

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

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M100827/219 Version 1 MSG/STEG

Curtain fabric Relate by Kvadrat A/S

Measurement of sound absorption in the reverberation room acc. to DIN EN ISO 354

Test Report No. M100827/219

| | |
|-------------------------------|---|
| Client: | Kvadrat A/S Lundbergsvej 10 8400 Ebeltoft DENMARK |
| Consultant: | M. Eng. Philipp Meistring M. Sc. Paul Siegmüller |
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Müller-BBM GmbH
HRB Munich 86143
VAT Reg. No. DE812167190

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

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

1 Task

On behalf of the company Kvadrat A/S, 8400 Ebeltoft, Denmark, the sound absorption of the curtain fabric type "Relate" was to be measured according to DIN EN ISO 354 [1] in the reverberation room.

The fabric was tested as a curtain in a flat arrangement and a folded arrangement (+ 100 %) with a distance of 100 mm to the reflective 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 423-17: Standard Test Method for Sound Absorption and Sound Absorption Coefficients by the Reverberation Room Method. Revision: 17. February 2017.
- [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] E DIN EN ISO 12999-2 (draft): Acoustics - Determination and application of measurement uncertainties in building acoustics - Part 2: Sound absorption. August 2019. German and English version prEN ISO 12999-2:2019
- [6] Mueller-BBM test report no M100827/220: Fabric Type Relate, Manufacturer Kvadrat A/S - Determination of airflow resistance according to DIN EN ISO 9053-1. 2020-06-17

3 Test object and test assembly

3.1 Test object

The tested material is described by the client as follows:

- Designation "Relate"
- Material 100 % Trevira CS
- Area specific mass: $m'' = 312 \text{ g/m}^2$

The testing laboratory has measured as follows:

- Thickness: $t = 0.72 \text{ mm}$
- Specific air flow resistance acc. to DIN EN ISO 9053-1 [6]: $R_s = 2241 \text{ Pa}\cdot\text{s/m}$

3.2 Test assembly

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

The mounting details for the tested arrangements are as follows:

- fixed directly underneath the ceiling of the reverberation room, suspended from a metal rail (height 60 mm), distance to the reflecting back wall 100 mm
- test set-up without enclosing frame

a) flat arrangement (Appendix A, page 1)

- mounting type G-100 according to DIN EN ISO 354 [1] section 6.2.1 and appendix B.5
- arranged in three webs:
two webs 1.44 m x 3.00 m and one web 0.71 m x 3.00 m
approx. 50 mm overlap at curtain splices
- total dimensions of the test surface (starting at the lower border of the metal rail): width x height = 3.49 m x 2.94 m
- total test surface $S = 10.26 \text{ m}^2$

b) folded arrangement (Appendix A, page 2)

- in style of mounting type G-100 according to DIN EN ISO 354 [1]
- 100 % fabric addition
- arranged in five webs 1.44 m x 3.00 m
approx. 50 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
- total test surface $S = 10.29 \text{ m}^2$

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

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 423-17 [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.

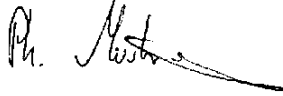
6 Measurement results

The sound absorption coefficients 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 certificate 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.



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: Kvadrat A/S
Lundbergsvej 10, 8400 Ebeltoft, Denmark

Test specimen: Fabric Relate
arranged as curtain (hanging flat, 100 mm distance to reflective wall)

Material details

Information provided by the client:

- fabric: Relate, color 401
- material: 100% Trevira CS

Properties determined by the testing laboratory

- area specific mass $m'' = 312 \text{ g/m}^2$
- airflow resistance $R_S = 2241 \text{ Pa s/m}$
- thickness $t = 0.72 \text{ mm}$

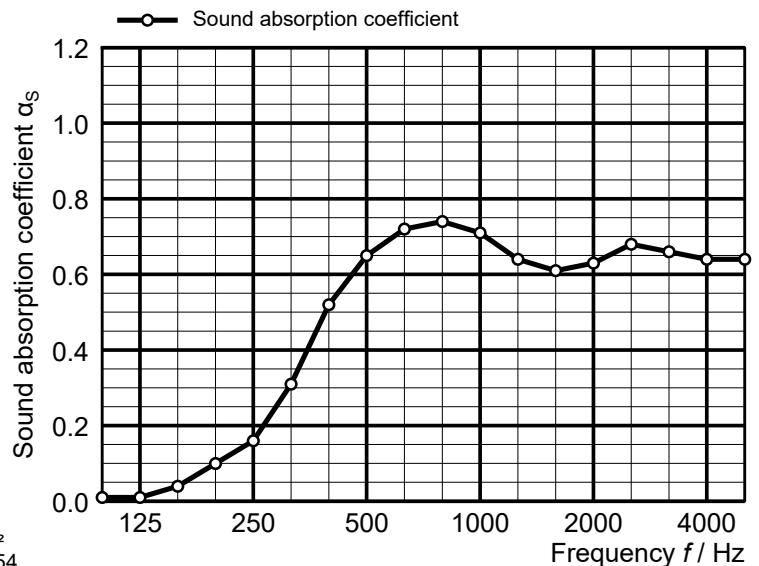
Test arrangement

- curtain arrangement following type G-100 acc. to DIN EN ISO 354, without enclosing frame
- flat arrangement, 100 mm clear distance to the reflective wall
- test set-up made of three webs, two webs 1.44 m x 3.00 m one web 0.71 x 3.00 m
50 mm overlap at curtain splices
- fixed directly underneath the ceiling on a metal rail ($h = 60 \text{ mm}$)
- test surface width x height = 3.49 m x 2.94 m (starting at the lower edge of the metal rail)

Room: E
Volume: 199.60 m³
Size: 10.26 m²
Date of test: 2020-06-15

| | θ [°C] | $r. h.$ [%] | B [kPa] |
|------------------|---------------|-------------|-----------|
| without specimen | 22.5 | 56.8 | 95.2 |
| with specimen | 22.4 | 57.3 | 95.2 |

| Frequency [Hz] | α_s 1/3 octave | α_p octave |
|----------------|-----------------------|-------------------|
| 100 | 0.01 | |
| 125 | 0.01 | 0.00 |
| 160 | 0.04 | |
| 200 | 0.10 | |
| 250 | 0.16 | 0.20 |
| 315 | 0.31 | |
| 400 | 0.52 | |
| 500 | 0.65 | 0.65 |
| 630 | 0.72 | |
| 800 | 0.74 | |
| 1000 | 0.71 | 0.70 |
| 1250 | 0.64 | |
| 1600 | 0.61 | |
| 2000 | 0.63 | 0.65 |
| 2500 | 0.68 | |
| 3150 | 0.66 | |
| 4000 | 0.64 | 0.65 |
| 5000 | 0.64 | |



α 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 $\alpha_w = 0.50 (H)$ Sound absorption class: D</p> | <p>Rating according to ASTM C423: Noise Reduction Coefficient NRC = 0.55 Sound Absorption Average SAA = 0.54</p> |
|--|--|

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Sound absorption coefficient ISO 354

Measurement of sound absorption in reverberation rooms

Client: Kvadrat A/S
Lundbergsvej 10, 8400 Ebeltoft, Denmark

Test specimen: Fabric Relate
arranged as curtain (100 % fabric addition, 100 mm distance to reflective wall)

Material details

Information provided by the client:

- fabric: Relate color 401
- material: 100% Trevira CS

Properties determined by the testing laboratory

- area specific mass $m'' = 312 \text{ g/m}^2$
- airflow resistance $R_S = 2241 \text{ Pa s/m}$
- thickness $t = 0.72 \text{ mm}$

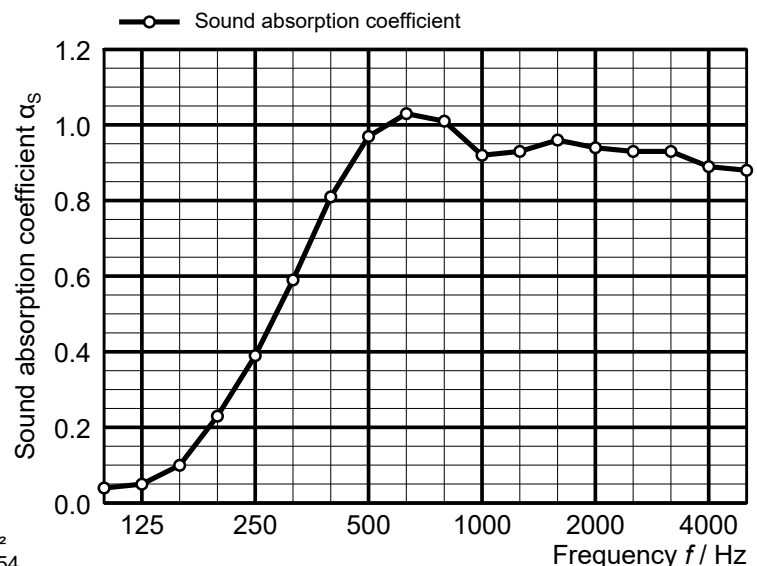
Test arrangement

- curtain arrangement following type G-100 acc. to DIN EN ISO 354, without enclosing frame
- folded arrangement, 100 mm clear distance to the reflective wall
- test set-up made of five webs 1.44 m x 3.00 m, 50 mm overlap at curtain splices
- fixed directly underneath the ceiling on a metal rail ($h = 60 \text{ mm}$)
- test surface width x height = 3.50 m x 2.94 m (starting at the lower edge of the metal rail)

Room: E
Volume: 199.60 m³
Size: 10.29 m²
Date of test: 2020-06-15

| | θ [°C] | $r. h.$ [%] | B [kPa] |
|------------------|---------------|-------------|-----------|
| without specimen | 22.5 | 56.8 | 95.2 |
| with specimen | 22.6 | 56.2 | 95.2 |

| Frequency [Hz] | α_s 1/3 octave | α_p octave |
|----------------|-----------------------|-------------------|
| 100 | 0.04 | |
| 125 | 0.05 | 0.05 |
| 160 | 0.10 | |
| 200 | 0.23 | |
| 250 | 0.39 | 0.40 |
| 315 | 0.59 | |
| 400 | 0.81 | |
| 500 | 0.97 | 0.95 |
| 630 | 1.03 | |
| 800 | 1.01 | 0.95 |
| 1000 | 0.92 | |
| 1250 | 0.93 | |
| 1600 | 0.96 | |
| 2000 | 0.94 | 0.95 |
| 2500 | 0.93 | |
| 3150 | 0.93 | |
| 4000 | 0.89 | 0.90 |
| 5000 | 0.88 | |



◦ 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 $\alpha_w = 0.70$ (MH) Sound absorption class: C | Rating according to ASTM C423: Noise Reduction Coefficient NRC = 0.80 Sound Absorption Average SAA = 0.81 |
|---|---|

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Appendix A

Page 2

Curtain fabric Relate, by Kvadrat A/S



Figure B.1. Test object in the reverberation room: Flat arrangement, frontal view.



Figure B.2. Test object in the reverberation room: Flat arrangement, diagonal view.

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Curtain fabric Relate, by Kvadrat A/S



Figure B.3. Test object in the reverberation room: Folded arrangement, frontal view.



Figure B.4. Test object in the reverberation room: Folded arrangement, 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 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 E DIN EN ISO 12999-2 [5].

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.

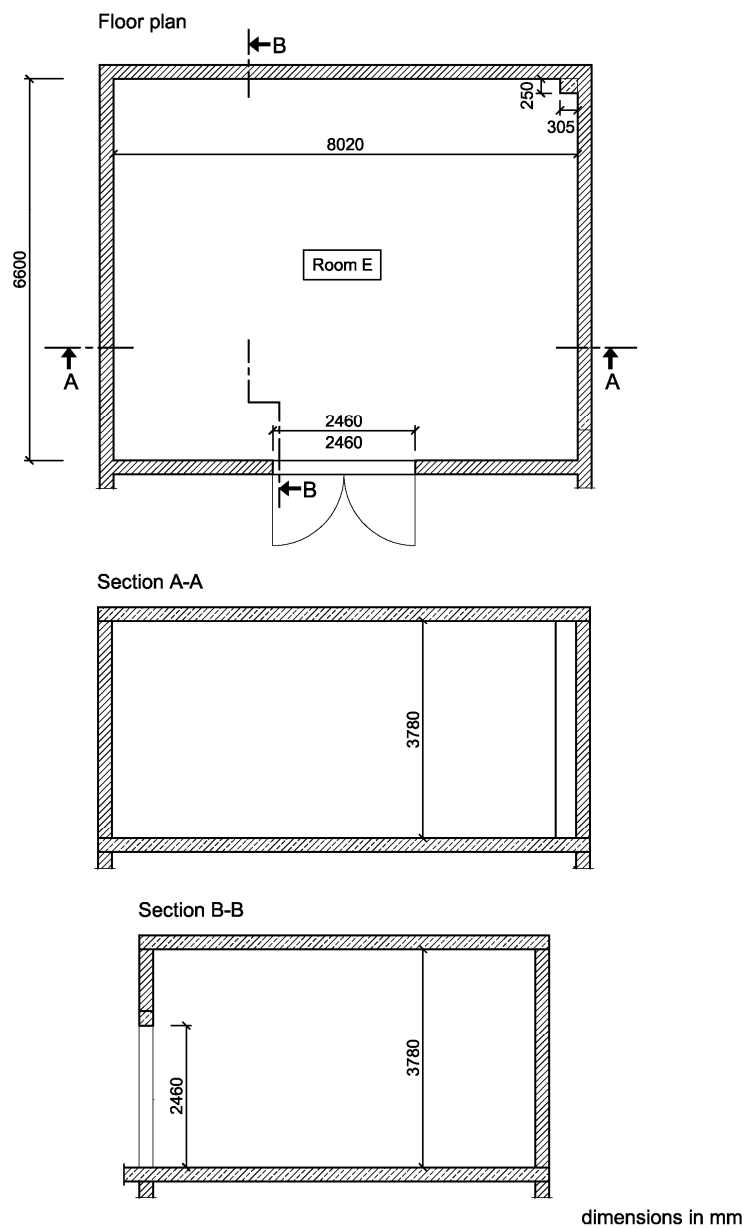


Figure C.1. Plan view and sections of the reverberation room.

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.

| Frequency in Hz | Reverberation time T in s | | |
|--------------------|--------------------------------|--------------------------------------|--|
| | T_1 (without test object) | T_2 (with test object) | |
| | | a) G-100 flat, Appendix A, page 1 | b) folded 100 %, Appendix A, page 2 |
| 100 | 5.37 | 5.28 | 4.99 |
| 125 | 5.63 | 5.50 | 5.19 |
| 160 | 6.15 | 5.71 | 5.11 |
| 200 | 5.66 | 4.77 | 3.97 |
| 250 | 5.85 | 4.48 | 3.38 |
| 315 | 5.62 | 3.59 | 2.73 |
| 400 | 5.56 | 2.90 | 2.27 |
| 500 | 5.48 | 2.57 | 2.03 |
| 630 | 5.19 | 2.37 | 1.91 |
| 800 | 4.84 | 2.25 | 1.88 |
| 1000 | 4.95 | 2.33 | 2.00 |
| 1250 | 4.99 | 2.46 | 2.00 |
| 1600 | 5.00 | 2.54 | 1.97 |
| 2000 | 4.72 | 2.42 | 1.94 |
| 2500 | 4.15 | 2.17 | 1.85 |
| 3150 | 3.49 | 2.01 | 1.71 |
| 4000 | 2.79 | 1.78 | 1.55 |
| 5000 | 2.34 | 1.58 | 1.40 |

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 |