

Müller-BBM GmbH  
Robert-Koch-Str. 11  
82152 Planegg bei München

Telephone +49(89)85602 0  
Telefax +49(89)85602 111

www.MuellerBBM.com

M. Eng. Philipp Meistring  
Telephone +49(89)85602 228  
Philipp.Meistring@mbbm.com

2014-10-27  
M76176/13 MSG/JRE

**Curtain fabric OXFORD  
gathered (fabric addition 100 %)  
Manufacturer Delius**

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

**Test Report No. M76176/13**

Client:	Delius GmbH Goldstraße 16 – 18 33602 Bielefeld Germany
Consultant:	M. Eng. Philipp Meistring
Date of report:	2014-10-27
Delivery date of test object:	2014-10-21
Date of test:	2014-10-24
Total number of pages:	In total 12 pages, thereof 6 pages text part, 1 page Appendix A, 1 page Appendix B and 4 pages Appendix C.

Certified quality management system according to ISO 9001  
Accredited testing laboratory according to ISO/IEC 17025

Müller-BBM GmbH  
HRB Munich 86143  
VAT Reg. No. DE812167190

Managing directors:  
Joachim Bittner, Walter Grotz,  
Dr. Carl-Christian Hantschk, Stefan Schierer,  
Elmar Schröder, Norbert Suritsch

**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 objects and test assembly</b>	<b>4</b>
3.1	Test object	4
3.2	Test assembly	4
<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: Figures

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

## 1 Task

On behalf of the company Delius GmbH, 33602 Bielefeld, Germany, the sound absorption of a curtain fabric (gathered with fabric addition of 100 %) type OXFORD was to be determined by measurements in the reverberation room according to EN ISO 354 [1]. The fabric was arranged with a distance to the reflecting wall of 100 mm.

The results are to be evaluated according to EN ISO 11654 [2] and ASTM C 423-09a [4].

## 2 Basis

This test report is based on the following documents:

- [1] EN ISO 354: Acoustics - Measurement of sound absorption in a reverberation room. 2003-05
- [2] EN ISO 11654: Acoustics – Sound absorbers for use in buildings – Rating of sound absorption. 1997-04
- [3] ISO 9613-1: Acoustics; Attenuation of sound during propagation outdoors; part 1: calculation of the absorption of sound by the atmosphere. 1993-06
- [4] ASTM C 423-09a: Standard Test Method for Sound Absorption and Sound Absorption Coefficients by the Reverberation Room Method. Revision: 09a. 2009-10
- [5] EN 29053 “Acoustics – Materials for acoustical applications – Determination of airflow resistance”. 1993-03

### 3 Test objects and test assembly

#### 3.1 Test object

The tested material is described as follows by the manufacturer:

- curtain fabric OXFORD, article No. 26944, color No. 1003
- material: 100 % wool
- area specific mass  $m'' = 390 \text{ g/m}^2$

The following parameters were determined by the testing laboratory:

- thickness: 1.28 mm
- specific airflow resistance  
acc. to EN 29053 [5]:  $R_s = 676 \text{ Pa} \cdot \text{s/m}$

The determination of the airflow resistance was effected according to EN 29053 [5].

By the manufacturer a factory-made ready-for-use curtain was delivered:

- width 3500 mm (addition 100% - width of fabric 7000 mm)
- height 2950 mm
- edging: at the bottom 100 mm hem (with inserted lead tape 50 g/m),  
20 mm lateral hem  
at the top universal curtain tape with plastic curtain sliders

#### 3.2 Test assembly

According to the client's specification the test assembly was effected according to EN ISO 354 [1], section 6.2.1 and Appendix B mounting type G-100.

Test objects were assembled in the reverberation room by employees of the testing laboratory.

By means of curtain sliders the curtain was fixed on a curtain rail with 100 mm distance to the wall of the reverberation room. The curtain rail was mounted parallel to the wall on the ceiling of the reverberation room with a wall distance of 100 mm. The curtain was arranged with the visible side facing the reverberation room.

There was no lateral enclosing frame.

The test surface was dimensioned width x height = 3500 mm x 2950 mm.

Further information on the test build-ups are presented in the test certificate in Appendix A and the figures in Appendix B.

## 4 Execution of the measurements

The measurements were effected according to EN ISO 354 [1].

The test method, the test facility and the test equipment used 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 EN ISO 354 [1].

In addition to the sound absorption coefficients the following characteristic values were determined according to 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 423-09a [4] 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 200 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 certificate in Appendix A.

## 7 Remarks

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



M. Eng. Philipp Meistring

This test report may only be published, shown or copied as a whole, including its appendices. The publishing of excerpts is only possible with prior consent of Müller-BBM.



Durch die DAKkS Deutsche Akkreditierungsstelle GmbH  
nach DIN EN ISO/IEC 17025 akkreditiertes Prüflaboratorium.  
Die Akkreditierung gilt für die in der Urkunde aufgeführten Prüfverfahren.

# Sound absorption coefficient ISO 354

## Measurement of sound absorption in reverberation rooms

**Client:** Delius GmbH, Goldstraße 16 - 18, 33602 Bielefeld, Germany  
**Test specimen:** Curtain OXFORD  
 distance to the wall 100 mm, gathered with 100 % fabric addition

**Curtain fabric:**

- manufacturer Delius
- curtain fabric type OXFORD, article No. 26944, color No. 1003 (manufacturer's specification)
- material 100 % wool (manufacturer's specification)
- area specific mass  $m'' = 390 \text{ g/m}^2$  (manufacturer's specification)
- air flow resistance  $R_S = 676 \text{ Pa s/m}$
- thickness  $t = 1.28 \text{ mm}$

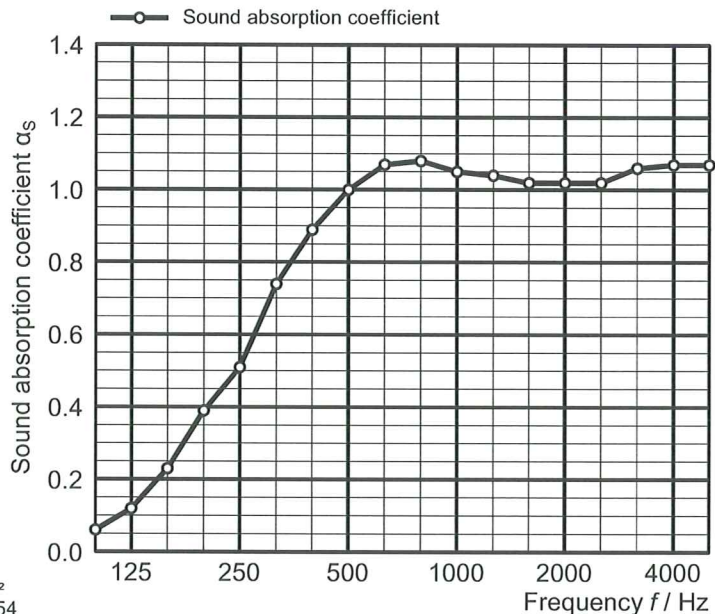
**Test arrangement:**

- hangig in front of a reflecting wall in a distance to the wall of 100 mm
- fixed to a curtain rail (U-profile) by means of curtain sliders
- test arrangement without enclosing frame
- curtain  $W \times H = 7000 \text{ mm} \times 3000 \text{ mm}$
- mounted gathered with fabric addition of 100 %
- dimensions of the test surface  $W \times H = 3500 \text{ mm} \times 2950 \text{ mm}$

Room: E  
 Volume: 199.60 m<sup>3</sup>  
 Size: 10.33 m<sup>2</sup>  
 Date of test: 2014-10-24

	$\theta$ [°C]	r. h. [%]	$B$ [kPa]
without specimen	20.0	44.2	95.7
with specimen	20.1	44.9	95.7

Frequency [Hz]	$\alpha_s$ 1/3 octave	$\alpha_p$ octave
100	0.06	
125	0.12	0.15
160	0.23	
200	0.39	
250	0.51	0.55
315	0.74	
400	0.89	
500	1.00	1.00
630	1.07	
800	1.08	
1000	1.05	1.00
1250	1.04	
1600	1.02	
2000	1.02	1.00
2500	1.02	
3150	1.06	
4000	1.07	1.00
5000	1.07	



◦ 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

Rating according to ISO 11654: <b>Weighted sound absorption coefficient</b> $\alpha_w = 0.85 (H)$ Sound absorption class: B	Rating according to ASTM C423: <b>Noise Reduction Coefficient <math>NRC = 0.90</math></b> <b>Sound Absorption Average <math>SAA = 0.90</math></b>
--	---

**MÜLLER-BBM**

Planegg, 2014-10-27  
 No. of test report M76 176/13

Appendix A  
 Page 1

**Curtain fabric OXFORD gathered (fabric addition 100 %)  
Manufacturer Delius**

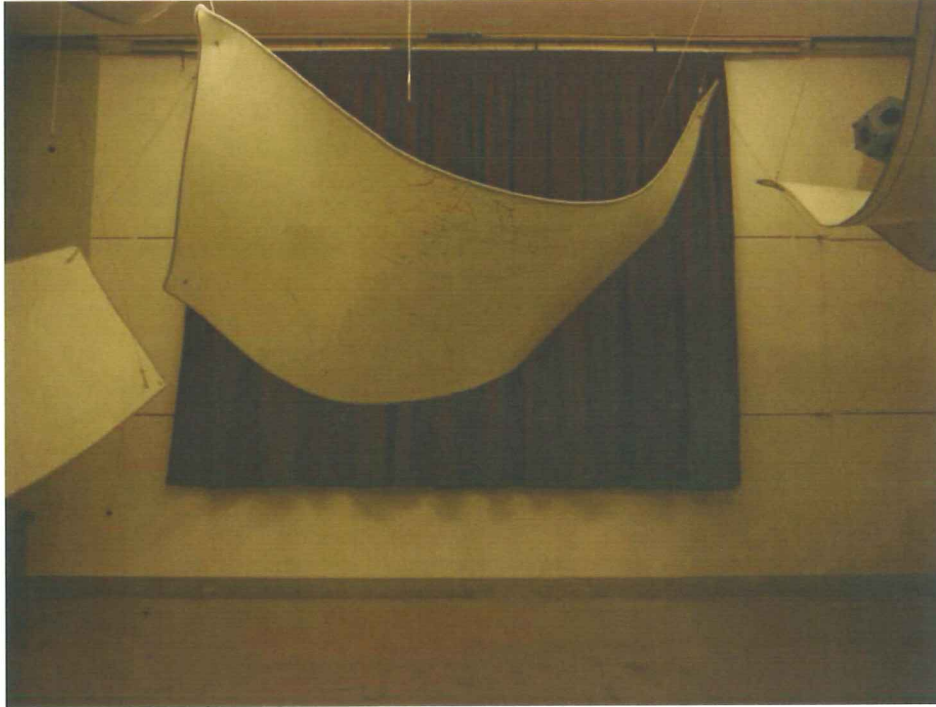


Figure B.1. Test arrangement in the reverberation room (total view).



Figure B.2. Test arrangement in the reverberation room (diagonal view).



## 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  $m^2$ ;
- $S$  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  $m^{-1}$ .

As area of the test object the area covered by the test object was used.

The different dissipation during the sound propagation in the air was taken into account according to paragraph 8.1.2 of EN ISO 354 [1]. The dissipation was calculated according to ISO 9613-1 [3]. 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 EN ISO 354 [1].

## 2 Test procedure

### 2.1 Description of the reverberation room

The reverberation room complies with the requirements according to 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.

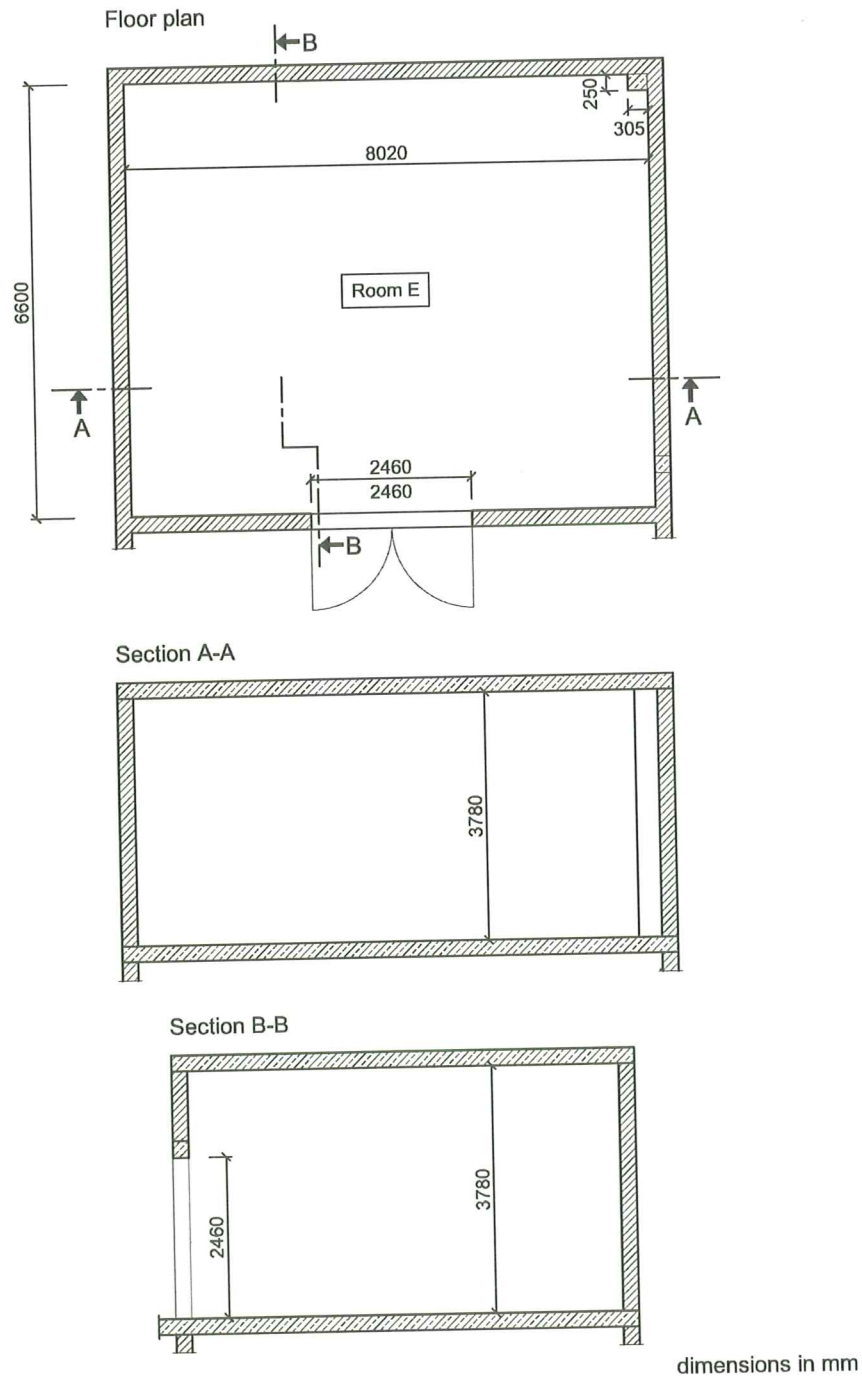


Figure C.1. Plan view and sections of the reverberation room.

S:\MIProj\076M76176\M76176\_13\_PBE\_1E.DOC : 25. 11. 2014

## 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 EN ISO 354 [1], using a linear regression for the calculation of the reverberation time  $T_{20}$  from the level of the a 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 $f$ / Hz	Reverberation time $T$ / s	
	$T_1$ (without test object)	$T_2$ (with test object)
100	4.74	4.32
125	4.81	4.04
160	5.38	3.85
200	5.51	3.27
250	5.12	2.78
315	5.14	2.31
400	5.36	2.11
500	5.35	1.96
630	5.16	1.86
800	4.96	1.82
1000	5.21	1.89
1250	5.38	1.93
1600	5.23	1.93
2000	4.72	1.86
2500	4.07	1.75
3150	3.30	1.56
4000	2.54	1.36
5000	1.94	1.17

### 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.
Sound card	RME	Multiface II	22460388
Amplifier	APart	Champ One	09070394
Dodecahedron	Müller-BBM	DOD130B	265201
Dodecahedron	Müller-BBM	DOD130B	265202
Dodecahedron	Müller-BBM	DOD130B	265203
Dodecahedron	Müller-BBM	DOD130B	265204
Microphone	Microtech	M360	1783
Microphone	Microtech	M360	1785
Microphone	Microtech	M360	1786
Microphone	Microtech	M360	1787
Microphone	Microtech	M360	1788
Microphone	Microtech	M360	1789
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 1.7