Fraunhofer IBP

Institution for testing, supervision and certification, officially recognized by the building supervisory authority. Approvals of new building materials, components and types of construction

Director
Prof. Dr. Philip Leistner

Test Report P-BA 147/2024e

Determination of the Acoustic Performance of a Pipe Lining for Wastewater Installation Systems in the Laboratory according to DIN EN 14366-1

Client: TEKNISOL srl
via 1° Maggio, 38/38A
20028 San Vittore Olona
Milan
Italy

Test specimen: Acoustic insulation for wastewater installation systems, type: "TEKNOSOUND", manufacturer: TEKNISOL srl, consisting of a 2 mm mass layer and a 10 mm elastomeric layer; in combination with a wastewater system consisting of plastic pipes and fittings (OD 110) mounted with pipe clamps.

Content:

Test date: The measurements were carried out on July 8th and 9th, 2024 in the test facilities of the Fraunhofer Institute for Building Physics in Stuttgart.

Stuttgart, November 15, 2024

Test Engineer: Dipl.-Ing. (FH) S. Müller

Head of the test laboratory: M.BP. Dipl.-Ing. (FH) S. Öhler

The test was carried out in laboratory facilities of the IBP which is accredited according to DIN EN ISO/IEC 17025:2018 by the DAkkS. The accreditation certificate is D-PL-11140-11-00.

Fraunhofer-Institut für Bauphysik IBP - Prüflabor Akustik
Nobelstraße 12, D-70569 Stuttgart
Telefon +49(0) 711/970-3314; Fax -3406
akustik@ibp.fraunhofer.de
www.pruefstellen.ibp.fraunhofer.de/en/Test_Laboratories.html

ilac-MRA DAkkS Deutsche Akkreditierungsstelle D-PL-11140-11-00

Acoustic performance of a pipe lining acc. DIN EN 14366-1 **Client:** TEKNISOL srl, via 1° Maggio, 38/38A, 20028 San Vittore Olona, Milan, Italy	**P-BA 147/2024e** **Sheet 1**

Test specimen: Acoustic insulation for wastewater installation systems, type: "TEKNOSOUND", manufacturer: TEKNISOL srl, consisting of a 2 mm mass layer and a 10 mm elastomeric layer; in combination with a wastewater system consisting of plastic pipes and fittings (OD 110) mounted with standard pipe clamps.

Test set-up: The pipe system was mounted according to Figures 3 and 4 (see also Annex A).
The pipe system consisted of straight wastewater pipes (nominal size OD 110), three inlet tees (~88°), a 2 x 45° basement bend and a horizontal drain section. The inlet tees in the basement and on the ground floor were closed by lids supplied by the manufacturer.

- Insulation: Acoustic insulation for wastewater installation systems, type: "TEKNOSOUND", manufacturer: TEKNISOL srl, is a flexible sound barrier consisting of a mass layer (thickness: approx. 2 mm, weight: approx. 4.0 kg/m², hardness: 75 shore) and an elastomeric layer with open cells for noise absorption (thickness: approx. 10 mm, density: approx. 60 kg/m³).

  All straight pipes, fittings and pipe clamps were covered with cut sheet material of "TEKNOSOUND" (weight approx. 4.7 kg/m², total thickness approx. 12 mm). All gaps between the material were taped.
  The Measurement set-up (according to Figure 3; Annex A and M):

- Pipe system: Commercial wastewater system consisting of plastic pipes and fittings (straight pipes, three inlet tees, 2 x 45°-basement bend and a horizontal drain section) – one-layer pipes, material: PP, OD 110, wall thickness: 4.5 mm, weight: 2.7 kg/m, density: 1.8 g/cm³. The inlet tees in the basement and on the ground floor were closed by lids.
- Pipe clamps: Steel pipe clamps with elastomer inlay, type: " BISMAT® 2000", Walraven, tightening torque: 3 Nm, mounted with plastic dowels and thread rods to the installation wall. In each storey (EG and UG) two pipe clamps were installed.

  - Test set-up (with pipe lining): Wastewater system covered with acoustic insulation, type: "TEKNOSOUND", manufacturer: TEKNISOL srl
  - Reference set-up (without pipe lining): Wastewater system without insulation.

The wastewater installation system and the pipe insulation were mounted by a technician under the authority of Fraunhofer IBP.

Test facility: Installation test facility P12, mass per unit area of the installation wall 220 kg/m², mass per unit area of the ceiling 440 kg/m². Installation rooms sub-basement (KG), basement (UG) front, ground floor (EG) front and top floor (DG), measuring rooms: UG front, UG rear (details in Annex P and DIN EN 14366-1:2023-09).

Test method: The measurements were performed according to DIN EN 14366-1, Annex B; noise excitation by steady water flow with 0.5 l/s, 1.0 l/s, 2.0 l/s and 4.0 l/s. Measured and calculated variables: airborne sound power level and single equivalent blocked force level (Results 4 (with pipe lining) and Results 6 (without pipe lining)), single equivalent free velocity level and magnitude of single equivalent source mobility (Results 5 (with pipe lining) and Results 6 (without pipe lining)) as well as airborne sound power insertion loss (Results 2), structure-borne sound power insertion loss for low mobility receivers (Results 3) and structure-borne sound power insertion loss (Results 4) for lightweight buildings acc. DIN EN 12354-5, Annex G.4.3. Details see Annex A, Annex F and Annex H.

Comparing products: Calculated Single Number Quantities (SNQ): Please use the calculated values according to DIN EN 12354-5:2023-08, Annex G.4 in Results 1, stating the flow rates, mounting conditions, used pipe clamps and details of the pipe lining for advertisement.

Note:

Fraunhofer IBP

The test was carried out in laboratory facilities of the IBP which is accredited according to DIN EN ISO/IEC 17025:2018 by the DAkkS. The accreditation certificate is D-PL-11140-11-00.

Stuttgart, November 15, 2024
Head of the test laboratory:

Comparing products: Calculated Single Number Quantities (SNQ)	**P-BA 147/2024e**
Client: TEKNISOL srl, via 1° Maggio, 38/38A, 20028 San Vittore Olona, Milan, Italy	**Results 1**

Test specimen: Acoustic insulation for wastewater installation systems, type: "TEKNOSOUND", manufacturer: TEKNISOL srl, consisting of a 2 mm mass layer and a 10 mm elastomeric layer; in combination with a wastewater system consisting of plastic pipes and fittings (OD 110) mounted with standard pipe clamps.

Mounting conditions see Sheet 1.

According to DIN EN 14366-1, two quantities are used for comparing products (wastewater systems):

- A-weighted airborne sound power level for the radiated airborne sound in the source/installation room,
- A-weighted apparent structure-borne sound pressure level generated in buildings.

In the two building examples given below, one for heavy buildings and one for lightweight buildings, the single number quantities (SNQ) and the insertion losses are calculated. Details of the example buildings are shown in DIN EN 12354-5, Annex G.4. However, the SNQ obtained here shall not be used in context with requirements in any other buildings. A prediction for the building considered is then required and shall be performed according to DIN EN 12354-5.

a) Heavy building (DIN EN 12354-5, Annex G.4.2):
The heavy building configuration has 18 cm concrete floors and separating walls with a surface mass of 220 kg/m². The values for $L'_{n,wall}$ are given in Table G.12 in DIN EN 12354-5, Annex G for the horizontal transmission indicated in Figure G.6 and are used for calculating the SNQ in the table below.

b) Lightweight building (DIN EN 12354-5, Annex G.4.3):
The building configuration has a timber frame structure and the separating wall is similar to the one used in G.3.1 but with timber studs; its mobility, required to calculate the installed power, is given in Table G.14. The values for $L'_{ne,s,0,wall}$ are given in Table G.13 in DIN EN 12354-5, Annex G for the horizontal transmission indicated in Figure G.6 and are used for calculating the SNQ in the table below.

Acoustic insulation for wastewater installation systems, type: "TEKNOSOUND", manufacturer: TEKNISOL srl, consisting of a 2 mm mass layer and a 10 mm elastomeric layer; in combination with a wastewater system consisting of plastic pipes and fittings (OD 110) mounted with standard pipe clamps.

Calculated Single Number Quantities (SNQ) for the insertion loss	Flow rate [l/s]			
	0.5	1.0	2.0	4.0
Airborne sound power in the installation room (source room):				
A-weighted airborne sound power level $L_{Wa,A}$ (50 Hz – 5 kHz) [dB] without pipe lining	47.1	49.7	51.5	55.5
A-weighted airborne sound power level $L_{Wa,A,lining}$ (50 Hz – 5 kHz) [dB] with pipe lining	28.3	32.1	36.1	40.1
Airborne sound power insertion loss of the lining $D_{Wa,A}$ (50 Hz – 5 kHz) [dB]	**18.8**	**17.6**	**15.4**	**15.5**
a) Example of SNQ for heavy building acc. DIN EN 12354-5, Annex G.4.2:				
$L'_{ne,s,A,heavy}$ (receiving room) (50 Hz – 3150 Hz) [dB] without pipe lining	19.0	19.8	21.2	25.9
$L'_{ne,s,A,heavy,lining}$ (receiving room) (50 Hz – 3150 Hz) [dB] with pipe lining	< 10	10.4	15.5	20.5
Insertion loss of the lining for the heavy building $D_{ne,s,A,heavy}$ (50 Hz – 3150 Hz)	**12.6**	**9.4**	**5.7**	**5.4**
b) Example of SNQ for lightweight building acc. DIN EN 12354-5, Annex G.4.3:				
$L'_{ne,s,A,light}$ (receiving room) (50 Hz – 2500 Hz) [dB] without pipe lining	24.9	25.9	27.9	32.8
$L'_{ne,s,A,light,lining}$ (receiving room) (50 Hz – 2500 Hz) [dB] with pipe lining	15.0	19.2	24.0	28.9
Insertion loss of the lining for the lightweight building $D_{ne,s,A,light}$ (50 Hz – 2500 Hz)	**9.9**	**6.7**	**3.9**	**3.9**

Note: - The SNQ obtained here shall not be used in context with requirements in any other buildings.
- $L'_{ne,s,A}$ corresponds to an $L_{Aeq,n}$.
- Please use these values stating the flow rates, mounting conditions and used pipe clamps for advertisement.
- Sound levels below 10 dB are not mentioned in the test report, since they are subject to an increased measurement uncertainty and moreover are not noticeable in a normal living environment.

Fraunhofer IBP

The test was carried out in laboratory facilities of the IBP which is accredited according to DIN EN ISO/IEC 17025:2018 by the DAkkS. The accreditation certificate is D-PL-11140-11-00.

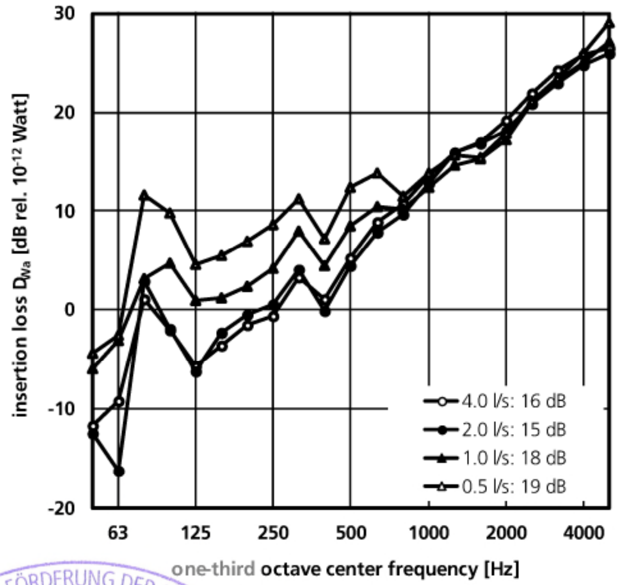
Stuttgart, November 15, 2024
Head of the test laboratory:

Test specimen: Acoustic insulation for wastewater installation systems, type: "TEKNOSOUND", manufacturer: TEKNISOL srl, consisting of a 2 mm mass layer and a 10 mm elastomeric layer; in combination with a wastewater system consisting of plastic pipes and fittings (OD 110) mounted with standard pipe clamps.

Mounting conditions see Sheet 1.

The airborne sound power insertion loss D_{Wa} of the pipe insulation was determined according to DIN EN 14366-1, Annex B (see Annex H in this test report). The measurement results of the wastewater system with pipe lining see Results 5 and Figure 1, for the wastewater system without pipe lining see Results 7 and Figure 2.

f [Hz]	Airborne sound power insertion loss D_{Wa} [dB]			
	0.5 l/s	1.0 l/s	2.0 l/s	4.0 l/s
50	-4.4	-5.9	-12.5	-11.7
63	-2.6	-3.1	-16.2	-9.3
80	11.6	3.1	2.9	1.1
100	9.8	4.7	-1.9	-2.0
125	4.6	1.0	-6.2	-5.7
160	5.5	1.2	-2.3	-3.6
200	6.9	2.4	-0.4	-1.5
250	8.6	4.2	0.5	-0.6
315	11.2	7.9	4.1	3.3
400	7.2	4.5	-0.1	1.1
500	12.3	8.5	4.4	5.3
630	13.8	10.5	7.9	8.9
800	11.5	10.2	9.7	10.7
1000	13.8	12.3	12.7	13.6
1250	15.7	14.6	15.9	15.9
1600	15.4	15.3	16.8	17.0
2000	17.8	17.1	18.1	19.2
2500	21.1	20.9	20.8	22.0
3150	23.4	23.2	22.9	24.2
4000	25.9	25.0	24.7	25.7
5000	29.0	27.1	26.0	26.5



Note: - Please use these values stating the flow rates, mounting conditions and used pipe clamps for advertisement.

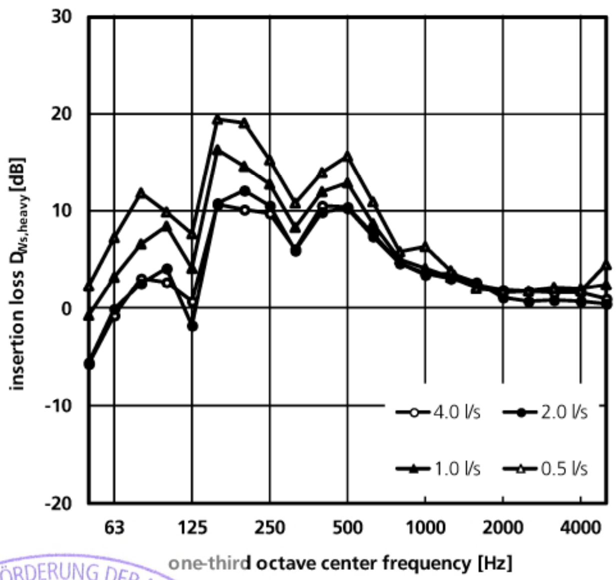
Detailed results: Structure-borne sound power insertion loss $D_{Ws,heavy}$	**P-BA 147/2024e**
Client: TEKNISOL srl, via 1° Maggio, 38/38A, 20028 San Vittore Olona, Milan, Italy	**Results 3**

Test specimen: Acoustic insulation for wastewater installation systems, type: "TEKNOSOUND", manufacturer: TEKNISOL srl, consisting of a 2 mm mass layer and a 10 mm elastomeric layer; in combination with a wastewater system consisting of plastic pipes and fittings (OD 110) mounted with standard pipe clamps.

Mounting conditions see Sheet 1.

The structure-borne sound power insertion loss $D_{Ws,heavy}$ of the pipe insulation was determined and calculated according to DIN EN 14366-1, Annex B and DIN EN 12354-5 (see Annex H in this test report). The measurement results of the wastewater system with pipe lining see Results 5 and Figure 1, for the wastewater system without pipe lining see Results 7 and Figure 2.

f [Hz]	Structure-borne sound power insertion loss $D_{Ws,heavy}$ [dB]			
	0.5 l/s	1.0 l/s	2.0 l/s	4.0 l/s
50	2.3	-0.8	-5.6	-5.7
63	7.3	3.3	-0.1	-0.8
80	11.9	6.6	2.6	3.1
100	9.9	8.4	4.1	2.7
125	7.7	4.2	-1.7	0.7
160	19.5	16.3	10.9	10.6
200	19.0	14.7	12.1	10.2
250	15.3	12.8	10.5	9.7
315	10.8	8.4	6.0	6.1
400	14.0	12.0	9.9	10.5
500	15.7	12.9	10.3	10.4
630	11.0	8.7	7.4	7.7
800	5.9	5.0	4.6	4.7
1000	6.4	4.2	3.5	3.7
1250	3.8	3.3	3.6	3.1
1600	2.0	2.2	2.7	2.5
2000	1.7	1.6	1.1	1.9
2500	1.8	1.7	0.7	1.8
3150	2.0	2.2	0.8	1.7
4000	1.8	2.0	0.7	1.7
5000	4.6	2.4	0.4	1.0



FRAUNHOFER GESELLSCHAFT ZUR FÖRDERUNG DER ANGEWANDTEN FORSCHUNG E.V. Fraunhofer IBP 1

Note: - Please use these values stating the flow rates, mounting conditions and used pipe clamps for advertisement.
- The value $D_{Ws,heavy}$ mentioned in this test report corresponds to $D_{Ws,low}$ in DIN EN 14366-1, Annex B. For a standardised readability, the term "heavy" (heavy building configuration) was chosen in this test report instead of "low" (low mobility building element).

Fraunhofer IBP

The test was carried out in laboratory facilities of the IBP which is accredited according to DIN EN ISO/IEC 17025:2018 by the DAkkS. The accreditation certificate is D-PL-11140-11-00.

Stuttgart, November 15, 2024
Head of the test laboratory:

Detailed results: Structure-borne sound power insertion loss $D_{Ws,light,wall}$ | **P-BA 147/2024e**

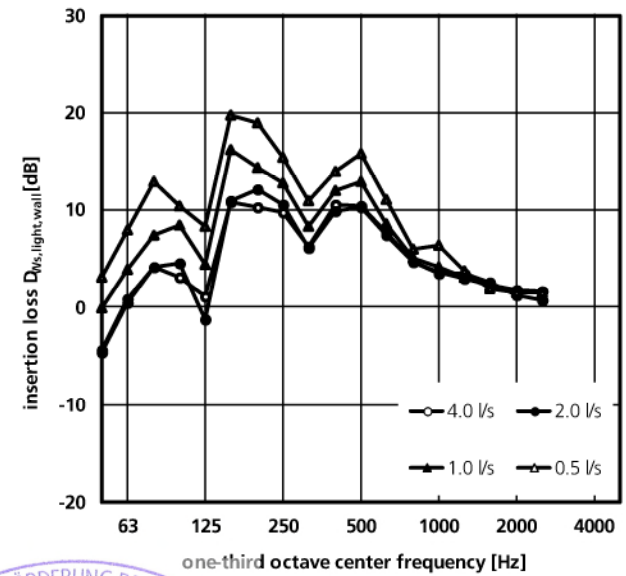
Client: TEKNISOL srl, via 1° Maggio, 38/38A, 20028 San Vittore Olona, Milan, Italy | **Results 4**

Test specimen: Acoustic insulation for wastewater installation systems, type: "TEKNOSOUND", manufacturer: TEKNISOL srl, consisting of a 2 mm mass layer and a 10 mm elastomeric layer; in combination with a wastewater system consisting of plastic pipes and fittings (OD 110) mounted with standard pipe clamps.

Mounting conditions see Sheet 1.

The structure-borne sound power insertion loss $D_{Ws,light,wall}$ of the pipe lining was determined and calculated according to DIN EN 14366-1, Annex B and DIN EN 12354-5 (see Annex H in this test report). The measurement results of the wastewater system with pipe lining see Results 6 and Figure 1, for the wastewater system without pipe lining see Results 8 and Figure 2. For the calculation of the values $D_{Ws,light,wall}$ the wall in the example for lightweight structures specially given in DIN EN 12354-5, G.4 for application to DIN EN 14366-1 was considered as receiving element i.

f [Hz]	Structure-borne sound power insertion loss $D_{Ws,light,wall}$ [dB]			
	0.5 l/s	1.0 l/s	2.0 l/s	4.0 l/s
50	3,0	-0,1	-4,5	-4,6
63	8,0	3,8	0,8	0,5
80	12,9	7,5	4,2	4,1
100	10,4	8,5	4,5	3,1
125	8,4	4,4	-1,2	1,1
160	19,7	16,2	11,0	10,8
200	18,9	14,3	12,1	10,2
250	15,4	12,8	10,5	9,8
315	10,9	8,4	6,1	6,2
400	14,0	12,0	9,9	10,5
500	15,8	12,9	10,3	10,4
630	11,1	8,6	7,4	7,7
800	5,9	5,0	4,6	4,7
1000	6,4	4,1	3,5	3,6
1250	3,7	3,1	3,5	3,0
1600	1,9	2,1	2,6	2,3
2000	1,6	1,5	1,2	1,8
2500	1,5	1,5	0,8	1,6



FRAUNHOFER-GESELLSCHAFT ZUR FÖRDERUNG DER ANGEWANDTEN FORSCHUNG E.V. Fraunhofer IBP 1

Note: - Please use these values stating the flow rates, mounting conditions and used pipe clamps for advertisement.
- The value $D_{Ws,light}$ mentioned in this test report corresponds to $D_{Ws,high}$ in DIN EN 14366-1, Annex B. For a standardised readability, the term "light" (lightweight building configuration) was chosen in this test report instead of "high" (high mobility building element).

Fraunhofer IBP

The test was carried out in laboratory facilities of the IBP which is accredited according to DIN EN ISO/IEC 17025:2018 by the DAkkS. The accreditation certificate is D-PL-11140-11-00.

Stuttgart, November 15, 2024

Head of the test laboratory:

Acoustic performance of a pipe lining acc. DIN EN 14366-1	**P-BA 147/2024e**
Client: TEKNISOL srl, via 1° Maggio, 38/38A, 20028 San Vittore Olona, Milan, Italy	**Results 5**

Test specimen: Acoustic insulation for wastewater installation systems, type: "TEKNOSOUND", manufacturer: TEKNISOL srl, consisting of a 2 mm mass layer and a 10 mm elastomeric layer; in combination with a wastewater system consisting of plastic pipes and fittings (OD 110) mounted with standard pipe clamps.

Test set-up, test facility and test method see Sheet 1.

Test set-up (with pipe lining): Wastewater system covered with acoustic insulation, type: "TEKNOSOUND", manufacturer: TEKNISOL srl.

Results: The airborne sound power level and single equivalent blocked force level are used to carry out a prediction according to DIN EN 12354-5 in heavy buildings (see example on page Results 1). The single equivalent free velocity level and the magnitude of the single equivalent source mobility for the general case see Results 6.
Case "≤" in table see Annex F.

f [Hz]	airborne sound power level L_{Wa} [dB rel. 10^{-12} W]			
	0.5 l/s	1.0 l/s	2.0 l/s	4.0 l/s
50	25.2	31.4	38.3	44.0
63	27.0	30.9	38.9	42.6
80	≤ 18.7	≤ 24.6	≤ 30.0	≤ 34.7
100	24.7	27.7	35.6	40.5
125	26.6	30.2	38.1	42.7
160	23.8	27.7	34.7	39.4
200	21.0	26.1	32.0	37.3
250	21.2	26.1	31.8	36.5
315	20.7	24.9	30.0	34.2
400	22.8	26.5	31.3	34.6
500	22.5	26.5	31.0	34.2
630	20.9	24.4	27.9	32.0
800	20.0	23.0	26.2	30.3
1000	17.1	20.9	24.4	29.2
1250	14.5	18.5	22.2	27.7
1600	14.7	18.4	22.2	26.5
2000	14.7	18.9	22.1	25.1
2500	15.2	19.0	21.2	23.5
3150	13.2	17.1	19.2	21.9
4000	13.4	17.1	18.8	21.5
5000	13.0	16.5	17.6	20.3

f [Hz]	single equivalent blocked force level $L_{Fb,eq}$ [dB rel. 10^{-6} N]			
	0.5 l/s	1.0 l/s	2.0 l/s	4.0 l/s
50	96.4	101.8	108.2	114.1
63	95.3	100.2	106.4	112.1
80	≤ 92.4	98.0	103.4	108.6
100	88.1	92.5	98.1	103.1
125	88.2	91.4	97.7	101.8
160	77.6	80.9	86.4	91.1
200	71.8	76.7	81.3	87.5
250	68.9	73.0	77.6	82.3
315	68.4	72.0	75.7	80.3
400	69.0	72.4	76.0	80.4
500	69.4	73.3	77.3	81.7
630	70.4	73.4	76.9	81.8
800	67.8	70.3	73.4	78.0
1000	64.6	68.8	72.3	77.6
1250	67.3	70.7	0.0	80.6
1600	68.2	70.9	75.3	79.6
2000	67.3	71.0	75.4	78.5
2500	66.6	70.3	74.1	76.6
3150	≤ 63.5	67.0	70.7	72.9
4000	≤ 61.4	63.8	66.7	69.2
5000	≤ 63.5	67.5	70.1	71.8

Note:

FRAUNHOFER-GESELLSCHAFT ZUR FÖRDERUNG DER ANGEWANDTEN FORSCHUNG E.V.
Fraunhofer IBP
1

Fraunhofer IBP

The test was carried out in laboratory facilities of the IBP which is accredited according to DIN EN ISO/IEC 17025:2018 by the DAkkS. The accreditation certificate is D-PL-11140-11-00.
Stuttgart, November 15, 2024
Head of the test laboratory:

Test specimen: Acoustic insulation for wastewater installation systems, type: "TEKNOSOUND", manufacturer: TEKNISOL srl, consisting of a 2 mm mass layer and a 10 mm elastomeric layer; in combination with a wastewater system consisting of plastic pipes and fittings (OD 110) mounted with standard pipe clamps.

Test set-up, test facility and test method see Sheet 1.

Test set-up (with pipe lining): Wastewater system covered with acoustic insulation, type: "TEKNOSOUND", manufacturer: TEKNISOL srl.

Results: The single equivalent free velocity level and the magnitude of the single equivalent source mobility are additionally required to perform predictions according to DIN EN 12354-5 in the general case (mainly lightweight buildings, see example on page Results 1). Airborne sound power level and single equivalent blocked force level see Results 5.

f [Hz]	single equivalent free velocity level $L_{vf,eq}$ [dB rel. 10^{-9} m/s]			
	0.5 l/s	1.0 l/s	2.0 l/s	4.0 l/s
50	87.0	91.6	96.7	102.9
63	84.9	89.3	95.1	99.8
80	80.0	86.1	89.4	96.8
100	77.5	84.7	87.8	93.6
125	76.1	83.5	87.4	92.5
160	71.5	78.9	82.0	86.9
200	69.7	77.9	79.9	84.4
250	68.5	77.9	79.1	83.0
315	68.5	78.1	79.4	83.4
400	69.2	78.3	79.7	83.5
500	69.4	77.4	79.4	83.2
630	69.3	77.1	79.2	83.2
800	72.0	77.9	80.5	84.7
1000	72.4	77.9	80.0	84.6
1250	70.7	74.8	78.0	83.1
1600	70.5	73.3	77.8	81.6
2000	66.9	70.5	74.7	78.1
2500	66.4	69.7	72.2	75.0
3150	61.3	65.0	67.2	70.0
4000	57.3	61.7	63.0	65.5
5000	51.4	55.9	56.9	59.3

f [Hz]	magnitude of single equivalent source mobility $\left|Y_{s,eq}\right|$ [10^{-4} m/sN]			
	0.5 l/s	1.0 l/s	2.0 l/s	4.0 l/s
50	3.4	3.1	2.7	2.8
63	3.0	2.9	2.7	2.4
80	2.4	2.5	2.0	2.6
100	2.9	4.1	3.1	3.4
125	2.5	4.0	3.1	3.4
160	4.9	8.0	6.0	6.1
200	7.8	11.4	8.5	7.0
250	9.6	17.5	11.8	10.8
315	10.1	20.1	15.4	14.2
400	10.2	19.7	15.3	14.3
500	10.0	16.0	12.7	12.0
630	8.9	15.3	13.0	11.7
800	16.1	24.1	22.7	21.7
1000	24.6	28.6	24.2	22.4
1250	14.8	16.0	14.1	13.3
1600	13.0	13.2	13.5	12.7
2000	9.6	9.5	9.2	9.5
2500	9.8	9.2	8.0	8.3
3150	7.8	7.9	6.6	7.2
4000	6.2	7.8	6.5	6.6
5000	2.5	2.7	2.2	2.4

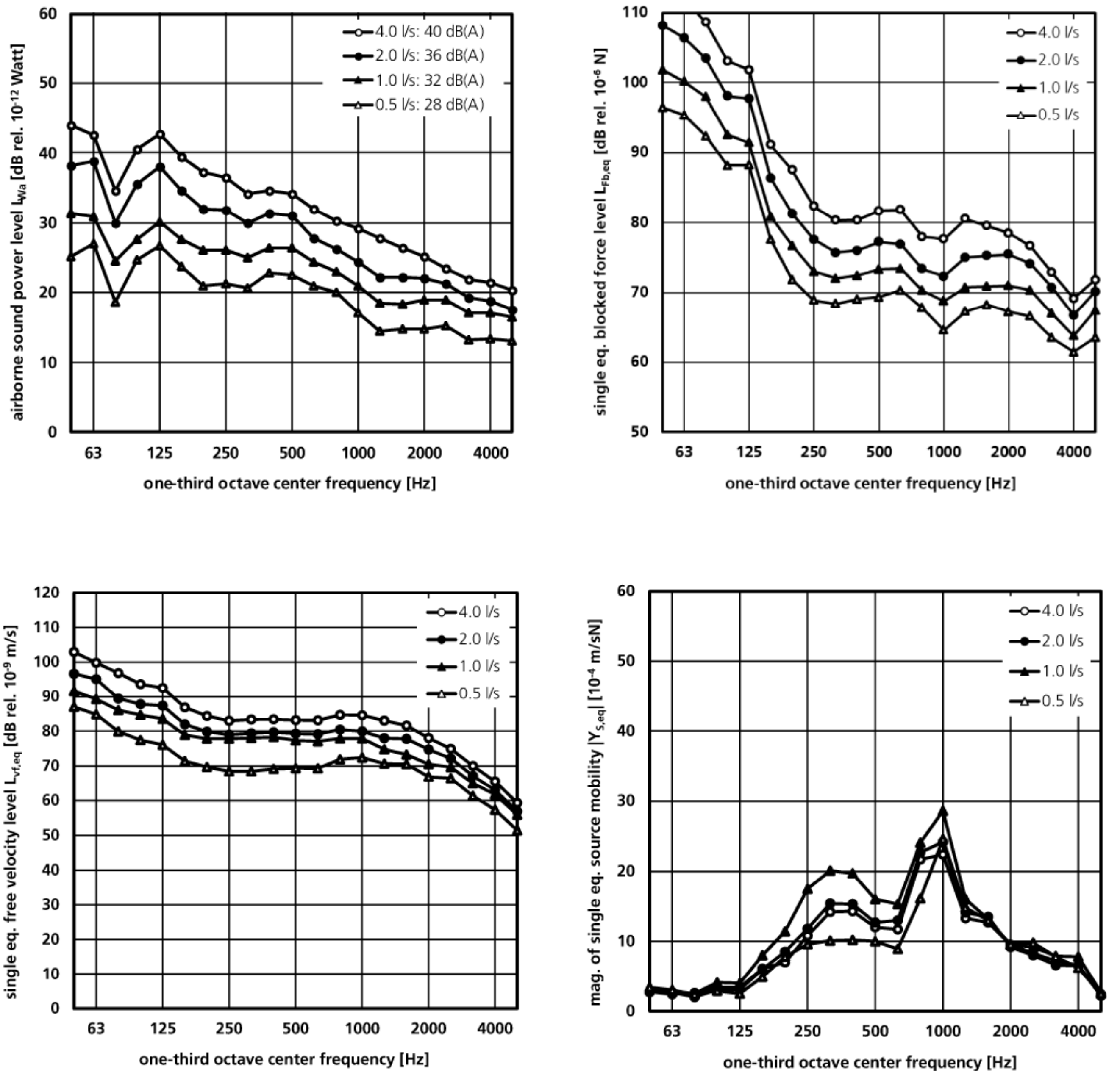
Note:

FRAUNHOFER-GESELLSCHAFT ZUR FÖRDERUNG DER ANGEWANDTEN FORSCHUNG E.V. Fraunhofer IBP 1

Fraunhofer IBP

The test was carried out in laboratory facilities of the IBP which is accredited according to DIN EN ISO/IEC 17025:2018 by the DAkkS. The accreditation certificate is D-PL-11140-11-00.

Stuttgart, November 15, 2024
Head of the test laboratory:



Frequency spectrum of the airborne sound power level (top left), the single equivalent blocked force level (top right), single equivalent free velocity level (bottom left) and the magnitude of single equivalent source mobility (bottom right) measured at various flow rates **according to DIN EN 14366-1**.

Test specimen: Acoustic insulation for wastewater installation systems, type: "TEKNOSOUND", manufacturer: TEKNISOL srl, consisting of a 2 mm mass layer and a 10 mm elastomeric layer; in combination with a wastewater system consisting of plastic pipes and fittings (OD 110) mounted with standard pipe clamps.

Test set-up, test facility and test method see Sheet 1.

Test set-up (with pipe lining): Wastewater system covered with acoustic insulation, type: "TEKNOSOUND", manufacturer: TEKNISOL srl.

Acoustic performance of a wastewater system acc. DIN EN 14366-1	**P-BA 147/2024e**
Client: TEKNISOL srl, via 1° Maggio, 38/38A, 20028 San Vittore Olona, Milan, Italy	**Results 7**

Test specimen: Acoustic insulation for wastewater installation systems, type: "TEKNOSOUND", manufacturer: TEKNISOL srl, consisting of a 2 mm mass layer and a 10 mm elastomeric layer; in combination with a wastewater system consisting of plastic pipes and fittings (OD 110) mounted with standard pipe clamps.

Test set-up, test facility and test method see Sheet 1.

Reference set-up (without pipe lining): Wastewater system without insulation.

Results: The airborne sound power level and single equivalent blocked force level are used to carry out a prediction according to DIN EN 12354-5 in heavy buildings (see example on page Results 1). The single equivalent free velocity level and the magnitude of the single equivalent source mobility for the general case see Results 8.
Case "≤" in table see Annex F.

f [Hz]	airborne sound power level L_{Wa} [dB rel. 10^{-12} W]			
	0.5 l/s	1.0 l/s	2.0 l/s	4.0 l/s
50	20.9	25.5	25.8	32.3
63	24.4	27.8	22.6	33.3
80	30.3	27.7	32.9	35.8
100	34.5	32.4	33.7	38.5
125	31.2	31.2	31.9	37.0
160	29.3	28.9	32.3	35.8
200	28.0	28.5	31.6	35.7
250	29.8	30.3	32.3	35.9
315	31.9	32.9	34.1	37.5
400	30.0	31.0	31.3	35.8
500	34.8	35.0	35.4	39.5
630	34.8	34.8	35.7	40.9
800	31.5	33.2	35.9	41.0
1000	30.9	33.2	37.2	42.8
1250	30.2	33.1	38.2	43.6
1600	30.2	33.6	39.0	43.5
2000	32.6	36.1	40.2	44.3
2500	36.3	39.9	42.0	45.4
3150	36.6	40.2	42.2	46.1
4000	39.3	42.2	43.5	47.2
5000	42.0	43.6	43.6	46.8

f [Hz]	single equivalent blocked force level $L_{Fb,eq}$ [dB rel. 10^{-6} N]			
	0.5 l/s	1.0 l/s	2.0 l/s	4.0 l/s
50	98.8	101.0	102.6	108.5
63	102.6	103.4	106.3	111.3
80	104.3	104.5	106.0	111.7
100	98.1	101.0	102.1	105.8
125	95.9	95.6	96.0	102.5
160	97.1	97.2	97.2	101.8
200	90.9	91.4	93.4	97.7
250	84.2	85.8	88.1	92.1
315	79.2	80.4	81.7	86.5
400	83.0	84.5	85.9	90.9
500	85.1	86.3	87.5	92.0
630	81.3	82.1	84.3	89.5
800	73.7	75.3	78.0	82.7
1000	71.0	72.9	75.9	81.3
1250	71.1	74.0	78.6	83.7
1600	70.2	73.1	78.0	82.0
2000	69.0	72.6	76.6	80.4
2500	68.4	72.1	74.8	78.4
3150	65.5	69.2	71.6	74.5
4000	≤ 63.3	65.8	67.5	70.8
5000	68.1	69.9	70.5	72.9

FRAUNHOFER-GESELLSCHAFT ZUR FÖRDERUNG DER ANGEWANDTEN FORSCHUNG E.V.
Fraunhofer IBP
1

Note:

Fraunhofer IBP

The test was carried out in laboratory facilities of the IBP which is accredited according to DIN EN ISO/IEC 17025:2018 by the DAkkS. The accreditation certificate is D-PL-11140-11-00.
Stuttgart, November 15, 2024
Head of the test laboratory:

Acoustic performance of a wastewater system acc. DIN EN 14366-1	**P-BA 147/2024e**
Client: TEKNISOL srl, via 1° Maggio, 38/38A, 20028 San Vittore Olona, Milan, Italy	**Results 8**

Test specimen: Acoustic insulation for wastewater installation systems, type: "TEKNOSOUND", manufacturer: TEKNISOL srl, consisting of a 2 mm mass layer and a 10 mm elastomeric layer; in combination with a wastewater system consisting of plastic pipes and fittings (OD 110) mounted with standard pipe clamps.

Test set-up, test facility and test method see Sheet 1.

Reference set-up (without pipe lining): Wastewater system without insulation.

Results: The single equivalent free velocity level and the magnitude of the single equivalent source mobility are additionally required to perform predictions according to DIN EN 12354-5 in the general case (mainly lightweight buildings, see example on page Results 1). Airborne sound power level and single equivalent blocked force level see Results 7.
Case "≤" in table see Annex F.

f [Hz]	single equivalent free velocity level $L_{vf,eq}$ [dB rel. 10^{-9} m/s]			
	0.5 l/s	1.0 l/s	2.0 l/s	4.0 l/s
50	98.4	97.6	103.0	108.8
63	97.2	95.8	101.0	107.2
80	100.1	99.2	103.7	108.7
100	95.6	94.7	99.0	105.1
125	93.0	91.6	96.0	101.7
160	94.0	93.1	96.9	101.6
200	86.7	86.3	90.6	95.8
250	88.5	88.4	91.5	96.4
315	95.0	94.6	96.6	99.7
400	86.8	87.6	89.9	94.0
500	88.9	88.0	90.8	94.5
630	83.1	83.5	86.4	91.0
800	79.2	80.7	84.2	88.8
1000	77.6	79.7	82.4	86.9
1250	72.6	75.5	79.7	84.6
1600	71.3	74.6	79.3	82.9
2000	67.8	71.7	76.2	79.4
2500	66.4	70.2	73.2	75.8
3150	61.5	65.4	67.8	70.6
4000	57.9	61.4	63.2	65.8
5000	53.6	56.9	58.3	60.7

f [Hz]	magnitude of single equivalent source mobility $\lvert Y_{s,eq} \rvert$ [10^{-4} m/sN]			
	0.5 l/s	1.0 l/s	2.0 l/s	4.0 l/s
50	9.6	6.7	10.4	10.4
63	5.3	4.1	5.4	6.2
80	6.2	5.4	7.7	7.0
100	7.6	4.9	7.0	9.2
125	7.2	6.4	10.0	9.1
160	7.0	6.2	9.7	9.8
200	6.2	5.6	7.2	8.1
250	16.5	13.4	14.7	16.5
315	61.8	51.4	55.4	45.8
400	15.6	14.3	15.9	14.3
500	15.5	12.3	14.5	13.4
630	12.3	11.9	12.7	11.8
800	19.0	18.6	20.3	20.2
1000	21.3	21.7	21.3	19.1
1250	11.9	11.9	11.4	11.1
1600	11.3	11.9	11.6	11.1
2000	8.7	9.1	9.5	8.9
2500	8.0	8.1	8.3	7.4
3150	6.3	6.5	6.5	6.3
4000	5.4	6.0	6.1	5.6
5000	1.9	2.2	2.5	2.5

FRAUNHOFER-GESELLSCHAFT ZUR FÖRDERUNG DER ANGEWANDTEN FORSCHUNG E.V.
Fraunhofer IBP
1

Note:

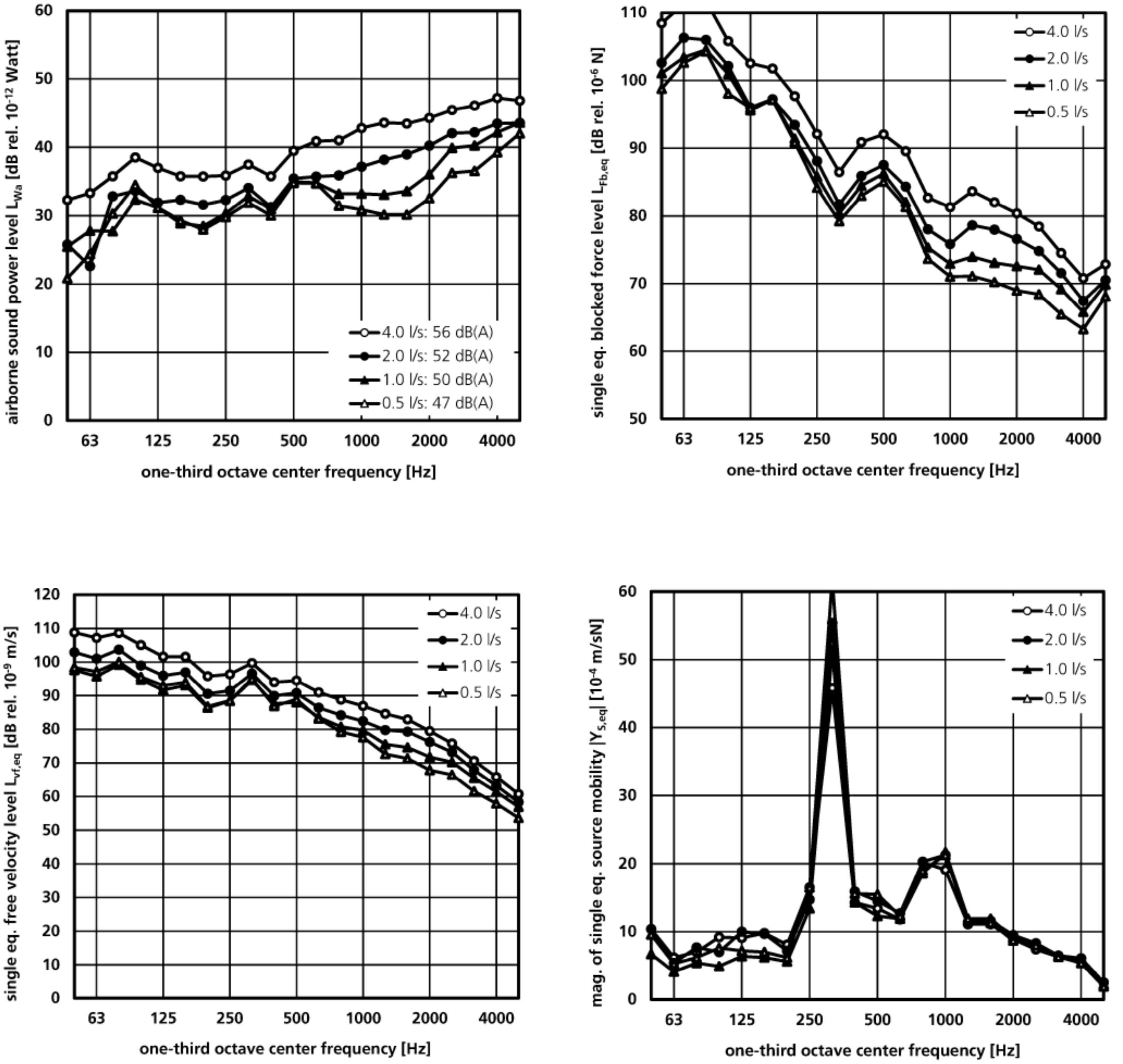
Fraunhofer IBP

The test was carried out in laboratory facilities of the IBP which is accredited according to DIN EN ISO/IEC 17025:2018 by the DAkkS. The accreditation certificate is D-PL-11140-11-00.

Stuttgart, November 15, 2024
Head of the test laboratory:

Detailed results | **P-BA 147/2024e**

Client: TEKNISOL srl, via 1° Maggio, 38/38A, 20028 San Vittore Olona, Milan, Italy | **Figure 2**

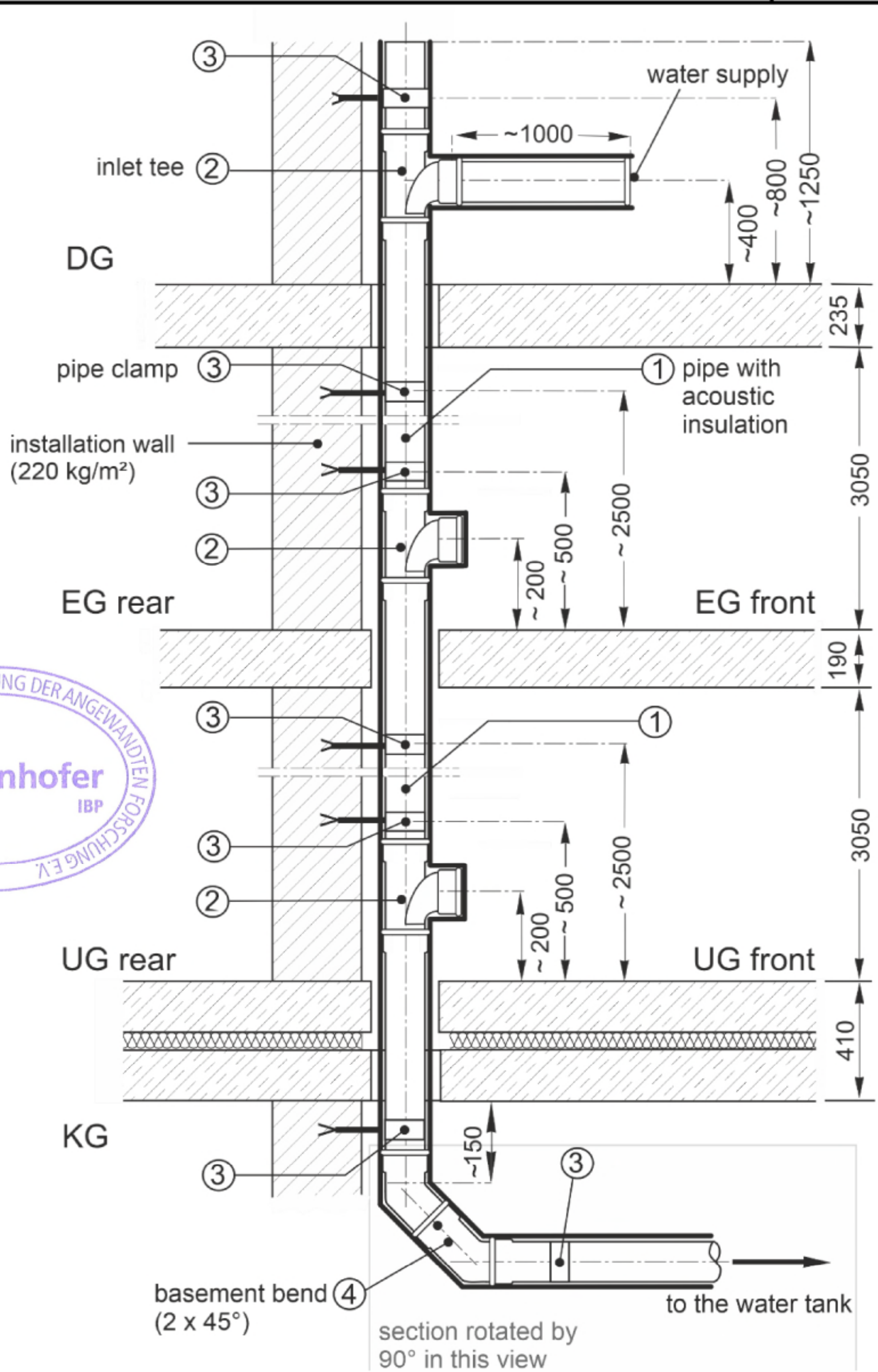


Frequency spectrum of the airborne sound power level (top left), the single equivalent blocked force level (top right), single equivalent free velocity level (bottom left) and the magnitude of single equivalent source mobility (bottom right) measured at various flow rates **according to DIN EN 14366-1**.

Test specimen: Acoustic insulation for wastewater installation systems, type: "TEKNOSOUND", manufacturer: TEKNISOL srl, consisting of a 2 mm mass layer and a 10 mm elastomeric layer; in combination with a wastewater system consisting of plastic pipes and fittings (OD 110) mounted with standard pipe clamps.

Test set-up, test facility and test method see Sheet 1.

Reference set-up (without pipe lining): Wastewater system without insulation.



Installation plan of the test set-up in the test facility. Illustration simplified, schematically drawn and not to scale.

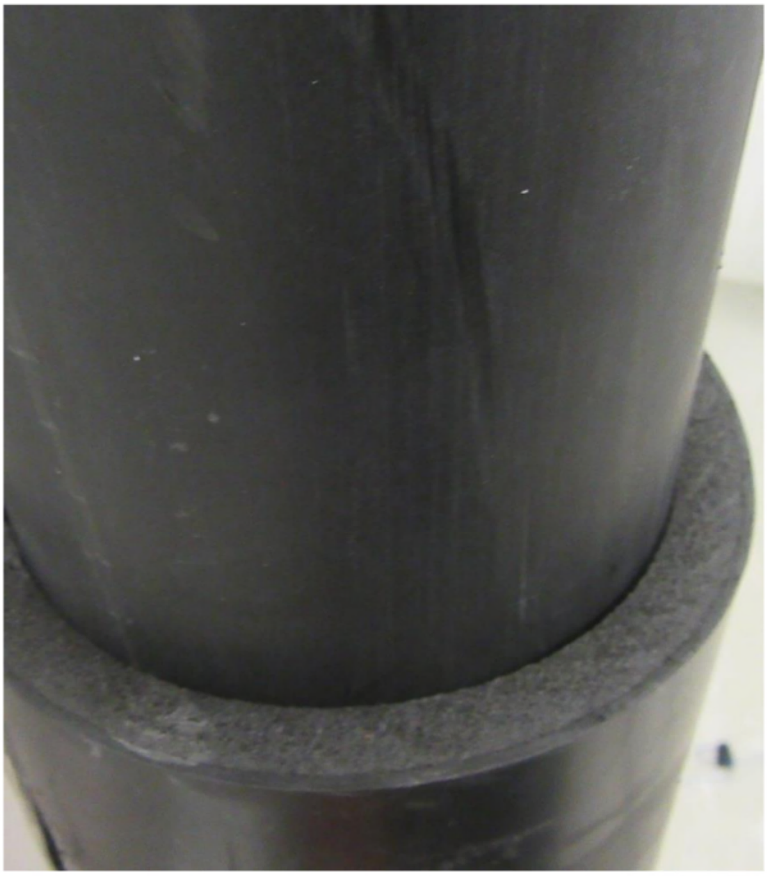
<u>Test specimen</u>: Acoustic insulation for wastewater installation systems, type: "TEKNOSOUND", manufacturer: TEKNISOL srl, consisting of a 2 mm mass layer and a 10 mm elastomeric layer; in combination with a wastewater system consisting of plastic pipes and fittings (OD 110) mounted with standard pipe clamps.

Left: Wastewater system with pipe insulation, type: "TEKNOSOUND" in the room UG front.

Upper right: Inlet tee, pipe clamp at the lower wall area (front view).

Bottom right: Two 45°-basement bends.

Test specimen: Acoustic insulation for wastewater installation systems, type: "TEKNOSOUND", manufacturer: TEKNISOL srl, consisting of a 2 mm mass layer and a 10 mm elastomeric layer; in combination with a wastewater system consisting of plastic pipes and fittings (OD 110) mounted with standard pipe clamps.



Left: Wastewater pipe with pipe insulation, type: "TEKNOSOUND".

Right: Pipe insulation, type: "TEKNOSOUND".

Test specimen: Acoustic insulation for wastewater installation systems, type: "TEKNOSOUND", manufacturer: TEKNISOL srl, consisting of a 2 mm mass layer and a 10 mm elastomeric layer; in combination with a wastewater system consisting of plastic pipes and fittings (OD 110) mounted with standard pipe clamps.

Measurement set-up and assessment of measurement results

Measurement set-up

Standard set-up

In the water-installation test-facility run by the Fraunhofer Institute of Building Physics, a down pipe is installed leading from the top floor (DG) down to the sub-basement (KG) (for further details, please see Annex P). This down pipe is connected to a (OD 110) water inlet pipe on the top-floor level. The water is introduced through an S-shaped bend according to the standard DIN EN 14366-1. In the sub-basement, the down pipe is connected to a bend (2 x 45 degree, usually) and merges into a horizontal discharge section, which in turn is joined to a water receptacle. The wastewater pipe on the ground floor (EG) and in the basement (UG) is fitted with conventional branches from main lines (usually, OD 110). Pipes and fittings are mounted according to the instructions given by the manufacturer. The air gaps between the tube and floor in the entrance and exit openings are loosely closed with porous absorber in order to prevent any structure-borne sound bridges influencing the building. The wastewater piping is fastened to the installation wall (mass per unit surface m'' = 220 kg/m^2) by means of pipe clamps supplied by the client, which are adapted to the external diameter of the pipes. The used pipe clamps in the installation and measuring rooms (EG front and UG front) relevant for the sound transmission have to be designed and installed in such a way, that when opening the pipe clamps in the lower basement (KG) this will not lead to a sliding down of the pipe system. The locations of the fixation points and further dimensions are specified in the installation plan that is included in the test report.

Noise excitation and evaluation parameters

Any defined and metrological reproducible noise excitation requires steady state flow conditions inside the wastewater pipes. As the noise generation in wastewater systems depends on the flow rate, noise measurements are performed at several flow rates Q which are typically encountered in practice:

(1) Q = 0.5 l/s, corresponding to Q = 30 l/min,
(2) Q = 1.0 l/s, corresponding to Q = 60 l/min,
(3) Q = 2.0 l/s, corresponding to Q = 120 l/min,
(4) Q = 4.0 l/s, corresponding to Q = 240 l/min.

- Here, a flow rate of Q = 2.0 l/s roughly corresponds to the average flow rate required for flushing a toilet.
- According to Prandtl-Colebrook, the highest flow rate results from the admissible hydraulic charge of the horizontal pipe sections, which is Q_{max} = 4.0 l/s for OD 110 pipes.

Measurement of the airborne sound power level and single equivalent blocked force level

The measurements take place in the installation room (UG front) and in the room behind the installation wall (UG rear). The water flow generates vibrations of the wastewater pipe. In the test room UG front the airborne sound pressure level, which is radiated from the wastewater system and the installation wall, is measured. The structure-borne contribution radiated by the installation wall is then subtracted to obtain the airborne sound power level L_{Wa} of the piping system.

The vibrations of the wastewater system generated by the water flow are transmitted to the installation wall through pipe clamps and/or other structure-borne sound bridges (e.g. fire protection sleeves), and then radiated by the wall (and to a lesser extent, also by the adjoining building parts) as airborne sound into the test room behind the installation wall. According to DIN EN ISO 10140-4 the airborne sound pressure levels in UG rear (as well as in UG front) are picked up at six points in the room, to be space and time-averaged and corrected for the background noise. Deviating from DIN EN 14366-1 the piping system single equivalent blocked force level $L_{Fb,eq}$ is indirectly obtained according to DIN EN ISO 10848-1 using the power substitution method.

Measurement of the single equivalent free velocity level and magnitude of single equivalent source mobility

The specimen free velocity $L_{vf,eq}$ is directly measured at the two fixing points of the piping system, with the piping system being disconnected from the test wall. To avoid undesirable influence on the vibration behaviour, the pipe system is kept in exact the same position as for the measurement while connected to the wall. For the connection of the accelerometers to the threaded socket of the pipe clamps, the pipe clamps are turned 180°, oriented in the opposite direction of the test wall. The measurement results at the two positions (upper and lower wall area) are corrected for background noise and energetically summed up.

The specimen single equivalent mobility magnitude $|Y_{s,eq}|$ is approximated from the specimen single equivalent free velocity level and the specimen single equivalent blocked force level.

Note

With stationary signals (e.g. wastewater noise with a constant flow rate), it is not the maximum value ($L_{AFmax,n,}$ or $\overline{L_{AFmax,nT}}$) but rather the temporally and spatially averaged level ($L_{AFeq,n,}$ or $\overline{L_{AFeq,nT}}$) that is measured. This guarantees compliance with the reproducibility and accuracy requirements that are mandatory for test bench measurements (e.g. through the possibility of background noise correction), which would not be realisable with use of the maximum level that is determined according to the aforementioned standards for measurements on the building. On the basis of extensive experience, it is necessary to assume that the difference between $L_{AFmax,n}$ and $L_{AFeq,n}$, or between $\overline{L_{AFmax,nT}}$ and $\overline{L_{AFeq,nT}}$ is a maximum 2-3 dB under normal circumstances.

Assessment of measurement results

Product comparison and comparison of measurement results with requirements

DIN EN 14366-1 specifies laboratory measuring methods for determining the input data required for both comparing products and materials, and predicting sound levels in buildings using DIN EN 12354-5. These input quantities are the piping system sound power level for airborne sound and three quantities for structure-borne sound (piping system free velocity, blocked force and mobility), from which the piping system installed power, source input for DIN EN 12354-5, is determined.

For product comparison the sound power level for airborne sound can directly be used. For comparison of the vibration performance, the quantities for structure-borne sound of the wastewater system can be used as input data for the prediction calculation with the building examples in DIN EN 12354-5, Annex G.4. The single number quantities (SNQ) obtained here shall not be used in context with requirements in any other buildings.

With the standard DIN EN 12354-5, it is also possible to predict the noise pressure level in rooms requiring sound insulation, in any building configuration. The calculated values can be subsequently compared directly with noise insulation requirements. Therfore, the calculated value at a volumetric flow of 2.0 l/s should be used as a comparable value with the requirements, because this roughly equates to the mean volumetric flow when a WC is flushed.

Furthermore, when comparing with the requirements, it is necessary to note that simultaneous operation of sanitary installations and possible interactions between the sanitary components could lead to other results.

Comparability and reproducibility of measurement results

For noise measurements of wastewater systems, the results are dependent not only on the pipe clamps used, but to a large extent on the installation conditions, such as the mounting of the clamps, the precise vertical alignment of the pipes, the de-burring of the pipe ends, and the insertion depth of the pipes in the sleeves. By optimising these influences, experience shows that it is possible to reduce the noise level by multiple decibel.
A comparison between different wastewater systems therefore requires that all systems be fitted with the same degree of care and attention.

Statement on measurement uncertainty

For wastewater pipe measurements, the accuracy is expressed in terms of the following quantities:

- for the airborne sound power:
  The measurement procedure is particular and its accuracy differs from the one indicated in DIN EN ISO 3743-1, where measurements are not performed in one-third octave bands and don't include frequency bands down to 50 Hz. In DIN EN 14366-1, the same measurement procedure as in DIN EN 14366:2004+A1:2019 is used.
- for the specimen structure-borne sound characteristics: according to the Round Robin performed on standard DIN EN 15657 using a reference source, the following averaged standard deviation of reproducibility is obtained for each source characteristics per one-third octave band:
  - single blocked force level: 3 dB,
  - single free velocity level: 4 dB,
  - single equivalent source mobility: ratio to mean value of 1.2 if linear values (in m/sN) are used on a log scale (corresponding to 1 dB).

Note: For a better accuracy estimation, the testing laboratories that have participated to the development of this document have made the decision of performing a Round Robin based on this document for both airborne and structure-borne sound, as soon as the document is published.

Values for the uncertainty by measuring installation noise in buildings can be found in DIN 4109-4. The measurement uncertainty can be adopted for the results determined in prototype buildings.

The measurement uncertainty is given as follows:

$$u_{situ} = \begin{cases} 5.0\ \text{dB} - 0.1 \times L_{AF,...}, & \text{for } L_{AF,...} < 35\ \text{dB} \\ 1.5\ \text{dB}, & \text{for } L_{AF,...} \geq 35\ \text{dB} \end{cases}$$

with

u_{situ} uncertainty by measuring installation noise in buildings (situ),
$L_{AF,...}$ measured value $L_{AF,max,n}$ oder $L_{AF,max,nT}$ bzw. $L_{AFeq,n}$ oder $L_{AFeq,nT}$.

Conformity statements in test reports, e.g. for the approval of sound protection requirements, are made by taking in account the measurement uncertainties according to the procedures (e.g. standard or guideline) mentioned in the test report. The metrological traceability on reference measurement standards is given for all calibrated measurement equipment.

Evaluation of measurements

Determination of airborne sound quantities

The measured sound pressure level is given as time and space averaged one-third octave spectrum in the frequency range between 50 Hz to 5 kHz. First, the measured level is corrected for background noise and normalized to an equivalent sound absorption area of A_0 = 10 m^2 and A-weighted:

(1) $$L_{\mathrm{i,Aeq,\,n}} = 10\ \mathrm{lg}\left(10^{\frac{L_{\mathrm{i,eq}}}{10}} - 10^{\frac{L_{\mathrm{i,eq,GG}}}{10}}\right) + 10\ \mathrm{lg}\frac{\mathrm{A}_i}{A_0} + k_{i,A}$$ [dB]

$L_{i,Aeq,n}$	A-weighted normalized standard sound pressure level in the third-octave band i [dB]	
$L_{i,eq}$	spatially-averaged, energy-equivalent continuous sound pressure level in the third-octave band i	[dB]
$L_{i,eq,GG}$	spatially-averaged, energy-equivalent external sound level in the third-octave band i	[dB]
$A_i = \frac{0{,}16 \cdot V_E}{T_i}$	sound absorption area of test room for one-third octave band i	[m^2]
V_E	volume of test room	[m^3]
T_i	reverberation time of the measurement room in the third-octave band i	[s]
$k_{i,A}$	A-weighting correction in the third-octave band i	[dB]

If the difference between the measured one-third-octave level and the external noise level is less than 3 dB, the correction for background noise will not be performed. Instead, the measured background noise level will be used as test result (as largest possible value). The overall sound pressure level is obtained by energetically adding the one-third-octave values:

(2) $$L_{\mathrm{Aeq,\,n}} = 10\ \mathrm{lg}\left(\sum_{i=1}^{21} 10^{\frac{L_{\mathrm{i,\,Aeq,\,n}}}{10}}\right)$$ [dB]

$L_{Aeq,n}$	A-weighted normalized standard sound pressure level	[dB]

where i indicates the number of one-third octave bands from 50 Hz to 5 kHz.

The A-weighted standard sound pressure level $L_{Aeq,nT}$ in the receiving room is determined similarly to the Equation (1) with

(3) $$L_{\mathrm{Aeq,\,nT}} = 10\ \mathrm{lg}\left(10^{\frac{L_{\mathrm{i,}}}{10}} - 10^{\frac{L_{\mathrm{i,GG}}}{10}}\right) + 10\ \mathrm{lg}\frac{\mathrm{T}_i}{T_0} + k(A)_{\ i}$$ [dB]

and can be calculated from the normalized standard sound pressure level.

(4) $$L_{\mathrm{Aeq,\,nT}} = L_{\mathrm{Aeq,n}} + 10\ \mathrm{lg}\left(\frac{31{,}25}{V_{\mathrm{E}}}\right)$$ [dB]

$L_{Aeq,nT}$	A-weighted standard sound pressure level in the receiving room	[dB]
T_0	reference reverberation time (T_0 = 0,5 s)	[s]

Determination of airborne sound power:
The airborne sound power level resulting from the determined A-weighted standard sound pressure level in the source room is calculated according to the following relationship.

(5) $$L_{\mathrm{W,a,total}} = L_{\mathrm{Aeq,n}} + 4 - k_A$$ [dB]

$L_{Wa,total}$	total airborne sound power level	[dB]
$L_{Aeq,n}$	A-weighted normalized standard sound pressure level in the source room	[dB]
$k_{i,A}$	A-weighting correction in one-third octave band i	[dB]

Subsequently, the airborne sound power of a building installations (e.g. waste water system) is calculated from the airborne sound power determined in the source room, subtracting the portion radiated by the building structure, determined from the A-weighted standard sound pressure level in the receiving room, according to the following relationship.

(6) $$L_{\mathrm{Wa}} = 10\ \lg\left(10^{\frac{L_{Wa,total}}{10}} - 10^{\frac{L_{Wa,struc}}{10}}\right)$$ [dB]

L_{Wa}	airborne sound power level of the source	[dB]
$L_{Wa,total}$	total airborne sound power level	[dB]
$L_{Wa,struc}$	airborne sound power level determined from the A-weighted standard airborne sound pressure level in the receiving room	[dB]

Determination of Structure-borne Sound Quantities

Determination of Blocked Force:
The single equivalent blocked force of the source (building service equipment) is indirectly determined using the sound power substitution method defined in DIN EN 15657. This involves measuring the A-weighted standard sound pressure level in the receiving room when the building service equipment is excited and when excited by the reference sound source with known power, as specified in DIN EN ISO 10848-1.

(7) $$L_{\mathrm{Ws}} = 10\ \lg\left(\sum_j 10^{\frac{L_{\mathrm{Ws,cal,j}}}{10}}\right) + L_{\langle p\rangle} - 10\ \lg\left(\sum_j 10^{\frac{L_{\langle p\rangle,\mathrm{cal,j}}}{10}}\right)$$ [dB]

L_{Ws}	installed structure-borne sound power level	[dB]
$L_{Ws,cal,j}$	installed structure-borne sound power level of the reference sound source at contact point j	[dB]
$L_{<p>}$	spatially-averaged, energy-equivalent continuous sound pressure level in the receiving room during operation of the building service equipment	[dB]
$L_{<p>,cal,j}$	spatially-averaged, energy-equivalent continuous sound pressure level in the receiving room during operation of the reference sound source at contact point j	[dB]

Subsequently, the single equivalent blocked force of the source is calculated from the installed power and the arithmetic mean receiver mobility at the contact points of the excited component.

(8) $$L_{\mathrm{Fb,eq}} \approx L_{Ws} - \left(10 \lg \left(Re\left(Y_{R,low,eq}\right)/Y_0\right)\right)$$ [dB]

$L_{Fb,eq}$	single equivalent blocked force level of the source	[dB]
L_{Ws}	installed structure-borne sound power level	[dB]
$Y_{R,low,eq}$	mean receiver mobility at the contact points of the excited component	[ms/sN]
Y_0	reference value of mobility (Y_0 = 1 ms/sN)	[ms/sN]

Determination of Free Velocity:
The single equivalent free velocity is directly measured at the piping systems two fixing points according to DIN EN 15657, the piping system being disconnected from the test wall.

(9) $$L_{\mathrm{vf,eq}} = 10 \lg \left(\sum_j 10^{\frac{L_{\mathrm{vf,j}}}{10}}\right)$$ [dB]

$L_{vf,eq}$	single equivalent free velocity level of the specimen	[dB]
$L_{vf,eq,j}$	single equivalent free velocity level of the specimen at contact j	[dB]

Determination of Source Mobility:
The magnitude of the single equivalent mobility of the source is approximately determined according to DIN EN15657, based on the single equivalent free velocity of the source and individual equivalent blocked force of the source, as follows:

(10) $$\left|Y_{S,eq}\right|^2 \approx 10\, lg^{\frac{\left(L_{\mathrm{vf,eq}} - L_{\mathrm{Fb,eq}}\right)}{10}} \cdot 10^{-6}$$

$Y_{S,eq}$	single equivalent mobility of the specimen	[ms/sN]
$L_{vf,eq}$	single equivalent free velocity level of the specimen	[dB]
$L_{Fb,eq}$	single equivalent blocked force level of the specimen	[dB]

Explanations to the indication of the measurement results on the result sheets

Results marked with "≤" in the tables indicate that a background noise correction has been carried out. This means that the actual result for the test specimen is lower than the measured value, however cannot be determined in more detail by the applied test facility.

Realization of measurements and evaluation for pipe linings

The acoustic performance of a pipe lining for wastewater installation systems is described by the airborne sound power insertion loss D_{Wa} and the structure-borne sound power insertion loss $D_{Ws,i}$. The lining will probably have an effect on both, airborne sound and structure-borne sound. In addition the insertion loss for the predicted single number values using the examples given in DIN EN 12354-5:2023, G.4, first without pipe lining and then with pipe lining are given.

The measurements and the dertermination of the different quantities are performed according to DIN EN 14366-1, Annex B. The execution of the measurements take place in two steps:

1. Measurements of a reference set-up with a bare (unlagged) wastewater pipe. The pipe was installed according to DIN EN 14366-1 with foam in the floor openings (pipe <u>not</u> grouted into ceiling and floor openings).
2. Measurements of the same pipe supplied with the pipe lining under test.

<u>Reference set-up</u>
To determin the insertion loss of the pipe lining a bare wastewater pipe is installed according to DIN EN 14366-1 (see Annex A) with foam in the floor openings (pipe <u>not</u> grouted into ceiling and floor openings). The test facility is shown schematically in Annex P.

<u>Measurement set-up with test object</u>
The measurement set-up with test object is almost identical with the reference set-up. The only difference is, that the pipe is now completely covered by the pipe lining under test. The floor openings were closed with foam (pipe <u>not</u> grouted into ceiling and floor openings).
The measurement set-up with the object under test (pipe lining) resembles in all details (except for the pipe lining) the reference set-up.

Details about measurement set-up and assessment of measurement results see Annex A.

Evaluation of measuring data and determination of acoustic parameters for pipe linings

The acoustic influence of the pipe lining under test is described by the quantities airborne sound power insertion loss and structure-borne sound power insertion loss.

<u>Determination of airborne sound power insertion loss:</u>
The airborne sound power of the piping system with lining $L_{Wa,lining}$ is measured using the same procedure as described in Annex A and Annex F. With the airborne sound power of the piping system without lining L_{Wa} the airborne sound power insertion loss D_{Wa} is calculated as:

(1) $$D_{\mathrm{Wa}} = L_{\mathrm{Wa}} - L_{\mathrm{Wa,lining}}$$ [dB]

D_{Wa}	airborne sound power insertion loss	[dB]
L_{Wa}	airborne sound power level of the piping system	[dB]
$L_{Wa,lining}$	airborne sound power level of the piping system covered with pipe lining	[dB]

Single number quantities for airborne sound power insertion loss:
The difference of the single number values of the airborne sound power levels of the piping system without lining and with lining, each expressed in dB(A) leads to the single number quantity for the pipe lining airborne sound insertion loss $D_{Wa,A}$:

(2) $$D_{\mathrm{Wa,A}} = L_{\mathrm{Wa,A}} - L_{\mathrm{Wa,A,lining}}$$ [dB]

Determination of structure-borne sound power insertion loss:
For heavy building configurations (low mobility) the structure-borne sound power insertion loss $D_{Ws,heavy}$ (corresponds to $D_{Ws,low}$ in DIN EN 14366-1, Annex B) can be calculated with the single equivalent blocked force level of the piping system itself $L_{Fb,eq}$ and the piping system with lining $L_{Fb,eq,lining}$:

(3) $$D_{\mathrm{Ws,heavy}} = L_{\mathrm{Fb,eq}} - L_{\mathrm{Fb,eq,lining}}$$ [dB]

$D_{Ws,heavy}$	structure-borne sound power insertion loss for heavy structures	[dB]
$L_{Fb,eq}$	single equivalent blocked force level of the piping system	[dB]
$L_{Fb,eq,lining}$	single equivalent blocked force level of the piping system covered with pipe lining	[dB]

The value $D_{Ws,heavy}$ mentioned in this test report corresponds to $D_{Ws,low}$ in DIN EN 14366-1, Annex B. For a standardised readability, the term "heavy" (heavy building configuration) was chosen in this test report instead of "low" (low mobility building element).

For other configurations, mostly ligthweigth builing configurations (high mobility), the structure-borne sound power insertion loss $D_{Ws,light,i}$ (corresponds to $D_{Ws,high,i}$ in DIN EN 14366-1, Annex B) can be calculate with the installed power levels of the piping system without $L_{Ws,i}$ and with lining $L_{Ws,i,lining}$ of a considered receiving element i. For the calculation of the values given in the test report the wall in the example for lightweight structures specially given in DIN EN 12354-5:2023, G.4 for application to DIN EN 14366-1 was considered as receiving element i:

(4) $$D_{\mathrm{Ws,light,wall}} = L_{\mathrm{Ws,wall}} - L_{\mathrm{Ws,wall,lining}}$$ [dB]

$D_{Ws,light,wall}$	structure-borne sound power insertion loss for ligthweight structures	[dB]
$L_{Ws,wall}$	installed power levels of the piping system	[dB]
$L_{Ws,wall,\ lining}$	installed power levels of the piping system covered with pipe lining	[dB]

The value $D_{Ws,light}$ mentioned in this test report corresponds to $D_{Ws,high}$ in DIN EN 14366-1, Annex B. For a standardised readability, the term "light" (lightweight building configuration) was chosen in this test report instead of "high" (high mobility building element).

Single number quantities for structure-borne sound power insertion loss:
As single number quantities for the structure-borne sound power insertion loss the difference of the calculated - A-weighted apparent structure-borne sound pressure level for the piping system without and with lining for the two building examples given in DIN EN 12354-5, Annex G4, one for heavy buildings $L'_{ne,s,A,heavy}$ and one for lightweight buildings $L'_{ne,s,A,light}$ is determined.

Insertion loss for the example for the heavy building acc. to DIN EN 12354-5, Annex G.4.2:

(5) $$D_{ne,s,A,heavy} = L'_{ne,s,A,heavy} - L'_{ne,s,A,heavy,lining}$$ [dB]

$D_{ne,s,A,heavy}$	single number value for structure-borne sound power insertion loss for the heavy building	[dB]
$L'_{ne,s,A,heavy}$	A-weighted apparent structure-borne sound pressure level of the piping system	[dB]
$L'_{ne,s,A,heavy,lining}$	A-weighted apparent structure-borne sound pressure level of the piping system covered with pipe lining	[dB]

Insertion loss for the example for the lightweight building acc. DIN EN 12354-5, Annex G.4.3:

(6) $$D_{ne,s,A,light} = L'_{ne,s,A,light} - L'_{ne,s,A,light,lining}$$ [dB]

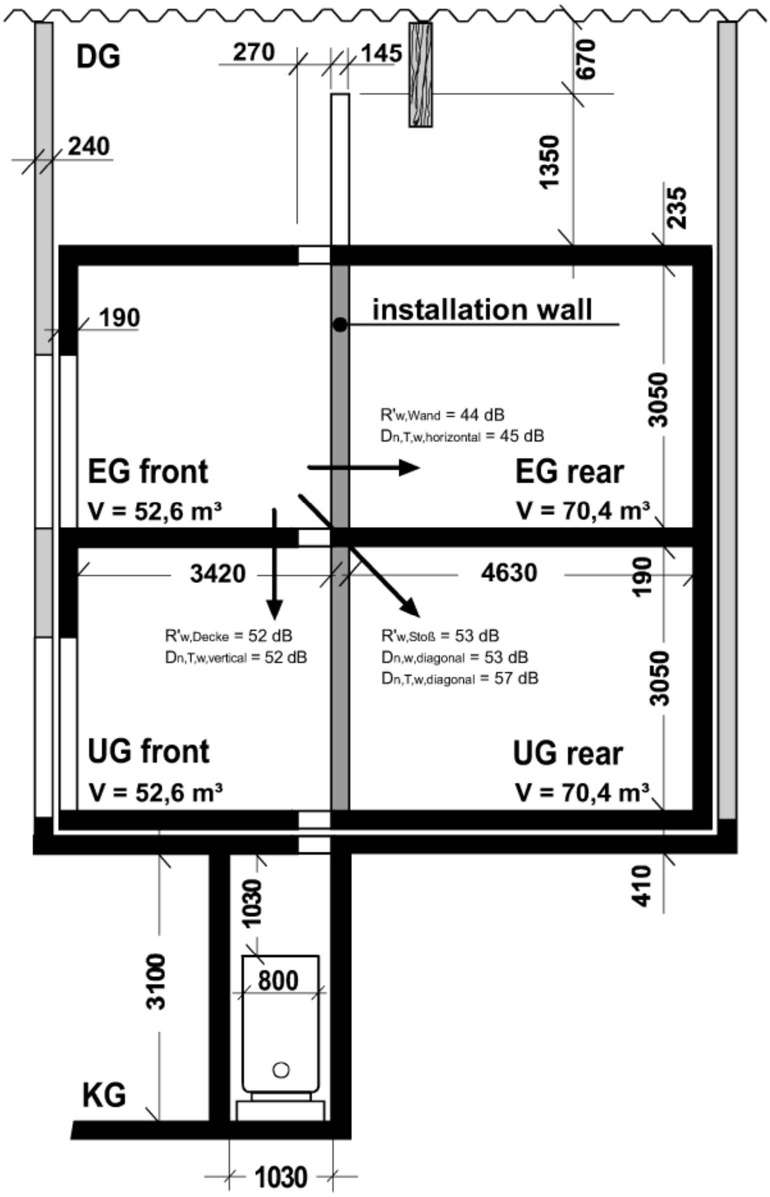
$D_{ne,s,A,light}$	single number value for structure-borne sound power insertion loss for the lightweight building	[dB]
$L'_{ne,s,A,light}$	A-weighted apparent structure-borne sound pressure level of the piping system	[dB]
$L'_{ne,s,A,light,lining}$	A-weighted apparent structure-borne sound pressure level of the piping system covered with pipe lining	[dB]

Scope of the measurements

Transferability of the results to other building situations
Concerning the practical application of the measuring results it has to be noted that the insertion losses achieved in situ can deviate from the values indicated in the test report, if wastewater systems are used, whose shape or nominal diameter differs substantially from the system under test. The same applies to wastewater systems with different materials (cast iron, steel, or plastic). Different variations of installation, as for example the mounting under plaster, the mounting with other elastic mounting elements, etc., likewise influence the insertion losses. Moreover it has to be considered, that the attainable noise reduction in practice can be decreased by structure-borne sound bridges between the tap or the pipe and the building. In the values given here these side paths are not considered.

The information about measurement uncertainty see in the statement on measurement uncertainty in Annex A.

Test facility



Sectional drawing of the installation test facility in the Fraunhofer-Institute of Building Physics (dimensions given in mm). The test facility comprises two couples of rooms in the ground floor (EG) and in the basement (UG) that are located above each other. Due to this construction, including the top floor (DG) and the sub-basement (KG), it is possible to perform tests on installation systems which extend across several floors, e.g. waste-water installation systems. The installation walls in the ground floor and in the basement can be substituted according to actual requirements. In the standard case, single-leaf solid walls with a mass per unit area of 220 kg/m^2 (according to German standard DIN 4109) are used. Since the sound insulation of these walls do not meet the requirements to be fulfilled by a wall separating different occupancies within the same building ($R'_w \geq 53$ dB), the next adjacent rooms to be protected from noise are located diagonally above or below the installation room (in case of a usual design of the ground plan). Due to its double-leaf construction with an additional structure-borne sound insulation, the installation test facility is particularly suited for measuring low sound pressure levels. The measuring rooms are designed in such a way that the reverberation times are between 1 s and 2 s within the examined frequency range. The flanking walls, with an average mass per unit area of approximately 440 kg/m^2, are made of concrete.

Measurement equipment

Following measurement equipment was used for the measurments in the installation test facility P12 of the Fraunhofer-Institute for Building Physics:

Device	Description, Type and Serial Number	Manufacturer
Analysator	Soundbook_MK2_8L, S/N 07082 Software: Sinus Samurai Ver. 3.x	Sinus Messtechnik
½"-microphone-set	46 AF (cartridge: Typ 40 AF-Free Field; pre-amp: Typ 26 TK) CH1: S/N 97112 CH2: S/N 58588 CH3: S/N 58591 CH4: S/N 58596	G.R.A.S
1"-microphone-set	40HF (cartridge: Typ 40EH-LowNoise; pre-amp: Typ 26HF; Power Module: Typ 12HF) CH 1: S/N 201166 and S/N 207665 CH 2: S/N 201167 and S/N 207666 CH 3: S/N 60860 and S/N 43399 CH 4: S/N 40943 and S/N 77978	G.R.A.S
Microphone-calibrator	4231, S/N 2594557	Bruel & Kjær
Accelerometer (IEPE)	352B, S/N 215542, S/N 215543, S/N 215544, S/N 231003	PCB Piezotronics, Inc.
Force sensor (IEPE)	208C02, S. Nr. LW58707	PCB Piezotronics, Inc.
Accelerometer-calibrator	VC11, S/N 091458	MMF
Amplifier	LBB 1935/20, S/N 405025800300113361	Bosch Plena
Loudspeaker	MLS 82	Lanny
Reference sound source	4204, S/N 317484	Bruel & Kjær
Standard tapping machine	211, S/N 12958	Norsonic
Flowmeter	PROMAG W 50W40, S/N 6A07D519000	Endress+Hauser
Pressure sensor	SITRANS P200, S/N LKKK205852010120	Siemens

The used Analyser is a type-approved Class 1 sound level meter. All measurement devices are tested frequently by internal and external testing laboratories, are calibrated and if necessary gauged.

Test conditions

The measurements are carried out under the following climatic conditions:
Air temperature: 18 - 23°C
Rel. humidity: 35 - 65%
Static air pressure: 950 - 990 hPa