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2020-02-03
M77692/25 Version 1 MR/JRE

**Curtain type
ECHOVELOUR Lightsorber D18,
Manufacturer Tüchler,
flat and folded arrangement**

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

Test Report No. M77692/25

Client:

TÜCHLER Bühnen- & Textiltechnik GmbH
Rennbahnweg 78
1220 Wien
Austria

Consultant:

Dr.-Ing. Andreas Meier
M. Sc. Paul Siegmüller

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1 page Appendix B and
4 pages Appendix C.

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test facility and test equipment

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1 Task

On behalf of the company TÜCHLER Bühnen- & Textiltechnik GmbH the sound absorption of the curtain type "ECHOVELOUR Lightsorber D18" was to be determined by measurements in the reverberation room according to DIN EN ISO 354 [1]. The fabric was tested as a single-layer curtain in a flat and a folded arrangement with a distance of 100 mm to the reflective wall.

2 Basis

- [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. 1997-04
- [3] ASTM C 423-17: Standard Test Method for Sound Absorption and Sound Absorption Coefficients by the Reverberation Room Method. Revision: 17. February 2017
- [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 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 assembly and test objects

3.1 Test object

The following article was tested:

- curtain type ECHOVELOUR Lightsorber D18
- area specific mass $m'' = 667 \text{ g/m}^2$
- airflow resistance acc. to DIN EN ISO 9053-1 [5] $R_s > 40000 \text{ Pa s/m}$

The specific airflow resistance was determined by the testing laboratory Müller-BBM.

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3.2 Test assembly

The arrangements tested are indicated in Table 1.

Table 1. Arrangements tested.

Assembly No.	Article	Arrangement
1	ECHOVELOUR Lightsorber D18	flat arrangement, single layer with 100 mm distance, mounting type G-100
2	ECHOVELOUR Lightsorber D18	folded arrangement with 100 % fabric addition, single layer with 100 mm distance, mounting type G-100

The curtain was fixed underneath the ceiling at a steel angle. It was mounted freely suspended. The test was carried out without enclosing frame.

The installation of the test objects in the reverberation room was carried out by employees of the testing laboratory. The test objects were assembled according to DIN EN ISO 354 [1], section 6.2.2 in mounting type G, Appendix B.

Further information on the test assemblies are included in the test certificate in Appendix A, pages 1 and 2. Appendix B shows figures of the test assemblies.

4 Execution of the measurements

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

The test procedure, 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.

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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 certificates in Appendix A.

7 Remarks

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



Dr.-Ing. Andreas Meier
(Project Manager)



M.Sc. Paul Siegmüller
(Responsible)

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Sound absorption coefficient ISO 354

Measurement of sound absorption in reverberation rooms

Client: TÜCHLER Bühnen- und Textiltechnik GmbH,
Rennbahnweg 78, 1220 Wien, Austria

Test specimen: ECHOVELOUR Lightsorber D18, type G-100, flat arrangement

Curtain fabric:

Indications from the client

- material description: ECHOVELOUR Lightsorber D18
- material 100 % cotton

Indications from the testing laboratory

- area-related mass $m'' = 667 \text{ g/m}^2$
- airflow resistance $R_S > 40000 \text{ Pa s/m}$
- thickness $t = 2.1 \text{ mm}$

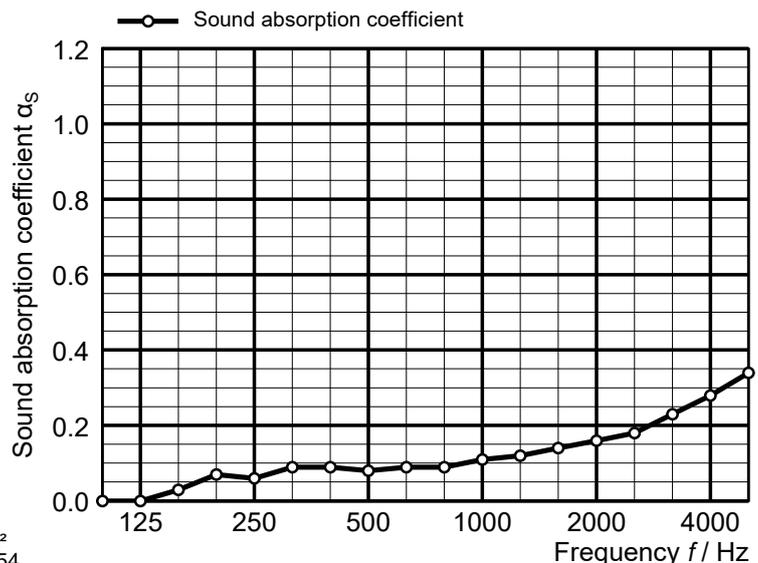
Test arrangement:

- arrangement of the curtain in the style of mounting type G-100 acc. to DIN EN ISO 354
- hanging flat in front of the wall
- suspended on 60 mm high ceiling rail (25 mm overlap), distance to the back wall 100 mm
- construction without enclosing frame
- arranged as ready-to-use curtain 3000 mm x 3500 mm, top edge reinforced with webbing and eyelets every 10 cm, lower edge and sides refined
- test surface width x height = 3.50 m x 2.975 m (starting at the lower edge of the ceiling rail)

Room: E
Volume: 199.60 m³
Size: 10.41 m²
Date of test: 2020-01-22

	θ [°C]	r. h. [%]	B [kPa]
without specimen	19.9	32.1	96.6
with specimen	18.1	30.0	96.6

Frequency [Hz]	α_s 1/3 octave	α_p octave
100	0.00	0.00
125	0.00	0.00
160	0.03	
200	0.07	
250	0.06	0.05
315	0.09	
400	0.09	
500	0.08	0.10
630	0.09	
800	0.09	
1000	0.11	0.10
1250	0.12	
1600	0.14	
2000	0.16	0.15
2500	0.18	
3150	0.23	
4000	0.28	0.30
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: Weighted sound absorption coefficient $\alpha_w = 0.15 (H)$ Sound absorption class: E	Rating according to ASTM C423: Noise Reduction Coefficient Sound Absorption Class: E
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Sound absorption coefficient ISO 354

Measurement of sound absorption in reverberation rooms

Client: TÜCHLER Bühnen- und Textiltechnik GmbH,
Rennbahnweg 78, 1220 Wien, Austria

Test specimen: ECHOVELOUR Lightsorber D18, type G-100, folded with 100 % fabric addition

Curtain fabric:

Indications from the client

- material description: ECHOVELOUR Lightsorber D18
- material 100 % cotton

Indications from the testing laboratory

- area-related mass $m'' = 667 \text{ g/m}^2$
- airflow resistance $R_S > 40000 \text{ Pa s/m}$
- thickness $t = 2.1 \text{ mm}$

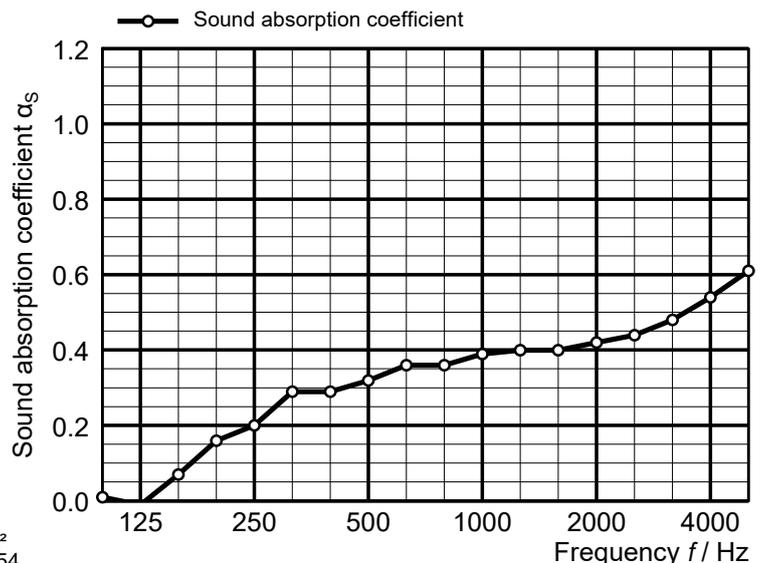
Test arrangement:

- arrangement of the curtain in the style of mounting type G-100 acc. to DIN EN ISO 354
- hanging folded in front of the wall
- suspended on 60 mm high ceiling rail (25 mm overlap), distance to the back wall 100 mm
- construction without enclosing frame
- arranged as ready-to-use curtain 3000 mm x 3500 mm, top edge reinforced with webbing and eyelets every 10 cm, lower edge and sides refined
- test surface width x height = 3.50 m x 2.975 m (starting at the lower edge of the ceiling rail)

Room: E
Volume: 199.60 m³
Size: 10.41 m²
Date of test: 2020-01-22

	θ [°C]	r. h. [%]	B [kPa]
without specimen	18.2	33.7	96.6
with specimen	18.1	34.8	96.6

Frequency [Hz]	α_s 1/3 octave	α_p octave
100	0.01	
125	-0.01	0.00
160	0.07	
200	0.16	
250	0.20	0.20
315	0.29	
400	0.29	
500	0.32	0.30
630	0.36	
800	0.36	
1000	0.39	0.40
1250	0.40	
1600	0.40	
2000	0.42	0.40
2500	0.44	
3150	0.48	
4000	0.54	0.55
5000	0.61	



◦ 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: Weighted sound absorption coefficient $\alpha_w = 0.40$ (H) Sound absorption class: D	Rating according to ASTM C423: Noise Reduction Coef Sound Absorption Av
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Curtain ECHOVELOUR Lightsorber D18, company TÜCHLER arrangement with 100 mm wall distance



Figure B.1. Fabric in the reverberation room, flat arrangement.



Figure B.2. Fabric in the reverberation room, folded arrangement.

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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 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 E DIN EN ISO 12999-2.

2 Test procedure

2.1 Description of the reverberation room

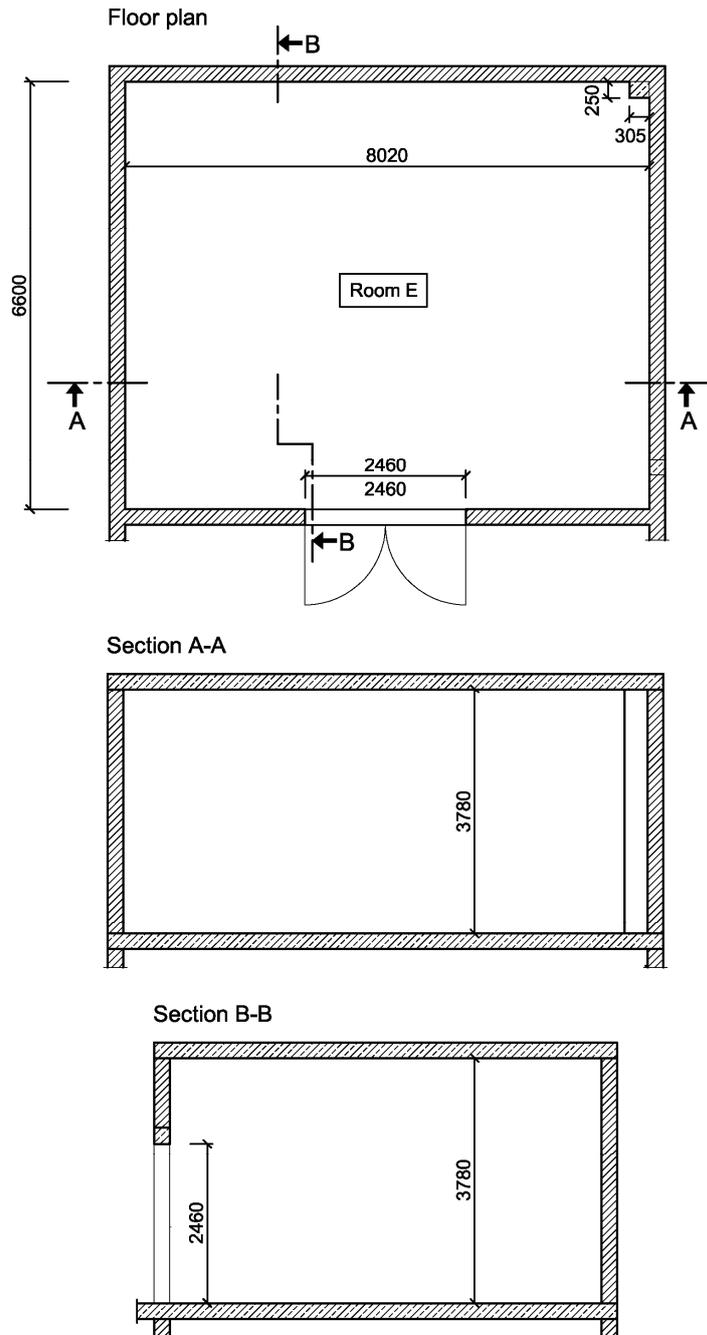
WARNING: The reverberation room complies with the requirements according to DIN EN ISO 354 [1]. **Bühnen- & Textiltechnik GmbH.**
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Six omni-directional microphones and four loudspeakers were installed in the reverberation room.

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.



dimensions in mm

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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 f / Hz	Reverberation time T / 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	4.99	4.99	4.88
125	5.15	5.15	5.24
160	5.40	5.18	4.79
200	5.16	4.63	4.10
250	5.18	4.77	3.90
315	5.03	4.39	3.43
400	5.40	4.70	3.61
500	5.44	4.79	3.48
630	5.29	4.59	3.29
800	4.92	4.30	3.11
1000	5.07	4.31	3.10
1250	5.02	4.17	3.06
1600	4.80	3.87	2.97
2000	4.41	3.47	2.78
2500	3.54	2.80	2.37
3150	2.77	2.16	1.96

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2.3 List of test equipment

The test equipment used is listed in Table C.2

Table C.2. 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 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

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