

## Determination of sound absorption coefficients in a reverberation room according to ISO 354 and ISO 11654 (8 appendices)

### Client

Ovacon AB

### Test object

Sound absorption panels delivered by Ovacon AB and made by fiberglass materials applied by SprayTec technology. The panels were tested in 8 different thicknesses.

### Date of test

November 30<sup>th</sup> and December 1<sup>th</sup>, 2020.

### Results

The sound absorption coefficient ( $\alpha_s$ ) and the practical sound absorption coefficient ( $\alpha_p$ ) are given in the enclosures 1-8. The weighted sound absorption coefficient ( $\alpha_w$ ) and the sound absorption classes have been calculated according to ISO 11654 and the results are given in table 1 below.

Table 1 – Summary of results

Test object:	ISO 11654		Enclosure
	Absorption class	$\alpha_w$	
Spray-Tech-G, thickness 30 mm	C	0,70 (MH)	1
Spray-Tech-G, thickness 40 mm	B	0,85 (H)	2
Spray-Tech-G, thickness 50 mm	A	0,95	3
Spray-Tech-G, thickness 63 mm	A	1,00	4
Spray-Tech-G, thickness 75 mm	A	1,00	5
Spray-Tech-G, thickness 104 mm	A	1,00	6
Spray-Tech-G, thickness 150 mm	A	1,00	7
Spray-Tech-G, thickness 200 mm	A	1,00	8

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Each test object consisted of 16 parts that were placed on the floor in the reverberation room in a rectangular shape. For practical reasons, the fiberglass material were applied on 12,5 mm plasterboards as a base on each part.

The thickness of the test objects are reported as a mean value from five measurements on each part taken randomly. The thickness is the distance from the upper side of the plasterboard to the top side of the sound absorber material.

In table 2 the area mass of the test object including plasterboard is presented together with the estimated density of the fibre glass material. The density is based on assumption that the area mass of the plasterboard is 9 kg/m<sup>2</sup>.

*Table 2 – Measured area mass and density of the test objects*

Test object:	Area mass incl. plasterboard kg/m <sup>2</sup>	Estimated density fibre glass kg/m <sup>3</sup>
Spray-Tech-G, thickness 30 mm	10,6	54,2
Spray-Tech-G, thickness 40 mm	11,4	69,6
Spray-Tech-G, thickness 50 mm	12,7	74,4
Spray-Tech-G, thickness 63 mm	13,4	69,6
Spray-Tech-G, thickness 75 mm	13,7	62,5
Spray-Tech-G, thickness 104 mm	15,6	63,1
Spray-Tech-G, thickness 150 mm	19,1	67,2
Spray-Tech-G, thickness 200 mm	21,0	60,1

The area mass of the 12,5 mm plasterboard is estimated to 9 kg/m<sup>2</sup>.

### Measurement method

The measurements have been carried out according to ISO 354:2003, which is equivalent to EN ISO 354 and SS-EN ISO 354. The evaluation has been carried out according to ISO 11654, which is equivalent to EN ISO 11654 and SS-EN ISO 11654. 4 loudspeaker positions and 6 microphone positions have been used giving 24 different combinations for the reverberation time measurements. For empty room 3 decays have been used for averaging the time and for test objects 5 decays have been used, for each combination of loudspeaker and microphone.

The absorption coefficient  $\alpha_s$  has been evaluated from:

$$\alpha_s = \frac{55.3 V}{c \cdot S} \left( \frac{1}{T_2} - \frac{1}{T_1} \right)$$

where

- V = Volume of the reverberation room (m<sup>3</sup>)
- S = Area of the test object (m<sup>2</sup>)
- c = Speed of sound in air (m/s)

- c = 331 + 0.6t
- t = Temperature in the air (°C)
- T<sub>1</sub> = Reverberation time of the room without test object (s)
- T<sub>2</sub> = Reverberation time of the room with test object (s)

The reverberation time of the empty room in each frequency band is expressed by the arithmetic mean of the total number of reverberation time measurements made in that frequency band. In table 3 the reverberation time for the empty room, T<sub>1</sub>, is given.

*Table 3 – The reverberation time of the empty reverberation room measured November 30<sup>th</sup> and December 1<sup>th</sup> respectively.*

Frequency [Hz]	T <sub>1</sub> [s]	T <sub>1</sub> [s]
50	10,87	10,80
63	13,21	12,76
80	9,22	8,74
100	7,96	8,11
125	6,29	6,36
160	6,26	6,14
200	6,68	6,55
250	6,49	6,62
315	6,16	6,09
400	5,67	5,73
500	5,12	5,12
630	5,10	5,02
800	5,52	5,42
1000	5,63	5,54
1250	5,44	5,30
1600	4,99	4,90
2000	4,48	4,43
2500	3,86	3,80
3150	3,44	3,38
4000	3,00	2,95
5000	2,53	2,46

### Measurement uncertainty

From a world wide Round Robin<sup>1)</sup>, in which SP took part, with 23 participating laboratories from 11 countries, the measurement uncertainties in table 3 has been calculated.

*Table 3*

Frequencies (Hz)	Uncertainty
100-630	± 0,15
800-1250	± 0,10
1600-2500	± 0,15
3150-5000	± 0,20

<sup>1)</sup> The figures are calculated from twice the standard deviations, rounded to the nearest 0,05. The data from the Round Robin is documented in a letter from the ASTM to the participating laboratories.

**Pictures of the test objects**

*Picture 1 – Shows Spray-Tec-G with thickness 150 mm mounted on the floor in the reverberation room.*



*Picture 2 – Spray-Tec -G with thickness 200 mm.*

### Test room

A reverberation room with the dimensions 7,64 m x 6,16 m x 4,25 m giving the volume 200 m<sup>3</sup> and the total surface area 211 m<sup>2</sup> was used.

### Mounting

The panels were placed on the floor and the edges were sealed with a wooden frame and a tape (made of an elastic woven material) to prevent air leakage. The mounting depth is the distance between the floor and the front surface (upper) of the test objects.

### List of instruments

Instrument	Manufacturer	Type	Serial no/SP no.
Microphone	Brüel & Kjaer	4943	BX41346
Microphone	Brüel & Kjaer	4943	503326
Microphone	Brüel & Kjaer	4943	503324
Microphone	Brüel & Kjaer	4943	503325
Microphone	Brüel & Kjaer	4943	503323
Microphone	Brüel & Kjaer	4943	503322
Microphone Preamplifier	Brüel & Kjaer	2619	502246
Microphone Preamplifier	Brüel & Kjaer	2619	502244
Microphone Preamplifier	Brüel & Kjaer	2619	502259
Microphone Preamplifier	Brüel & Kjaer	2619	502217
Microphone Preamplifier	Brüel & Kjaer	2619	502225
Microphone Preamplifier	Brüel & Kjaer	2619	503322
Analyzer	Norsonic	850	BX41346
Hygrometer/ Temperature meter	Testo	605i	BX80648
Microphone	Brüel & Kjaer	4943	BX41346
Microphone	Brüel & Kjaer	4943	503326
Microphone	Brüel & Kjaer	4943	503324
Microphone	Brüel & Kjaer	4943	503325
Loudspeakers	SP	HGT2, HGT7, HGT4, HGTak	

### RISE Research Institutes of Sweden AB Building Technology - Sound and vibration

Performed by



Geir Andresen

Examined by

Dag Glebe

### Appendices





Appendix 2

### Sound absorption coefficient according to EN-ISO 11654

Measurement of sound absorption coefficient in a reverberation room

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Client: Ovacon AB Date of test: 2020-12-01  
 Description: Spray-Tec-G 40 mm

Object:

Empty reverberation room: Reverberation room with object:  
 Relative humidity: 81,2 % Relative humidity: 79,6 %  
 Temperature: 19,4 °C Temperature: 19,6 °C  
 Barometric pressure: 99,5 kPa Barometric pressure: 99,6 kPa

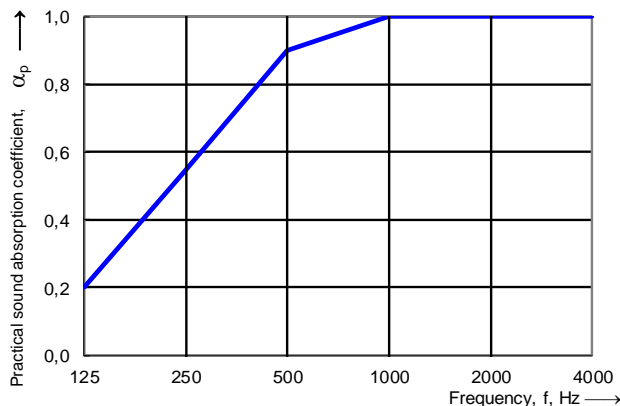
Surface area: 11,81 m<sup>2</sup>  
 Room volume: 200,0 m<sup>3</sup>  
 Total room area S<sub>r</sub>: 211,4 m<sup>2</sup>

Frequency f [Hz]	$\alpha_s$ 1/3 octave
50	0,00
63	0,02
80	0,04
100	0,09
125	0,19
160	0,28
200	0,39
250	0,54
315	0,67
400	0,84
500	0,94
630	0,98
800	1,05
1000	1,01
1250	1,04
1600	1,00
2000	1,00
2500	1,00
3150	1,00
4000	1,01
5000	1,02

Frequency, f, Hz →



Appendix 2

<b>Sound absorption coefficient according to EN-ISO 11654</b>																																									
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Client:	Ovacon AB	Date of test:	2020-12-01																																						
Description:	Spray-Tec-G 40 mm																																								
Object:																																									
Empty reverberation room:		Reverberation room with object:																																							
Relative humidity:	81,2 %	Relative humidity:	79,6 %																																						
Temperature:	19,4 °C	Temperature:	19,6 °C																																						
Barometric pressure:	99,5 kPa	Barometric pressure:	99,6 kPa																																						
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Appendix 3

**Sound absorption coefficient according to EN-ISO 11654**

Measurement of sound absorption coefficient in a reverberation room

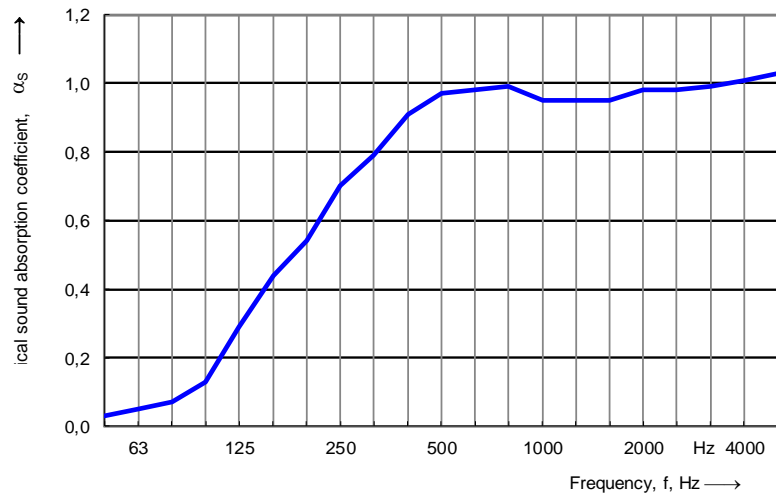
Client: Ovacon AB Date of test: 2020-11-30  
Description: Spray-Tec-G 50 mm

Object:

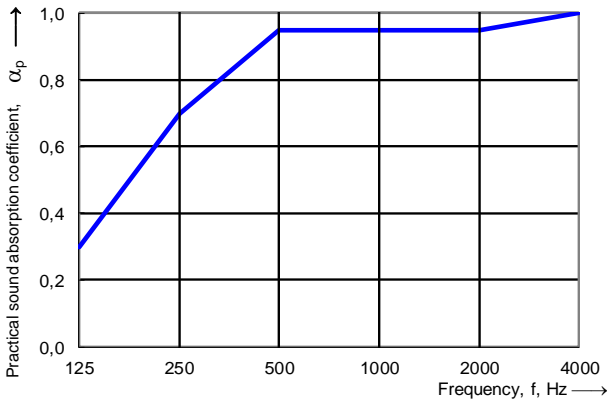
Empty reverberation room:		Reverberation room with object:	
Relative humidity:	83,0 %	Relative humidity:	80,3 %
Temperature:	19,2 °C	Temperature:	19,6 °C
Barometric pressure:	99,8 kPa	Barometric pressure:	99,7 kPa

Surface area: 12,16 m<sup>2</sup>  
Room volume: 200,0 m<sup>3</sup>  
Total room area S<sub>r</sub>: 211,4 m<sup>2</sup>

Frequency f [Hz]	$\alpha_s$ 1/3 octave
50	0,03
63	0,05
80	0,07
100	0,13
125	0,29
160	0,44
200	0,54
250	0,70
315	0,79
400	0,91
500	0,97
630	0,98
800	0,99
1000	0,95
1250	0,95
1600	0,95
2000	0,98
2500	0,98
3150	0,99
4000	1,01
5000	1,03



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Appendix 4

**Sound absorption coefficient according to EN-ISO 11654**

Measurement of sound absorption coefficient in a reverberation room

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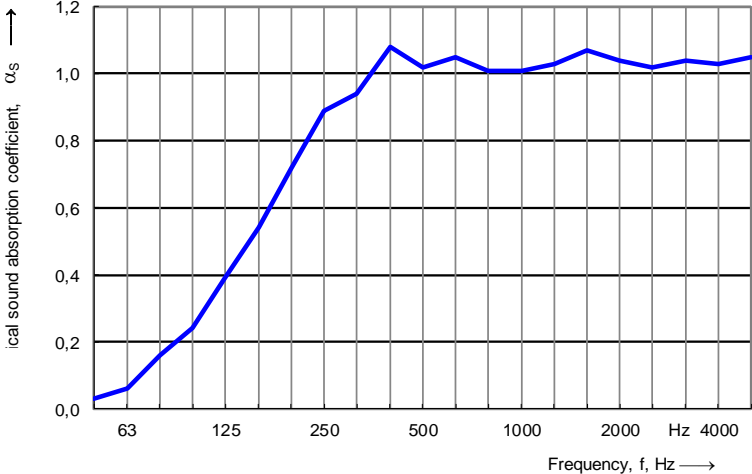
Client: Ovacon AB Date of test: 2020-11-30  
 Description: Spray-Tec-G 63 mm

Object:

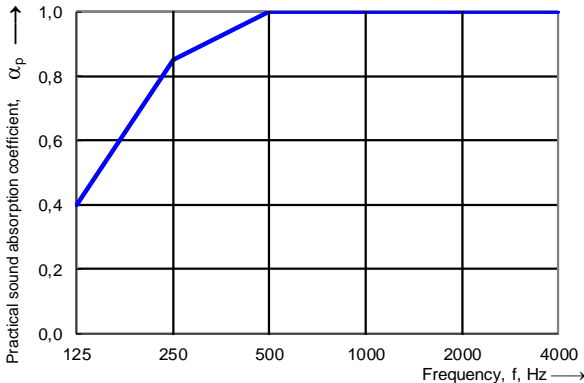
Empty reverberation room: Reverberation room with object:  
 Relative humidity: 83,0 % Relative humidity: 82,2 %  
 Temperature: 19,2 °C Temperature: 19,6 °C  
 Barometric pressure: 99,8 kPa Barometric pressure: 99,7 kPa

Surface area: 12,23 m<sup>2</sup>  
 Room volume: 200,0 m<sup>3</sup>  
 Total room area S<sub>i</sub>: 211,4 m<sup>2</sup>

Frequency f [Hz]	$\alpha_s$ 1/3 octave
50	0,03
63	0,06
80	0,16
100	0,24
125	0,39
160	0,54
200	0,72
250	0,89
315	0,94
400	1,08
500	1,02
630	1,05
800	1,01
1000	1,01
1250	1,03
1600	1,07
2000	1,04
2500	1,02
3150	1,04
4000	1,03
5000	1,05



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Appendix 5

<b>Sound absorption coefficient according to EN-ISO 11654</b>			
Measurement of sound absorption coefficient in a reverberation room			
Client:	Ovacon AB	Date of test:	2020-11-30
Description:	Spray-Tec-G 75 mm		
Object:			
Empty reverberation room:		Reverberation room with object:	
Relative humidity:	83,0 %	Relative humidity:	81,4 %
Temperature:	19,2 °C	Temperature:	19,6 °C
Barometric pressure:	99,8 kPa	Barometric pressure:	99,7 kPa
Surface area: 12,37 m <sup>2</sup>			
Room volume: 200,0 m <sup>3</sup>			
Total room area S <sub>i</sub> : 211,4 m <sup>2</sup>			
Frequency	f	α <sub>s</sub>	1/3 octave
	[Hz]		
	50	0,07	
	63	0,12	
	80	0,15	
	100	0,24	
	125	0,39	
	160	0,61	
	200	0,76	
	250	0,87	
	315	1,04	
	400	1,08	
	500	1,01	
	630	1,00	
	800	0,98	
	1000	0,96	
	1250	1,00	
	1600	1,01	
	2000	1,02	
	2500	1,00	
	3150	1,00	
	4000	0,98	
	5000	0,97	

Frequency f [Hz]	Sound absorption coefficient α <sub>s</sub>
50	0,07
63	0,12
80	0,15
100	0,24
125	0,39
160	0,61
200	0,76
250	0,87
315	1,04
400	1,08
500	1,01
630	1,00
800	0,98
1000	0,96
1250	1,00
1600	1,01
2000	1,02
2500	1,00
3150	1,00
4000	0,98
5000	0,97

Appendix 5

### Sound absorption coefficient according to EN-ISO 11654

Measurement of sound absorption coefficient in a reverberation room

---

Client: Ovacon AB Date of test: 2020-11-30  
 Description: Spray-Tec-G 75 mm

Object:

Empty reverberation room: Reverberation room with object:  
 Relative humidity: 83,0 % Relative humidity: 81,4 %  
 Temperature: 19,2 °C Temperature: 19,6 °C  
 Barometric pressure: 99,8 kPa Barometric pressure: 99,7 kPa

Surface area: 12,37 m<sup>2</sup>  
 Room volume: 200,0 m<sup>3</sup>  
 Total room area S<sub>r</sub>: 211,4 m<sup>2</sup>

Frequency f [Hz]	$\alpha_p$ 1/1 octave
100	0,40
125	
160	
200	0,90
250	
315	
400	1,00
500	
630	
800	1,00
1000	
1250	
1600	1,00
2000	
2500	
3150	1,00
4000	
5000	

Practical sound absorption coefficient,  $\alpha_p$  vs Frequency, f, Hz

Weighted sound absorption coefficient according to ISO 11654

$\alpha_w = 1,00$  Classification: A

Appendix 6

### Sound absorption coefficient according to EN-ISO 11654

Measurement of sound absorption coefficient in a reverberation room

---

Client: Ovacon AB Date of test: 2020-11-30  
 Description: Spray-Tec-G 104 mm

Object:

Empty reverberation room: Reverberation room with object:  
 Relative humidity: 83,0 % Relative humidity: 81,0 %  
 Temperature: 19,2 °C Temperature: 19,6 °C  
 Barometric pressure: 99,8 kPa Barometric pressure: 99,7 kPa

Surface area: 12,45 m<sup>2</sup>  
 Room volume: 200,0 m<sup>3</sup>  
 Total room area S<sub>i</sub>: 211,4 m<sup>2</sup>

Frequency f [Hz]	$\alpha_s$ 1/3 octave
50	0,12
63	0,18
80	0,25
100	0,41
125	0,52
160	0,69
200	0,97
250	1,04
315	1,05
400	1,06
500	1,02
630	1,03
800	1,00
1000	1,03
1250	1,04
1600	1,05
2000	1,04
2500	1,02
3150	1,04
4000	1,02
5000	1,05

Frequency, f, Hz →







Appendix 7

**Sound absorption coefficient according to EN-ISO 11654**

Measurement of sound absorption coefficient in a reverberation room

---

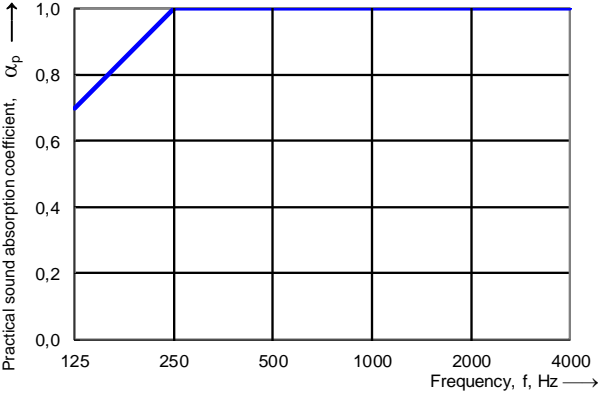
Client: Ovacon AB Date of test: 2020-11-30  
 Description: Spray-Tec-G 150 mm

Object:

Empty reverberation room: Reverberation room with object:  
 Relative humidity: 83,0 % Relative humidity: 83,0 %  
 Temperature: 19,2 °C Temperature: 19,6 °C  
 Barometric pressure: 99,8 kPa Barometric pressure: 99,7 kPa

Surface area: 12,34 m<sup>2</sup>  
 Room volume: 200,0 m<sup>3</sup>  
 Total room area S<sub>i</sub>: 211,4 m<sup>2</sup>

Frequency f [Hz]	$\alpha_p$ 1/1 octave
100	0,70
125	
160	
200	1,00
250	
315	
400	1,00
500	
630	
800	1,00
1000	
1250	
1600	1,00
2000	
2500	
3150	1,00
4000	
5000	



Weighted sound absorption coefficient according to ISO 11654

$\alpha_w = 1,00$  Classification: A

Appendix 8

### Sound absorption coefficient according to EN-ISO 11654

Measurement of sound absorption coefficient in a reverberation room

---

Client: Ovacon AB Date of test: 2020-12-01  
 Description: Spray-Tec-G 200 mm

Object:

Empty reverberation room: Reverberation room with object:  
 Relative humidity: 81,2 % Relative humidity: 78,6 %  
 Temperature: 19,4 °C Temperature: 19,6 °C  
 Barometric pressure: 99,5 kPa Barometric pressure: 99,6 kPa

Surface area: 12,26 m<sup>2</sup>  
 Room volume: 200,0 m<sup>3</sup>  
 Total room area S<sub>r</sub>: 211,4 m<sup>2</sup>

Frequency f [Hz]	$\alpha_s$ 1/3 octave
50	0,25
63	0,33
80	0,55
100	0,88
125	0,78
160	0,80
200	0,98
250	0,90
315	0,94
400	1,01
500	0,98
630	0,99
800	1,02
1000	1,02
1250	1,05
1600	1,04
2000	1,06
2500	1,04
3150	1,04
4000	1,04
5000	1,04

Frequency, f, Hz →

Appendix 8

**Sound absorption coefficient according to EN-ISO 11654**

Measurement of sound absorption coefficient in a reverberation room

---

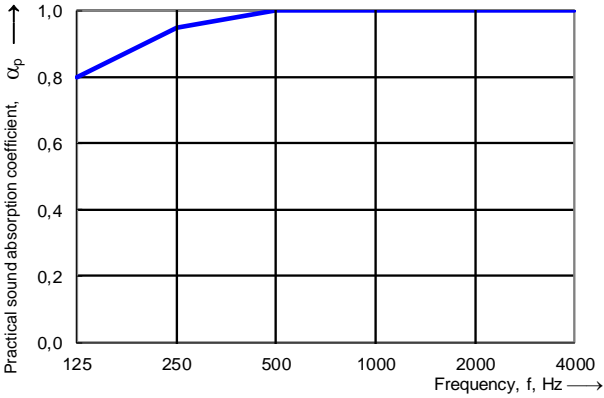
Client: Ovacon AB Date of test: 2020-12-01  
 Description: Spray-Tec-G 200 mm

Object:

Empty reverberation room: Reverberation room with object:  
 Relative humidity: 81,2 % Relative humidity: 78,6 %  
 Temperature: 19,4 °C Temperature: 19,6 °C  
 Barometric pressure: 99,5 kPa Barometric pressure: 99,6 kPa

Surface area: 12,26 m<sup>2</sup>  
 Room volume: 200,0 m<sup>3</sup>  
 Total room area S<sub>i</sub>: 211,4 m<sup>2</sup>

Frequency f [Hz]	$\alpha_p$ 1/1 octave
100	0,80
125	
160	
200	0,95
250	
315	
400	1,00
500	
630	
800	1,00
1000	
1250	
1600	1,00
2000	
2500	
3150	1,00
4000	
5000	



The graph shows the practical sound absorption coefficient ( $\alpha_p$ ) on the y-axis (ranging from 0.0 to 1.0) against frequency (f, Hz) on the x-axis (logarithmic scale from 125 to 4000). The curve starts at approximately 0.8 at 125 Hz, rises to 0.95 at 250 Hz, and reaches 1.0 at 500 Hz, remaining constant at 1.0 for higher frequencies.

Weighted sound absorption coefficient according to ISO 11654

$\alpha_w = 1,00$  Classification: A