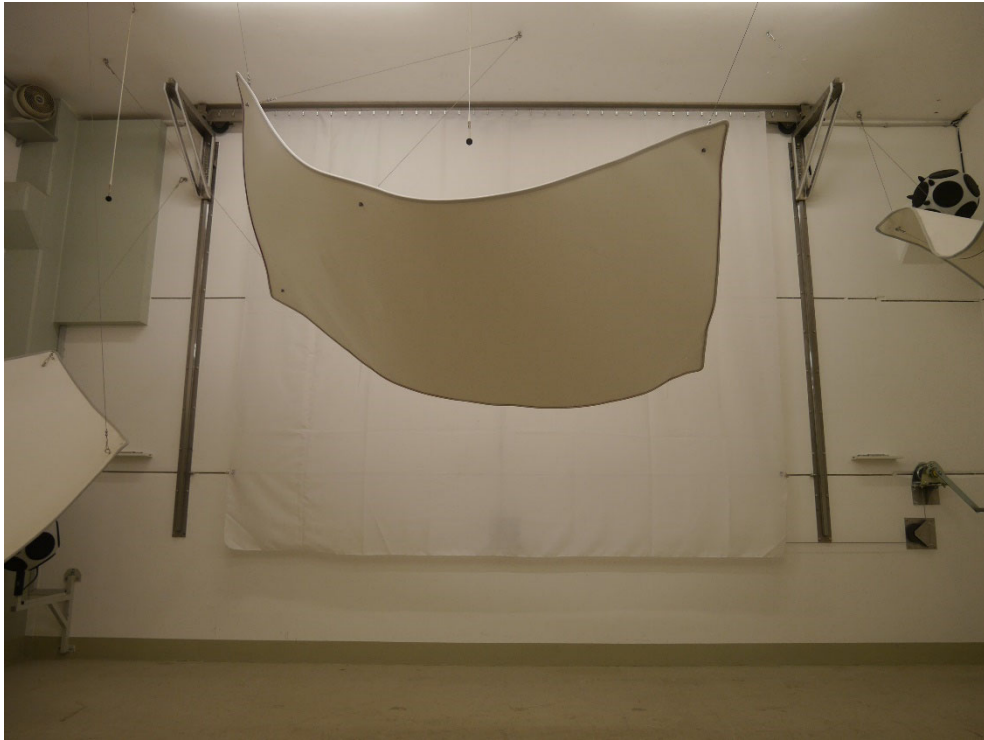| Rating according to ISO 11654:	Rating according to ASTM C423:
Weighted sound absorption coefficient $\alpha_w = 0.50$ Sound absorption class: D	**Noise Reduction Coefficient NRC = 0.45** **Sound Absorption Average SAA = 0.47**

Curtain fabric Marmara by Vescom B.V.

Figure B.1. Test object in the reverberation room: hanging flat, frontal view.

Figure B.2. Test object in the reverberation room: hanging flat, diagonal view.
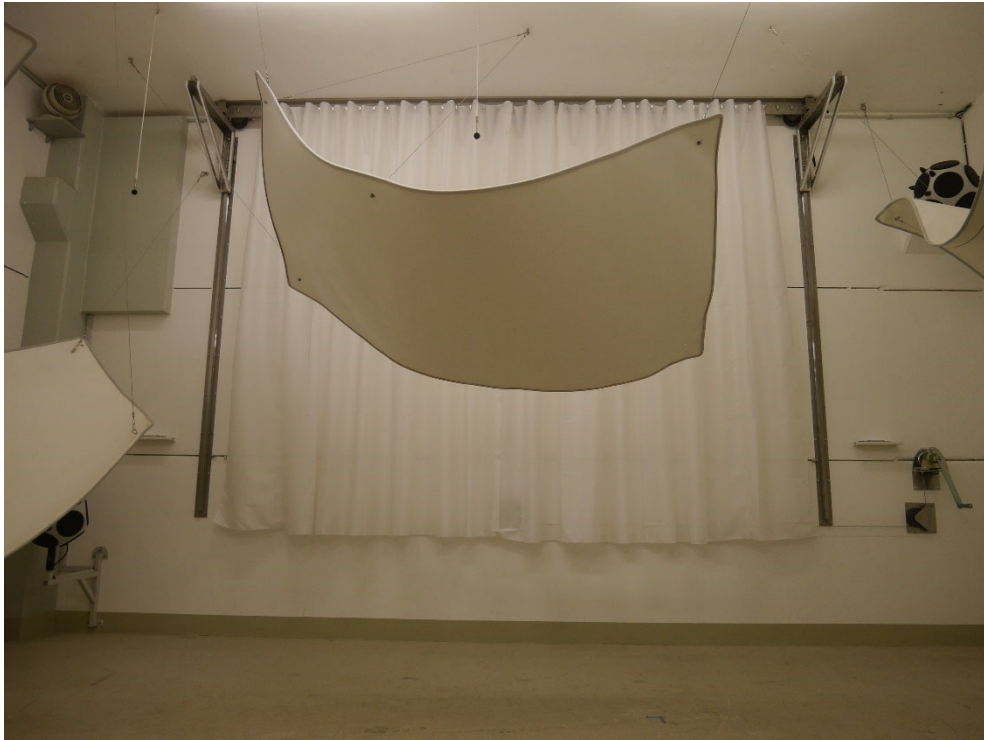
Curtain fabric Marmara by Vescom B.V.

Figure B.3. Test object in the reverberation room: hanging pleated, frontal view.

Figure B.4. Test object in the reverberation room: hanging pleated, 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 area of the test object was the area covered by the test object.

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 calculation of the power attenuation coefficients was effected 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.

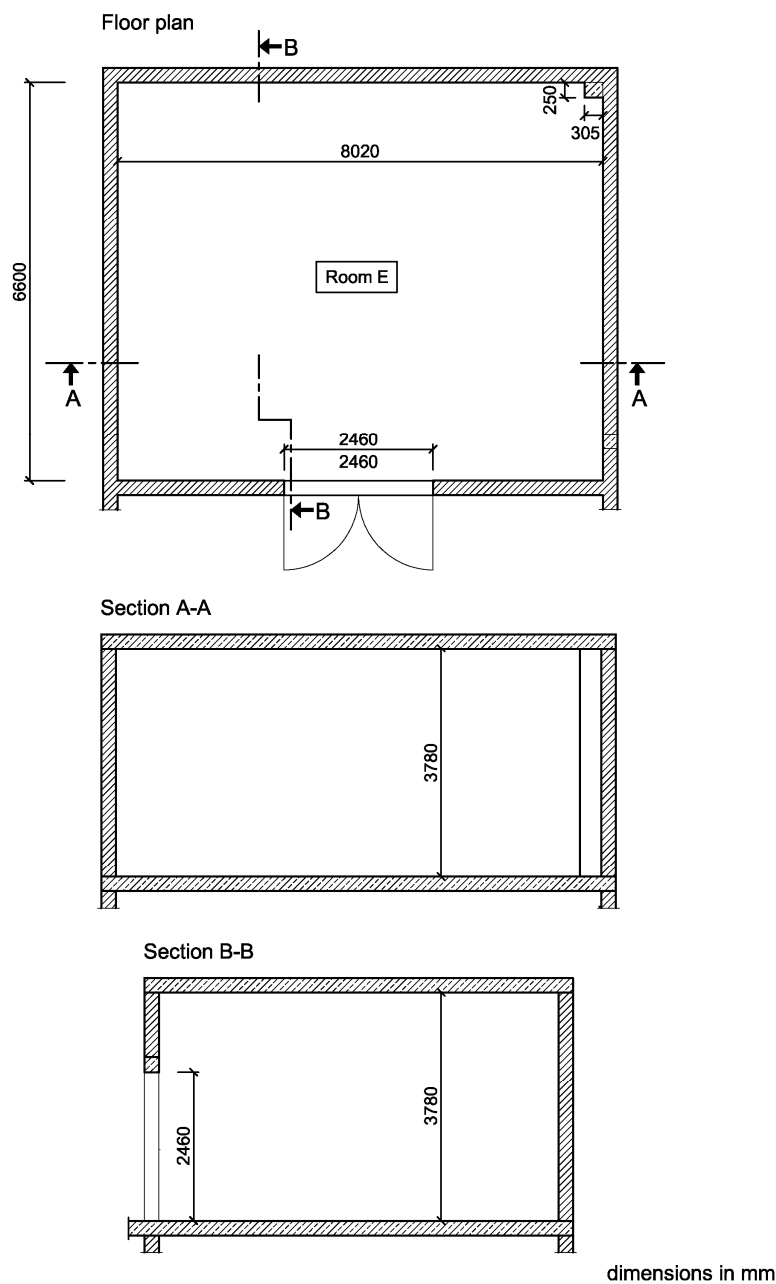Figure C.1 shows the drawings of the reverberation room.

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 Table C.1.

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

Frequency f / Hz	Reverberation time T / s		
	T_1 (without test object)	T_2 (with test object, flat)	T_2 (with test object, pleated)
100	5.71	5.63	5.08
125	6.28	6.01	4.85
160	6.41	5.87	4.47
200	5.39	4.70	3.56
250	5.83	4.69	3.33
315	5.67	4.12	3.04
400	5.70	3.70	2.96
500	5.57	3.34	2.82
630	5.35	3.10	2.81
800	4.98	2.94	2.79
1000	5.09	3.28	2.80
1250	5.17	3.77	2.77
1600	5.15	3.53	2.74
2000	4.94	3.13	2.68
2500	4.33	2.99	2.45
3150	3.65	2.57	2.23
4000	2.95	2.21	1.92
5000	2.47	1.93	1.69

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	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	030.0910.0003.9.4.1.30
Software for measurement and evaluation	Müller-BBM	Bau 4	Version 1.11
Thickness gauge	Hans Schmidt & Co GmbH	D-2000-C0913	2985
Electronic balance	Kern	KB1200-2N	W1402353