

Laboratory for Acoustics

*Determination of the sound absorption
(reverberation room method) of Single Layer
PET Felt panels type Mute, manufacturer De
Vorm*





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Determination of the sound absorption (reverberation room method) of Single Layer PET Felt panels type Mute, manufacturer De Vorm

Principal	De Vorm Leemansweg 45 6827 BX Arnhem The Netherlands
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BTW NL004933837B01 KvK: 12028033

mook – zoetermeer – groningen – düsseldorf – dortmund – berlijn – leuven – parijs – lyon

A 3229-3E-RA-002 2

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1 Introduction

At the request of De Vorm based in Arnhem (The Netherlands), laboratory measurements of the sound absorption (reverberation room method) were carried out on:

**Single Layer PET Felt panels
type Mute
manufacturer De Vorm**

in the Laboratory for Acoustics of Peutz bv, at Mook, the Netherlands (see figure 1).



For these type of measurements the Laboratory for Acoustics has been accredited by the Dutch Accreditation Council (RvA).

The RvA is member of the EA MLA (**EA MLA: European Accreditation Organisation MultiLateral Agreement**: <http://www.european-accreditation.org>).

EA: "Certificates and reports issued by bodies accredited by MLA and MRA members are considered to have the same degree of credibility, and are accepted in MLA and MRA countries."

2 Standards and guidelines

The measurements have been carried out according to the Quality Manual of the Laboratory for Acoustics as well as:

ISO 354:2003¹ Acoustics Measurement of sound absorption in a reverberation room
NOTE: this international standard has been accepted within all EU-countries as European standard EN ISO 354:2003

Various other related norms:

EN ISO 11654:1997 Acoustics Sound absorbers for use in buildings Rating of sound absorption

ASTM C423-17 Standard Test Method for Sound Absorption and Sound Absorption Coefficients by the Reverberation Room Method

¹ According to this norm, the report should include for each measurement the mean reverberation times T_1 and T_2 at each frequency. Because these figures are not relevant for judging the quality of the product being tested, but merely for judging the accuracy of the calculations, they have been omitted in this report. It is possible of course to reproduce those figures at any time if the principal requests this.

3 Tested construction

The data presented here have been received from the principal or obtained by own observations.

Used materials;

Mute

material: PET Felt
 type: Single Layer
 manufacturer: De Vorm
 dimensions: 790 mm x 2390 mm
 thickness: ≈ 12 mm
 mass: 3,35 kg/m²



Stone wool 50 mm

dimensions: 800 mm x 1000 mm
 thickness: ≈ 50 mm
 mass: 45 kg/m³



Stone wool 100 mm

dimensions: 800 mm x 1000 mm
 thickness: ≈ 100 mm
 mass: 45 kg/m³

The following systems have been tested

variant	Top	cavity	cavity filling
1	Mute	-	-
2	Mute	50 mm	-
3	Mute	50 mm	50 mm stone wool
4	Mute	100 mm	50 mm stone wool
5	Mute	100 mm	-
6	Mute	100 mm	100 mm stone wool
7	Mute	150 mm	50 mm stone wool
8	Mute	200 mm	100 mm stone wool



The results as presented here relate only to the tested items and laboratory conditions as described in this report. The laboratory can make no judgement about the representativity of the tested samples. The test report ahead is valid as long as the tested constructions and/or materials are unchanged.

4 Measurements

The panels to be measured (see chapter 3) have been put directly on the floor of the reverberation room or on a support structure at about 50, 100, 150 or 200 mm above it, the facing side of the panels was up. No suspension-system has been used, the panels were put tight to each other. The sides of the setup were enclosed by 18 mm thick plastic covered chipwood board.

4.1 Method

The tests were conducted in accordance with the provisions of the test method ISO 354 in the reverberation room of "Peutz bv" in Mook (the Netherlands) (see figure 1). The relevant data regarding the reverberation room are given in figure 2 of this report.

By means of reverberation measurements the reverberation time of the room is measured under two conditions:

- when the reverberation room is empty
- when the construction under test is inside the reverberation room

In general, once material is placed into the reverberation room a lower reverberation time will result.

The difference in reverberation times is a measure of the amount of absorption brought into the room.

Measurements and calculations were carried out in 1/3-octave bandwidth from 100 to 5000 Hz, according to the norms. Where applicable the octave values have been calculated from these 1/3-octave values.

From the reverberation measurements in the empty reverberation room the equivalent sound absorption A_1 is calculated (per frequency band) according to formula 1 and expressed in m^2

$$A_1 = \frac{55,3V}{cT_1} - 4V m_1 \quad (1)$$

in which:

- V = the volume of the reverberation room [m^3]
- T_1 = the reverberation time in the empty reverberation room [sec.]
- m_1 = "power attenuation coefficient" in the empty room,
calculated according to formula [m^{-1}]
- c = the speed of sound in the air, in m/s, calculated according to [m/s]

$$c = 331 + 0,6t \quad (2)$$

in which:

t = the temperature; this formula is valid for temperatures between 15 and 30 °C [°C]

$$m = \frac{\alpha}{10 \log(e)} \quad (3)$$

in which:

α = "attenuation coefficient" according to ISO 9613-1

In the same manner the equivalent sound absorption A_2 for the room with the test specimen is calculated according to formula 4, also expressed in m^2

$$A_2 = \frac{55,3 V}{c T_2} - 4 V m_2 \quad (4)$$

in which:

c and V have the same definition as in formula 1 and

T_2 = the reverberation time of the reverberation room with the test specimen placed inside [sec]

m_2 = "power attenuation coefficient" in the room with the test specimen placed inside, calculated according to formula 3 [m^{-1}]

The equivalent sound absorption A of the test specimen has been calculated according to formula 5 and is expressed in m^2

$$A = A_2 - A_1 \quad (5)$$

When the test specimen consists of one plane with an area between 10 and 12 m^2 the sound absorption coefficient α_s has to be calculated according to formula 6:

$$\alpha = \frac{A}{S} \quad (6)$$

in which:

S = the area of the test specimen [m^2]

4.2 Accuracy

The accuracy of the sound absorption as calculated can be expressed in terms of repeatability (tests within one laboratory) and reproducibility (between various laboratories).

When:

- two tests are performed on identical test material
- within a short period of time
- by the same person or team
- using the same instrumentation
- under unchanged environmental conditions

the probability will be 95% that the difference between the two test results will be less than or equal to r .

In order to evaluate the repeatability r for the sound absorption measurements performed in the reverberation room of "Peutz bv" in Mook (the Netherlands) eight series of measurements have been carried out according to ISO 354:1985 annex C. From the results of those measurements the repeatability r has been calculated. It was found that for the frequency range from 100 to 200 Hz and at 5000 Hz the repeatability r is 0,21 as a maximum. For the frequency range 250 to 4000 Hz the repeatability r is 0,09 as a maximum.

4.3 Environmental conditions during the measurements

t4.1 Environmental conditions during the measurements

reverberation room	temperature [°C]	barometric pressure [kPa]	relative humidity [%]
empty	17,4	102,6	52,1
with panels	17,4 – 17,7	102,6 – 102,7	55,4 – 56,3

4.4 Results

The results of the measurements are given in table 4.2 and 4.3 and in the figures 3 up till and including 10. The measurements were made in 1/3-octave bands. The results presented in octave-bands are the arithmetic average of the results of the three 1/3-octave bands belonging to that octaveband.

From those values the following one-figure ratings have been calculated and stated :

- the "weighted sound absorption coefficient α_w " according to ISO 11654
- the "Noise Reduction Coefficient NRC" according to ASTM C423, being the average of the absorption coefficients (1/3 octave values) at the frequencies of 250, 500, 1000 and 2000 Hz, rounded to the nearest 0,05.
- the "Sound Absorption Average SAA" according to ASTM-C423, being the average of the absorption coefficients (1/3 octave values) at the frequencies of 200 Hz up to 2500 Hz, rounded to the nearest 0,01.

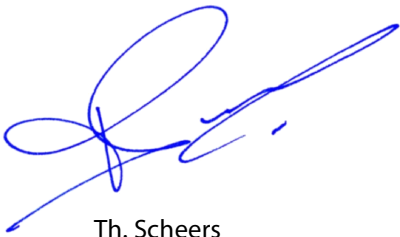
t4.2 measurement results

sound absorption coefficient α_s								
measurement nr.	1		2		3		4	
top	Mute		Mute		Mute		Mute	
cavity high	-		50 mm		50 mm		100 mm	
cavity filling	-		-		50 mm stone wool		50 mm stone wool	
record nr.	#924		#961		#998		#1037	
figure nr.	3		4		5		6	
frequency [Hz]	1/3 oct.	1/1 oct.	1/3 oct.	1/1 oct.	1/3 oct.	1/1 oct.	1/3 oct.	1/1 oct.
100	0,02		0,06		0,31		0,42	
125	0,04	0,04	0,15	0,14	0,70	0,61	0,77	0,68
160	0,06		0,22		0,83		0,85	
200	0,09		0,23		0,79		0,87	
250	0,18	0,16	0,35	0,38	0,92	0,89	0,76	0,85
315	0,22		0,55		0,96		0,91	
400	0,33		0,70		0,95		0,89	
500	0,45	0,46	0,82	0,80	0,90	0,93	0,86	0,88
630	0,60		0,87		0,93		0,90	
800	0,75		0,93		0,94		0,92	
1000	0,86	0,83	0,93	0,95	0,89	0,93	0,91	0,93
1250	0,89		0,99		0,97		0,95	
1600	0,92		0,96		0,96		0,97	
2000	0,95	0,95	0,98	0,96	0,98	0,98	1,00	0,99
2500	0,97		0,95		1,00		0,99	
3150	0,98		0,95		0,98		1,01	
4000	1,00	1,00	0,98	0,98	0,99	0,98	1,03	1,01
5000	1,03		1,02		0,98		0,99	
α_w	0,45(MH)		0,70(MH)		1,00		0,95	
NRC	0,60		0,75		0,90		0,90	
SAA	0,60		0,77		0,93		0,91	

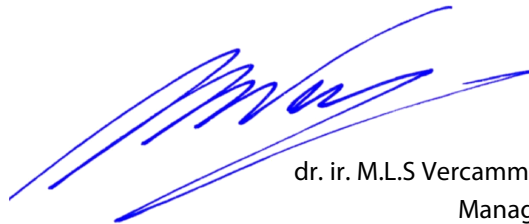
t4.3 measurement results

sound absorption coefficient α_s								
measurement nr.	5		6		7		8	
top	Mute		Mute		Mute		Mute	
cavity high	100 mm		100 mm		150 mm		200 mm	
cavity filling	-		100 mm stone wool		50 mm stone wool		100 mm stone wool	
record nr.	#1148		#1185		#1074		#1111	
figure nr.	7		8		9		10	
frequency [Hz]	1/3 oct.	1/1 oct.	1/3 oct.	1/1 oct.	1/3 oct.	1/1 oct.	1/3 oct.	1/1 oct.
100	0,15		0,86		0,52		0,82	
125	0,29	0,30	0,84	0,85	0,84	0,73	0,89	0,84
160	0,47		0,84		0,82		0,80	
200	0,55		0,88		0,78		0,74	
250	0,71	0,71	0,87	0,89	0,81	0,81	0,83	0,79
315	0,86		0,92		0,85		0,80	
400	0,84		0,88		0,87		0,84	
500	0,89	0,90	0,89	0,90	0,89	0,88	0,89	0,88
630	0,96		0,92		0,88		0,90	
800	0,97		0,94		0,91		0,92	
1000	0,96	0,94	0,93	0,94	0,94	0,93	0,95	0,95
1250	0,89		0,95		0,95		0,98	
1600	0,85		0,97		0,97		0,98	
2000	0,95	0,93	1,01	1,00	0,97	0,98	0,99	1,00
2500	1,00		1,02		1,00		1,02	
3150	0,97		0,99		1,00		1,02	
4000	1,00	0,97	1,01	0,99	1,00	0,99	1,03	1,01
5000	0,95		0,97		0,97		0,99	
α_w	0,95		0,95		0,95		0,95	
NRC	0,90		0,95		0,90		0,90	
SAA	0,87		0,93		0,90		0,90	

The sound absorption coefficient of a material is not a material property. It should be taken into account that the sound absorption of a construction depends on the dimensions, the way of mounting of the material and its position in the room.



Th. Scheers
Laboratory Supervisor



dr. ir. M.L.S Vercammen
Manager

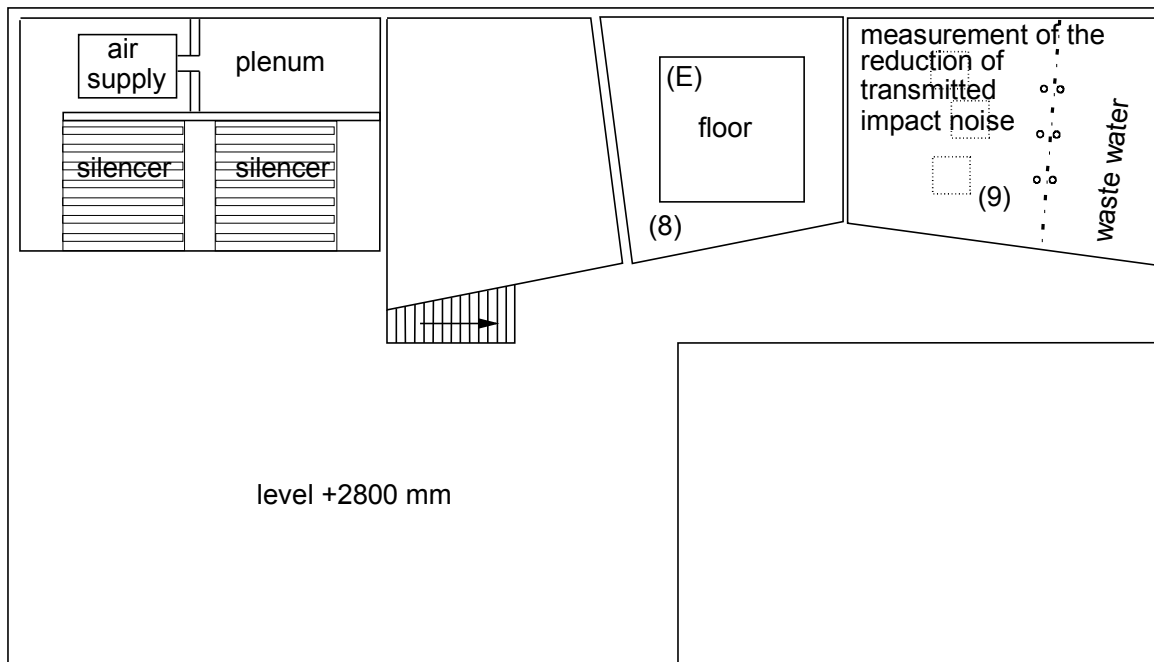
Mook,

This report contains 13 pages, 10 figures.

PEUTZ bv
Lindenlaan 41, NL-6584 AC MOLENHOEK (LB), THE NETHERLANDS

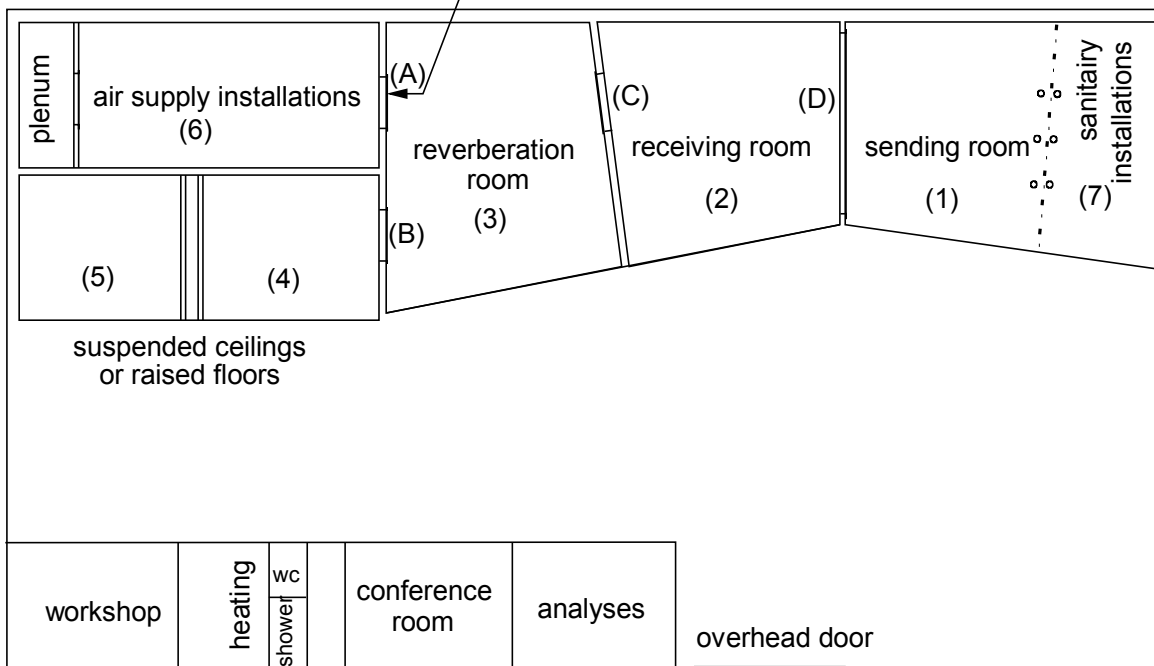
OVERVIEW

Story



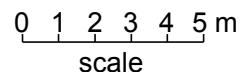
Ground level

opening (A) (closed)
w x h = 1300 x 1905 mm



TEST OPENINGS (w x h in mm)

- (B) 1000 x 2200
- (C) 1500 x 1250
- (D) 4300 x 2800
- (E) 4000 x 4000



PEUTZ bv
Lindenlaan 41, 6584 AC MOLENHOEK (LB)

REVERBERATION ROOM

The reverberation room meets the requirements of ISO 354:2003.

additional data:

volume : 214 m³

total area S_t (walls, floor and ceiling) : 219 m²

diffusion: by the shape of the room and by adding 6 curved and 2 flat reflecting elements with a total area of approx. 13 m² a sufficient diffusion has been gained.

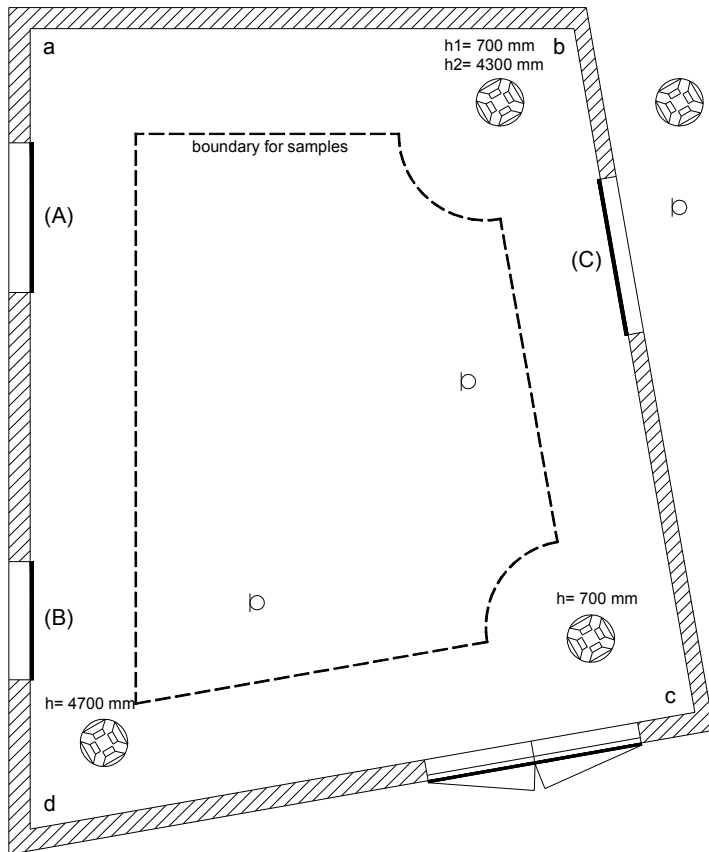
reverberation time of the empty reverberation room during measurements of 07-04-2017

frequency (1/1 oct.)	125	250	500	1000	2000	4000	Hz
reverberationtime	7,60	6,22	5,96	5,40	4,13	2,65	sec.

repeatability r (1/1 oct.) c.f. ISO 354:1985 annex C (see chapter 4.2 of this report).

r bij hoge α	0.13	0,04	0,04	0,02	0,02	0,08	-
r bij lage α	0,09	0.02	0.01	0.02	0.02	0,04	-

plan

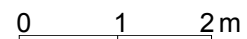


loudspeaker (4x)

microphone (3x)

(closed) testopenings
(width x height in mm)
(A): 1300 x 1800
(B): 1000 x 2200
(C): 1500 x 1250

height at:
a: 5573 mm
b: 5102 mm
c: 5000 mm
d: 5580 mm



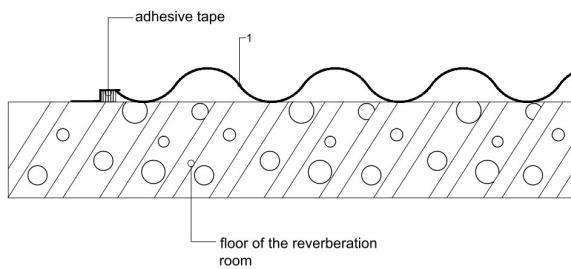
Absorb, versie 5.8.4 mode 7, PM: JK, file: a3229 E#:592-620 T₁ = 15,8 °C p₁ = 100,0 kPa h₁ = 49,7 %

MEASUREMENT OF SOUND ABSORPTION IN A REVERBERATION ROOM
ACCORDING TO ISO 354:2003



principal: De Vorm

variant	Top	cavity	cavity filling
1	Mute	-	-



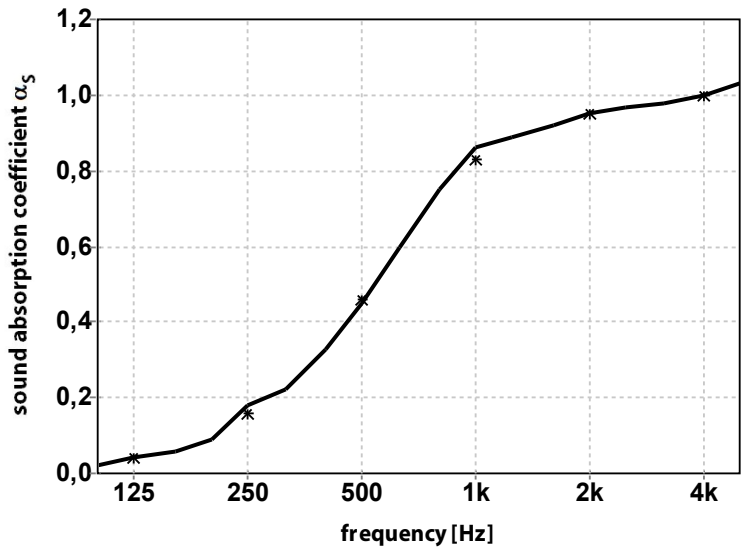
Absorb, versie 5.8.4 mode 7, PM: JK, file: a32229 E#:594-629 F#:888-923 A#:924 T₁ = 17,4 °C T₂ = 17,6 °C p₁ = 102,6 kPa p₂ = 102,7 kPa h₁ = 52,1 % h₂ = 55,4 %

volume reverberation room: 214 m³
 surface area sample: 11,3 m²
 measured at: Peutz Laboratory for Acoustics
 signal: broad-band noise
 bandwidth: 1/3 octave

α_w (ISO 11654) = 0,45(MH)

NRC (ASTM - C423) = 0,60

SAA (ASTM - C423) = 0,60



	0,02	0,09	0,33	0,75	0,92	0,98
1/3 oct.	0,04	0,18	0,45	0,86	0,95	1,00
	0,06	0,22	0,60	0,89	0,97	1,03
1/1 oct.	0,04	0,16	0,46	0,83	0,95	1,00

publication is permitted for the entire page only

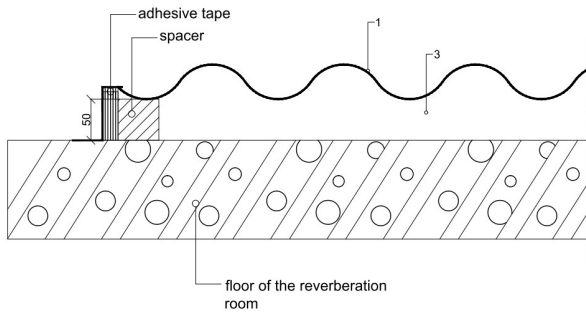
Mook, measured at 07-04-2017

MEASUREMENT OF SOUND ABSORPTION IN A REVERBERATION ROOM ACCORDING TO ISO 354:2003



principal: De Vorm

variant	Top	cavity	cavity filling
2	Mute	50 mm	-



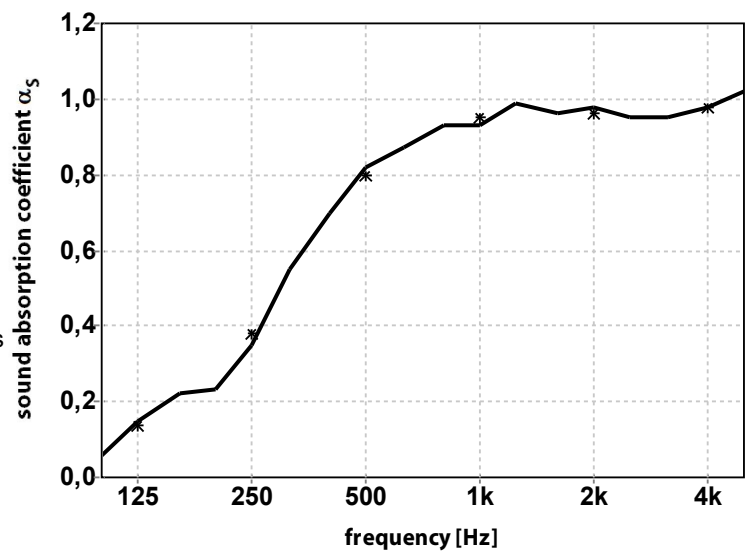
Absorb, versie 5.8.4 mode 7, PM: JK, file: a32229 E#:594-629 F#:925-960 A#:961 T₁ = 17,4 °C T₂ = 17,7 °C p₁ = 102,6 kPa p₂ = 102,7 kPa h₁ = 52,1 % h₂ = 55,7 %

volume reverberation room: 214 m³
 surface area sample: 11,3 m²
 height of the construction: 0.050 m
 measured at: Peutz Laboratory for Acoustics
 signal: broad-band noise
 bandwidth: 1/3 octave

α_w (ISO 11654) = 0,70(MH)

NRC (ASTM - C423) = 0,75

SAA (ASTM - C423) = 0,77



	0,06	0,23	0,70	0,93	0,96	0,95
1/3 oct.	0,15	0,35	0,82	0,93	0,98	0,98
	0,22	0,55	0,87	0,99	0,95	1,02
1/1 oct.	0,14	0,38	0,80	0,95	0,96	0,98

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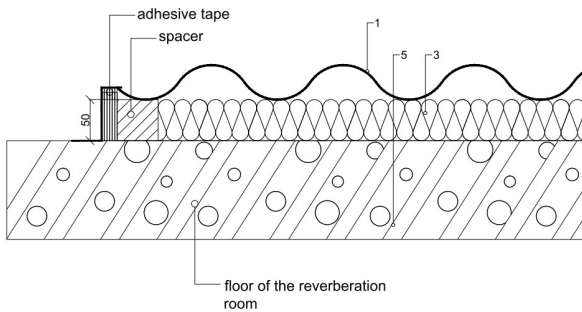
Mook, measured at 07-04-2017

MEASUREMENT OF SOUND ABSORPTION IN A REVERBERATION ROOM ACCORDING TO ISO 354:2003



principal: De Vorm

variant	Top	cavity	cavity filling
3	Mute	50 mm	50 mm stone wool



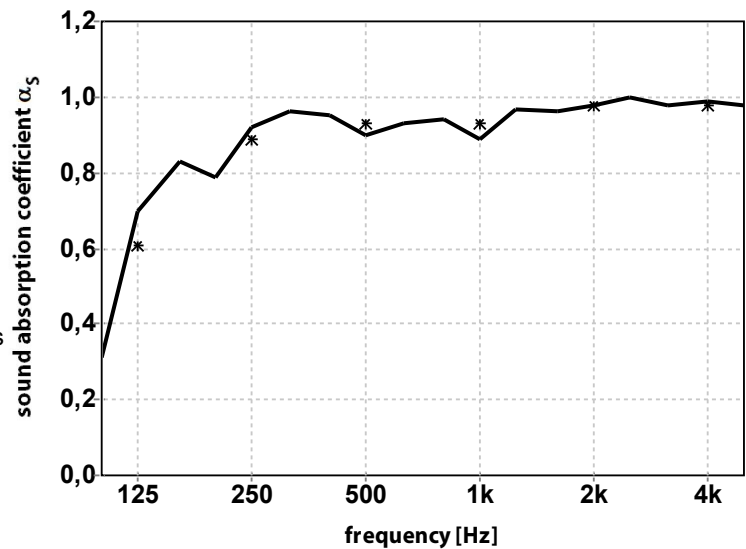
Absorb, versie 5.8.4 mode 7, PM, JK, file: a32229 E#:594-629 F#:962-997 A#:998 T₁ = 17,4 °C T₂ = 17,4 °C p₁ = 102,6 kPa p₂ = 102,7 kPa h₁ = 52,1 % h₂ = 56,3 %

volume reverberation room: 214 m³
 surface area sample: 11,3 m²
 height of the construction: 0.050 m
 measured at: Peutz Laboratory for Acoustics
 signal: broad-band noise
 bandwidth: 1/3 octave

α_w (ISO 11654) = 1,00

NRC (ASTM - C423) = 0,90

SAA (ASTM - C423) = 0,93



	0,31	0,79	0,95	0,94	0,96	0,98
1/3 oct.	0,70	0,92	0,90	0,89	0,98	0,99
	0,83	0,96	0,93	0,97	1,00	0,98
1/1 oct.	0,61	0,89	0,93	0,93	0,98	0,98

publication is permitted for the entire page only

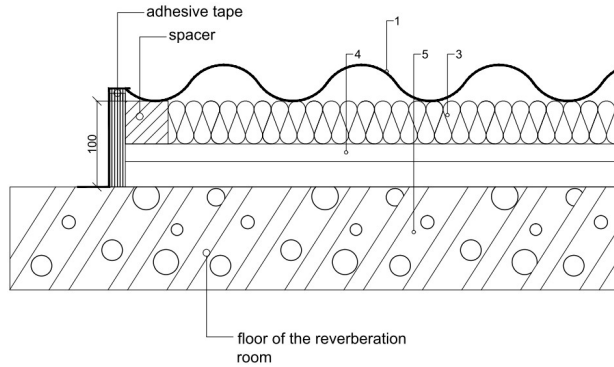
Mook, measured at 07-04-2017

MEASUREMENT OF SOUND ABSORPTION IN A REVERBERATION ROOM ACCORDING TO ISO 354:2003



principal: De Vorm

variant	Top	cavity	cavity filling
4	Mute	100 mm	50 mm stone wool



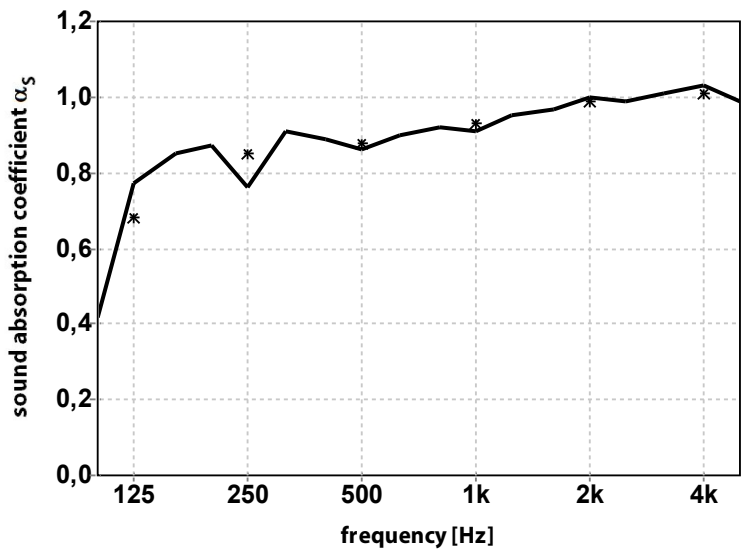
Absorb, versie 5.8.4 mode 7, PM, JK, file: a32229 E#:594-629 F#:1001-1036 A#:1037 T₁ = 17,4 °C T₂ = 17,7 °C p₁ = 102,6 kPa p₂ = 102,7 kPa h₁ = 52,1 % h₂ = 56,1 %

volume reverberation room: 214 m³
 surface area sample: 11,3 m²
 height of the construction: 0.100 m
 measured at: Peutz Laboratory for Acoustics
 signal: broad-band noise
 bandwidth: 1/3 octave

α_w (ISO 11654) = 0,95

NRC (ASTM - C423) = 0,90

SAA (ASTM - C423) = 0,91



	0,42	0,87	0,89	0,92	0,97	1,01
1/3 oct.	0,77	0,76	0,86	0,91	1,00	1,03
	0,85	0,91	0,90	0,95	0,99	0,99
1/1 oct.	0,68	0,85	0,88	0,93	0,99	1,01

publication is permitted for the entire page only

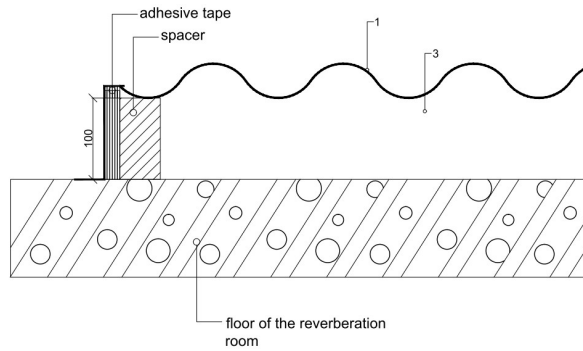
Mook, measured at 07-04-2017

MEASUREMENT OF SOUND ABSORPTION IN A REVERBERATION ROOM ACCORDING TO ISO 354:2003



principal: De Vorm

variant	Top	cavity	cavity filling
5	Mute	100 mm	-



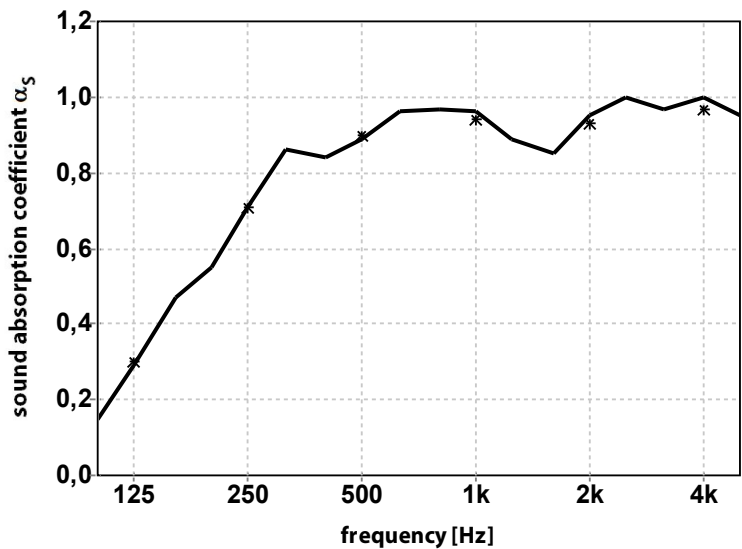
Absorb, versie 5.8.4 mode 7, PM, JK, file: a32229 E#:594-629 F#:1112-1147 A#:1148 T₁ = 17,4 °C T₂ = 17,7 °C p₁ = 102,6 kPa p₂ = 102,6 kPa h₁ = 52,1 % h₂ = 56,3 %

volume reverberation room: 214 m³
 surface area sample: 11,3 m²
 height of the construction: 0.100 m
 measured at: Peutz Laboratory for Acoustics
 signal: broad-band noise
 bandwidth: 1/3 octave

α_w (ISO 11654) = 0,95

NRC (ASTM - C423) = 0,90

SAA (ASTM - C423) = 0,87



	0,15	0,55	0,84	0,97	0,85	0,97
1/3 oct.	0,29	0,71	0,89	0,96	0,95	1,00
	0,47	0,86	0,96	0,89	1,00	0,95
1/1 oct.	0,30	0,71	0,90	0,94	0,93	0,97

publication is permitted for the entire page only

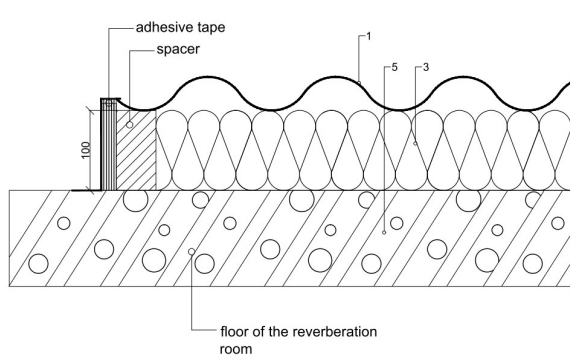
Mook, measured at 07-04-2017

MEASUREMENT OF SOUND ABSORPTION IN A REVERBERATION ROOM ACCORDING TO ISO 354:2003



principal: De Vorm

variant	Top	cavity	cavity filling
6	Mute	100 mm	100 mm stone wool



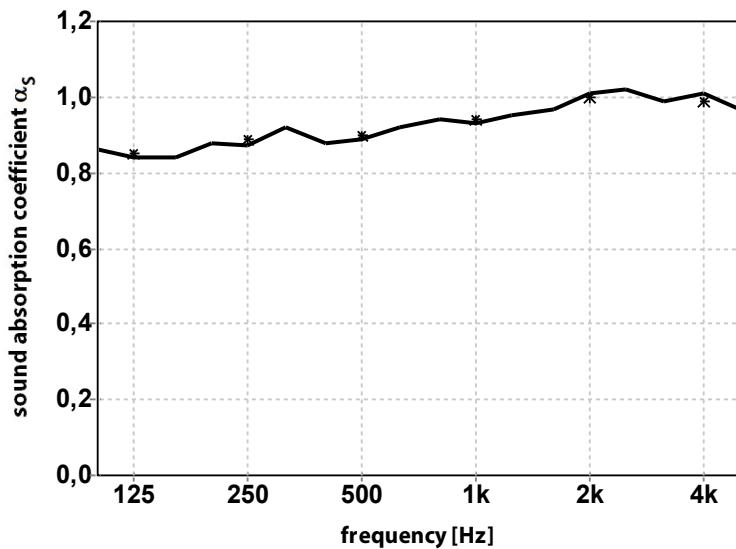
Absorb, versie 5.8.4 mode 7, PM, JK, file: a32229 E#:594-629 F#:1149-1184 A#:1185 T₁ = 17,4 °C T₂ = 17,7 °C p₁ = 102,6 kPa p₂ = 102,6 kPa h₁ = 52,1 % h₂ = 56,1 %

volume reverberation room: 214 m³
 surface area sample: 11,3 m²
 height of the construction: 0.100 m
 measured at: Peutz Laboratory for Acoustics
 signal: broad-band noise
 bandwidth: 1/3 octave

α_w (ISO 11654) = 0,95

NRC (ASTM - C423) = 0,95

SAA (ASTM - C423) = 0,93



	0,86	0,88	0,88	0,94	0,97	0,99
1/3 oct.	0,84	0,87	0,89	0,93	1,01	1,01
	0,84	0,92	0,92	0,95	1,02	0,97
1/1 oct.	0,85	0,89	0,90	0,94	1,00	0,99

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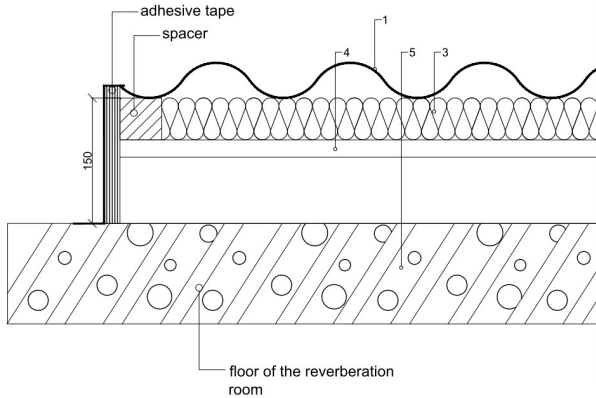
Mook, measured at 07-04-2017

MEASUREMENT OF SOUND ABSORPTION IN A REVERBERATION ROOM
ACCORDING TO ISO 354:2003



principal: De Vorm

variant	Top	cavity	cavity filling
7	Mute	150 mm	50 mm stone wool



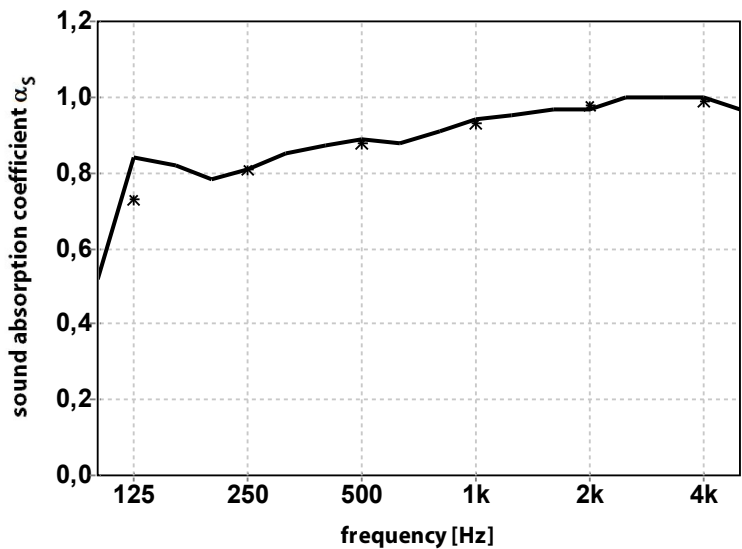
Absorb, versie 5.8.4 mode 7, PM, JK, file: a32229 E#:594-629 F#:1038-1073 A#:1074 T₁ = 17,4 °C T₂ = 17,7 °C p₁ = 102,6 kPa p₂ = 102,7 kPa h₁ = 52,1 % h₂ = 56,2 %

volume reverberation room: 214 m³
 surface area sample: 11,3 m²
 height of the construction: 0.150 m
 measured at: Peutz Laboratory for Acoustics
 signal: broad-band noise
 bandwidth: 1/3 octave

α_w (ISO 11654) = 0,95

NRC (ASTM - C423) = 0,90

SAA (ASTM - C423) = 0,90



	0,52	0,78	0,87	0,91	0,97	1,00
1/3 oct.	0,84	0,81	0,89	0,94	0,97	1,00
	0,82	0,85	0,88	0,95	1,00	0,97
1/1 oct.	0,73	0,81	0,88	0,93	0,98	0,99

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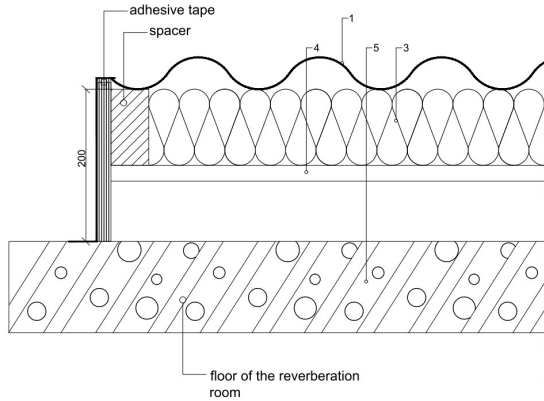
Mook, measured at 07-04-2017

MEASUREMENT OF SOUND ABSORPTION IN A REVERBERATION ROOM ACCORDING TO ISO 354:2003



principal: De Vorm

variant	Top	cavity	cavity filling
8	Mute	200 mm	100 mm stone wool



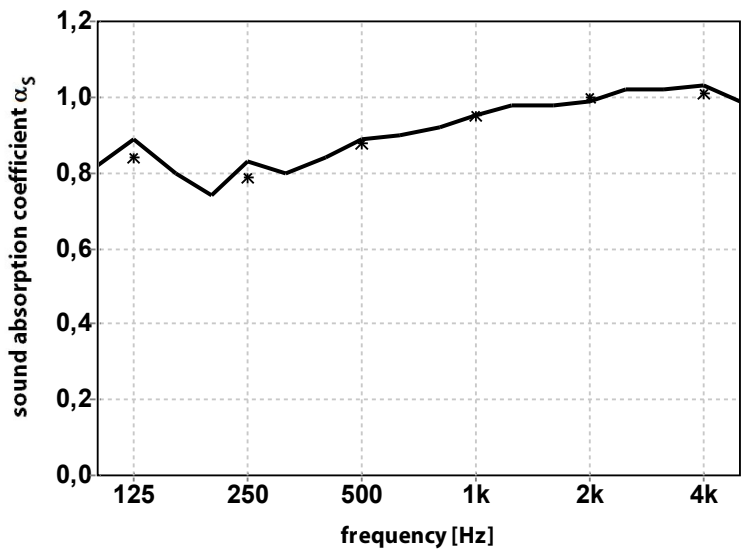
Absorb, versie 5.8.4 mode 7, PM, JK, file: a32229 E#:594-629 F#:1075-1110 A#:1111 T₁ = 17,4 °C T₂ = 17,7 °C p₁ = 102,6 kPa p₂ = 102,6 kPa h₁ = 52,1 % h₂ = 56,0 %

volume reverberation room: 214 m³
 surface area sample: 11,3 m²
 height of the construction: 0.200 m
 measured at: Peutz Laboratory for Acoustics
 signal: broad-band noise
 bandwidth: 1/3 octave

α_w (ISO 11654) = 0,95

NRC (ASTM - C423) = 0,90

SAA (ASTM - C423) = 0,90



	0,82	0,74	0,84	0,92	0,98	1,02
1/3 oct.	0,89	0,83	0,89	0,95	0,99	1,03
	0,80	0,80	0,90	0,98	1,02	0,99
1/1 oct.	0,84	0,79	0,88	0,95	1,00	1,01

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Mook, measured at 07-04-2017