ZERTIFIKAT ◆ CERTIFICATE ◆ 認證證書 ◆ СЕРТИФИКАТ ◆ CERTIFICADO ◆ CERTIFICAT

Management Service

# СЕРТИФИКАТ

**Сертифициращият орган**
**TÜV SÜD Management Service GmbH**

**удостоверява, че**

PEŠTAN

**PEŠTAN d.o.o.**
**ул. 1300 капрала № 189**
**34301 Аранджеловац**
**Сърбия**

**в областта:**

**Развитие, подготовка на суровини за производство на PE и PVC свързващи елементи, PE, PP и PVC тръби и фитинги, отоци и шахти, градински мебели от пластмаса, пластмасови съдове, PVC профили, PVC и алуминиеви прозорци и врати**

**е въвел и прилага системата за управление на качеството.**

**След проведен надзорен одит е изготвен доклад № 70077767, който удостоверява, че са изпълнени условията на стандарт**

**ISO 9001:2015.**

**Този сертификат е валиден от 17.02.2020 до 16.02.2023 година.**
**Регистрационен номер на сертификата: 12 100 59527 TMS.**

Product Compliance Management
Minhen, 2020-02-18

IAF DAkkS Deutsche Akkreditierungsstelle D-ZM-14143-01-00

ZERTIFIKAT ◆ CERTIFICATE ◆ 認證證書 ◆ СЕРТИФИКАТ ◆ CERTIFICADO ◆ CERTIFICAT

TÜV SÜD Management Service

# CERTIFICATE

**The Certification Body**
**of TÜV SÜD Management Service GmbH**

certifies that

PEŠTAN

**PEŠTAN d.o.o.**
**1300 kaplara 189**
**34301 Aranđelovac**
**Serbia**

has established and applies
a Quality Management System for

**Design, preparation of raw materials for production, and manufacturing of PE and PVC fittings, PE, PP and PVC pipes and fittings, sinks and tubs, garden furniture made of plastic, plastic vessels, PVC profiles, PVC and aluminum windows and doors.**

An audit was performed, Order No. **70077767**.

Proof has been furnished that the requirements according to

## ISO 9001:2015

are fulfilled.

The certificate is valid from **2020-02-17** until **2023-02-16**.

Certificate Registration No.: **12 100 59527 TMS**.

Product Compliance Management
Munich, 2020-02-18

IAF · DAkkS Deutsche Akkreditierungsstelle D-ZM-14143-01-00



TÜV®

MS/01.01/2019

ZERTIFIKAT ◆ CERTIFICATE ◆ 認證證書 ◆ СЕРТИФИКАТ ◆ CERTIFICADO ◆ CERTIFICAT

# СЕРТИФИКАТ

**Сертифициращият орган**
**TÜV SÜD Management Service GmbH**

**удостоверява, че**

**PEŠTAN d.o.o.**
**ул. 1300 капрала № 189**
**34301 Аранджеловац**
**Сърбия**

**в областта:**

**Развитие, подготовка на суровини за производство на PE и PVC свързващи елементи, PE, PP и PVC тръби и фитинги, отоци и шахти, градински мебели от пластмаса, пластмасови съдове, PVC профили, PVC и алуминиеви прозорци и врати**

**е въвел и прилага системата за управление на опазване на околната среда.**

**След проведен надзорен одит е изготвен доклад № 70077767, който удостоверява, че са изпълнени условията на стандарт**

## ISO 14001:2015

**Този сертификат е валиден от 17.02.2020 до 16.02.2023 година.**
**Регистрационен номер на сертификата: 12 104 59527 TMS.**

Product Compliance Management
Munich, 2020-02-18

Management Service

# CERTIFICATE

The Certification Body
of TÜV SÜD Management Service GmbH

certifies that

**PEŠTAN**

**PEŠTAN d.o.o.**
**1300 kaplara 189**
**34301 Aranđelovac**
**Serbia**

has established and applies
an Environmental Management System for

**Design, preparation of raw materials for production, and manufacturing of PE and PVC fittings, PE, PP and PVC pipes and fittings, sinks and tubs, garden furniture made of plastic, plastic vessels, PVC profiles, PVC and aluminum windows and doors.**

An audit was performed, Order No. **70077767**.

Proof has been furnished that the requirements according to

## ISO 14001:2015

are fulfilled.

The certificate is valid from **2020-02-17** until **2023-02-16**.

Certificate Registration No.: **12 104 59527 TMS**.

Product Compliance Management
Munich, 2020-02-18

IAF DAkkS Deutsche Akkreditierungsstelle D-ZM-14143-01-00

BUREAU VERITAS
Certification

# СЕРТИФИКАТ

## PEŠTAN d.o.o.

**ул. 1300 капрала № 189, 34301 Аранджеловац, Сърбия**

**Бюро Веритас удостоверява, че системата за управление на горепосочената организация е оценена и е установено нейното съответствие с изискванията на стандарта за управление, посочен по-долу:**

**Стандарт**

## ISO/IEC 27001:2013

**обхват на сертификация**

**Системата за управление сигурността на информацията, приложена за:**

**РАЗВИТИЕ, ПРОИЗВОДСТВО И ПРОДАЖБИ НА PVC И PE СВЪРЗВАЩИ ЕЛЕМЕНТИ, PVC И PE ТРЪБИ, PP ТРЪБИ И ФИТИНГИ, ОТОЦИ И ШАХТИ, ГРАДИНСКИ МЕБЕЛИ ОТ ПЛАСТМАСА, ПЛАСТМАСОВИ СЪДОВЕ, PVC И АЛУМИНИЕВИ ПРОЗОРЦИ И ВРАТИ, PVC ПРОФИЛИ И МИКРОНИЗИРАНЕ НА КАЛЦИЕВ КАРБОНАТ, КАКТО Е УКАЗАНО В ДЕКЛАРАЦИЯТА ЗА СЪОТВЕТСТВИЕ ВЕРСИЯ 2.1 PE P-440-01/02.06, ОКТОМВРИ 2018 ГОДИНА.**

**Първоначална дата на сертификация: 15 юли 2019 година**
**Начало на сертификационен цикъл: 15 юли 2019 година**
**Край на сертификационен цикъл: 14 юли 2022 година**

**При постоянно поддържане на системата за управление, този сертификат е валиден до: 14 юли 2022 година**

**За валидността на този сертификат, моля обадете се на номер: + 420 210 088 215.**

Version 1, Revision Date: 15th July 2019

Certificate Number: CZE-190063

S 3100

BUREAU VERITAS
Certification

# Certificate

Awarded to

## PEŠTAN d.o.o.

1300 kaplara 189, 34301 Arandjelovac, Serbia

Bureau Veritas certifies that the Information Security Management System of the above organisation has been audited and found to be in accordance with the requirements of the management system standard detailed below:

Standard

## ISO/IEC 27001:2013

Scope of supply

THE MANAGEMENT OF INFORMATION SECURITY MANAGEMENT SYSTEM (ISMS) TO PROVIDE IT SUPPORT FOR THE DESIGN ; MANUFACTURING AND SALES OF PVC AND PE FITTINGS, PVC AND PE PIPES, PP PIPES AND FITTINGS, DRAINS AND MANHOLES, PLASTIC VESSELS AND GARDEN SEATS (PLASTIC SEATS), PLASTIC WASTE CONTAINERS, PVC AND ALUMINIUM WINDOWS AND DOORS, PVC PROFILES AND MICRONISATION OF CALCIUM CARBONATE AS STATED IN STATEMENT OF APPLICABILITY VERSION 2.1 PE P-440-01/02.06, OCTOBER 2018.

Original Approval Date: 15th July 2019

Certification Cycle Start Date: 15th July 2019

Certification Cycle End Date: 14th July 2022

Subject to the continued satisfactory operation of the organisation's Management System, this certificate is valid until: 14th July 2022

To check this certificate validity please call: +420 210 088 215

Further clarifications regarding the scope of this certificate and the applicability of the Information Security management system requirements may be obtained by consulting the organisation.

Version 1, Revision Date: 15th July 2019

Certificate Number: CZE-190063

S 3100

MANAGING OFFICE: BUREAU VERITAS CZECH REPUBLIC, spol. s r.o., Olbrachtova 1, 140 02 Praha 4, Czech Republic

ISSUING OFFICE ADDRESS: BUREAU VERITAS CZECH REPUBLIC, spol. s r.o., Olbrachtova 1, 140 02 Praha 4, Czech Republic

TÜV SÜD
Management Service

# СЕРТИФИКАТ

**Сертифициращият орган**
**TÜV SÜD Management Service GmbH**

**удостоверява, че**

PEŠTAN

**PEŠTAN d.o.o.**
**ул. 1300 каптала № 189**
**34301 Аранджеловац**
**Сърбия**

**в областта:**

**Развитие, подготовка на суровини за производство на PE и PVC свързващи елементи, PE, PP и PVC тръби и фитинги, отоци и шахти, градински мебели от пластмаса, пластмасови съдове, PVC профили, PVC и алуминиеви прозорци и врати**

**е въвел и прилага системата за управление на системи за здравето и безопасността при работа.**

**След проведен надзорен одит е изготвен доклад № 70077767, който удостоверява, че са изпълнени условията на стандарт**

**ISO 45001:2018**

**Този сертификат е валиден от 17.02.2020 до 16.02.2023 година.**
**Регистрационен номер на сертификата: 12 117 59528 TMS.**

Product Compliance Management
Munich, 2020-02-18

DAkkS
Deutsche Akkreditierungsstelle
D-ZM-14143-01-00

ZERTIFIKAT ◆ CERTIFICATE ◆ 認證證書 ◆ СЕРТИФИКАТ ◆ CERTIFICADO ◆ CERTIFICAT

ZERTIFIKAT ◆ CERTIFICATE ◆ 認證證書 ◆ СЕРТИФИКАТ ◆ CERTIFICADO ◆ CERTIFICAT

TÜV SÜD
Management Service

# CERTIFICATE

**The Certification Body**
**of TÜV SÜD Management Service GmbH**

certifies that

PEŠTAN

**PEŠTAN d.o.o.**
**1300 kaplara 189**
**34301 Aranđelovac**
**Serbia**

has established and applies
an Occupational Health and Safety Management System for

**Design, preparation of raw materials for production, and manufacturing of PE and PVC fittings, PE, PP and PVC pipes and fittings, sinks and tubs, garden furniture made of plastic, plastic vessels, PVC profiles, PVC and aluminum windows and doors.**

An audit was performed, Order No. **70077767**.

Proof has been furnished that the requirements according to

## ISO 45001:2018

are fulfilled.

The certificate is valid from **2020-02-17** until **2023-02-16**.

Certificate Registration No.: **12 117 59528 TMS**.

Product Compliance Management
Munich, 2020-02-18

DAkkS
Deutsche
Akkreditierungsstelle
D-ZM-14143-01-00

Privredno društvo Peštan d.o.o.
Br. 2152
07 APR 2017 god.
BUKOVIK ARANĐELOVAC

**AUTHORIZED BODY No. 224**
**Institute for Testing and Certification, Inc., T. Bati 299, Louky, 763 02 Zlín, Czech Republic**
*Authorization granted by the Decision No. 2/2014 dated 10th March 2014*

# PRODUCT CERTIFICATE

## No. 17 0134 V/AO

In compliance with the provision of Section 5a, Subsection 2 of the Government Order No. 163/2002, Collection of Laws, as amended by the Government Order No. 312/2005, Collection of Laws and Government Order No. 215/2016, Collection of Laws, which lays down technical requirements for selected building products, the Authorized Body No. 224 confirms that for the construction product

**PPC/PPM/PPC pipes and PPMD fittings for soil and waste discharge systems (low and high temperature) within the building structure, type S LINE, DN 32 – DN 160, application area code „B"**

placed on the market by the manufacturer
**PEŠTAN d.o.o.**
**1300 Kaplara 189, 34301 Bukovik, Serbia**

from production site
**PEŠTAN d.o.o.**
**1300 Kaplara 189, 34301 Bukovik, Serbia**

it has reviewed the documents submitted by the applicant, carried out the initial type testing on a sample and assessed the factory production control. The Authorized Body No. 224 ascertained conformity of the product properties with essential requirements of the GO 163, which are specified by the following technical standard **ČSN EN 1451-1.**
Further, the Authorized Body No. 224 ascertained that the factory production control complies with the submit-ted technical documentation and ensures that the products placed on the market fulfil the requirements laid down by the above mentioned Standard and by the technical documentation pursuant to Section 4, Subsection 3 of the GO 163.
A part of the present Certificate is the Final Report No. **793501520/2017** dated 2017-03-23 containing conclusions of the assessment, the test results obtained and basic description of the product, as necessary for its identification.
*This Certificate remains valid as long as the requirements laid down in the technical documentation and/or Construction Technical Approval in reference or the manufacturing conditions in the factory or the method of checks on the products are not modified significantly.*
*The Authorized Body No. 224 performs at least once per year a surveillance of the factory production control in the production site with the requirements of the norms according to the Section 5a, of the mentioned Government Order. If the Authorized Body finds any shortcomings it has the right to cancel or amend the Certificate it has issued.*

AUTORIZOVANÁ OSOBA 224 — ITC — INSTITUT PRO TESTOVÁNÍ A CERTIFIKACI, a.s. — 3

Issued in Zlín on **2017-03-23**

RNDr. Radomír Čevelík
Representative of the Authorized Body No. 224

**Audit Service Company**

## United Registrar of Systems – South d.o.o.

Jug Bogdanova 49b
18000 Niš
PIB 109 752 542
M. br. 212 360 80

www.urs-south.rs
office@urs-south.rs
018 350 41 02

# Certification Confirmation

To whome it may concern,

This is to certify that organization:

**PEŠTAN d.o.o.**
**1300 kaplara 189**
**RS – 34301 Aranđelovac**

has successfully completed certification audit according to standard ISO 50001:2011.
Certificate will be issued by certification body URS - South Ltd.
After successfully completed certification, certificates are will be issued with a validity of three years, with the obligation of successful annual surveillance audits.

Client no: 008500
DAkkS no: 861

Date:
10.02.2020.

Approved by:

Nemanja Stojanović
director

**Audit Service Company**

## United Registrar of Systems – South d.o.o.

Jug Bogdanova 49b
18000 Niš
PIB 109 752 542
M. br. 212 360 80

www.urs-south.rs
office@urs-south.rs
018 350 41 02

# Потвърждение за сертифициране

**До всички заинтересовани,**

**С настоящото удостоверяваме, че организацията:**

**PEŠTAN d.o.o.**
**ул. 1300 каплара 189**
**RS – 34301 Аранджеловац**

**проведе успешен одит за сертифициране съгласно стандарт ISO 50001:2011.**
**Сертификатът ще бъде издаден от сертифициращия орган Ю АР ЕС – Саут Лтд.**
**След успешно извършено сертифициране, сертификатите ще се издават със**
**срок на валидност от три години, при задължение за успешни ежегодни контролни одити.**

**Клиент №: 008500**
DAkkS no: 861

**Дата:**
10.02.2020.

**Одобрен от:**

Nemanja Stojanović
director

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
Prof. Dr. Klaus Peter Sedlbauer

## Test Report P-BA 94/2016e

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

**Client:** Pestan D.O.O.
1300 Kaplara 189
Bukovik, 34300 Arandelovac
Serbia

**Test object:** Wastewater installation system consisting of plastic pipes and fittings "S Line" (manufacturer: Pestan) with pipe clamps "Bismat 2000" made by Walraven.

**Content:**

| | |
|---|---|
| Results sheet 1: | Summary of test results |
| Figures 1 to 3: | Detailed results |
| Figures 4 and 5: | Test set-up |
| Annex A: | Measurement set-up, noise excitation, acoustic parameters |
| Annex F: | Evaluation of measurements |
| Annex P: | Description of the test facility |
| Annex V: | Assessment according to VDI 4100 |

**Test date:** The measurement was carried out on April 22, 2016 in the test facilities of the Fraunhofer Institute for Building Physics in Stuttgart.

Stuttgart, May 9, 2016

Responsible Test Engineer: Head of Laboratory:

M.Sc. B. Kaltbeitzel 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.

| **Determination of the Installation Sound Level $L_{In}$ in the Laboratory** | **P-BA 94/2016e**<br>**Results sheet 1** |
|---|---|

**Client:** Pestan D.O.O., 1300 Kaplara 189, Bukovik, 34300 Arandelovac, Serbia

**Test specimen:** Wastewater installation system consisting of plastic pipes and fittings "S Line" (manufacturer: Pestan) with pipe clamps "Bismat 2000" made by Walraven. (test object no.: 10943-2; 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 (87.5°), two 45°-basement bends and a horizontal drain section. The inlet tees in the basement and in the ground floor were closed by lids.

  - Pipe system: three layer pipes "S Line", material PPC/PPM/PPC, size OD 110, wall thickness 3.4 mm (measured: 3.7 mm), weight 1.6 kg/m, density 1.3 g/cm³. single layer fittings, material PP, size OD 110, wall thickness 3.7 mm, density 1.4 g/cm³. Plug connection of the pipes and fittings.

  - Pipe clamps "Bismat 2000": Steel clamp with elastomer inlay and with a clamping range of 108 – 114 mm. The clamps were closed with 3 Nm (clamps were completely closed, see figure 5). In each storey (EG and UG) one clamp was installed at the lower wall area and one at the upper wall area. The Bismat 2000 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 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:**

| "S Line" (manufacturer: Pestan) with pipe clamps "Bismat 2000" 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 | 54 |
| | **UG rear** | 21 | 24 | 27 | 30 |
| Installation sound level $\overline{L_{AFeq,nT}}$ ($L_{In}$) [dB(A)] **according to VDI 4100** measured in the basement test-room | **UG front** | 41 | 45 | 48 | 51 |
| | **UG rear** | 17 | 21 | 23 | 26 |
| Airborne sound pressure level $L_{a,A}$ [dB(A)] **according to EN 14366** in the basement test-room **UG front** | | 44 | 47 | 50 | 54 |
| Structure-borne sound characteristic level $L_{sc,A}$ [dB(A)] **according to EN 14366** in the basement test-room **UG rear** | | 19 | 22 | 25 | 28 |

**Test date:** April 22, 2016

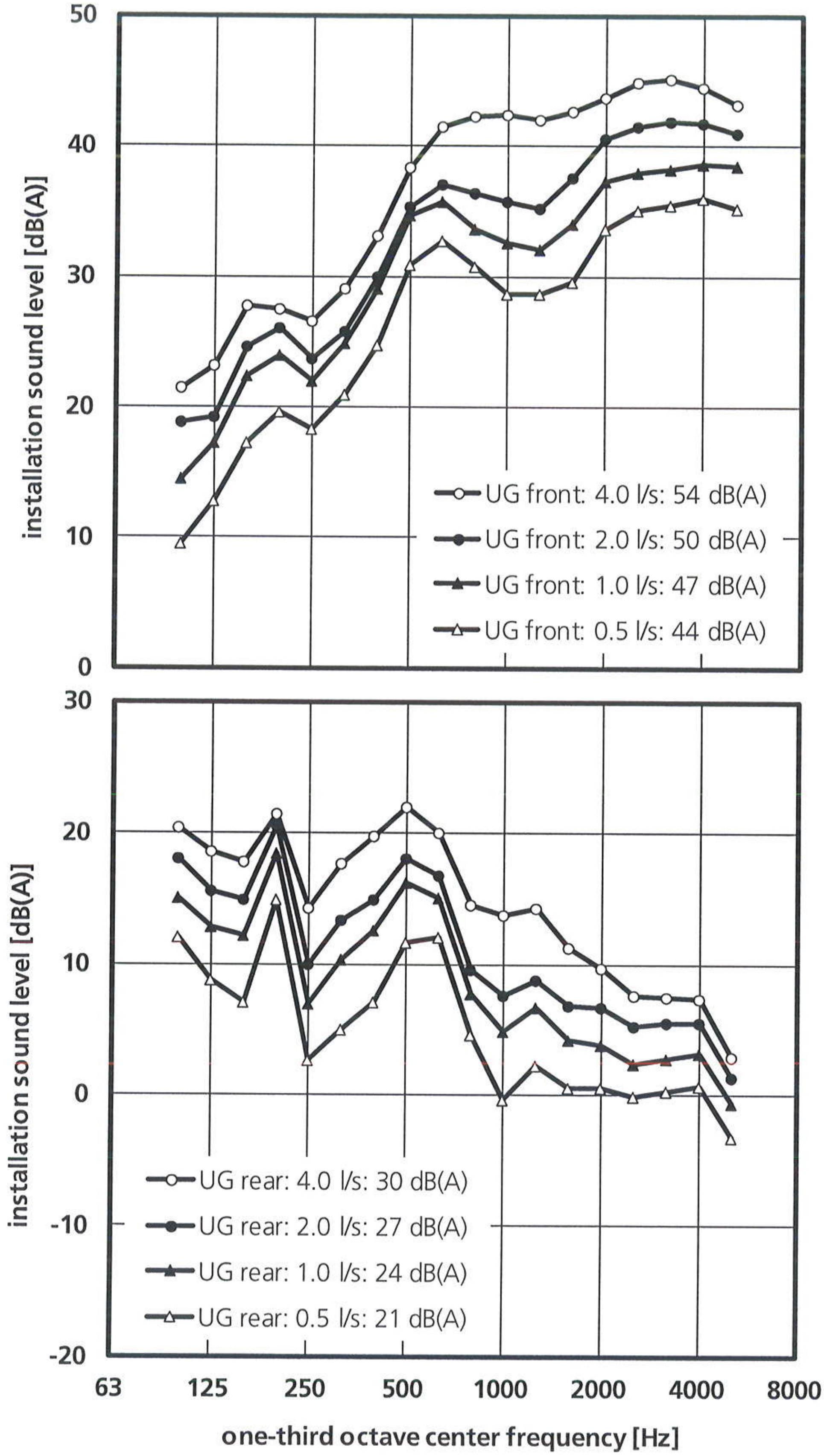
**Notes:** - The requirements of DIN 4109 and VDI 4100 only apply for the test room UG rear.

Fraunhofer-Gesellschaft zur Förderung der angewandten Forschung e.V. Fraunhofer IBP 1

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.

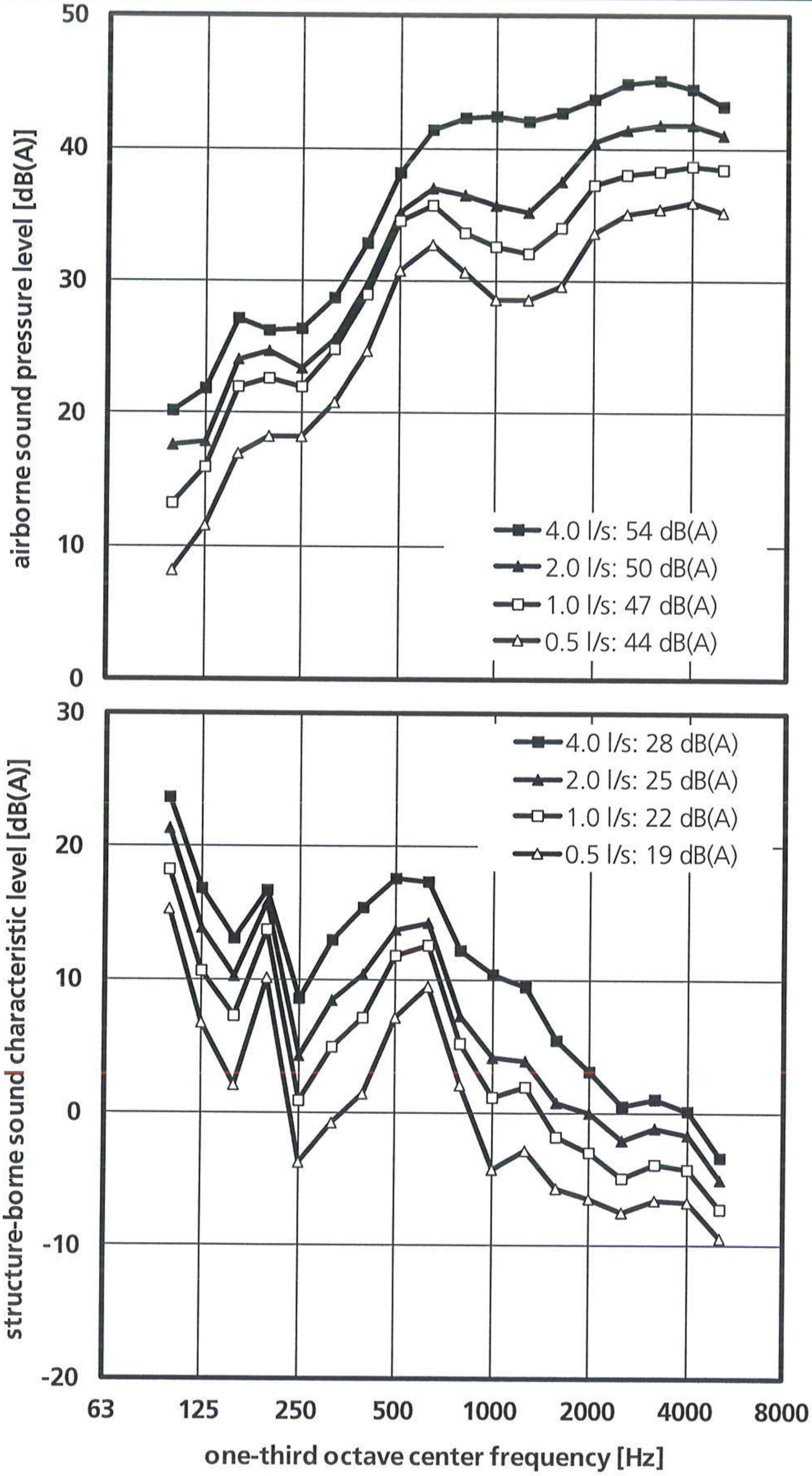
Stuttgart, May 9, 2016
Head of Laboratory:




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 to 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 "S Line" (manufacturer: Pestan) with pipe clamps "Bismat 2000" made by Walraven.

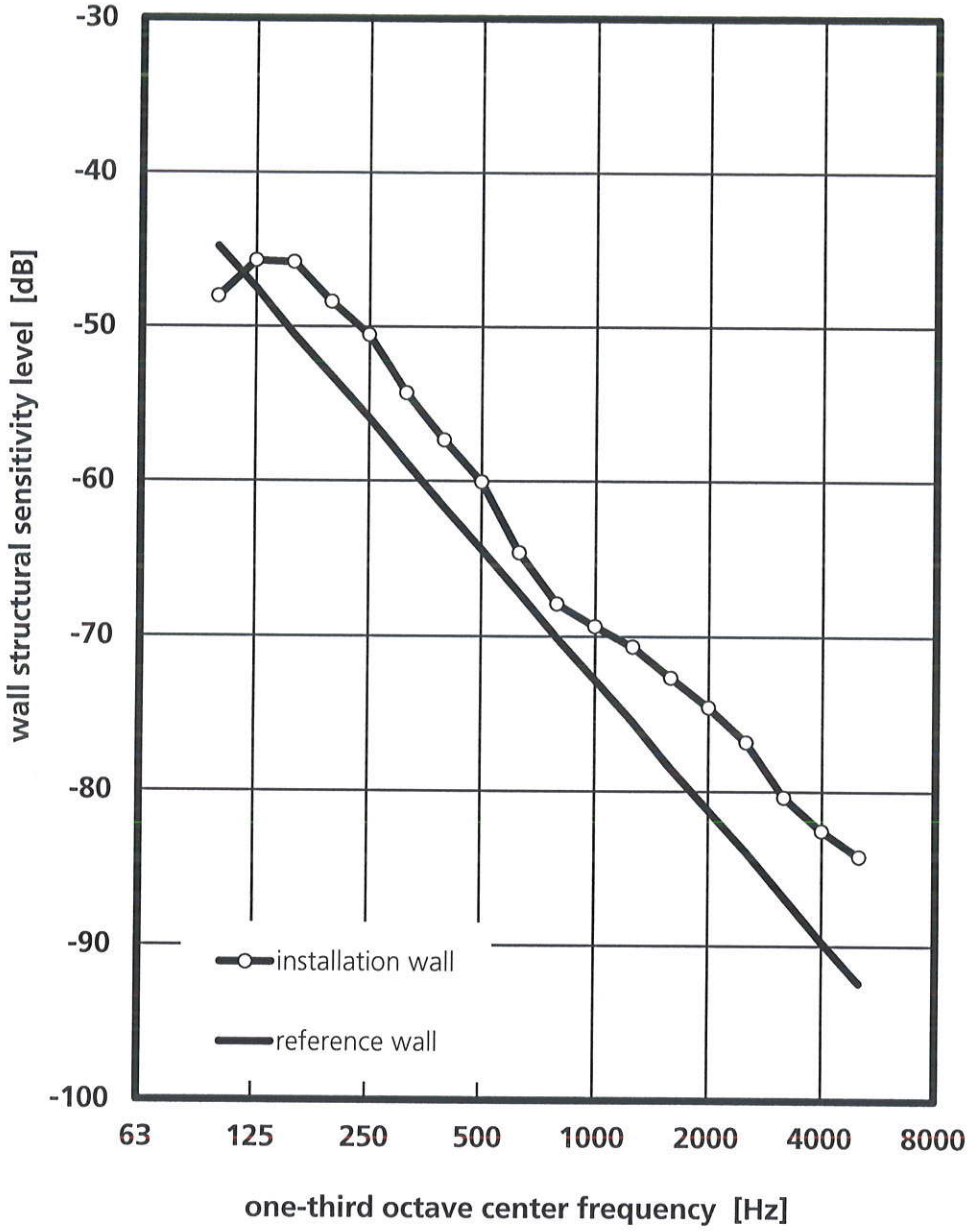
| **Detailed results** | **P-BA 94/2016e** |
|---|---|
| Client: Pestan D.O.O., 1300 Kaplara 189, Bukovik, 34300 Arandelovac, Serbia | **figure 2** |




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**.

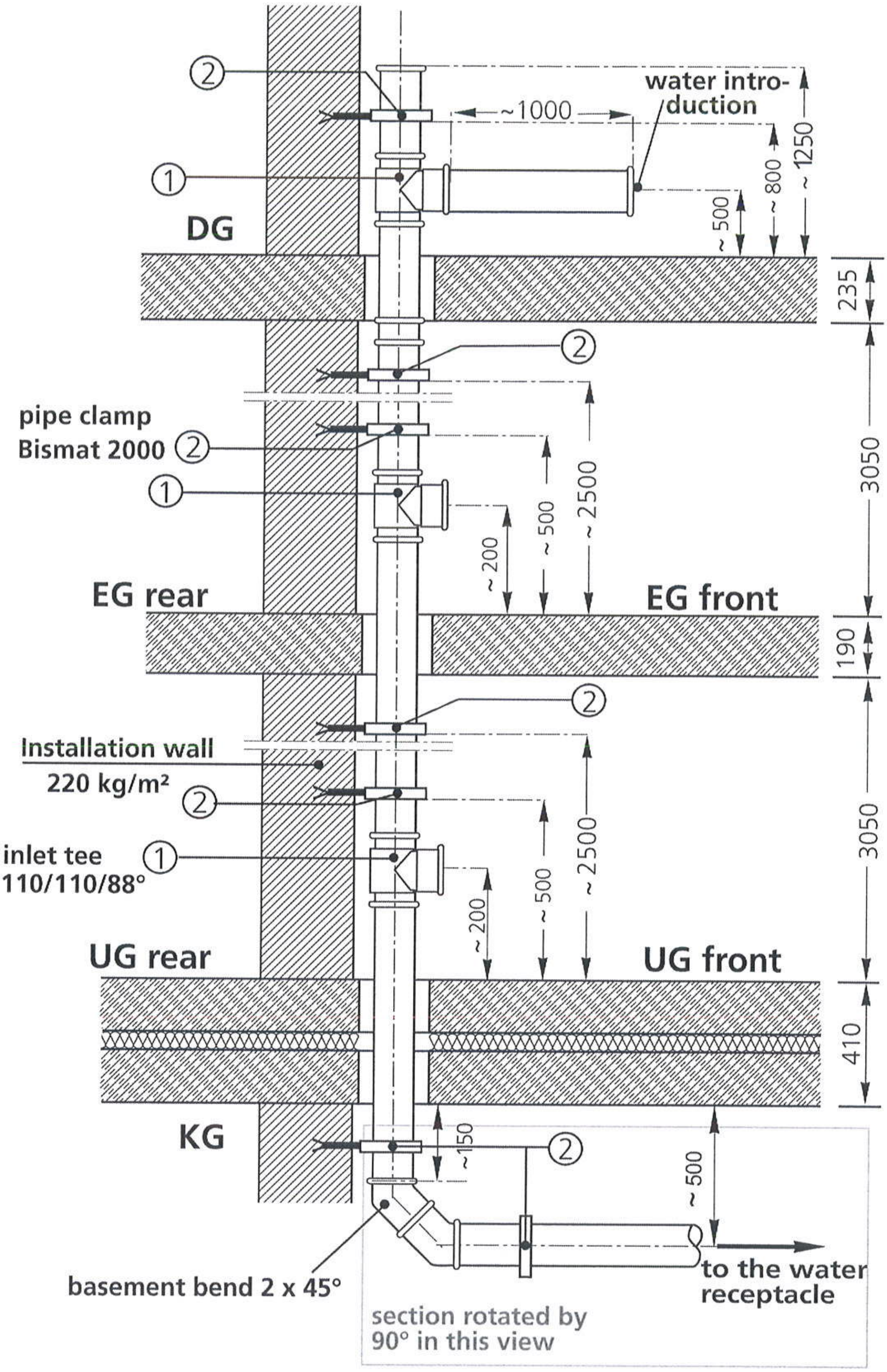
Test specimen: Wastewater installation system consisting of plastic pipes and fittings "S Line" (manufacturer: Pestan) with pipe clamps "Bismat 2000" made by Walraven.

| **Detailed results** | **P-BA 94/2016e** |
|---|---|
| Client: Pestan D.O.O., 1300 Kaplara 189, Bukovik, 34300 Arandelovac, Serbia | **figure 3** |



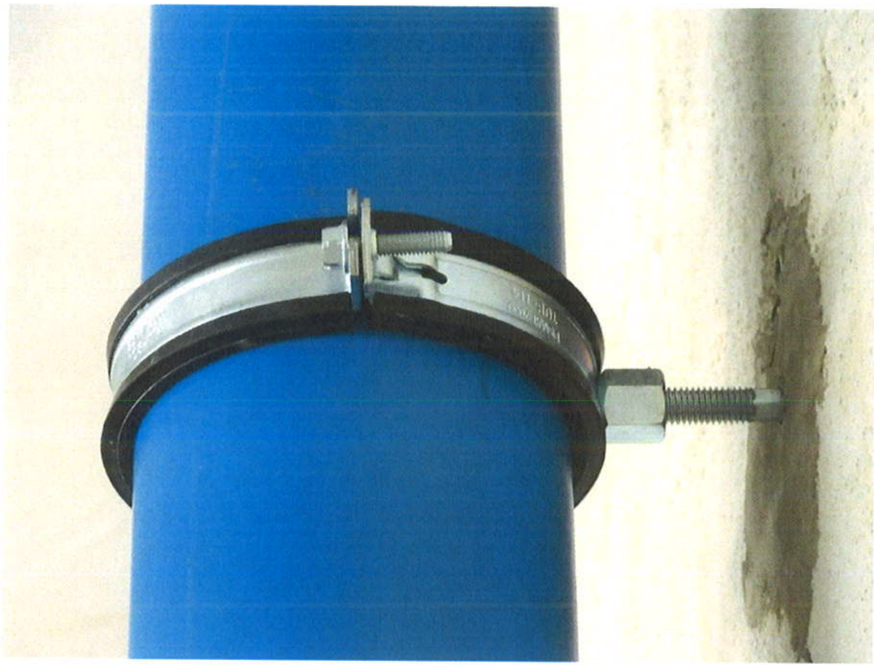

Wall structural sensitivity level $L_{SS}$ of the installation wall between the test rooms UG front and UG rear in the installation test facility in the Fraunhofer-Institute of Building Physics. The installation wall consists of calcium silicate blocks (thickness 115 mm, ceiled on both sides) with a 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 "S Line" (manufacturer: Pestan) with pipe clamps "Bismat 2000" made by Walraven.




Installation plan of the test set-up in the test facility. (Drawing not to scale, dimensions in mm)

<u>Test specimen</u>: Wastewater installation system consisting of plastic pipes and fittings "S Line" (manufacturer: Pestan) with pipe clamps "Bismat 2000" made by Walraven.



Upper picture: Pipe clamp "Bismat 2000" at the upper wall area.

Lower picture: Inlet tee at the bottom and one pipe clamp "Bismat 2000" at the lower wall area.

Test specimen: Wastewater installation system consisting of plastic pipes and fittings "S Line" (manufacturer: Pestan) with pipe clamps "Bismat 2000" 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 m² 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.

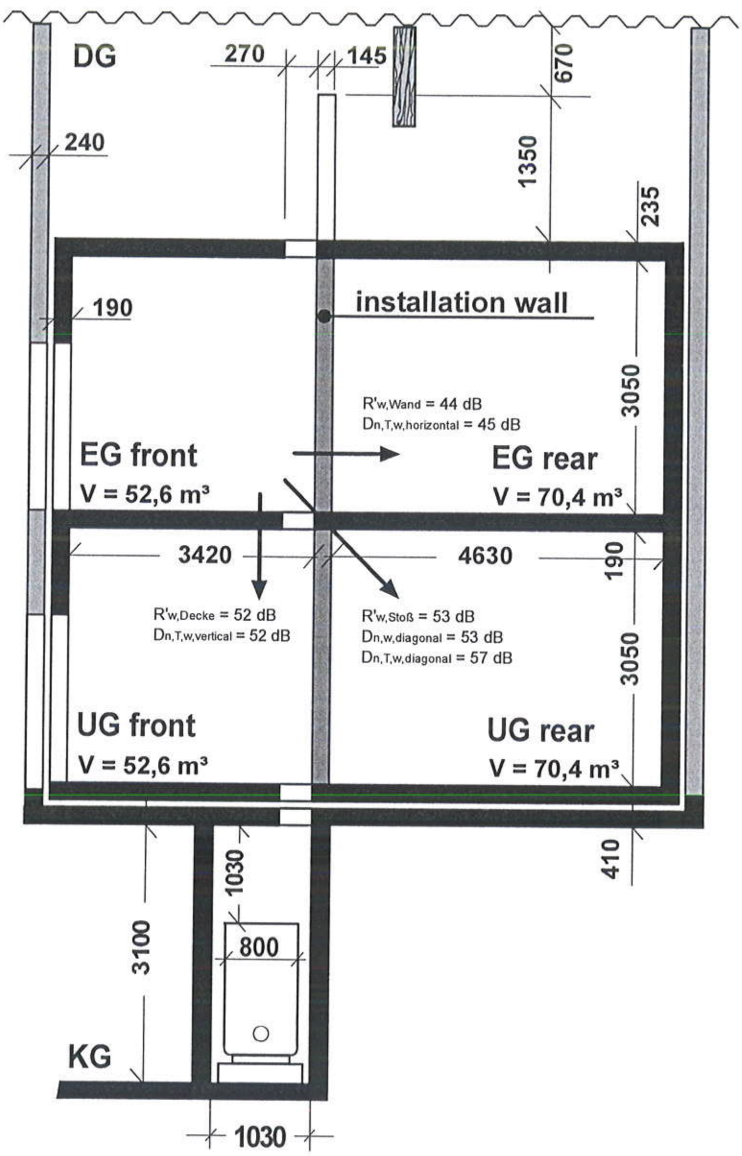
(2) $$L_{AF,10} = 10 \cdot \lg\left(\sum_{n=1}^{18} 10^{\frac{L_{n,AF,10}}{10}}\right),$$ [dB(A)]

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 0.125 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-Set | 40HF (Kapsel: Typ 40EH-LowNoise; Vorverstärker: Typ 26HF; Power Module: Typ 12HF) | 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 m², 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 [m³]

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:

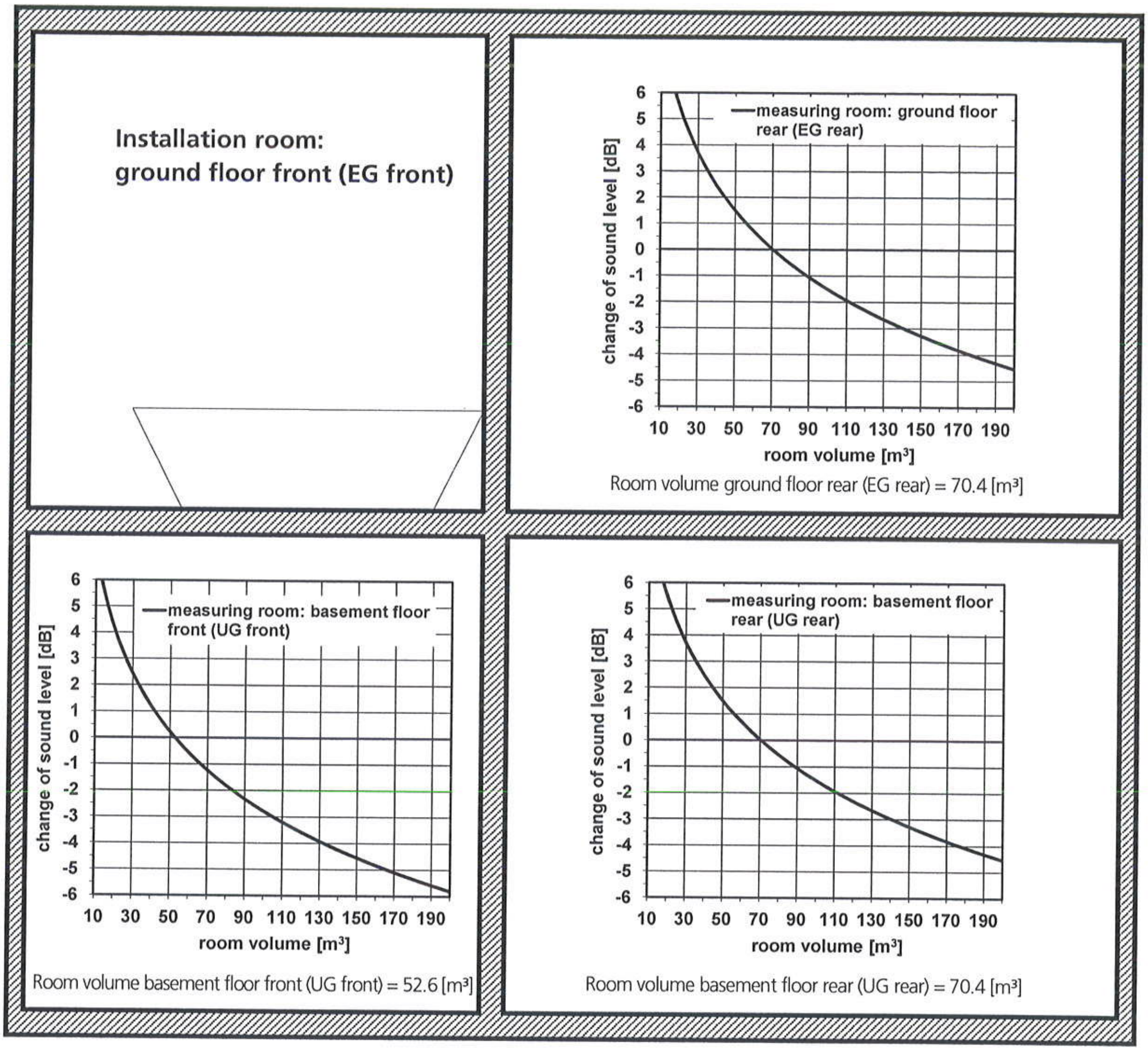



**Fig. 1:** Modification of the standardized sound level measured in the installation test facility P12 for rooms with deviating volume. The resulting change of sound level in comparison to the measured value indicated in the test report in dependence of the new room volume is specified in the diagrams 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.

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
Prof. Dr. Klaus Peter Sedlbauer

## Test Report P-BA 213/2016e

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

**Client:** Pestan D.O.O.
1300 Kaplara 189
Bukovik, 34300 Arandelovac
Serbia

**Test object:** Wastewater installation system consisting of plastic pipes and fittings "S Line" (manufacturer: Pestan) with pipe clamps "Bismat 1000" made by Walraven.

**Content:**

| | |
|---|---|
| Results sheet 1: | Summary of test results |
| Figures 1 to 3: | Detailed results |
| Figures 4 and 5: | Test set-up |
| Annex A: | Measurement set-up, noise excitation, acoustic parameters |
| Annex F: | Evaluation of measurements |
| Annex P: | Description of the test facility |
| Annex V: | Assessment according to VDI 4100 |

**Test date:** The measurement was carried out on September 30, 2016 in the test facilities of the Fraunhofer Institute for Building Physics in Stuttgart.

Stuttgart, October 12, 2016

Responsible Test Engineer: M.Sc. B. Kaltbeitzel

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

Fraunhofer-Gesellschaft zur Förderung der angewandten Forschung e.V. Fraunhofer IBP 1

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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ilac-MRA DAkkS Deutsche Akkreditierungsstelle D-PL-11140-11-01

| **Determination of the Acoustic Performance of a Wastewater Installation System in the Laboratory** | **P-BA 213/2016e**<br>**Results sheet 1** |
|---|---|

**Client:** Pestan D.O.O., 1300 Kaplara 189, Bukovik, 34300 Arandelovac, Serbia

**Test specimen:** Wastewater installation system consisting of plastic pipes and fittings "S Line" (manufacturer: Pestan) with pipe clamps "Bismat 1000" made by Walraven. (test object no.: 10998-1; 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 (87.5°), two 45°-basement bends and a horizontal drain section. The inlet tees ("Arched Branch") in the basement and in the ground floor were closed by lids. A "Low Noise Branch" was used for the water inlet in the top floor. Plug connection of the pipes and fittings (shaped pipe sockets).
  - Pipe system: three layer pipes "S Line", material PPC/PPM/PPC, size OD 110, wall thickness 3.4 mm (3.8 mm, measured by IBP), weight 1.62 kg/m measured by IBP, density 1.3 g/cm³ measured by IBP. single layer fittings, material PP, size OD 110, wall thickness 3.6 mm measured by IBP, density 1.4 g/cm³ measured by IBP.
  - 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 15 mm space between the locking tabs of the clamp (two 7.5 mm spacers on each side). At the upper wall area one "Bismat SL" was mounted as loose clamp (two 7.5 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. (fix clamps in the sub-basement: "Bismat HD1501", manufacturer Walraven).

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 according to EN 14366; noise excitation by steady water flow with 0.5 l/s, 1.0 l/s, 2.0 l/s and 4.0 l/s. Additional evaluation for comparison with requirements following German standards DIN 4109-1:2016-07 and VDI 4100:2012-10 (details in Annexes A, F and V).

**Result:**

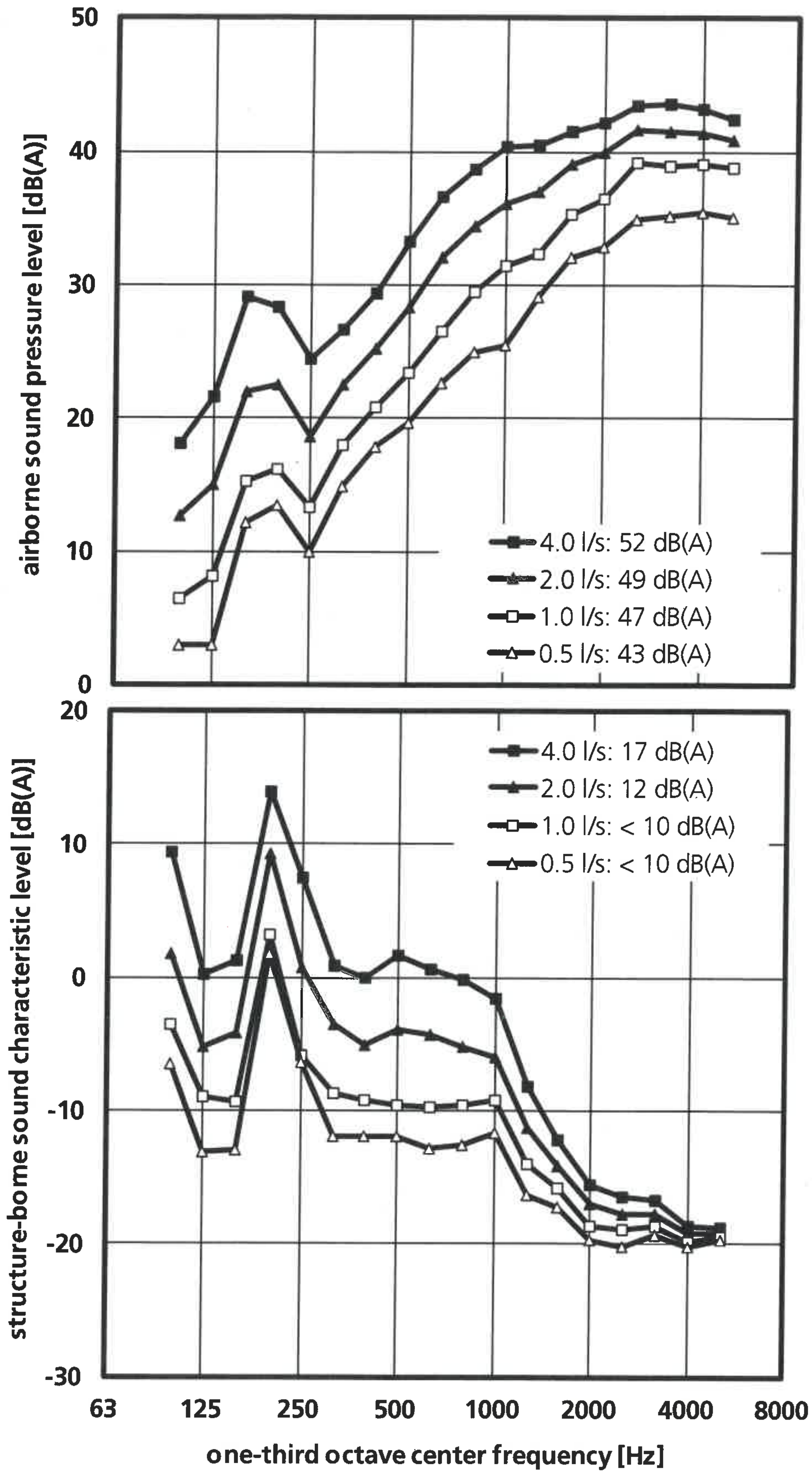
| "S Line" (manufacturer: Pestan) with pipe clamps "Bismat 1000" made by Walraven | | Flow rate [l/s] 0.5 | 1.0 | 2.0 | 4.0 |
|---|---|---|---|---|---|
| Airborne sound pressure level $L_{a,A}$ [dB(A)] **according to EN 14366** for the basement test-room | UG front | 43 | 47 | 49 | 52 |
| Structure-borne sound characteristic level $L_{sc,A}$ [dB(A)] **according to EN 14366** for the basement test-room | UG rear | < 10 | < 10 | 12 | 17 |
| Installation sound level $L_{AFeq,n}$ [dB(A)] **following DIN 4109** in the basement test-room | UG front | 43 | 47 | 49 | 52 |
| | UG rear | < 10 | 10 | 16 | 21 |
| Installation sound level $\overline{L_{AFeq,nT}}$ [dB(A)] **following VDI 4100** in the basement test-room | UG front | 40 | 44 | 47 | 50 |
| | UG rear | < 10 | < 10 | 13 | 18 |



**Test date:** September 30, 2016

**Notes:**
- For comparing test results with requirements note Annex A.
- 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.

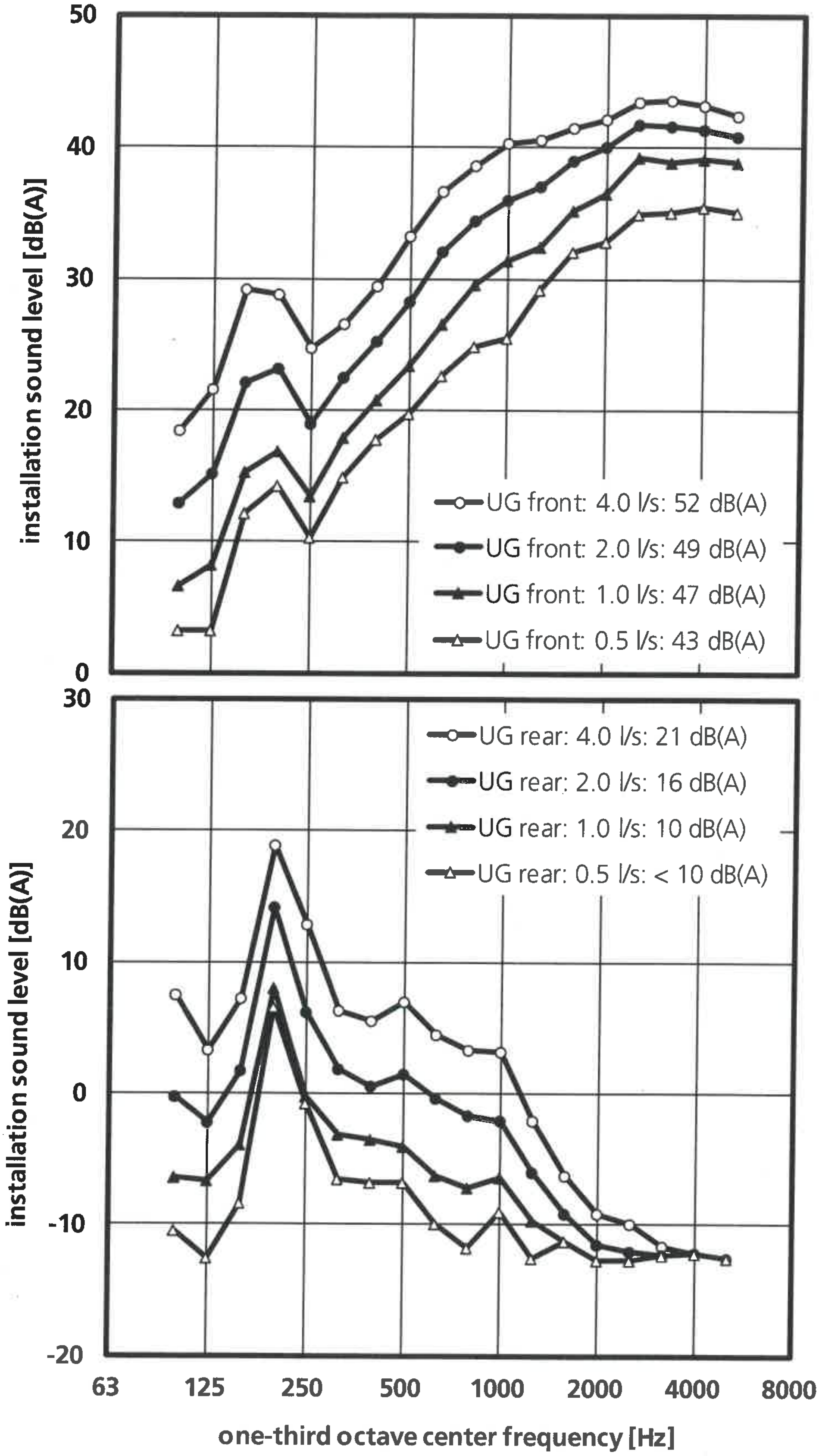
| Detailed results | P-BA 213/2016e |
|---|---|
| Client: Pestan D.O.O., 1300 Kaplara 189, Bukovik, 34300 Arandelovac, Serbia | figure 1 |




Frequency spectrum 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**.

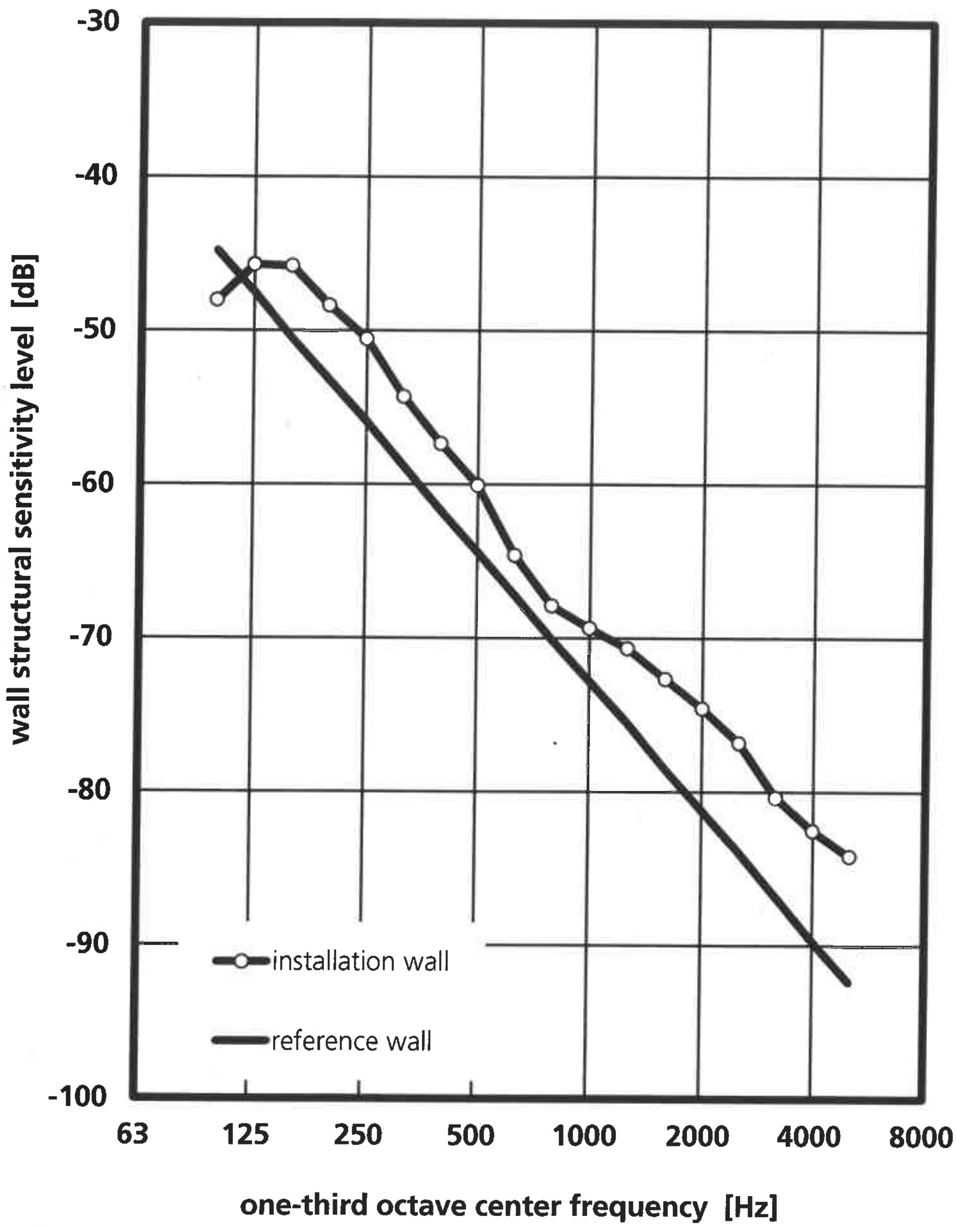
Test specimen: Wastewater installation system consisting of plastic pipes and fittings "S Line" (manufacturer: Pestan) with pipe clamps "Bismat 1000" made by Walraven.

| **Detailed results** | **P-BA 213/2016e** |
|---|---|
| Client: Pestan D.O.O., 1300 Kaplara 189, Bukovik, 34300 Arandelovac, Serbia | **figure 2** |



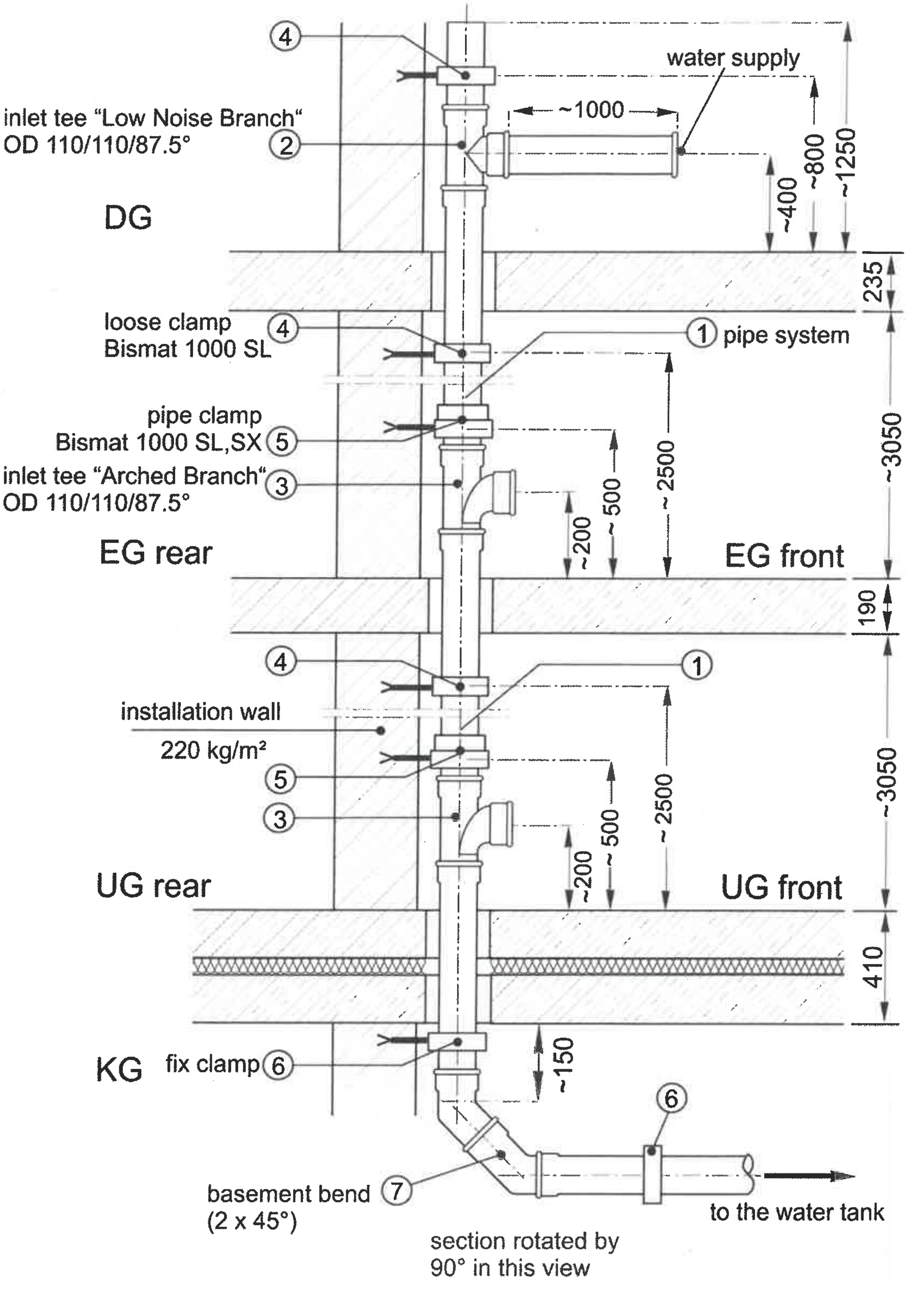

Frequency spectrum of the installation sound level $L_{AFeq,n}$ measured at various flow rates in the test rooms UG front (above) and UG rear (below). The installation sound levels $L_{AFeq,n}$ in dB(A) **following to DIN 4109**, for the reproduced frequency range from 100 to 5000 Hz, are represented in the legend.

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



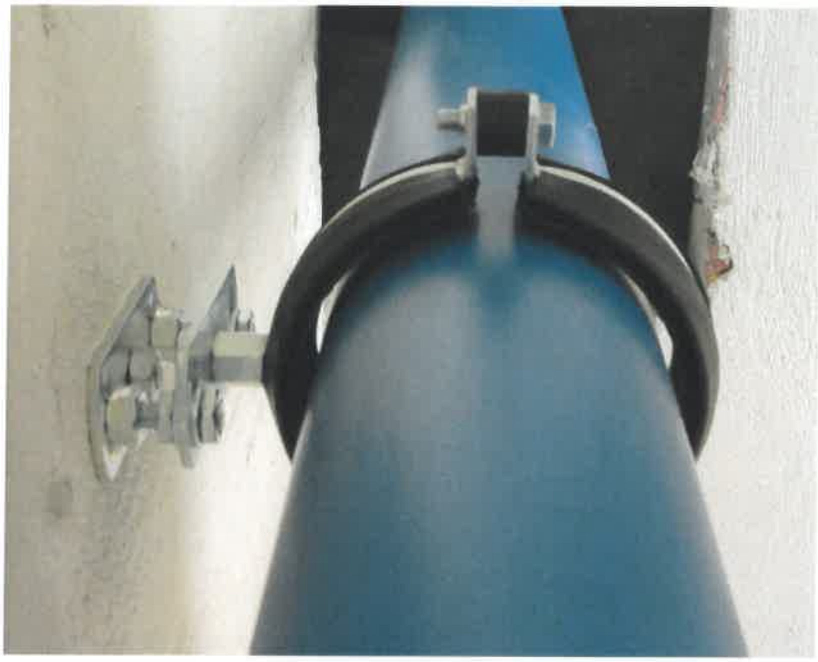

Wall structural sensitivity level $L_{SS}$ of the installation wall between the test rooms UG front and UG rear in the installation test facility in the Fraunhofer-Institute of Building Physics. The installation wall consists of calcium silicate blocks (thickness 115 mm, ceiled on both sides) with a 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 "S Line" (manufacturer: Pestan) with pipe clamps "Bismat 1000" made by Walraven.




Installation plan of the test set-up in the test facility. Upper clamps "Bismat SL", lower clamps "Bismat 1000", consisting of Bismat SL guidance clamp and Bismat SX socket clamp. Illustration simplified, schematically drawn and not to scale.

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



Upper picture: Pipe clamp "Bismat SL, loose clamp" (two 7.5 mm spacers on each side) at the upper wall area.

Lower picture: "Bismat 1000", consisting of Bismat SL guidance clamp with two 7.5 mm spacers on each side and Bismat SX socket clamp without spacer at the lower wall area.
Mounting details see test set-up.

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

**Measurement set-up, noise excitation and evaluation parameters, comparison of measurement results with the requirements, comparability and reproducibility 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 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.

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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,
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(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 DIN EN ISO 10 140-4 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 or following to VDI 4100 per Annex V.

With stationary signals (e.g. waste water noise with a constant flow rate), in deviation from DIN 4109-4 and DIN EN ISO 10052 or VDI 4100 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.

Comparison of measurement results with the requirements

The measurement results facilitate the comparison of products, materials and system components of waste water installations in terms of their noise insulation properties (component testing). Furthermore, it is also possible to compare the noise pressure levels (installation noise level) detected during the tests with the requirements in DIN 4109 and VDI 4100. A precondition for this is that the structural conditions in the real construction situation are comparable with or acoustically more favourable than those on the test bench at the Fraunhofer Institute for Building Physics. 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. The measured value at a volumetric flow of 2 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.

With the standard DIN EN 12354-5, it is also possible to predict the noise pressure level in other rooms requiring sound insulation, also for deviating building situations and with consideration to additional values for the installation noise from further domestic systems, such as WC systems, shower cubicles, baths, etc. Alternatively, it is possible to perform so-called design model tests, in which waste water systems can be tested on our test benches in conjunction with further sanitary installations connected in accordance with practice (system measurement). The measured values can be subsequently compared directly with the noise insulation requirements.

Comparability and reproducibility of measurement results

For noise measurements of waste water systems, the results are dependent not only on the pipe clamps used, but to a large extent on the installation conditions, such as 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 dB.

A comparison between different waste water systems therefore requires that all systems be fitted with the same degree of care and attention.

## 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) $$L_{i,AFeq,n} = 10 \cdot \lg\left(10^{\frac{L_{i,F}}{10}} - 10^{\frac{L_{i,F,GG}}{10}}\right) + 10 \cdot \lg\frac{A_i}{A_0} + k(A)_i$$ [dB(A)]

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

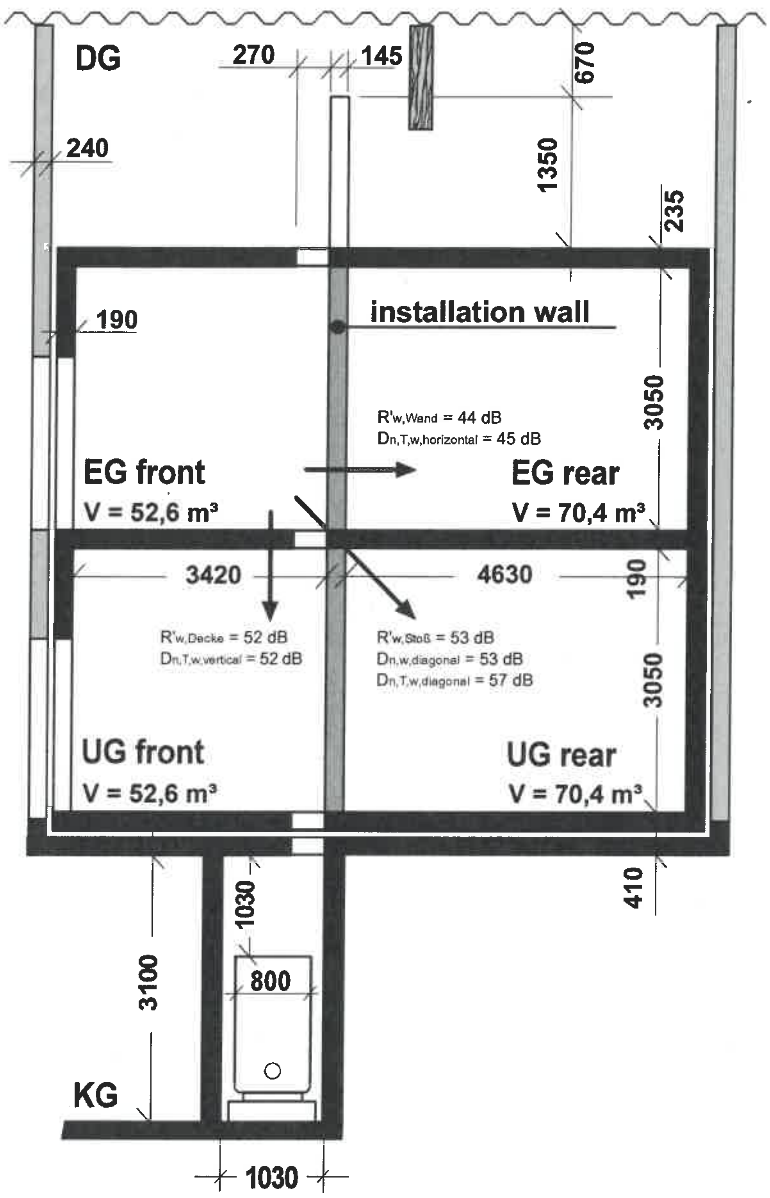
(2) $$L_{AFeq,n} = 10 \cdot \lg\left(\sum_{i=1}^{18} 10^{\frac{L_{i,AFeq,n}}{10}}\right),$$ [dB(A)]

where i indicates the number of one-third octave bands from 100 Hz to 5 kHz. The calculated level $L_{AFeq,n}$ corresponds to the sound pressure level that would arise in a sparsely furnished reception room under otherwise equal conditions. The value represents the installation sound level 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 0.125 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 ($L_{AFmax,n}$) 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-Set | 40HF (Kapsel: Typ 40EH-LowNoise; Vorverstärker: Typ 26HF; Power Module: Typ 12HF) | 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:

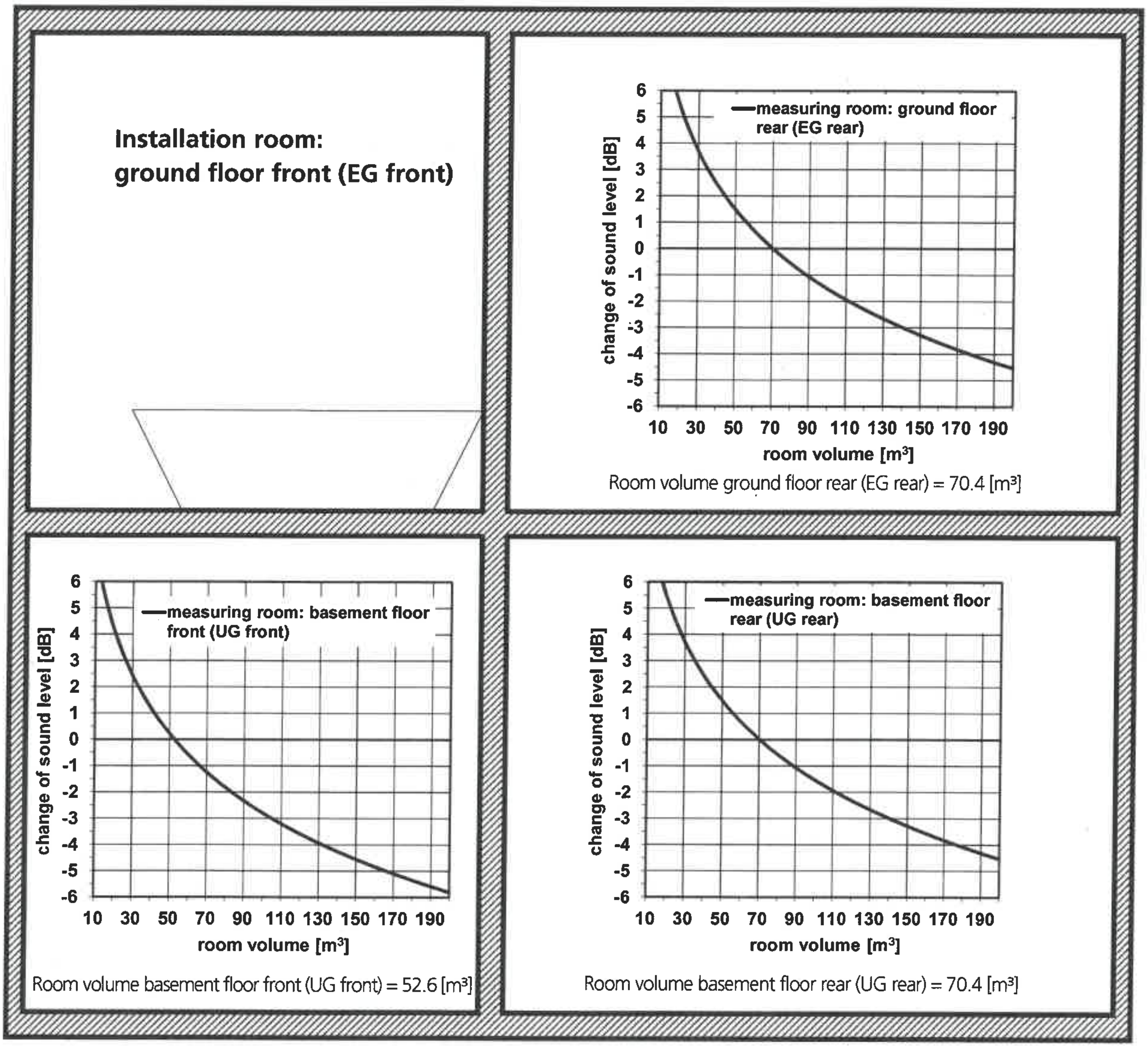



**Fig. 1:** Modification of the standardized sound level measured in the installation test facility P12 for rooms with deviating volume. The resulting change of sound level in comparison to the measured value indicated in the test report in dependence of the new room volume is specified in the diagrams 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.

<u>Note to handle noise emitted by users in VDI 4100:</u>
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.

Fraunhofer
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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
Prof. Dr. Klaus Peter Sedlbauer

**Test Report P-BA 94/2016e**

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

**Client:** Pestan D.O.O.
1300 Kaplara 189
Bukovik, 34300 Arandelovac
Serbia

**Test object:** Wastewater installation system consisting of plastic pipes and fittings "S Line" (manufacturer: Pestan) with pipe clamps "Bismat 2000" made by Walraven.

**Content:**

| | |
|---|---|
| Results sheet 1: | Summary of test results |
| Figures 1 to 3: | Detailed results |
| Figures 4 and 5: | Test set-up |
| Annex A: | Measurement set-up, noise excitation, acoustic parameters |
| Annex F: | Evaluation of measurements |
| Annex P: | Description of the test facility |
| Annex V: | Assessment according to VDI 4100 |

**Test date:** The measurement was carried out on April 22, 2016 in the test facilities of the Fraunhofer Institute for Building Physics in Stuttgart.

Stuttgart, May 9, 2016

Responsible Test Engineer: Head of Laboratory:

M.Sc. B. Kaltbeitzel 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 94/2016e<br>Results sheet 1 |
|---|---|

**Client:** Pestan D.O.O., 1300 Kaplara 189, Bukovik, 34300 Arandelovac, Serbia

**Test specimen:** Wastewater installation system consisting of plastic pipes and fittings "S Line" (manufacturer: Pestan) with pipe clamps "Bismat 2000" made by Walraven. (test object no.: 10943-2; 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 (87.5°), two 45°-basement bends and a horizontal drain section. The inlet tees in the basement and in the ground floor were closed by lids.

  - Pipe system: three layer pipes "S Line", material PPC/PPM/PPC, size OD 110, wall thickness 3.4 mm (measured: 3.7 mm), weight 1.6 kg/m, density 1.3 g/cm³. single layer fittings, material PP, size OD 110, wall thickness 3.7 mm, density 1.4 g/cm³. Plug connection of the pipes and fittings.

  - Pipe clamps "Bismat 2000": Steel clamp with elastomer inlay and with a clamping range of 108 – 114 mm. The clamps were closed with 3 Nm (clamps were completely closed, see figure 5). In each storey (EG and UG) one clamp was installed at the lower wall area and one at the upper wall area. The Bismat 2000 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 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:**

| "S Line" (manufacturer: Pestan) with pipe clamps "Bismat 2000" 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 | 54 |
| | **UG rear** | 21 | 24 | 27 | 30 |
| Installation sound level $\overline{L_{AFeq,nT}}$ ($L_{In}$) [dB(A)] **according to VDI 4100** measured in the basement test-room | **UG front** | 41 | 45 | 48 | 51 |
| | **UG rear** | 17 | 21 | 23 | 26 |
| Airborne sound pressure level $L_{a,A}$ [dB(A)] **according to EN 14366** in the basement test-room **UG front** | | 44 | 47 | 50 | 54 |
| Structure-borne sound characteristic level $L_{sc,A}$ [dB(A)] **according to EN 14366** in the basement test-room **UG rear** | | 19 | 22 | 25 | 28 |

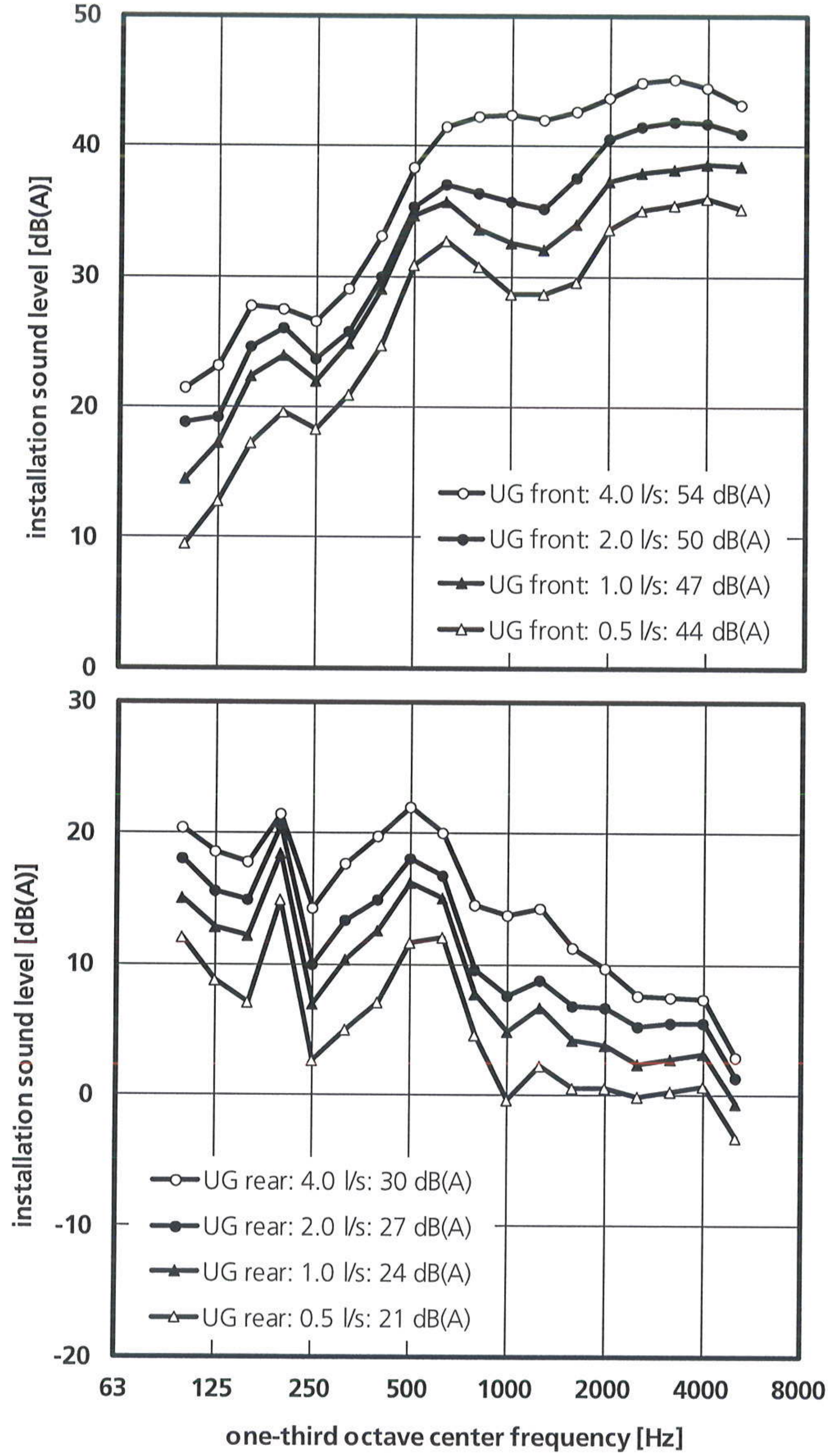
**Test date:** April 22, 2016

**Notes:** - The requirements of DIN 4109 and VDI 4100 only apply for the test room UG rear.

Fraunhofer IBP

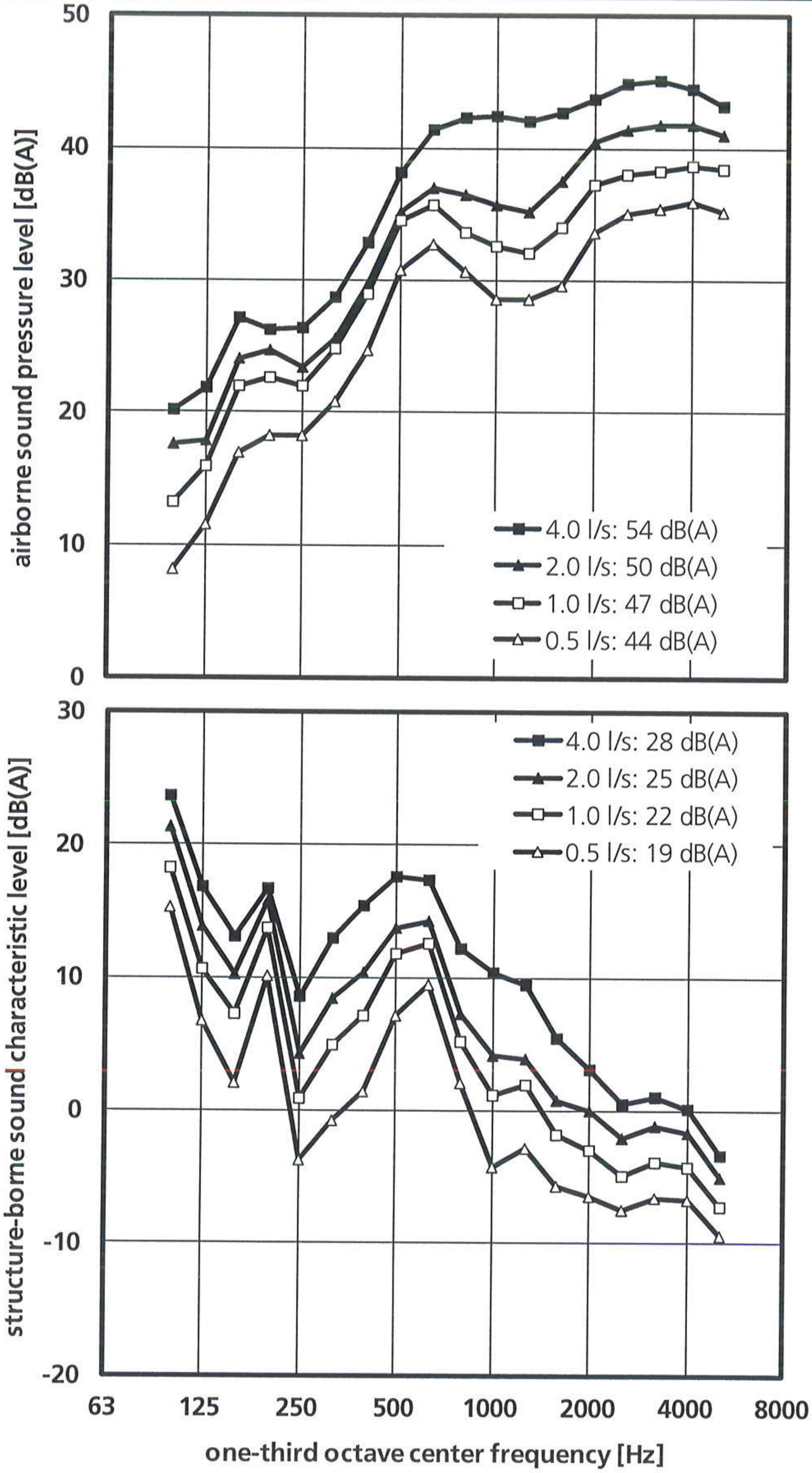
The test was carried out in a laboratory, accredited according to DIN EN ISO/IEC 17025:2005 by DAkkS. The accreditation certificate is D-PL-11140-11-01.

Stuttgart, May 9, 2016
Head of Laboratory:




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 to DIN 4109**, for the reproduced frequency range from 100 to 5000 Hz, are represented in the legend.

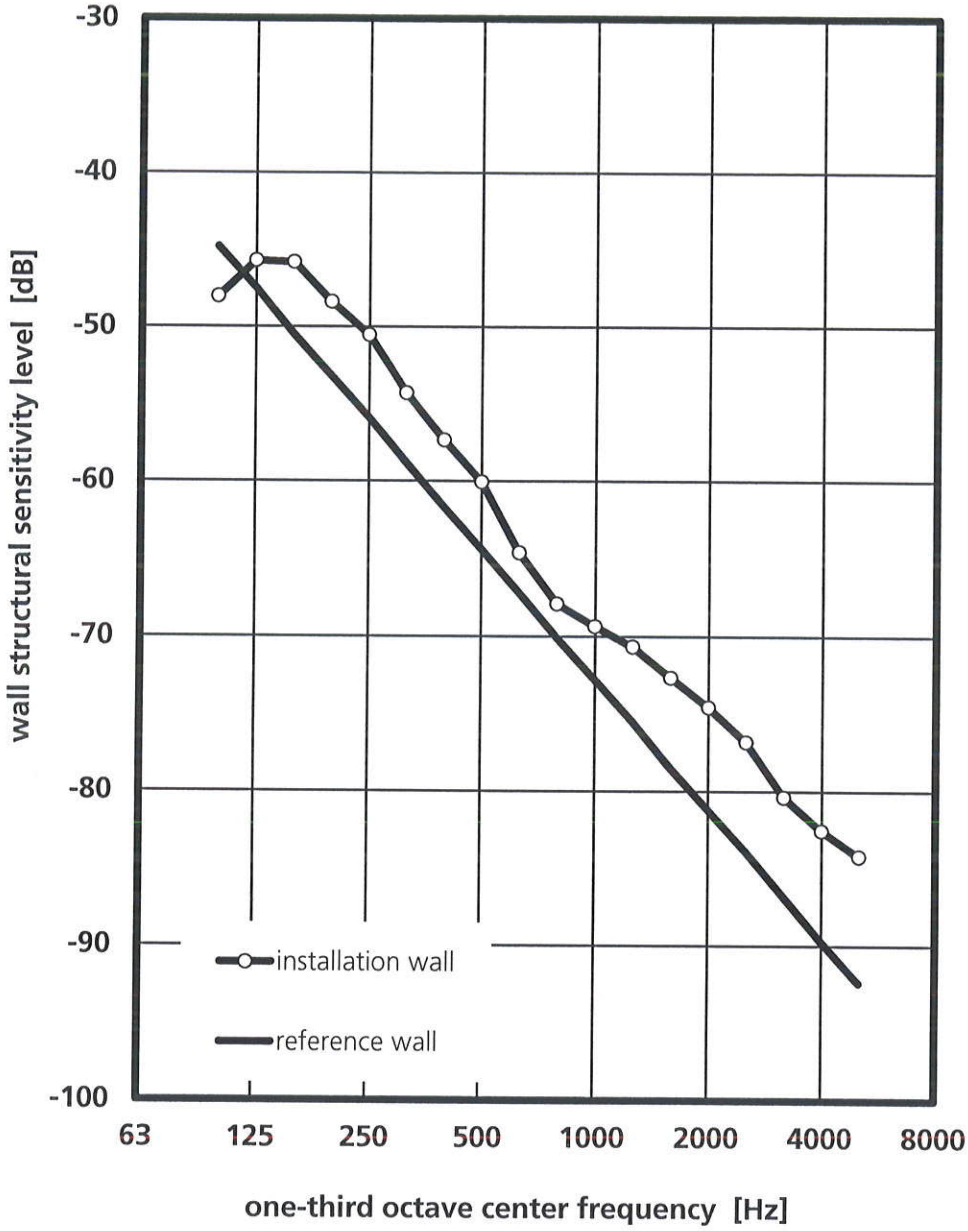
Test specimen: Wastewater installation system consisting of plastic pipes and fittings "S Line" (manufacturer: Pestan) with pipe clamps "Bismat 2000" made by Walraven.




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**.

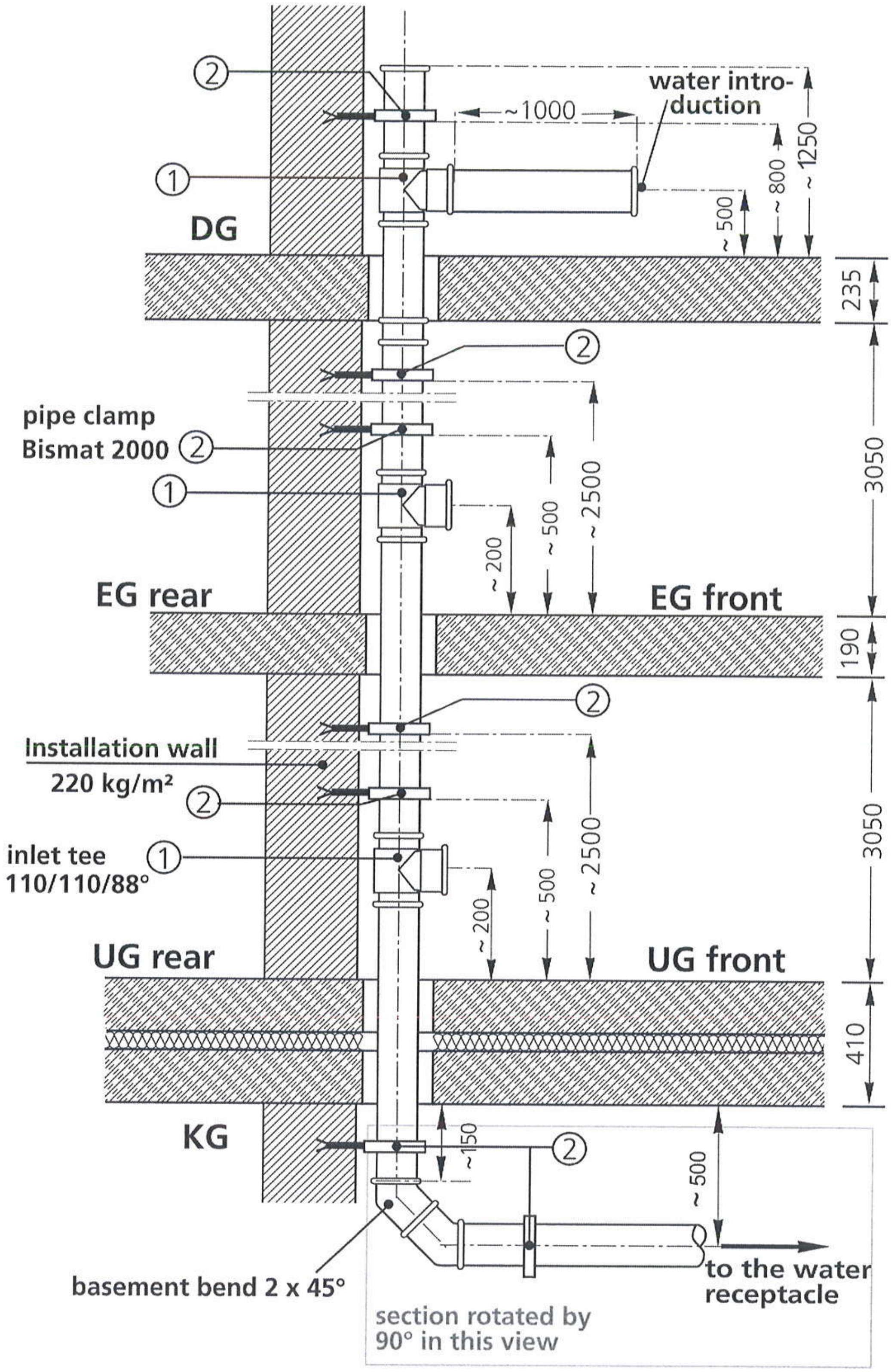
Test specimen: Wastewater installation system consisting of plastic pipes and fittings "S Line" (manufacturer: Pestan) with pipe clamps "Bismat 2000" made by Walraven.

| Detailed results | P-BA 94/2016e |
|---|---|
| Client: Pestan D.O.O., 1300 Kaplara 189, Bukovik, 34300 Arandelovac, Serbia | figure 3 |



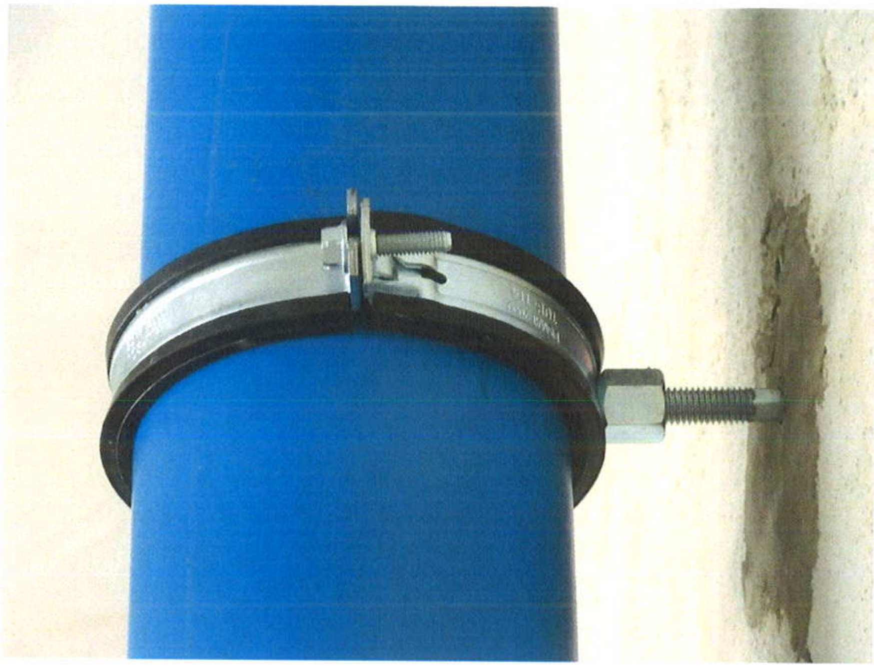

Wall structural sensitivity level $L_{SS}$ of the installation wall between the test rooms UG front and UG rear in the installation test facility in the Fraunhofer-Institute of Building Physics. The installation wall consists of calcium silicate blocks (thickness 115 mm, ceiled on both sides) with a 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 "S Line" (manufacturer: Pestan) with pipe clamps "Bismat 2000" made by Walraven.




Installation plan of the test set-up in the test facility. (Drawing not to scale, dimensions in mm)

Test specimen: Wastewater installation system consisting of plastic pipes and fittings "S Line" (manufacturer: Pestan) with pipe clamps "Bismat 2000" made by Walraven.



Upper picture: Pipe clamp "Bismat 2000" at the upper wall area.

Lower picture: Inlet tee at the bottom and one pipe clamp "Bismat 2000" at the lower wall area.

Test specimen: Wastewater installation system consisting of plastic pipes and fittings "S Line" (manufacturer: Pestan) with pipe clamps "Bismat 2000" 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 m² 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.

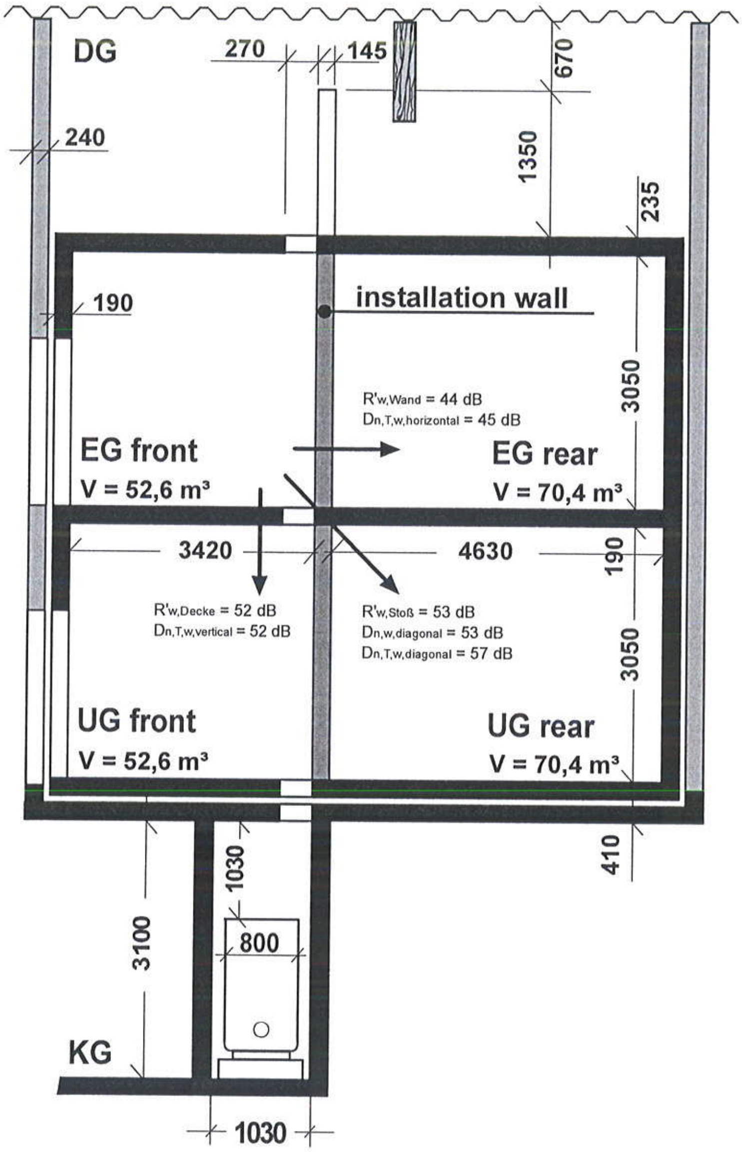
(2) $$L_{AF,10} = 10 \cdot \lg\left(\sum_{n=1}^{18} 10^{\frac{L_{n,AF,10}}{10}}\right),$$ [dB(A)]

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 0.125 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-Set | 40HF (Kapsel: Typ 40EH-LowNoise; Vorverstärker: Typ 26HF; Power Module: Typ 12HF) | 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 m², 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 [m³]

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:

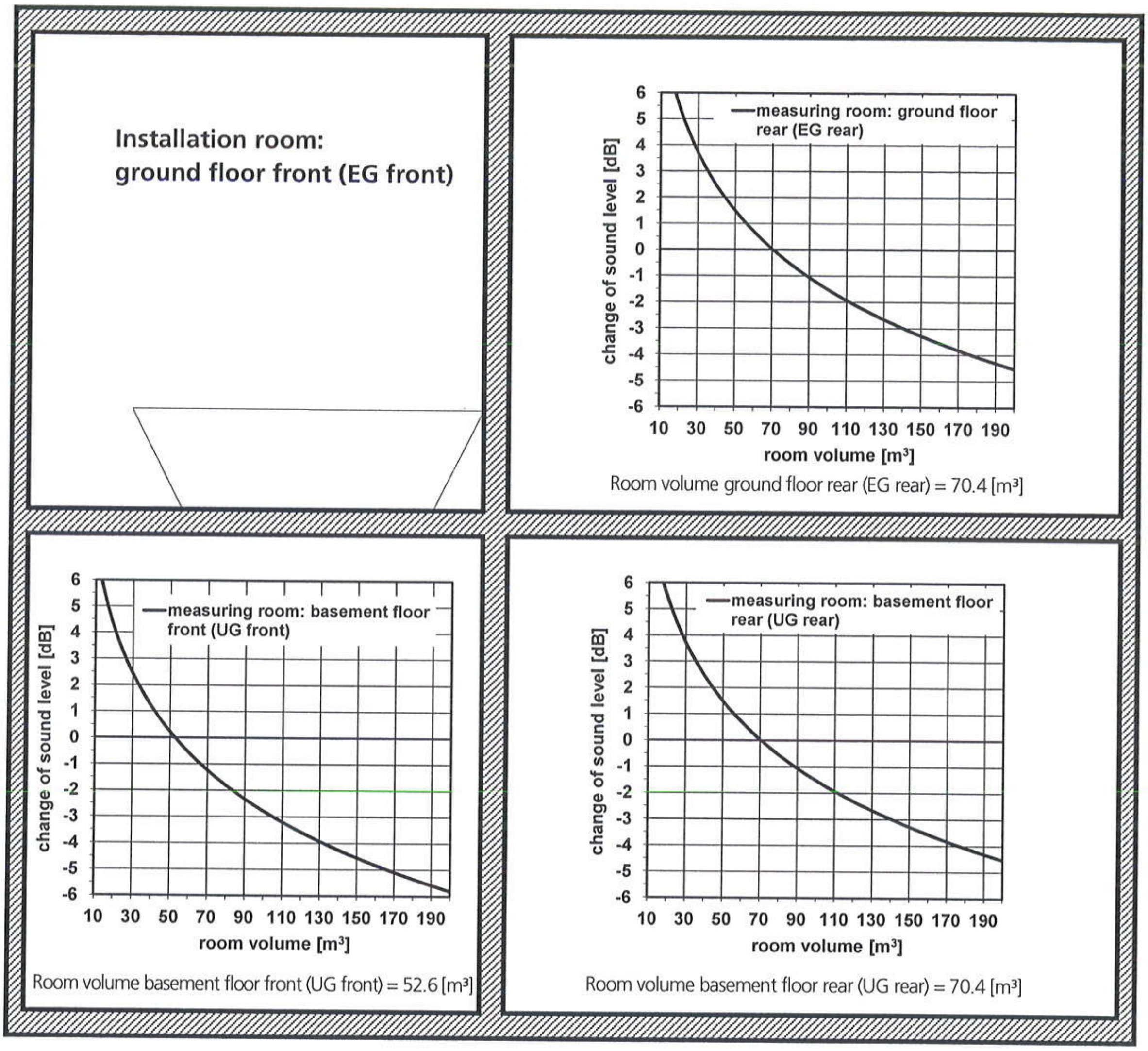



**Fig. 1:** Modification of the standardized sound level measured in the installation test facility P12 for rooms with deviating volume. The resulting change of sound level in comparison to the measured value indicated in the test report in dependence of the new room volume is specified in the diagrams 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.

Fraunhofer
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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
Prof. Dr. Klaus Peter Sedlbauer

## Test Report P-BA 213/2016e

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

**Client:** Pestan D.O.O.
1300 Kaplara 189
Bukovik, 34300 Arandelovac
Serbia

**Test object:** Wastewater installation system consisting of plastic pipes and fittings "S Line" (manufacturer: Pestan) with pipe clamps "Bismat 1000" made by Walraven.

**Content:**

| | |
|---|---|
| Results sheet 1: | Summary of test results |
| Figures 1 to 3: | Detailed results |
| Figures 4 and 5: | Test set-up |
| Annex A: | Measurement set-up, noise excitation, acoustic parameters |
| Annex F: | Evaluation of measurements |
| Annex P: | Description of the test facility |
| Annex V: | Assessment according to VDI 4100 |

**Test date:** The measurement was carried out on September 30, 2016 in the test facilities of the Fraunhofer Institute for Building Physics in Stuttgart.

Stuttgart, October 12, 2016

Responsible Test Engineer: Head of Laboratory:

M.Sc. B. Kaltbeitzel M.BP. Dipl.-Ing.(FH) S. Öhler

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

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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ilac-MRA DAkkS Deutsche Akkreditierungsstelle D-PL-11140-11-01

| **Determination of the Acoustic Performance of a Wastewater Installation System in the Laboratory** | **P-BA 213/2016e**<br>**Results sheet 1** |
|---|---|

**Client:** Pestan D.O.O., 1300 Kaplara 189, Bukovik, 34300 Arandelovac, Serbia

**Test specimen:** Wastewater installation system consisting of plastic pipes and fittings "S Line" (manufacturer: Pestan) with pipe clamps "Bismat 1000" made by Walraven. (test object no.: 10998-1; 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 (87.5°), two 45°-basement bends and a horizontal drain section. The inlet tees ("Arched Branch") in the basement and in the ground floor were closed by lids. A "Low Noise Branch" was used for the water inlet in the top floor. Plug connection of the pipes and fittings (shaped pipe sockets).
  - Pipe system: three layer pipes "S Line", material PPC/PPM/PPC, size OD 110, wall thickness 3.4 mm (3.8 mm, measured by IBP), weight 1.62 kg/m measured by IBP, density 1.3 g/cm³ measured by IBP. single layer fittings, material PP, size OD 110, wall thickness 3.6 mm measured by IBP, density 1.4 g/cm³ measured by IBP.
  - 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 15 mm space between the locking tabs of the clamp (two 7.5 mm spacers on each side). At the upper wall area one "Bismat SL" was mounted as loose clamp (two 7.5 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. (fix clamps in the sub-basement: "Bismat HD1501", manufacturer Walraven).

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 according to EN 14366; noise excitation by steady water flow with 0.5 l/s, 1.0 l/s, 2.0 l/s and 4.0 l/s. Additional evaluation for comparison with requirements following German standards DIN 4109-1:2016-07 and VDI 4100:2012-10 (details in Annexes A, F and V).

**Result:**

| "S Line" (manufacturer: Pestan) with pipe clamps "Bismat 1000" made by Walraven | | Flow rate [l/s] 0.5 | 1.0 | 2.0 | 4.0 |
|---|---|---|---|---|---|
| Airborne sound pressure level $L_{a,A}$ [dB(A)] **according to EN 14366** for the basement test-room | UG front | 43 | 47 | 49 | 52 |
| Structure-borne sound characteristic level $L_{sc,A}$ [dB(A)] **according to EN 14366** for the basement test-room | UG rear | < 10 | < 10 | 12 | 17 |
| Installation sound level $L_{AFeq,n}$ [dB(A)] **following DIN 4109** in the basement test-room | UG front | 43 | 47 | 49 | 52 |
| | UG rear | < 10 | 10 | 16 | 21 |
| Installation sound level $\overline{L_{AFeq,nT}}$ [dB(A)] **following VDI 4100** in the basement test-room | UG front | 40 | 44 | 47 | 50 |
| | UG rear | < 10 | < 10 | 13 | 18 |

**Test date:** September 30, 2016

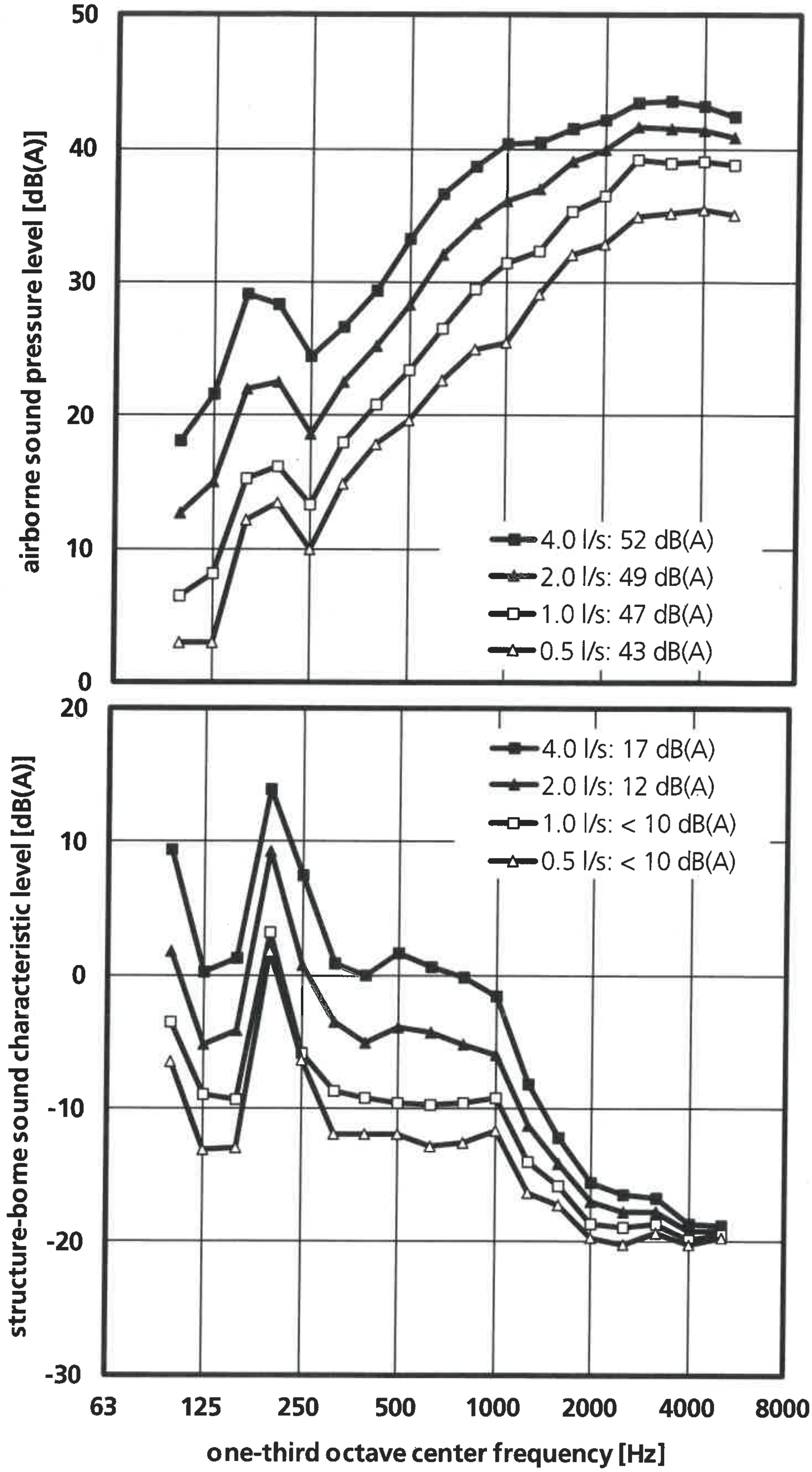
**Notes:**
- For comparing test results with requirements note Annex A.
- For the experimental setup investigated in the test facility the used supporting and fixing clips Bismat 1000 normally doesn't guarantee a realistic load transmission. Consequently, in case of practical application in a real building, 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, October 12, 2016
Head of Laboratory:

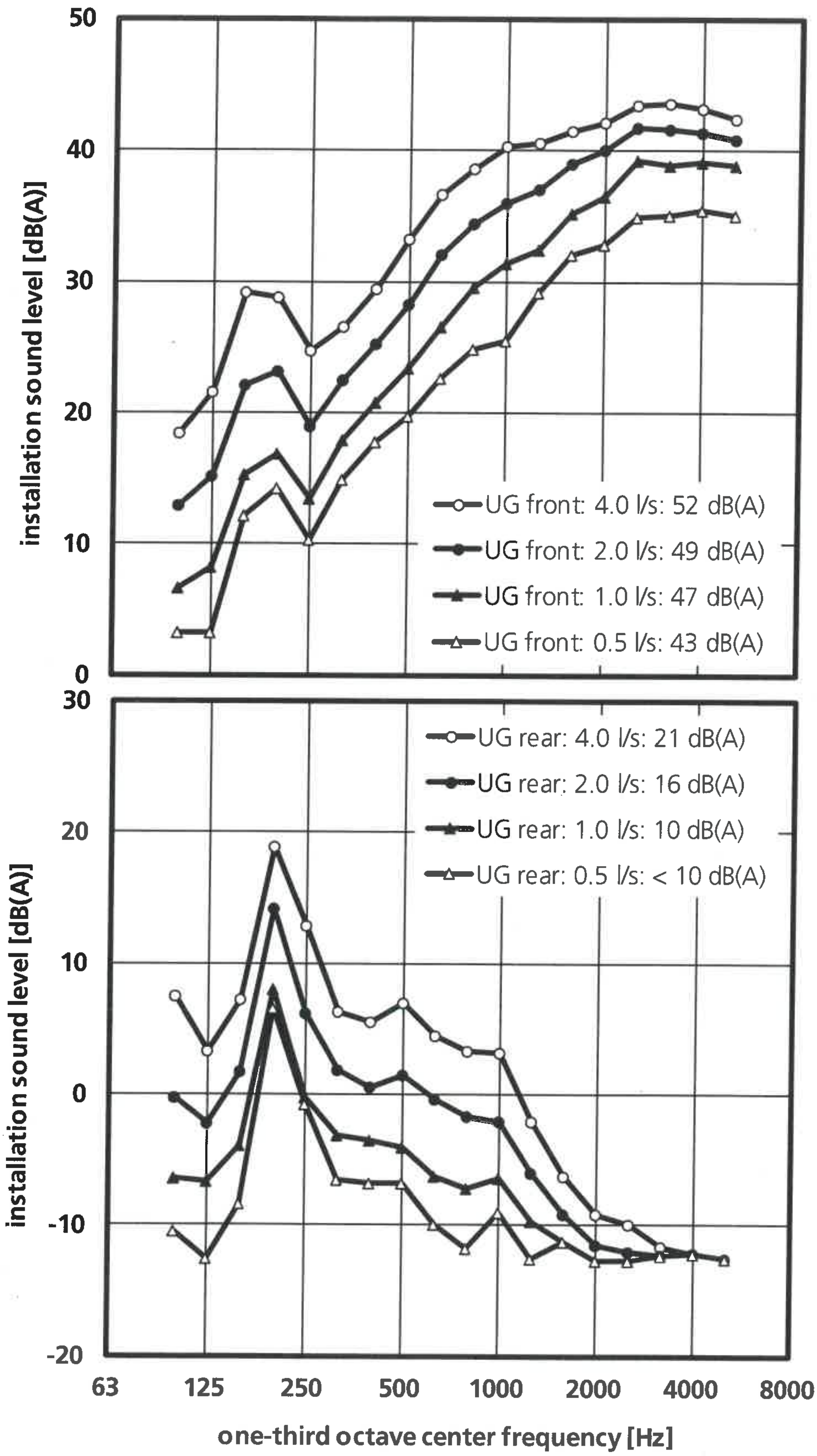
| **Detailed results** | **P-BA 213/2016e** |
|---|---|
| Client: Pestan D.O.O., 1300 Kaplara 189, Bukovik, 34300 Arandelovac, Serbia | **figure 1** |




Frequency spectrum 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**.

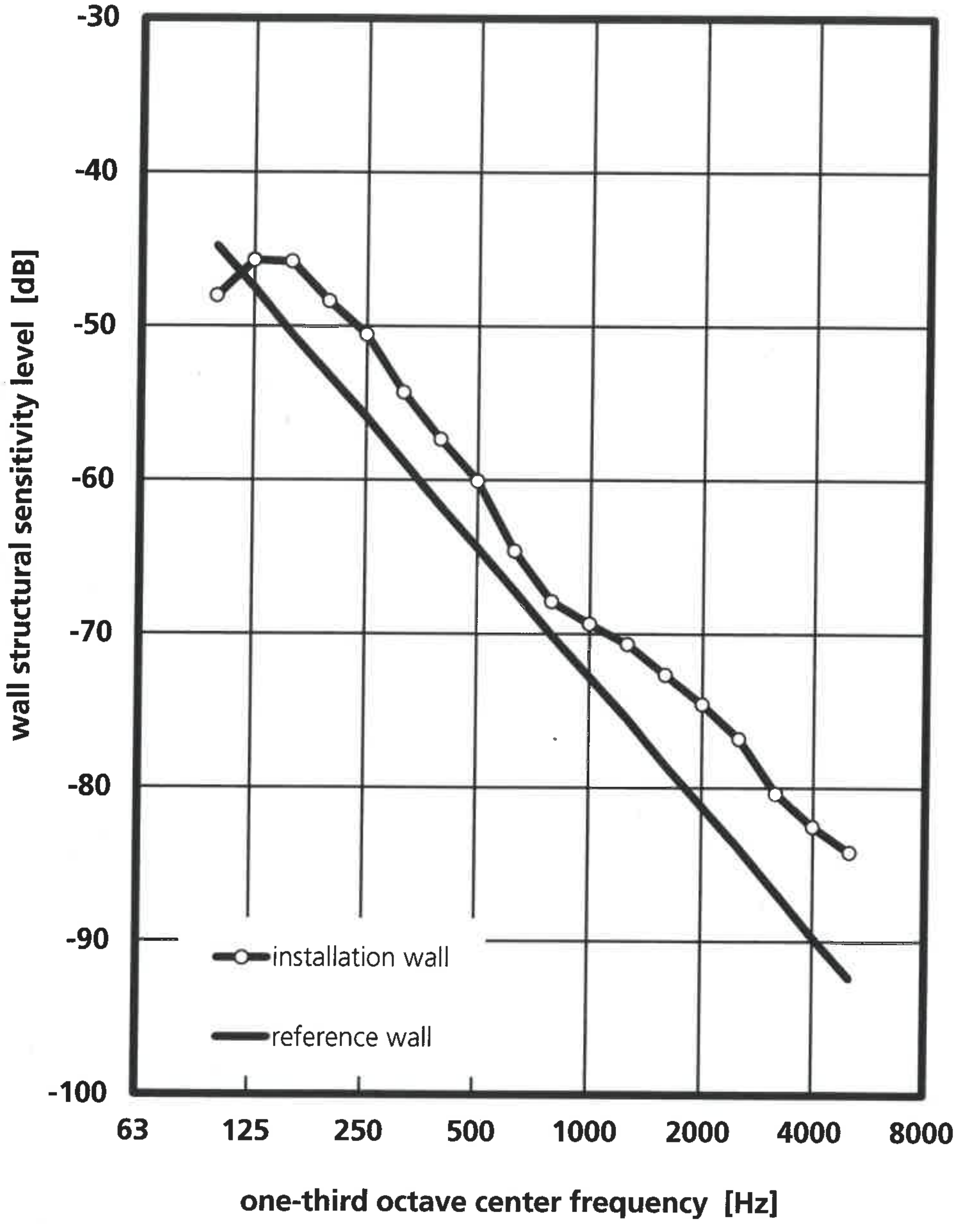
Test specimen: Wastewater installation system consisting of plastic pipes and fittings "S Line" (manufacturer: Pestan) with pipe clamps "Bismat 1000" made by Walraven.

| **Detailed results** | **P-BA 213/2016e** |
|---|---|
| Client: Pestan D.O.O., 1300 Kaplara 189, Bukovik, 34300 Arandelovac, Serbia | **figure 2** |



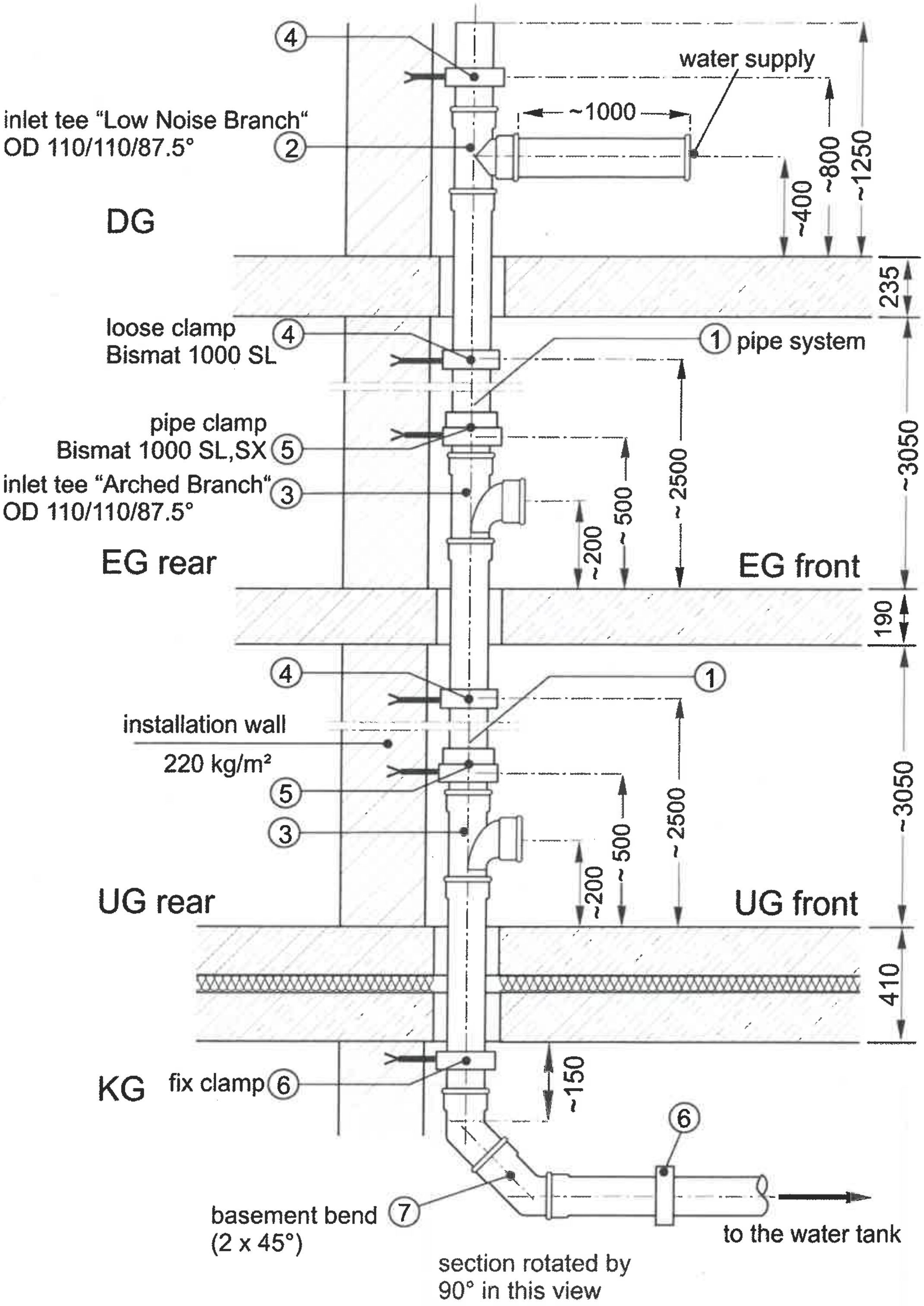

Frequency spectrum of the installation sound level $L_{AFeq,n}$ measured at various flow rates in the test rooms UG front (above) and UG rear (below). The installation sound levels $L_{AFeq,n}$ in dB(A) **following to DIN 4109**, for the reproduced frequency range from 100 to 5000 Hz, are represented in the legend.

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



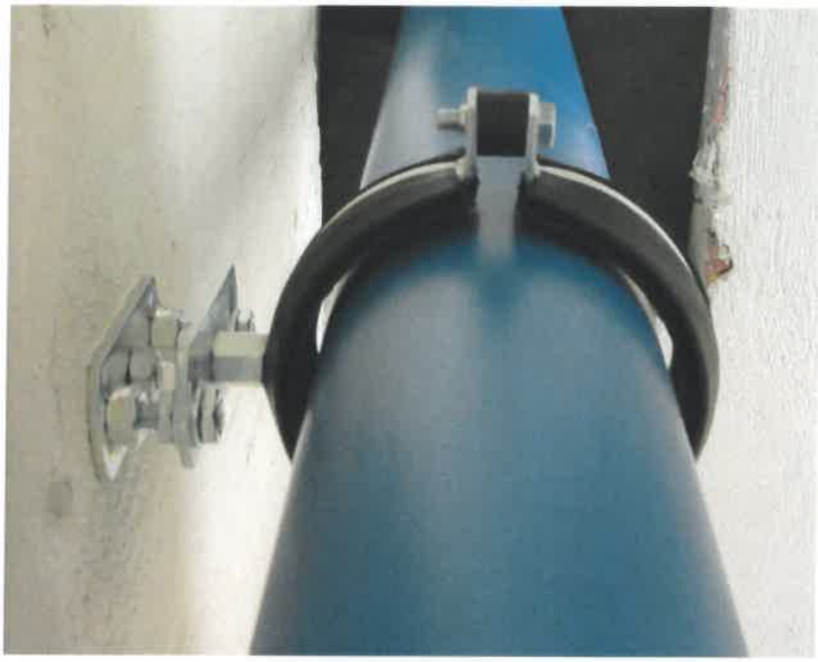

Wall structural sensitivity level $L_{SS}$ of the installation wall between the test rooms UG front and UG rear in the installation test facility in the Fraunhofer-Institute of Building Physics. The installation wall consists of calcium silicate blocks (thickness 115 mm, ceiled on both sides) with a 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 "S Line" (manufacturer: Pestan) with pipe clamps "Bismat 1000" made by Walraven.




Installation plan of the test set-up in the test facility. Upper clamps "Bismat SL", lower clamps "Bismat 1000", consisting of Bismat SL guidance clamp and Bismat SX socket clamp. Illustration simplified, schematically drawn and not to scale.

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



Upper picture: Pipe clamp "Bismat SL, loose clamp" (two 7.5 mm spacers on each side) at the upper wall area.

Lower picture: "Bismat 1000", consisting of Bismat SL guidance clamp with two 7.5 mm spacers on each side and Bismat SX socket clamp without spacer at the lower wall area.
Mounting details see test set-up.

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

**Measurement set-up, noise excitation and evaluation parameters, comparison of measurement results with the requirements, comparability and reproducibility 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 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 DIN EN ISO 10 140-4 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 or following to VDI 4100 per Annex V.

With stationary signals (e.g. waste water noise with a constant flow rate), in deviation from DIN 4109-4 and DIN EN ISO 10052 or VDI 4100 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.

Comparison of measurement results with the requirements

The measurement results facilitate the comparison of products, materials and system components of waste water installations in terms of their noise insulation properties (component testing). Furthermore, it is also possible to compare the noise pressure levels (installation noise level) detected during the tests with the requirements in DIN 4109 and VDI 4100. A precondition for this is that the structural conditions in the real construction situation are comparable with or acoustically more favourable than those on the test bench at the Fraunhofer Institute for Building Physics. 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. The measured value at a volumetric flow of 2 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.

With the standard DIN EN 12354-5, it is also possible to predict the noise pressure level in other rooms requiring sound insulation, also for deviating building situations and with consideration to additional values for the installation noise from further domestic systems, such as WC systems, shower cubicles, baths, etc. Alternatively, it is possible to perform so-called design model tests, in which waste water systems can be tested on our test benches in conjunction with further sanitary installations connected in accordance with practice (system measurement). The measured values can be subsequently compared directly with the noise insulation requirements.

Comparability and reproducibility of measurement results

For noise measurements of waste water systems, the results are dependent not only on the pipe clamps used, but to a large extent on the installation conditions, such as 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 dB.

A comparison between different waste water systems therefore requires that all systems be fitted with the same degree of care and attention.

## 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 m² and A-weighted:

(1) $$L_{i,AFeq,n} = 10 \cdot \lg\left(10^{\frac{L_{i,F}}{10}} - 10^{\frac{L_{i,F,GG}}{10}}\right) + 10 \cdot \lg\frac{A_i}{A_0} + k(A)_i$$ [dB(A)]

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

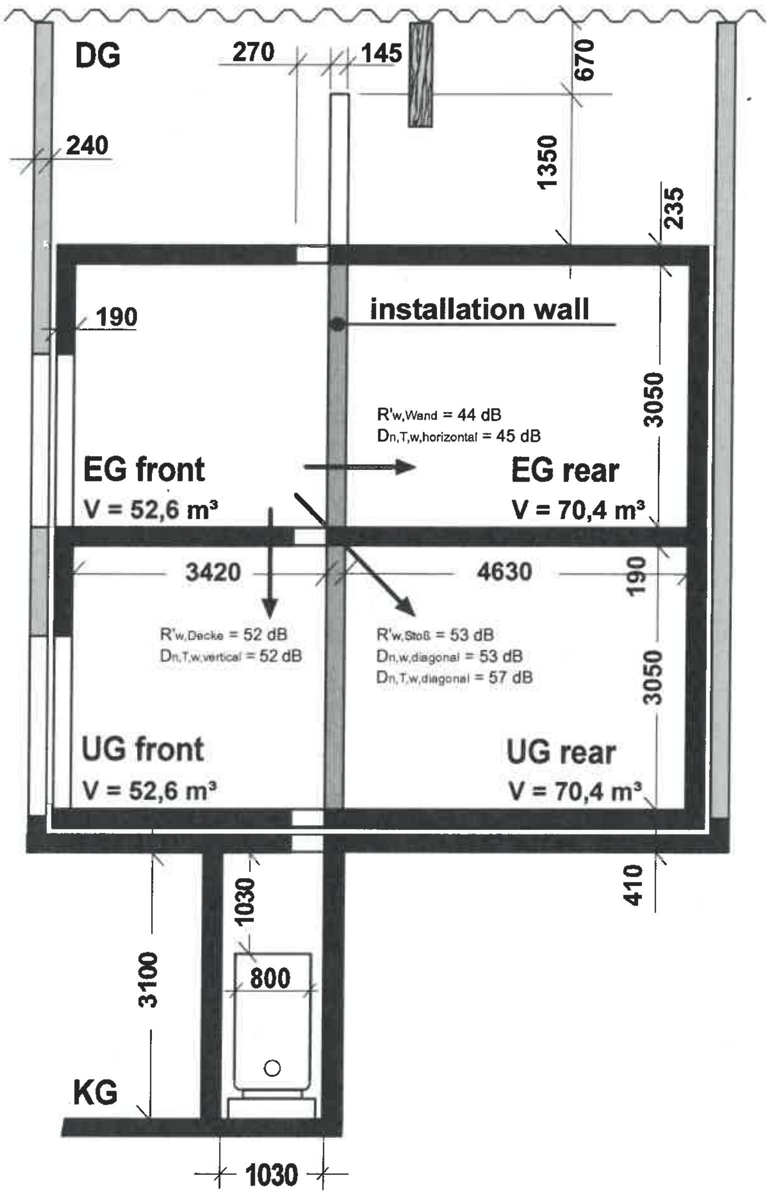
(2) $$L_{AFeq,n} = 10 \cdot \lg\left(\sum_{i=1}^{18} 10^{\frac{L_{i,AFeq,n}}{10}}\right),$$ [dB(A)]

where i indicates the number of one-third octave bands from 100 Hz to 5 kHz. The calculated level $L_{AFeq,n}$ corresponds to the sound pressure level that would arise in a sparsely furnished reception room under otherwise equal conditions. The value represents the installation sound level 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 0.125 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 ($L_{AFmax,n}$) 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-Set | 40HF (Kapsel: Typ 40EH-LowNoise; Vorverstärker: Typ 26HF; Power Module: Typ 12HF) | 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:

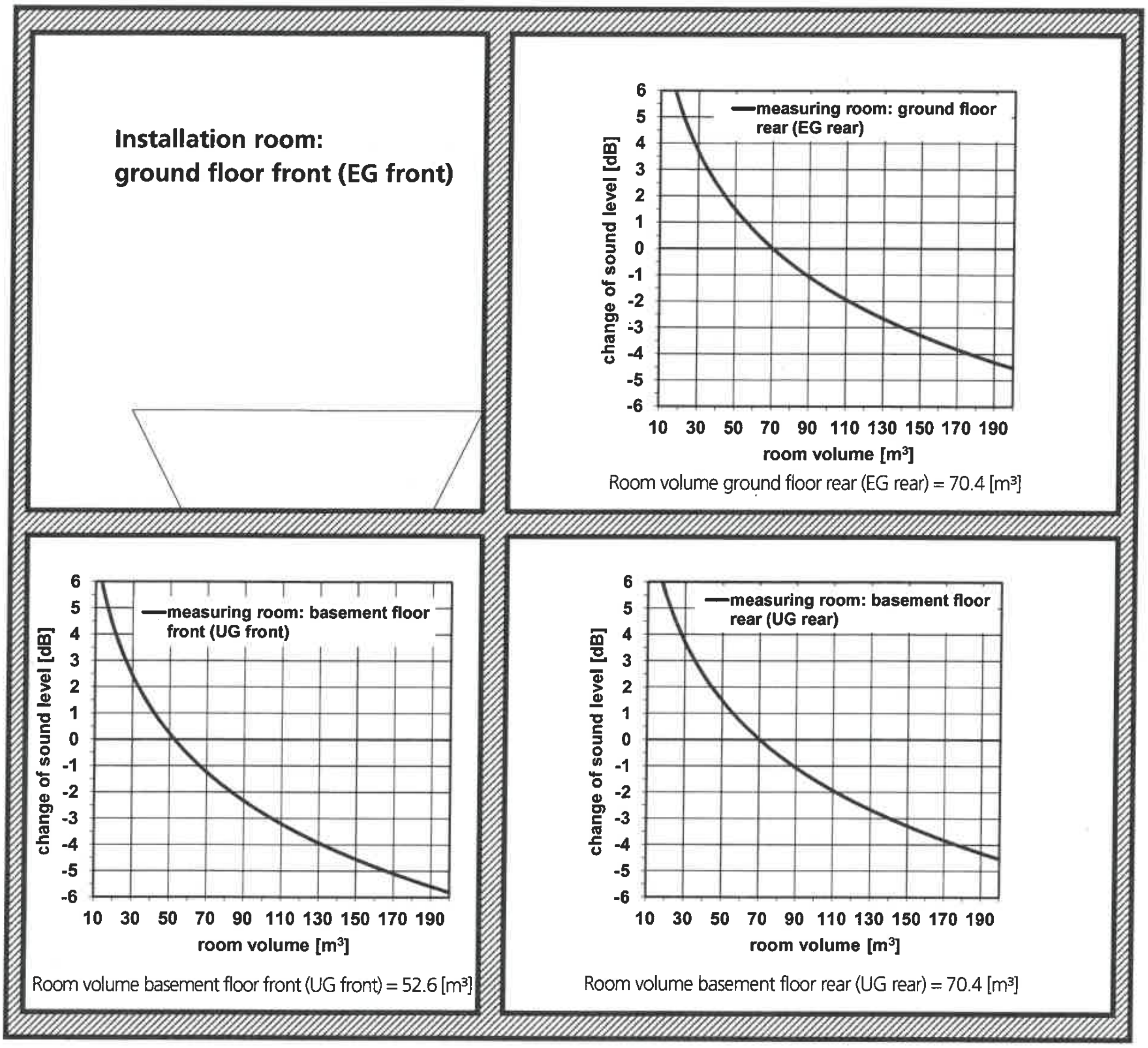



**Fig. 1:** Modification of the standardized sound level measured in the installation test facility P12 for rooms with deviating volume. The resulting change of sound level in comparison to the measured value indicated in the test report in dependence of the new room volume is specified in the diagrams 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 m$^2$ 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.