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# Laboratory test method to determine noise from wastewater installations

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**Abstract**
We are working on a project which aims at improving sewage pipe material and piping system to reduce the radiated noise. One challenge we faced initially was to identify a suitable experimental method that fulfilled following requirements: allows for testing of the complete system and single components, fits our standard laboratory, suitable for measuring both airborne and structure-borne noise, reliable and cost effective. EN 14366 describes a laboratory measurement procedure to determine noise from wastewater installations. This method requires a setup comprising of two rooms: a source room to determine the airborne sound and a receiving room to indirectly determine the structure-borne sound by measuring the sound pressure level. As the test method was designed to compare pipe systems, the system layout is strictly defined, and the setup is not well suited to investigate system components or selected system sections for R&D purposes. The requirements on the laboratory facility are extensive and test of single components is not foreseen in the standard. In this paper we briefly present findings from a literature survey on the measurements of noise from wastewater installations. Moreover, we present an alternative setup and test method that we designed for our purposes. This setup allows the investigation of vertical and horizonal pipes or even just single components (e.g., bends). We will present sample results and are looking forward to an active discussion of pros and cons.

**Keywords:** wastewater pipes, sound radiation, measurement setup.

## 1 Introduction

The noise emissions from waste-water pipe installations can be a source of annoyance in buildings. The densification of the urban space, the limited space available for technical installations together with the use of lightweight constructions increase the risk of unwanted noise from the waste-water installations. Building users are increasingly aware towards noise levels [1]. Building constructors look constantly for options to reduce space requirements for technical installation and reduce installation costs without increasing the risk for complaints. This makes low noise piping systems attractive and the major wastewater system manufacturers responds accordingly developing low noise pipes and piping systems [e.g., Geberit, Wavin, Pipelife]. Increased development effort demands more effective and flexible test method than the established standards as, e.g., the EN 14366:2004 [2].

The vibrations induced by the water flow on the pipe walls produce directly airborne sound and structure-borne sound when they are transmitted to other building components by the pipe clamps. Field measurement results shows that structure-borne sound often dominates the sound pressure level in practical application. However, reducing the direct airborne sound might offer advantages in terms of lower requirements on the pipe enclosure or even allow for visible pipes in certain applications. Having to control both aspects makes measurement setups rather demanding. Moreover, different pipe system sections are exposed to different flow and are excited in different ways. These generates the different characteristics sounds as e.g., the splash sound at the bend or at the branch and the flow noise in a vertical or horizontal section [3]. Also, the flow noise appears to be different in the vertical section where the water flow tends to lean on the walls in a helicoidal shape and in the horizontal section where the flow fills the lower half of the pipe.

We are currently involved in a research project leaded by a Norwegian pipe manufacturer aiming at developing even quieter pipes by gaining a better understanding of the noise generating mechanisms and sound radiation from the pipe and pipe components. A significant part of the project comprises the acoustic testing of material and components. For this purpose, a flexible yet reliable and accurate test method was needed.

In this paper, after a brief literature review, we present the setup we designed with the aim of overcoming the limitations of the current measurement standard and aim towards the project goals.

## 2 Literature

EN 14366:2004 [2] describes the laboratory measurement procedure to determine noise from waste-water installations and it is the reference standard for the topic. The standard test setup requires a rig comprising two rooms as shown in Figure 1. In this way it is possible to determine the directly radiated airborne sound and the structure-borne sound radiated in an adjacent room. The standard focuses on the comparison of pipe system with a very specific setup: it is limited to vertical pipes only, and the bend shall be mounted specifically below and outside the test room. The setup allows for different height differences between the water inlet and the bottom bend. The flow shall be continuous, ranging from 0,5 to 8 l/sec. The standard was often criticized because of the comprehensive requirements and because the data collected is not well suited for the available prediction models (see Amendment A1:2019). A review of the standard is ongoing to overcome the latter limitations.

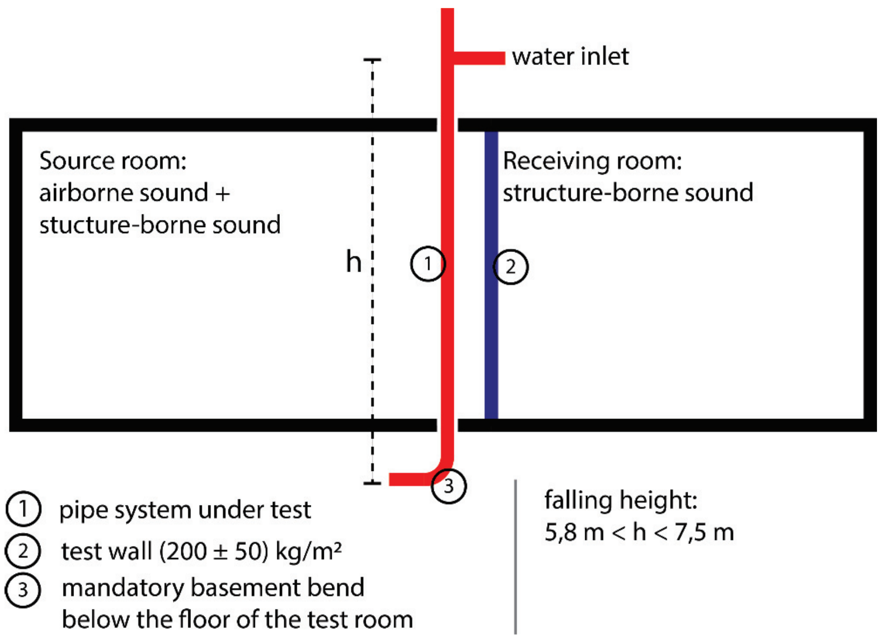



Figure 1 Measurement setup concept from EN14366.

The standard EN 15657:2017 [4] can be successfully used to determine the structure borne sound generated by a pipe system as described in [5] but the method does not cover the direct sound radiation.

A very interesting alternative measurement method is presented in [6]. The method combines the application of sound intensity measurements according to ISO 9614 [7] and structure-borne sound power according to EN 15657 to determine the airborne and the structure-borne sound directly on a power basis without the need of any specific room. The method appears to be very flexible and effective. The major drawbacks relate to the need of sound intensity measurement equipment and the corresponding requirements.

The paper [8] was a precious resource in this work: they installed a pipe system in a reverberation chamber and performed measurements on vertical and horizontal pipes, including also vertical offsets (i.e. a shift of the pipe axis achieved through two consecutive bends) as one of the tests. They tested products based on different materials and the effects of various types of pipe shielding (gypsum enclosure, external acoustic insulation, ceiling tiles). They measured with constant flow and with toilet discharge and conclude that a constant flow rate of 3 l/s gives sound pressure levels comparable with the level of a flushing toilet.

The work from Van Der Jagt [9] must be included in this brief overview since it offers many important insights on possible measurement setups. However, the analysis presented therein is about the applicability of the SEA method and focuses on mode count rather than on the sound radiation properties of the pipes and components.

Earlier works present measurement setups and theory that might be relevant for studying the material properties, e.g., [10] and [11]. Finally, it is worth mentioning the textbook [12] which covers the underlying theory of sound radiation from pipes.

# 3 Alternative measurement setup

We developed a measurement setup aimed at comparing different pipe materials and components for R&D purposes. Besides the obvious criteria that the setup needed to fit our available facilities, key requirements were a) allows the investigation of vertical and horizonal pipes or even just single components (e.g., bends), b) cost effective and c) easy to adapt to different research aspects.

Figure 2 shows a schematic of the test rig that we used. The measurement room has a volume of 200 m$^3$ and fulfil the requirements of ISO 10140 [13]. We have two tanks; an upper one that serve as source and a lower one that serve as sink. The flow regulation is made by a passive siphon to avoid pumping noise. In the current setup we used 1 l/s, 2 l/s, 3 l/s and 4 l/s. Other flow rates are possible but the measurement time available at higher rates than 4 l/s becomes relatively short due to the volume of the tanks. Up to now we used a constant flow rate. It would be possible to adapt the setup to measure with transient excitation as well.
Two alternative inlets are available. Both inlets are designed according to the specifications from EN 14366. Using the higher inlet, it is possible to obtain a falling height of 5,4 m. The minimum falling height that we can use is 0,5 s determined by the ceiling construction of the measurement room. A vibration decoupling element is used to prevent vibration transmission along the pipe outside of the measurement room. This allows for quick shifting of the pipe system and reduces the effect of the inlet and outlet fixtures. The pipe system can be installed hanging free in the room or installed by means of clamps on the two available reception plates (vertical and horizontal). In the latter case measurements can be carried out according to EN 15657.

We measured the sound pressure level in the room by means of two microphones mounted on rotating booms. In addition, we measured the reverberation time. In this way, it is possible to correct the sound pressure level to a standardized equivalent sound absorption area as described in EN 14366. Alternatively, it is possible to calculate the sound power which could be used as input data to prediction models.

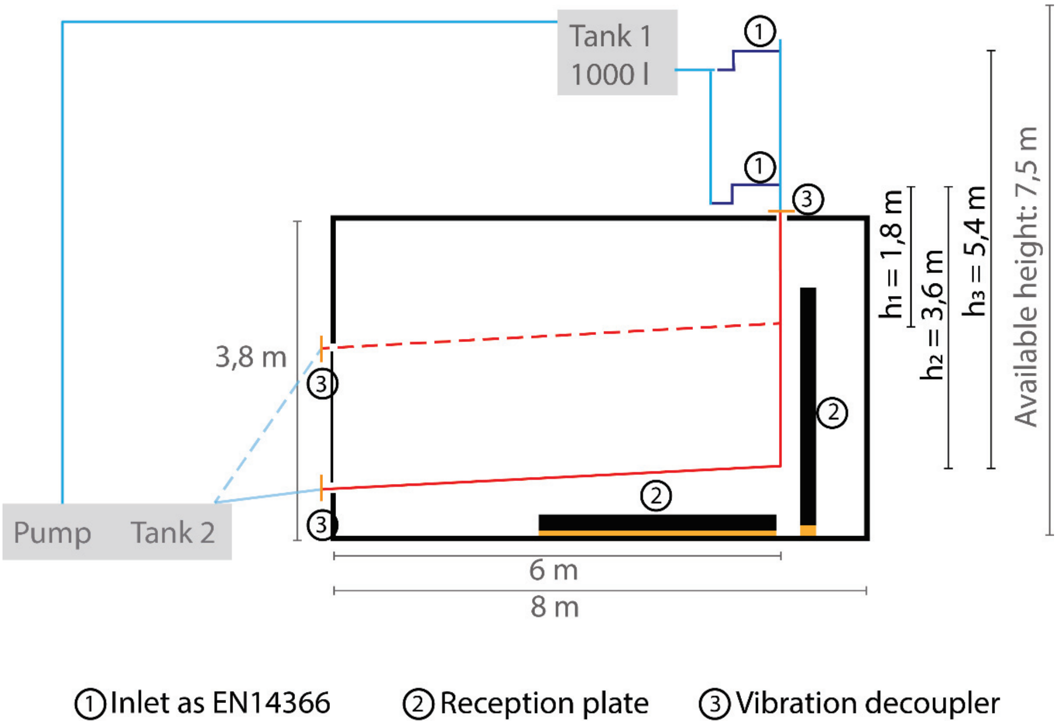



Figure 2 Proposed measurement setup

# 4 Some results

## 4.1 Reproducibility and mounting details

Figure 3 shows a picture of one of the configurations we measured. The pipe system was installed without brackets, resting on resilient material pads at two points on the horizontal section. We installed the very same system from scratch twice to get a rough estimate of the reproducibility of the setup. In addition, we performed a third measurement where at the bends we pulled apart the pipe by 10 mm. The aim was to verify how installation details might affect the overall sound radiation.
The results are shown in Figure 4. The values of the airborne sound pressure level $L_{a,A}$ are corrected with the equivalent absorption area according to EN14366.

We see that the variation between repetitions is below 1 dB at the higher flow rates while it is slightly above at lower flow rates. We observe a similar behaviour when we look at the test with bend and pipe pulled apart: very little difference at the higher flow rates (0,2 dB to 0,3 dB at 3 l/s and 4 l/s) and larger difference at low flow rates (1,4 to 1,7 dB at 1 l/s and 2 l/s). We have no good explanations for this effect, but we observe in other papers that measurements at low flow rates deviate slightly from general trends, as e.g. in [14]. We assume that this might be due to the water flow which is less stable at low flow rates.

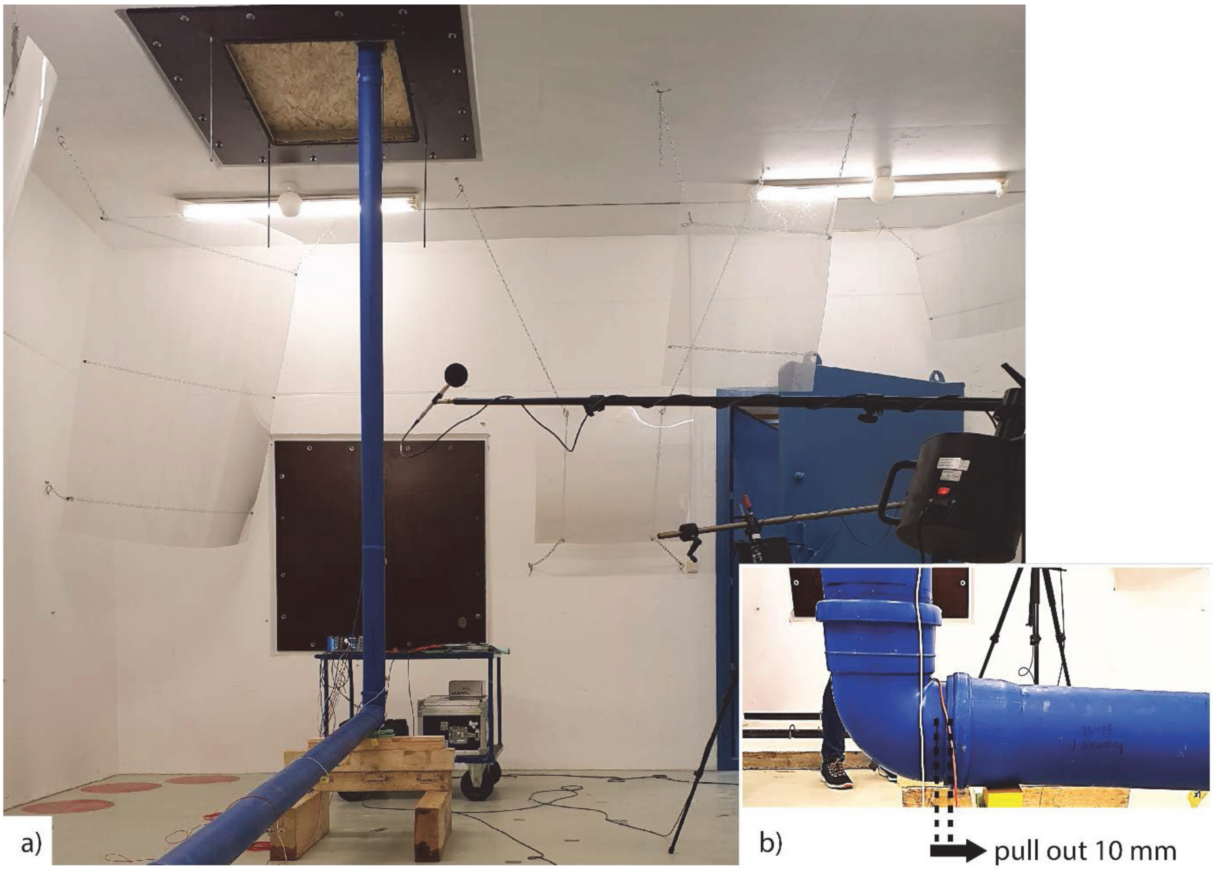
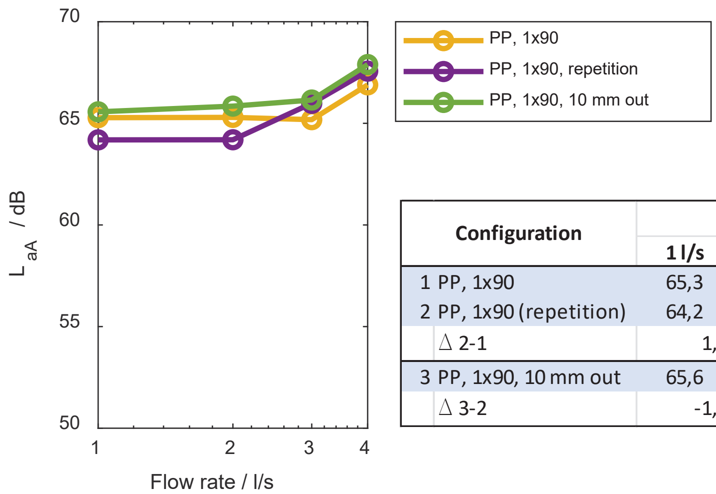



Figure 3 a) Configuration with pipe system installed without brackets. b) Test with pipe and bend pulled apart by 10 mm.




| Configuration | $L_{a,A}$ / dB | | | |
|---|---|---|---|---|
| | 1 l/s | 2 l/s | 3 l/s | 4 l/s |
| 1 PP, 1x90 | 65,3 | 65,3 | 65,2 | 66,9 |
| 2 PP, 1x90 (repetition) | 64,2 | 64,2 | 66,0 | 67,6 |
| Δ 2-1 | 1,1 | 1,1 | -0,8 | -0,7 |
| 3 PP, 1x90, 10 mm out | 65,6 | 65,8 | 66,1 | 67,9 |
| Δ 3-2 | -1,4 | -1,7 | -0,2 | -0,3 |

Figure 4 Measured airborne sound pressure levels at four different flow rates. Two repetitions and one measurement with bend and pipe pulled 10 mm apart.

### 4.2 Sound radiation from different components

Each section of the pipe system contributes to the radiated sound to different extents. One might experience the larger contribution to the sound pressure level from the bend. The radiated sound power from the vertical section is not the same as the one from the horizontal section. To investigate in detail these aspects, we shielded different sections of the pipe and measured the radiated sound pressure level. Figure 5 shows the measurement setup. The picture in a) was taken while installing the shield around the bend. The box made of OSB boards is still open: you recognize the mineral wool used as absorption (50 mm – 100 mm placed in contact with the wall box, without pressing on the pipe). The picture b) shows a configuration with the shields in place on the bend and 1 m before and after it. The openings around the pipe were sealed with mineral wool so to prevent direct mechanical contact between the pipe and the box and airborne transmission. In Figure 6, we show the measurement result obtained for 4 different configurations:

1) no shielding: we measure the sound pressure level from the whole system,
2) shielding of a section of the horizontal pipe: the sound pressure is now dominated by the sound radiation from the bend and the vertical pipe,
3) same as 2) with an additional shield on the bend: the sound pressure is determined by the sound radiation from the vertical pipe,
4) the shields prevent sound radiation from the bend itself and 1m before and after it: the measured sound pressure in the room is now dominated by the flow noise from the pipe sections away from the bend.

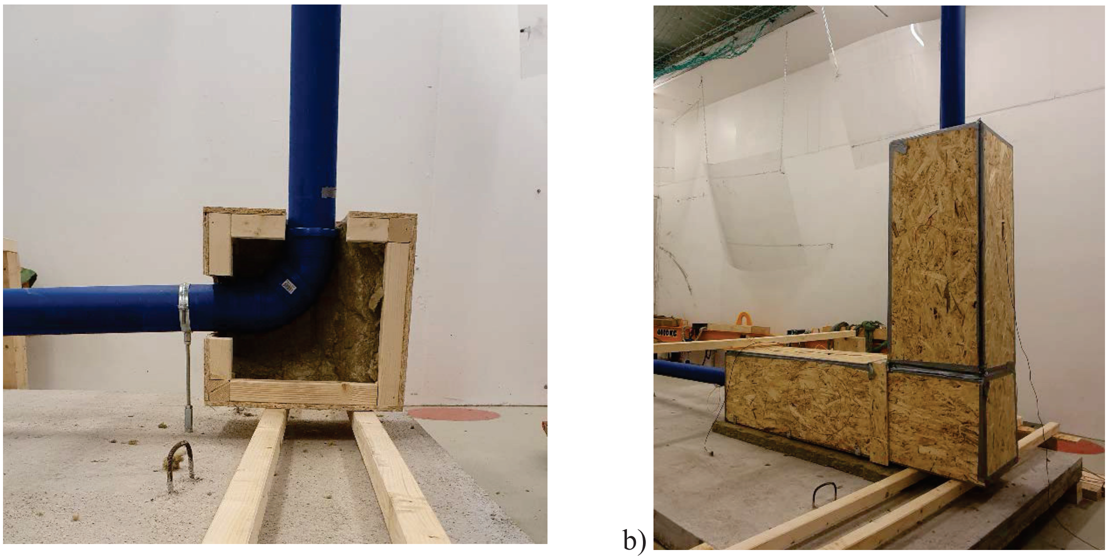
a) b)


Figure 5 a) Mounting the shielding around the bend. b) Installed shielding on the bend and 1m before and after it.

The results confirm that the bend and the pipe section close to it dominates the sound radiation as described, e.g., in [8]. The shielding appears to have little effect or even an amplification effect below 400 Hz. This might be due to following effects or a combination of them: a) the shield is not good enough at frequencies below 400 Hz, b) the vibration field in the pipe at frequencies below 400 Hz decreases at a lower rate with distance compared to higher frequencies and therefore sound radiation from the straight sections is more relevant at further distance from the bend and/or c) modal resonances of the shielding box. An improved version of the shields or longer shielding would clarify these aspects.

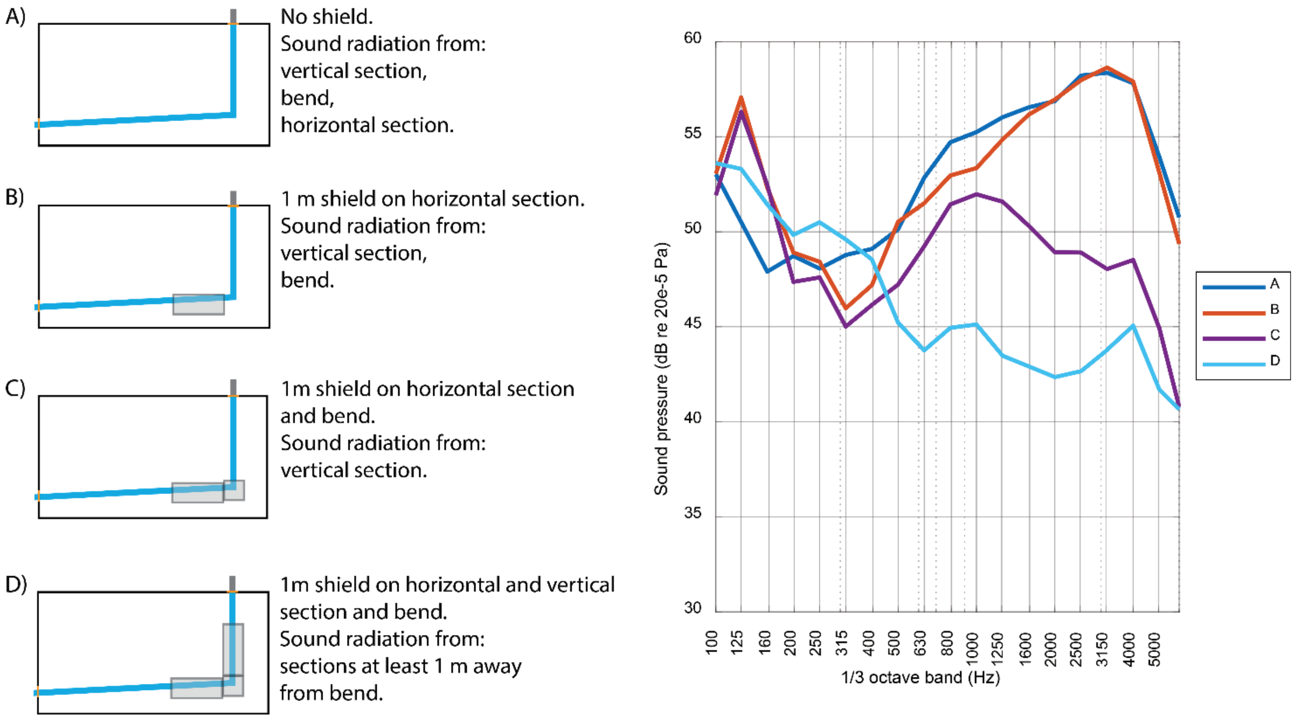



Figure 6 Measurement results obtained shielding different parts of the pipe system.

## 5 Conclusions and discussion

Increasing effort to reduce the sound radiated by drainage pipes requires a flexible and accurate measurement setup that allow for the investigation of both components and the full system. In this paper we presented the measurement setup we are using in a current research project. The setup was realised in our acoustic laboratory and overcomes some of the limitations of standard measurement setup realised according to EN14366.
We presented and discussed some selected results, focusing on the reproducibility of the measurements results (< 1 dB at higher flow rates) and showing how it possible to investigate sound radiation from different sections of the pipe system within one single installation.

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