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B173016/18 Version 1 MSG/STEG

Curtain fabric Mani Delitherm of the company Delius GmbH & Co. KG

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

Test Report No. B173016/18

Client:	Delius GmbH & Co. KG Goldstraße 16 - 18 33502 Bielefeld Germany
Consultant:	M. Eng. Philipp Meistring Jan-Lieven Moll
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Date of test:	2024-04-30
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1 Task

On behalf of the company Delius GmbH & Co. KG, 33502 Bielefeld, Germany, the sound absorption of the curtain fabric type Mani Delitherm was to be determined by measurements in the reverberation room according to DIN EN ISO 354 [1].

The fabric was tested as a pleated hanging curtain with 100 % fullness and a distance of 100 mm from the reflecting wall.

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 5084: Textiles – Determination of thickness of textiles and textile products (ISO 5084:1996); German Version EN ISO 5084: 1996. October 1996

[7] 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

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3 Test object and test assembly

3.1 Test object

The tested material is described by the client as follows:

- type: Mani Delitherm, article no. KMAT 61000644
- colour: 8002
- material: 60 % Polyester FR, 40 % Polyester FR film yarn

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 [6]
  (3 positions, pressure 1.00 kPa, pressure-foot 2000 mm²): t = 0.32 mm
- specific airflow resistance
  acc. to DIN EN ISO 9053-1 [7]: R_s = 114 Pa · s/m
- area specific mass: m'' = 104 g/m^2

3.2 Test assemblies

The installation of the test object was carried out by employees of the test laboratory at the reverberation room of Müller-BBM. The test object was installed as a pleated hanging curtain in the style of mounting type G-100 according to DIN EN ISO 354 [1].

The mounting details for the tested arrangement are as follows:

- 100 % fullness, pleated hanging curtain
- fixed directly underneath the ceiling, suspended from a metal rail, height of the rail 90 mm, fabric with 40 mm overlap at the ceiling of the reverberation room
- factory-made ready-for-use curtain: 2950 mm x 3500 mm (100 % fullness, width of fabric 6990 mm), with 50 mm universal curtain tape, lateral hem 2 cm, lower hem 10 cm with inserted lead tape 50 g
- 100 mm distance to reflective wall
- test arrangement without enclosing frame
- dimensions of the test surface (starting at the lower border of the metal rail): width x height = 3.50 m x 2.91 m = 10.19 m²

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

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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* 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].

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7 Remarks

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

M. Eng. Philipp Meistring
(Project manager)

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Sound absorption coefficient ISO 354

Measurement of sound absorption in reverberation rooms

Client: Delius GmbH & Co. KG, Goldstraße 16 - 18, 33602 Bielefeld, Germany

Test specimen: Curtain fabric Mani Delitherm,
arranged as pleated hanging curtain with 100 mm wall distance, 100 % fullness

Curtain fabric:

Information provided by the client

- designation Mani Delitherm, article no. KMAT 61000644, colour 8002
- material 60 % polyester FR, 40 % polyester FR film yarn

Information provided by testing laboratory

- area specific mass m'' = 104 g/m²
- airflow resistance R_S = 114 Pa s/m
- thickness t = 0.32 mm

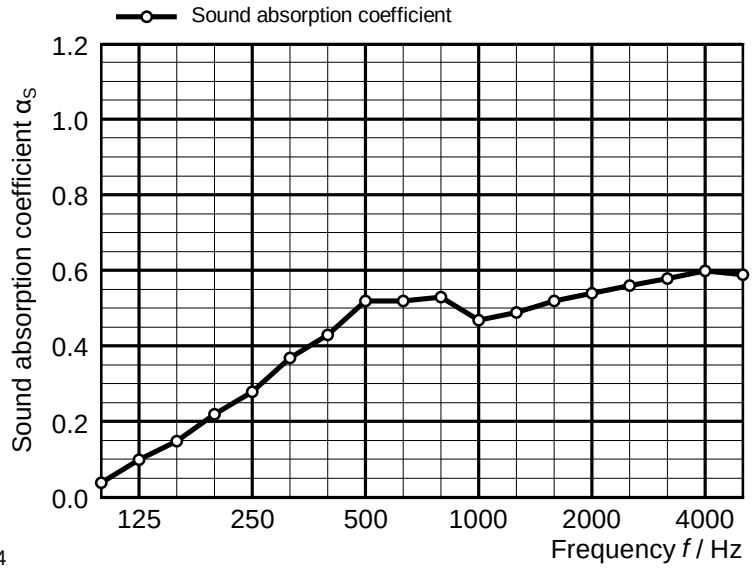
Test arrangement:

- curtain arranged in the style of mounting type G-100 acc. to DIN EN ISO 354
- arranged as pleated hanging curtain in front of a reflecting wall
- fixed directly underneath the ceiling of the reverberation room, suspended from a metal rail (height 90 mm, overlap 40 mm), distance to the back wall 100 mm
- test arrangement without enclosing frame
- factory-made ready-for-use curtain 2950 mm x 3500 mm (100 % fullness; width of fabric 6990 mm), with 50 mm universal curtain tape, lateral hem 2 cm, lower hem 10 cm with inserted lead tape
- 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: 2024-04-30

	θ [°C]	*r. h.* [%]	*B* [kPa]
without specimen	21.0	41.0	95.1
with specimen	21.3	41.0	94.7

Frequency [Hz]	α_S 1/3 octave	α_p octave
100	◦ 0.04	
125	0.10	0.10
160	0.15	
200	0.22	
250	0.28	0.30
315	0.37	
400	0.43	
500	0.52	0.50
630	0.52	
800	0.53	
1000	0.47	0.50
1250	0.49	
1600	0.52	
2000	0.54	0.55
2500	0.56	
3150	0.58	
4000	0.60	0.60
5000	0.59	



◦ 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	**Noise Reduction Coefficient *NRC* = 0.45**
Sound absorption class: D	**Sound Absorption Average *SAA* = 0.45**

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Curtain fabric Mani Delitherm, company Delius GmbH & Co. KG

Figure B.1. Pleated hanging curtain in the reverberation room (frontal view).

Figure B.2. Pleated hanging curtain in the reverberation room (diagonal view).

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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 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.

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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.

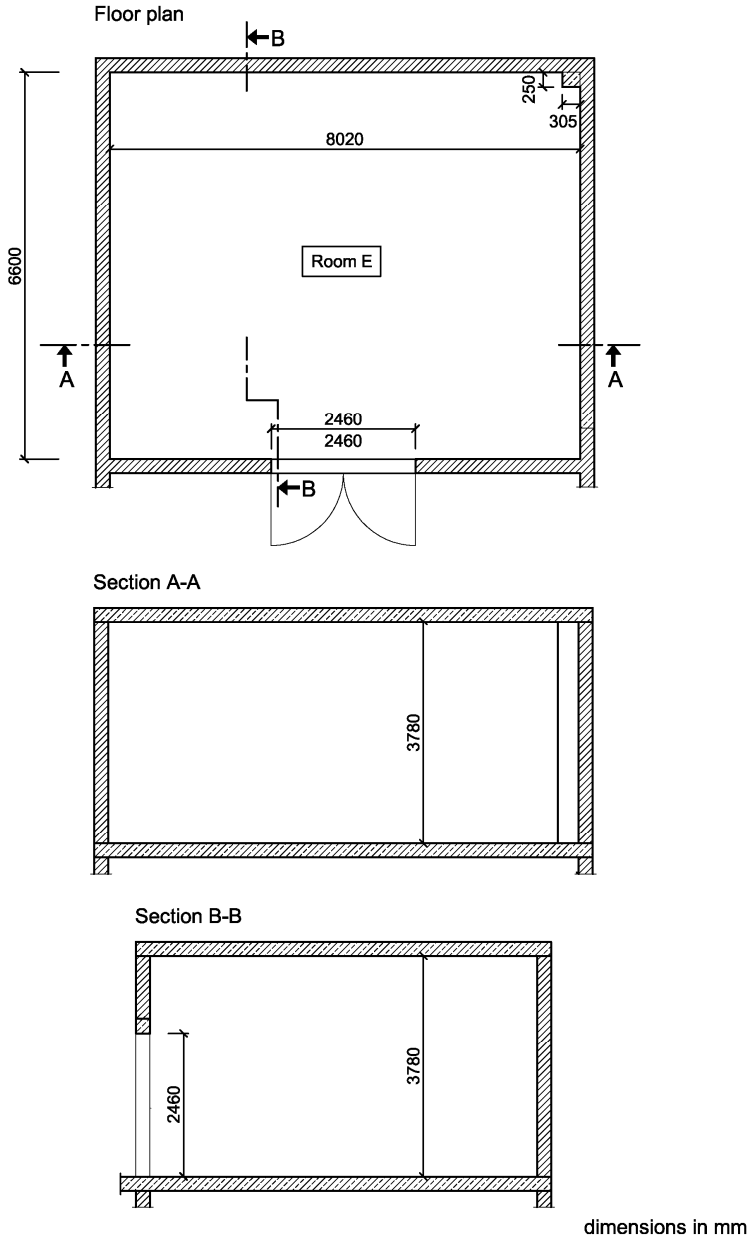

Figure C.1. Plan view and sections of the reverberation room.

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2.2 Measurement of reverberation time

The determination of the impulse responses was 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)**
100	5.40	5.02
125	5.84	4.89
160	5.64	4.47
200	5.22	3.84
250	5.35	3.64
315	5.27	3.26
400	5.26	3.05
500	5.37	2.84
630	5.23	2.81
800	4.98	2.71
1000	5.03	2.87
1250	5.02	2.81
1600	4.92	2.71
2000	4.62	2.58
2500	3.90	2.31
3150	3.20	2.01
4000	2.48	1.69
5000	1.95	1.43

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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	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
Electronic balance	Kern	DE120K10N	WD200002751

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