INSITER INTUITIVE SELF-INSPECTION TECHNIQUES

# D6.1 Training modules and pilot training courses

# ANNEX 3b

Ultrasound and Ultragraphic Measurements

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**Annex 3b –Ultrasound and Ultragraphic measurements**

**INSITER - Intuitive Self-Inspection Techniques using Augmented Reality for construction, refurbishment and maintenance of energy-efficient buildings made of prefabricated components.**

INSITER INTUITIVE SELF-INSPECTION TECHNIQUES

# D6.1 Training modules and pilot training courses

## Ultrasound and Ultragraphic Measurements

*'Knowledge transfer through awareness, training and self-instruction'*

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| Produced by | DEMO Consultants |
| Main author | Ruud Geerligs |
| Co-authors | Theo d'Achard van Enschut (Gevelscan) / Luc Holtkamp (Leakworx) |
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| Reviewed by | Jan Cromwijk, Arjan Broers (ISSO) |
| Approved by | <<…>> |
| Dissemination | <<…>> |

### Colophon



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# Note

The training material for Ultrasonic and Ultragraphic measurements is made for testing the content on the Dutch market. For this reason, the training is originally in Dutch. The training material is translated in English as well (this document).

# Contents

# 1. Introduction Ultrasound and Ultragraphic

## 1.1 Importance of Ultrasound Measure

Due to ever higher energetic demands on buildings, it becomes more important to assure the quality of the construction. It must be built as agreed. One of the important aspects is the air tightness of the building envelope. Not only for energy efficiency, but also for the prevention of problems with building physics and comfort and health complaints.

A good air tightness check is essential.

This check consists of the following parts:

- Are the right materials used;
- Are the airtight sealing materials appropriately applied;
- Check if the connection is tight;
- Measurement how tight the connection is.

The most well-known way of measuring is the blower door test. This will put the entire building over or under pressure and measures how much air is lost through the building envelope. Another way is to perform ultrasound measurements, possibly in combination with ultragraphic.

Ultrasound measurements can be applied at the beginning of the construction, even if the building is not yet wind and waterproof. This measurement gives a good idea if the connection is airtight and any deviations can be repaired immediately. Additional advantages are that the measurement does not depend on a temperature difference over the façade and can be performed at all weather conditions. Furthermore, the building does not need to be evacuated and can be measured while the property is in use.

*Figure 1 Ultragraphic setup [Source: Sonotec]*

## 1.2 What is Ultrasound?

Not all sound is hearable. Sound with a very low frequency (less than 20Hz) and sound with a very high frequency (more than 20,000 Hz) we cannot hear.

As we age, our hearing worsens and we can hear less.

Sound with a very low frequency (< 20Hz) that we cannot hear we call infrasound.

Sound with a very high frequency (> 20,000 Hz) which we cannot hear we call ultrasound.

*Figure 2 Hearing*

Sound with high frequency has high tone a short sound wave. (Blue Line)

Low-frequency sound has a low tone and a long sound wave. (Red Line)

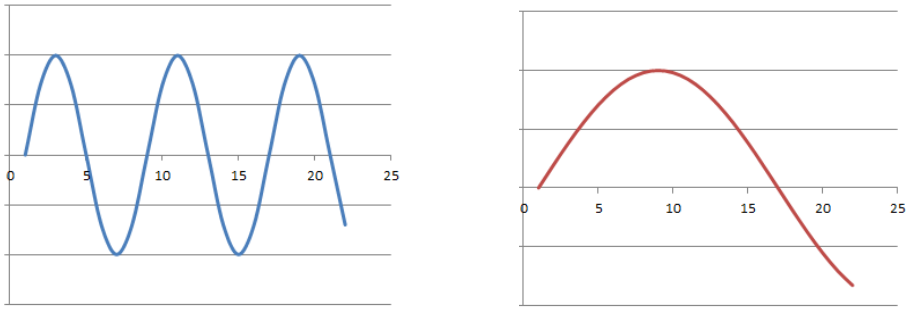


*Figure 3 Sound waves (higher frequency and lower frequency)*

## 1.3 What is the difference between Ultrasound and ultragraphic?

For Ultrasound measurements, the sound pressure is recorded on one side of the construction, which is emitted by the Ultrasound transmitter on the other side of the construction. The differences in the received sound at certain locations indicate possible air leakages.

In the case of ultragraphic, the measured sound pressure is displayed as a colour image on a digital image of the relevant construction part. The colours correspond to the measured sound pressure (in dB) and is an indication of the

presence and severity of gaps in the connectors.

## 1.4 What equipment is used

Ultrasound measurements are made using Ultrasound waves. A sound source emits sound waves with a frequency that the human hearing cannot observe. High-frequency sound, due to its small wavelength, has little difficulty in reaching the other side of the construction by very small openings. On the other side, a receiver registers the signal which transmits the source and converts it into a sound (Ultrasound) or image (ultragraphic) that is audible to people.

**The following equipment is required:**

### *Sound source and Ultrasound generator*

The generator makes high frequency sound and the sound source emits it.


*Figure 4 Ultrasound generator and sound source. [Source: Insiter]*

### *Ultrasound receiver*

Ultrasound receiver registers the Ultrasound waves

*Figure 5 Sonotec ultrasound receiver. [Source: Sonotec]*

### *Ultragraphic*

For ultrasound, a receiver is needed, a camera and a laptop with software to process the data.

*Figure 6 Receiver, camera and laptop with software for ultrasound [Source: Insiter]*

## 1.5 Process Quality assurance air-tight connection

For a good airtight connection, it is important to check step by step:

1. Do I have the right materials to make the connection airtight?

   The materials for the air sealant have to be suitable for the application and the specific opening to be sealed. To bear in mind: environmental pressure, durability, elasticity, expansion of the construction part in combination with the ability of the sealant to absorb this expansion, temperature differences in the joint, shrinkage by drying or swelling due to moisture, building tolerances and scope of appliance.

   See further the module airtight buildings in BuildUpSkills.


*Figure 7 different sealing materials for different applications [Source: BuildUpSkills]*

2. Did I process the materials correctly?

   The supplier's guidelines must be followed, the sealant must be placed in the right place, the correct way and the application of sealant must not be interrupted. The sealant should not be damaged when the elements/parts are connected together. Take photos as proof that it is properly applied.

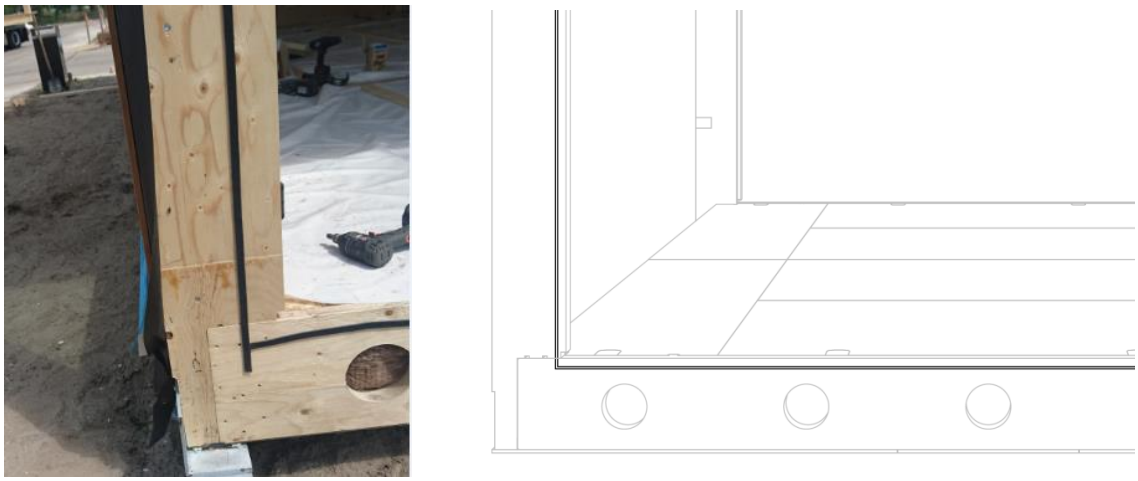

*Figure 8 Practice and drawing. [Source: Insiter]*

3. Do I still see imperfections after the connection is made?
   See if the connection is properly closed. Not to be shifted, no light to see through and gapless.

*Figure 9 A connection with light seeing through and a connection tight together. [Source: Insiter]*

4. Check critical connections with ultrasound to ensure that the connection is properly closed.
   After the steps one to three are carefully passed, it is recommended that critical connections are being checked with ultrasound immediately after the elements/components are connected. Not all deviations are visible and during installation, the seal may have been moved or damaged unnoticed. With ultrasound, the air seals can be checked per component when the rest of the building is not finished yet.


*Figure 10 Setup Ultra Photography measurement: 1. Camera 2. Receiver 3. Laptop with software. The Ultrasound sound source is outside and is not visible in this photograph. [Source: Insiter]*

5. Check when the building is ready (airtight) with blower door test for air tightness.

If the building is airtight it can be checked for the total air tightness.

*Figure 11 BlowerDoor test*

## 1.6 Who, when and the results of used measuring equipment for air tightness?

| Inspection method | Result | When | By whom |
|---|---|---|---|
| Visual inspection<br><br>of received goods | Ensures that the right material is used for making the joints airtight.<br><br>Ensures that the prefab elements are in the right condition to make an airtight connection | At reception of the incoming goods | Performing inspection:<br><br>by worker on site (carpenter, prefab element assembler)<br>Judgement of results: supervisor. |
| Visual inspection of the work | Ensures that the work is well performed. Link photo of work to specific building part to BIM | Direct after the work is done and still visible. | Performing inspection:<br><br>by worker on site (carpenter, prefab element assembler)<br>Judgement of results: supervisor. |
| Ultrasound (prescan) | Gives an indication by a sound signal of possible air leakages. Quick method. | As soon as the connection or lead through is made and adjustment of joint is still possible. | Performing measurement:<br>by worker on site (carpenter, prefab element assembler)<br>Judgement of results: supervisor. |
| Ultragraphics | Gives an indication and graduation by an image with the possible air leakages. Link image to specific building part to BIM. | As soon as the connection or lead through is made and adjustment of joint is still possible.<br><br>Can also be used by completion of the building for quality assurance. (no limitations for temperature and wind speed) | Performing measurement: by expert Ultragraphics.<br><br>Judgement of results: by expert Ultragraphics in consultation with supervisor. |
| Blowerdoor | Air leakage loss measured by bringing a building on over pressure and/or/ under pressure. (n50 / qv10-waarde) | Building envelop has to be closed and wind speed < 3 Bft.<br><br>1. For method B the airtightness of the building envelop is determined when building envelop is closed and depending on the situation there are possibilities to improve the air tightness.<br><br>2. For method A the airtightness of the building envelop is determined when the building is complete ready. | Performing measurement: Expert Blower Door<br><br>Judgement of results: by expert Blower Door in consultation with supervisor |
| Thermographics for air tightness | Loss of warmth caused by air leakage made visible by IR camera. | In combination with Blower Door test.<br><br>Only possible in case of a temperature difference between inside and outside (around 12 to 15 °C) | Performing measurement: Expert Thermographics<br><br>Judgement of results: by expert Thermographics in consultation with supervisor |

## 1.7 How does the Ultrasound measurement method gets put into practice?

The procedure for an Ultrasound measurement is described on the basis of photographs in a project in Delft, the Netherlands.

1. Draw sound source with Ultrasound generator.

The receiver is placed on the side with the least ambient sound.

The sound source on the other side of the building envelope.

*Figure 12 Setup sound source. [Source: Insiter]*

2. Setting up Receiver

The Ultrasound hand receiver can measure directly at the connection to be tested.

*Figure 13 Measurement Ultrasound Sound [Source: Insiter]*

Ultrasound measurement

https://youtu.be/uO6rmq1ia4E

*Figure 14 Cable entry[Source: Insiter]*

***For ultrasound There are a number of additional steps***

a. Setting up camera aimed at the connection to be examined (1)
b. Start-up computer and software for ultragraphic measurement. Connecting Camera to Computer (3)
c. Taking a picture of the connection to be examined
d. Checking connection (Wi-Fi) between camera and receiver
e. Scanning of the connection to be examined (2)
f. Image of ultrasound editing and saving


*Figure 15 Setup Ultragrapic measurement [Source: Insiter]*

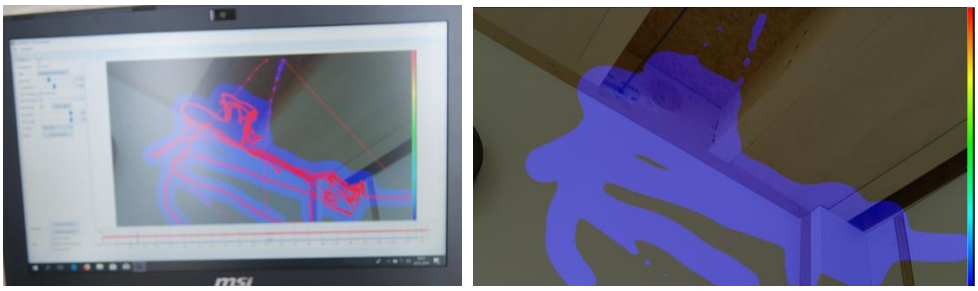

*Figure 16 Raw data and the processed ultragraphic image.* [*Source: Insiter*]

Ultragraphic measurement

https://youtu.be/CH3608Hu6RA


*Figure 17 Ultragraphics measurement[Source: Insiter]*

## 1.8 What do you see in ultrasound?

The sound received is not audible. To give insight into the ultrasound that is received, it is converted into audible sound (Ultrasound) or in an image (ultragraphic). In the case of ultragraphic (as with thermal imaging), the colours indicate the noise level.

Without understanding the values that belong to the colours, you can quickly draw wrong conclusions. The scale that belongs to the ultrasound image of the window frame below runs from -86dB for the red area to -100dB for the blue area. It is therefore an indication for the decrease in noise levels. The more the sound is stopped at the connection, the better the connection is.

***Question:***

*At what point is the connection the least airtight and how do you see it?*

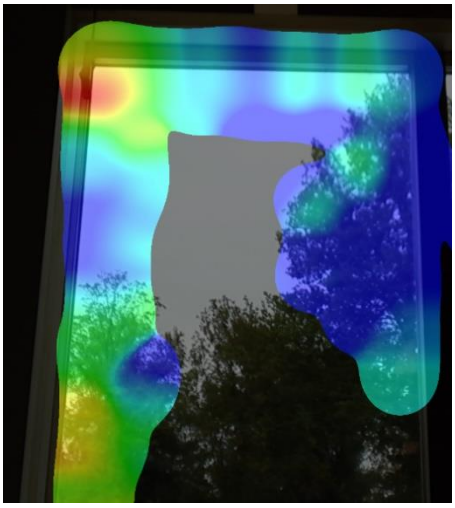

*Figure 18 [Source: [Gevelscan Ultragraphyx (www.ultragraphyx.com)]*

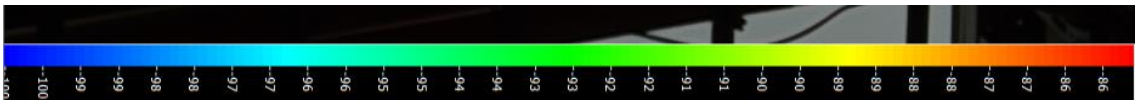


*Figure 19 Scale dB values Source: [Gevelscan Ultragraphyx (www.ultragraphyx.com)]*

***Answer***

*In the red area at the top left of the window frame, the connection is the least airtight.*

*The red colour indicates that most ultrasound comes through the connection. Or as the scale indicates the least ultrasound is stopped.*

When reading, two things are important:

- Are there any clear differences between the different locations
- These differences are so large that this indicates a leakage. As a rule of thumb, a difference of at least 20dB can be taken for a considerable air leakage.

***Example of an ultrasound measurement***

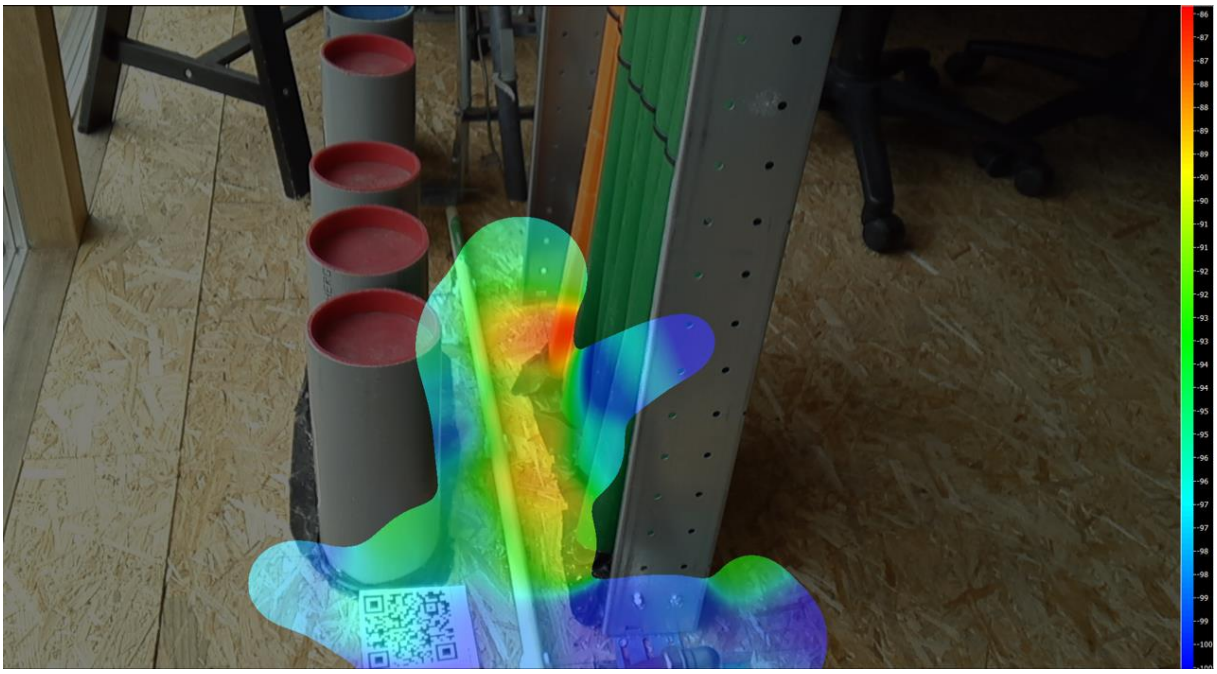

*Figure 20 Ultra Photography recording cable throughput [Source: Gevelscan Ultragraphyx (www.ultragraphyx.com)]*

This is an image of a cable throughput through a wooden floor with the colours of an Ultrasound measurement. The sound is thus made visible. (ultragraphic)

*Figure 21 Scale dB values [Source: Gevelscan Ultragraphyx (www.ultragraphyx.com)]*

In red, there is more Ultrasound noise along the cables. Decrease in sound is 86dB. Blue comes with little Ultrasound waves along the cables. Decrease in sound is-100dB. The difference is less than 20 dB and the expectation is that this is a small air leakage. Further research shows that the airtightness of the orange cables is not entirely good.

*Figure 22 Detail cable entry [Source: Insiter]*

The Ultrasound measurement gives a good impression about the air tightness of the connection. But does not indicate how big the leakage is and what the final impact of the leakage is on the overall performance of the building.
If a possible defect is detected, this will need to be investigated further.
The use of Ultrasound measurements requires experience and knowledge. Knowledge of the measuring equipment and knowledge of the behaviour of Ultrasound waves in relation to distance, materials in the construction and the road that the Ultrasound wave has to make in the construction. Analysis of the results is always necessary to draw the right conclusions.

# 2. Assignments

***Question:*** What do you see on the picture below?

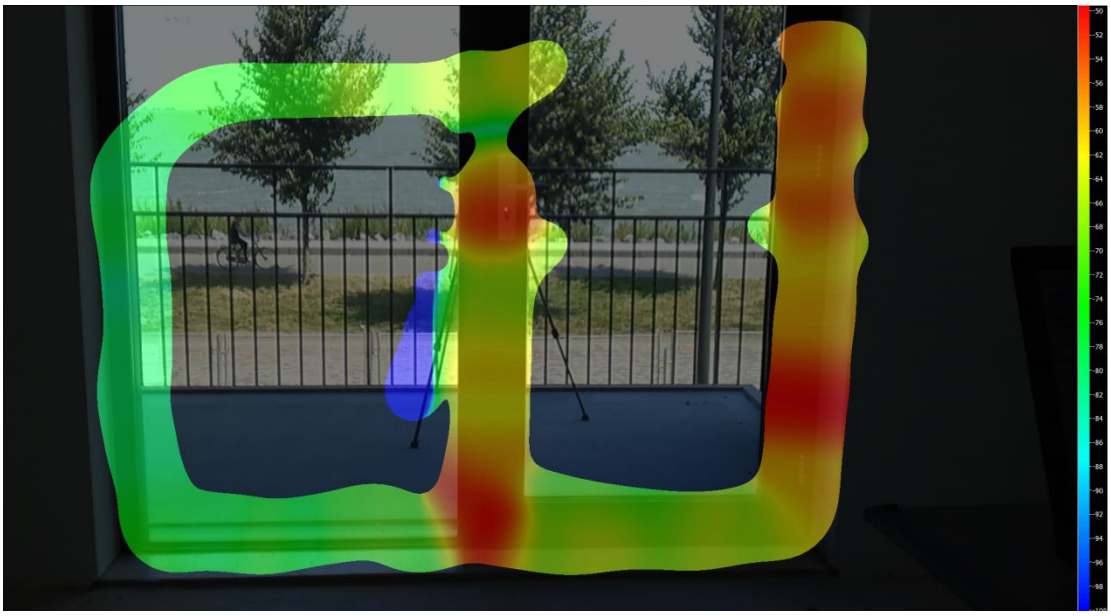

*Figure 23 Ultragrapic recording* []*Source: Gevelscan Ultragraphyx (www.ultragraphyx.com)*

*Figure 24 Scale dB values Source:* [*Gevelscan Ultragraphyx (www.ultragraphyx.com)*]

***Answer:***

- Double door;
- Ultragraphic (Ultrasound sound is made visible);
- Transmitter is outside, so receiver is inside (not visible);
- In the red spots the emitted sound is the least stopped, or in other words, the most sound is let through;
- Difference in decrease of sound between red (50 dB) and blue (98 dB) = 48 dB;
- The red colour is a clear indication that there may be an air leakage. Further investigation is required;
- Possible air leaks especially at door batter, bottom connection and on right hinge side.

***Question:*** What do you see on the picture below?

*Figure 25 Ultragraphic recording [Source: Gevelscan Ultragraphyx (www.ultragraphyx.com)]*

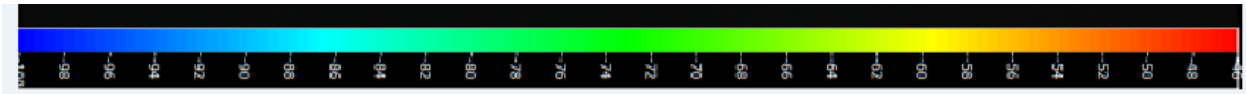


*Figure 26 Scale dB values [Source: Gevelscan Ultragraphyx (www.ultragraphyx.com)]*

***Answer:***

- Double door with window above;
- Ultragraphic (Ultrasound sound is made visible);
- In the red spots the emitted sound is the least stopped, or in other words, the most sound is let through;
- Difference in decrease of sound between red (48 dB) and blue (98 dB) = 50 dB;
- The red colour is a clear indication that there may be an air leakage. Further investigation is required;
- Possible air leaks especially when connecting doors in the middle of the photo and right-side hinge side.

# 3. Credentials

The content of the module measuring airtightness – Ultrasound and ultragraphic is achieved through the use of knowledge and materials from Gevelscan Ultragraphyx (www.ultragraphyx.com) on Insiter (www.insiter-project.eu/en) and in cooperation with the EU project BuildUpSkills.

Medefinancierd door het programma Intelligente energie Europa van de Europese Unie

The online course can be followed via the BuildUpSkills Adviser app.