

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

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

www.MuellerBBM.de

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

2013-09-17
M100827/21 MSG/MOL

Curtain fabric type Frost Manufacturer Kvadrat A/S

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

Test Report No. M100827/21

| | |
|--------------------------------|--|
| Client: | Kvadrat A/S Lundbergsvej 10 DK – 8400 Ebeltoft |
| Consultant: | M.Eng. Philipp Meistring Jan-Lieven Moll |
| Date of report: | 2013-09-17 |
| Delivery date of test objects: | 2013-08-23 |
| Date of measurements: | 2013-09-05/ 2013-09-10 |
| Total number of pages: | In total 14 pages: 6 pages text, 2 pages Appendix A, 1 page Appendix B, 1 page Appendix C and 4 pages Appendix D. |

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: Horst Christian Gass,
Dr. Carl-Christian Hantschk, Stefan Schierer,
Dr. Edwin Schorer, Norbert Suritsch

Table of contents

| | | |
|----------|---------------------------------------|----------|
| 1 | Task | 3 |
| 2 | Basis | 3 |
| 3 | Test object and test assembly | 3 |
| 3.1 | Test object | 3 |
| 3.2 | Test assembly | 4 |
| 4 | Execution of the measurements | 5 |
| 5 | Evaluation | 5 |
| 6 | Measurement results | 6 |
| 7 | Remarks | 6 |
| 1 | Measurand | 1 |
| 2 | Test procedure | 1 |
| 2.1 | Description of the reverberation room | 1 |
| 2.2 | Measurement of reverberation time | 3 |
| 2.3 | List of test equipment | 4 |

Appendix A: Test certificates

Appendix B: Photographs

Appendix C: Drawings

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

1 Task

On behalf of the company Kvadrat A/S, DK – 8400 Ebeltoft, the sound absorption of the curtain fabric type Frost had to be measured according to EN ISO 354 [1] in the reverberation room. The fabric was tested in a flat and a folded arrangement with a distance of 100 mm to the reflective wall.

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. June 1993
- [4] ASTM C 423-09a: Standard Test Method for Sound Absorption and Sound Absorption Coefficients by the Reverberation Room Method. Revision: 09a
- [5] EN 29053: Acoustics – Materials for acoustical applications – Determination of airflow resistance. March 1993

3 Test object and test assembly

3.1 Test object

The tested material is described by the manufacturer as follows:

- manufacturer Kvadrat A/S
- type Frost
- curtain fabric
- single layer, material 50 % Trevira CS, 50 % polyester FR

The testing laboratory has measured as follows:

- area specific mass: $m'' = 50.5 \text{ g/m}^2$
- thickness: $t = 0.13 \text{ mm}$
- air flow resistance acc. to EN 29053 [5]: $R_s < 10 \text{ Pa s/m}$

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 test object was installed in a flat (G-100) and a folded arrangement.

The mounting details are as follows:

- clear distance to the wall 100 mm, construction without enclosing frame
- fixed directly underneath the ceiling, suspended from a metal rail, height 50 mm

The mounting details for the tested arrangements are as follows:

a) flat arrangement G-100

- mounting type G-100 according to EN ISO 354 [1] section 6.2.1 and appendix B.5 of EN ISO 354 [1]
- arranged in 2 curtains (1 curtain width x height = 3.00 m x 3.00 m, 1 curtain width x height = 0.52 m x 3.00 m), overlapping approx. 20 mm
- total dimensions of the test surface (starting at the lower border of the metal rail): width x height = 3.50 m x 2.95 m
- total test surface $S = 10.33 \text{ m}^2$

b) folded arrangement

- 100 % folded as shown in Figures C.1 – C.2 in Appendix C
- arranged in 3 curtains (2 curtains width x height = 3.00 m x 3.00 m, 1 curtain width x height = 1.04 m x 3.00 m), overlapping approx. 20 mm
- total dimensions of the test surface (starting at the lower border of the metal rail): width x height = 3.50 m x 2.95 m
- total test surface $S = 10.33 \text{ m}^2$

The tested arrangements are indicated in Table 1.

Table 1. Test arrangements, fabric type Frost.

| Appendix A, page | Arrangement type |
|------------------|-------------------------------------|
| 1 | a) flat G-100 |
| 2 | b) 100 % folded, 100 mm distance |

The photographs in Appendix B and the drawings in Appendix C show details of the test arrangements.

4 Execution of the measurements

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

The test procedure, the test stand and the test equipment used for the measurements are described in Appendix D.

5 Evaluation

The sound absorption coefficient α_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 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 423-09a [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 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.

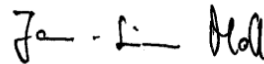
7 Remarks

The determined test results only refer to the test specimens and prevailing conditions on the day of measurements.

This test report may only be published and copied as a whole including all of its appendixes. The publishing of extracts requires the prior written consent of Müller-BBM GmbH.



M. Eng. Philipp Meistring



Jan-Lieven Moll



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: Kvadrat A/S
DK-8400 Ebeltøft

Test specimen: Fabric "Frost" Kvadrat A/S,
Mounting type G-100, flat arrangement

Material details

- manufacturer Kvadrat A/S
- curtain fabric type "Frost"
- single layer, material 50 % Trevira CS, 50 % polyester FR
- area specific mass app. $m'' = 50.5 \text{ g/m}^2$
- air flow resistance $R_s < 10 \text{ Pa s/m}$
- thickness $t = 0.13 \text{ mm}$

Tested construction

- 0.13 mm fabric "Frost"
- 100 mm air gap
- reflective wall

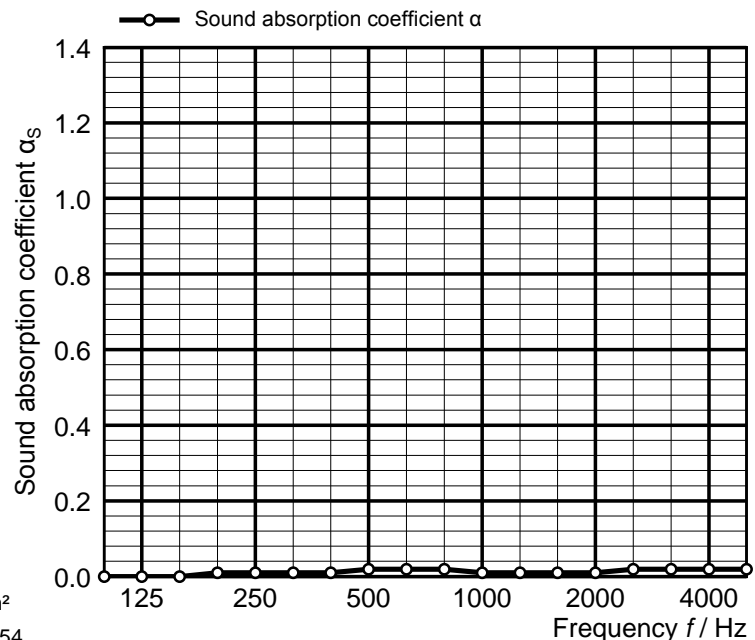
Mounting

- clear distance to the wall 100 mm, arranged without enclosing frame
- arranged flat in 2 curtains (1 curtain width 3000 mm, 1 curtain width 520 mm)
overlap 20 mm
- total dimensions of the test surface: width x height = 3.50 m x 2.95 m

Room: E
Volume: 199.60 m³
Size: 10.33 m²
Date of test: 2013-09-10

| | θ [°C] | r. h. [%] | B [kPa] |
|------------------|---------------|-----------|-----------|
| without specimen | 21.8 | 52.8 | 95.1 |
| with specimen | 21.9 | 52.6 | 95.1 |

| Frequency [Hz] | α_s 1/3 octave | α_p octave |
|----------------|-----------------------|-------------------|
| 100 | 0.00 | 0.00 |
| 125 | -0.00 | 0.00 |
| 160 | -0.00 | 0.00 |
| 200 | 0.01 | 0.00 |
| 250 | 0.01 | 0.00 |
| 315 | 0.01 | 0.00 |
| 400 | 0.01 | 0.00 |
| 500 | 0.02 | 0.00 |
| 630 | 0.02 | 0.00 |
| 800 | 0.02 | 0.00 |
| 1000 | 0.01 | 0.00 |
| 1250 | 0.01 | 0.00 |
| 1600 | 0.01 | 0.00 |
| 2000 | 0.01 | 0.00 |
| 2500 | 0.02 | 0.00 |
| 3150 | 0.02 | 0.00 |
| 4000 | 0.02 | 0.00 |
| 5000 | 0.02 | 0.00 |



◦ 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 $\alpha_w = 0.00$ Sound absorption class: not classified | Rating according to ASTM C423: Noise Reduction Coefficient $NRC = 0,00$ Sound Absorption Average $SAA = 0,01$ |
|---|---|

Sound absorption coefficient ISO 354

Measurement of sound absorption in reverberation rooms

Client: Kvadrat A/S
DK-8400 Ebeltøft

Test specimen: Fabric "Frost" Kvadrat A/S,
Mounting type G-100, folded arrangement

Material details

- manufacturer Kvadrat A/S
- curtain fabric type "Frost"
- single layer, material 50 % Trevira CS, 50 % polyester FR
- area specific mass app. $m'' = 50.5 \text{ g/m}^2$
- air flow resistance $R_S < 10 \text{ Pa s/m}$
- thickness $t = 0.13 \text{ mm}$

Tested construction

- 0.13 mm fabric "Frost"
- 100 mm air gap
- reflective wall

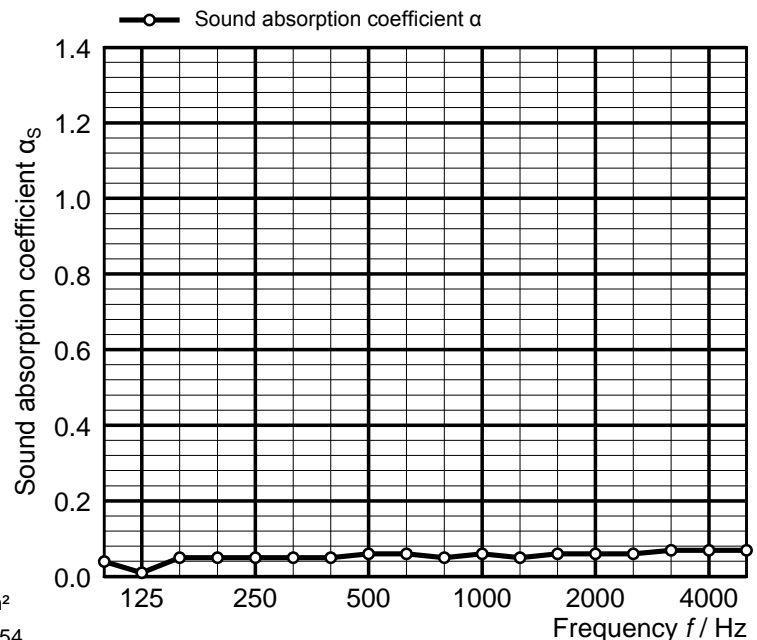
Mounting

- clear distance to the wall 100 mm, arranged without enclosing frame
- arranged folded (100 %) in 3 curtains (2 curtains width 3000 mm, 1 curtain width 1040 mm) overlap 20 mm
- total dimensions of the test surface: width x height = 3.50 m x 2.95 m

Room: E
Volume: 199.60 m³
Size: 10.33 m²
Date of test: 2013-09-05

| | θ [°C] | r. h. [%] | B [kPa] |
|------------------|---------------|-----------|-----------|
| without specimen | 22.2 | 55.0 | 95.1 |
| with specimen | 22.2 | 55.0 | 95.1 |

| Frequency [Hz] | α_s 1/3 octave | α_p octave |
|----------------|-----------------------|-------------------|
| 100 | 0.04 | 0.05 |
| 125 | 0.01 | 0.05 |
| 160 | 0.05 | 0.05 |
| 200 | 0.05 | 0.05 |
| 250 | 0.05 | 0.05 |
| 315 | 0.05 | 0.05 |
| 400 | 0.05 | 0.05 |
| 500 | 0.06 | 0.05 |
| 630 | 0.06 | 0.05 |
| 800 | 0.05 | 0.05 |
| 1000 | 0.06 | 0.05 |
| 1250 | 0.05 | 0.05 |
| 1600 | 0.06 | 0.05 |
| 2000 | 0.06 | 0.05 |
| 2500 | 0.06 | 0.05 |
| 3150 | 0.07 | 0.05 |
| 4000 | 0.07 | 0.05 |
| 5000 | 0.07 | 0.05 |



◦ 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

| | |
|--|--|
| <p>Rating according to ISO 11654: Weighted sound absorption coefficient $\alpha_w = 0.05$ Sound absorption class: not classified</p> | <p>Rating according to ASTM C423: Noise Reduction Coefficient $NRC = 0,05$ Sound Absorption Average $SAA = 0,06$</p> |
|--|--|

MÜLLER-BBM

Planegg, 2013-09-17

No. of test report M10 0827/2 *M. Müller*

Appendix A

Page 2

Curtain fabric type Frost, Manufacturer Kvadrat A/S



Figure B1. Flat arrangement: test object mounted in the reverberation room.

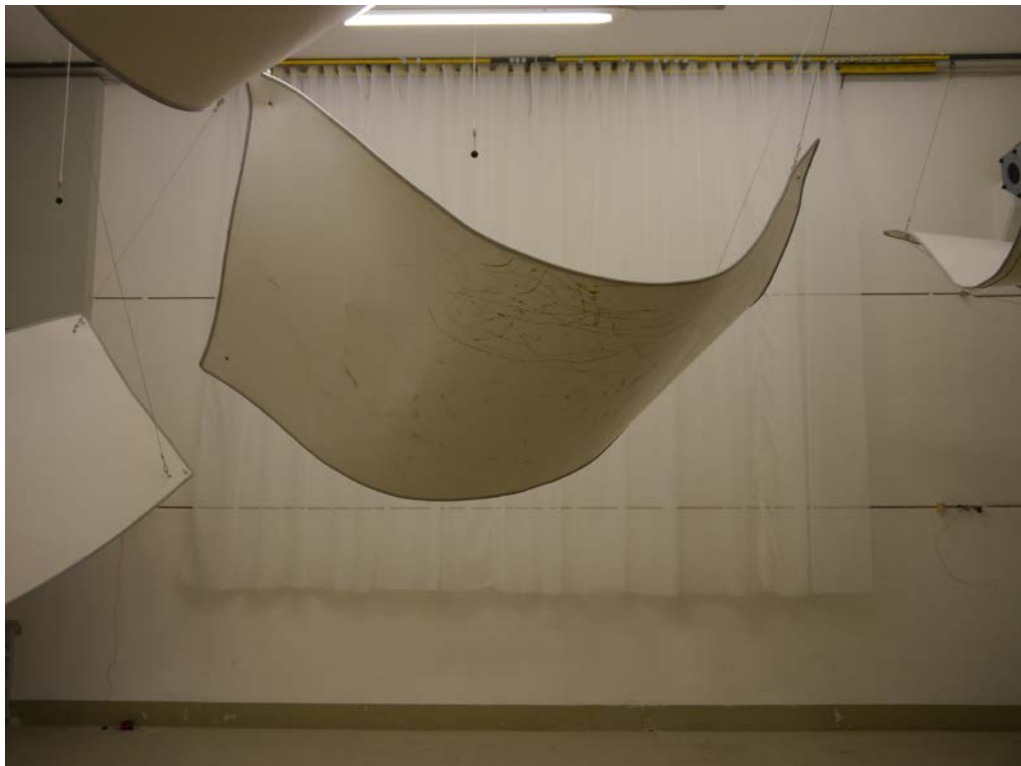


Figure B2. Folded arrangement: test object mounted in the reverberation room.

Curtain fabric type Frost, Manufacturer Kvadrat A/S

(schematic sketches, not scaled, dimensions in mm)

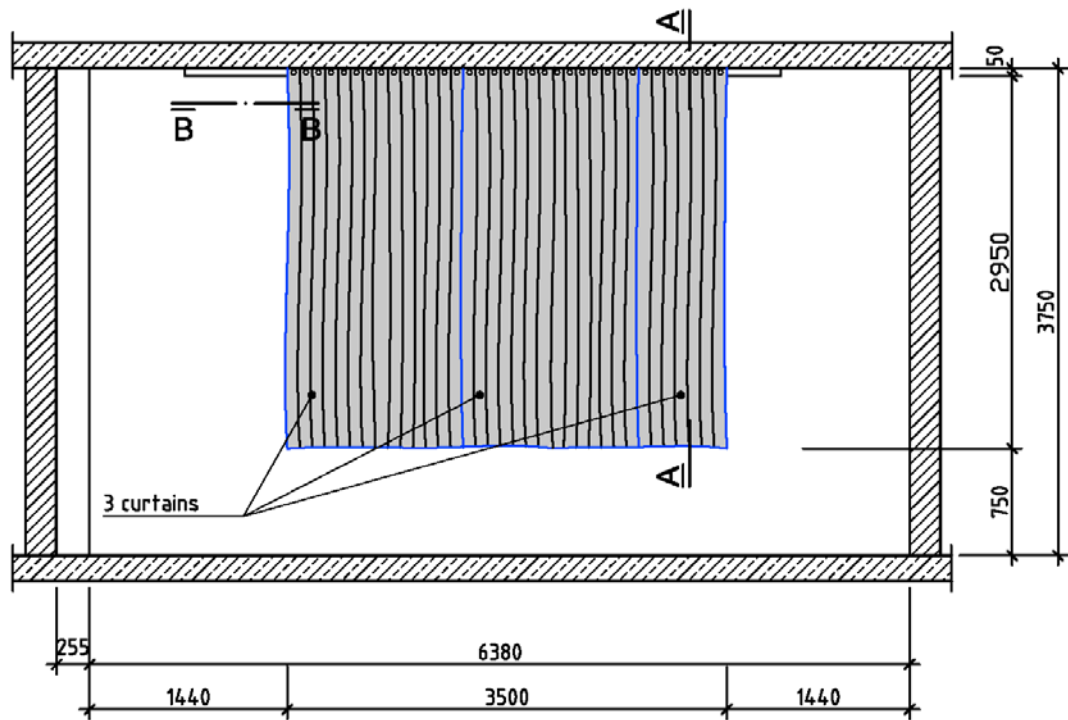


Figure C1. Folded arrangement: front view.

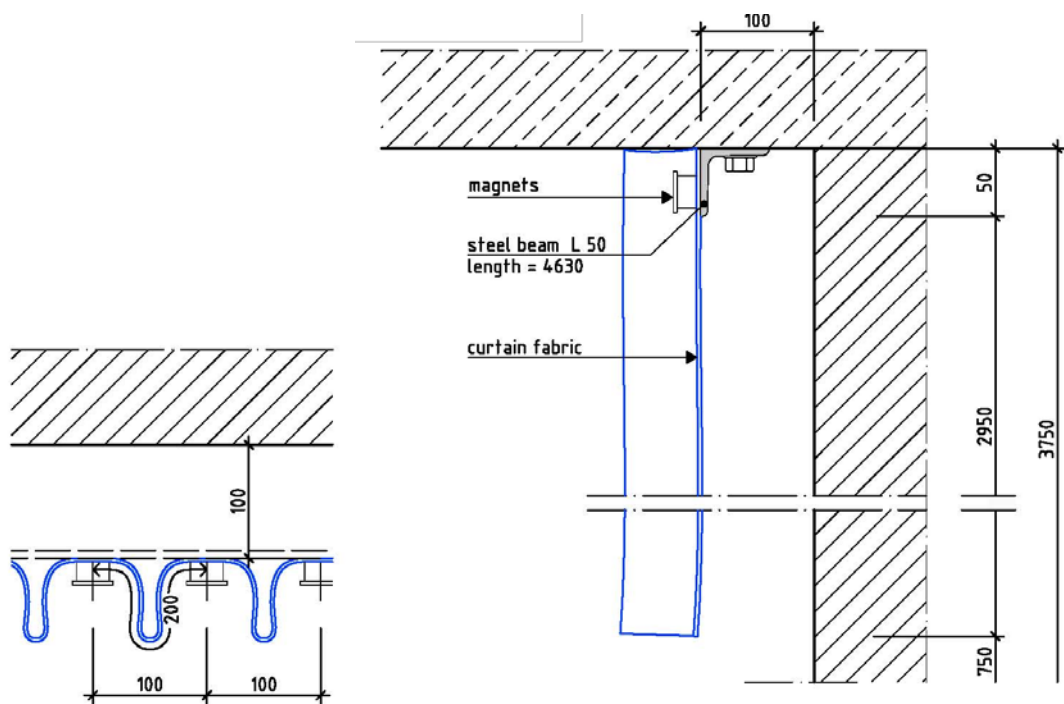


Figure C2. Folded arrangement: details sections B-B (left) and A-A (right).

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 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 $V = 199.6 \text{ m}^3$ 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 (1.2 m x 2.4 m) and six composite sheet metal boards (1.2 m x 1.2 m) were suspended curved and irregularly.

Figure D1 shows the drawings of the reverberation room.

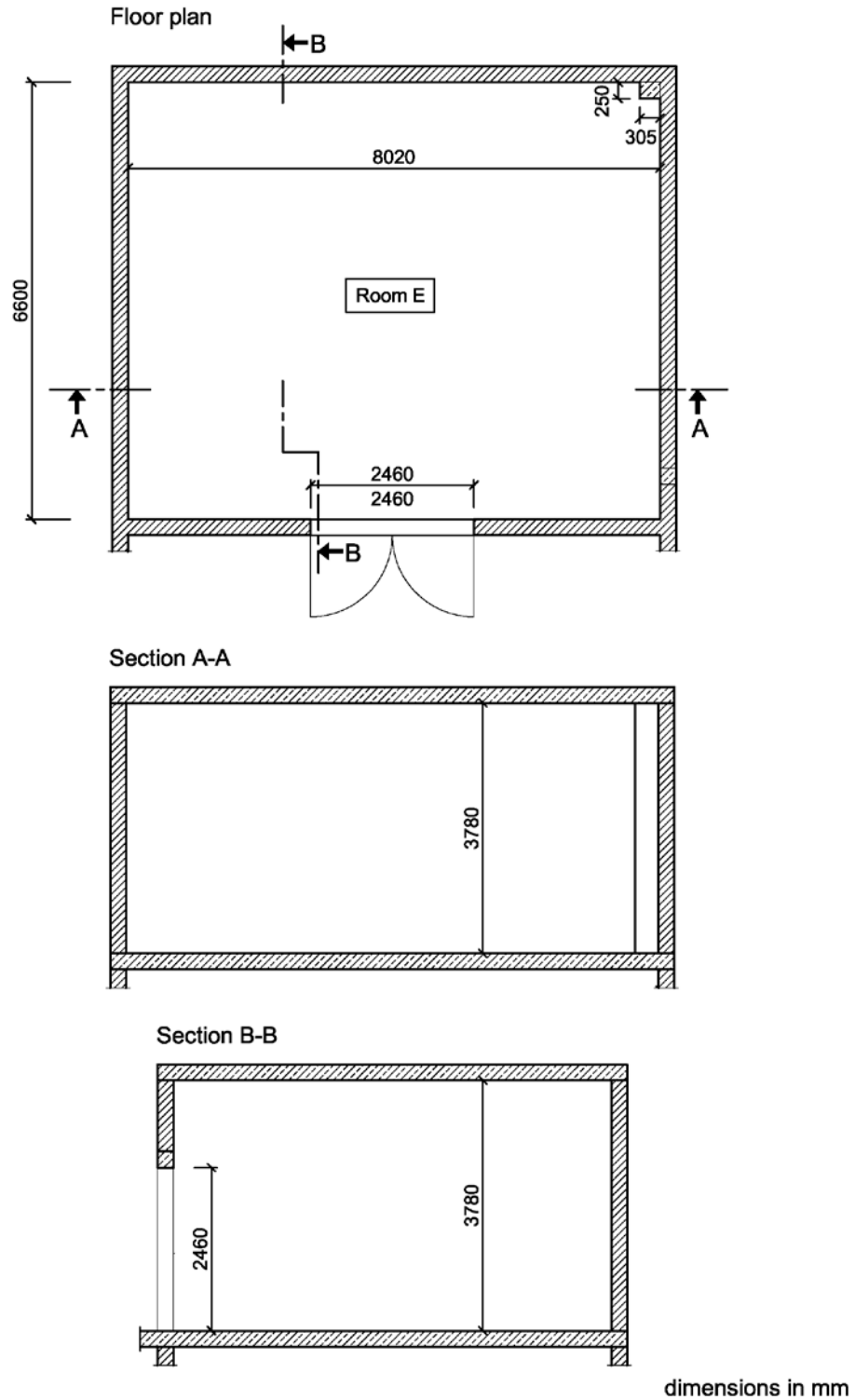


Figure D1. Plan view and sections of the reverberation room.

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 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 in the reverberation room with and without test object are indicated in Table D1.

Table D1. Reverberation times.

| frequency in Hz | Reverberation time T in s | | | |
|--------------------|-------------------------------------|---------------------------------------|-------------------------------------|---------------------------------------|
| | T_1 (without test object) | | T_2 (with test object) | |
| | Appendix A, page 1 G-100 flat | Appendix A, page 2 G-100 folded | Appendix A, page 1 G-100 flat | Appendix A, page 2 G-100 folded |
| 100 | 4.85 | 4.91 | 4.83 | 4.60 |
| 125 | 4.77 | 4.80 | 4.78 | 4.69 |
| 160 | 4.84 | 4.98 | 4.87 | 4.63 |
| 200 | 5.33 | 5.40 | 5.25 | 4.99 |
| 250 | 5.19 | 5.27 | 5.08 | 4.86 |
| 315 | 5.02 | 5.14 | 4.96 | 4.75 |
| 400 | 5.29 | 5.40 | 5.18 | 4.97 |
| 500 | 5.32 | 5.35 | 5.12 | 4.88 |
| 630 | 5.05 | 5.17 | 4.91 | 4.72 |
| 800 | 4.95 | 4.98 | 4.81 | 4.58 |
| 1000 | 5.09 | 5.20 | 5.00 | 4.76 |
| 1250 | 5.23 | 5.37 | 5.18 | 4.91 |
| 1600 | 5.29 | 5.40 | 5.19 | 4.92 |
| 2000 | 4.89 | 5.04 | 4.81 | 4.59 |
| 2500 | 4.31 | 4.40 | 4.21 | 4.05 |
| 3150 | 3.59 | 3.70 | 3.52 | 3.41 |
| 4000 | 2.87 | 2.94 | 2.82 | 2.76 |
| 5000 | 2.27 | 2.34 | 2.23 | 2.23 |

S:\M\Proj\100\M100827\M100827_21_Pbe_1E.DOC: 17.09.2013

2.3 List of test equipment

The test equipment used is listed in Table D2.

Table D2. 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 1.6 |