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M146189/14 Version 1 MSG/STEG

## **Fabric art.-no. 10935, Zimmer + Rohde GmbH**

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

**Test Report No. M146189/14**

Client:	Zimmer + Rohde GmbH Zimmermühlenweg 14-18 61440 Oberursel Germany
Consultant:	M. Eng. Philipp Meistring
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**Table of contents**

<b>1</b>	<b>Task</b>	<b>3</b>
<b>2</b>	<b>Basis</b>	<b>3</b>
<b>3</b>	<b>Test object and test assembly</b>	<b>4</b>
<b>4</b>	<b>Execution of the measurements</b>	<b>5</b>
<b>5</b>	<b>Evaluation</b>	<b>5</b>
<b>6</b>	<b>Measurement results</b>	<b>5</b>
<b>7</b>	<b>Remarks</b>	<b>6</b>

Appendix A: Test certificate

Appendix B: Photographs

Appendix C: Description of test method,  
test facility and test equipment

## 1 Task

On behalf of the company Zimmer + Rohde GmbH, 61440 Oberursel, Germany, the sound absorption of the fabric art.-no. 10935 was to be measured according to DIN EN ISO 354 [1] in the reverberation room. The fabric was tested as a pleated curtain with 100 % fullness and with a distance of 100 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] 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 manufacturer as follows:

- Zimmer + Rohde GmbH fabric art.-no. 10935
- material 100 % PES FR

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 mm<sup>2</sup>):  $t = 1.22 \text{ mm}$
- area specific mass:  $m'' = 347 \text{ g/m}^2$
- airflow resistance acc. to DIN EN ISO 9053-1 [6]:  $R_S = 367 \text{ Pa s/m}$

#### 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 mounting details are as follows:

- curtain arrangement following type G-100 acc. to DIN EN ISO 354
- arranged as pleated curtain with 100 % fullness hanging in front of a reflecting wall
- clear distance to the wall 100 mm, construction without enclosing frame
- fixed directly underneath the ceiling, suspended from a metal rail, height of the rail 90 mm, overlap of the fabric at the rail 60 mm
- test set-up made of five webs, four webs 1.42 m x 3.00 m and one web 1.42 m x 2.70 m, 20 mm overlap at curtain splices
- total dimensions of the test surface (starting at the lower border of the metal rail): width x height = 3.50 m x 2.94 m, less 0.70 m x 0.30 m (for one web with lower height)
- total test surface  $S = 10.08 \text{ m}^2$

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

## 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  $\alpha_s$  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  $\alpha_p$  in octave bands
- Weighted sound absorption coefficient  $\alpha_w$  as single value

The weighted sound absorption coefficient  $\alpha_w$  is determined from the practical sound absorption coefficients  $\alpha_p$  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  $\alpha_s$  in one-third octave bands, the practical sound absorption coefficients  $\alpha_p$  in octave bands and the single values  $\alpha_w$ , *NRC* and *SAA* are indicated in the test certificates 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 objects and conditions described.



M. Eng. Philipp Meistring  
(Project Manager)

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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:** Zimmer + Rohde GmbH  
Zimmermühlenweg 14-18, 61440 Oberursel, Germany

**Test specimen:** Fabric art.-no. 10935,  
pleated curtain with 100 % fullness, 100 mm wall distance

**Material details**

*Information provided by the client:*

- fabric art.-no. 10935,
- material 100 % PES FR

*Properties determined by the testing laboratory*

- area specific mass  $m'' = 347 \text{ g/m}^2$
- airflow resistance  $R_S = 367 \text{ Pa s/m}$
- thickness  $t = 1.22 \text{ mm}$

**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
- test set-up made of five webs, four webs 1.42 m x 3.00 m and one web 1.42 m x 2.70 m, 20 mm overlap at curtain splices
- test surface width x height = 3.50 m x 2.94 m, less 0.70 m x 0.30 m for one web with reduced height, (dimensions starting at the lower edge of the metal rail)

Room: Reverberation Room

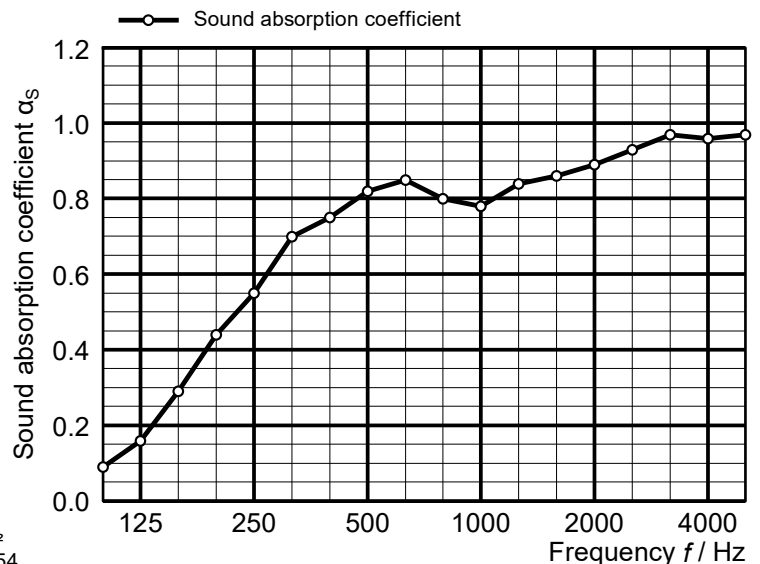
Volume: 199.60 m<sup>3</sup>

Size: 10.08 m<sup>2</sup>

Date of test: 2022-04-21

	$\theta$ [°C]	r. h. [%]	B [kPa]
without specimen	21.2	32.2	94.1
with specimen	21.2	31.9	94.1

Frequency [Hz]	$\alpha_s$ 1/3 octave	$\alpha_p$ octave
100	0.09	
125	0.16	0.20
160	0.29	
200	0.44	
250	0.55	0.55
315	0.70	
400	0.75	
500	0.82	0.80
630	0.85	
800	0.80	
1000	0.78	0.80
1250	0.84	
1600	0.86	
2000	0.89	0.90
2500	0.93	
3150	0.97	
4000	0.96	0.95
5000	0.97	



◦ Equivalent sound absorption area less than 1.0 m<sup>2</sup>  
 $\alpha_s$  Sound absorption coefficient according to ISO 354  
 $\alpha_p$  Practical sound absorption coefficient according to ISO 11654

<p>Rating according to ISO 11654:  <b>Weighted sound absorption coefficient</b>  <math>\alpha_w = 0.80 (H)</math>                  Sound absorption class: B</p>	<p>Rating according to ASTM C423:  <b>Noise Reduction Coefficient NRC = 0.75</b>  <b>Sound Absorption Average SAA = 0.77</b></p>
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**Fabric art.-no. 10935, Zimmer + Rohde GmbH**

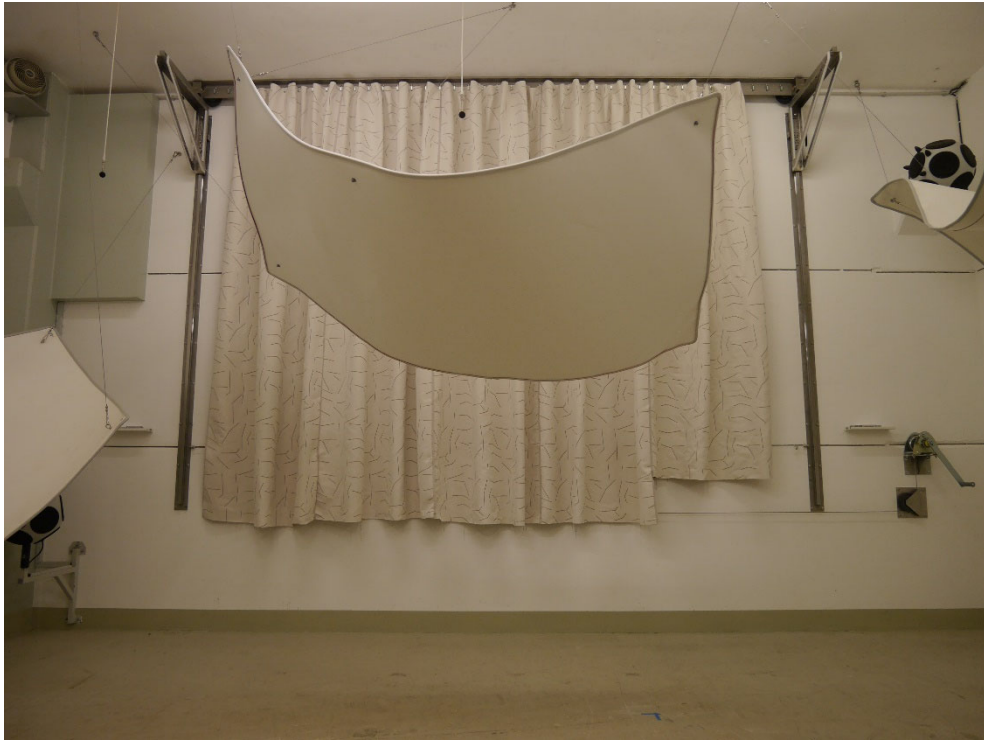


Figure B.1. Test object mounted in the reverberation room, frontal view.



Figure B.2. Test object mounted 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  $\alpha$  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:

- $\alpha_S$  sound absorption coefficient;
- $A_T$  equivalent sound absorption area of the test object in m<sup>2</sup>;
- $S$  area covered by the test object in m<sup>2</sup>;
- $V$  volume of the reverberation room in m<sup>3</sup>;
- $c_1$  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<sup>-1</sup>;
- $m_2$  power attenuation coefficient in the reverberation room with test object in m<sup>-1</sup>.

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 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  $\alpha_w$  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  $\alpha_w$ .

## 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  $V = 199.6 \text{ m}^3$  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.

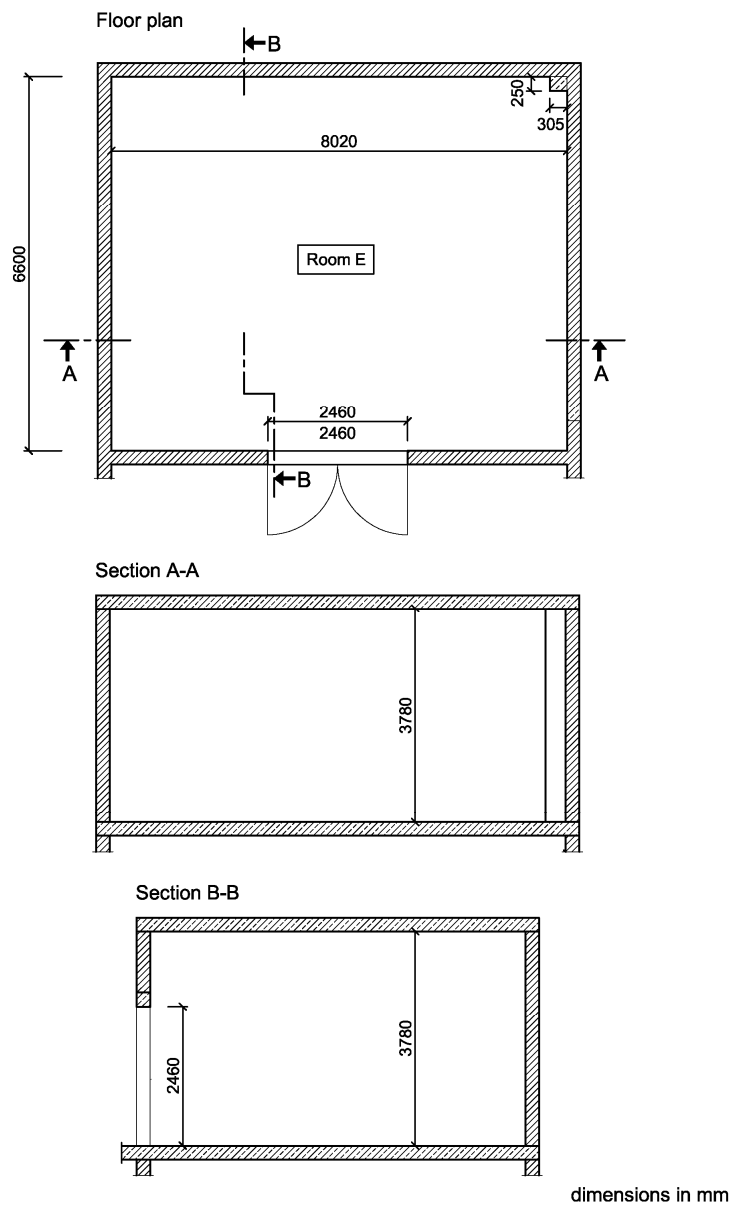


Figure C.1. Plan view and sections of the reverberation room.

## 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.

Frequency in Hz	Reverberation time $T$ in s	
	$T_1$ (without test object)	$T_2$ (with test object)
100	5.57	4.79
125	6.03	4.61
160	6.37	4.03
200	5.29	3.05
250	5.83	2.89
315	5.68	2.53
400	5.81	2.46
500	5.76	2.32
630	5.47	2.23
800	5.09	2.24
1000	5.17	2.29
1250	5.14	2.19
1600	4.93	2.12
2000	4.52	1.99
2500	3.70	1.77
3150	2.90	1.54
4000	2.20	1.32
5000	1.67	1.10

## 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	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
Measurement system airflow resistance	Müller-BBM	M89319-00	315003
Software for measurement and evaluation of airflow resistance	Müller-BBM Acoustic Solution	m ars	Version 1.14.7256. 28813
Thickness gauge	Hans Schmidt & Co GmbH	D-2000-C0913	2985
Digital measuring slide	Mitutoyo	CD-15PPR	07019377
Electronic balance	Kern	KB1200-2N	W1402353