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. Klaus Peter Sedlbauer

Test Report P-BA 158/2015e

Determination of the Acoustic Performance of a Wastewater Installation System in the Laboratory

Client: UPONOR Infra
Kouvolantie 365
FI-15521 Nastola
FINLAND

Test object: Wastewater installation system consisting of plastic pipes and fittings "Uponor Decibel" (manufacturer: UPONOR Infra) with pipe clamps "Bismat 1000" made by Walraven.

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Test date: The measurement was carried out on July 14, 2015 in the test facilities of the Fraunhofer Institute for Building Physics in Stuttgart.

Stuttgart, December 23, 2015

Responsible Test Engineer: M.Sc. B. Kaltbeitzel

Head of Laboratory: M.BP. Dipl.-Ing.(FH) S. Öhler

The test was carried out in a laboratory, accredited according to DIN EN ISO/IEC 17025:2005 by DAkkS. The accreditation certificate is D-PL-11140-11-01.

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Determination of the Installation Sound Level L_{In} in the Laboratory	P-BA 158/2015e Results sheet 1

Client: UPONOR Infra, Kouvolantie 365, FI-15521 Nastola, FINLAND

Test specimen: Wastewater installation system consisting of plastic pipes and fittings "Uponor Decibel" (manufacturer: Uponor Infra) with pipe clamps "Bismat 1000" made by Walraven. (test object no.: 10834-2; see figure 4 and 5)

Test set-up:
- The pipe system was mounted according to figure 4 (see also Annex A).
- The system consisted of wastewater pipes (nominal size OD 110), three inlet tees (45°), two 45°-basement bends and a horizontal drain section. The inlet tees in the basement and in the ground floor were closed by lids supplied by the manufacturer.
  - Pipe system: three layer pipes "Uponor Decibel", material PP (outer), PP-MD (center), PP (inner), mineral filled polypropylene, size OD 110, wall thickness 3.8 mm, weight 1.9 kg/m, density 1.6 g/cm³. Single layer fittings, material PP-MD, size OD 110, wall thickness 3.7 mm, density 1.6 g/cm³ (values are manufacturers' information). Plug connection of the pipes and fittings.
  - Pipe clamps "Bismat 1000" (figure 5): Structure-borne sound insulating support attachment consisting of Bismat SL guidance clamps and Bismat SX socket clamps. In each storey (EG and UG) respectively one double clamp was installed at the lower wall area. To prevent contact to the pipe, the guidance clamp (SL) was mounted with 14 mm space between the locking tabs of the clamp (two 7.0 mm spacers on each side). At the upper wall area one "Bismat SL" was mounted as loose clamp (two 7.0 mm spacers on each side) without contact to the pipe (figure 5). The Bismat 1000 clamps were fixed to the installation wall with an adjustable wall plate 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 EN 14366: 2005-02)

Test method: The measurements were performed following German standard DIN 4109 and EN 14366; noise excitation by constant water flow with 0.5 l/s, 1.0 l/s, 2.0 l/s and 4.0 l/s (details in Annexes A and F).

Result:

"Uponor Decibel" (manufacturer: UPONOR Infra) with pipe clamps "Bismat 1000" made by Walraven.

Flow rate [l/s]	0.5	1.0	2.0	4.0
Installation sound level $L_{AFeq,n}$ (L_{In}) [dB(A)] **according to DIN 4109** measured in the basement test-room UG front	44	47	50	53
Installation sound level $L_{AFeq,n}$ (L_{In}) [dB(A)] **according to DIN 4109** measured in the basement test-room UG rear	<10	<10	13	19
Installation sound level $\overline{L_{AFeq,nT}}$ (L_{In}) [dB(A)] **according to VDI 4100** measured in the basement test-room UG front	42	45	48	50
Installation sound level $\overline{L_{AFeq,nT}}$ (L_{In}) [dB(A)] **according to VDI 4100** measured in the basement test-room UG rear	<10	<10	10	15
Airborne sound pressure level $L_{a,A}$ [dB(A)] **according to EN 14366** in the basement test-room UG front	44	47	50	53
Structure-borne sound characteristic level $L_{sc,A}$ [dB(A)] **according to EN 14366** in the basement test-room UG rear	<10	<10	<10	14

Test date: July 14, 2015

Notes:
- The requirements of DIN 4109 and VDI 4100 only apply for the test room UG rear.
- For the experimental setup investigated in the test facility the used supporting and fixing clips Bismat 1000 normally doesn't guarantee a realistic load transmission. Consequently, in case of practical application in a real building, higher levels of installation noise may be expected.
- Sound levels below 10 dB(A) 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 a laboratory, accredited according to DIN EN ISO/IEC 17025:2005 by DAkkS. The accreditation certificate is D-PL-11140-11-01.

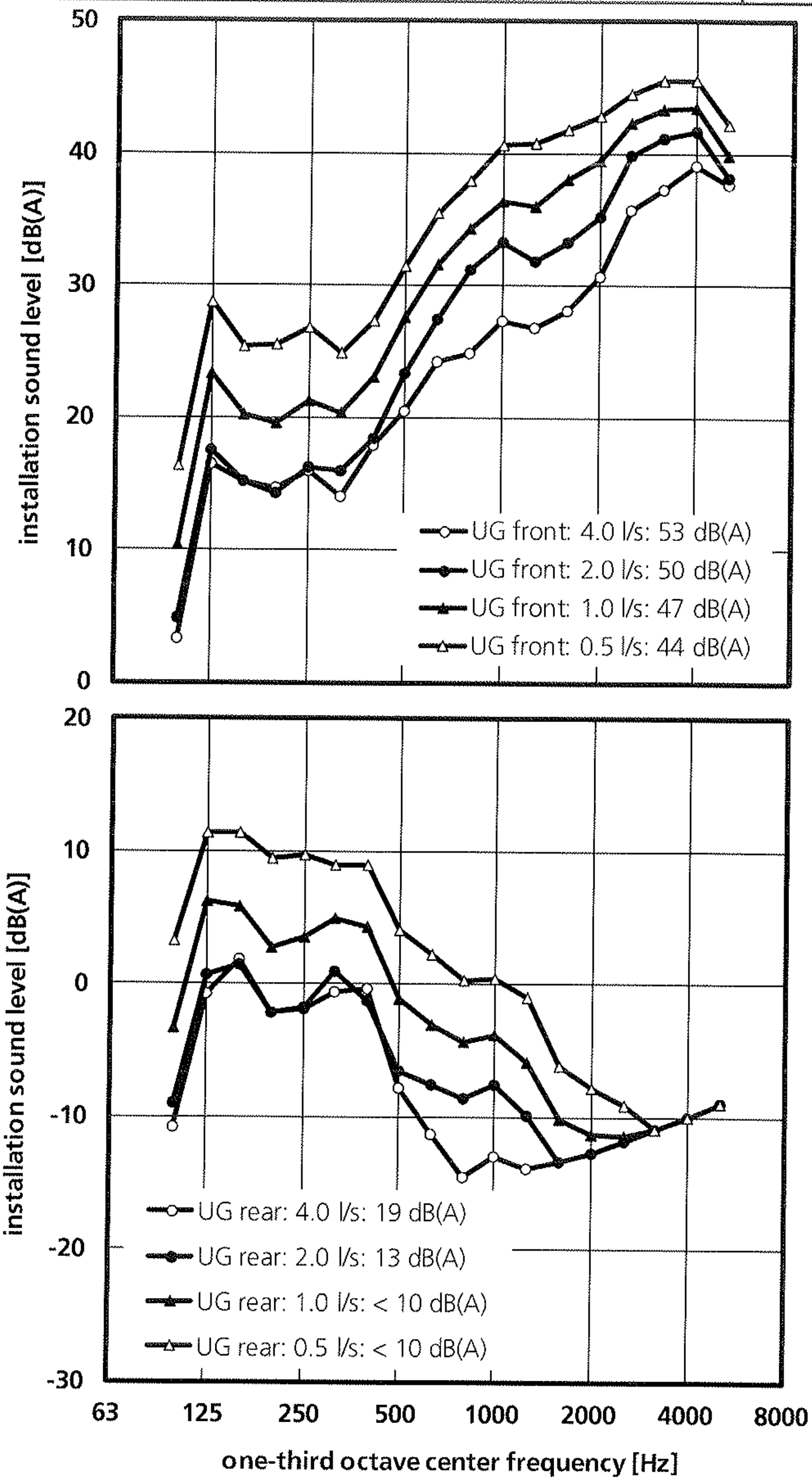
Stuttgart, December 23, 2015
Head of Laboratory:

Detailed results

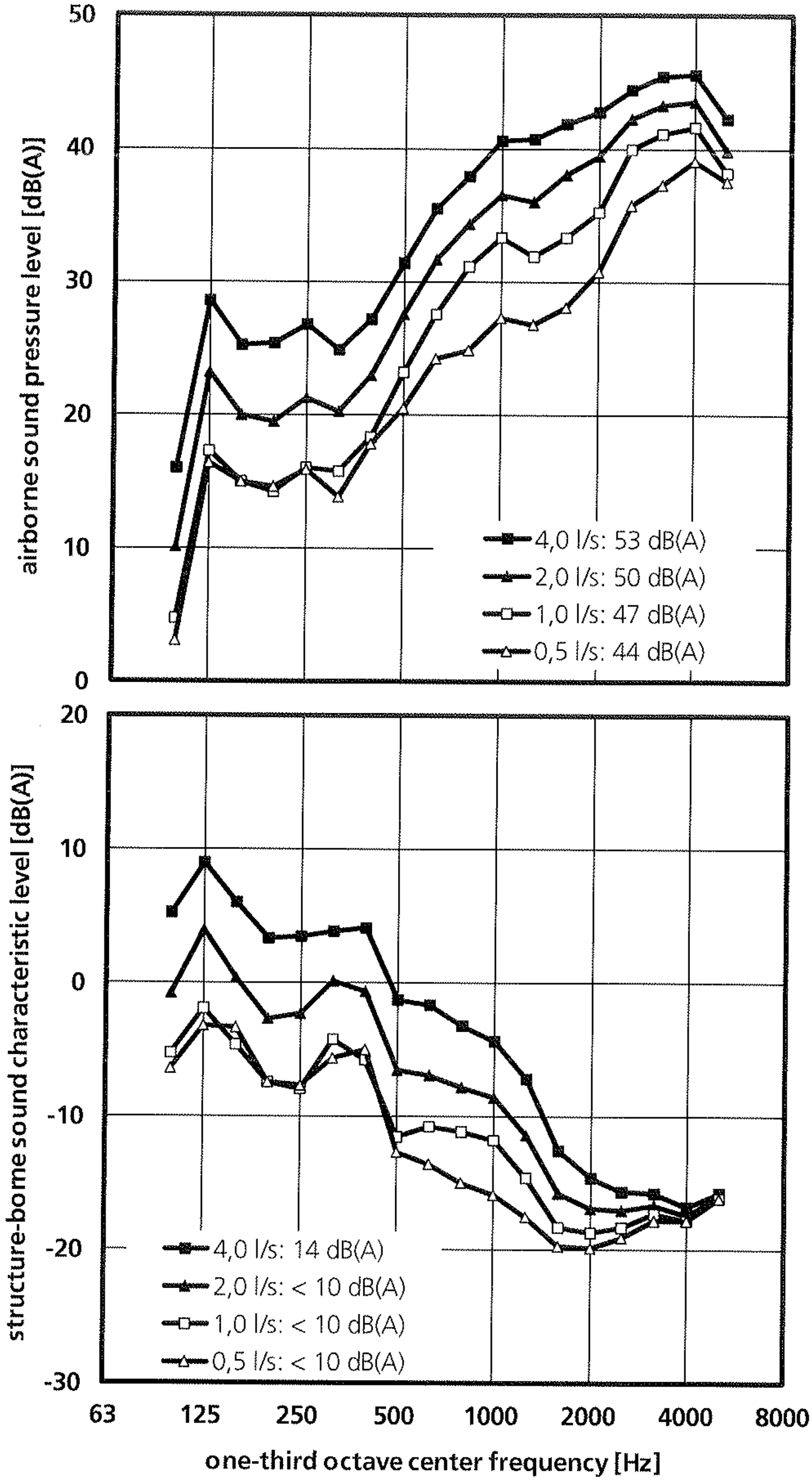
Client: UPONOR Infra, Kouvolantie 365, FI-15521 Nastola, FINLAND

P-BA 158/2015e

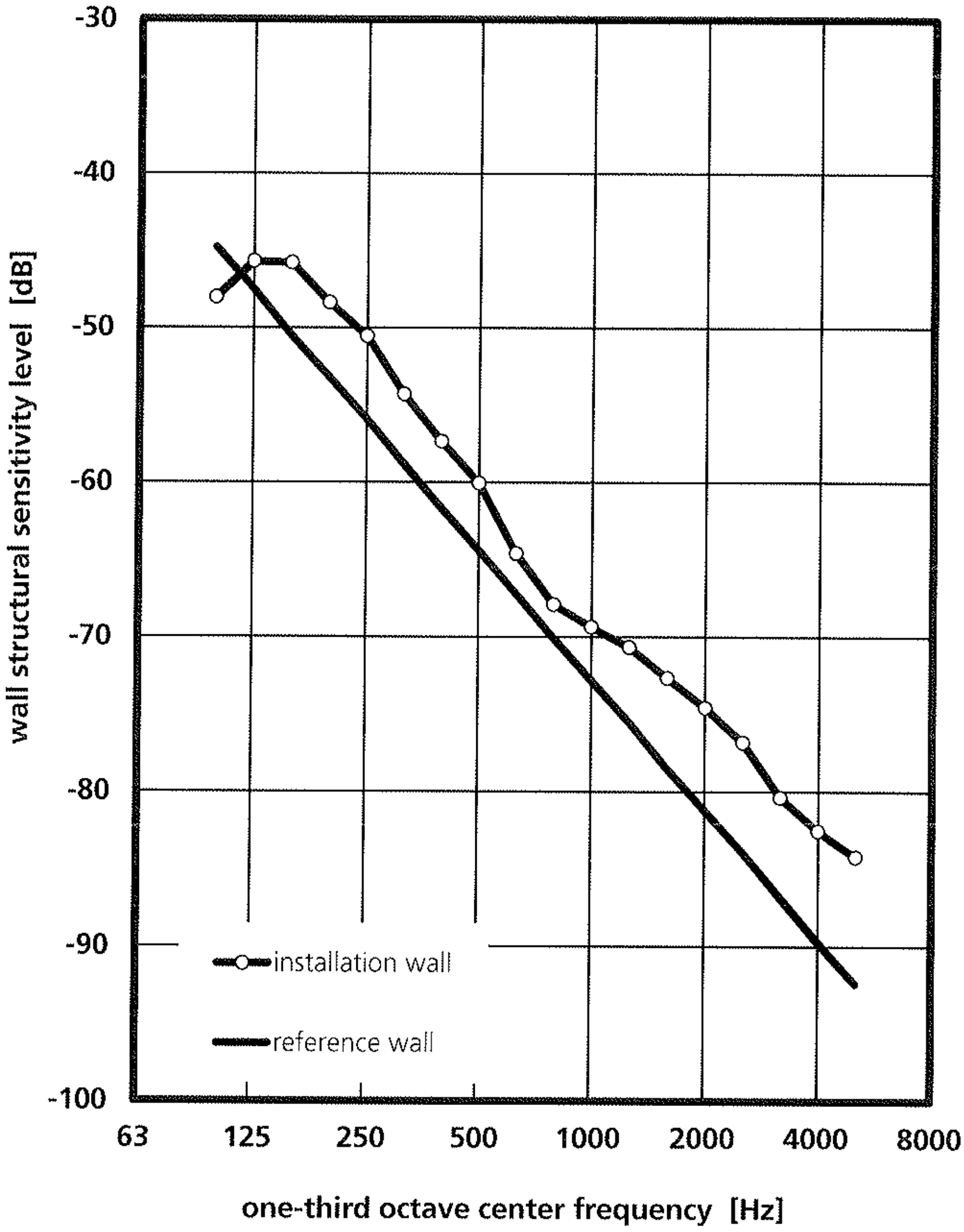
figure 1



Frequency response of the installation sound level $L_{AFeq,n}$ (L_{In}) measured at various flow rates in the test rooms UG front (above) and UG rear (below). The installation sound levels $L_{AFeq,n}$ (L_{In}) in dB(A) **according DIN 4109**, for the reproduced frequency range from 100 to 5000 Hz, are represented in the legend. Test specimen: Wastewater installation system consisting of plastic pipes and fittings "Uponor Decibel" (manufacturer: Uponor Infra) with pipe clamps "Bismat 1000" made by Walraven.

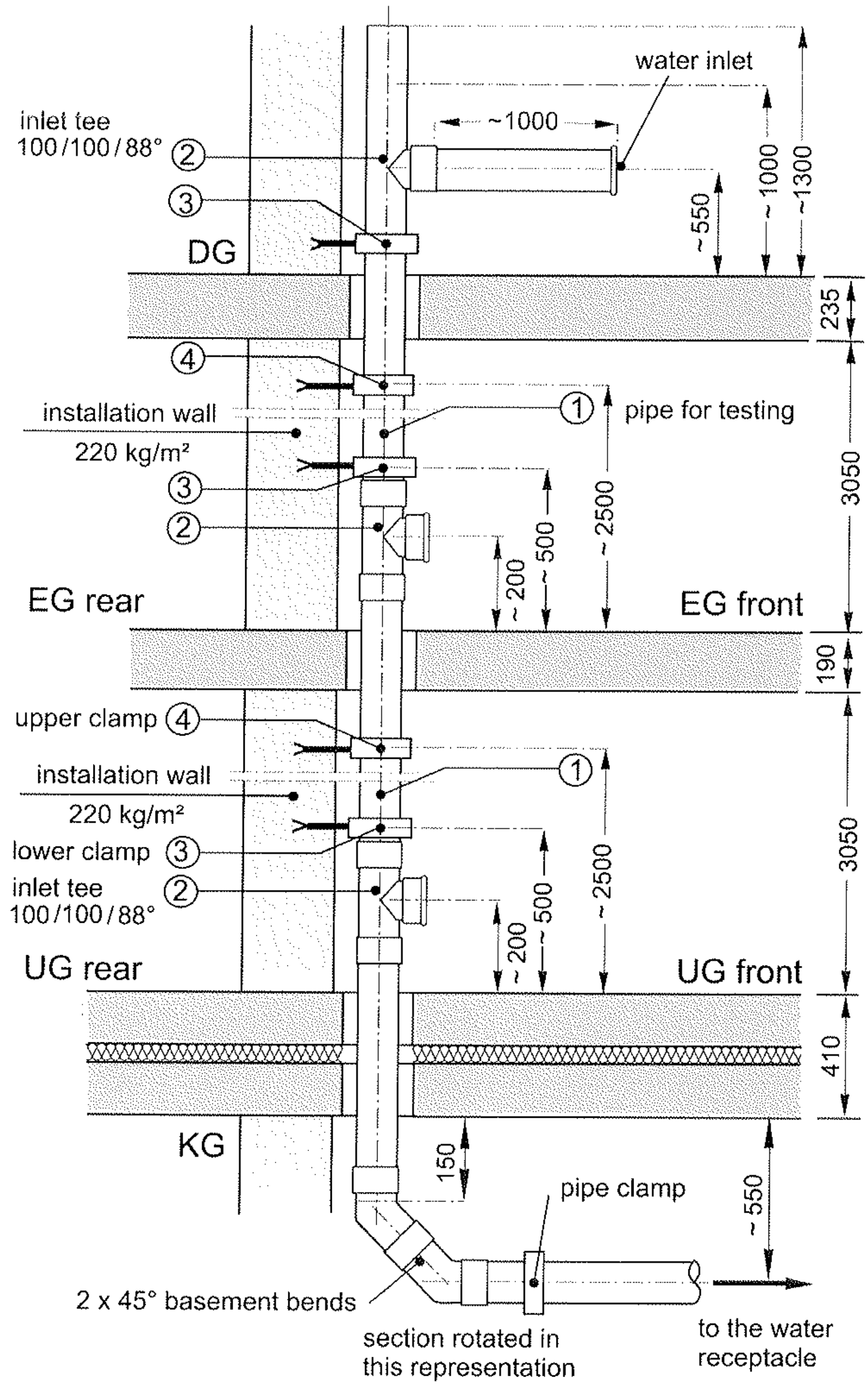


Frequency response of the airborne sound pressure level $L_{a,A}$ (above) and structure-borne sound characteristic level $L_{sc,A}$ (below) measured at various flow rates **according to EN 14366**.
Test specimen: Wastewater installation system consisting of plastic pipes and fittings "Uponor Decibel" (manufacturer: Uponor Infra) with pipe clamps "Bismat 1000" made by Walraven.



Wall structural sensitivity level L_{SS} of the installation wall between the test rooms UG front and UG rear in the installation test facility in the Fraunhofer-Institute of Building Physics. The installation wall consists of calcium silicate blocks (thickness 115 mm, ceiled on both sides) with a mass per unit area of 220 kg/m². The indicated structural sensitivity level L_{SS} refers to the mounting position of the waste water system according to figure 4. For comparison the wall structural sensitivity level L_{SSR} of the reference wall is also indicated (evaluation according to DIN EN 14366).

Test specimen: Wastewater installation system consisting of plastic pipes and fittings "Uponor Decibel" (manufacturer: Uponor Infra) with pipe clamps "Bismat 1000" made by Walraven.



Installation plan of the test set-up in the test facility. Upper clamps④"Bismat SL", lower clamps③ "Bismat 1000", consisting of Bismat SL guidance clamp and Bismat SX socket clamp
Test specimen: Wastewater installation system consisting of plastic pipes and fittings "Uponor Decibel" (manufacturer: Uponor Infra) with pipe clamps "Bismat 1000" made by Walraven.

Upper picture: Pipe clamp "Bismat SL, loose clamp" (two 7.0 mm spacers on each side) at the upper wall area.

Lower picture: "Bismat 1000", consisting of Bismat SL guidance clamp with two 7.0 mm spacers on each side and Bismat SX socket clamp without spacer at the lower wall area.

Mounting details see test set-up.

<u>Test specimen</u>: Wastewater installation system consisting of plastic pipes and fittings "Uponor Decibel" (manufacturer: Uponor Infra) with pipe clamps "Bismat 1000" made by Walraven.

Measurement set-up, noise excitation and evaluation parameters

Measurement 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 EN 14366. 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 waste-water 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 stuffed with porous absorber in order to prevent any structure-borne sound bridges influencing the building. The waste-water 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 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 waste-water pipes. As the noise generation in waste water 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 used results from the admissible hydraulic charge of the horizontal pipe sections, which is $Q_{max} = 4$ l/s for OD 110 pipes.

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. These vibrations 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. In the test room UG front additionally the airborne sound which is radiated from the waste water system is measured. According to EN ISO 140-3 the sound pressure level is picked up at six points in the room, to be space and time-averaged and corrected for the background noise. With this value the airborne sound pressure level $L_{a,A}$ and the structure-borne sound characteristic level $L_{sc,A}$ is calculated according to EN 14366. The installation sound level is determined following Annex F. Thereby the rounded $L_{AF,10}$ is equivalent to the installation sound level L_{In} (or $L_{AFmax,n}$) according to DIN 52219, DIN EN ISO 10052, DIN 4109-11 and DIN 4109.

Evaluation of Measurements

Stationary noise

The measured sound pressure level is given as time and space averaged one-third octave spectrum in the frequency range between 100 Hz and 5 kHz. First, the measured value is corrected for background noise. Subsequently, it is normalized to an equivalent sound absorption area of $A_0 = 10\ m^2$ and A-weighted:

(1) $$L_{n,AF,10} = 10 \cdot lg\left(10^{\frac{L_{n,F}}{10}} - 10^{\frac{L_{n,S}}{10}}\right) + 10 \cdot lg\frac{A_n}{A_0} + k(A)_n$$ [dB(A)]

$L_{n,F}$	space and time averaged sound pressure level in one-third octave band n (time constant: fast)	[dB]
$L_{n,S}$	background noise level in one-third octave band n	[dB]
$A_n = \frac{0.16 \cdot V}{T_n}$	sound absorption area of test room for one-third octave band n	[m²]
V	volume of test room	[m³]
T_n	reverberation time of test room in one-third octave band n	[s]
$k(A)_n$	A-weighting for one-third octave band n	[dB]

If the difference between the measured one-third octave level and the background 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 total sound pressure level is obtained by energetically adding the one-third octave values.

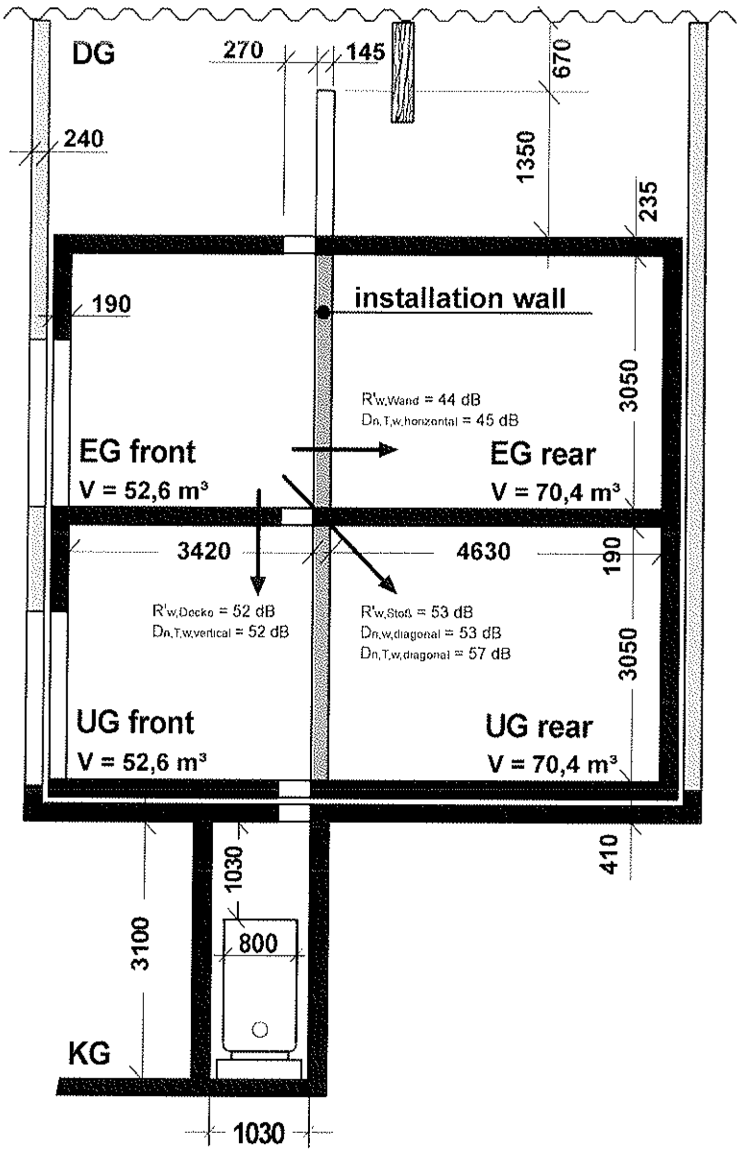
(2) $$L_{AF,10} = 10 \cdot lg\left(\sum_{n=1}^{18} 10^{\frac{L_{n,AF,10}}{10}}\right),$$ [dB(A)]

where n indicates the number of one-third octave bands from 100 Hz to 5 kHz. The calculated level $L_{AF,10}$ corresponds to the sound pressure level that would arise in a sparsely furnished reception room under otherwise equal conditions. The value ($L_{AF,10}$) represents the installation sound level L_{In} (or $L_{AFmax,n}$) in the test facility.

Time-dependent noise

In this case, the measurement signal consists of a series of one-third octave spectra (frequency range from 100 Hz through 5 kHz) which are consecutively measured at the same place with a time interval of 0.128 s. The evaluation is performed in the same way as in the case of stationary noise, with the exception that background noise correction is not performed. After evaluation the maximum value ($L_{AF,10,max}$) is determined from the measured time response.

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/m² (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/m², 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	Type	Manufacturer
Analyser	Soundbook_MK2_8L	Sinus Messtechnik
½"-microphone-Set	46 AF (Kapsel: Typ 40 AF-Free Field; Vorverstärker: Typ 26 TK)	G.R.A.S
1"-microphone	4179	Bruel & Kjær
1"-preamplifier	2660	Bruel & Kjær
Microphone-calibrator	4231	Bruel & Kjær
Accelerometer	4371 und 4370	
Conditioning amplifier	Nexus 2692-A-0I4	Bruel & Kjær
Accelerometer-calibrator	VC11	MMF
Amplifier	LBB 1935/20	Bosch Plena
Loudspeaker	MLS 82	Lanny
Reference sound source	382	Rox
Standard tapping machine	211	Norsonic

All measurement devices are tested frequently by internal and external testing laboratories and, if possible and necessary, are calibrated and gauged.

Assessment of increased noise protection according to VDI 4100

The directive VDI 4100 contains suggestions for increased sound insulation in apartments. These suggestions outreach the minimum requirements of DIN 4109, and in addition, can be agreed by the client and the responsible company.

The measurement of noise of sanitary installations is equally carried out in accordance with VDI 4100 and DIN 4109. Details of the method and the evaluation of the results are described in Annex F. The only difference between the two standards is that the measured sound levels in DIN 4109 are related to the equivalent sound absorption area of $A_0 = 10\ m^2$, whereas in VDI 4100 the reverberation time of $T_0 = 0.5$ s is used as a reference value. The relation between the two sound levels is as follows:

$$L_{AF,nT} = L_{AF,n} - 10\ lg(V) + 15$$

with $L_{AF,nT}$ = standardized sound level of noise of sanitary installations according to VDI 4100 [dB(A)]
$L_{AF,n}$ = normalized sound level of noise of sanitary installations according to DIN 4109 [dB(A)]
V = volume of the receiving room [m^3]

The indices A and F describe the frequency weighting "A" and the time weighting "Fast". Depending on whether a time-averaged value or a maximum level is measured, the index "eq" or "max" is added to theses indices. This equally applies for the standardized and normalized sound level, for example $L_{AFeq,nT}$ or $L_{AFmax,n}$.

The standardized sound level according to VDI 4100 and the normalized sound level according to DIN 4109 differ in a constant value which is only dependent on the volume of the receiving room. Whereas the normalized sound level (DIN 4109) is independent of the room volume, the standardized sound level (VDI 4100) is reduced by an increasing room volume. Since the requirements of sound insulation of VDI 4100 are related to the standardized sound level, the values measured in the test facilities of noise of sanitary installations of the IBP must be converted to the volume of the in-situ rooms in need of protection as verification of the requirements. Conversion is carried out according to the following relation:

$$L_{AF,nT,Building} = L_{AF,nT,Lab} + 10\ lg(V_{Lab}/V_{Building})$$

with $L_{AF,nT,Building}$ = standardized sound level of the tested installation at the building
$L_{AF,nT,Lab}$ = standardized sound level of the tested installation in the test facility
V_{Lab} = volume of the receiving room in the test facility
$V_{Building}$ = volume of the room in the building in need of protection

The volumes of the three receiving rooms in the sanitary installation noise test facility of the IBP and diagrams of the previous calculation formula for direct reading of the results can be found in the following:

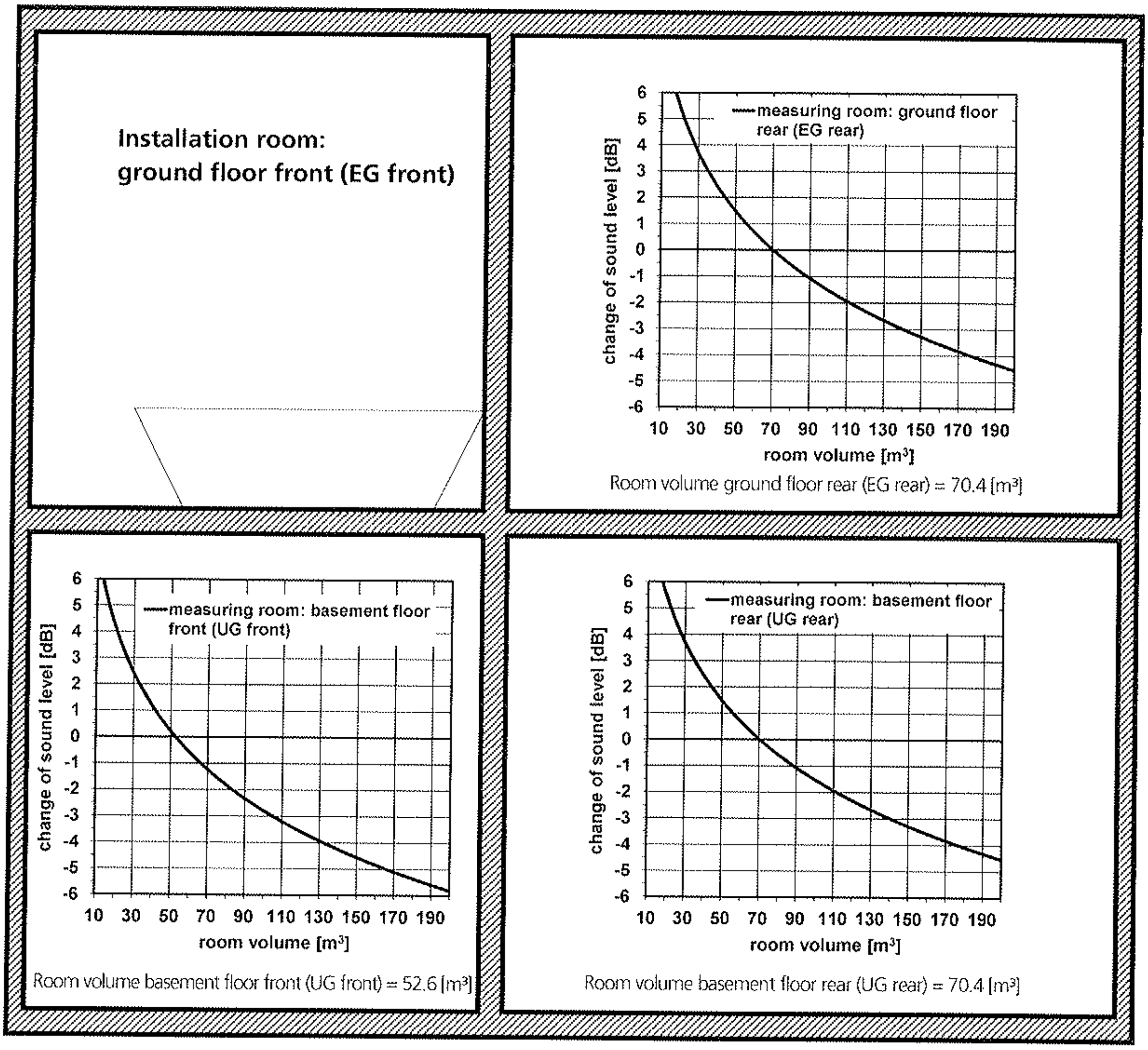


Fig. 1: Modification of the standardized sound level measured in the installation test facility P12 for rooms with deviating volume. The resulting change of sound level in comparison to the measured value indicated in the test report in dependence of the new room volume is specified in the diagrams for the three measuring rooms basement floor front (UG front), basement floor rear (UG rear), and ground floor rear (EG rear). If the volumes of the new room comply with the respective measuring room, the sound level will remain unchanged (modification of level $\Delta L = 0$ dB). If the new room is larger than the respective measuring room, the sound level will be reduced ($\Delta L < 0$). If it is smaller, the sound level will increase ($\Delta L > 0$).

Requirements

According to VDI 4100 all rooms in an apartment with a ground area ≥ 8 m² are considered as rooms in need of protection. Kitchens, bathrooms, WCs, halls and side rooms, however, are explicitly exempted from building installation noise and from impact sound. For common floor plan configuration (bathroom above bathroom) normally the room in the basement floor rear (UG rear) is for the values measured in the test facility the one to be primarily considered as room in need of protection.

The required values are divided according to the sound insulation levels (SSt) in VDI 4100 complying with various comfort levels:

Table 1: Comfort level and acoustic situation for the sound insulation levels I to III according to VDI 4100.

SSt I	„raised in the design and construction compared to a simple one regarding design and construction features"
	„unreasonable annoyance are in general avoided "
SSt II	„average requirements of comfort"
	„in general not disturbing"
SSt III	„special comfort requirements"
	„not or only seldom disturbing"

Different requirements are indicated respectively for the three sound protection levels in VDI 4100. Since sound insulation level III represents the highest comfort level the strictest requirements must be applied, i.e. sound levels allowable for noise of sanitary installations are lowest in this case. The required values for apartment houses or one-family terrace houses and one-family semi-detached houses are represented in the following table:

Table 2: The requirements of sound insulation of building service equipment in for apartment houses or one-family terrace houses and one-family semi-detached houses according to VDI 4100 for sound protection levels I to III. The requirements apply for sound transmission between separated apartments. Noise from water supply installations and sewage systems are considered together.

Building	**Acoustic parameter [dB(A)]**	**Sound protection level I**	**Sound protection level II**	**Sound protection level III**
Apartment houses	$\overline{L_{AFmax,nT}}$ or $\overline{L_{AFeq,nT}}$ a) b)	**≤ 30**	**≤ 27**	**≤ 24**
One-family terrace houses and one-family semi-detached houses	$\overline{L_{AFmax,nT}}$ or $\overline{L_{AFeq,nT}}$ a) b)	**≤ 30**	**≤ 25**	**≤ 22**

a) Individual short-term noise peaks during actuation (opening, closing, adjusting, interrupting, etc.) the fittings and equipment of the plumbing system should not exceed the characteristic values of SSt II and SSt III by more than 10 dB. Here, the intended use is required

b) Since noise of sanitary installations are frequently temporary changing signals, VDI 4100 provides for the measurement the maximum level $\overline{L_{AFmax,nT}}$. For stationary signals such as impact noise from water jets, however, it is more efficient to determine the average noise level $\overline{L_{AFeq,nT}}$ instead, since only in this way it is possible to observe the requirements for reproducibility and accuracy obligatory for measurements in the test facility. The measured average noise level is generally slightly lower than the maximum level, however, the difference is not more than a maximum of 2 to 3 dB according to extensive experience.

Besides the previously described requirements for sound transmission between separate apartments, VDI 4100 also contains recommendations for sound protection in one's own living space. The effective required values and the importance of the respective sound protection levels can be found in VDI 4100.

Note to handle noise emitted by users in VDI 4100:

For user noises, which often result in complaints (e.g. putting down a toothbrush tumbler on a storage board, opening and closing the toilet cover, use of toilets, sliding in the bath tub, striking the doors – also of wall cabinets and built-in cabinets, etc.) neither to the noise control classes SSt II and SSt III no characteristic values were specified, since these noises are very difficult to reproduce and depend on the specific building situation. It is assumed, however, that these noises – by intended use – are reduced as much as possible by application of conventional arrangements for the impact sound insulation when mounting the sanitary equipment.