Osaamista
ja oivallusta
tulevaisuuden
tekemiseen

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Desibeliviemäreiden akustinen vertailu

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Opinnäytetyön tavoitteena oli laatia vertailutaulukko desibeliviemäreiden akustisista ominaisuuksista. Vertailutaulukkoon tarvittavat mittauspöytäkirjat hankittiin tuotteiden valmistajilta. Vertailutaulukkoa tarvitaan rakennusteollisuudessa puuttuvien ja monitulkinnallisten standardien sekä julkaisemattomien tutkimustulosten vuoksi.

Mittaukset on tehty Fraunhofer-instituutin mittauslaboratoriossa ja tulokset on esitetty akustiikkamittausraporteissa. Raportit esittivät desibeliputkien akustiset ominaisuudet laboratorio-olosuhteissa vertailukelpoisessa muodossa. Vertailutaulukon laatimiseen osallistui vapaaehtoisesti suurimpia alan toimijoita. Taulukosta puuttuvilla valmistajilla ei ollut vastaavaa vertailukelpoista akustiikkamittausraporttia tai valmistaja kieltäytyi yhteistyöstä.

Raportin teoriaosuudessa on käsitelty äänen peruskäsitteitä ja esitetty desibeliputken kannatuksen metodeja sekä merkitystä rakennuksen ilma- ja runkoääneen. Mittaukset on tehty virtaamilla 0,5 l/s, 1,0 l/s, 2,0 l/s ja 4,0 l/s, joista tärkein virtaama on 2,0 l/s, joka vastaa normaalia WC-istuimen tuottamaa virtaamaa.

Raportin mittaustuloksista ilmeni, että kannakkeilla ja niiden oikealla asennuksella voidaan vaikuttaa desibeliviemärin äänen tuottoon. Oikein asennettuna ääntä eristävällä kannakkeella voidaan saada useiden desibeleiden vaimennus. Mikäli viemärit on asennettu eristettyyn kuiluun, pelkästään oikealla kannakoinnilla voidaan teoriassa saada sama äänen vaimennus kuin käyttämällä desibeliputkea.

Avainsanat	desibeliputki, akustiikka, vertailutaulukko, Fraunhofer-instituutti

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The purpose of this thesis was to create a comparison table of the acoustic properties of decibel sewage pipes. The data used in the comparison table were obtained from the manufacturers of the products. A comparison table was needed in the constuction industry, because of missing and unclear standards, and unpublished testing reports of many of the products studied in this thesis.

To ensure that the results would be compareable, the data used in this thesis were acquired from acoustic test reports from the Fraunhofer institute produced in laboratory conditions, and conducted under supervision. Many of the largest manufacturers have participated in the comparison table voluntarily by providing the necessary information.

The thesis also discussed basic concepts of sound, the methods of supporting decibel pipes, and their impact on air and structure-born noise in buildings and structures.

The results of this thesis showed that in most cases, a correctly made supporting system can be used to affect the sound made by the decibel sewage installation as a properly installed support system can have damp the sound by several decibels. The effect of proper supporting system was calculated to be the same as that of decibel sewage pipes in an insulated shaft.

Keywords	decibel pipe, acoustic, comparison table, Fraunhofer

Sisällys

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Lyhenteet ja käsitteet

A-painotettu äänenpainetaso

L_{pA} on äänitasomittarin painotussuodattimella A mitattu äänenpainetaso, joka jäljittelee kuulon herkkyyden taajuusriippuvuutta dB(A)).

desibeli äänenvoimakkuutta kuvaava suhdeluku (dB).

desibeliasteikko

logaritminen asteikko, joka yhdistää äänenpaineen suhteelliset muutokset kuulon vasteeseen.

desibeliviemäri

viemäri, joka rakenteeltaan tai materiaaleiltaan vaimentaa käytöstä syntyvää tai johtuvaa ilma- tai rakenneääntä.

ekvivalenttiäänitaso

Keskiäänitaso, $L_{Aeq,T}$ on jatkuva vakioäänitaso, jonka tehollisarvo on sama kuin vaihtelevan äänitason keskimääräinen tehollisarvo määritellyllä ajanjaksolla. (dB)

ilmaääni äänilähteestä ympäristöön ilman välityksellä leviävä ääni.

ilmaääneneristävyys

Rakenteen ilmaäänien vaimennuskyvyn yksikkö. Riippuvainen mitattavien kohteiden äänenpainetasoista, rakenteen alasta sekä absorptioalasta.

jälkikaiunta-aika

Aika, jonka kuluessa äänilähteen tilaan tuottama äänenpainetaso äänilähteen vaiettua alenee 60 dB (s).

runkoääni kiinteän kappaleen johtama värähtely.

äänenpainetaso

äänen voimakkuuden suure, yksikkönä desibeli (dB).

äänitaso taajuudesta riippuvainen, havaittava äänen voimakkuus (dB).

äänitehotaso
äänilähteestä säteilevä äänienergian mitta suhteutettuna aikaan (dB).

ääntä vaimentava kannake
rakenteeltaan tai materiaaliltaan runkoäänen johtumista vaimentava yksiosainen kannake.

ääntä vaimentava tuplakannake
rakenteeltaan tai materiaaliltaan runkoäänen johtumista vaimentava kaksi- tai useampiosainen kannake.

1 Johdanto

Tämän opinnäytetyön tarkoituksena oli laatia vertailukelpoinen taulukko desibeliviemäreiden akustisista ominaisuuksista eri valmistajien välillä. Tarve vertailutaulukolle on ollut olemassa jo pitkään, mutta vertailukelpoisen taulukon laatiminen on osoittautunut haastavaksi tehtäväksi saatavilla olevan datan sekä yhteensopimattomien testimenetelmien vuoksi. Tämä opinnäytetyö on tehty REHAU Oy:n toimeksiantona, ja tarkoituksena oli tuottaa selkeä vertailutaulukko alan suunnittelijoille ja urakoitsijoille käytettäväksi desibeliputkien vertailussa. Tässä opinnäytetyössä käytetyt akustiikkaraportit ovat testiraportteja Fraunhofer-instituutista. Mittauspöytäkirjat on saatu suoraan tuotteiden valmistajilta tai tuotteiden jälleenmyyjiltä. Tutkimusraportit ovat edelleenkin salassa pidettäviä dokumentteja. Näiden julkaisuun kuitenkin saatiin lupa osallistuvilta valmistajilta sekä Fraunhofer-instituutilta sillä ehdolla, että mittausraportteja lähettävät tahot ovat tietoisia ehdoista, joilla mittausraportteja hyödynnetään tässä opinnäytetyössä.

2 Desibeliputket Suomessa

2.1 Desibeliputki

Desibeliputkeksi kutsutaan putkea, joka rakenteeltaan vaimentaa ilmaääntä tai äänen siirtymistä rakenteisiin. Suomessa desibeliputken käyttö on yleistynyt vasta noin 5 vuotta sitten rakennuksien kasvaneiden tarpeiden ja akustisten vaatimusten vuoksi. Desibeliputkia on eniten käytössä sairaaloissa, uusissa kerrostaloissa, julkisissa rakennuksissa ja kauppakeskuksissa. Rakennuksissa, joissa akustiselle suunnittelulle on asetettu tavanomaista korkeammat tavoitearvot, panostetaan myös enemmän viemäreiden aiheuttamien äänien vaimennukseen. Pientaloissa desibeliputkien käyttö ja tarve on vähäisempää.

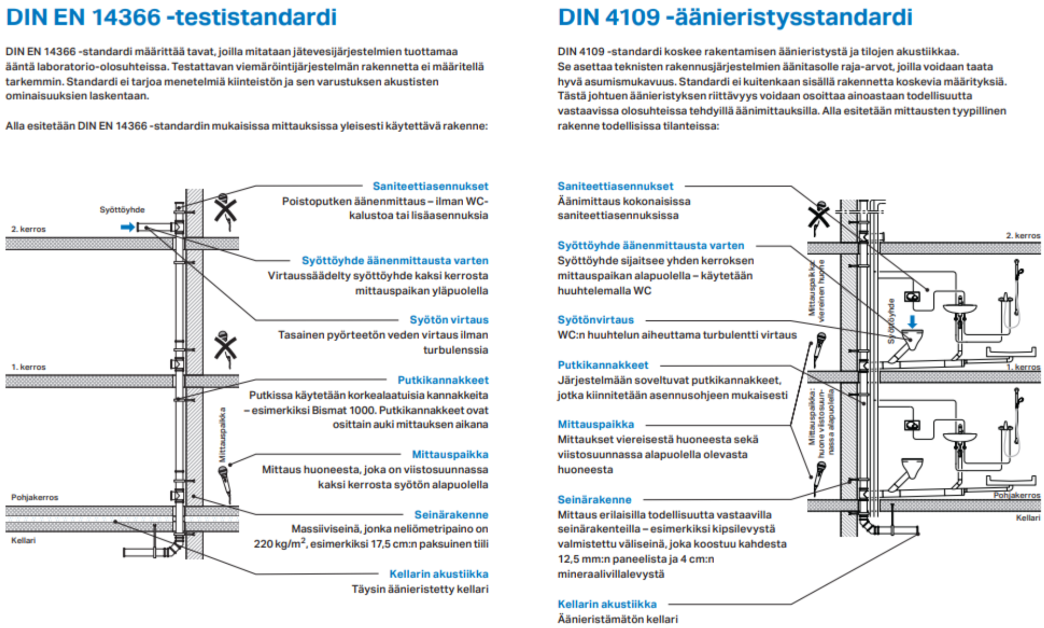
Ennen desibeliputkien yleistymistä Suomessa on käytetty laajasti valurautaista viemäriä, joka massiivisen rakenteensa vuoksi on toiminut ääntä vaimentavana ratkaisuna verrattuna tavalliseen muoviviemäriin. Desibeliputket muistuttavat ulkomuodoltaan muoviviemäriä. Käytetyt materiaalit ovat raskaampia, ja absorboivat hyvin syntyvää ääntä.

Viemäreistä peräisin oleva ääni syntyy pääasiassa putkessa virtaavan materiaalin aiheuttamasta paineenmuutoksesta sekä mekaanisesta värinästä, joka siirtyy ilma- ja rakenneäänenä viereisiin tiloihin. Desibeliputken materiaali vaimentaa ilmaääntä ja muoviviemäriä raskaamman rakenteensa vuoksi myös vähentää värinää. Tarkoituksenmukaiset putkiston kannakkeet myös vähentävät huomattavasti rakenteisiin siirtyvää mekaanista värinää.

Suomessa seurataan eurooppalaista standardia SFS-EN 14366:2005+A1:2019 akustisten ominaisuuksien selvittämiseksi laboratorio-olosuhteissa. Valmistajat käyttävät laajasti eurooppalaista DIN EN 14366 -testausstandardia, joka määrittää tavat jätevesiviemäreiden tuottaman äänen mittaamiseen laboratorio-olosuhteissa. [1]

2.2 Standardit

Desibeliviemäreiden testaukseen ja äänieritykseen käytetään standardeja DIN EN 14366, DIN 4109 ja VDI 4100. Standardit eroavat toisistaan monin tavoin. DIN EN 14366:n mukaan testattavan viemärijärjestelmän rakennetta ei määritellä, eikä standardi tarjoa menetelmiä kiinteistön ja sen varustuksen akustisten ominaisuuksien laskentaan. DIN 4109 ei sisällä rakennetta koskevia määrityksiä, jolloin mittaukset on suoritettava todellisuutta vastaavissa olosuhteissa realististen tulosten varmistamiseksi. VDI 4100 -standardissa esitetään arviointeja ja ehdotuksia tilojen välisen äänieristyksen parantamiseksi. [2] Testausmenetelmien eroavuuksia on esitetty kuvassa 1.



Kuva 1. DIN EN 14366- ja DIN 4109 -standardin mukaiset äänen mittaustavat.

3 Ääni

3.1 Äänen määritelmä

Ääni on kaasuissa ja nesteissä pitkittäin etenevä ja kiinteässä väliaineessa pitkittäinen tai poikittainen etenevä aaltoliike. Ilmaääni syntyy värähtelyn edetessä ilmassa ja runkoääni värähtelyn edetessä rakennuksen runko-osassa.

Ääni syntyy ilmanpaineen muutoksesta, aiheuttaen liikettä äänen lähtökohdasta alkaen. Ääniaallot värähtelevät eri taajuuksilla, jolloin niitä voidaan mitata taajuutena (Hz, 1/s). Mitä lyhyempi on aallonpituus, sitä korkeampi on taajuus. Äänivärähtelyn laajuus eli amplitudi määrittää äänen voimakkuuden. Mitä suurempi on äänivärähtelyn laajuus, sitä suurempia ovat amplitudi ja äänen voimakkuus. [3]

3.2 Äänen mittaaminen

Äänimittauksessa käytetään tätä tarkoitusta varten suunniteltuja mittalaitteita, joiden tarkkuus on osoitettu luotettavaksi. Mittalaitteiden täytyy olla kalibroituja ja tarkastettuja ennen äänimittauksia. Mittalaitteen tulee olla tarkoitettu käytettäväksi äänen mittauksessa vallitsevissa olosuhteissa.

Äänimittausmenetelmä riippuu mittauskohteesta ja tarkoituksesta. Meluhaittaa mitatessa ääntä mitataan alueelta, jossa melu kohdistuu. Tutkimustarkoituksissa ääntä mitataan tutkittavana olevalta alueelta. [4] Mittausmenetelmistä ja -laitteista on selostettu laajasti muun muassa Valviran asumisterveysasetuksen soveltamisohjeen osassa 2, pykälissä 11–13.

Äänen voimakkuutta mitataan desibeleissä. Ihmisen korva kuulee taajuudet 20–20 000 Hz, mutta herkimmin taajuudet 3 000–4 000 Hz. Ihmisen äänen herkkyydessä on suuria eroja henkilöiden välillä. Meluksi kutsutaan ääntä, joka koetaan epämiellyttäväksi ääneksi. [5]

4 Kannatukset ja kiinnitykset

4.1 Kannatuksen asetus

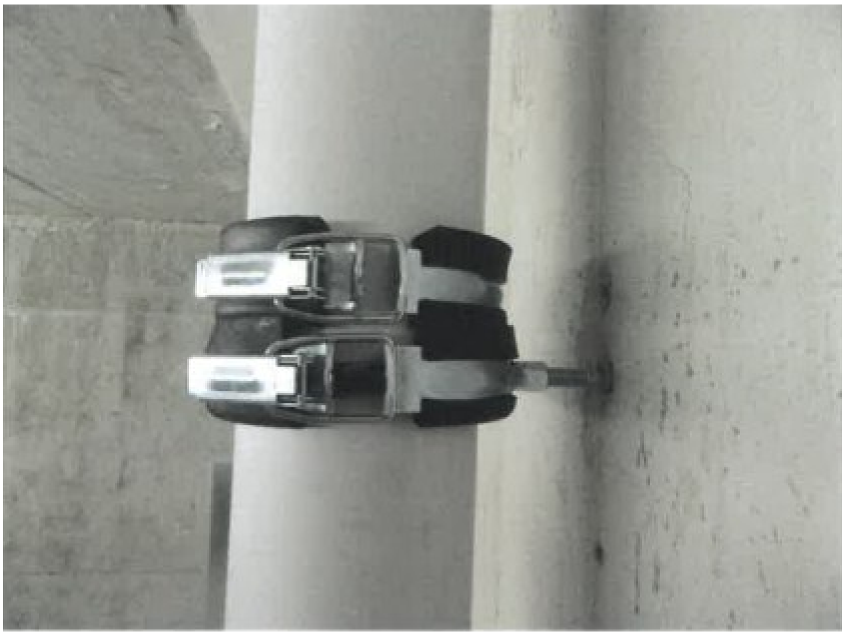
Viemäreiden kannatus tulee olla kiinnitetty rakenteisiin siten, etteivät mekaanisesti vaikuttavat tekijät tai mahdollinen lämpölaajeneminen, pääse aiheuttamaan haitallisia muutoksia viemäreihin tai niiden rakenteeseen. Mikäli viemärin kuljettaman materiaalin aiheuttama voima viemäriin on suurempi kuin viemärin kannatuksen kannatuskyky, tulee viemäri ankkuroida rakenteeseen. Kaikkien viemärin kannattamisessa käytettävien komponenttien tulee olla tarpeenmukaiset ympäristöönsä nähden sekä säilyä ilman korroosiovaurioita. [6]

Kannatuksen on oltava tarpeeksi kestävä kestääkseen putkien, venttiilien, kanavien, nesteiden, eristeiden sekä mahdollisten muiden sisäisten ja ulkoisten kuormituksien tuoma rasite. Ääniteknisesti huomioitavissa kannatuksissa on otettava huomioon putkien ja kanavien eristäminen rakenteista ja kannakkeista. [7] Kannatusmenetelmiä on kuvattu laajemmin LVI-kortissa 12 - 10370

4.2 Kannatusmenetelmät

Fraunhofer-instituutin tutkimusraporteissa mainittu referenssikannake koostuu kiristettävästä teräskannakkeesta kumisella sisäkkeellä [1]. Eri valmistajilla on omat tuotteensa, jotka ovat usein variaatioita referenssikannakkeesta.

Tuplakannake koostuu kahdesta kannakkeesta, joista toinen kannake on kiristetty putkeen mutta ei ole fyysisesti kiinnitetty seinään. Tämä kannake on toisen kannakkeen varassa, joka on fyysisesti kiinnitetty kiintopisteeseen, mutta on osittain irti kannatettavasta putkesta. Tämä vähentää huomattavasti rakenteisiin aiheutuvaa tärinää putken käytön aikana. [1] Esimerkki tuplakannakkeesta on esitetty kuvassa 2.



Kuva 2. Ääntä vaimentava tuplakannake

Referenssikannakkeen kaltainen erikoiskannake koostuu kiristettävästä ulkoreunasta ja putkea ympäröivästä tärinää absorboivasta pehmokumisisäkkeestä [4]. Esimerkki tällaisesta kannakkeesta on esitetty kuvassa 3.

Kuva 3. POLIclamp-erikoiskannake.

4.3 Kannatuksen vaikutus ja erot mittauksissa

Desibeliviemäreissä kannatuksella on suuri merkitys. Referenssikannakkeella mitattuna desibeliarvot ovat suurimmilta osin 3 dB:n epävarmuuskertoimen sisäpuolella. Valmistajien kehittämillä kannakkeilla on huomattava osuus desibeliviemärin tuottaman äänen vaimentamisessa. [7]

5 Fraunhofer-instituutti

Fraunhofer-instituutti on saksalainen tekniikan tutkimusyhteisö. Fraunhofer-instituutissa suoritetaan useita standardien mukaisia mittauksia ja tutkimuksia lähes 70 tutkimuslaitoksessa. [9]

5.1 Testausstandardit

Fraunhofer-instituutti noudattaa akustiikkamittauksissa DIN EN 14366 -standardia mittausten ja laboratorio-olosuhteiden osalta sekä DIN 4109 -standardia yksiosaisten kiinteiden seinien massan 220 kg/m^2 osalta [1]. Standardin EN 14366 mukaisesti toteutetut mittaukset soveltuvat ainoastaan pystykokoojaviemärille. Muita, esimerkiksi WC-tilasta syntyvää melua ei oteta mittauksissa huomioon. [8]

5.2 Mittausten luotettavuus

Fraunhofer-instituutti on akkreditoitu DIN EN ISO/IEC 17025:2005 mukaan DAkkS:n toimesta [9]. Mittauspöytäkirjat ovat tämän opinnäytetyön liitteinä.

Fraunhofer-instituutti on julkaissut huomiokirjeen koskien ennen vuotta 2013 suorittuja akustiikkamittauksia. Valmistajat ovat voineet antaa erilaisia vaatimuksia mittausten suorittamiseen, kuten kannakkeiden sijaintien ja asennustapojen muutoksia. Tästä syystä Fraunhofer-instituutti on ottanut käyttöön uusia käytäntöjä testirakenteisiin poiketen EN 14366 -standardista parantaakseen tulosten vertailukelpoisuutta. [8]

Vuodesta 2014 Fraunhofer-instituutti on tarjonnut ylimääräistä mittausta IBP:n määrittelemällä referenssikannakkeella. Referenssikannake on normaali teräskannake kumisisäkkeellä. Referenssikannakkeiden asennustapa pysyy vakiona, ja kannakkeille suoritetaan vertailumittauksia mahdollisten ääniteknisten ominaisuuksien muutoksen varalta. [8]

Fraunhofer-instituutti on todennut ennen vuotta 2013 tehtyjen mittausten tulokset vertailukelvottomiksi suurien poikkeamien ja väärinkäytön vuoksi. Jos kuitenkin ennen vuotta 2013 tehtyjä pöytäkirjoja on tarpeellista käyttää, tulee niissä kiinnittää huomiota kannakkeisiin ja niiden asennustapaan. [8]

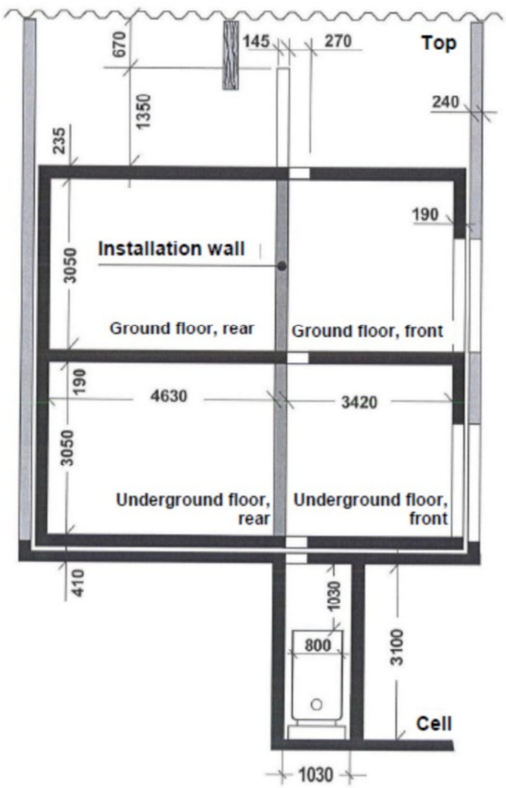
Ennen vuotta 2013 tehtyjä testejä, joissa on maininta valmistajan suorasta osallistumisesta akustiikkamittausten suorituksen kannalta oleellisiin osa-alueisiin, ei esitetä vertailutaulukossa tulosten mahdollisen manipuloinnin vuoksi. [8]

5.3 Testausolosuhteet

Fraunhofer-instituutin akustiikkatestauslaboratorio koostuu kahdesta päällekkäin olevasta huoneesta sekä pohjakerroksesta. Useamman kerroksen lävistäviä asennuksia voidaan testata kellarin ja ylimmän kerroksen välillä. [1] Kuvassa 4 on esitetty leikkauskuva rakenteesta.

Mittauspisteet on sijoitettu kerroksien välissä olevan seinän taakse runkoäänen mittausta varten (DG, EG rear, UG rear, KG) sekä avoimeen tilaan pystykokoojaviemärin eteen ilmaääntä varten (EG front, UG front). Mittauksilla saadaan tarkka tulos kerrosten sisäisestä sekä välisestä äänen tuotosta. Mittauspisteet on esitetty kuvassa 5.

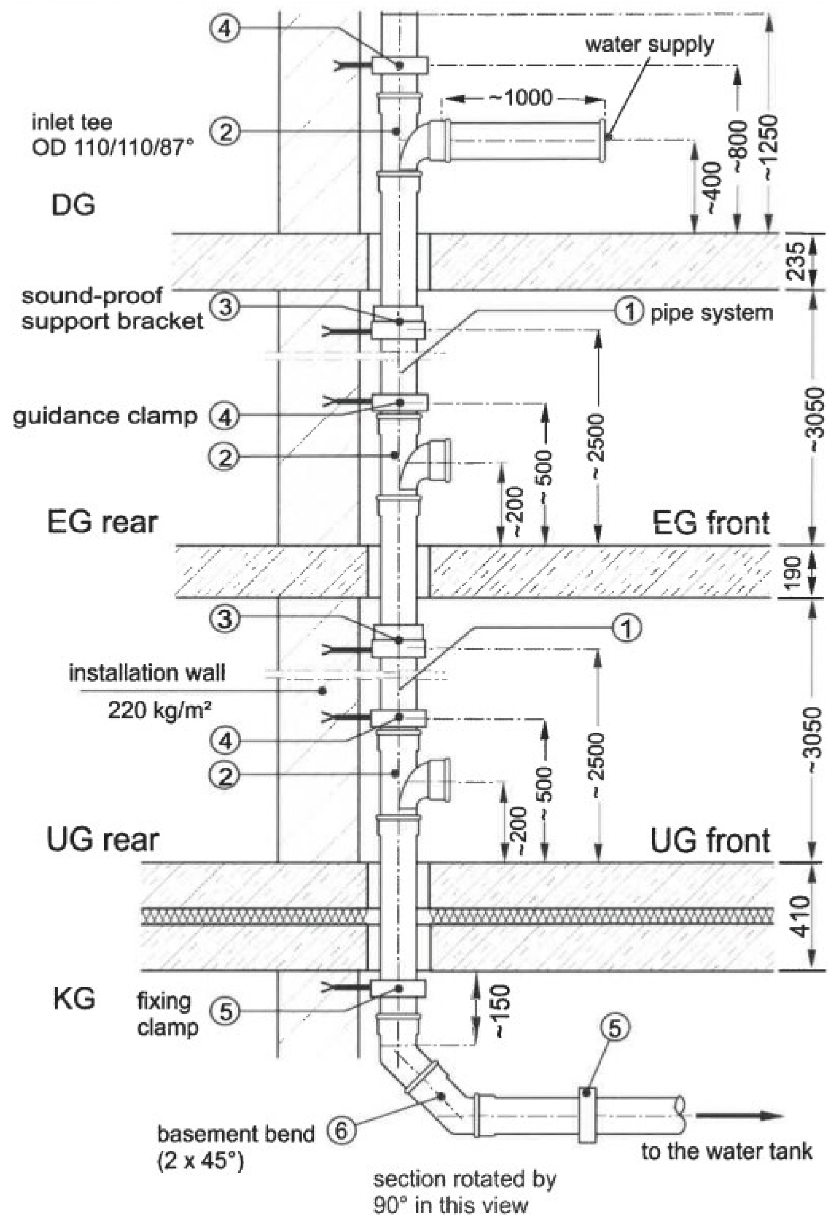
Mittaukset suoritetaan neljällä virtaamalla (0.5 l/s, 1.0 l/s, 2.0 l/s ja 4.0 l/s) Mittausolosuhteet ja mittauspisteet säilyvät eri mittauksissa vakiona. Mittauksen kohteena oleva järjestelmä ja kannakointi saattavat muuttua valmistajan ja mitattavan kohteen mukaan.



Kuva 4. Havaintokuva mittauslaboratoriosta. Mitat millimetreinä.

5.4 Mittauksen kohteena olevan putkiston rakenne

Pystyviemäri kootaan mittausta varten identtisesti testien välissä. Viemärin yläpäässä on vaakatasossa säädettävä veden syöttö, kellarikerroksessa veden ulostulo. [1] Esimerkki rakennelmasta on esitetty kuvassa 5.



Kuva 5. Esimerkki putkiston aiheuttaman äänen mittauksesta. Mitat millimetreinä.

5.5 Raportin tulkinta

Uudemmissa, vuoden 2013 jälkeisissä mittauspöytäkirjoissa on ilmoitettu äänen taso EN 14366:n, DIN 4109:n ja VDI 4100:n mukaan virtaamilla 0,5 l/s, 1,0 l/s, 2,0 l/s, 4,0 l/s.

Ennen vuotta 2013 tehdyissä tutkimuksissa äänen taso on ilmoitettu vain EN 14366:n mukaisesti. Poikkeuksena on mittauspiste UG rear, joka on rakenteeltaan DIN 4109:n mukainen. [1]

6 Vertailukohteet

6.1 Yritykset

Tässä opinnäytetyössä esitetään Fraunhofer-instituutin tulokset alan suurimmista toimijoista, jotka ovat suostuneet luovuttamaan mittauspöytäkirjansa vertailtavaksi. Vertailusta puuttuvilla toimijoilla ei ole ollut luovutettavaa vertailukelpoista aineistoa tai aineistoa ei ole haluttu luovuttaa vertailutaulukkoon.

6.2 Vertailukohteiden tasavertaisuus

Vertailussa on tarkasteltu Fraunhofer-instituutin tuloksia desibelien ja virtaaman osalta. Tärkein vertailukohta on 2 l/s, joka vastaa normaalia WC-istuimen tuottamaa virtaamaa. Suurimman äänentuoton vuoksi myös virtaama 4 l/s on suunnittelijoita ja urakoitsijoita kiinnostava tieto. [1] Vertailutaulukkoon on merkattu tuotteen valmistaja, tuotteen nimi sekä mittauksessa käytetty kannake. Taulukossa on mukana valmistajia, joiden testit on suoritettu ennen vuotta 2013. Näissä tuloksissa on jätetty kirjaamatta ne testien osat, joissa on ilmoitettu valmistajan itse asentaneen tai muutoin suorasti vaikuttaneen testattavan putkiston kannakointiin tai asentamiseen. Päätös perustuu Fraunhofer-instituutin ilmoitukseen mahdollisesta manipulaatiosta akustiikkamittausten tuloksiin. [8]

Mittausten tulokset ovat riippuvaisia käytetyistä kannakkeista ja asennusolosuhteista. Pystyrungon vertikaalinen suoruus, kulmien asema ja muhvien oikea asennus voivat vaikuttaa tuloksiin usean desibelin verran. [1] Vertailussa ilmoitetuista tuloksista edellä mainitut osuudet oli tarkastettu Fraunhofer-instituutin toimesta. Mittaukseen käytetyt laitteet on eritelty Fraunhofer-instituutin raportissa liitteessä 1. Mittauslaitteisto on myös esitetty taulukossa 1.

Taulukko 1. Fraunhofer-instituutin mittauslaitteisto

Fraunhofer-Institut für Bauphysik Annex P

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.

7 Tulokset

7.1 Vertailutaulukko

Tuloksista johdettu vertailutaulukko on esitetty alla taulukossa 2. Taulukon osiot ovat virtaamakohtaiset. Vertailutaulukossa käytettävä putkikoko on 110. Mittapisteiden sijainnit on esitetty kuvassa 5. Tuloksista johdetut standardi- ja mittapistesijaintikohtaiset käyrästöt ääntä eristävillä kannatuksilla on esitetty seuraavissa kuvissa 6–11 vakiokannakkein.

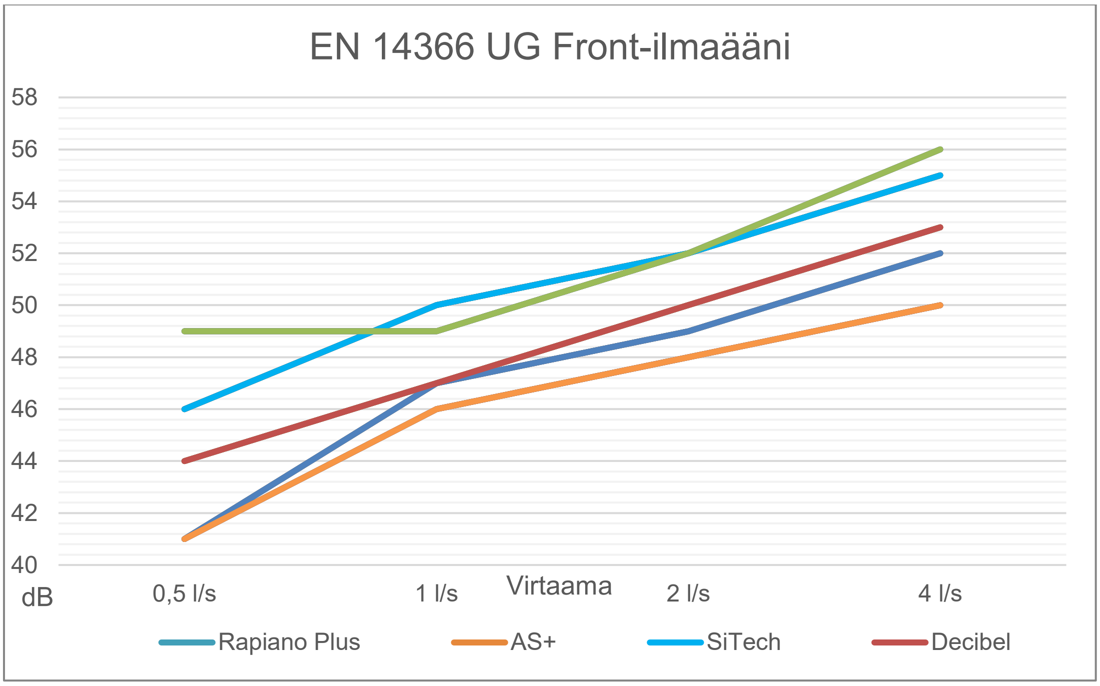
Taulukko 2. Desibeliputkien akustinen vertailutaulukko

Virtaama 0.5 l/s	DN 110					
Sijainti ja standardi	**REHAU**	**Wavin**	**Wavin**	**Wavin**	**Uponor**	**Poliplast**
Tuote ->	Raupiano Plus	AS+	AS+	SiTech	Decibel	dBlue
Kannake ->	Ääntä vaimentava tuplakannake	Ääntä vaimentava tuplakannake	Ääntä vaimentava kannake	Ääntä vaimentava kannake	Ääntä vaimentava kannake	Ääntä vaimentava kannake
EN 14366						
UG front ilmaääni	41 dB	41 dB	41 dB	46 dB	44 dB	49 dB
UG rear rakenneääni	< 10 dB	<10 dB	<10 dB	<10 dB	<10 dB	15 dB
DIN 4109						
UG front runkoääni	41 dB	41 dB	41 dB	46 dB	44 dB	49 dB
UG rear runkoääni	< 10 dB	<10 dB	<10 dB	<10 dB	<10 dB	13 dB
VDI 4100						
UG front runkoääni	39 dB	38 dB	39 dB	44 dB	42 dB	-
UG rear runkoääni	< 10 dB	<10 dB	<10 dB	<10 dB	<10 dB	-

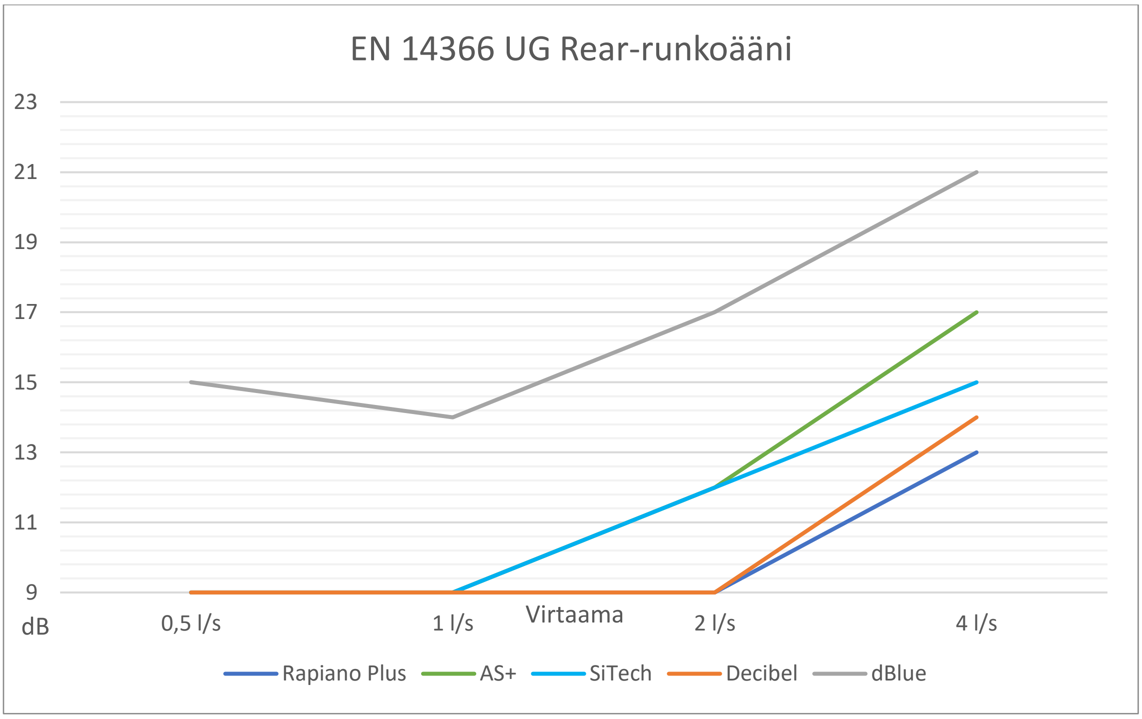
Virtaama 1.0 l/s	DN 110					
Sijainti ja standardi	**REHAU OY**	**Wavin**	**Wavin**	**Wavin**	**Uponor**	**Poliplast**
	Raupiano Plus	AS+	AS+	SiTech	Decibel	dBlue
Kannake ->	Ääntä vaimentava tuplakannake	Ääntä vaimentava tuplakannake	Ääntä vaimentava kannake	Ääntä vaimentava kannake	Ääntä vaimentava kannake	Ääntä vaimentava kannake
EN 14366						
UG front ilmaääni	47 dB	45 dB	46 dB	50 dB	47 dB	49 dB
UG rear rakenneääni	< 10 dB	<10 dB	<10 dB	11 dB	<10 dB	14 dB
DIN 4109						
UG front runkoääni	47 dB	45 dB	46 dB	50 dB	47 dB	49 dB
UG rear runkoääni	< 10 dB	10 dB	<10 dB	15 dB	<10 dB	11 dB
VDI 4100						
UG front runkoääni	45 dB	43 dB	43 dB	47 dB	45 dB	-
UG rear runkoääni	< 10 dB	<10 dB	<10 dB	11 dB	<10 dB	-

Virtaama 2.0 l/s	DN 110					
Sijainti ja standardi	**REHAU OY**	**Wavin**	**Wavin**	**Wavin**	**Uponor**	**Poliplast**
	Raupiano Plus	AS+	AS+	SiTech	Decibel	dBlue
Kannake ->	Ääntä vaimentava tuplakannake	Ääntä vaimentava tuplakannake	Ääntä vaimentava kannake	Ääntä vaimentava kannake	Ääntä vaimentava kannake	Ääntä vaimentava kannake
EN 14366						
UG front ilmaääni	49 dB	48 dB	48 dB	52 dB	50 dB	52 dB
UG rear rakenneääni	< 10 dB	12 dB	<10 dB	12 dB	<10 dB	17 dB
DIN 4109						
UG front runkoääni	49 dB	48 dB	48 dB	52 dB	50 dB	52 dB
UG rear runkoääni	13 dB	14 dB	<10 dB	15 dB	13 dB	15 dB
VDI 4100						
UG front runkoääni	47 dB	45 dB	45 dB	49 dB	48 dB	-
UG rear runkoääni	10 dB	11 dB	<10 dB	12 dB	10 dB	-

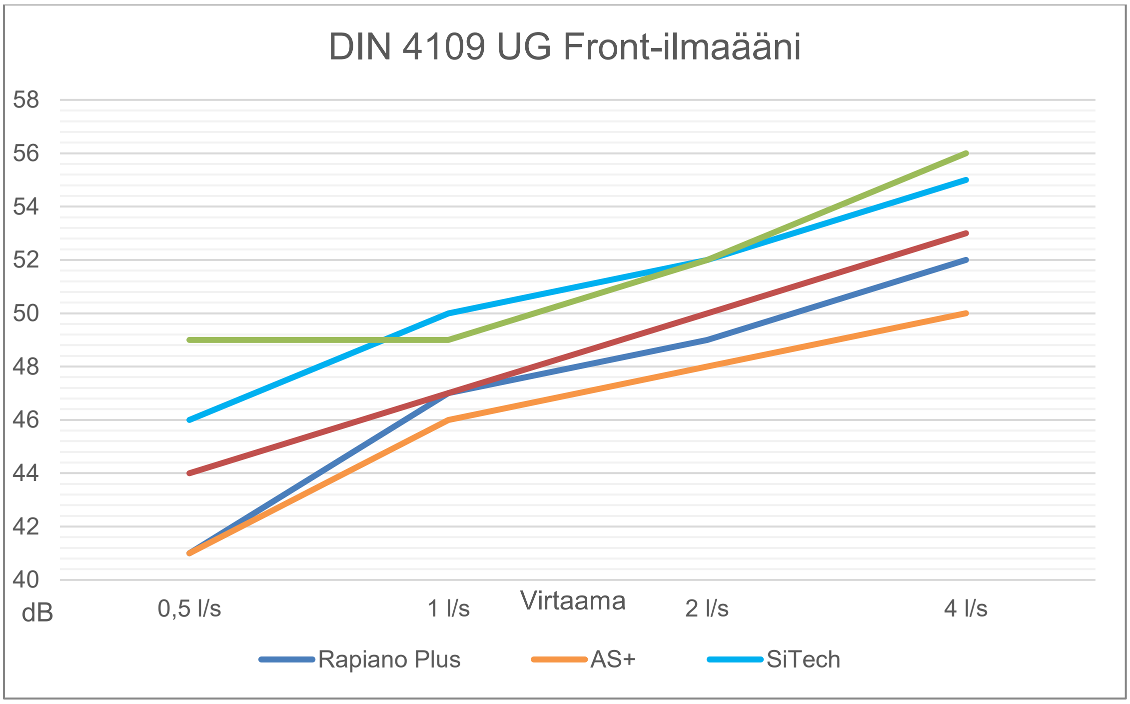
Virtaama 4.0 l/s	DN 110					
Sijainti ja standardi	**REHAU OY**	**Wavin**	**Wavin**	**Wavin**	**Uponor**	**Poliplast**
	Raupiano Plus	AS+	AS+	SiTech	Decibel	dBlue
Kannake ->	Ääntä vaimentava tuplakannake	Ääntä vaimentava tuplakannake	Ääntä vaimentava kannake	Ääntä vaimentava kannake	Ääntä vaimentava kannake	Ääntä vaimentava kannake
EN 14366						
UG front ilmaääni	52 dB	50 dB	50 dB	55 dB	53 dB	56 dB
UG rear rakenneääni	13 dB	10 dB	17 dB	15 dB	14 dB	21 dB
DIN 4109						
UG front runkoääni	52 dB	50 dB	50 dB	55 dB	53 dB	56 dB
UG rear runkoääni	17 dB	13 dB	19 dB	19 dB	19 dB	19 dB
VDI 4100						
UG front runkoääni	49 dB	48 dB	48 dB	53 dB	50 dB	-
UG rear runkoääni	14 dB	10 dB	16 dB	15 dB	15 dB	-



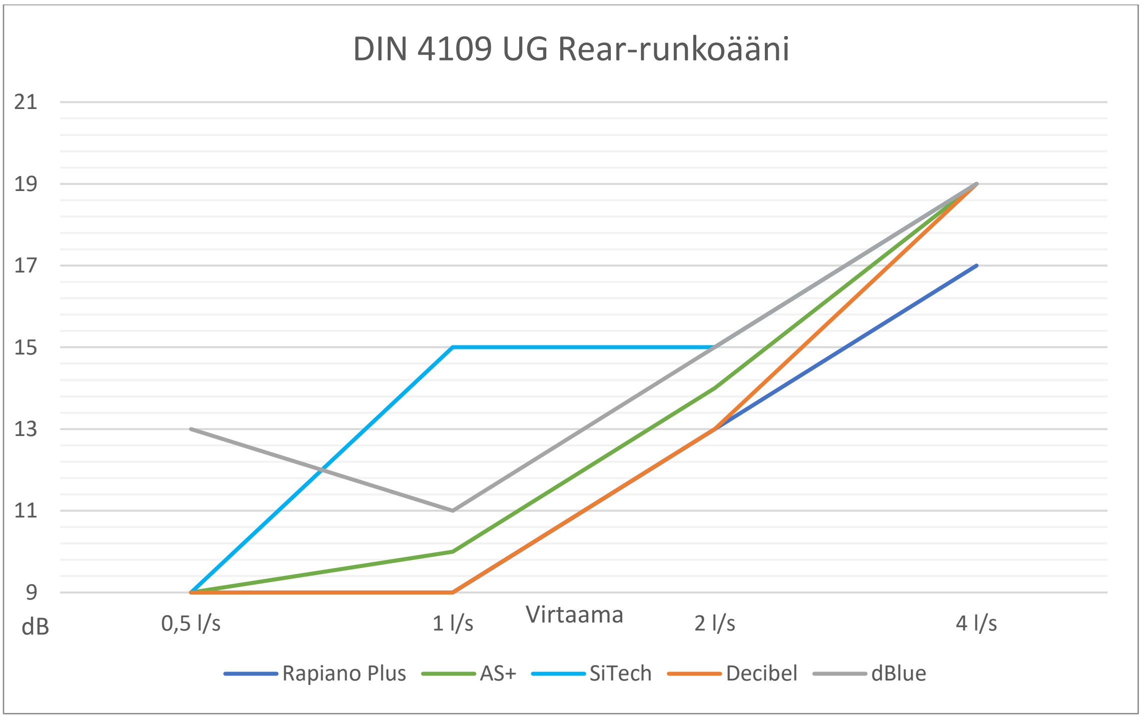
Kuva 6. Standardin EN 14366 mukainen äänenpainetaso mittauspisteestä UG-Front ääntä vaimentavalla kannatuksella.



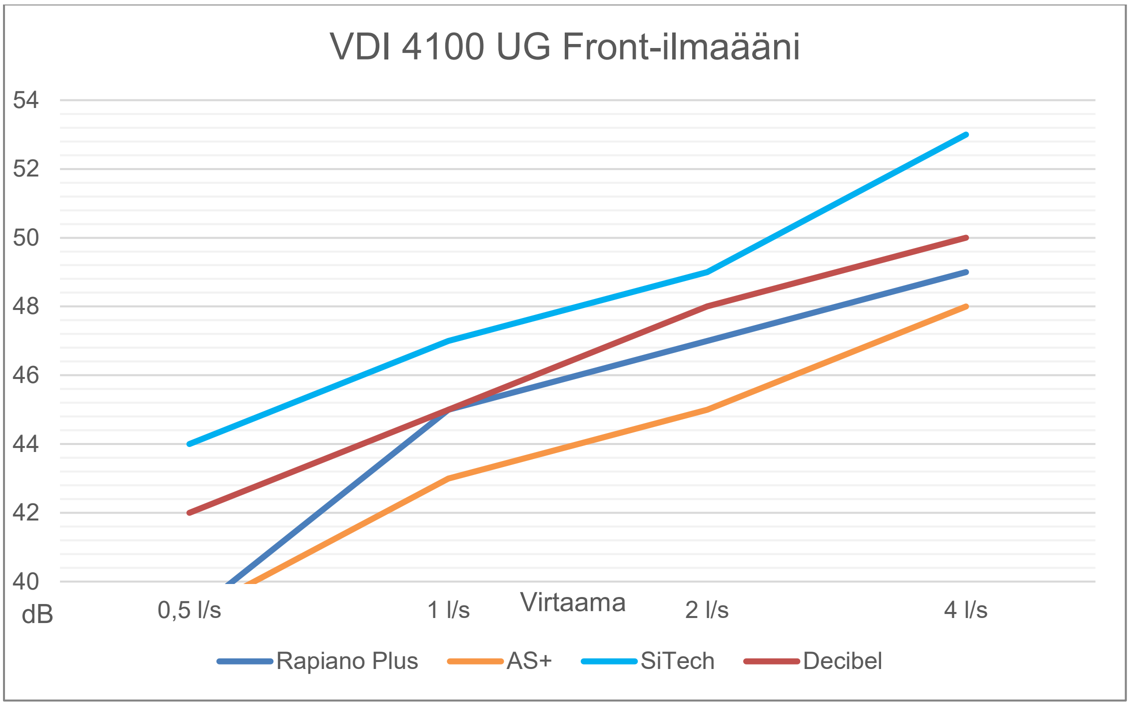
Kuva 7. Standardin EN 14366 mukainen äänenpainetaso mittauspisteestä UG-Rear ääntä vaimentavalla kannatuksella.



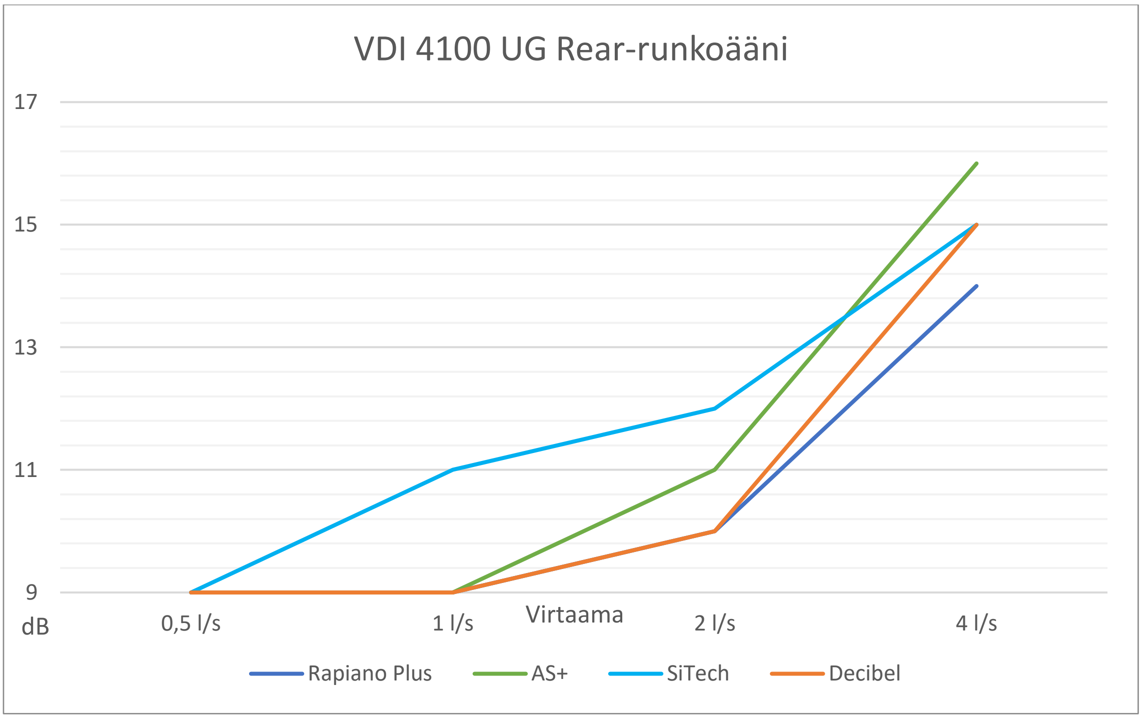
Kuva 8. Standardin DIN 4109 mukainen äänenpainetaso mittauspisteestä UG-Front ääntä vaimentavalla kannatuksella.



Kuva 9. Standardin DIN 4109 mukainen äänenpainetaso mittauspisteestä UG-Rear ääntä vaimentavalla kannatuksella.



Kuva 10. Standardin VDI 4100 mukainen äänenpainetaso mittauspisteestä UG-Front ääntä vaimentavalla kannatuksella.



Kuva 11. Standardin VDI 4100 mukainen äänenpainetaso mittauspisteestä UG-Rear ääntä vaimentavalla kannatuksella.

7.2 Tulosten tulkinta

Tuloksista on nähtävissä desibelierot tuotteiden ja virtaamien välillä. Suurin merkitys tuotetun äänen vähentämisessä on kannatuksella sekä oikealla asennustavalla. Fraunhofer-instituutin asiantuntijalausunnon mukaan useimmiten, valmistajasta riippumatta, tulosten ääniarvot ovat 3 desibelin epävarmuuskertoimen sisällä toisistaan. [8] Akustiikkamittausraportit, joista tulokset on tehty, on liitetty liiteluetteloon. Akustiikkamittauksissa käytetyt valmistajan omat erikoiskannakkeet sekä testilaboratorion omat kannakkeet luokitellaan molemmat ääntä vaimentaviksi kannakkeiksi.

Taulukossa mainitut standardin EN 14366 UG-Front mukaiset mittaustulokset ovat mitatut ilmaäänet. EN 14366 UG-Rearin mukaiset mittaustulokset ovat rakenneääniä pystykokoojaviemärin kannatusseinän takaa. Muut standardit sisällyttävät ilma- ja rakenneäänet samaan mittaustulokseen, mittauspistekohtaisesti. Mittauspisteet säilyvät vakiona standardeista riippumatta. Mittaustapa näkyy taulukossa 2, sarakkeessa 1.

Virtauksen aiheuttama äänentuotto näkyy selvimmin ilmaäänenä standardin EN 14366 mukaisesti, mittauspisteestä UG/EG-Front. Kannakkeen tai rakenteen läpi johtuvaa värähtelyä on havaittavissa selvimmin standardin EN 14366 mittauspisteestä UG/EG-Rear.

8 Päätelmä

Suomessa noudatetaan ympäristöministeriön asetusta 796/2017 melun ja tärinän torjumisessa rakennuksissa, mikä antaa taloteknisille laitteistoille asetuksen äänen tuotosta. Suomessa käytetään eurooppalaisia SFS EN -standardeja sekä kansallisia VDI-standardeja. Yritykset tuottavat tuotteilleen akustiikkamittaukset ulkomailla, mikä mahdollistaa ilmoitettavien tulosten epärelevanttisuuden kaupallisessa tarkoituksessa, tarkoittaen että markkinoinnissa ollaan harmaalla alueella. Markkinoitavasta tuotteesta voidaan ilmoittaa tutkimustuloksia, jotka eivät ole relevantteja myytävään tarkoitukseen nähden. Fraunhofer-instituutti on myöntänyt akustiikkatestauksiin liittyvien testien tulosten manipuloinnin olleen mahdollista Fraunhoferin testilaboratoriossa ennen vuotta 2013.

Desibeliviemäriä valitessa tulee kiinnittää huomiota oikeaan asennukseen. Materiaalilla on merkitystä tiettyyn pisteeseen asti, minkä jälkeen oikealla asennuksella voidaan vaikuttaa lopulliseen tulokseen. Ääntä vaimentavalla kannakkeella voidaan saada useiden desibelien vaimennus oikein asennettuna. Mikäli viemärit on asennettu eristettyyn kuiluun, pelkästään oikealla kannakoinnilla voidaan teoriassa saavuttaa sama äänen vaimennus kuin käyttämällä desibeliputkea.

Lähteet

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Fraunhofer-instituutti REHAU AG+CO Raupiano Plus, akustiikkamittausraportti

Fraunhofer-instituutin suorittama akustiikkamittausraportti Rehau Raupiano Plus -desibeliviermärille ääntä vaimentavilla kannakkeilla.

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 274/2016e

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

Client: Rehau AG + CO
Rheniumhaus
Otto-Hahn-Str. 2
95111 Rehau
Germany

Test object: Wastewater installation system consisting of plastic pipes and fittings "Rehau Raupiano Plus" (OD 110 x 2.7, manufacturer: Rehau AG + CO) with the corresponding fixing system "Sound-dampening bracket".

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 December 7, 2016 in the test facilities of the Fraunhofer Institute for Building Physics in Stuttgart.

Stuttgart, July 4, 2017

Responsible Test Engineer: Head of Laboratory:

M.Sc. B. Kaltbeitzel   MBP 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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www.ibp.fraunhofer.de/de/pruefstellen/bauakustik.html

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

Determination of the Acoustic Performance of a Wastewater Installation System in the Laboratory	P-BA 274/2016e Results sheet 1

Client: Rehau AG + CO, Rheniumhaus, Otto-Hahn-Str. 2, 95111 Rehau, Germany

Test specimen: Wastewater installation system consisting of plastic pipes and fittings "Rehau Raupiano Plus" (OD 110 x 2.7, manufacturer: Rehau AG + CO) with the corresponding fixing system "Sound-dampening bracket". (test object no.: 11035-02)

Test set-up: The pipe system was mounted according to figure 4 and 5 (see also Annex A).

- The pipe system "Rehau Raupiano Plus" consisted of straight wastewater pipes with the nominal size OD 110 x 2.7, with three layers of PP-MD (inner and outer layer) and PP mineral reinforced (middle layer), wall thickness 3.0 mm, density 1.8 g/cm³, weight 1.9 kg/m (measured by IBP). Single layer fittings size OD 110 (three inlet tees 87.5°, arched, two 45°-basement bends), material PP mineral reinforced, wall thickness 3.1 mm, density 1.9 g/cm³ (measured by IBP). The inlet tees in the basement and in the ground floor were closed by lids. Plug connection of the pipes and fittings (shaped pipe sockets).
- Corresponding fixing system: "Sound-dampening bracket", consisting of a supporting/guidance clamp with a socket clamp and a single guidance clamp (all with quick-locking mechanism). In every storey (EG and UG) two pipe clamps were mounted: In the upper wall area a "Sound-dampening bracket" consisting of a supporting/guidance clamp and a socket clamp and in the lower wall area a single guidance clamp. The supporting and guidance clamps were fixed (without contact to the pipe) 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 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:

Wastewater installation system consisting of plastic pipes and fittings "Rehau Raupiano Plus" (OD 110 x 2.7, manufacturer: Rehau AG + CO) with the corresponding fixing system "Sound-dampening bracket".		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	41	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	< 10	13
Installation sound level $L_{AFeq,n}$ [dB(A)] **following DIN 4109** in the basement test-room	UG front	41	47	49	52
	UG rear	< 10	< 10	13	17
Installation sound level $\overline{L_{AFeq,nT}}$ [dB(A)] **following VDI 4100** in the basement test-room	UG front	39	45	47	49
	UG rear	< 10	< 10	10	14

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

Test date: December 7, 2016

Notes:

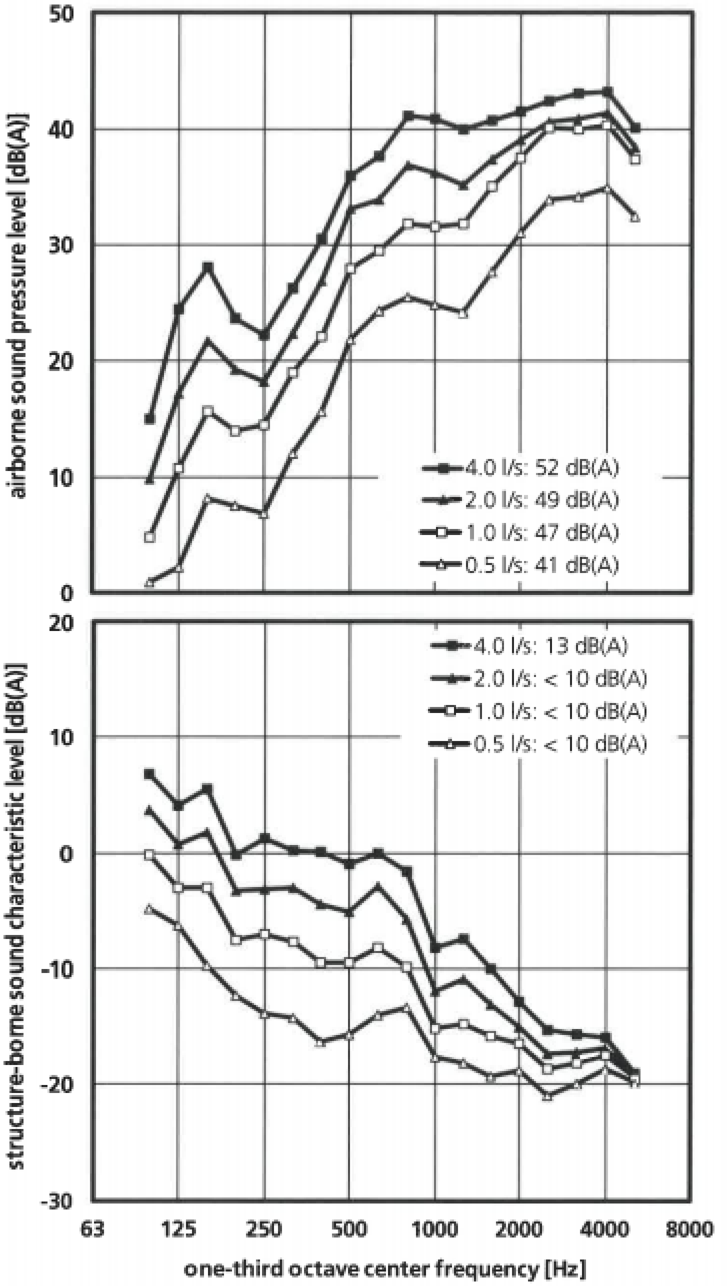
- For comparing test results with requirements note Annex A.
- Sound levels below 10 dB(A) are not mentioned in the test report, since they are subject to an increased measurement uncertainty and moreover are not noticeable in a normal living environment.
- The test results require an accurate installation of the pipe clamps (see test set-up)

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, July 4, 2017
Head of Laboratory:

Detailed results	P-BA 274/2016e
Client: Rehau AG + CO, Rheniumhaus, Otto-Hahn-Str. 2, 95111 Rehau, Germany	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 "Rehau Raupiano Plus" (OD 110 x 2.7, manufacturer: Rehau AG + CO) with the corresponding fixing system "Sound-dampening bracket".

Fraunhofer IBP

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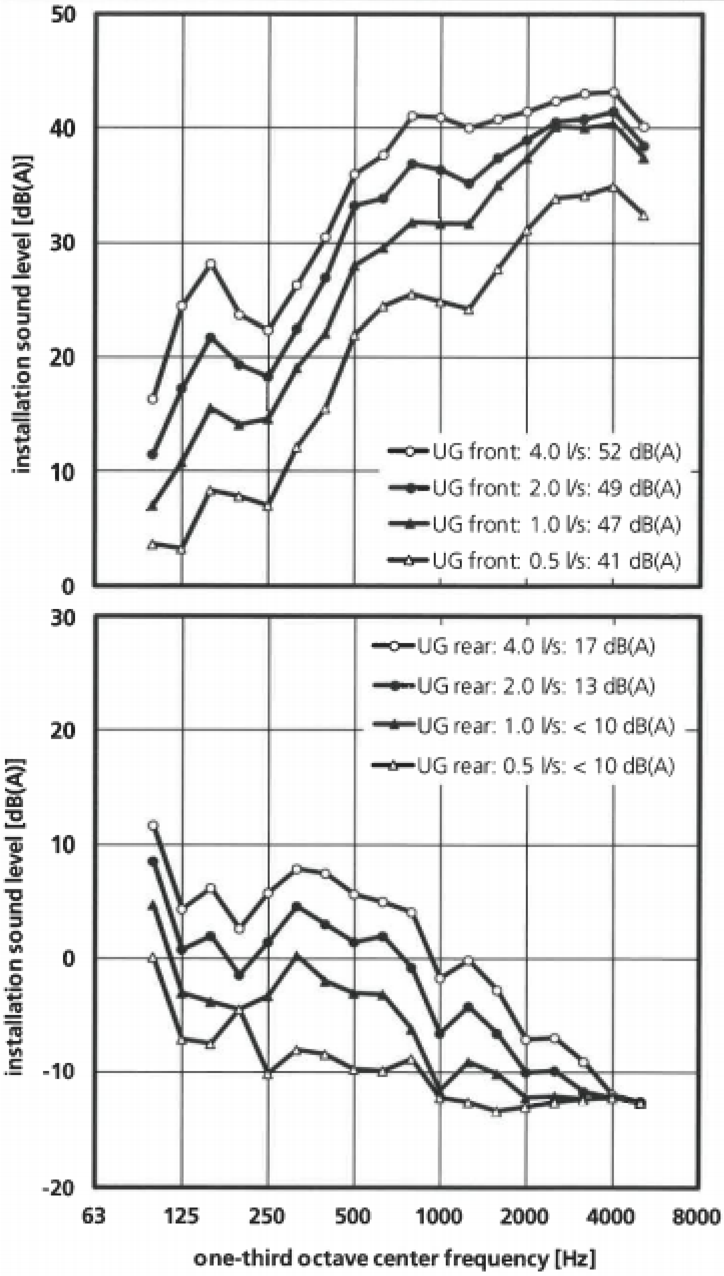
Detailed results | **P-BA 274/2016e**

Client: Rehau AG + CO, Rheniumhaus, Otto-Hahn-Str. 2, 95111 Rehau, Germany | **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 "Rehau Raupiano Plus" (OD 110 x 2.7, manufacturer: Rehau AG + CO) with the corresponding fixing system "Sound-dampening bracket".

Fraunhofer IBP

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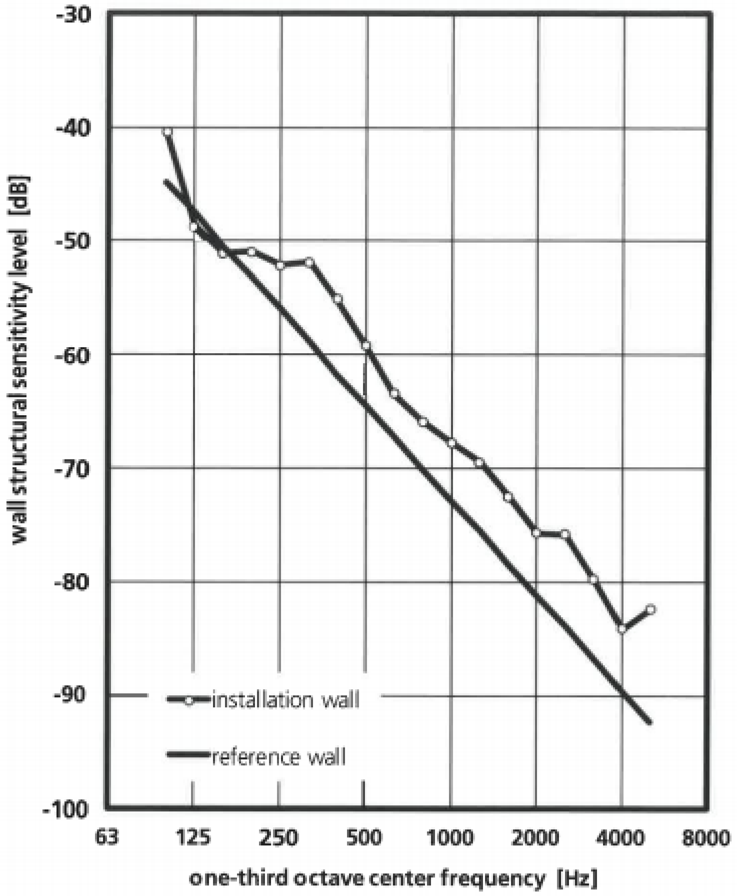
Detailed results Client: Rehau AG + CO, Rheniumhaus, Otto-Hahn-Str. 2, 95111 Rehau, Germany	P-BA 274/2016e figure 3

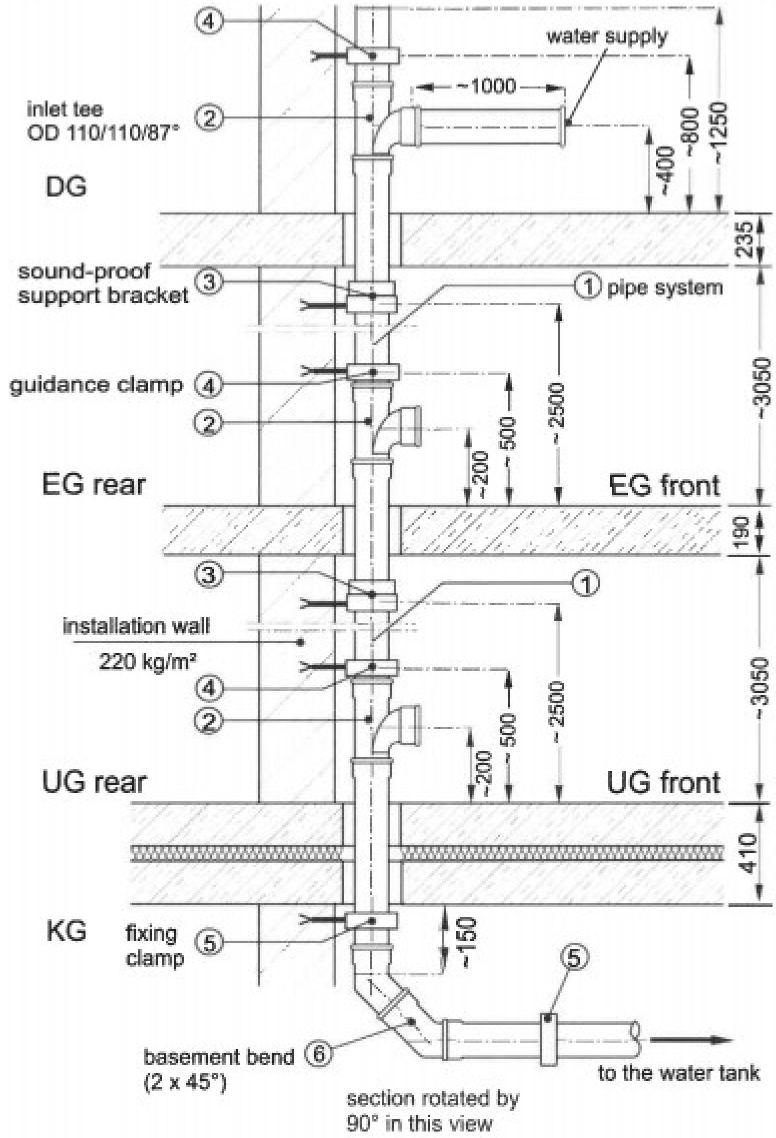


Wall structural sensitivity level L_{SS} of the installation wall between the test rooms UG front and UG rear in the installation test facility in the Fraunhofer-Institute of Building Physics. The installation wall consists of calcium silicate blocks (thickness 115 mm, ceiled on both sides) with a mass 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 "Rehau Raupiano Plus" (OD 110 x 2.7, manufacturer: Rehau AG + CO) with the corresponding fixing system "Sound-dampening bracket".

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.

Detailed results Client: Rehau AG + CO, Rheniumhaus, Otto-Hahn-Str. 2, 95111 Rehau, Germany	P-BA 274/2016e figure 4



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

Test specimen: Wastewater installation system consisting of plastic pipes and fittings "Rehau Raupiano Plus" (OD 110 x 2.7, manufacturer: Rehau AG + CO) with the corresponding fixing system "Sound-dampening bracket".

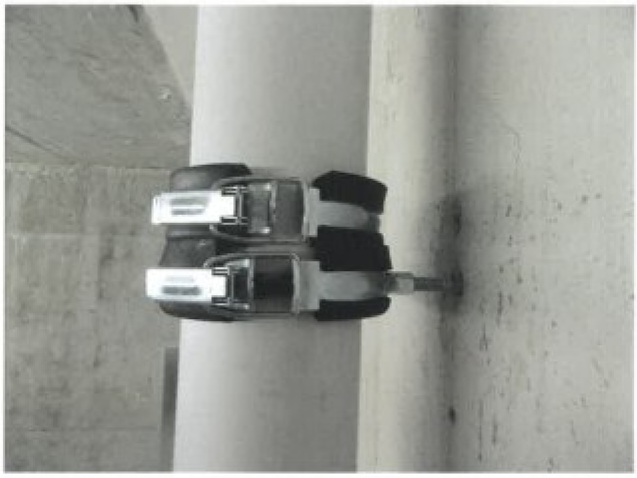
Fraunhofer IBP	The test was carried out in a laboratory, accredited according to DIN EN ISO/IEC 17025:2005 by DAkkS. The accreditation certificate is D-PL-11140-11-01.

Detailed results

Client: Rehau AG + CO, Rheniumhaus, Otto-Hahn-Str. 2, 95111 Rehau, Germany

P-BA 274/2016e

figure 5



Upper picture: Waste water system with "Sound-dampening bracket" in the upper wall area.

Lower picture: Waste water system with guidance clamp in the lower wall area.

Test specimen: Wastewater installation system consisting of plastic pipes and fittings "Rehau Raupiano Plus" (OD 110 x 2.7, manufacturer: Rehau AG + CO) with the corresponding fixing system "Sound-dampening bracket".

Fraunhofer IBP

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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/m²) 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.

Status: August 2, 2016

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:

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

$L_{i,F}$	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.

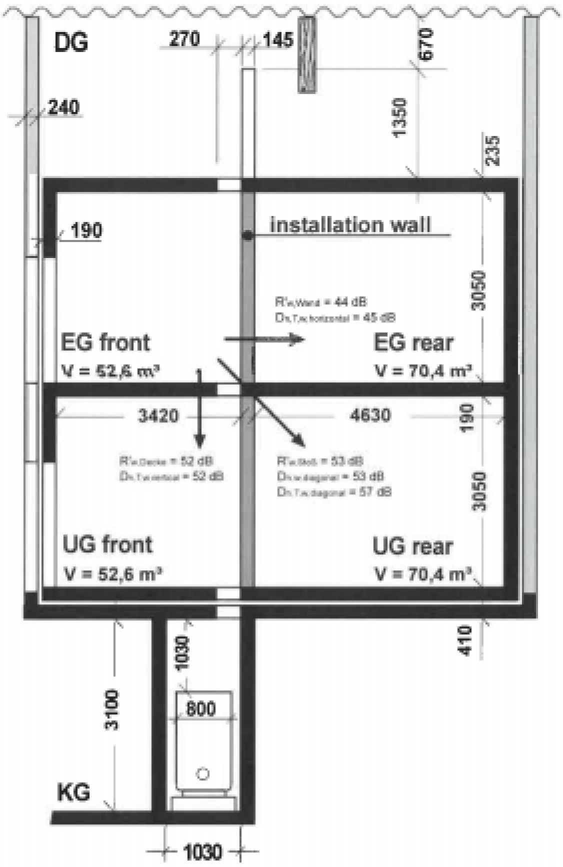
$$L_{AFeq,n} = 10 \cdot \lg\left(\sum_{i=1}^{18} 10^{\frac{L_{i,AFeq,n}}{10}}\right), \quad (2) \quad [dB(A)]$$

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.

Status: March 2, 2017

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 [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:

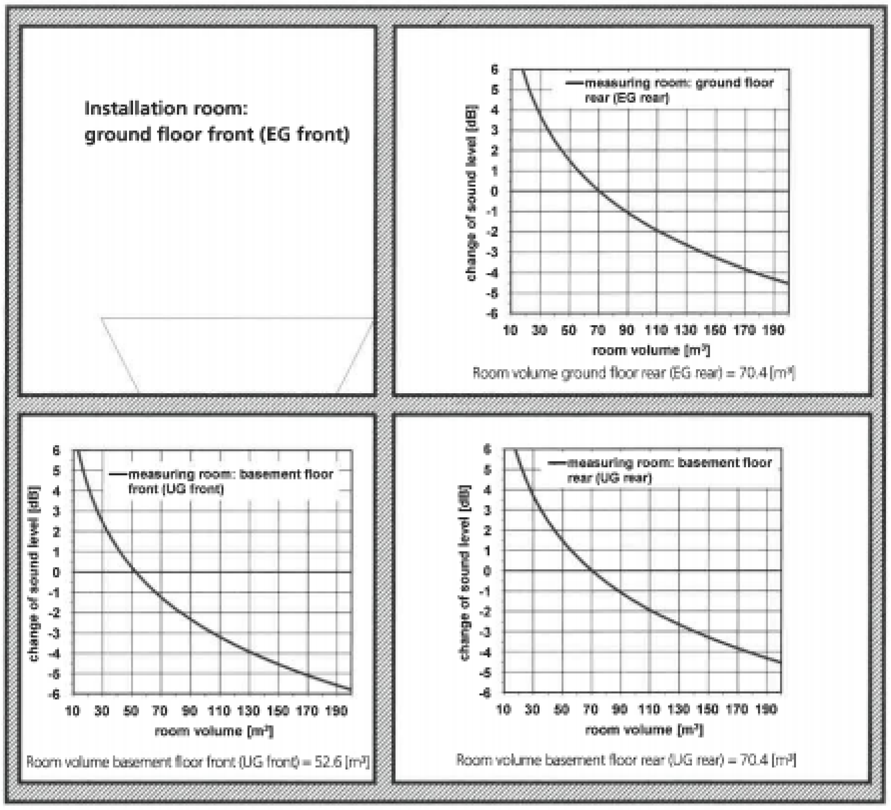


Fig. 1: Modification of the standardized sound level measured in the installation test facility P12 for rooms with deviating volume. The resulting change of sound level in comparison to the measured value indicated in the test report in dependence of the new room volume is specified in the diagrams for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

Status: December 10, 2013

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.

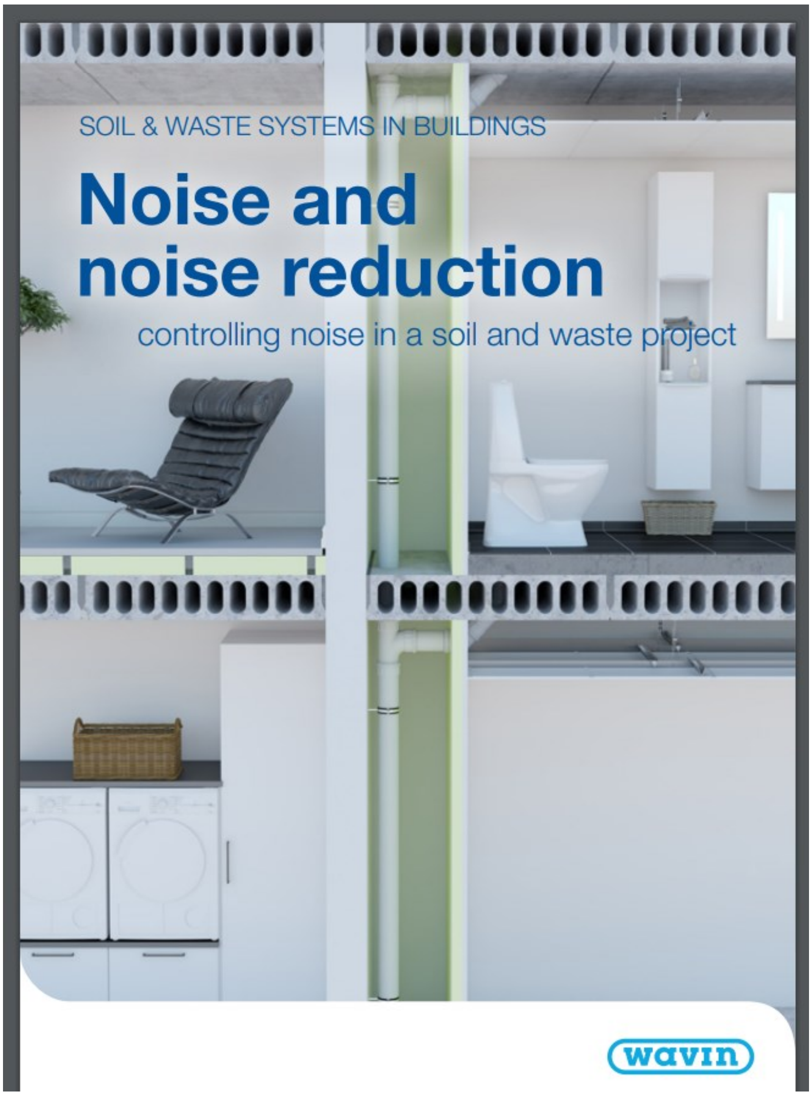
Status: December 10, 2013

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.

Soil & waste systems in buildings. Noise and noise reduction. Controlling noise in a soil and waste product

Wavinin toimittama pdf-tiedosto joka käsittelee äänen syntyä ja vaimentamista.



Do you know the difference between structure-born and airborn sound?

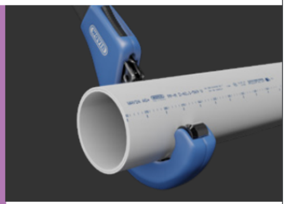
Did you know?

WHAT A FRAUENHOFER REPORT REVEALS

A Frauenhofer report gives different noise readings. Apart from structure-born sound and airborn sound, Frauenhofer also tests different flow rates in the pipes.

The figures normally used are for a noise reading taken at a flow rate of two litres, which is the amount of water passing through the pipe from a standard toilet flush. This represents the legal threshold value for noise values.

A Frauenhofer report also shows the test construction in detail. For instance, it states which pipe supports and wall thicknesses are used, and describes the standards the test conforms to.



Are you looking at the right data when choosing low-noise soil and waste pipes? To help you choose the right product, here we explain the difference between different noise readings here.

What are 'structure-born' and 'airborn' sound?
When choosing soil and waste pipes, you need to be sure they will meet noise and technical installation requirements according to the threshold values in the Building Rules and DS 490. But how can you be sure you are looking at the right noise data when choosing a low-noise pipe? Should you use the data for structure-born sound or for airborn sound? And what's the difference?

The wall thickness and density of the pipes determine how low-noise a soil and waste pipe is. The thicker and heavier the pipe, the lower the noise. The vast majority of soil and waste pipes are tested in impartial test laboratories – in many cases at the Frauenhofer Institute in Germany. The pipes are installed in a test building to ensure uniform testing methods for all types of pipe.

Why is the difference important?
Frauenhofer reports give two test results: **structure-born** and **airborn** sound. We know that not everyone differentiates between the two readings. Instead they choose a pipe based on the lowest reading, which is structure-born sound. In many cases, this represents no problem. But because the results from Frauenhofer reports are taken from a test environment with specific materials from the building's construction, structure-born sound cannot be used as a direct indicator of structure-born sound in any building. Depending on the choice of materials, structure-born sound in an actual building will differ from the test results.

Following is an explanation of the two types of readings and the consequence of basing your choice of pipe on the wrong data. We will also give you an insight into the Frauenhofer test environment, and where the two results are read.

The difference between structure-born and airborn sound
Airborn sound is the amount of noise that can be heard if standing in the same room in which the pipe is installed. airborn sound is reduced via the net weight of the material, or the encapsulation.

Structure-born sound is the amount of noise that can be heard from the pipe after the noise from water passing through it has permeated into the building construction (walls, pipe supports, brackets). Structure-born sound is reduced via the material's elasticity and insulation in the pipe supports and penetrations.

Structure-born sound is not a certainty
Readings for structure-born sound often look good on paper, as they are often much lower than airborn sound, and lower than the requirement for noise from technical installations. But they offer no guarantee that you are complying with noise requirements overall throughout a given building project. Firstly, the pipe supports, wall brackets and wall materials have considerable influence on how much noise from the pipe is reduced. Structure-born sound can only be used in those rooms where it permeates through the building construction, and not on the actual installation side of the pipes. Secondly, the test result can only be used if the pipes in a given building project are installed in the same materials as in Frauenhofer's test facility.

Airborn sound is used during installation
Airborn sound can be used on the installation side, as it is a much more reliable figure. The noise that the pipe emits itself will be the same, regardless of how it is installed. But you can only use airborn sound on the installation side if the pipe runs in a shaft, or is enclosed in some other way. However, what you can do, is calculate how and with what you can enclose it to meet the building rule requirements.

Do not simply accept the test results
If using structure-born sound as the benchmark when choosing low-noise soil and waste pipes, you can risk choosing a solution that cannot meet the building rule requirements in all rooms. However, if you use the airborn sound reading, you have a certain amount of control over the project yourself. When it comes to reducing noise in those rooms where noise permeates through the construction, a calculation based on the materials to be used for a given project will be the best way of ensuring noise requirements are met.

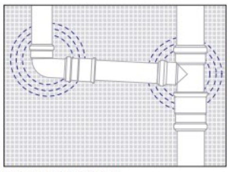
The risk of simply accepting test results is that a test performed at an inspection may result in you being required to replace the pipes, or provide additional noise insulation around them – which takes time and money. Using airborn sound from the pipe as benchmark means that the reduction value for the building materials is deducted if, for instance, the pipe is installed behind plasterboard, a wall or a ceiling. The result is the level of noise the pipe will emit in a room on the installation side.

How does noise occur?

Noise is mechanical oscillations that can be defined as a pressure variation in air, water or building elements.

How does noise occur?

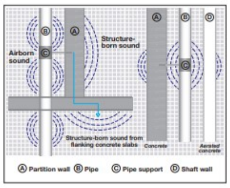
- When water and air pass each other
- When waste water changes direction at branch pipes and in bends, or passes a reduction
- When water falls through a vertical soil and waste pipe, and hits a solid surface, such as bend at the foot.



Examples of where noise can occur.

Who does noise travel?

- Through water
- Through pipe walls
- Noise radiation from soil and waste pipes
- Via pipe support to building constructions
- Via radiation from flanking building constructions

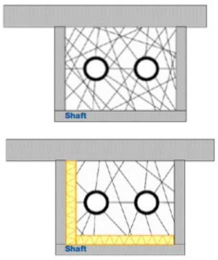


Example of noise radiation from flanking building constructions

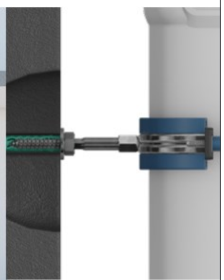
How noise can be further reduced::

- Reduce the water flow rate if possible
- Reduce water speed as much as possible
- Use soft direction changes, e.g. 2 x 45° bends, instead of 1 x 88.5° bend
- A 250mm pipe should be installed between two 45° bends when space permits in buildings with more than three storeys
- Use pipe supports with rubber inlays (reduce noise by up to 3dB)
- Mount pipe supports on the heaviest wall, which is most resistant to vibration
- Use the lowest possible number of pipe supports to limit transfer of noise to the wall. However, the max. distance between supports must be observed
- Avoid fixed connections between pipe and floor slabs as much as possible
- Separate pipes from building elements, e.g. by wrapping two or three layers of felt or fibre sheeting around the pipe.

Airborn sound in shafts
Noise in shafts increases by 10dB(A) due to reflection from the shaft. By insulating two of the shaft sides with 30 mm mineral wool, improved absorption will prevent this.



Frauenhofer test environment



The Frauenhofer Test Environment
Noise measurements are performed in the test environment at the Frauenhofer institute in Stuttgart on soil and waste pipes on the installation side, and in a room behind the installation wall two floors under the water inlet.

The importance of knowing the test environment for noise measurement lies quite simply in knowing the difference between the materials, dimensions, location and set-up of the elements in the test environment, compared to the situation the installer faces when you choose a low-noise pipe.

Soil and waste pipes are installed in the Frauenhofer test environment on a 115mm plastered concrete wall with a density of 220kg/m², and a floor or reinforced concrete with a density of 440kg/m². The rooms are empty and not enclosed.

How to calculate noise reduction

According to D490, the requirement for noise in a house room is maximum 30dB(A)¹). All types of Soil and waste pipes should be insulated on the installation side, or encapsulated in some other manner to meet the requirement.

Wavin's low noise pipes have the following noise level at a **flow rate of 2.0L/s**, which is the noise occurring from a standard toilet flush, and used as the benchmark for building rule noise requirement:

Product	Airborn Flow rate 2,0 ltr/s	Structure-born Flow rate 2,0 ltr/s
Wavin AS+ with Wavin system pipe supports	48 dB(A)	< 10 dB(A)
Wavin AS+ with standard pipe support	48 dB(A)	12 dB(A)
Wavin SiTech+ with Wavin system pipe supports	52 dB(A)	12 dB(A)
Wavin SiTech+ with standard pipe support	52 dB(A)	20 dB(A)

Calculating airborn sound

Once you know the airborn sound reading for your soil and waste pipe, you can calculate how to reduce it through encapsulation and the building construction to meet the requirements for each room.

Using the benchmark for airborn sound from the pipe, deduct the reduction value for building materials if, for example, the pipe is behind plasterboard, a wall or a ceiling. The result is the level of noise the pipe will emit in a room on the installation side. The table shows the reduction values for different material types in walls and ceilings – or how much they attenuate airborn sound from the pipe.

Example

If noise from soil and waste pipes must not exceed 30dB(A), none of the pipes can meet the requirement themselves. But airborn sound can be reduced using other materials to be able to meet the requirement.

- Wavin AS+ has an airborn sound of 48dB(A), and if you install it behind a 13mm plasterboard, the noise level is reduced by 20dB(A). You thus reach a level of 28dB(A) and meet the requirement.
- If using Wavin SiTech+, 13mm plasterboard is sufficient. This pipe has an airborn sound reading of 52dB(A), and even with 13mm plasterboard, the noise level will not be under 30dB(A). Two 13 mm plasterboards (-25dB(A)) will solve the problem, as will 16 mm chipboard (-24dB(A)).

Wall and ceiling construction	Recommended reduction figures
Perforated metal panels, ceiling	0 dB(A)
Solid metal panels, ceiling	5 dB(A)
12mm hard-pressed mineral wool panels, ceiling	10 dB(A)
40 mm concrete	35 dB(A)
60 mm concrete	40 dB(A)
100 mm concrete	40 dB(A)
70 mm Aerated concrete	25 dB(A)
100 mm Leca + plaster	35 dB(A)
½ brick wall	35 dB(A)
1 x 13 mm plasterboard	20 dB(A)
2 x 13 mm plasterboard	25 dB(A)
3 x 13 mm plasterboard	30 dB(A)
16 mm chipboard	24 dB(A)
22 mm chipboard	25 dB(A)

Calculating structure-born sound

Structure-born sound is a much more complicated affair, as it can vary in relation to the materials around the pipe.

As referred to earlier, structure-born sound in a Frauenhofer report is solely based on tests performed in its own test environment. The noise level will be different in any other construction. Therefore, no single formula or rule of thumb be composed that will indicate whether the requirement for noise will be met using a given pipe. It will always depend on a specific calculation for each project based on the materials chosen for walls, ceilings etc.

How much influence do you have on noise level?

The actual noise level will depend on a number of criteria which you may or may not be able to influence. You can see which you do have influence on, and which are given beforehand, but that have to form part of your calculations and choice of pipe. To ensure your installation meets the noise requirements, you should therefore obtain information on those factors you can influence.

IMPORTANT!

Noise and insulation are a complex affair. If in doubt whether reduction is sufficient, contact our Technical Support Department for advice. You can also talk to a consulting engineer, or acoustics expert.

	Pipe system
✓	Type of pipe system
✓	Type of pipe supports
✗	Pipe diameter

	Shaft/suspended ceiling
✓	Material choice for shaft wall-cladding
✓	Material choice for suspended ceiling
✗	Weight of the load-bearing wall structures
✓	Installation of noise-absorbent insulation in the shaft
✗	Shaft size

	Water volume
✗	Dimensioning water volume
✗	Fall height of downpipe

	Other factors
✓	Use noise insulation materials
✗	Room size

✓ Factors you can influence ✗ Factors you cannot influence

¹ DS 490 is used for homes, including hotels, student accommodation, boarding houses, inns, club apartments, boarding schools, nursing homes, homes for the elderly, childcare institutions and similar buildings used for accommodation. The benchmark for noise classification is Noise Class C, equivalent to the former minimum requirement of building legislation for terraced houses. 'Accommodation rooms' are lounge/dining room and bedrooms etc., in a home. NB: small rooms such as a hall, foyer, kitchen, bathroom etc. are not classified as accommodation rooms in DS 490.

Wavin SoundCheck Tool

Use our free tool to calculate noise reduction of Wavin SiTech+ and Wavin AS+ for your building project.

Find the Wavin SoundCheckTool at wavin.com.

Fraunhofer-instituutin akustiikkamittausten luotettavuuden selostus

Fraunhofer-instituutin julkaisema raportti ennen vuotta 2014 suoritettuihin desibeliviemäreiden mittaustuloksien luotettavuuteen.

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Technische Stellungnahme über die Messung der Geräusche von Abwasserinstallationen im Prüfstand nach DIN EN 14366: 2005. Vergleichbarkeit und Übertragbarkeit von Messergebnissen.

Sehr geehrte Damen und Herren,

Seit dem Jahr 2005 gibt es mit der DIN EN 14366 eine europäische Norm in der die Messung der Geräusche von Abwasserinstallationen im Prüfstand geregelt ist. Ein Großteil der Messungen nach dieser Norm erfolgt im Installations-Prüfstand des Fraunhofer-Instituts für Bauphysik in Stuttgart (Bild 1). Die daraus hervorgehenden Messergebnisse werden weltweit in Produktunterlagen dargestellt und bei Ausschreibungen in Form unserer Prüfberichte vorgelegt. Basierend auf der jahrelangen Erfahrung mit Geräuschmessungen an Abwasserinstallationen werden in dieser Stellungnahme die Probleme und zukünftigen Verbesserungsmaßnahmen bei der Vergleichbarkeit und Übertragbarkeit von Messergebnissen erläutert.

1. Messung der Geräusche von Abwasserinstallationen im Prüfstand nach DIN EN 14366

Die Norm beschreibt ein Messverfahren für Abwasserinstallationen im Prüfstand und ermöglicht den Vergleich von Messergebnissen aus unterschiedlichen Prüflaboratorien. Die Norm ist anwendbar auf Abwasser Rohrleitungssysteme und deren Teile, jedoch nicht auf die eigentlichen Abwasserquellen, z. B. Waschräume, Toiletten und Badewannen oder alle aktiven Elemente. In der Norm werden Anforderungen an die Prüflaboratorien und an die Messtechnik beschrieben. Der Aufbau des geprüften Abwassersystems bleibt hingegen weitgehend offen. Selbst bei der in der Norm informativ beschriebenen Standardkonfiguration werden über Art und Position der verwendeten Rohrschellen keine Aussagen gemacht. Die erhaltenen Ergebnisse können für den Vergleich von Produkten und Werkstoffen verwendet werden. Er kann zur Einschätzung des Verhaltens von Abwassersystemen in einem Gebäude unter bestimmten Bedingungen dienen. Diese Norm liefert jedoch kein normiertes Verfahren zur Berechnung der akustischen Eigenschaften solcher Installationen in einem Gebäude. Weiterhin sind die nach dieser Norm resultierenden Messwerte (Luftschalldruckpegel $L_{a,A}$ und charakteristischer Körperschallpegel $L_{sc,A}$) nur nach komplizierten Berechnungen mit den gültigen Anforderungen für Geräusche aus haustechnischen Anlagen vergleichbar.

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2. Einflussgrößen auf das Geräuschverhalten von Abwassersystemen

Der Versuchsaufbau nach DIN EN 14366 (vgl. Bild 2) besteht also aus mehreren Komponenten die zu einer Abwasser-Fallleitung zusammengefügt werden. Die Anregung des Versuchsaufbaus erfolgt durch Wasserströmung in den Fallrohren. Hierdurch wird das Abwassersystem zu Schwingungen angeregt, die dann über die Rohrschellen auf die Installationswand übertragen werden. Die Schwingungen werden in Form von Körperschall in die Gebäudestruktur eingeleitet und in den angrenzenden Räumen von Decken und Wänden als hörbarer Luftschall wieder abgestrahlt. Neben der Körperschallübertragung über die Rohrschellen liefert auch die direkte Schallabstrahlung des Abwasserrohrs einen - wenn auch im Allgemeinen kleinen - Beitrag zu dem im Empfangsraum erzeugten Installations-Schallpegel.

2.1 Einfluss der Wasserströmung

Die Wasserströmung innerhalb der Fallrohre wird beeinflusst durch Unstetigkeitsstellen innerhalb der Abwasserrohre, wie z.B. Umlenkungen und Geschossabzweige, sowie durch Spalten und Versatz beim Übergang zwischen den einzelnen Rohrstücken. Betrachtet man die Wasserströmung innerhalb eines transparenten Abwassersystems, erkennt man, dass sich die Strömungsbilder ständig verändern. Wobei es durchaus vorkommen kann, dass sich ein bestimmtes Strömungsbild über eine gewisse Zeit einstellt und dann ohne ersichtlichen Grund zu einem völlig anderen Strömungsbild wechselt. Durch das wechselnde Strömungsbild kommt es zu einer ungleichmäßigen Anregung des Rohrsystems. Dies hat wiederum Einfluss auf die Luftschallabstrahlung des Rohrs in den Installationsraum und die Körperschalleinleitung in die Installationswand. Bei ungünstigen Verhältnissen (verzogene Rohre, großer Spalt zwischen den Rohrstücken) kann es so zu erheblichen Unterschieden bei den Messwerten für vermeintlich gleiche Abwassersysteme kommen.

Durch den ständigen Wechsel der Strömungsverhältnisse ist die akustische Anregung des Rohrsystems in der Praxis nicht genau vorhersehbar. Der Einfluss der Rohrbeschaffenheit mit allen Komponenten (Muffen, Abzweige, etc.) auf das Strömungsverhältnis im Rohr bildet somit eine grundlegende Unsicherheit bezüglich der Wiederholgenauigkeit.

2.2 Einfluss der Rohrschellen

Neben der Wasserströmung führen die verwendeten Rohrschellen und im Wesentlichen deren Montagebedingungen zu großen Abweichungen beim Geräuschverhalten von Abwassersystemen. Hierbei reicht die Bandbreite von sogenannten Gleit- oder Losschellen, welche im Extremfall nahezu keinen Kontakt zum Rohr haben, bis zu Standardschellen die bei der Montage in der Praxis häufig so stark gepresst werden, dass eine Verformung des Stahlkörpers der Schelle und eine Verformung des Abwasserrohres erfolgen kann. In direkter Abhängigkeit von der Befestigungsart des Rohres, können für den in die Installationswand eingeleiteten Körperschall und anschließend in den Empfangsraum hinter der Installationswand (schutzbedürftiger Nachbarraum) abgestrahlten Luftschallpegel, die Unterschiede in den Messwerten bis zu 20 dB betragen. Im Gegensatz zu der oben beschriebenen Wasserströmung sind diese Einflüsse jedoch steuerbar und dadurch auch manipulierbar. So wurden bei Prüfstandsmessungen in der Vergangenheit die Rohrschellen häufig so montiert, dass zwar sehr gute Werte erzielt wurden, jedoch keineswegs mehr eine praxisgerechte Befestigung des Rohres gegeben war.

Da es nach DIN EN 14366 derzeit noch keine Vorschriften für die Art und die Montage der Rohrschellen gibt, stellen diese Abweichungen derzeit die größte Unsicherheit beim Vergleich von Abwassermessungen dar. Im Prinzip können Messungen nur dann miteinander verglichen werden, wenn die Art und die Montage der Rohrschellen exakt übereinstimmt. Für die Praxis am Bau stellt dies ein erhebliches Problem dar, vor allem wenn man bedenkt dass auf der Baustelle die Abwassersysteme oft mit anderen (kostengünstigeren) Rohrschellen montiert werden, als bei der Messung im Prüflabor.

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2.3. Einfluss des Rohraufbaus

Der Aufbau des untersuchten Rohrs (Steifigkeit, Rohdichte, sowie Dicke der Rohrwand) hat einen wichtigen Einfluss auf das Geräuschverhalten der Abwassersysteme. Jedoch ist dieser Einfluss dem oben beschriebenen Einfluss von Art und Montage der verwendeten Rohrschellen untergeordnet und relativ einfach beschreibbar. Stark vereinfacht gilt: je schwerer das Rohr, umso besser sein akustisches Verhalten. Erfahrungsgemäß ergeben sich für die derzeit auf dem Markt verfügbaren Abwassersysteme im Installations-Schallpegel maximale Abweichungen durch den Rohraufbau von ca. 10 dB. Die durch den unterschiedlichen Rohraufbau hervor-gerufenen Pegelunterschiede äußern sich besonders deutlich in dem bei offenen Schellen gemessenen Luftschallpegel $L_{a,A}$, da hier der Einfluss der Rohrschellen auf das Messergebnis entfällt. Im Marktsegment der derzeitig hauptsächlich verwendeten leichten Abwassersysteme aus Kunststoff (nahezu gleiches Rohrgewicht und gleiche Rohrwanddicke), betragen die Abweichungen wenn überhaupt nur wenige Dezibel. Dies gilt natürlich nur dann, wenn die Abwassersysteme mit Rohrschellen montiert werden, deren Art und Montage vergleichbar sind.

3. Vergleichbarkeit von Messungen an Abwassersystemen im Prüfstand nach DIN EN 14366

Grundsätzlich sollte bewusst sein, dass die dargestellten Messergebnisse nicht für ein spezielles Abwasserrohr gelten, sondern für die Kombination aus Abwasserrohr und verwendeter Rohrschelle. Auch bei sehr genauer Beschreibung der verwendeten Rohrschellen und deren Montage sind diese Einflussparameter nur mit erheblichem Aufwand exakt reproduzierbar. Eine Vergleichbarkeit von verschiedenen Messungen an Abwassersystemen kann nur dann gewährleistet werden, wenn die Art der verwendeten Rohrschellen und deren Montagemöglichkeiten vereinheitlicht werden. Um trotzdem einen Vergleich von verschiedenen Prüfaufbauten zu ermöglichen, wird empfohlen zusätzlich zu dem Körperschalldruckpegel ($L_{sc,A}$, gemessen im Raum hinter der Installationswand) auch den Luftschalldruckpegel ($L_{a,A}$, gemessen im Installationsraum) in die Betrachtungen mit einzubeziehen. Der Körperschallpegel wird hauptsächlich durch die Art und die Montage der Rohrschelle beeinflusst, während der Luftschallpegel - bei gleicher Geometrie des Abwassersystems - hauptsächlich die akustischen Eigenschaften des Rohrmaterials wiedergibt.

Bei Messergebnissen mit außergewöhnlich niedrigen Schallpegeln liegt die Vermutung nahe, dass die Rohrschellen nicht praxisgerecht montiert wurden, oder dass spezielle Rohrschellen (z.B. Stütz- und Fixierschellen) verwendet wurden, die nur nach aufwendiger Justierung niedrige Schallpegel ermöglichen. In der Praxis werden diese Spezialschellen aufgrund ihres hohen Preises nur sehr selten eingesetzt und leider im Normalfall am Bau oft falsch montiert. Beim Vergleich von unterschiedlichen Abwassersystemen sollte bei diesen Messergebnissen zusätzlich der Luftschallpegel betrachtet werden.

Das Fraunhofer-Institut für Bauphysik hat hierzu bereits neue Vorgaben für den Versuchsaufbau bei Abwassermessungen umgesetzt, um einen besseren Vergleich der Messergebnisse zu ermöglichen. Derzeit werden weitere Vorschläge entwickelt, um die Prüfbedingungen an Abwassersystemen weiter zu vereinheitlichen (siehe Abschnitt 6).

4. Vergleichbarkeit von Messergebnissen nach DIN EN 14366 mit den Anforderungen (Normen und Richtlinien)

Die nach DIN EN 14366 erhaltenen Messergebnisse gelten nur für reine Abwassergeräusche in Fallleitungen. Zusätzliche Geräuschanteile von z.B. WC-Anlagen werden nicht erfasst. Für eine Gesamtbetrachtung einer Hausinstallation sollte daher eine komplette Musterinstallation bestehend aus den unterschiedlichen Komponenten (Zu- und Abwasserführung, Sanitärobjekte, etc.) geprüft werden, da diese Ergebnisse direkt mit den Anforderungen verglichen werden können. Ansonsten müssen die Schallanteile der einzelnen Komponenten aufaddiert werden, was wegen der Zeitabhängigkeit der Geräusche nur schwer möglich ist. Alternativ kann mit Hilfe einer Maximalwertabschätzung der einzelnen schallschutztechnisch beurteilten Sanitärkomponenten der akustisch maßgebliche Geräuschanteil als Vergleichswert herangezogen werden. Allerdings gibt es auch Konstellationen bei denen in Gebäuden reine Abwassergeräusche auftreten oder die Abwassergeräusche maßgeblich für störende Installationsgeräusche sind.

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Die nach DIN EN 14366 resultierenden Messwerte (Luftschalldruckpegel $L_{a,A}$ und charakteristischer Körperschallpegel $L_{sc,A}$) sind nur nach aufwendigen Berechnungen mit den gültigen Anforderungen für Geräusche aus haustechnischen Anlagen vergleichbar. Der vom IBP zusätzlich angegebene Installations-Schallpegel kann zwar (unter Berücksichtigung der oben genannten Einschränkungen) direkt mit den Anforderungen verglichen werden, gilt aber nur für die baulichen Gegebenheiten im Installationsprüfstand des Fraunhofer-Instituts für Bauphysik, mit einer flächenbezogenen Masse der Installationswand von 220 kg/m². Als Vergleichswert mit den Anforderungen sollte der im Prüfstand bei einem Volumenstrom von 2 l/s gemessene Wert herangezogen werden, da dieser Volumenstrom in etwa der Geräuschentwicklung bei einem üblichen WC-Spülvorgang gleichzusetzen ist.

5. Übertragbarkeit von Messergebnissen nach DIN EN 14366 auf die Praxis

Die auf dem Markt kursierenden sehr niedrigen Messergebnisse bei schalltechnischen Untersuchungen an Abwassersystemen sind in der Praxis aus verschiedenen Gründen nicht erreichbar. Zum einen liegt der normale Grundgeräuschpegel in einem allgemein als sehr leise empfundenen Wohngebäude schon über 20 dB(A). Weiterhin muss zur Erreichung sehr niedriger Schallpegel eine aufwendige Justierung der Rohrschellen und des Abwassersystems erfolgen, was in der Praxis am Bau, aufgrund von Zeitdruck und vor Allem der fehlenden Rückmeldung über den gemessenen Schallpegel, im Normalfall nicht möglich ist. Da die Abwassersysteme zudem in der Praxis aus Kostengründen meist mit günstigen Standard-Rohrschellen anstelle der für die Prüfungen verwendeten Spezialschellen montiert werden, wären für die praktische Beurteilung eigentlich Messungen mit diesen Rohrschellen sinnvoll. Hierbei sollten die Rohrschellen, wie in der Praxis üblich, auch bei der Messung im Labor vollständig geschlossen werden.

Bei bauüblicher Montage kann davon ausgegangen werden, dass mit herkömmlichen Abwassersystemen (z.B. HT-Rohre) und Standard-Rohrschellen mit Elastomereinlage lediglich die Mindestanforderungen nach DIN 4109 und VDI 4100 eingehalten werden können. Bei erhöhten Anforderungen an den Schallschutz sollten, im Verbund mit aufeinander abgestimmten schalltechnisch geprüften Sanitär-Installationssystemen, Abwassersysteme mit hohem Gewicht und mit speziell auf das Rohr abgestimmten Rohrschellen eingesetzt werden. Die Spannweite der Rohrschellen muss dabei so ausgewählt werden, dass bei vollständig geschlossenen Rohrschellen die Elastomereinlage nicht zu stark gepresst wird. Spezielle zweiteilige Schallschutzschellen (Stütz- und Fixierschellen) sollten nur in Kombination mit schweren Rohren eingesetzt werden (Masse-Feder-System) und müssen genau nach Montageanleitung installiert werden. Um einen noch besseren Schallschutz zu erreichen, können die Abwasserrohre und Formteile zusätzlich mit einer luftschalldämmenden Rohrummantelung (mit Schwermatte) versehen werden. Optimal sind die Ergebnisse, wenn die Rohrschellen über der Rohrummantelung angebracht werden. Grundsätzlich müssen bei der Montage der Abwassersysteme Körperschallbrücken zum Bauwerk (z.B. in Installationsschächten und Deckendurchbrüchen) vermieden werden.

Bei der Übertragung der Messwerte auf die Praxis (individuelles Bauwerk) muss die vom Prüflabor abweichende Bauweise berücksichtigt werden. Hierzu steht mit der DIN EN 12354-5 ein Berechnungsverfahren zur Verfügung, mit Hilfe dessen aus den nach EN 14366 ermittelten Messwerten (Luftschalldruckpegel und charakteristischer Körperschallpegel) ein Raumschallpegel für die jeweiligen schutzbedürftigen Räume im geplanten Gebäude ermittelt werden kann. Die Berechnungen sind allerdings sehr aufwändig und die Berechnungsunsicherheit ist derzeit noch groß.

Alternativ kann mit dem vom Fraunhofer-Institut für Bauphysik entwickelten vereinfachten Berechnungsverfahren der Raumschallpegel im geplanten Gebäude hinter der Installationswand abgeschätzt werden. Hierbei wird der in den Prüfberichten angegebene Installations-Schallpegel, in Abhängigkeit von der Flächenmasse der Installationswand, an der das Abwassersystem angebracht ist, auf die tatsächlich vorhandene Bausituation umgerechnet. Beide Berechnungsverfahren sind derzeit nur für den Massivbau anwendbar.

6. Vorschläge zur Verbesserung der Vergleichbarkeit von Abwassermessungen nach DIN EN 14366

Das Fraunhofer-Institut für Bauphysik forscht seit einiger Zeit an Verfahren und Möglichkeiten, um die Vergleichbarkeit von Abwassermessungen zu verbessern und bei den Labormessungen praxisnahe Messergebnisse zu erreichen. Folgende Vorgaben für die Durchführung von schalltechnischen Untersuchungen an Abwassersystemen wurden bereits eingeführt:

- Messergebnisse unter 10 dB(A) werden im Prüfbericht nicht mehr angegeben, da sie eine erhöhte Messunsicherheit aufweisen und außerdem in normaler Wohnumgebung nicht wahrnehmbar sind.
- Der Versuchsaufbau für Abnahmemessungen darf ausschließlich durch IBP-eigenes Handwerkspersonal erfolgen. Direkt nach dem Versuchsaufbau erfolgt die Abnahmemessung. Nachträgliche Veränderungen am Abwassersystem und an den Rohrschellen zur Verbesserung der Messergebnisse sind nicht mehr möglich.
- Die verwendeten Rohrschellen in den für die Schallübertragung relevanten Installations- und Messräumen (EG vorne und UG vorne) müssen so gestaltet und montiert sein, dass beim Öffnen der Rohrschellen im Kellergeschoss kein Abrutschen der Rohre nach unten erfolgt.

Ab 2014 wird bei jeder Abnahmemessung eine zusätzliche Messung mit einer vom IBP vorgegebenen Referenzschelle angeboten. Bei der Referenzschelle handelt es sich um eine bauübliche Standard-Stahlrohrschellen mit Elastomereinlage. Die Montage der Referenzschellen erfolgt immer an der gleichen Stelle und auf die gleiche Art und Weise (vollständig geschlossen). Durch Vergleichsmessungen an einem Referenz Abwassersystem wird in bestimmten Zeitintervallen geprüft, ob sich das Geräuschverhalten der Referenzschellen verändert. Zusätzlich wird das akustische Langzeitverhalten der Referenzschellen regelmäßig an einem Kleinprüfstand überwacht.

7. Zusammenfassung

Geräuschmessungen an Abwassersystemen erfolgen seit dem Jahre 2005 nach DIN EN 14366. Die Norm enthält zwar Vorschläge für den Aufbau des Abwassersystems im Prüfstand, jedoch wird die Art und Montage der verwendeten Rohrschellen weitgehend offen gelassen. Dies führte in der Vergangenheit dazu, dass die Rohrschellen im Prüfstand so montiert wurden, dass immer niedrigere Messergebnisse erreicht wurden. Die dabei verwendete Befestigungsart des Abwasserrohres war jedoch häufig völlig praxisfern, da z.B. das Abwasserrohr nicht durch die Rohrschellen in den Stockwerken gehalten wurde. Zudem sind die auf diese Art und Weise erreichten Messwerte nur in einem akustischen Labor mit wiederholter Geräuschmessung und anschließender Nachjustierung des Rohrsystems realisierbar.

Die ermittelten Messergebnisse gelten nicht für das jeweilige Abwasserrohr alleine, sondern für die Kombination aus Abwasserrohr und Rohrschelle. Die Art und die Montage der verwendeten Rohrschellen haben dabei einen wesentlich höheren Einfluss auf die in die benachbarten Räume übertragenen Abwassergeräusche als der Rohraufbau (Steifigkeit, Rohdichte und Rohrwanddicke). Ein Vergleich von Messungen an Abwasserrohren ist nur möglich, wenn die Art und die Montage der verwendeten Rohrschellen exakt gleich sind. Durch die bis Ende 2013 geduldete Praxis bei der Montage von Prüfaufbauten und den damit verbundenen hohen Abweichungen der Messergebnisse war dieser Vergleich nicht möglich. Ab 2014 bietet das Fraunhofer-Institut für Bauphysik deshalb zusätzliche Messungen mit einer Referenz-Rohrschelle (vollständig geschlossene Standard-Rohrschelle mit Elastomereinlage) an, wodurch eine bessere Vergleichbarkeit unterschiedlicher Abwasserrohre und praxisnahe Ergebnisse erreicht werden sollen.

Beim Vergleich bereits veröffentlichter Messergebnisse (vor 2014) an Abwassersystemen sollte, vor allem bei niedrigen Werten, genauestens auf die Beschreibung der Art und Montage der verwendeten Rohrschellen geachtet werden. Zusätzlich zu dem angegebenen Körperschallpegel sollte immer auch der von der Rohrschelle weitestgehend unabhängige Luftschallpegel im Installationsraum für einen Vergleich von Abwasserrohren herangezogen werden.

i.A.
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Anlagen: Bilder 1 und 2

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Dr. rer. nat. Lutz Weber

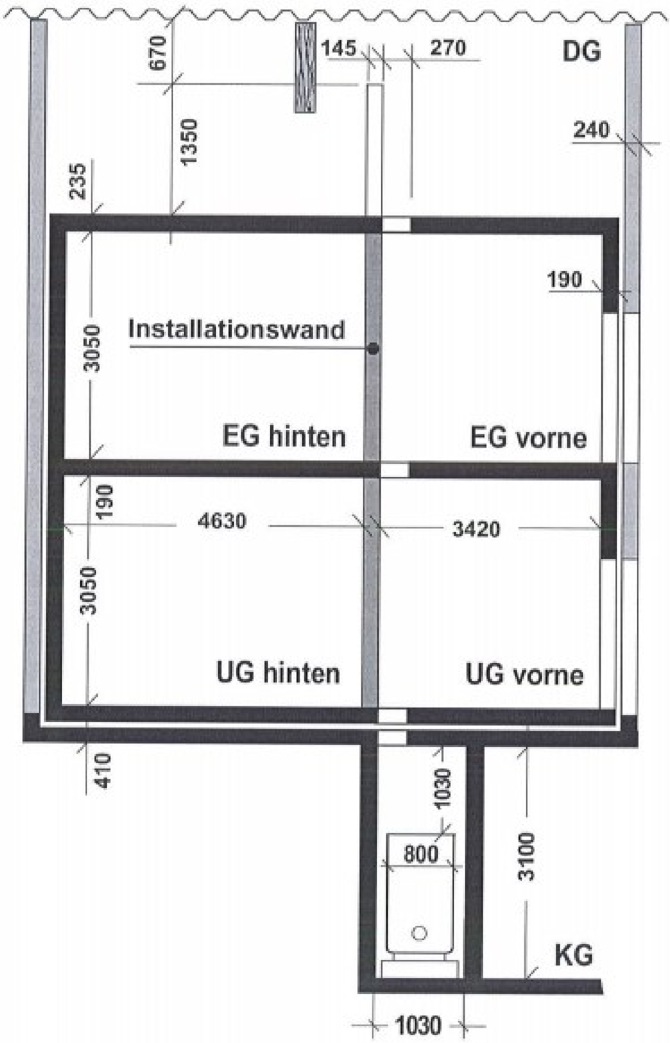

Bild 1 Schnittzeichnung des Installationsprüfstands im Fraunhofer-Institut für Bauphysik (Maßangaben in mm). Der Prüfstand besteht aus je zwei übereinanderliegenden Räumen im Erd- und Untergeschoss (EG und UG), so dass in Verbindung mit Dach- und Kellergeschoss (DG und KG) auch über mehrere Stockwerke reichende Installationen, wie z. B. Abwassersysteme, geprüft werden können.

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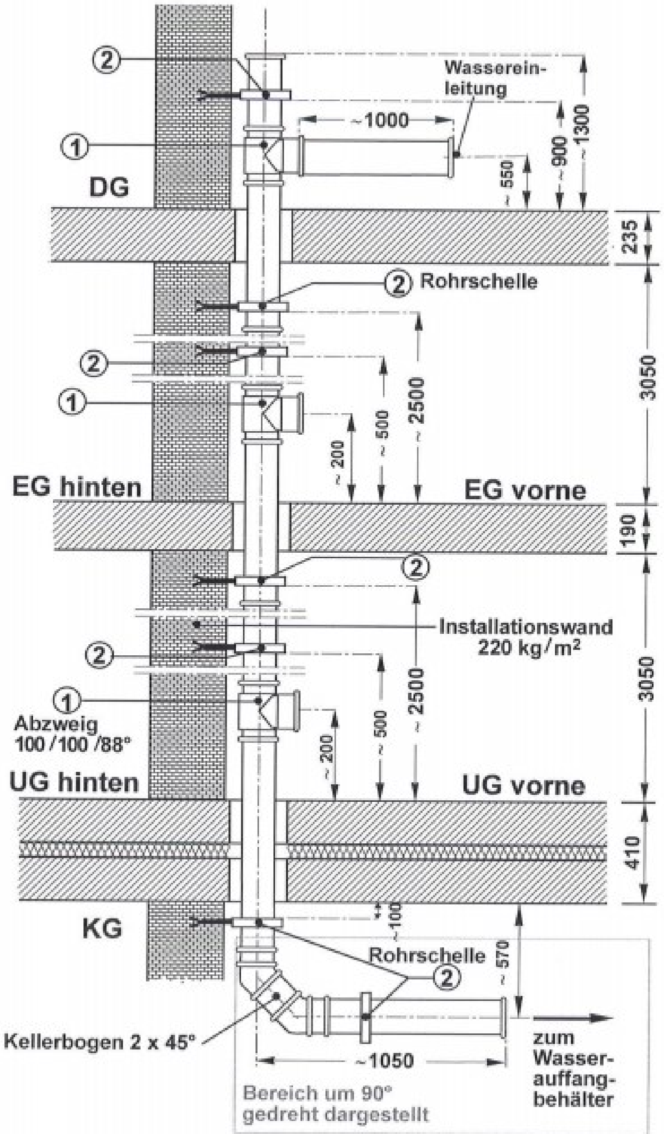

Bild 2 Prinzipieller Installationsplan für die schalltechnische Untersuchung eines Abwassersystems (Darstellung nicht maßstäblich, Maßangaben in mm).

Fraunhofer-instituutti Poliplast dBlue, akustiikkamittausraportti

Fraunhofer-instituutin suorittama akustiikkamittausraportti Poliplast dBlue -desibeliviermärille ääntä vaimentavilla POLIclamp-kannakkeilla.

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Institutsleitung
Univ.-Prof. Dr.-Ing. Gerd Hauser
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Test report P-BA 74-3/2010e

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

Client: Poliplast Sp. z o.o.
ul. Energetyczna 6
PL 56-400 OLESNICA
POLAND

Test specimen: Wastewater installation system consisting of "dBlue" plastic pipes (manufacturer: Poliplast) mounted with pipe clamps "POLIclamp".

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Annex F:	Evaluation of measurements
Annex P:	Description of test facility

The tests were performed in a laboratory accredited by the German Accreditation System for Testing (DAP, file no. PL-3743.26) according to standard EN ISO/IEC 17025.

Object under test and measurement results are identical to those in test report P-BA 74/2010e
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Stuttgart, May 27, 2011

Responsible Test Engineer: Head of Laboratory:

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Determination of the installation sound level L_{In} in the laboratory

P-BA 74-3/2010e

Table 1

Client: Poliplast Sp. z o.o., ul. Energetyczna 6, PL 56-400 OLESNICA, POLAND

Test specimen: Wastewater installation system (test specimen S 10255-01) consisting of "dBlue" plastic pipes (manufacturer: Poliplast) mounted with pipe clamps "POLIclamp" (manufacturer: Poliplast)

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 (90°), two 45°-basement bends with intermediate calming section (250 mm) and a horizontal drain section. The inlet tees in the basement and in the ground floor were closed by lids supplied by the manufacturer. The pipe system was mounted by the client.
- Pipe system "dBlue": size OD 110, three-layer pipe with attached sleeve. Internal layer: PP copo; medial layer: PP MD, external layer: pp copo. Wall thickness 3.4 mm, weight 1.4 kg/m, density 1.15 g/cm³. One-layer fittings: pp MD, wall thickness 3.4 mm, density 1.12 – 1.3 g/cm³. Connection of the pipes by plug-on socket connection.
- Pipe clamps "POLIclamp" (figure 5): Plastic clamps with three elastomer inlays. The clamps were completely closed and they were fixed to the installation wall with dowels and thread rods.

Test facility: Installation test facility P12, mass per unit area of the installation wall: 220 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 52 219: 1993-07 and EN 14366; noise excitation by stationary 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).

Results:

Waste water system "dBlue" with pipe clamps "POLIclamp"				
Flow rate [l/s]	0,5	1,0	2,0	4,0
Installation sound level L_{Is} [dB(A)] measured in the basement test-room UG front	49	49	52	56
Installation sound level L_{In} [dB(A)] measured in the basement test-room UG rear	15	14	17	21
Airborne sound pressure level $L_{a,A}$ [dB(A)] [1]	49	49	52	56
Structure-borne sound characteristic level $L_{sc,A}$ [dB(A)] [1]	13	11	15	19

[1] Evaluation according to DIN EN 14366.

Date of tests: March 9, 2010

Comments: - The requirements of DIN 4109 only apply for the test room UG rear.

Fraunhofer IBP

The tests were performed in a laboratory accredited by the German Accreditation System for Testing (DAP, file no. PL-3743.26) according to standard EN ISO/IEC 17025.
Stuttgart, May 27, 2011
Head of Laboratory:

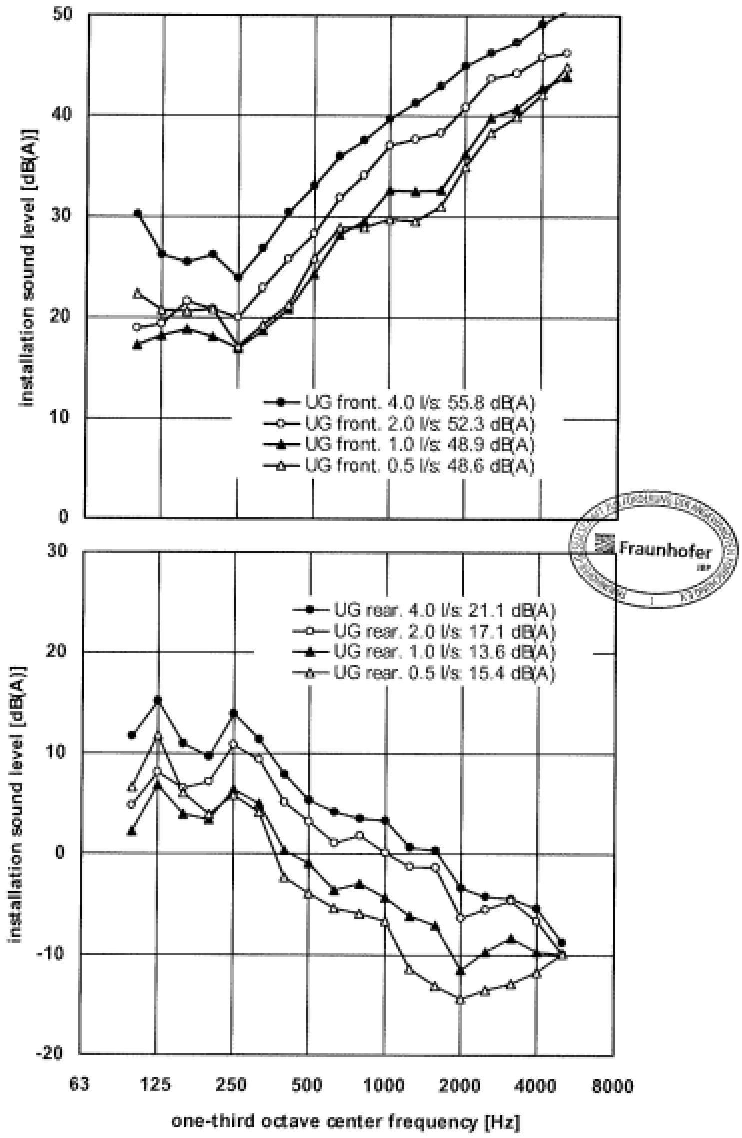


Figure 1 Wastewater pipe system "dBlue" mounted in sub-basement (KG), basement (UG front), ground floor (EG front) and top floor (DG) using pipe clamps "POLIclamp". The installation sound level L_{in} was measured at various flow rates in the test rooms UG front (above) and UG rear (below).

The tests were performed in a laboratory accredited by the German Accreditation System for Testing (DAP, file no. PL-3743.26) according to standard EN ISO/IEC 17025.

Fraunhofer-Institute of Building Physics P-BA 74-3/2010e

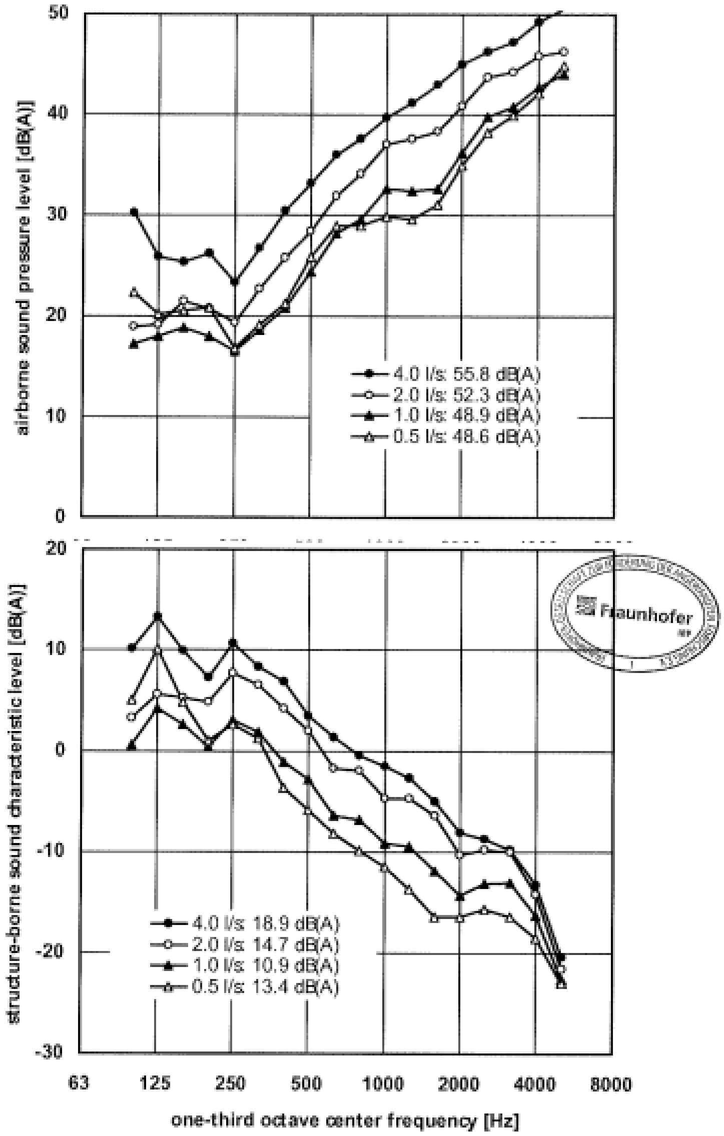


Figure 2 Wastewater pipe system "dBlue" mounted in sub-basement (KG), basement (UG front), ground floor (EG front) and top floor (DG) using pipe clamps "POLIclamp". Airborne sound pressure level (above) and structure-borne sound characteristic level (below) measured at various flow rates according to DIN EN 14366.

The tests were performed in a laboratory accredited by the German Accreditation System for Testing (DAP, file no. PL-3743.26) according to standard EN ISO/IEC 17025.

Fraunhofer-Institute of Building Physics P-BA 74-3/2010e

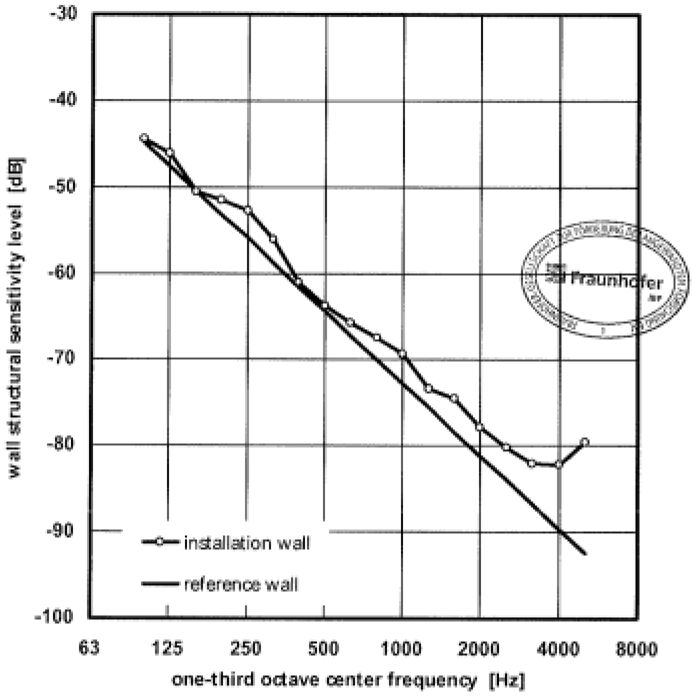


Figure 3 Wall structural sensitivity level L_{SS} of the installation wall between the test rooms UG front and UG rear in the installation test facility in the Fraunhofer-Institute of Building Physics. The installation wall consists of lime stones (thickness 115 mm, ceiled on both sides) with a mass 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).

The tests were performed in a laboratory accredited by the German Accreditation System for Testing (DAP, file no. PL-3743.26) according to standard EN ISO/IEC 17025.

Fraunhofer-Institute of Building Physics P-BA 74-3/2010e

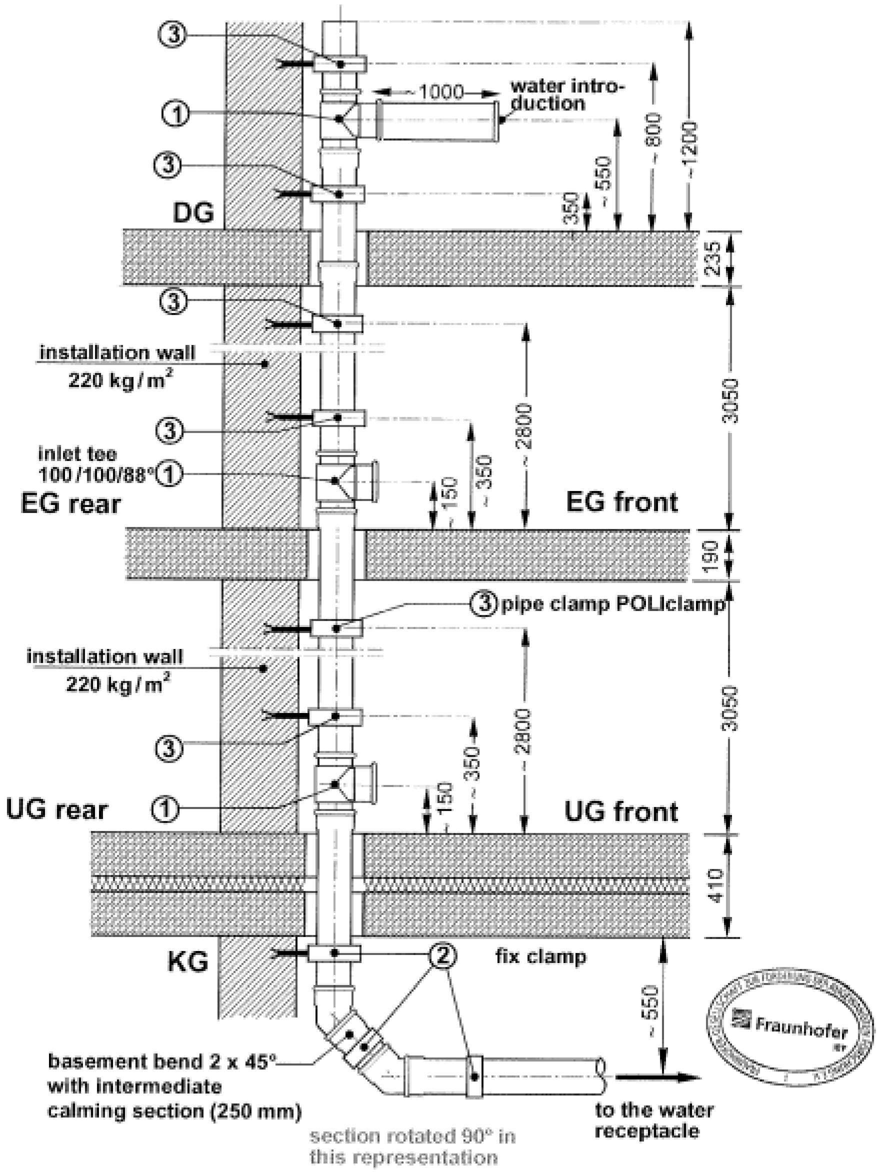


Figure 4 Installation plan of the pipe system "dBlue" (manufacturer: Poliplast), mounted with clamps "POLIclamp" (drawing not to scale, dimensions in mm).

Fraunhofer-Institute of Building Physics P-BA 74-3/2010e

Figure 5 Pipe clamp "POLIclamp" manufactured by Poliplast.

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/m²) 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]

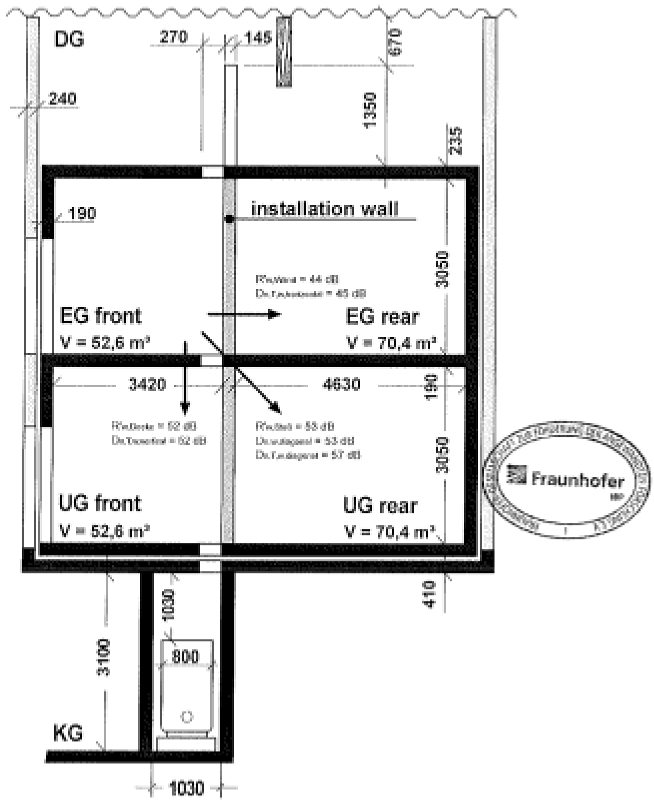
If the difference between the measured one-third octave level and the background noise level is less than 3 dB, the correction for background noise will not be performed. Instead, the measured background noise level will be used as test result (as largest possible value). The total sound pressure level 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 0.128 s. The evaluation is performed in the same way as in the case of stationary noise, with the exception that background noise correction is not performed. After evaluation the maximum value ($L_{AF,10,max}$) is determined from the measured time response.



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.

Status: 23 June 2010

Fraunhofer-instituutti Wavin AS+, akustiikkamittausraportti P-BA 63/2019e

Fraunhofer-instituutin suorittama akustiikkamittausraportti Wavin AS+ -desibeliviermärille Ääntä vaimentavilla Wavin Low Noise liuku- ja kiinteillä kannakkeilla.

Determination of the Acoustic Performance of a Wastewater Installation System in the Laboratory according to EN 14366	P-BA 63/2019e Results sheet 1

Client: Wavin T&I, Rollepaal 20, 7701 BS Dedemsvaart, Netherlands

Test specimen: Wastewater system "Wavin AS+, DN/OD 110 x 5.3, 05.11.2018" (manufacturer: Wavin). The wastewater system consisted of straight plastic pipes and fittings and pipe clamps "Wavin Low Noise bracket" with elastic inlay and spacers (manufactured by Walraven) mounted as sliding and fixing clamps. Test object no.: 11065-10; 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°), two 45°-basement bends and a horizontal drain section. The inlet tees in the basement and in the ground floor were closed by plugs supplied by the manufacturer.
  - Pipe system: "Wavin AS+, DN/OD 110 x 5.3, 05.11.2018": Three-layer pipes: Material PP, wall thickness 5.7 mm, weight 3.45 kg/m, density 1.87 g/cm³, values measured by IBP. One-layer fittings: Material PP, wall thickness 4.8 mm, density 1.85 g/cm³, values measured by IBP. Plug connection of the pipes and fittings (shaped pipe sockets).
  - Pipe clamps: Steel pipe clamps "Wavin Low Noise bracket" with elastic inlay and with spacers (manufactured by Walraven) mounted as sliding and fixing clamps. In every storey (EG and UG) two pipe clamps were installed. In the upper wall area one clamp was mounted as a sliding clamp with one white spacer (15.3 mm) on both sides of the clamp. In the lower wall area one clamp was mounted as a fixing clamp with one black spacer (10 mm) on both sides of the clamp. The clamps were fixed to the installation wall with dowels and thread rods (figure 5).

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 14366:2005-02; 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 4109:2018-01 and VDI 4100:2012-10 (details in Annexes A, F and V).

Result:

Wastewater system "Wavin AS+, DN/OD 110 x 5.3, 05.11.2018" (manufacturer: Wavin). The wastewater system consisted of straight plastic pipes and fittings and pipe clamps "Wavin Low Noise bracket" with elastic inlay and spacers (manufactured by Walraven) mounted as sliding and fixing clamps.		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	41	46	48	50
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	41	46	48	50
	UG rear	<10	10	14	19
Installation sound level $L_{AFeq,nT}$ [dB(A)] **following VDI 4100** in the basement test-room	UG front	39	43	45	48
	UG rear	<10	<10	11	16

Test date: April 17, 2019

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

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 14, 2019
Head of Laboratory:

Fraunhofer-instituutti Wavin AS+, akustiikkamittausraportti P-BA 64/2019e

Fraunhofer-instituutin suorittama akustiikkamittausraportti Wavin AS+ -desibeliviermärille ääntä vaimentavilla Wavin Low Noise tuplakannakkeilla.

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

P-BA 64/2019e

Results sheet 1

Client: Wavin T&I, Rollepaal 20, 7701 BS Dedemsvaart, Netherlands

Test specimen: Wastewater system "Wavin AS+, DN/OD 110 x 5.3, 05.11.2018" (manufacturer: Wavin). The wastewater system consisted of straight plastic pipes and fittings and pipe clamps "Wavin Low Noise bracket" with elastic inlay and spacers (manufactured by Walraven) mounted as acoustic double clamps. Test object no.: 11065-11; 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°), two 45°-basement bends and a horizontal drain section. The inlet tees in the basement and in the ground floor were closed by plugs supplied by the manufacturer.
  - Pipe system: "Wavin AS+, DN/OD 110 x 5.3, 05.11.2018": Three-layer pipes: Material PP, wall thickness 5.7 mm, weight 3.45 kg/m, density 1.87 g/cm³, values measured by IBP. One-layer fittings: Material PP, wall thickness 4.8 mm, density 1.85 g/cm³, values measured by IBP. Plug connection of the pipes and fittings (shaped pipe sockets).
  - Pipe clamps: Steel pipe clamps "Wavin Low Noise bracket" with elastic inlay and with spacers (manufactured by Walraven) mounted as acoustic double clamps. In every storey (EG and UG) two pipe clamps were mounted: In the upper wall area a single guidance clamp with one white spacer (15.3 mm) on both sides of the clamp. In the lower wall area a double clamp consisting of a supporting/guidance clamp with one white spacer (15.3 mm) on both sides of the clamp and above a fixing clamp with one black spacer (10 mm) on both sides of the clamp. The supporting and guidance clamps were fixed to the installation wall with dowels and thread rods. The fixing clamp had no contact to the wall (figure 5).

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 14366:2005-02; 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 4109:2018-01 and VDI 4100:2012-10 (details in Annexes A, F and V).

Result:

Wastewater system "Wavin AS+, DN/OD 110 x 5.3, 05.11.2018" (manufacturer: Wavin). The wastewater system consisted of straight plastic pipes and fittings and pipe clamps "Wavin Low Noise bracket" with elastic inlay and spacers (manufactured by Walraven) mounted as acoustic double clamps.		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	41	45	48	50
Structure-borne sound characteristic level $L_{sc,A}$ [dB(A)] **according to EN 14366** for the basement test-room	UG rear	<10	<10	<10	10
Installation sound level $L_{AFeq,n}$ [dB(A)] **following DIN 4109** in the basement test-room	UG front	41	45	48	50
	UG rear	<10	<10	<10	13
Installation sound level $\overline{L_{AFeq,nT}}$ [dB(A)] **following VDI 4100** in the basement test-room	UG front	38	43	45	48
	UG rear	<10	<10	<10	10

Test date: April 17, 2019

Notes:

- For comparing test results with requirements note Annex A.
- The above-mentioned measurement results require careful assembly of the pipe clamps (see test set-up).

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 14, 2019

Head of Laboratory:

Fraunhofer-instituutti Wavin SiTech+, akustiikkamittausraportti

Fraunhofer-instituutin suorittama akustiikkamittausraportti Wavin SiTech+ -desibeliviermärille ääntä vaimentavilla Bismat 1000-kannakkeilla.

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

Directors:
Prof. Dr. Philip Leistner
Prof. Dr. Klaus Peter Sedlbauer

Test Report P-BA 24/2016e

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

Client: Wavin GmbH
Industriestraße 20
49767 Twist

Test object: Wastewater installation system consisting of plastic pipes and fittings "SiTech+, OD 110", manufacturer: Wavin 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 28 October 2015 in the test facilities of the Fraunhofer Institute for Building Physics in Stuttgart.

Stuttgart, 05 February 2016

Responsible Test Engineer: M.BP. Dipl.-Ing. (FH) S. Öhler

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

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

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www.ibp.fraunhofer.de/de/pruefstellen/bauakustik.html

DAkkS

Determination of Installation Sound Level L_{in} in the Laboratory	P-BA 24/2016e Results sheet 1

Client: Wavin GmbH, Industriestraße 20, 49767 Twist

Test specimen: Wastewater installation system consisting of plastic pipes and fittings "SiTech+, OD 110" manufacturer: Wavin with pipe clamps "Bismat 1000" made by Walraven. (no.: S 10904-3)

Test set-up:

- The waste water pipe system "SiTech+, OD 110", manufacturer: Wavin, consisted of straight pipes with nominal size OD 110, material: three layers of polypropylene (mineral filled), wall thickness: 3.4 mm (measured: 3.7 mm), density: 1.3 g/cm³, fittings with nominal size OD 110 (three inlet tees (Ø110, 87.5°), 2 x 45°-basement bend and a horizontal drain section), material: single layer polypropylene (mineral filled), wall thickness: 3.4 mm (measured: 3.6 mm), density: 1.5 g/cm³. The inlet tees in the basement and in the ground floor were closed by lids supplied by the manufacturer. Plug connection of the pipes and fittings. Values are manufacturers' information.
- Pipe clamps "Bismat 1000" made by Walraven (see figure 5): Structure-borne sound insulating support attachment consisting of Bismat "SL" guidance clamps and Bismat "SX" socket clamps. The clamps were fixed to the installation wall with an adjustable wall plate with dowels and thread rods. In each storey (EG and UG) two clamps were installed. In the upper wall area one "Bismat 1000" was mounted as loose clamp (guidance clamp "SL", DN 100). In the lower wall area one "Bismat 1000" double clamp consisting of Bismat "SL" guidance clamp and Bismat "SX" socket clamp was installed. To prevent contact to the pipe, all guidance clamps "SL" were mounted with spacers between both sides of the locking tabs of the clamp (2 x 7.5 mm, black).

The wastewater installation system was mounted according to figure 4 and 5 (see also Annex A), 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 room: EG front; measuring rooms: UG front, UG rear and EG rear. (For further details, please refer to 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, F). Additional calculations of the measurement values according VDI 4100 (Annex V).

Result:

Wastewater plastic pipe system "SiTech+, OD 110" made by Wavin with pipe clamps "Bismat 1000" made by Walraven.		Flow rate [l/s] 0,5	1,0	2,0	4,0
Installation sound level $L_{AFmax,n}$ (L_{in}) [dB(A)] acc. **DIN 4109** for the basement test room	UG front	46	50	52	55
	UG rear	<10	15	15	19
Installation sound level $\overline{L_{AFmax,nT}}$ [dB(A)] acc. **VDI 4100** for the basement test room	UG front	44	47	49	53
	UG rear	<10	11	12	15
Airborne sound pressure level $L_{a,A}$ [dB(A)] acc. **EN 14366**		46	50	52	55
Structure-borne sound characteristic level $L_{sc,A}$ [dB(A)] acc. **EN 14366**		<10	11	12	15

Test date: 28 October 2015

Notes:

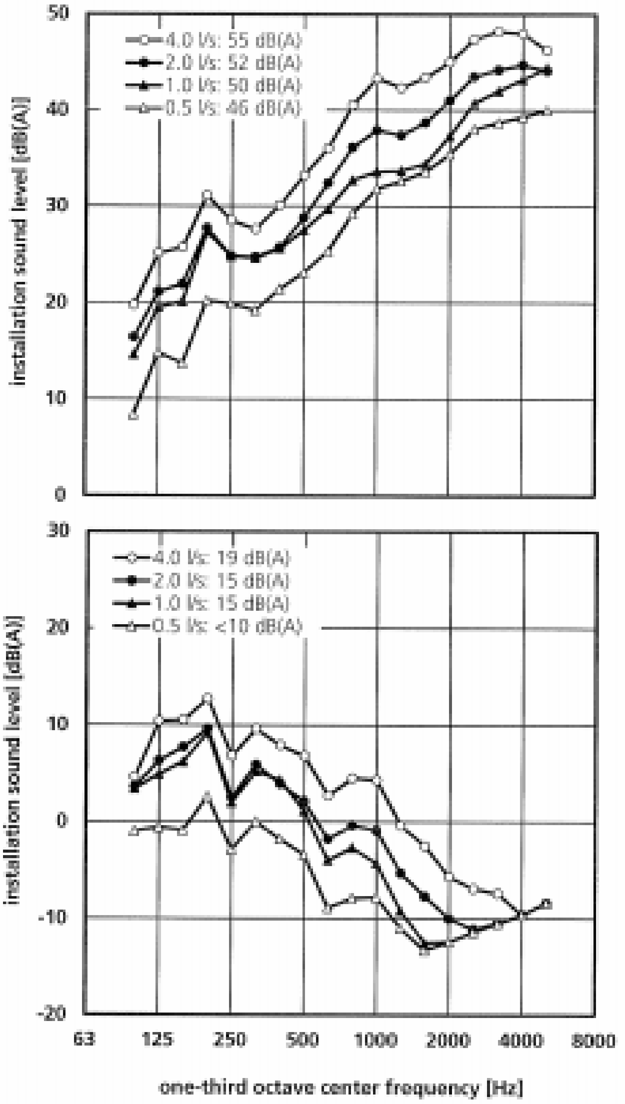
- The requirements of German standard DIN 4109 apply in the present building situation only for the test room UG rear.
- Sound levels below 10 dB(A) are not mentioned in the test report, since they are subject to an increased measurement uncertainty and moreover are not noticeable in a normal living environment.
- 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.

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, 05 February 2016
Head of Laboratory: i.V. [signature]

Detailed results Client: Wavin GmbH, Industriestraße 20, 49767 Twist	P-BA 24/2016e figure 1



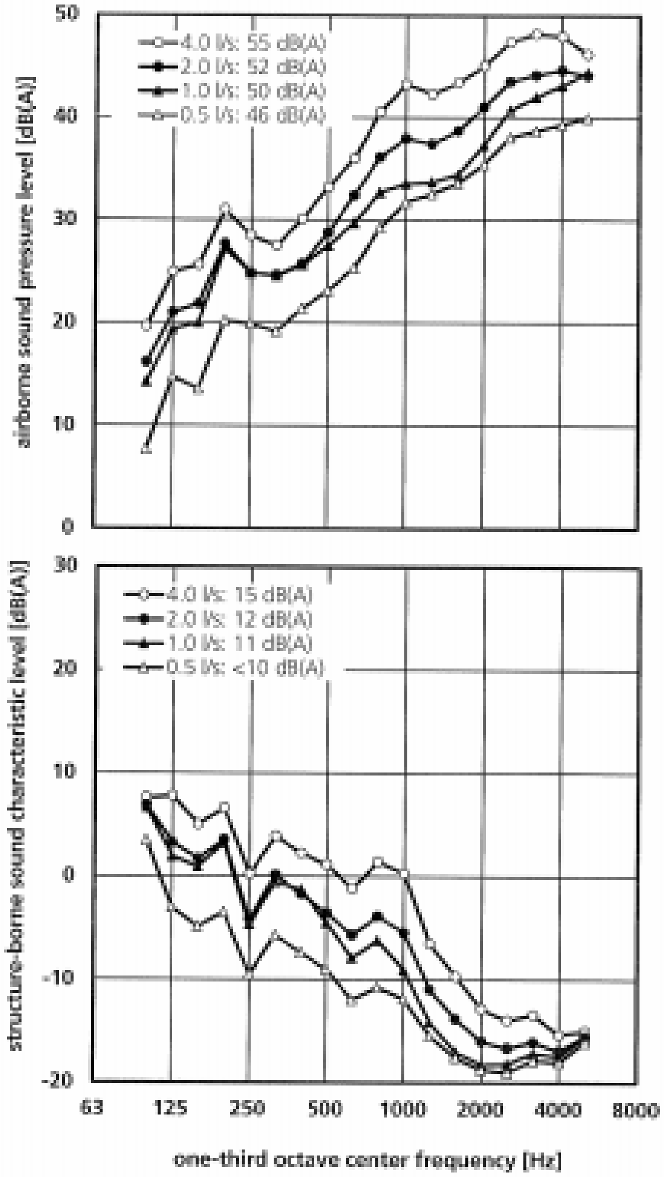
Frequency response of the installation sound level $L_{AFmax,n}$ (L_{in}) measured at various flow rates in the test rooms UG front (above) and UG rear (below). The installation sound levels $L_{AFmax,n}$ (L_{in}) in dB(A) acc. DIN 4109, for the frequency range from 100 to 5000 Hz, are represented in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

Test specimen: Wastewater plastic pipe system "SiTech+, OD 110" made by Wavin with pipe clamps "Bismat 1000- all guidance clamps "SL" with spacers (2 x 7.5 mm)" made by Walraven.

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.

Detailed results | **P-BA 24/2016e**

Client: Wavin GmbH, Industriestraße 20, 49767 Twist | figure 2



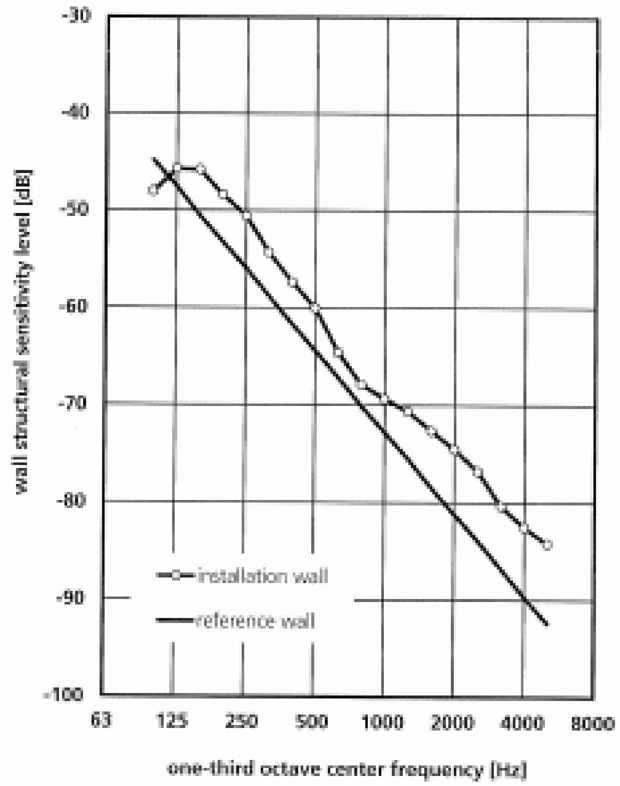
Frequency response of the airborne sound pressure level $L_{a,A}$ (above) and structure-borne sound characteristic level $L_{sc,A}$ (below) measured at various flow rates according to EN 14366. The single values acc. EN 14366, for the frequency range from 100 to 5000 Hz, are represented in the legend.

Test specimen: Wastewater plastic pipe system "SiTech+, OD 110" made by Wavin with pipe clamps "Bismat 1000- all guidance clamps "SL" with spacers (2 x 7.5 mm)" made by Walraven.

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.

Detailed results Client: Wavin GmbH, Industriestraße 20, 49767 Twist	**P-BA 24/2016e** **figure 3**



Wall structural sensitivity level L_{SI} 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_{SI} refers to the mounting position of the waste water system according to figure 4. For comparison the wall structural sensitivity level L_{SIR} of the reference wall is also indicated (evaluation according to DIN EN 14366).

Test specimen: Wastewater plastic pipe system "SiTech+, OD 110" made by Wavin with pipe clamps "Bismat 1000- all guidance clamps "SL" with spacers (2 x 7.5 mm)" made by Walraven.

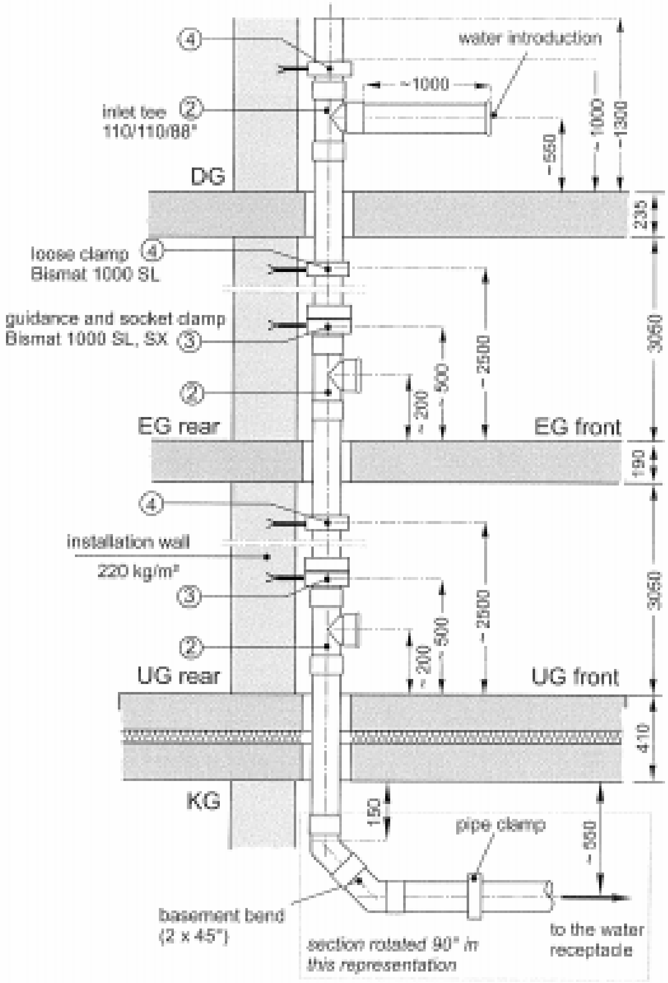
Fraunhofer IBP	The test was carried out in a laboratory, accredited according to DIN EN ISO/IEC 17025:2005 by DAkkS. The accreditation certificate is D-PL-11140-11-01.

Test set-up

Client: Wavin GmbH, Industriestraße 20, 49767 Twist

P-BA 24/2016e

figure 4



Installation plan of the test set-up in the test facility.

Test specimen: Wastewater plastic pipe system "SiTech+, OD 110" made by Wavin with pipe clamps "Bismat 1000- all guidance clamps "SL" with spacers (2 x 7.5 mm)" made by Walraven.

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.

Test set-up Client: Wavin GmbH, Industriestraße 20, 49767 Twist	P-BA 24/2016e figure 5

Oben: Upper wall area with Pipe clamp "Bismat 1000" made by Walraven. Loose clamp (guidance clamp "SL", DN 100), with two spacers on each side (2 x 7.5 mm, black).

Unten: Lower wall area with Pipe clamp "Bismat 1000" made by Walraven. Double clamp consisting of Bismat "SL" guidance clamp (DN 100) with two spacers on each side (2 x 7.5 mm, black) and Bismat "SX" socket clamp (DN 100) without spacer.

Test specimen: Wastewater plastic pipe system "SiTech+, OD 110" made by Wavin with pipe clamps "Bismat 1000- all guidance clamps "SL" with spacers (2 x 7.5 mm)" made by Walraven.

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.

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/m²) by means of pipe clamps supplied by the Client, which are adapted to the external diameter of the pipes. The locations of the fixation points and further dimensions are specified in the installation plan that is included in the test report.

Noise excitation and evaluation parameters

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

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

Here, a flow rate of Q = 2.0 l/s roughly corresponds to the average flow rate required for flushing a toilet. According to Prandtl-Colebrook, the highest flow rate used results from the admissible hydraulic charge of the horizontal pipe sections, which is Q_{max} = 4 l/s for OD 110 pipes.

The measurements take place in the installation room (UG front) and in the room behind the installation wall (UG rear). The water flow generates vibrations of the wastewater pipe. These vibrations are transmitted to the installation wall through pipe clamps and/or other structure-borne sound bridges (e.g. fire protection sleeves), and then radiated by the wall (and to a lesser extent, also by the adjoining building parts) as airborne sound into the test room behind the installation wall. In the test room UG front additionally the airborne sound which is radiated from the waste water system is measured. According to EN ISO 140-3 the sound pressure level is picked up at six points in the room, to be space and time-averaged and corrected for the background noise. With this value the airborne sound pressure level $L_{a,A}$ and the structure-borne sound characteristic level $L_{sc,A}$ is calculated according to EN 14366. The installation sound level is determined following Annex F. Thereby the rounded $L_{AF,10}$ is equivalent to the installation sound level L_{In} (or $L_{AFmax,n}$) according to DIN 52219, DIN EN ISO 10052, DIN 4109-11 and DIN 4109.

Evaluation of Measurements

Stationary noise

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

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

L_{nF}	space and time averaged sound pressure level in one-third octave band n (time constant: fast)	[dB]
L_{nS}	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.

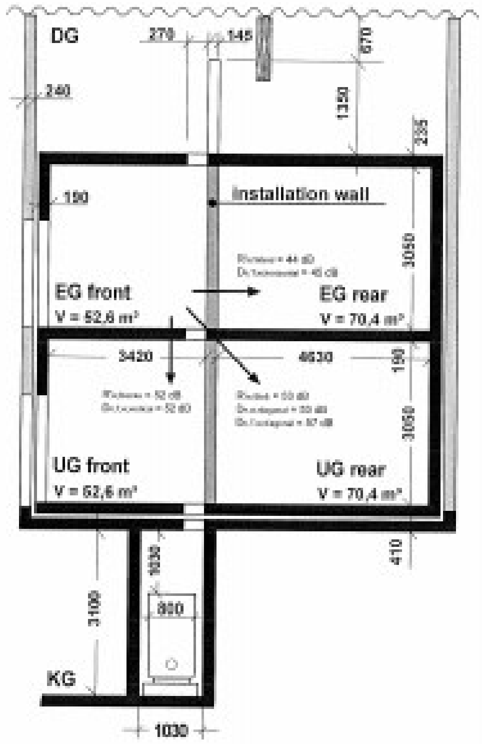
(2) $$L_{AF,10} = 10 \cdot \lg\left(\sum_{n=1}^{18} 10^{\frac{L_{n,AF,10}}{10}}\right),$$ [dB(A)]

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.

Status: 11 January 2016

Measurement equipment

Following measurement equipment was used for the measurements 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 [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:

Status: December 10, 2013

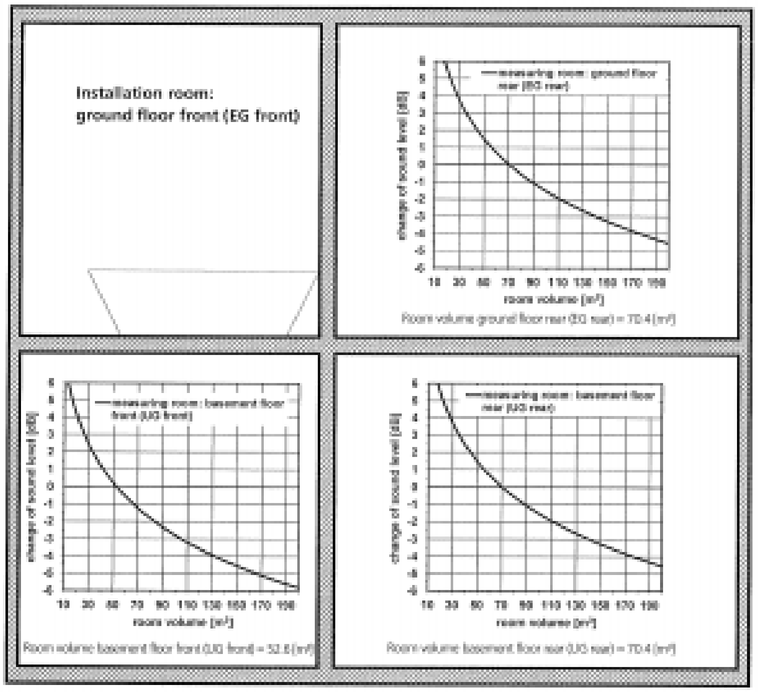


Fig. 1: Modification of the standardized sound level measured in the installation test facility P12 for rooms with deviating volume. The resulting change of sound level in comparison to the measured value indicated in the test report in dependence of the new room volume is specified in the diagrams for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

Status: December 10, 2013

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.

Status: December 10, 2013

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-instituutti Uponor Decibel, akustiikkamittausraportti

Fraunhofer-instituutin suorittama akustiikkamittausraportti Uponor Decibel -desibeliviermärille ääntä vaimentavilla Bismat 1000-kannakkeilla.

Fraunhofer
IBP

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

Director
Prof. Dr. Klaus Peter Sedlbauer

Test Report P-BA 158/2015e

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

Client: UPONOR Infra
Kouvolantie 365
FI-15521 Nastola
FINLAND

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

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 July 14, 2015 in the test facilities of the Fraunhofer Institute for Building Physics in Stuttgart.

Stuttgart, December 23, 2015

Responsible Test Engineer: M.Sc. B. Kaltbeitzel

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

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

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DAkkS D-PL-11140-11-01

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

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

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

Test set-up:
- The pipe system was mounted according to figure 4 (see also Annex A).
- The system consisted of wastewater pipes (nominal size OD 110), three inlet tees (45°), two 45°-basement bends and a horizontal drain section. The inlet tees in the basement and in the ground floor were closed by lids supplied by the manufacturer.
- Pipe clamps "Bismat 1000" (figure 5): Structure-borne sound insulating support attachment consisting of Bismat SL guidance clamps and Bismat SX socket clamps. In each storey (EG and UG) respectively one double clamp was installed at the lower wall area. To prevent contact to the pipe, the guidance clamp (SL) was mounted with 14 mm space between the locking tabs of the clamp (two 7.0 mm spacers on each side). At the upper wall area one "Bismat SL" was mounted as loose clamp (two 7.0 mm spacers on each side) without contact to the pipe (figure 5). The Bismat 1000 clamps were fixed to the installation wall with an adjustable wall plate with dowels and thread rods.

The wastewater installation system was mounted by a technician under the authority of Fraunhofer IBP.

Test facility: Installation test facility P12, mass per unit area of the installation wall: 220 kg/m², mass per unit area of the ceiling: 440 kg/m². Installation rooms: sub-basement (KG), basement (UG) front, ground floor (EG) front and top floor (DG), measuring rooms: UG front, UG rear (details in Annex P and EN 14366: 2005-02)

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

Result:

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

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

Test date: July 14, 2015

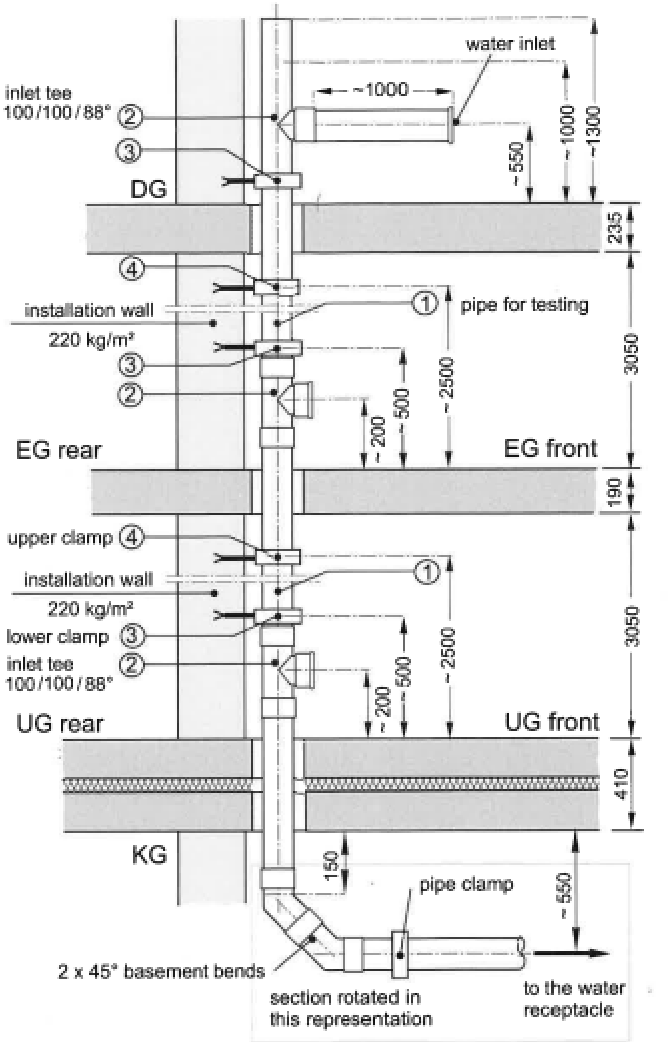
Notes:
- The requirements of DIN 4109 and VDI 4100 only apply for the test room UG rear.
- For the experimental setup investigated in the test facility the used supporting and fixing clips Bismat 1000 normally doesn't guarantee a realistic load transmission. Consequently, in case of practical application in a real building, higher levels of installation noise may be expected.
- Sound levels below 10 dB(A) are not mentioned in the test report, since they are subject to an increased measurement uncertainty and moreover are not noticeable in a normal living environment.

Fraunhofer IBP

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

Stuttgart, December 23, 2015
Head of Laboratory:

Detailed results	**P-BA 158/2015e**
Client: UPONOR Infra, Kouvolantie 365, FI-15521 Nastola, FINLAND	**figure 4**



Installation plan of the test set-up in the test facility. Upper clamps ④ "Bismat SL", lower clamps ③ "Bismat 1000", consisting of Bismat SL guidance clamp and Bismat SX socket clamp
Test specimen: Wastewater installation system consisting of plastic pipes and fittings "Uponor Decibel" (manufacturer: Uponor Infra) with pipe clamps "Bismat 1000" made by Walraven.

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.

Detailed results Client: UPONOR Infra, Kouvolantie 365, FI-15521 Nastola, FINLAND	**P-BA 158/2015e** **figure 5**

Upper picture: Pipe clamp "Bismat SL, loose clamp" (two 7.0 mm spacers on each side) at the upper wall area.
Lower picture: "Bismat 1000", consisting of Bismat SL guidance clamp with two 7.0 mm spacers on each side and Bismat SX socket clamp without spacer at the lower wall area.
Mounting details see test set-up.
Test specimen: Wastewater installation system consisting of plastic pipes and fittings "Uponor Decibel" (manufacturer: Uponor Infra) with pipe clamps "Bismat 1000" made by Walraven.

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.

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/m²) 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.

Measurement equipment

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

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

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

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