Report on sound absorption measurements in a reverberation chamber in accordance with EN ISO 354:2005

Report no: 642-24P-T42-2-001a

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1. Background information

NAME AND ADDRESS OF THE LABORATORY	KFB Acoustics Sp. z o.o. 8 Oławska Street, 55-040 Domasław
CHARACTERISTICS EXAMINED AND RESEARCH METHODS	sound absorption coefficient α_s determined in accordance with EN ISO 354:2005; practical sound absorption coefficient α_p and sound absorption coefficient α_w determined in accordance with EN ISO 11654:1999
CONTRACTING AUTHORITY	Fovere Sp. z o.o. 40 Warszawska Street, 05-082 Blizne Łaszczyńskiego, Poland
ELEMENTS TO BE EXAMINED	Fovere PET felt wall panel 12 mm thick. Fovere PET felt wall boxes. Box baffles on T-bars, suspended from ceiling. Flat ceiling baffles made of PET Fovere felt with a thickness of 12 mm.
ORDER NUMBER	642-24P-T42-2-001a
DATE OF ORDER	31.07.2024
DATE OF MEASUREMENT	20.08.2023 - 23.08.2023
DATE OF ISSUE OF THE REPORT	30.08.2024
MEASUREMENTS WERE TAKEN (, position)	Wojciech Bartnik, M.Sc. *(Deputy Head of Testing Laboratory)*
THE REPORT WAS COMPILED BY (, position)	Alan Sarota, M.Sc *(Measurement Specialist)*
CHECK (, position)	Wojciech Bartnik, M.Sc. *(Deputy Head of Testing Laboratory)*
REPORT AUTHORISED	Wojciech Bartnik, M.Sc. *(Deputy Head of Testing Laboratory)*

2. Basis of development

2.1 Formal basis of the study

This report contains the results of the measurement of the absorption coefficient of individual pieces of equipment in accordance with EN ISO 354:2003 Acoustics -- Measurement of sound absorption in a reverberation chamber.

The subjects of the study were flat and spatial absorbing materials manufactured by Fovere based on felt materials.

2.2 Substantive basis of the study

The following standards were referred to in the preparation of this report:

[1] PN-EN ISO 354:2005 Acoustics -- Measurement of sound absorption in a reverberation chamber

[2] EN ISO 12999-1:2021-05 Acoustics -- Determination and application of uncertainty of measurement in building acoustics -- Part 2: Sound absorption

[3] PN-EN ISO 11654:1999 Acoustics -- Sound-absorbing products used in construction -- Sound absorption coefficient

2.3 Definitions

[1] Coefficient absorption, α_s: the quotient of equivalent field of area
the sound absorption area of the test sample and the surface area of the test sample determined in accordance with EN ISO 354:2005.

[2] Index absorption sound α_w: single figure magnitude independent from frequency, the value of which is equal to the value of the reference curve for 500Hz, after shifting as specified in EN ISO 11654:1999.

[3] Practical coefficient absorption coefficient sound, α_p: value frequency dependent sound absorption coefficient, based on the measurement results
carried out in accordance with the ISO 354 standard in 1/3-octave bands and calculated for octave bands on the basis of the PN-EN ISO 11654:1999 standard.

3. Measuring station

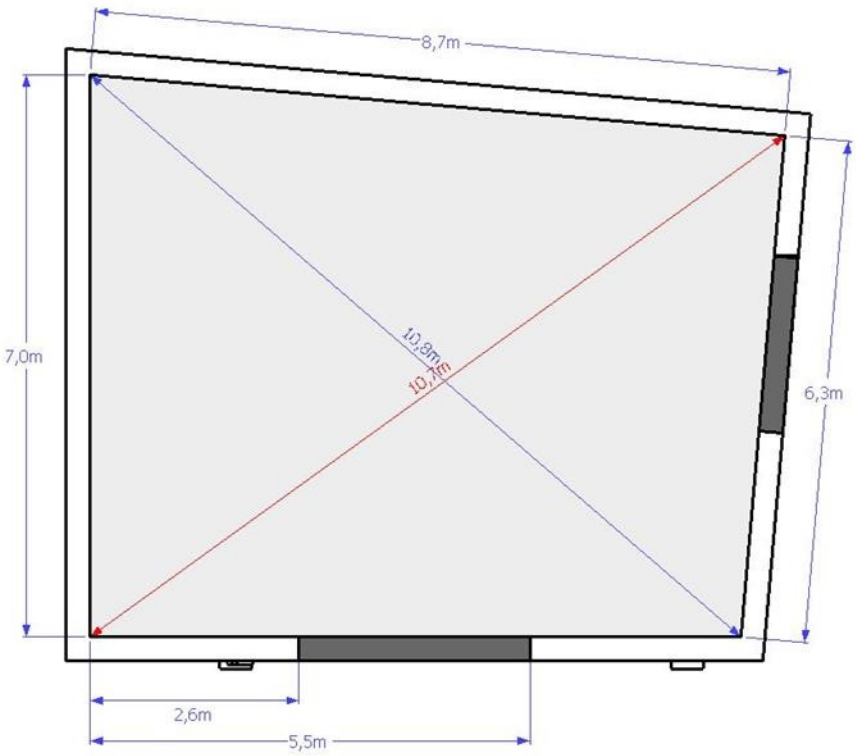
Name of laboratory: KFB Acoustics Ltd.

Laboratory address: 8 Oławska Street, 55-040 Domasław

Measurement location: P1 chamber 8 Oławska Street, Domasław

3.1 Description of the study site

Shape of the reverberation chamber	Reverberation chamber P1 volume V= 293.8 m^3 total surface area S= 263.7 m^2 reverberation chamber dimensions (length, width, height) - 8.7m x 7.0m x 5.4m
Method of dispersion (number and size of dispersion elements)	There are 10 scatterers installed in the chamber. The scatterers are made of polyurethane with a size of 2.0 m by 1.25 m (8 pieces) or 1.25 m x 1.25 m (2 pieces) with a weight of no less than 5kg/$m^{2.}$
number of microphone positions	6
number of positions sound sources	2



Top view of the reverberation chamber floor

Arrangement of diffusers in the reverberation chamber

4. Object under investigation

4.1 Description of the object under investigation

Description of the study object based on data provided by the Employer.

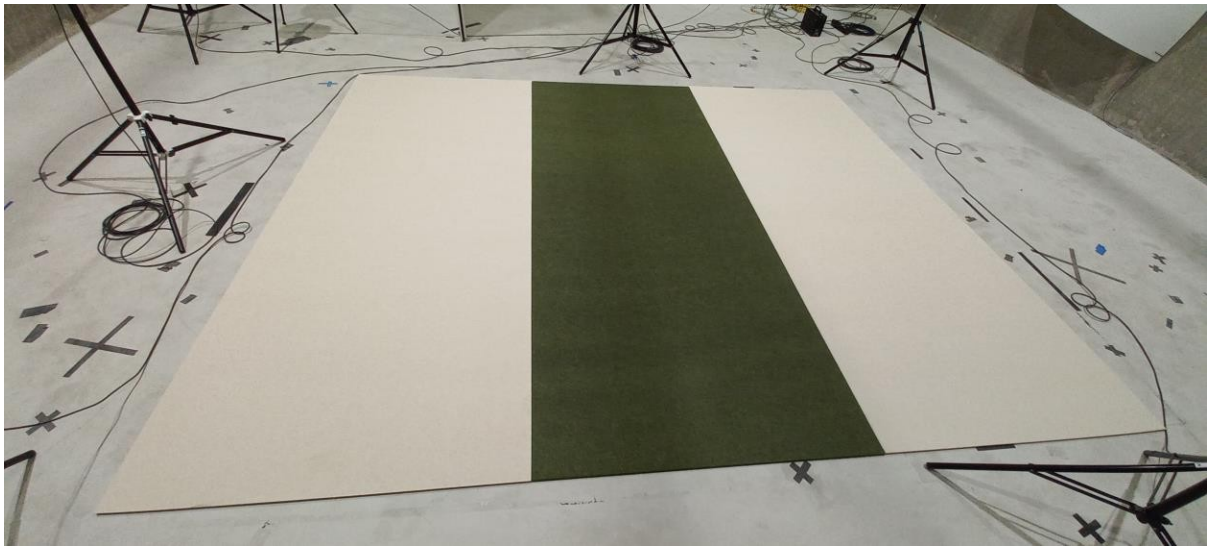
Category of tested facility	Flat products
Name of research facility	Fovere PET felt wall board 12 mm thick
Manufacturer	Fovere Sp. z o.o.
Description of the research facility	Fovere products are made from recycled PET plastic, containing 60% pre-consumer recyclate and 40% bicomponent. The PET plastic used in the production of the felt boards is Oeko-TEX accredited and the board weight is 2400 g/m².
Method installation w chamber reverberating (descriptive)	Type A assembly in accordance with EN ISO Annex B 354:2005. Sample composed of 3 panels with dimensions 3.0 x 1.2 x 0,012 m. Sample mounted directly on the floor without frame (edges side included in field area samples).

Category object under investigation	Flat products
Name of research facility	Fovere PET felt wall boxes
Manufacturer	Fovere Sp. z o.o.
Description of the research facility	Fovere products are made from recycled PET plastic, containing 60% pre-consumer recyclate and 40% bicomponent. The PET plastic used in the production of the felt boards is Oeko-TEX accredited and the board weight is 2400 g/m².
Method installation and arrangement in the reverberation chamber (description)	Type A assembly in accordance with annex B of EN ISO 354:2005. Composite sample of 6 panels measuring 0.5 x 2.6 m x 0.09 and 6 panels measuring 0.5 x 1.3 x 0.09 m. Sample mounted directly on the floor without a frame (side edges included in the sample area).

Category object under investigation	Spatial absorbers
Name of research facility	Box baffles on T-bars, suspended from the ceiling
Manufacturer	Fovere Sp. z o.o.
Description of the research facility	Fovere products are made from recycled PET plastic, containing 60% pre-consumer recyclate and 40% bicomponent. The PET plastic used in the production of the felt boards is Oeko-TEX accredited and the board weight is 2400 g/m².
Method installation in the reverberation chamber reverberation chamber (description)	Type J assembly in accordance with annex B of EN ISO 354:2005. The sample consisted of 20 panels measuring 0.15 x 2.8 x 0.05 m mounted in parallel rows with one edge resting on the floor of the chamber. The spacing between the rows was 15 cm. Sample assembled using system T-bars. Sample mounted in a plate well type frame in the centre of the chamber - distance of the frame and specimen from the walls of the chamber >1m.

Category object under investigation	Spatial absorbers
Name of research facility	Flat baffle ceiling of felt PET Fovere of thickness 12 mm.
Manufacturer	Fovere Sp. z o.o.
Description of the research facility	Fovere products are made from recycled PET plastic, containing 60% pre-consumer recyclate and 40% bicomponent. The PET plastic used in the production of the felt boards is Oeko-TEX accredited and the board weight is 2400 g/m².
Method installation in a reverberation chamber reverberation chamber (description)	Type J assembly in accordance with Annex B of EN ISO 354:2005. The sample consisted of 20 panels measuring 0.2 x 2.0 x 0.012 m mounted in parallel rows with one edge resting on the floor of the chamber. The spacing between the rows was 15 cm. Sample assembled using system T-bars. Sample mounted in a plate well type frame in the centre of the chamber - distance of the frame and specimen from the walls of the chamber >1m.

4.2 Arrangement of the test object in the chamber



Fovere PET felt wall board 12 mm thick

Fovere PET felt wall boxes

Box baffles on T-bars

Flat ceiling baffles made from 12 mm PET Fovere felt.

5. Apparatus and measurement procedure

5.1 Measuring apparatus

Lp	Name of apparatus	Type	Factory number	Date of calibration	Certificate No.
1.	Omni-directional noise source	Nor 276	2765609	-	-
	Amplifier	Nor 280	2803972	-	-
2.	Meter level sound	Nor850-MFI	8501221	-	-
2.1	Microphone (channel 1)	GRAS 40AE	460336	19.05.2022	1142/1/ 2022
	Preamplifier	GRAS 26CA	491786		
2.2	Microphone (channel 2)	GRAS 40AE	459990	23.05.2022	1142/2/ 2022
	Preamplifier	GRAS 26CA	491787		
2.3	Microphone (channel 3)	GRAS 146AE	478213	30.06.2022	1142/3/ 2022
	Preamplifier	GRAS 146AE			
2.4	Microphone (channel 4)	GRAS 146AE	478296	30.06.2022	1142/4/ 2022
	Preamplifier	GRAS 146AE			
2.5	Microphone (channel 5)	GRAS 146AE	478309	30.06.2022	1142/5/ 2022
	Preamplifier	GRAS 146AE			
2.6	Microphone (channel 6)	GRAS 146AE	467617	30.06.2022	1142/6/ 2022
	Preamplifier	GRAS 146AE			
4.	Acoustic calibrator	Nor1256	125626598	25.01.2023	185/K/2023
5.1.	Sensor climate conditions - barometer Transmission chamber	THPVoc 1W-UNI	6007470054	08.12.2022	85924/2022
	Sensor climatic conditions - thermhigromer Transmission chamber			08.12.2022	85920/2022
	Sensor conditions climate -		6007470159	08.12.2022	85926/2022

5.2.	barometer Receiving chamber	THPVoc 1W-UNI			
	Sensor climatic conditions - thermhigromer Receiving chamber			08.12.2022	85922/2022
6.	Tripod 6 pcs.	Manfrotto	-	-	-

5.2 Measurement procedure

The acoustic track was calibrated with a class 1 calibrator. Before measuring the absorption coefficient of the sample, the field scattering was measured and the number of scattering elements was selected so that adding more did not affect the measured coefficient. The primary measurement of the sound absorption coefficient consisted of measuring the sound pressure decay curves before and after mounting the test sample. In the reverberation chamber, the sound sources emitted white intermittent noise. The measurement microphones were mounted on movable tripods, and sound measurements were made at 6 points for 2 source positions (the number of microphone positions multiplied by the number of source positions was equal to 12). For averaging, three reverberation time measurements were taken at each point and the results were arithmetically averaged.

In the case of the measurement of the spatial absorbers, the measurement of the empty chamber took place
with a frame.

6. Findings

No.	Sample description	Parameter	Parameter value
1	Board wall from felt PET gr. 12mm mounted without frame	Sound absorption coefficient α_w	0,25 (H)
2	Boxes wall boxes z felt PET Fovere, 90 mm thick	Sound absorption coefficient α_w	1,00
3	Box baffles on T-bars 50 mm thick and 15 cm high at 15 cm intervals	Sound absorption coefficient α_w	0,60 (H)
4	Flat ceiling baffles made of PET Fovere felt, 12mm thick and 20cm high, spaced 15cm apart	Sound absorption coefficient α_w	0,40 (H)

Absorption coefficient determined in accordance with EN ISO 354:2005

Measurements of the absorption coefficient in a reverberation chamber

Object under study: **Wall panel in PET felt 12mm thick mounted without frame**

Date of survey: 20.08.2023

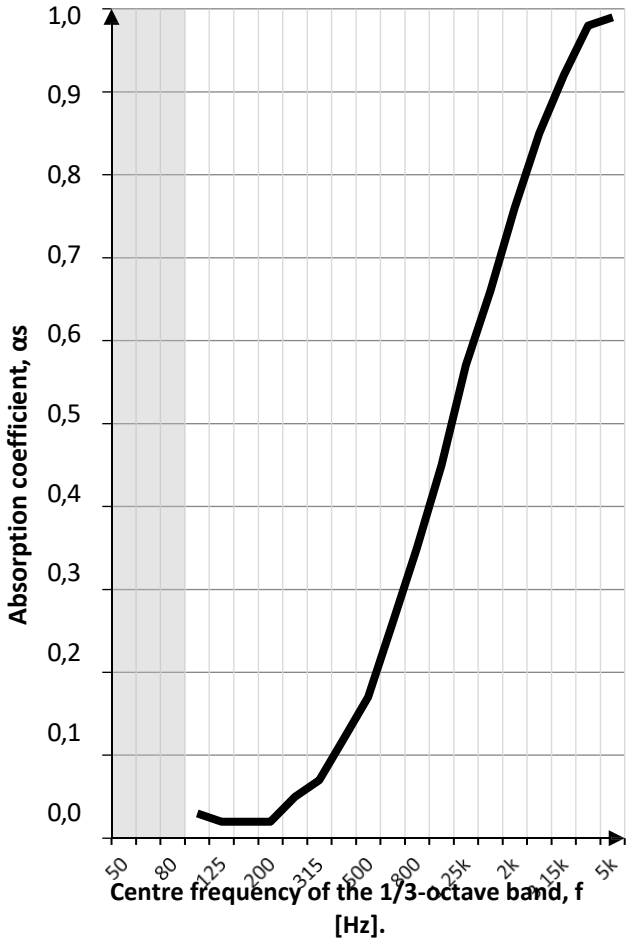
Sample area: 11,6 m²

Room parameter	**Empty room**	**Room with the object of the research**
Relative humidity [%]	61,8	61,8
Temperature [°C].	23,8	23,8
Atmospheric pressure [hPa]	99,7	99,7
Room volume [m³]	293,8	
Total surface area [m²]	263,7	

f [Hz].	αs	±U (95)	T1 [s]	T2 [s]
50				
63				
80				
100	0,03	0,04	12,2	11,1
125	0,02	0,04	11,85	11,3
160	0,02	0,04	11,64	10,9
200	0,02	0,04	10,4	9,9
250	0,05	0,04	10,5	9,3
315	0,07	0,04	10,7	9,0
400	0,12	0,04	11,6	8,6
500	0,17	0,04	11,9	8,0
630	0,26	0,06	11,7	6,7
800	0,35	0,06	10,8	5,6
1000	0,45	0,06	9,9	4,7
1250	0,57	0,08	8,9	4,0
1600	0,66	0,08	7,7	3,4
2000	0,76	0,10	6,7	3,0
2500	0,85	0,10	5,8	2,6
3150	0,92	0,12	5,0	2,3
4000	0,98	0,14	3,9	2,0
5000	0,99	0,18	3,3	1,8

Practical sound absorption coefficient according to PN-EN ISO 11654:1999

f [Hz].	αpi
63	
125	0,0
250	0,05
500	0,20
1000	0,45
2000	0,75
4000	0,95



Sound absorption index:

α_w= **0.25 (H)**

Index and its uncertainty U95 according to EN ISO 12999-1:2021-05 (reproducibility conditions):

α_w= **(0.25 ±0.10)**

Sound absorption class:

E

Date: Signature:

Absorption coefficient determined in accordance with EN ISO 354:2005

Measurements of the absorption coefficient in a reverberation chamber

Object under study: **Fovere PET felt wall boxes 90 mm thick**

Date of survey: 20.08.2023

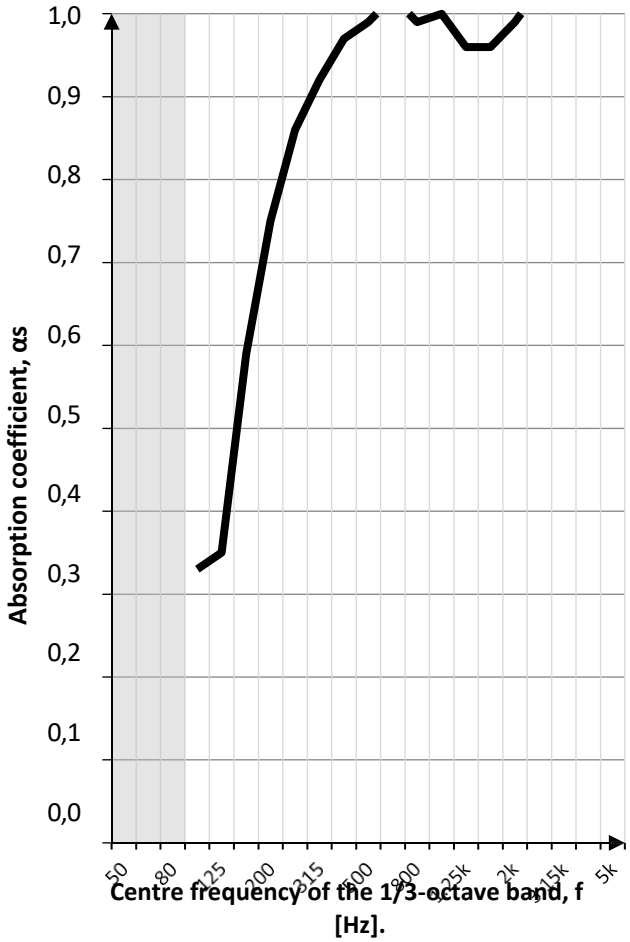
Sample area: 12,4 m²

Room parameter	**Empty room**	**Room with the object of the research**
Relative humidity [%]	61,8	62,1
Temperature [°C].	23,8	23,8
Atmospheric pressure [hPa]	99,7	99,7
Room volume [m³]	293,8	
Total surface area [m²]	263,7	

f [Hz].	αs	±U (95)	T1 [s]	T2 [s]
50				
63				
80				
100	0,33	0,18	12,2	5,9
125	0,35	0,16	11,85	5,68
160	0,59	0,20	11,64	4,16
200	0,75	0,20	10,4	3,4
250	0,86	0,18	10,5	3,1
315	0,92	0,16	10,7	3,0
400	0,97	0,14	11,6	2,9
500	0,99	0,12	11,9	2,9
630	1,02	0,12	11,7	2,8
800	0,99	0,10	10,8	2,8
1000	1,00	0,12	9,9	2,8
1250	0,96	0,10	8,9	2,7
1600	0,96	0,10	7,7	2,6
2000	0,99	0,12	6,7	2,4
2500	1,03	0,12	5,8	2,3
3150	1,05	0,12	5,0	2,1
4000	1,07	0,14	3,9	1,9
5000	1,05	0,18	3,3	1,7

Practical sound absorption coefficient according to PN-EN ISO 11654:1999

f [Hz].	αpi
63	
125	0,40
250	0,85
500	1,0
1000	1,0
2000	1,0
4000	1,0



Sound absorption index:

α_w= **1.00**

Index and its uncertainty U95 according to EN ISO 12999-1:2021-05 (reproducibility conditions):

α_w= **(1.00 ±0.10)**

Sound absorption class:

A

Date: Signature:

Absorption coefficient determined in accordance with EN ISO 354:2005

Measurements of the absorption coefficient in a reverberation chamber

Object under study: **Box baffles on T-bars 50 mm thick and 15 cm high at 15 cm intervals**

Date of survey: 22.08.2023

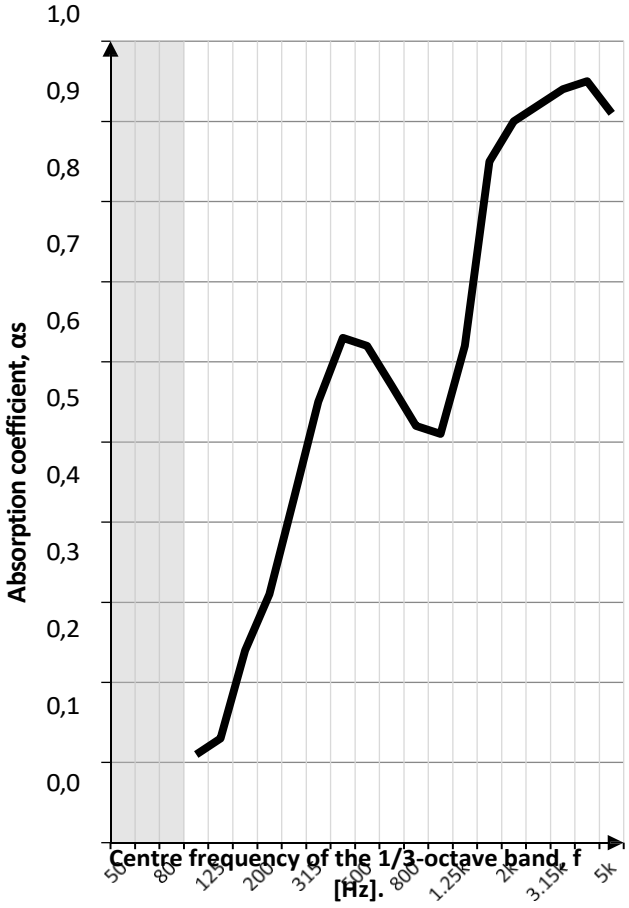
Sample area: 11,2 m²

Room parameter	Empty room	Room with the object of the research
Relative humidity [%]	50,0	50,0
Temperature [°C].	23,8	23,8
Atmospheric pressure [hPa]	99,7	99,7
Room volume [m³]	293,8	
Total surface area [m²]	263,7	

f [Hz].	αs	±U (95)	T1 [s]	T2 [s]
50				
63				
80				
100	0,11	0,08	11,7	8,9
125	0,13	0,08	11,25	8,30
160	0,24	0,10	11,53	6,95
200	0,31	0,10	10,1	5,8
250	0,43	0,10	9,7	4,8
315	0,55	0,12	9,9	4,3
400	0,63	0,10	10,6	4,1
500	0,62	0,10	10,8	4,2
630	0,57	0,08	10,8	4,4
800	0,52	0,08	10,1	4,5
1000	0,51	0,08	9,3	4,4
1250	0,62	0,08	8,3	3,7
1600	0,85	0,10	7,2	2,9
2000	0,90	0,10	6,1	2,6
2500	0,92	0,10	5,2	2,4
3150	0,94	0,12	4,4	2,2
4000	0,95	0,14	3,4	1,9
5000	0,91	0,16	2,8	1,7

Practical sound absorption coefficient according to PN-EN ISO 11654:1999

f [Hz].	αpi
63	
125	0,15
250	0,45
500	0,60
1000	0,55
2000	0,90
4000	0,95



Sound absorption index:

α_w= 0.60 (H)

Index and its uncertainty U95 according to EN ISO 12999-1:2021-05 (reproducibility conditions):

α_w= (0.60 ±0.10)

Sound absorption class:

C

Date: Signature:

Absorption coefficient determined in accordance with EN ISO 354:2005

Measurements of the absorption coefficient in a reverberation chamber

Object under study: **Flat ceiling baffles made of PET Fovere felt, 12mm thick and 20cm high, spaced 15cm apart**

Date of survey: 23.08.2023

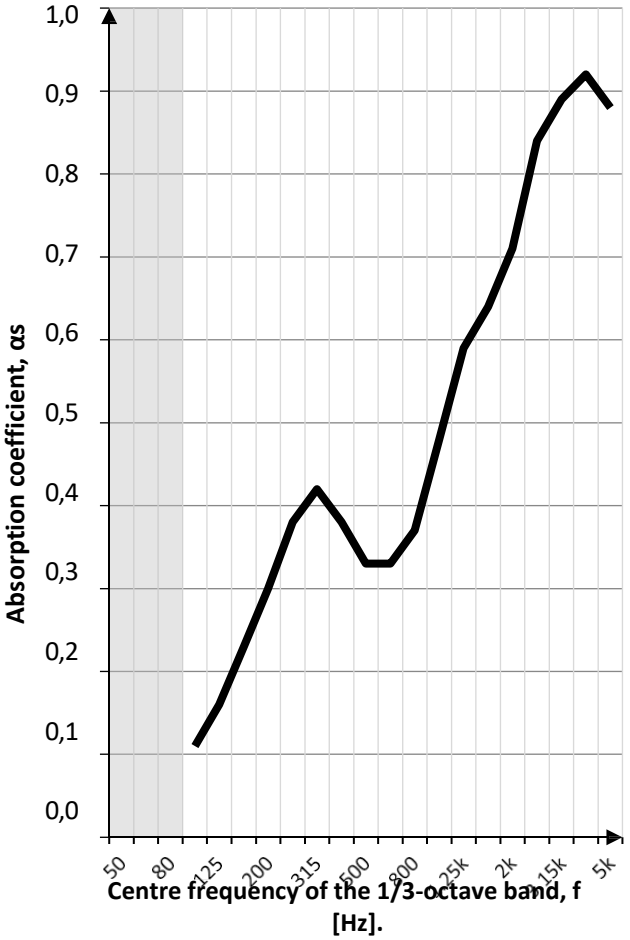
Sample area: 9,7 m²

Room parameter	**Empty room**	**Room with the object of the research**
Relative humidity [%]	55,6	54,9
Temperature [°C].	23,7	23,7
Atmospheric pressure [hPa]	99,7	99,7
Room volume [m³]	293,8	
Total surface area [m²]	263,7	

f [Hz].	αs	±U (95)	T1 [s]	T2 [s]
50				
63				
80				
100	0,11	0,04	10,8	8,6
125	0,16	0,04	11,17	8,17
160	0,23	0,04	10,70	7,11
200	0,30	0,04	9,7	6,1
250	0,38	0,04	9,5	5,5
315	0,42	0,04	9,8	5,3
400	0,38	0,04	10,4	5,7
500	0,33	0,04	10,5	6,1
630	0,33	0,04	10,5	6,2
800	0,37	0,04	9,9	5,7
1000	0,48	0,04	9,2	4,8
1250	0,59	0,04	8,2	4,1
1600	0,64	0,04	7,2	3,7
2000	0,71	0,04	6,1	3,2
2500	0,84	0,06	5,3	2,8
3150	0,89	0,06	4,6	2,5
4000	0,92	0,08	3,6	2,1
5000	0,88	0,12	3,0	1,9

Practical sound absorption coefficient according to PN-EN ISO 11654:1999

f [Hz].	αpi
63	
125	0,15
250	0,35
500	0,35
1000	0,50
2000	0,75
4000	0,90



Sound absorption index:

α_w= **0.40 (H)**

Index and its uncertainty U95 according to EN ISO 12999-1:2021-05 (reproducibility conditions):

α_w= **(0.40 ±0.10)**

Sound absorption class:

D

Date: Signature:

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