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Curtain type
STAGE VELVET PUCCINI,
Manufacturer Tüchler,
flat and pleated arrangement

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

Test Report No. M77692/31

Client:	TÜCHLER Bühnen- & Textiltechnik GmbH Rennbahnweg 78 1220 Wien Austria
Consultant:	Dr.-Ing. Andreas Meier Jan-Lieven Moll
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Table of contents

1	Task	3
2	Basis	3
3	Test object and test assembly	4
3.1	Test object	4
3.2	Test assembly	4
4	Execution of the measurements	5
5	Evaluation	5
6	Measurement results	5
7	Remarks	6

Appendix A: Test certificates

Appendix B: Figures

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

1 Task

On behalf of the company TÜCHLER Bühnen- & Textiltechnik GmbH the sound absorption of the curtain type "STAGE VELVET PUCCINI" 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 100 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: STAGE VELVET PUCCINI
- material composition: 100% Cotton

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): $t = 1.76 \text{ mm}$
- area specific mass: $m'' = 486 \text{ g/m}^2$
- specific airflow resistance
acc. to DIN EN ISO 9053-1 [6]: $R_s = 4782 \text{ Pa} \cdot \text{s/m}$

3.2 Test assembly

The installation of the test object was carried out at the reverberation room by employees of the test laboratory.

The test assemblies were made following mounting type G-100 according to DIN EN ISO 354 [1], annex B.5. The mounting details of the test set-ups are as follows:

- curtain webs fixed to a metal rail that was placed directly at the ceiling of the reverberation room, the height of the rail was 90 mm, the fabric was fixed at the rail with 60 mm overlap
- single webs arranged with 20 mm fabric overlap at vertical curtain splices and pleated with 100 % fullness
- test set-up with free curtain edges at sides and at bottom (no enclosing frame)

Testing was done in the test-assemblies as listed in Table 1.

Table 1. Overview of the tested curtain assemblies.

Test certificate Appendix A, page	Clear distance to the reflective wall (at fixing rail)	Drapery	Fabric dimensions $W \times H$	Dimensions of test surface (from lower border of the rail) $W \times H = S$
1	100 mm	Flat curtain	1 web 3.76 m x 2.83 m	3,76 m x 2,77 m = 10,41 m ²
2	100 mm	Pleated curtain, 100 % fullness	2 webs 3.76 m x 2.83 m	3,75 m x 2,77 m = 10,39 m ²

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

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 5.000 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 4.000 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, 1.000 Hz and 2.000 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 2.500 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* und *SAA*) are indicated in the test certificates in Appendix A.

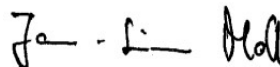
Information on the uncertainty of measurement is given in Annex C. When assigning the absorption group, the measurement uncertainty was not taken into account in accordance with DIN EN ISO 11654 [2].

7 Remarks

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



Dr.-Ing. Andreas Meier
(Project Manager)



Jan-Lieven Moll
(Responsible)

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

Test specimen: STAGE VELVET PUCCINI, , type G-100, flat arrangement

Curtain fabric:

Indications from the client

- description STAGE VELVET PUCCINI

- material 100 % Cotton

Indications from the testing laboratory

- area specific mass $m'' = 486 \text{ g/m}^2$
- airflow resistance $R_s = 4782 \text{ Pa s/m}$
- thickness $t = 1,76 \text{ mm}$

Test arrangement:

- type G-100 mounting acc. to DIN EN ISO 354
- arranged as a flat curtain 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 50 mm), distance to the back wall 100 mm
- construction without enclosing frame
- arranged as ready-to-use curtain 3760 mm x 2830 mm, top edge reinforced with webbing and eyelets every 10 cm
- test surface width x height = 3,76 m x 2,77 m (starting at the lower edge of the ceiling rail)

Room: E

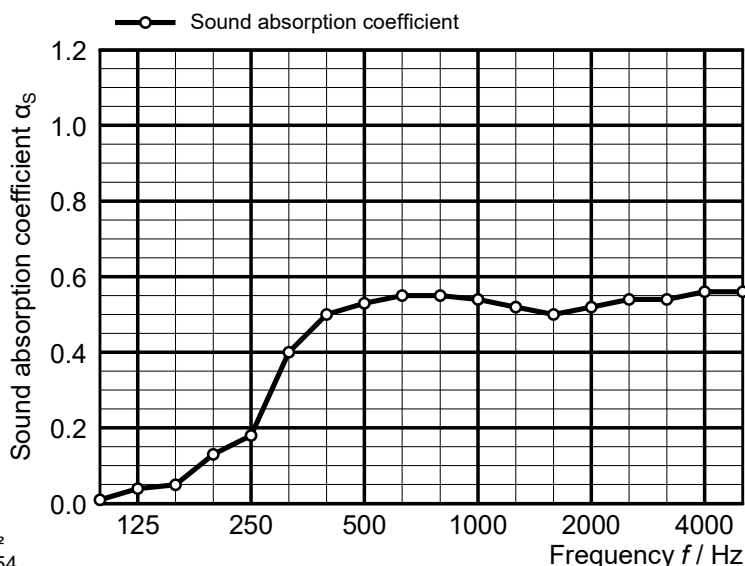
Volume: 199.60 m³

Size: 10.41 m²

Date of test: 2021-11-02

	θ [°C]	$r. h.$ [%]	B [kPa]
without specimen	21.0	39.7	93.8
with specimen	21.0	39.7	93.8

Frequency [Hz]	α_s 1/3 octave	α_p octave
100	0.01	0.05
125	0.04	
160	0.05	
200	0.13	0.25
250	0.18	
315	0.40	
400	0.50	0.55
500	0.53	
630	0.55	
800	0.55	0.55
1000	0.54	
1250	0.52	
1600	0.50	0.50
2000	0.52	
2500	0.54	
3150	0.54	0.55
4000	0.56	
5000	0.56	



◦ 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
 $\alpha_w = 0.50$
Sound absorption class: D

Rating according to ASTM C423:
Noise Reduction Coefficient $NRC = 0.45$
Sound Absorption Average $SAA = 0.45$

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Planegg, 2021-11-05

No. of test report M77 692/31

X. Heier

Appendix A
Page 1

Sound absorption coefficient ISO 354

Measurement of sound absorption in reverberation rooms

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

Test specimen: STAGE VELVET PUCCINI, type G-100, pleated arrangement with 100 % fullness

Curtain fabric:

Indications from the client

- description STAGE VELVET PUCCINI

- material 100 % Cotton

Indications from the testing laboratory

- area specific mass $m'' = 486 \text{ g/m}^2$

- airflow resistance $R_s = 4782 \text{ Pa s/m}$

- thickness $t = 1,76 \text{ mm}$

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

- construction without enclosing frame

- two curtain webs, fabric dimensions each 3760 mm x 2830 mm, with 20 mm overlap at vertical web joint

- top edge reinforced with webbing and eyelets every 10 cm

- test surface width x height = 3,75 m x 2,77 m (starting at the lower edge of the ceiling rail)

Room: E

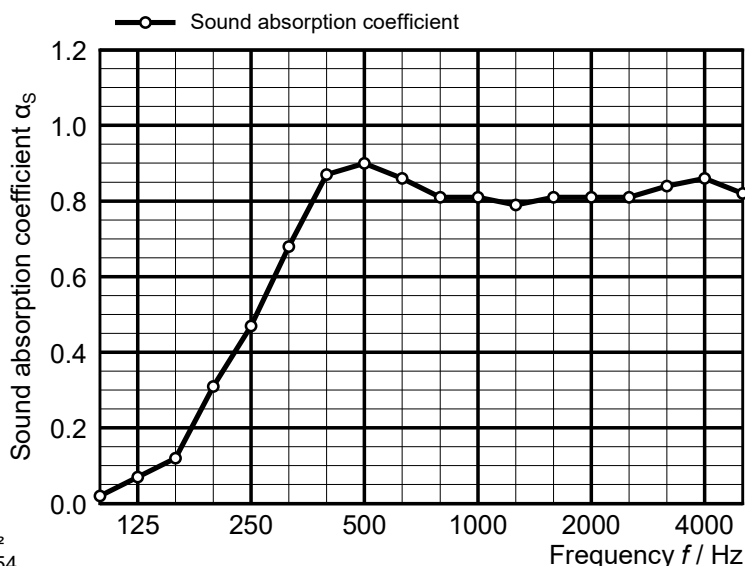
Volume: 199.60 m³

Size: 10.39 m²

Date of test: 2021-11-02

	θ [°C]	$r. h.$ [%]	B [kPa]
without specimen	21.0	39.7	93.8
with specimen	21.1	39.8	93.8

Frequency [Hz]	α_s 1/3 octave	α_p octave
100	0.02	0.05
125	0.07	
160	0.12	
200	0.31	0.50
250	0.47	
315	0.68	
400	0.87	0.90
500	0.90	
630	0.86	
800	0.81	0.80
1000	0.81	
1250	0.79	
1600	0.81	0.80
2000	0.81	
2500	0.81	
3150	0.84	0.85
4000	0.86	
5000	0.82	



◦ 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
 $\alpha_w = 0.80$
Sound absorption class: B

Rating according to ASTM C423:
Noise Reduction Coefficient $NRC = 0.75$
Sound Absorption Average $SAA = 0.74$

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No. of test report M77 692/31

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Appendix A

Page 2

Curtain fabric STAGE VELVET PUCCINI, company TÜCHLER



Figure B.1. Flat hanging curtain in the reverberation room: frontal view.

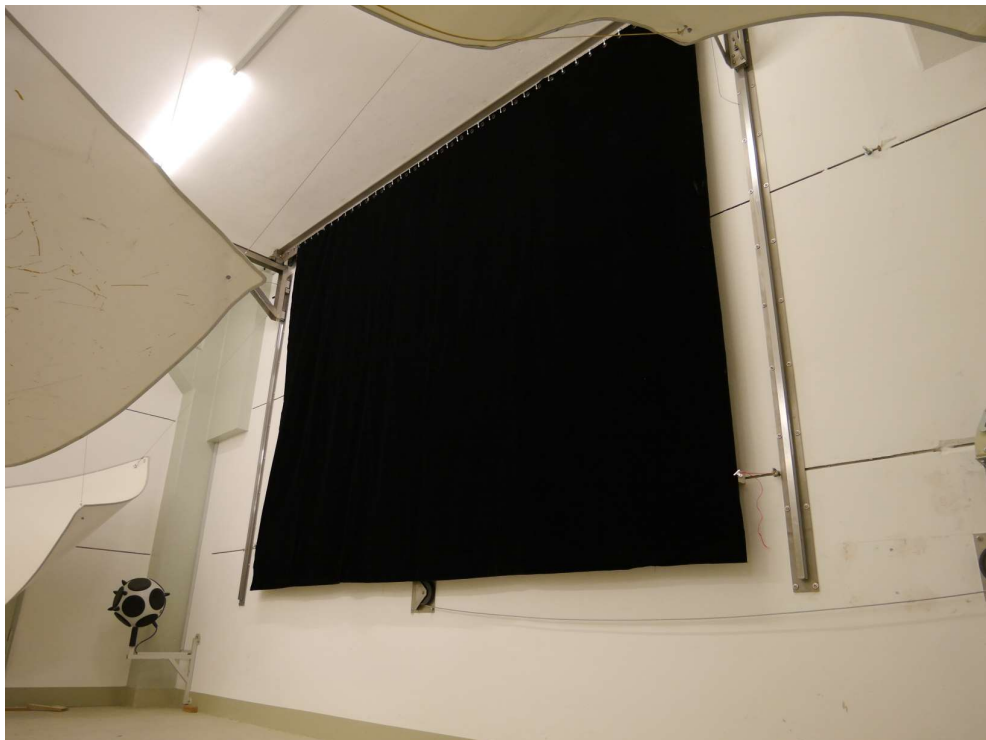


Figure B.2. Flat hanging curtain in the reverberation room: diagonal view.

Curtain fabric STAGE VELVET PUCCINI, company TÜCHLER



Figure B.3. Pleated hanging curtain, 100 % fullness in the reverberation room: frontal view.



Figure B.4. Pleated hanging curtain, 100 % fullness in the reverberation room: diagonal view.

Description of the test procedure for the determination of the sound absorption in a reverberation room

1 Measurand sound absorption coefficient

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 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 power attenuation coefficient was calculated 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 $V = 199.6 \text{ m}^3$ 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.

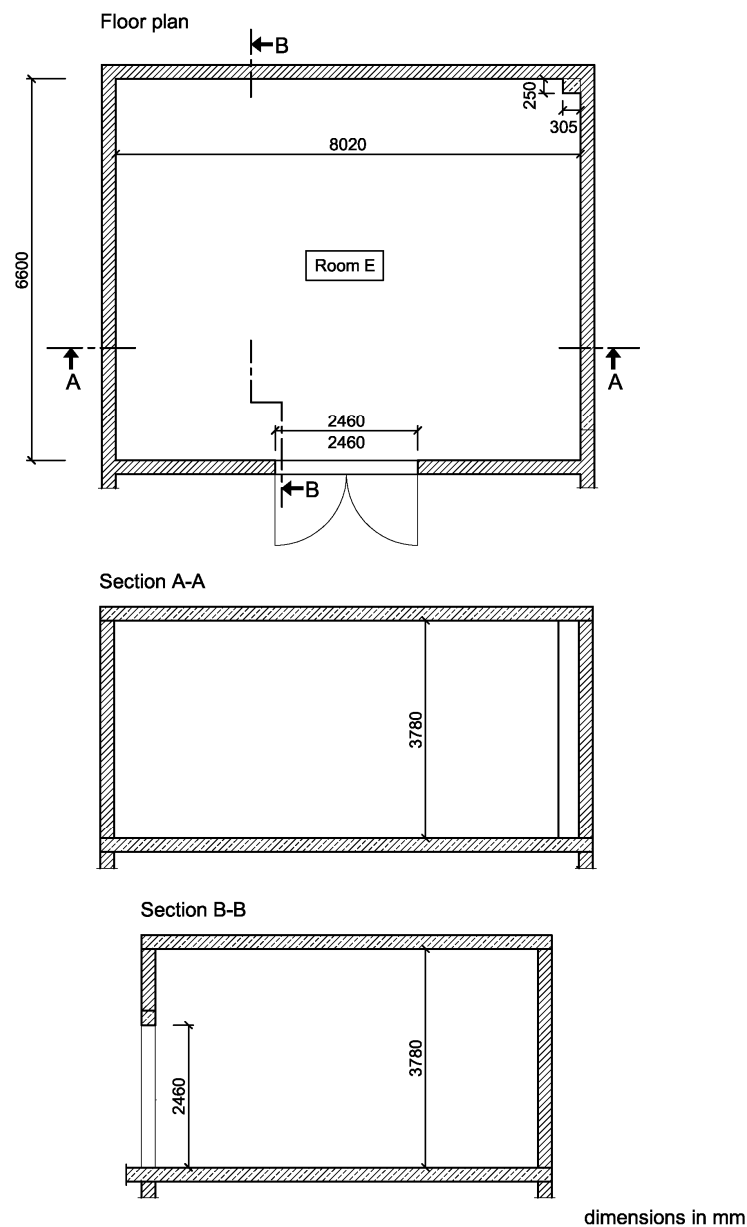


Figure C.1. Plan view and sections of the reverberation room.

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 the backward integrated impulse response.

The determined reverberation times are indicated in Table C.1.

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

Frequency in Hz	Reverberation time T in s		
	T_1 (without test object)	T_2 (with test object)	
	Appendix A, pages 1-2	Appendix A, page 1	Appendix A, page 2
100	5,37	5,31	5,15
125	6,39	5,86	5,61
160	6,19	5,63	4,98
200	5,77	4,62	3,66
250	5,78	4,33	3,06
315	5,76	3,30	2,54
400	5,84	2,99	2,21
500	5,72	2,88	2,15
630	5,42	2,75	2,16
800	5,07	2,66	2,18
1000	5,22	2,73	2,21
1250	5,29	2,81	2,25
1600	5,12	2,81	2,19
2000	4,75	2,65	2,12
2500	3,98	2,34	1,95
3150	3,19	2,05	1,71
4000	2,48	1,71	1,47
5000	1,94	1,44	1,29

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 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
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
Electronic balance	Kern	KB1200-2N	W1402353