

Test Report P-BA 166/2024e

Determination of the Acoustic Performance of a Wastewater Installation System in the Laboratory according to DIN EN 14366-1

Client: AENOR Confía, S.A.U.
C/ Génova, 6
28004 Madrid
Spain


Test specimen: Wastewater system made of plastic, type: "Phonoblack®" with fittings,
type: "Phonoblack®", OD 110 x 3.2 (manufacturer: Redi S.p.A.) mounted with
plastic pipe clamps, type: "Phonoklip®" (manufacturer: Girpi).

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Test date: The measurement was carried out on August 26th, 2024 in the test
facilities of the Fraunhofer Institute for Building Physics in Stuttgart.

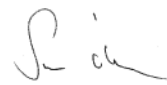
Stuttgart, November 11, 2024

Test Engineer:



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Head of the test laboratory:



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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.

The mentioned measuring results exclusively refer to the investigated test object. Any publication of this document in
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Test specimen: Wastewater system made of plastic, type: "Phonoblack®" with fittings, type: "Phonoblack®", OD 110 x 3.2 (manufacturer: Redi S.p.A.) mounted with plastic pipe clamps, type: "Phonoklip®" (manufacturer: Girpi). Test object no. S 12304-01; see Figures 2 and 3.

Test set-up: The pipe system was mounted according to Figures 2 and 3 (see also Annex A). The pipe system consisted of straight wastewater pipes (nominal size OD 110), three inlet tees (87.5°), 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.

Pipe system: Single-layer pipes with shaped pipe sockets, type: "Phonoblack®" (Phonoblack by REDI Ø 110x3.2; 22/01/2024). Material: PVC modified with mineral filler (PVC-U), size: OD 110, wall thickness: 3.7 mm, weight: 1.87 kg/m, density: 1.5 g/cm³, values measured by IBP; manufacturer information: pipe wall thickness: 3.2 mm, pipe density: 1.6 g/cm³.

One-layer fittings: Phonoblack® (phonoblack REDI 110-87°). Material: PVC modified with mineral filler (PVC-U), wall thickness: 3.2 mm, density: 1.5 g/cm³, values measured by IBP; manufacturer information: fitting wall thickness: 3.2 mm, fitting density: 1.4 g/cm³.

Plug connection of the pipes and fittings (shaped pipe sockets).

Pipe clamps: Plastic pipe clamps "Phonoklip®" 110 mm (manufacturer: Girpi) (see figure 3). In each storey (EG and UG) two clamps were installed, one in the lower and one in the upper wall area. Guide position in the upper wall area with red spacer (3 mm) and in the lower wall area the fix position (anchor position) without spacer. The pipe clamps were fixed to the installation wall with dowels and thread rods.

The wastewater installation system was 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; 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 1), single equivalent free velocity level and magnitude of single equivalent source mobility (Results 2). Details see Annex A and Annex F.

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 3, stating the flow rates, mounting conditions and used pipe clamps for advertisement. Additionally, Table 1 shows the predicted results for the test facility P12 at Fraunhofer IBP in Stuttgart.

Note:

Client: AENOR Confía, S.A.U.; C/ Génova, 6; 28004 Madrid; Spain

Results 1

Test specimen: Wastewater system made of plastic, type: "Phonoblack®" with fittings, type: "Phonoblack®", OD 110 x 3.2 (manufacturer: Redi S.p.A.) mounted with plastic pipe clamps, type: "Phonoklip®" (manufacturer: Girpi). Test object no. S 12304-01; see Figures 2 and 3.

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

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 3). The single equivalent free velocity level and the magnitude of the single equivalent source mobility for the general case see Results 2. 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	≤ 9.6	25.9	30.2	38.0
63	27.8	33.1	39.0	41.9
80	33.0	36.9	45.8	50.4
100	31.9	35.7	42.9	46.7
125	27.4	31.0	37.9	42.6
160	28.4	31.1	37.5	41.9
200	26.0	29.6	35.2	39.8
250	26.3	30.7	35.6	39.5
315	27.2	31.8	36.1	39.6
400	30.4	35.0	39.2	41.8
500	33.9	37.9	42.3	44.5
630	32.2	36.7	40.9	44.6
800	33.2	38.0	42.2	46.1
1000	33.8	38.3	42.4	46.4
1250	34.9	36.6	40.3	45.4
1600	34.5	38.1	41.5	45.4
2000	36.3	40.9	43.5	46.2
2500	39.2	43.8	45.3	47.3
3150	39.8	43.5	45.4	47.7
4000	40.7	44.7	46.5	48.7
5000	41.1	45.3	46.7	48.4

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	102.0	106.1	111.1	115.4
63	99.5	103.7	108.7	112.5
80	93.8	98.2	103.5	107.9
100	91.1	94.0	99.1	104.0
125	86.0	92.2	95.7	102.1
160	79.8	84.2	89.0	94.8
200	77.0	81.2	86.2	90.8
250	74.7	78.7	84.2	87.7
315	71.6	76.9	80.5	84.4
400	73.4	78.4	82.0	84.8
500	72.4	76.7	80.9	83.4
630	67.0	70.8	74.8	79.3
800	63.0	68.2	72.3	77.1
1000	≤ 60.7	65.2	69.3	73.6
1250	≤ 62.7	≤ 64.5	68.1	73.4
1600	≤ 64.8	67.9	71.7	75.5
2000	71.0	74.0	76.0	78.4
2500	67.5	71.2	73.1	75.0
3150	≤ 60.9	≤ 62.1	≤ 63.6	65.4
4000	≤ 59.5	≤ 60.5	≤ 61.8	≤ 63.2
5000	≤ 59.9	≤ 60.8	≤ 61.7	≤ 62.8

Note:



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 11, 2024
 Head of the test laboratory: *[Signature]*

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

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 3). Airborne sound power level and single equivalent blocked force level see Results 1. 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	94.9	102.8	106.5	112.7
63	92.1	98.1	102.8	108.0
80	97.2	101.1	108.2	113.4
100	96.6	99.8	105.8	110.6
125	89.4	95.2	99.5	104.5
160	89.6	93.0	99.6	104.5
200	91.4	94.8	101.2	105.3
250	97.7	100.7	106.1	109.5
315	92.7	97.4	101.6	105.5
400	90.5	94.3	98.6	102.0
500	86.7	87.4	93.1	95.5
630	73.7	75.9	81.3	84.6
800	65.1	69.3	72.7	77.2
1000	62.9	66.7	70.4	74.9
1250	61.6	65.5	68.0	72.9
1600	61.7	65.1	67.7	71.5
2000	63.9	68.3	68.7	70.6
2500	65.8	70.0	70.6	72.0
3150	55.2	59.6	61.3	63.1
4000	45.3	48.9	51.1	52.7
5000	34.8	39.0	42.0	43.5

f [Hz]	magnitude of single equivalent source mobility			
	Y _{s,eq} [10 ⁻⁴ m/sN]			
	0.5 l/s	1.0 l/s	2.0 l/s	4.0 l/s
50	4.4	6.8	5.9	7.3
63	4.3	5.2	5.1	5.9
80	14.9	14.0	17.1	18.9
100	18.7	19.6	21.9	21.2
125	14.9	14.2	15.5	13.1
160	30.7	27.6	33.7	30.7
200	52.6	47.9	55.9	53.0
250	141.0	125.4	125.2	123.2
315	113.4	105.6	113.6	113.9
400	71.5	62.4	67.7	72.3
500	51.9	34.3	40.6	40.5
630	21.5	18.1	21.2	18.5
800	12.7	11.4	10.5	10.1
1000	12.8	11.9	11.3	11.6
1250	8.8	11.3	9.9	9.5
1600	7.0	7.2	6.3	6.3
2000	4.4	5.1	4.3	4.1
2500	8.2	8.6	7.5	7.0
3150	5.2	7.5	7.6	7.6
4000	2.0	2.6	2.9	3.0
5000	0.6	0.8	1.0	1.1



Note:

Comparing products: Calculated Single Number Quantities (SNQ)

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Results 3

Test specimen: Wastewater system made of plastic, type: "Phonoblack®" with fittings, type: "Phonoblack®", OD 110 x 3.2 (manufacturer: Redi S.p.A.) mounted with plastic pipe clamps, type: "Phonoklip®" (manufacturer: Girpi). Test object no. S 12304-01; see Figures 2 and 3.

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) 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.

Wastewater system made of plastic, type: "Phonoblack®" with fittings, type: "Phonoblack®", OD 110 x 3.2 (manufacturer: Redi S.p.A.) mounted with plastic pipe clamps, type: "Phonoklip®" (manufacturer: Girpi). Test object no. S 12304-01; see Figures 2 and 3.

Calculated Single Number Quantities (SNQ), input data see Results 1 and 2.	Flow rate [l/s]			
	0.5	1.0	2.0	4.0
A-weighted airborne sound power level L _{wa,A} (50 Hz – 5 kHz) [dB] in the installation room (source room)	48.6	52.7	54.9	57.6
a) Example of SNQ for heavy buildings acc. DIN EN 12354-5, Annex G.4.2: Apparent structure-borne sound pressure level (receiving room) L' _{ne,s,A} (50 Hz – 3150 Hz) [dB]	< 10	12.6	17.1	21.5
b) Example of SNQ for lightweight buildings acc. DIN EN 12354-5, Annex G.4.3: Apparent structure-borne sound pressure level (receiving room) L' _{ne,s,A} (50 Hz – 2500 Hz) [dB]	16.9	21.2	25.5	29.7

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.



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Mounting conditions see Sheet 1.



Prediction method:

In this case the predicted values are calculated using a measured transfer function acc. to DIN EN ISO 10848 for the transmission from the source room to the receiving room in the test facility P12 at Fraunhofer IBP in Stuttgart. For the prediction only the structure borne sound is considered, but the airborne sound transmission is negligible for the SNQ.

Present building situation for this prediction:

In this case the calculations are based on the building situation in the test facility P12 at Fraunhofer IBP in Stuttgart, details see Annex P. The source room is the front room of the basement in the test facility ("UG front") and the receiving room is the horizontal room ("UG rear"). All floors/ceilings and all flanking walls to the installation wall are made of 19 cm thick concrete (weight per unit area approx. 440 kg/m²). The installation wall itself is 11.5 cm thick limestone, plastered on both sides (weight per unit area approx. 220 kg/m²).

#	Input data for prediction: - source data for wastewater system, see Results 1 and 2 and - present building situation, see above.	Flow rate [l/s]				
		0.5	1.0	2.0	4.0	
Normalized sound pressure level $L_{Aeq,n}$ [dB] – Installation sound level						
1	$L_{Aeq,n,50 - 5000 \text{ Hz}}$	source room	44.6	48.7	50.9	53.6
		receiving room	< 10	13.9	18.2	22.5
2	$L_{Aeq,n,100 - 5000 \text{ Hz}}$	source room	44.6	48.7	50.9	53.6
		receiving room	< 10	12.9	17.0	21.3
Standardized sound pressure level $L_{Aeq,nT}$ [dB] – Installation sound level						
3	$L_{Aeq,nT,50 - 5000 \text{ Hz}}$	source room	42.4	46.4	48.7	51.4
		receiving room	< 10	10.4	14.6	18.9
4	$L_{Aeq,nT,100 - 5000 \text{ Hz}}$	source room	42.4	46.4	48.7	51.4
		receiving room	< 10	< 10	13.4	17.8

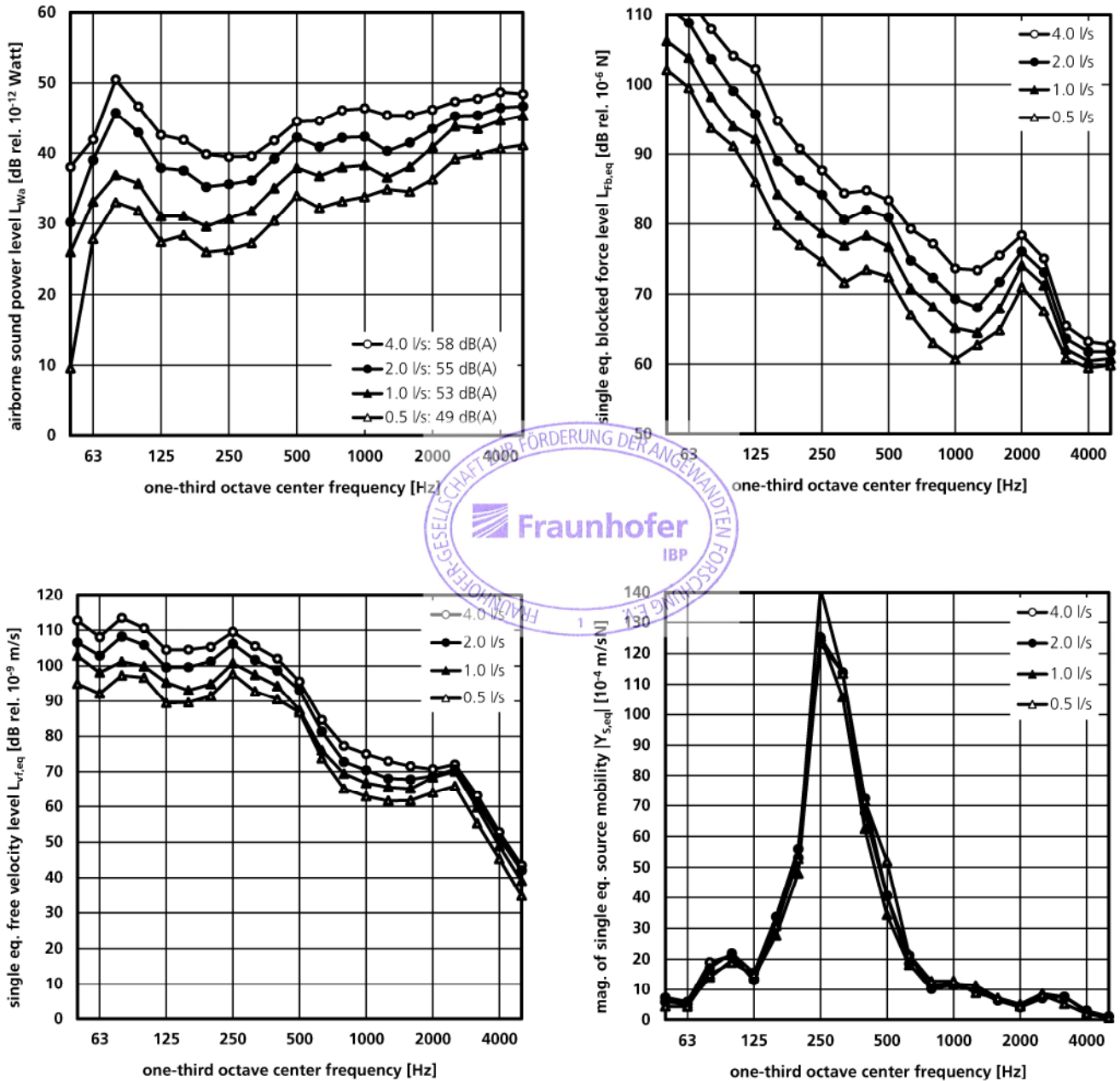
- Note:**
- Results in line #2 corresponds to DIN 4109-values and in line #4 to VDI 4100-values in old test reports.
 - The SNQ obtained here shall not be used in context with requirements in buildings that do not correspond to the building situation mentioned above. The prediction can be done for any other building situation.
 - 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.

Detailed results

Client: AENOR Confía, S.A.U.; C/ Génova, 6; 28004 Madrid; Spain

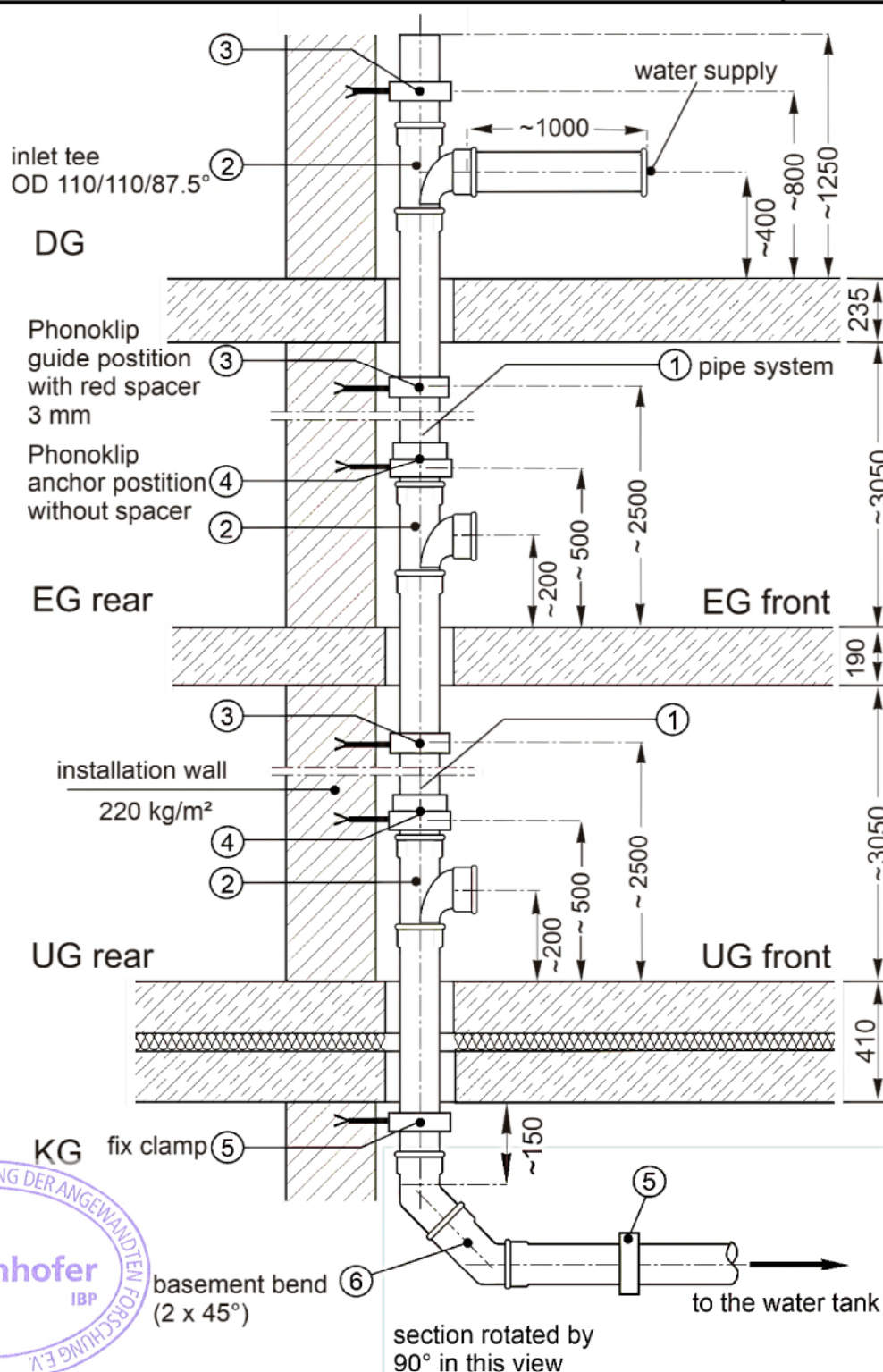
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Figure 1



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**.

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

Test specimen: Wastewater system made of plastic, type: "Phonoblack®" with fittings, type: "Phonoblack®", OD 110 x 3.2 (manufacturer: Redi S.p.A.) mounted with plastic pipe clamps, type: "Phonoklip®" (manufacturer: Girpi). Test object no. S 12304-01; see Figures 2 and 3.



Upper left: Wastewater system in the room UG front.

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

Middle: Two 45°-basement bends.

Bottom left: Pipe clamp, anchor position (without spacer) at the lower wall area.

Bottom right: Pipe clamp, guide position (with red spacer) at the upper wall area.

Test specimen: Wastewater system made of plastic, type: "Phonoblack®" with fittings, type: "Phonoblack®", OD 110 x 3.2 (manufacturer: Redi S.p.A.) mounted with plastic pipe clamps, type: "Phonoklip®" (manufacturer: Girpi). Test object no. S 12304-01; see Figures 2 and 3.

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 $m'' = 220 \text{ kg/m}^2$) 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) $Q = 0.5 \text{ l/s}$, corresponding to $Q = 30 \text{ l/min}$,
- (2) $Q = 1.0 \text{ l/s}$, corresponding to $Q = 60 \text{ l/min}$,
- (3) $Q = 2.0 \text{ l/s}$, corresponding to $Q = 120 \text{ l/min}$,
- (4) $Q = 4.0 \text{ l/s}$, corresponding to $Q = 240 \text{ l/min}$.

- Here, a flow rate of $Q = 2.0 \text{ l/s}$ 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 $Q_{\text{max}} = 4.0 \text{ l/s}$ 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. Therefore, 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:

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

with

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

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 measurementsDetermination 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 $A_0 = 10 \text{ m}^2$ and A-weighted:

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

$L_{i,\text{Aeq},n}$	A-weighted normalized standard sound pressure level in the third-octave band i [dB]	
$L_{i,\text{eq}}$	spatially-averaged, energy-equivalent continuous sound pressure level in the third-octave band i	[dB]
$L_{i,\text{eq},\text{GG}}$	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:

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

$L_{\text{Aeq},n}$ 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 $L_{\text{Aeq},nT}$ in the receiving room is determined similarly to the Equation (1) with

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

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

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

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

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

$L_{W,a,total}$ 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.

$$(6) \quad L_{W_a} = 10 \lg \left(10^{\frac{L_{W_a,total}}{10}} - 10^{\frac{L_{W_a,struct}}{10}} \right) \quad [dB]$$

L_{W_a} airborne sound power level of the source [dB]

$L_{W_a,total}$ total airborne sound power level [dB]

$L_{W_a,struct}$ 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.

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

L_{W_s} installed structure-borne sound power level [dB]

$L_{W_s,cal,j}$ installed structure-borne sound power level of the reference sound source at contact point j [dB]

$L_{\langle p \rangle}$ spatially-averaged, energy-equivalent continuous sound pressure level in the receiving room during operation of the building service equipment [dB]

$L_{\langle p \rangle,cal,j}$ 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.

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

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

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

$L_{\text{vf,eq}}$	single equivalent free velocity level of the specimen	[dB]
$L_{\text{vf,eq,j}}$	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:

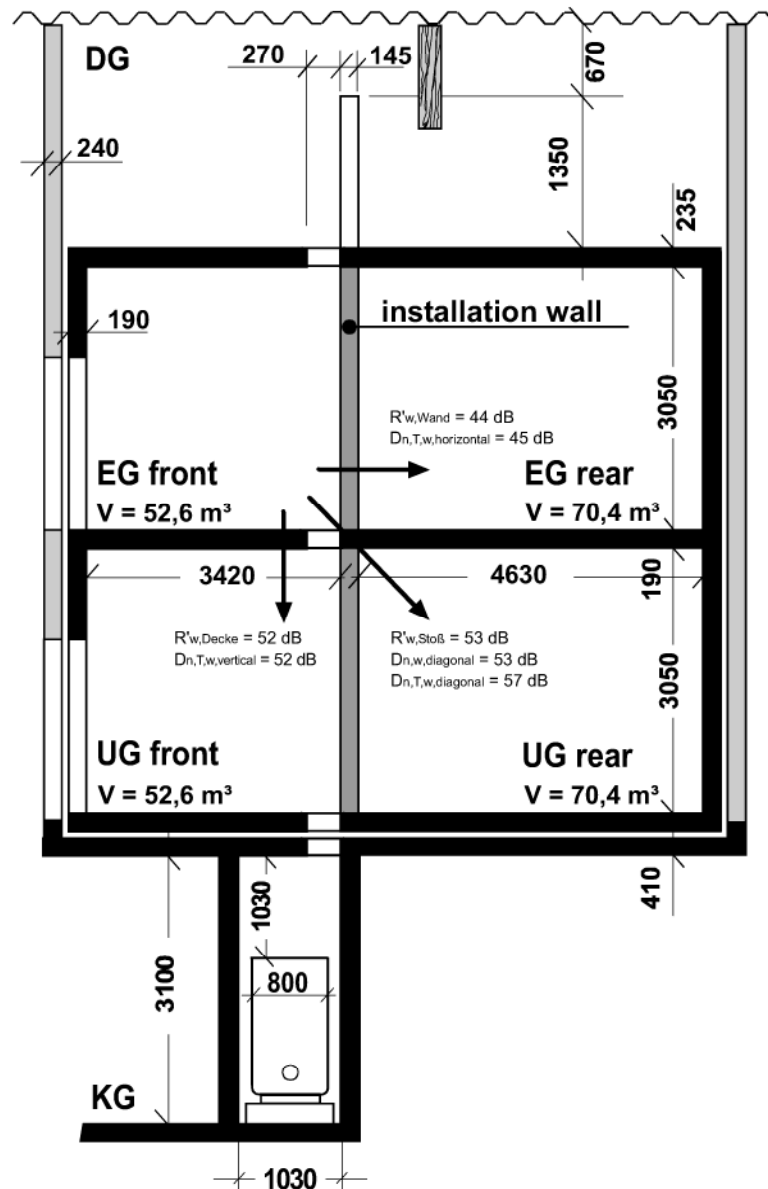
$$(10) \quad |Y_{\text{S,eq}}|^2 \approx 10 \lg \frac{(L_{\text{vf,eq}} - L_{\text{Fb,eq}})}{10} \cdot 10^{-6}$$

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

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

Results marked with " \leq " 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.

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 ($R'_w \geq 53 \text{ dB}$), 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 measurements 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