Technology Collaboration Programme
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Technology Collaboration Programme on Heat Pumping Technologies (HPT TCP)

Annex 51

Acoustic Signatures of Heat Pumps

Final Report – Part 7

2.2 Round Robin Tests
Air-to-Water Heat Pump
Heat Pump Water Heater

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Preface

This project was carried out within the Technology Collaboration Programme on Heat Pumping Technologies (HPT TCP), which is a Technology Collaboration Programme within the International Energy Agency, IEA.

The IEA

The IEA was established in 1974 within the framework of the Organization for Economic Cooperation and Development (OECD) to implement an International Energy Programme. A basic aim of the IEA is to foster cooperation among the IEA participating countries to increase energy security through energy conservation, development of alternative energy sources, new energy technology and research and development (R&D). This is achieved, in part, through a programme of energy technology and R&D collaboration, currently within the framework of nearly 40 Technology Collaboration Programmes.

The Technology Collaboration Programme on Heat Pumping Technologies (HPT TCP)

The Technology Collaboration Programme on Heat Pumping Technologies (HPT TCP) forms the legal basis for the implementing agreement for a programme of research, development, demonstration, and promotion of heat pumping technologies. Signatories of the TCP are either governments or organizations designated by their respective governments to conduct programmes in the field of energy conservation.

Under the TCP, collaborative tasks, or “Annexes”, in the field of heat pumps are undertaken. These tasks are conducted on a cost-sharing and/or task-sharing basis by the participating countries. An Annex is in general coordinated by one country which acts as the Operating Agent (manager). Annexes have specific topics and work plans and operate for a specified period, usually several years. The objectives vary from information exchange to the development and implementation of technology. This report presents the results of one Annex.

The Programme is governed by an Executive Committee, which monitors existing projects and identifies new areas where collaborative effort may be beneficial.

The Heat Pump Centre

A central role within the HPT TCP is played by the Heat Pump Centre (HPC).

Consistent with the overall objective of the HPT TCP, the HPC seeks to accelerate the implementation of heat pump technologies and thereby optimize the use of energy resources for the benefit of the environment. This is achieved by offering a worldwide information service to support all those who can play a part in the implementation of heat pumping technology including researchers, engineers, manufacturers, installers, equipment users, and energy policy makers in utilities, government offices and other organizations. Activities of the HPC include the production of a Magazine with an additional newsletter 3 times per year, the HPT TCP webpage, the organization of workshops, an inquiry service and a promotion programme. The HPC also publishes selected results from other Annexes, and this publication is one result of this activity.

For further information about the Technology Collaboration Programme on Heat Pumping Technologies (HPT TCP) and for inquiries on heat pump issues in general contact the Heat Pump Centre at the following address:

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Acoustic Signatures of Heat Pumps

IEA HPT Annex 51

2.2: Round Robin Tests

Air-to-Water Heat Pump

Heat Pump Water Heater

CETIAT

François BESSAC (CETIAT)

Date: November 2020	Final Version, Review: 03

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1 INTRODUCTION

This part of the Annex 51 pursues several objectives:

First, to perform a Round Robin Test between the laboratories to:

- Check that the measurements give close results ;
- Get a feedback on the standards implementation.

And then, to provide input to other Tasks of the Annex, e.g. noise levels during the unsteady running conditions (frosting/defrosting), noise levels at non-standard rating conditions:.

- Task 4: Analysis of the effect of operating conditions of heat pumps on acoustic behavior
- Task 5: Heat pump installation and effects on surrounding environment
- Task 6: Improved measuring techniques and description of the acoustic performance

This report describes the round robin tests performed by the participants and analyses the results on:

- An air-to-water heat pump (RRT1)
- A heat pump water heater (RRT4)

This RRT is also interesting as the laboratories use different acoustic test methods, diffuse field, intensity, free field methods, with all classes of precision (laboratory, engineering and survey). A short description of the laboratories is given in Annex 1 (page 34).

2 RRT1: AIR-TO-WATER HEAT PUMP

2.1 Protocol

A protocol is given to the laboratories, with the objectives of the round robin test:

- Evaluate and compare the different acoustic test methods when testing according to reference standards,
- Assess the influence of the behavior of the unit (frequency, frosting/defrosting,…) by testing at different operating conditions,
- Possibly identify new indicator(s) for the sound power level of heat pumps, based either on a “maximum” sound power level and/or on sound power level measured at different part load conditions.

The protocol (cf. Annex 2, page 39) specifies all the test conditions that may be performed, in accordance with the thermal and acoustic capacities of each laboratory.

The protocol reminds the way to prepare the split unit for the transportation to the next laboratory. It is based on EN 120102-1 standard for installation and testing.

2.2 Test program

The test program includes several operating conditions, not usually used for acoustic characterization.

The first one is based on EN 14511-2 operating conditions (#1), with a modulation of circulator (#2), and at maximum compressor frequency (#3).

The next operating point (#4) is at the part load condition C from EN 14825

The operating point (#5) is performed according to EN 12102-1 Annex A.4, i.e. in the EN 14511-2 conditions while the heating capacity measured at part load condition C shall be obtained. This requires to set the unit at a frequency that allows to reach this capacity r, and if necessary and to adjust the water flow rate while maintaining the outlet water temperature.

The next conditions encompass the EN 14825 conditions:

- Condition D: smallest part load capacity (#6),
- Condition B: where defrost would is expected to occur (#7)
- Conditions A/F: at which the unit is operating at full load (#8 and #9)
- Condition E: investigating the operating limit of the unit (#10).

Table 1 describes these different test conditions and the corresponding settings provided by the manufacturer.

Table 1: operating conditions of the RRT1 on the air-to-water unit

RRT1 Programme : Measurement Points									
Nr.	**Standard**	**Condition**	**Air dry bulb (wet bulb) temperatures (°C)**	**Water inlet/outlet temperatures (°C)**	**Setting from manufacturer table**	**Set temperature**	**Fan**	**Mode**	**Liquid circulator setting**
1	EN 14511	standard rating	7(6)	30/35	1	30	Auto	Heat (Sun)	max.
2	EN14511	standard rating	7(6)	30/35	1	30	Auto	Heat (Sun)	2
3	EN 14511	standard rating at max frequency	7(6)	30/35	10	21	Auto	Heat (Sun)	max.
4	EN 14825	C	7(6)	*/27	12	29	Medium (3 bars)	Heat (Sun)	max.
5	EN12102-1 A.4	reaching the same capacity as test C	7(6)	30/35				Heat (Sun)	max.
6	EN 14825	D	12(11)	*/24	11	30	Medium (3 bars)	Heat (Sun)	max.
7	EN 14825	B	2(1)	*/30	13	28	Medium (3 bars)	Heat (Sun)	max.
8	EN 14825	A/F (Tbiv)	-7(-8)	*/34	14	27	Medium (3 bars)	Heat (Sun)	max.
9	EN 14825	A/F (Tbiv) and maximum frequency	-7(-8)	*/34				Heat (Sun)	max.
10	EN 14825	E (TOL)	-10(-11)	*/35	15	25	Medium (3 bars)	Heat (Sun)	max.

(*) The water flow rate determined from test # 1 shall be used with the indicated outlet water temperature

The testing protocol is given in Annex A.

2.3 Heat pump under test

The air-to-water heat pump under test was provided by a French manufacturer. It is a 10 kW single split unit. The outdoor unit is floor mounted, with a single fan and a variable speed compressor. The indoor unit consists in a hydraulic kit, to be hung on a wall.

The unit was charged with 1.8 kg of R410A and refrigerant lines of 7.5m were provided.

As an example, Figure 2 depicts the installation of the unit in CETIAT's reverberant room.

Figure 1 : installation of the unit in a double reverberant room

2.4 Results

2.4.1 Test #1 - EN 14511 operating conditions

The first comparison deals with the sound power levels measured by the 6 laboratories, for this operating condition commonly used for rating the heating capacity of heat pumps.

The Figure 2 shows the spectrums, which clearly exhibit two peaks at 315 and 800 Hz, well observed by all laboratories, even though some differences appear, within a range of only 3 dB, which is quite a small deviation for a peak region.

The measured heating capacity is around 9.8/9.9 kW for two laboratories and around 10.3/10.4 kW for 4 others. No relation between the measured heating capacity and the noise level can be identified.

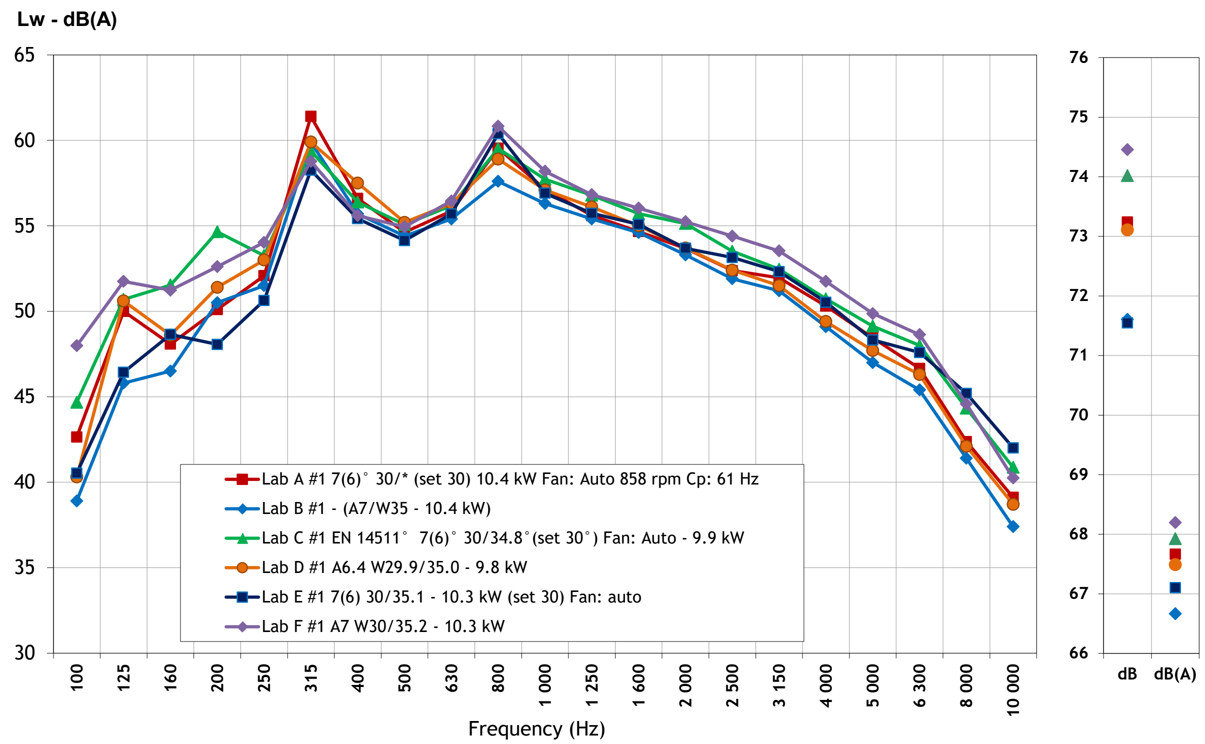


Figure 2 : sound power levels at EN 14511 operating condition (Test #1)

The low frequency range is quite scattered, as it is often the case for acoustic measurements, usually due to interaction with the modes of acoustic field.

The representation in octave (Figure 3) softens the curves and makes some peaks to disappear.

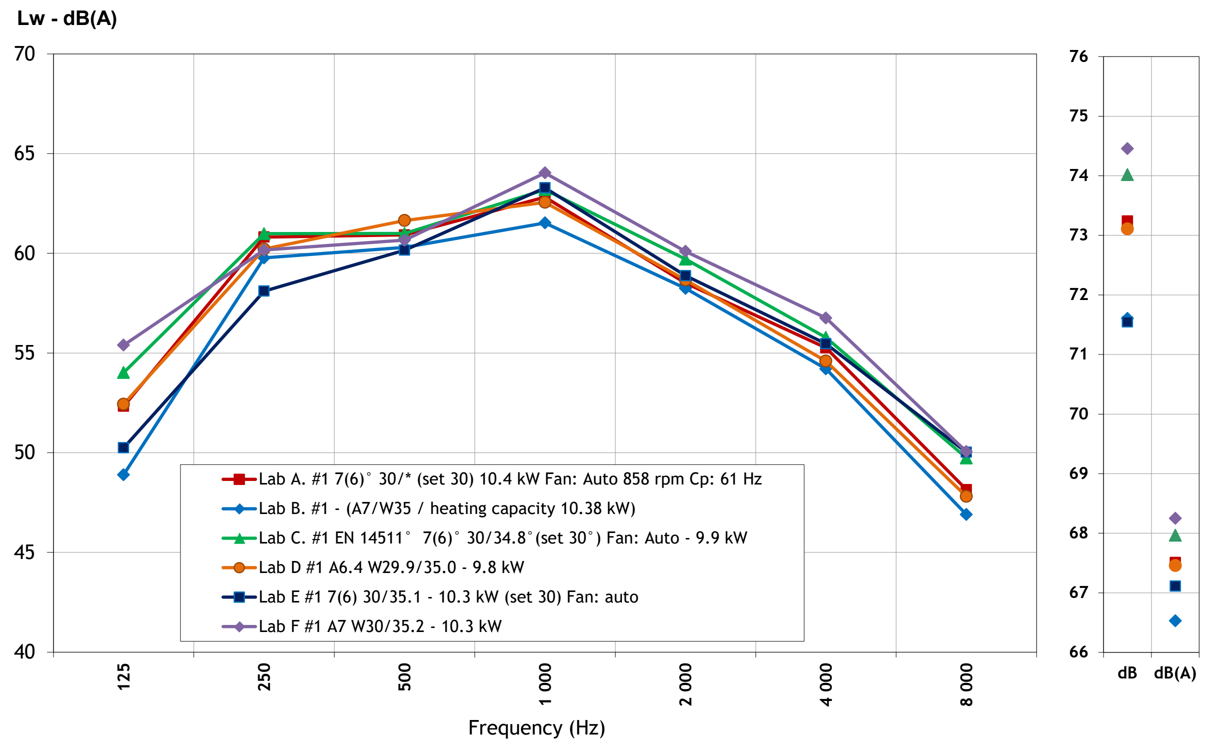


Figure 3 : sound power levels in octave bands at EN 14511 operating conditions (Test #1)

The min-max difference for octave bands remains in a 3.2 dB(A) range, except for 125 Hz band with 6.5 dB(A), while the overall dB(A) is 1.7 dB(A).

It is encouraging to see that all laboratories find quite close results, despite the various acoustic methods used (Annex 1 for laboratories description). This shows their reliability/robustness of the acoustic test methods and their implementation by different laboratories.

Despite the defined test conditons, once the results shared, it appeared that all laboratories did not necessariy adjust the unit the same way which can be seen on the resulting heating capacity (see key legend of Figures 3 and 4)

2.4.2 Test #3 - EN 14511 at maximum frequency

For this condition, the air and water temperature conditions remain the same, but both the compressor and the fan run at their maximum frequency.

For this test, results are more scattered, even for capacity, e.g. lab D measuring an unexpected 7.1 kW. The spectrums are not identical, except for labs A and D which are very close, the other being above (lab. F) or highly above (lab. C).

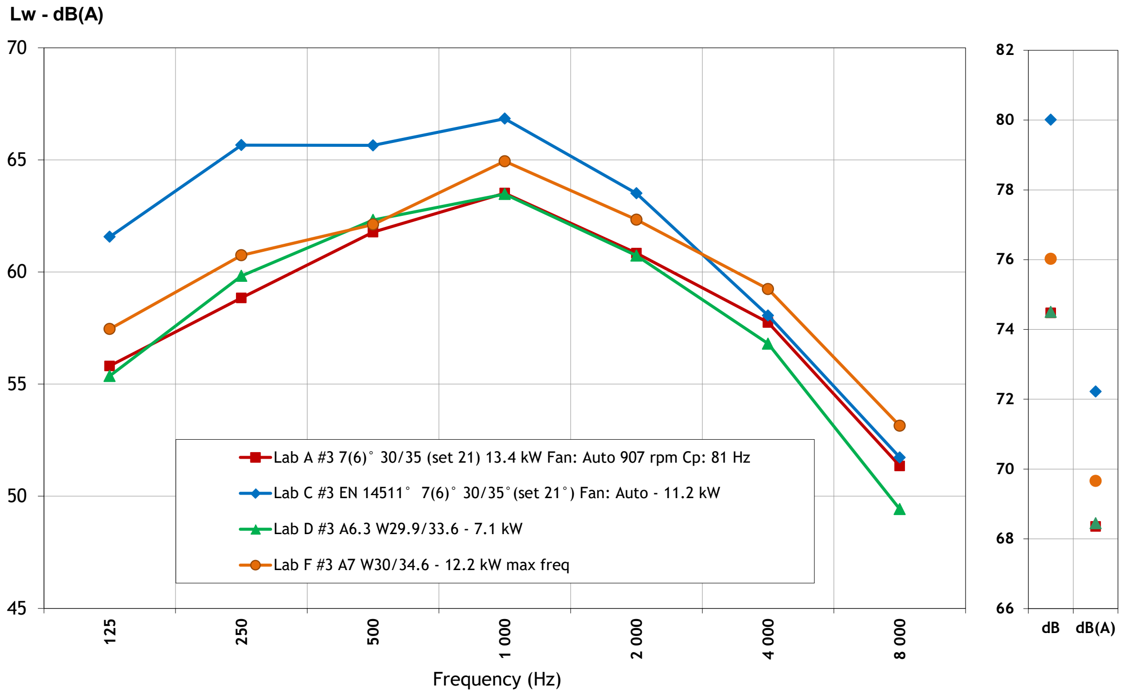


Figure 4 : sound power levels in octave bands at EN 14511 and max. frequency. (Test #3)

The 1/3 oct. band spectrum of lab A may give an explanation (Figure 5). The fan and compressor run at higher rotation speeds giving a higher sound level, easy to see on the major part of the spectrum. The peaks observed for the EN 14511 operating conditions at 315 and 800 Hz, totally disappear, these resonances probably being due to frequency coincidences in the unit.

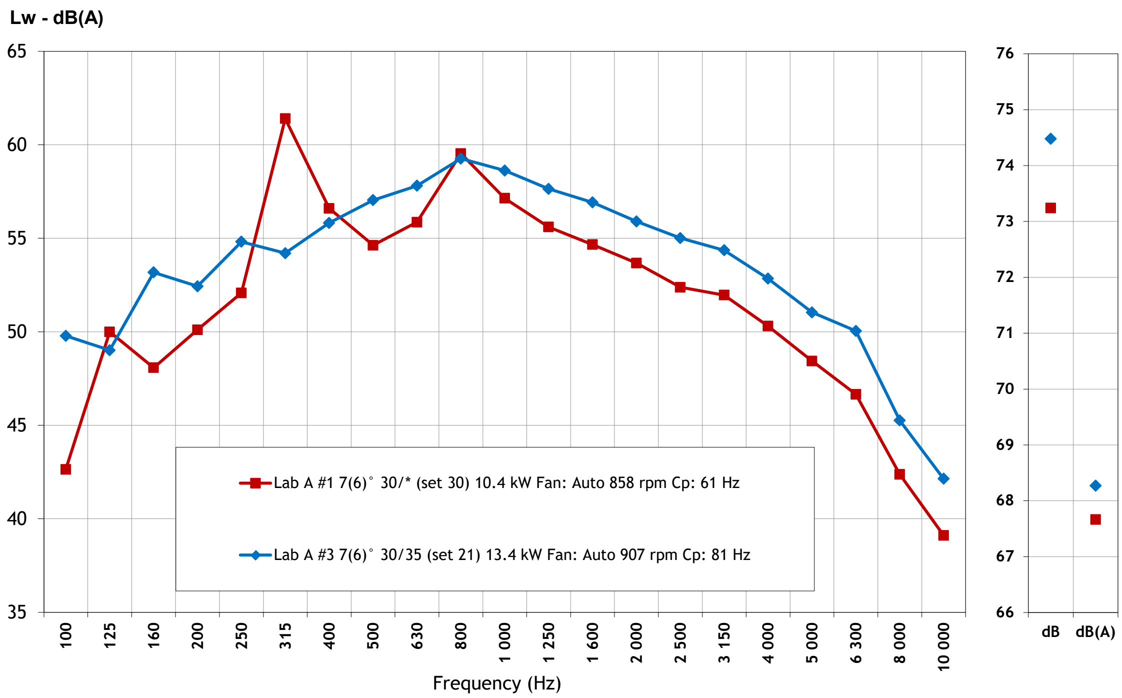


Figure 5 : sound power levels for EN 14511 max freq. (1/3 octave bands) for lab A (Test #3)

2.4.3 Tests # 3 & 4 - EN 14825 condition C & EN 12102-1

The part load conditions of EN 14825 is important as it allows giving the capacity to get during the acoustic operating condition according to EN 12102-1 – Annex A.4, but with a different setting in water temperature.

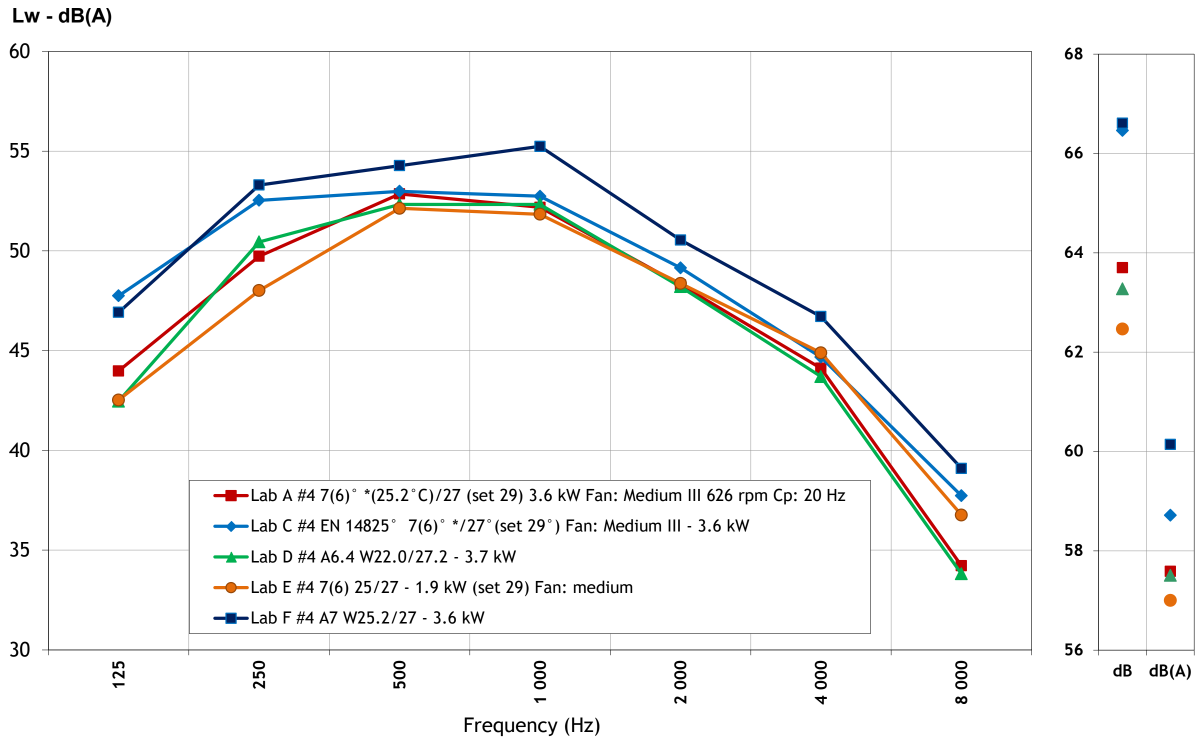


Figure 6 : sound power levels for EN 14825 point C (octave bands)

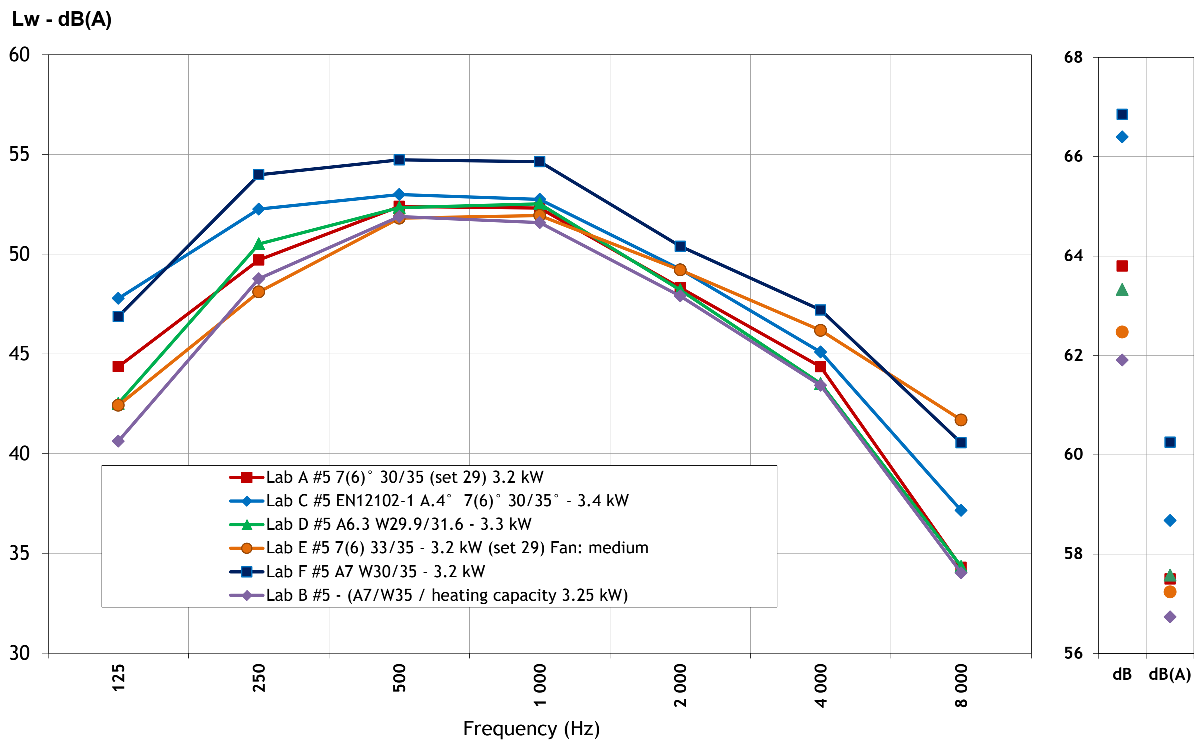


Figure 7 : sound power levels for EN 12102-1 (octave bands)

For EN 14825 point C, (Figure 6), the results are again very scattered, with higher sound level on all spectrum for lab F and high level at low frequencies for lab C. Otherwise, despite some significant differences in the spectrum, the overall value is close for labs A, D and E.

Before to analyze the acoustic results obtained with EN 12102-1 (Figure 7), let's give a brief remind about the operating condition for achieve.

The explanation of the operating condition of EN 12102-1 (annex A.4) is related to the ErP regulation 813/2013 which specifies how the sound power level of heat pumps shall be (measured and) declared.

The standard conditions given are for an air source and low temperature heat pump: 7(6)/30-35 °C, which are also the standard rating conditions given in EN 14511 and EN 12102-1. However, the sound power level shall be declared in association with a heating capacity ("and the same declared capacity shall be used"). Therefore the only capacity measured for the regulation at the same outdoor air temperature is the part load EN 14825 point C condition, .i.e. 7(6)/-30.*

It was confirmed by the Commission, and reported as Annex A.4 in EN 12102-1 that the conditions for rating the sound power level (for the labelling) are:

- *outdoor temperature: 7(6)°C*
- *inlet - outlet water temperature: 30°C - 35°C*
- *heating capacity: part load capacity at C condition*

If the unit cannot provide the C capacity in these operating conditions, then the settings of the unit such as compressor frequency and/or water flow rate can be modified in order to achieve at least:

- the heating capacity
- the outlet water temperature at 7(6)°C outdoor air temperature.

This approach is often not well understood by the EN 12102-1 users. And in fact, the ΔT = 5K is not fulfilled by all laboratories. For those who implement it, with capacity close to the one measured for EN 14825 point C, the spectrums are not so close, with more than 1 dB(A) overall difference between lab A and C. Lab F continues to find higher values in average.

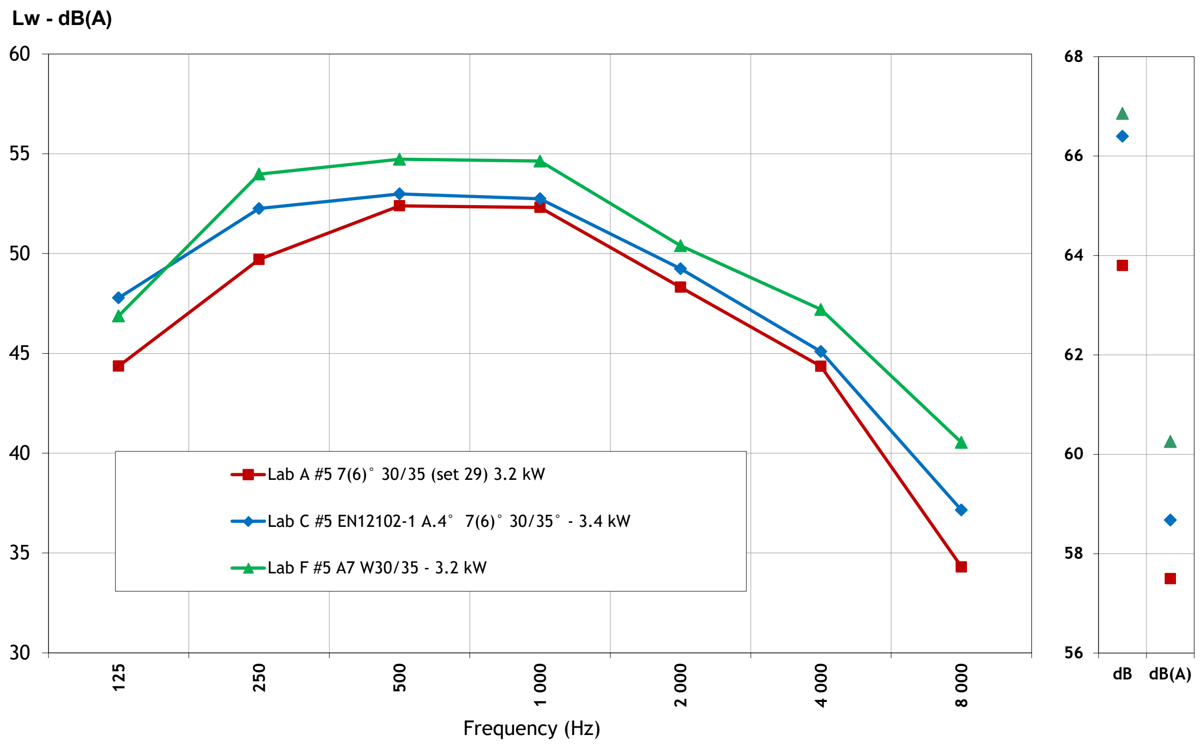


Figure 8 : sound power levels for EN 12102-1 with 30/35 °C on the water side (octave bands)

The difference between sound power levels during EN 14825 (C) and EN 12102-1 conditions are given in Figure 9. Its shows that results are really close (except 8 kHz for Lab E), at least for this unit, meaning that laboratories at least performed both tests in a similar way.

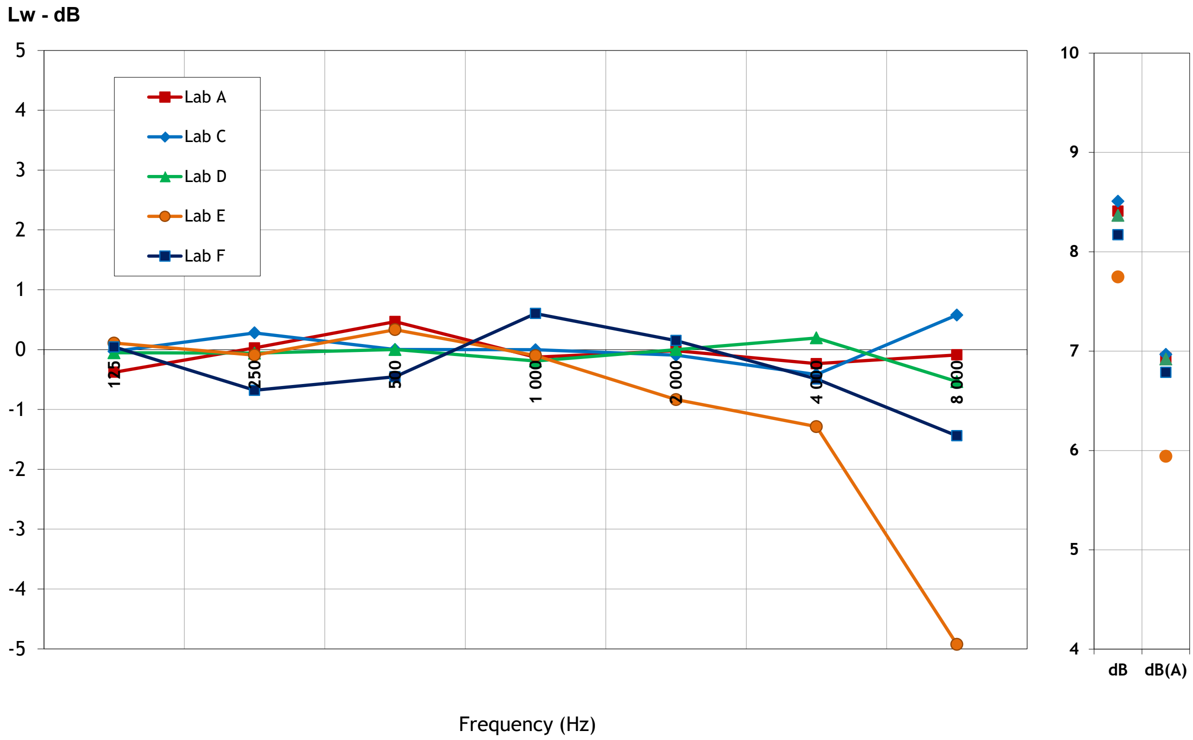


Figure 9 : comparison for EN 14825 and EN 12102-1

But the conditions of EN 12102-1 are not perfectly fulfilled as the conditions of operations are not exactly those required by the standard: the ΔT being not 30-35°C, or the capacity being (slightly or more) different between the part load point C and EN 12102-1 Annex 4.

To conclude, it appears that the setting of the EN 12102-1 is not clearly understood and had to be changed in some ways: it can be a better description in the standard or more, another setting for the "acoustic" condition.

2.4.4 Test #6 - EN 14825 condition D

The condition D of EN 14825 is performed for an outdoor temperature of 12 °C. The same conclusions can be stated than above with very close results for labs A, D then E, including spectrum values, but much higher sound level for lab F (looks like an offset), and lab C, again higher sound levels in the low frequency range.

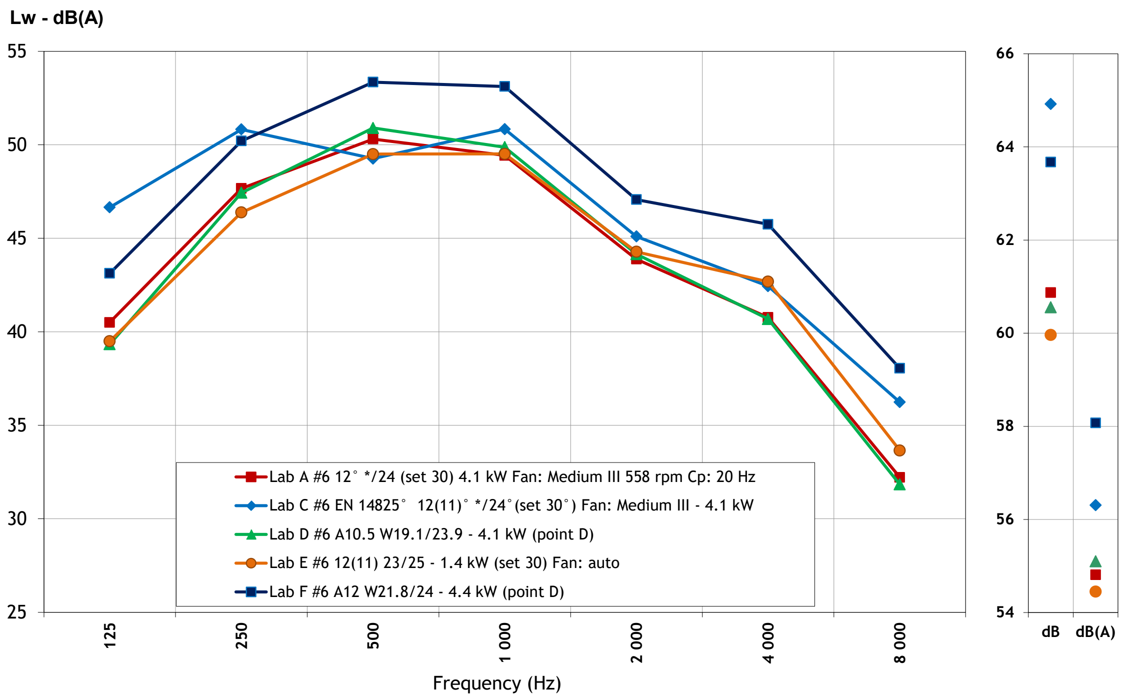


Figure 10: comparison at EN 14825 condition D (Test #6)

This operating point gives capacities close to 4.1 kW for all laboratories (except E, but it is probably a typing mistake).

Note: for this temperature and higher ones, in the real life, the unit may have a cycling behavior, with ON/OFF operation.

2.4.5 EN 14825 condition B (Test #7)

For this condition at 2°C outdoor air temperature, all results seem to be more consistent especially at high frequencies while some scattering remains on low and medium frequencies. Unfortunately, operating conditions and resulting measured heating capacities among the laboratories are also different. A clear conclusion is then not possible, especially without recorded data in rotation speeds of fan and compressor.

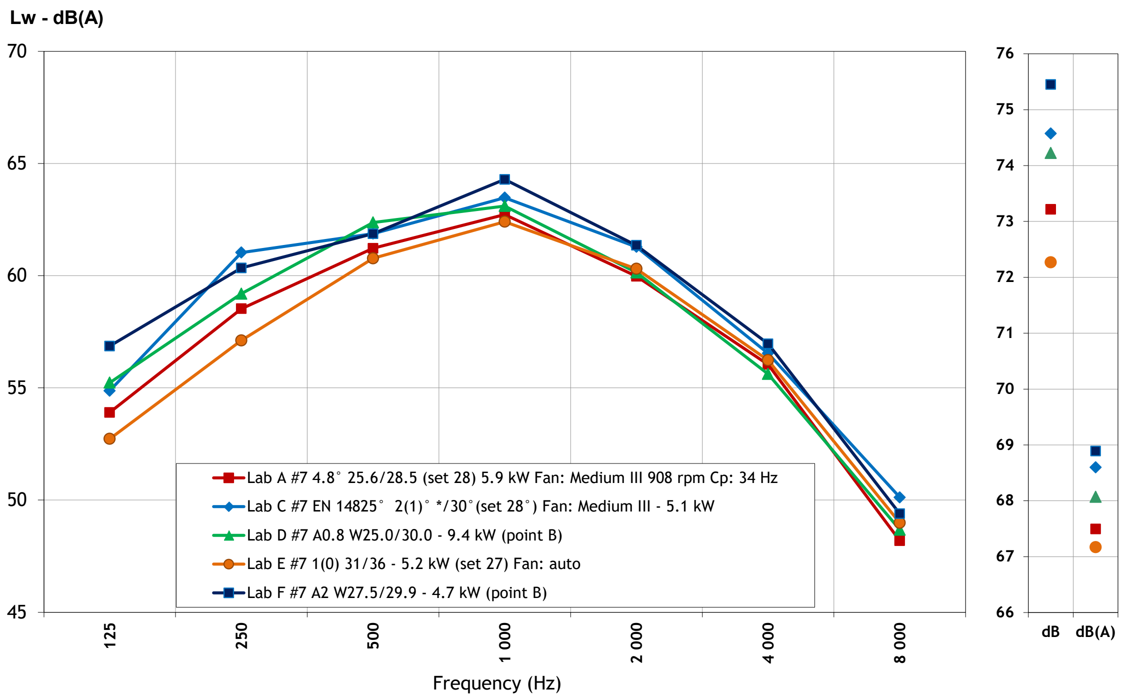


Figure 11: comparison for EN 14825 point B (Test #7)

Note: at this outdoor air temperature, one laboratory observed a frosting/defrosting cycle

2.4.6 Tests #8 and #9 - EN 14825 condition A/F

For this operating condition at -7 °C of outdoor air, the rotation speed of compressor is first set according to the instructions (#8) and then set at its maximum frequency (#9).

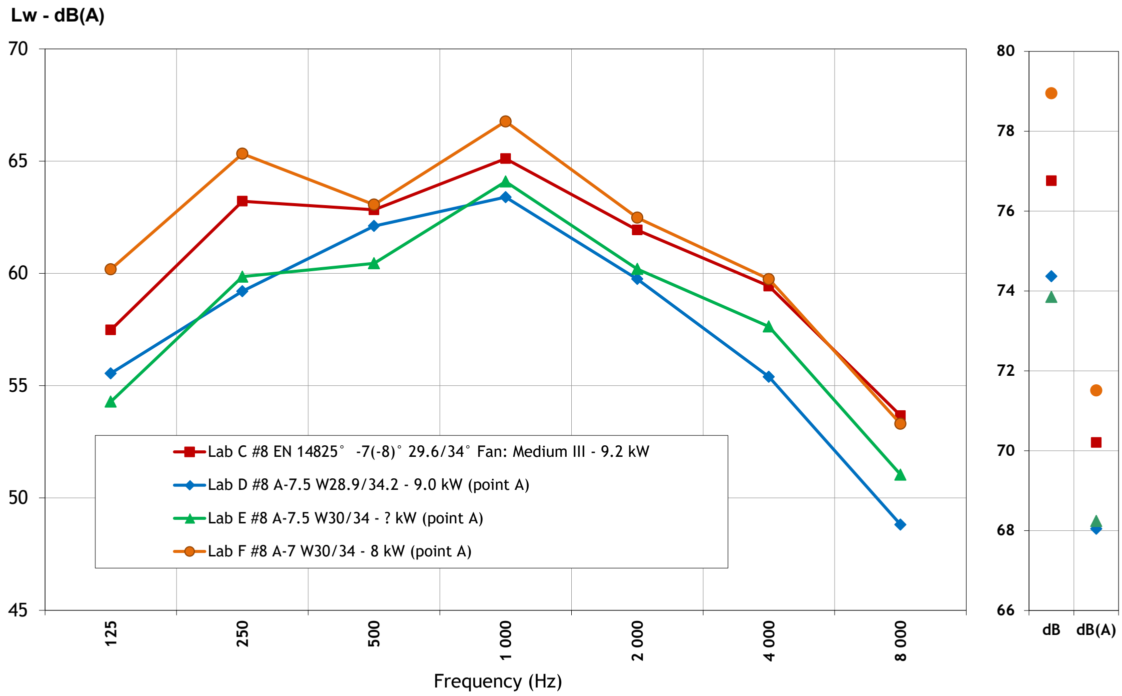


Figure 12: comparison at EN 14825 condition A (Test #8)

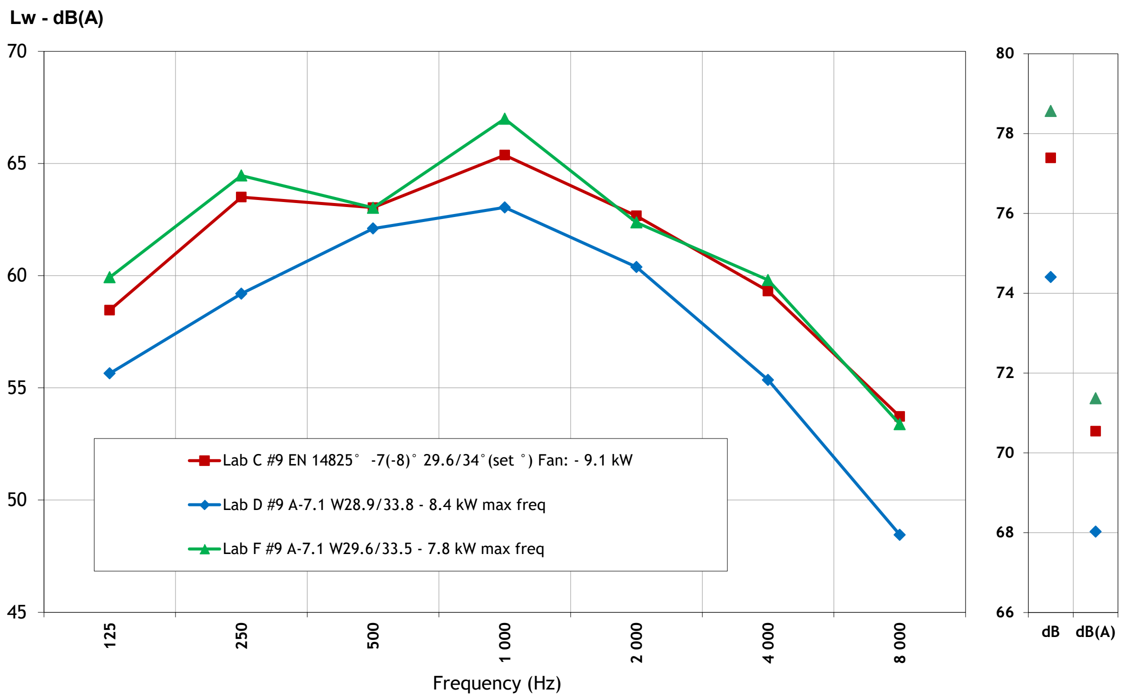


Figure 13: comparison at EN 14825 condition A and max frequency compressor (Test #9)

Figure 12 and Figure 13 lead to the same conclusions: with lab C and F as louder than the others, when lab D and E are very close, even if the measured heating capacities are not so close.

2.4.1 Test (#10 - EN 14825 condition E

At such a low outdoor air temperature, only 4 laboratories were able to perform the acoustic test. From these tests, two sets of results are identified.

- Labs C and F which applied different acoustic methods obtained very similar sound levels, the spectrum in 1/3 oct. bands speak for themselves, although the capacity is 8.4 vs 7.5 kW.
- Labs D and E again found lower sound levels than labs D and E for which the spectrums remains in the vicinity… but the capacities are again very different (5.9 vs 8.4 kW).

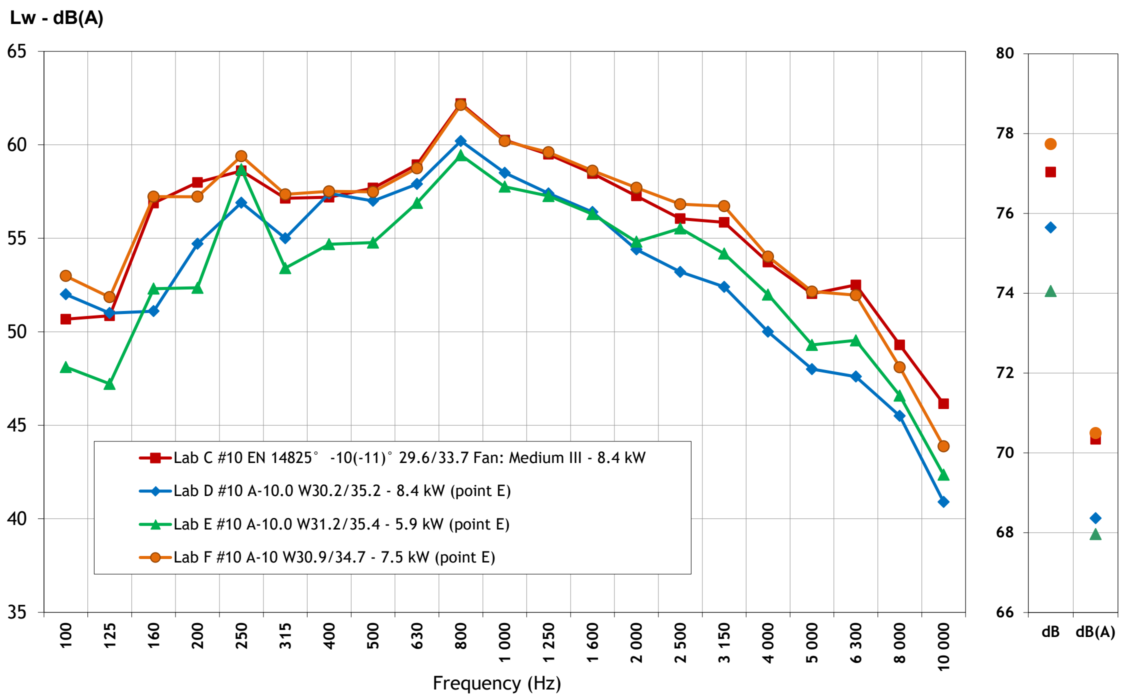


Figure 14: comparison at EN 14825 condition E (Test #10)

2.5 *Influence of operating conditions*

An overview on the influence of operating conditions on the sound power level can be done, by looking at the rotation speeds of fan and compressor, as laboratory A measured their value, unfortunately not for the lowest ambient temperature. Fortunately, these conditions lead to high capacities of the unit which were already described by #3 (EN 14511 max. frequency).

Figure 15 clearly shows that different operating conditions lead as expected to variable sound power levels and different spectrum shapes. In the present case, the standard rating condition (configuration #1) exhibits a peak at 315 Hz band which disappears when the compressor and the fan are boosted at their maximum frequency; the modal coincidences do not exist anymore. In spite of an average difference of 1.5 to 2.5 dB over the spectrum, the overall value only differs by 0.8 dB(A), due to the peaks removal.

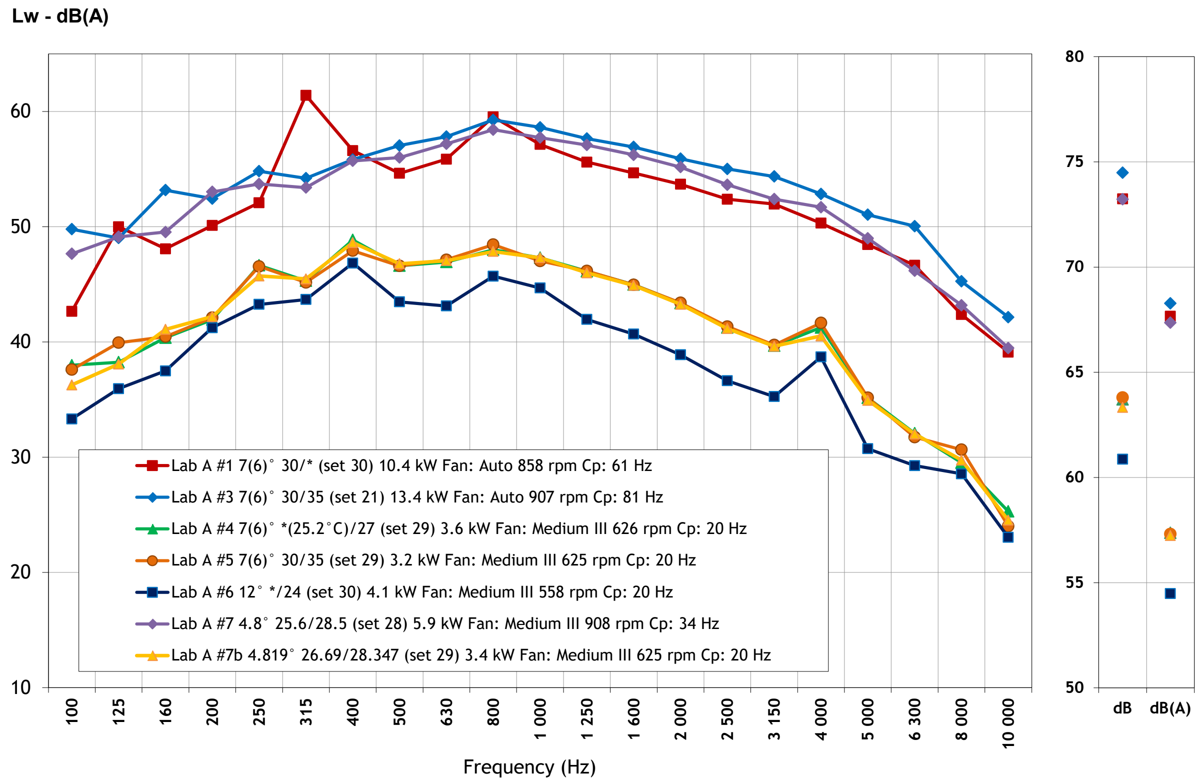


Figure 15: influence of operating conditions on the sound level

The noise levels for configuration #6 and configuration #5 are significantly lower,–13 and –10 dB(A) respectively compared to the standard rating conditions EN 14511 (#1). The heating capacity is then clearly lower, so does the fan rotation speed.

In a general approach, the noise level is the highest for high capacities and the lowest for small capacities, but it is not possible to find a relation for this unit between the noise level and the heating capacity. As an example, Figure 15 shows that configuration #5 is louder by 2.8 dB(A) than #6, due to the higher fan rotation speed (625 vs 558 rpm), despite a lower capacity.

Although the two configurations have the same fan rotation speed (908 rpm), configuration #3 is louder by 1.3 dB in average than #7, because compressor rotation frequency is 81 Hz instead of 34 Hz.

When the heating capacity increases (ex. for conditions with negative ambient air temperature), the sound level is close to the ones observed at the maximum heating capacity or at the max frequencies of both fan and compressor.

Figure 16 shows that the explored heating capacities are not related to the overall sound power levels. On the other hand, Figure 17 demonstrates that the fan rotation speed is the first order link with the overall L_{WA}. The compressor rotation speed is also linked to the sound level, but in a second order, meaning that it can only be seen if the fan speed is the same (cf. Figure 15, #3 vs #7).

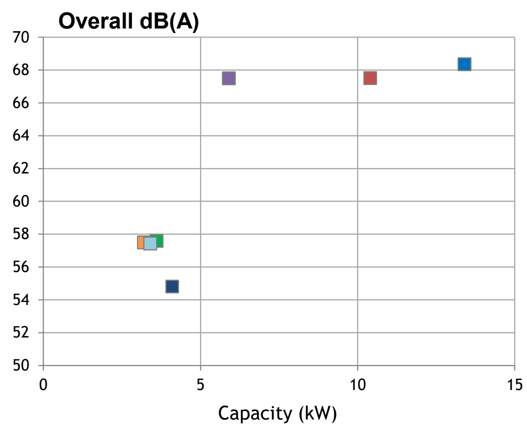


Figure 16: relation between capacity and overall LwA

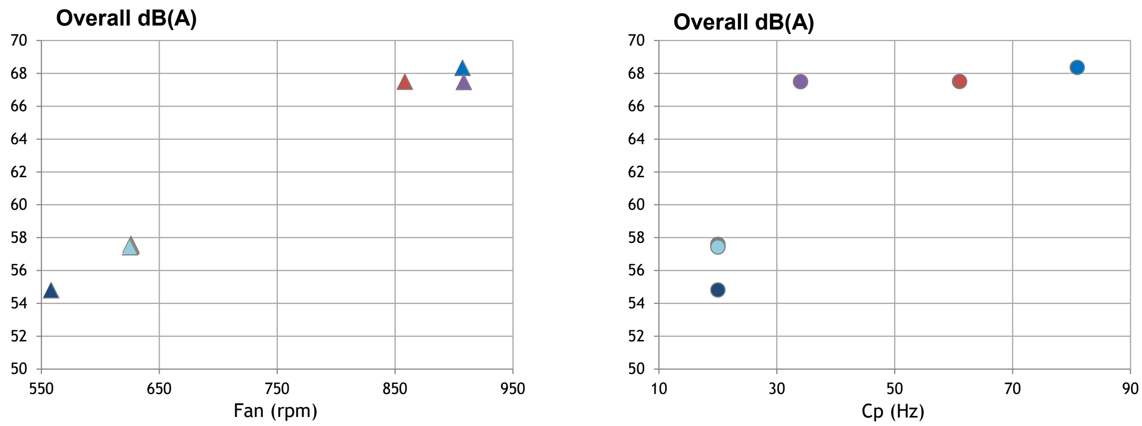


Figure 17: relation between fan rotation speed and compressor frequency vs overall LwA

2.6 Defrosting

This section gives some results from 2 laboratories related to the frosting/defrosting behavior of the heat pump.

Laboratory 1

Figure 18 shows the time evolution of the outdoor unit sound power level, the heating capacity, the electrical power input and the indoor sound power level. In the present conditions (around 4 °C ambient temperature), the sound power level slightly increases with the frosting. Then the defrosting cycle occurs, with various processes of the unit that will not be detailed here, to remove ice from the heat exchanger, and before the re-start of the unit for water heating. During this defrosting, the sound events are various and unsteady. We will just consider the sound level averaged on the 5 or 6 minutes of this period.

The outdoor unit sound power level, averaged on these 3 identified periods (frosting, defrosting, re-starting after defrosting), is shown on Figure 19.

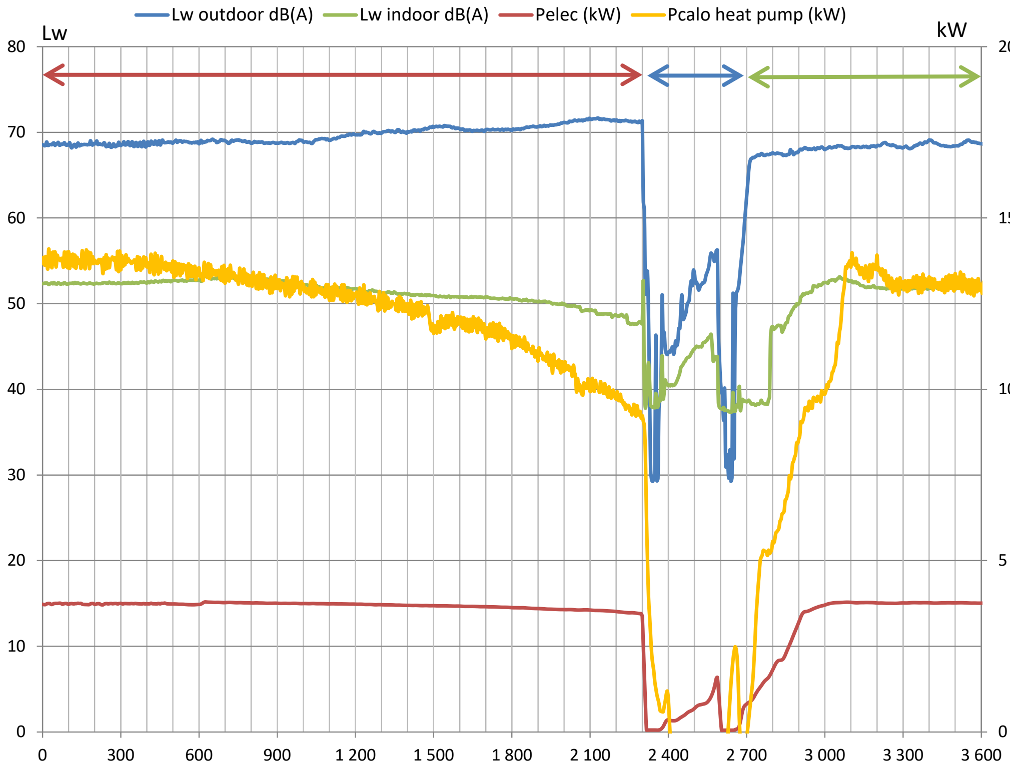


Figure 18 : sound power levels vs time during frosting and defrosting cycle

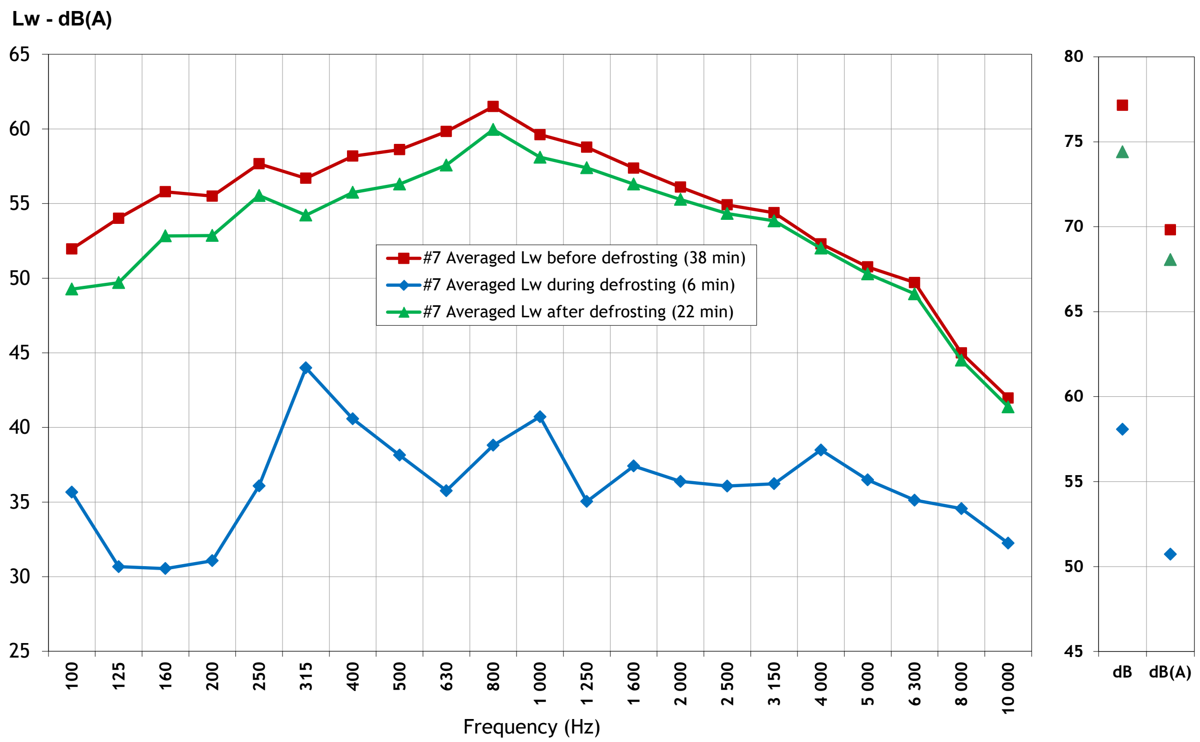


Figure 19 : averaged sound power levels for the 3 phases of frosting, defrosting (related to Figure 18).

The measurements of this laboratory allows to see the differences between the sound level just at the end of the frosting (and thus just before the defrosting cycle), compared to the sound level once the unit is coming back in the heating mode (the averaging periods are indicated by horizontal arrows on the top of Figure 18). It can be seen that for these conditions, the sound level increases at low and medium frequencies (between 3 to 10 dB).

Laboratory 2

From measurements of another laboratory, a similar increase of sound power level is observed on Figure 20 for the configuration #7 (EN 14825 point B) condition, with a smaller effect on the overall increase, which is around 2 dB(A). Almost all octave bands increase, except 4 and 8 kHz. Octave 125 Hz and 250 Hz increase a lot but do not really contribute to the overall value, which is mainly driven by the medium frequency bands.

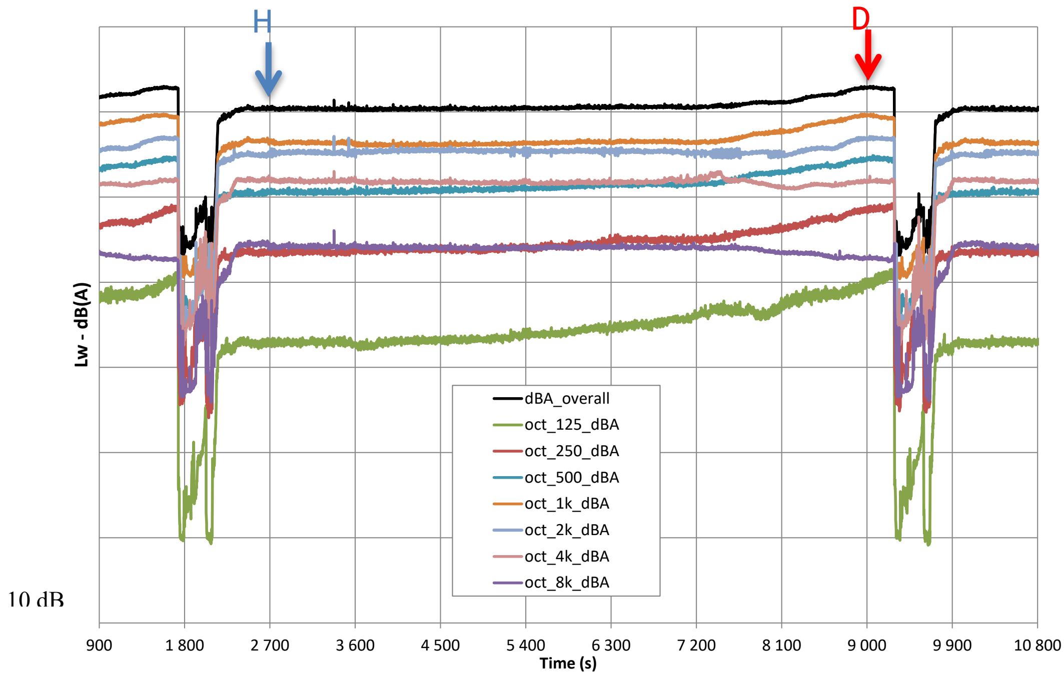


Figure 20 : Time dependent A-weighted sound power levels (in octave bands) between two defrosting phases configuration #3: EN 14511 frequency max

Figure 21 shows the spectrums at time H and D (cf. arrows on Figure 20), for #3 (EN 14511 max frequency) condition, and for #7 (EN 14825 point B at +2°C). The frosting induces an increase of the low and medium frequencies by 3 to 5 dB (consistent with the observations of lab 1).

Figure 22 shows the same quantities as Figure 20, but for negative outdoor air temperatures, leading to different behaviors of the sound power level. These levels are steadier, without noticeable increase before the defrosting starts, even though some accidents on frequency band may occur, but without larger influence on the overall level (see changes at 1800 s). However, this overall level quickly reaches the same magnitude than the one observed at the end of heating of Figure 20- arrow "D").

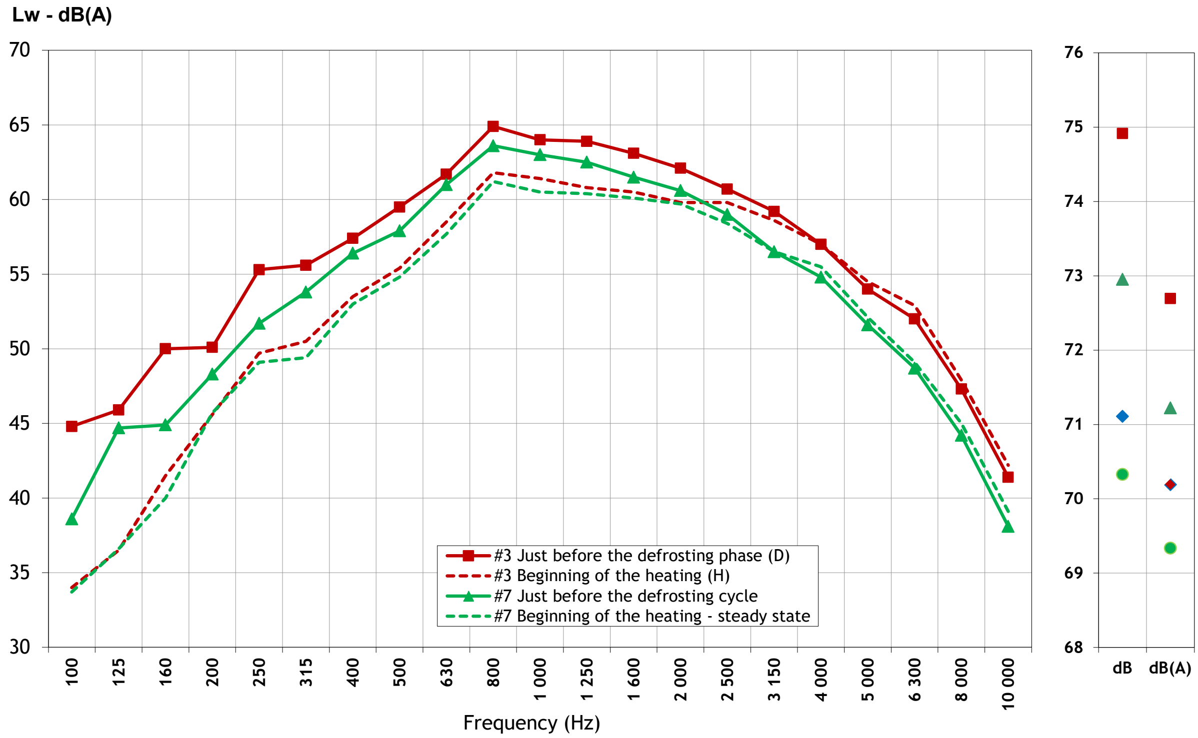


Figure 21 : averaged sound power levels for the 3 phases of frosting, defrosting (related to Figure 20).

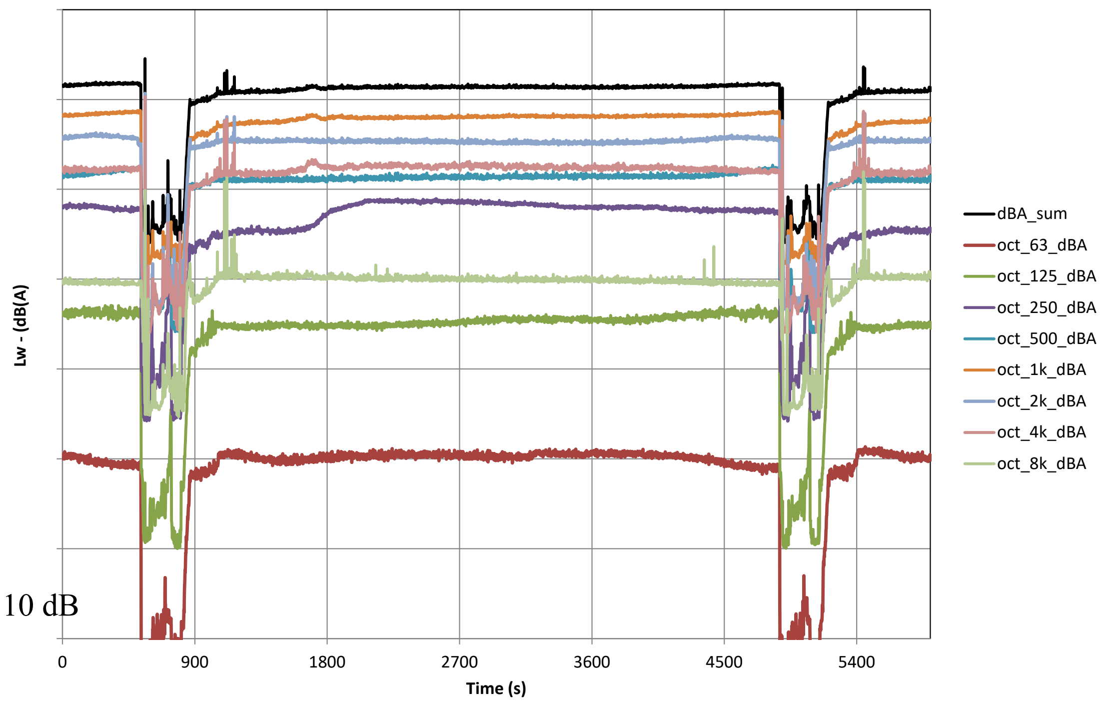


*Figure 22 : Time dependent A-weighted sound power levels (in octave bands) between two defrosting phases. Configuration #8: EN 14825 -7(-8) */34*

The influence of the frosting is clear, especially at positive ambient temperatures, for which an increase of the sound power level by almost 2 dB(A) is observed.

3 RRT4: HEAT PUMP WATER HEATER

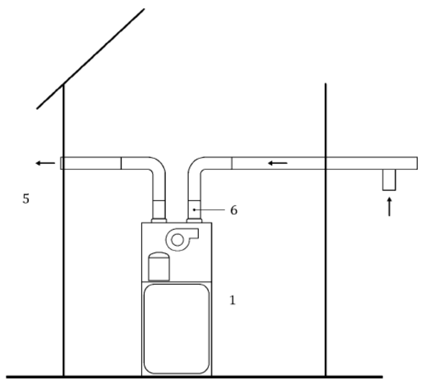
3.1 Protocol

3.1.1 Information shared between laboratories

The unit is an exhaust air unit requiring a is a double duct to the ventilation exhaust air circuit, adding some difficulty to the measurement due to the management of the airflow, the pressure drop, the necessity to have two rooms, and the background noise.

For heat pump water heaters (HPWH), the issue is to implement the project prEN 12102-2[1]. The test protocol is very much different to that of space heating units described in EN 12102-1. Heat pump water heaters are always operating in transient regime for reloading the water tank. Except for the first heating up of the water tank there is no possibility to perform a sound power level measurement. However, even during this heating up period, the temperature conditions at the condenser are at each time different. The goal is also to compare the results from different laboratories and to give a feedback about the comprehensiveness, the reproducibility and thus the validity of the method for improvement to the prEN 12102-2 standard.

The unit provided by a French manufacturer is an exhaust air unit with integrated fan configuration, having a nominal capacity of 780 W. It uses R134a as refrigerant, has a tank volume of about 210 liters and is equipped with an electrical heater of 2400 W which is not used for the acoustic test. The maximum volume flow rate is 265 m³/h. Its height is 1750 mm.



Key

1 noise radiated by the unit
5 noise radiated by the outlet opening
6 noise radiated by the unit inlet

Figure A.7 — Exhaust air with integrated fan

[1] At the time the RRT started under Annex 51 umbrella the standard EN 12102-2 was not published yet.

Figure 23: sketch of the exhaust air unit given in prEN 12102-2 - Annex A

The standard sketch explains what has to be measured on this configuration of unit (cf. Figure 23).

① the noise radiated by the casing of the unit

⑤ the exhaust noise radiated at the discharge duct opening

⑥ the in-duct noise "available" at the inlet of the unit. This means that the noise measured at the inlet duct opening has to be corrected by the duct end correction and (if necessary) the bend correction.

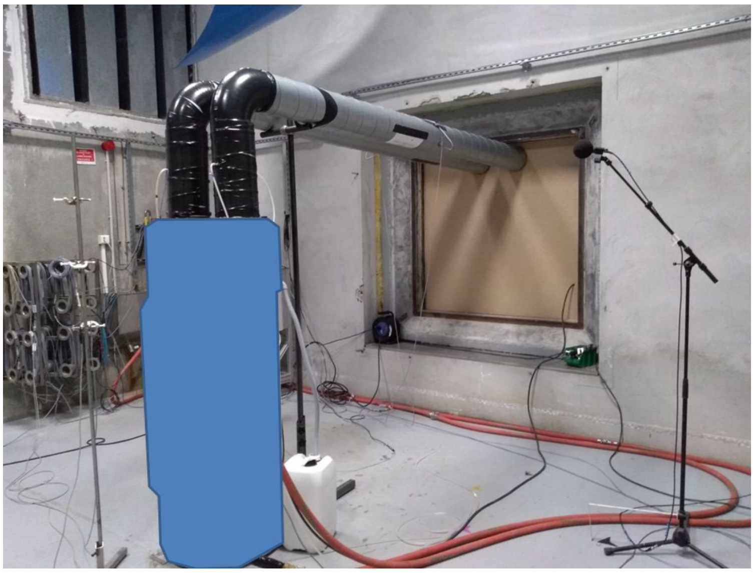


Figure 24 : installation of the unit in radiated noise configuration in CETIAT

An additional document has been written by CETIAT, the first lab to test this unit, to help the next laboratories to set the unit up:

- Connect the remote control (2 wires)
- Disconnect the spindle of electric booster to be sure it will be OFF during test
- Parameters:
  - P23: 1 (heat pump only)
  - P30: 100 Pa (arbitrary condition with 150 m³/h)
  - Control of under-pressure at the inlet of the device
  - ModeEco on the remote control

With this document, each laboratory was able to run the unit in a comparable way.

3.1.2 Installation and operating conditions according to the standard

The standard prEN12102-2 (date: 2018-06) requires to fill the tank with water at 20 °C and to switch the HPWH on to heat up the water.

According to the set temperature T_{set} declared by the manufacturer (T_{set} = 55 °C for this unit), the acoustic measurements have to be done at 3 target temperatures T_{hw} of the water taken from the tank by small tappings:

- 25 °C
- T_{set} – 5K = 50°C
- Average = (T_{set} + 25)/2 = 40°C

The dry inlet air temperature is 20 °C.

The standard requires the calculation of VPD, which gives the way to perform the test. As the heat pump capacity is small compared to the tank volume, the configuration VPD < 10 is applied. The acoustic measurement at each target temperature has to be done in a short window of 15 minutes, because the water tank temperature continuously increases, changing the conditions at the condenser, changing the noise level (unlike the other kinds of heat pump for which steady conditions are forced).

All acoustic measurement techniques are allowed for the heat pump water heater, but quick techniques such as reverberant room methods (ISO 3741 or 3743 … or ISO 3744 with a high number of microphones) are the most suitable, to fulfil the requested 15 minutes measurement duration.

It is worth mentioning that in all cases, the averaging time of sound pressure level measurement shall be 180 s instead of the usual 30 s. This can be arranged in 6 x 30 or 3 x 60 seconds.

Practically, during the heating up period, small tappings have to be done to check the water temperature inside the tank. When this measured temperature is in the range of the target temperature [± 1 K], the acoustic measurement can start.

For this unit, the fan flow rate has to be adjusted at 150 m^3/h @ 100 Pa, implying to measure and manage the airflow and the pressure inside the duct.

The heating up can be done continuously from the initial temperature (20 °C) of the tank water to the highest temperature, but in order to save time, the standard allows to fill the tank with water at a temperature close to the target temperature minus 5 degrees, these 5 last degrees being heated by the heat pump, respectively 20 ° / 35 ° / 45 °C for each of the 3 target temperatures.

3.2 Results

3.2.1 Radiated sound power level

The sound power level radiated by the casing (#1 of Figure 23) has been measured by 5 participating laboratories. It seems to be the easiest measurement to implement, especially for laboratories which are not especially designed for this kind of tests.

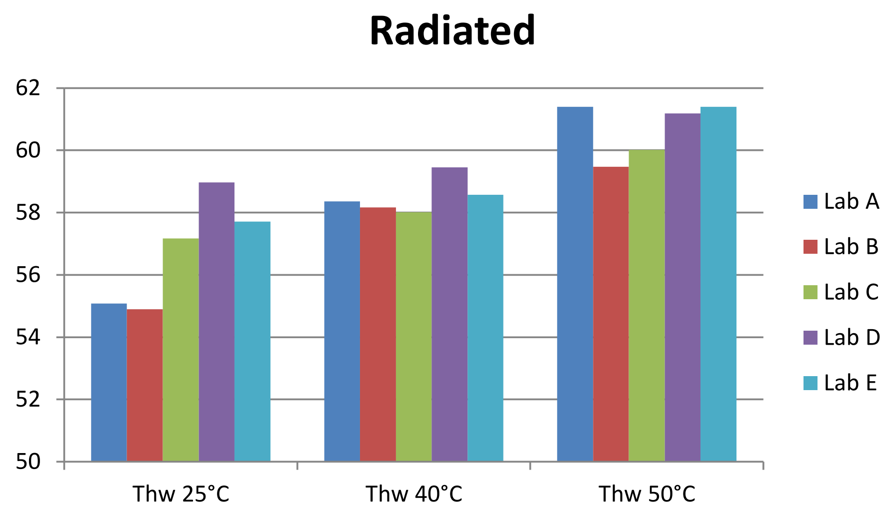


Figure 25 : overall dB(A) radiated sound power level for the 3 target Thw temperatures

Figure 25 shows the overall dB(A) values for the 5 laboratories. Differences are small at T_{hw} = 40 °C, larger at T_{hw} = 50°C and quite significant at T_{hw} = 25° C.

These overall values differences hide larger differences of spectrums.

Data comparison is done in 1/3 octave bands, even though lab B only provided octave bands results. In Figure 26, the lab B data has been oversampled to be artificially changed to 1/3 octave bands spectrums in dB(A).

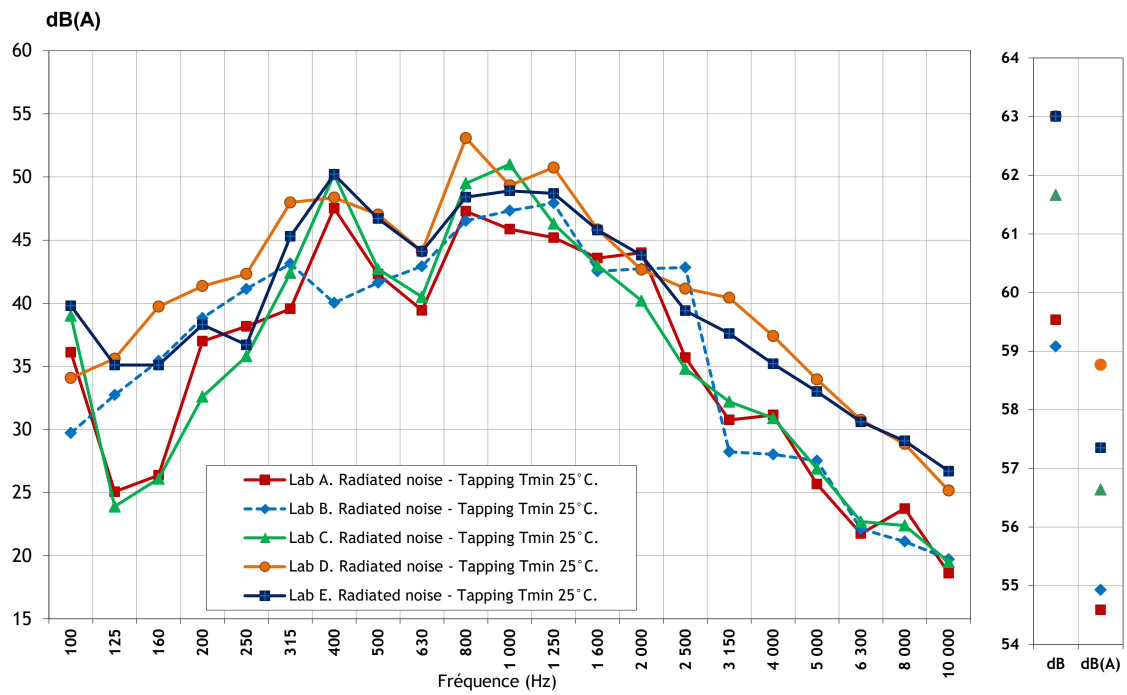


Figure 26 : radiated noise levels at Thw = 25 °C

Figure 26 shows that the results at T_{hw}=25°C from 3 laboratories are consistent in the high frequency range (labs A/B/C) whereas labs C & D found higher values.

The peak at 400 Hz has been detected by all laboratories (no peak for lab B due to oversampling process).

The off-peak at 630 Hz is also detected by all. Around 800 / 1000 Hz, the peaks are sometime very broad (lab E), only at 800 Hz (labs A & D), or at 1000 Hz (lab C) or even at 1250 Hz (lab D).

At low frequency, labs A, B and E detected a peak at 100 and 200 Hz.

Lab D gives values higher than the other laboratories at all frequencies: perhaps because of problems in the air flow or capacity settings of the unit?

This short factual analysis shows that significant discrepancies can be observed between the laboratories.

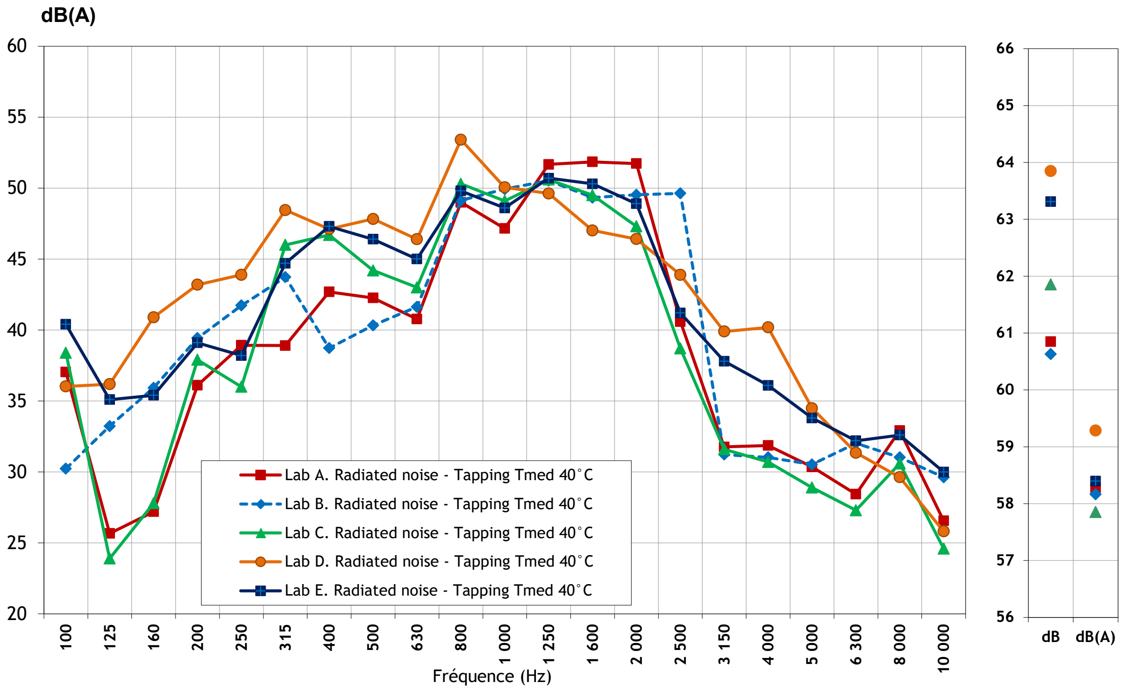


Figure 27 : radiated noise levels at T_{hw} = 40 °C

Figure 27 shows that the second target T_{hw} temperature of 40°C lead to very close overall dB(A) values (except for Lab D as for the 25 °C configuration). These good results hide again some big local differences. Examples are given for labs A and C, which are very close for the major part of the spectrum except at 315/400 Hz and conversely at 1600/2000 Hz.

Lab E probably had problems with background noise at low and high frequencies, but the levels on medium frequencies are consistent with the other results.

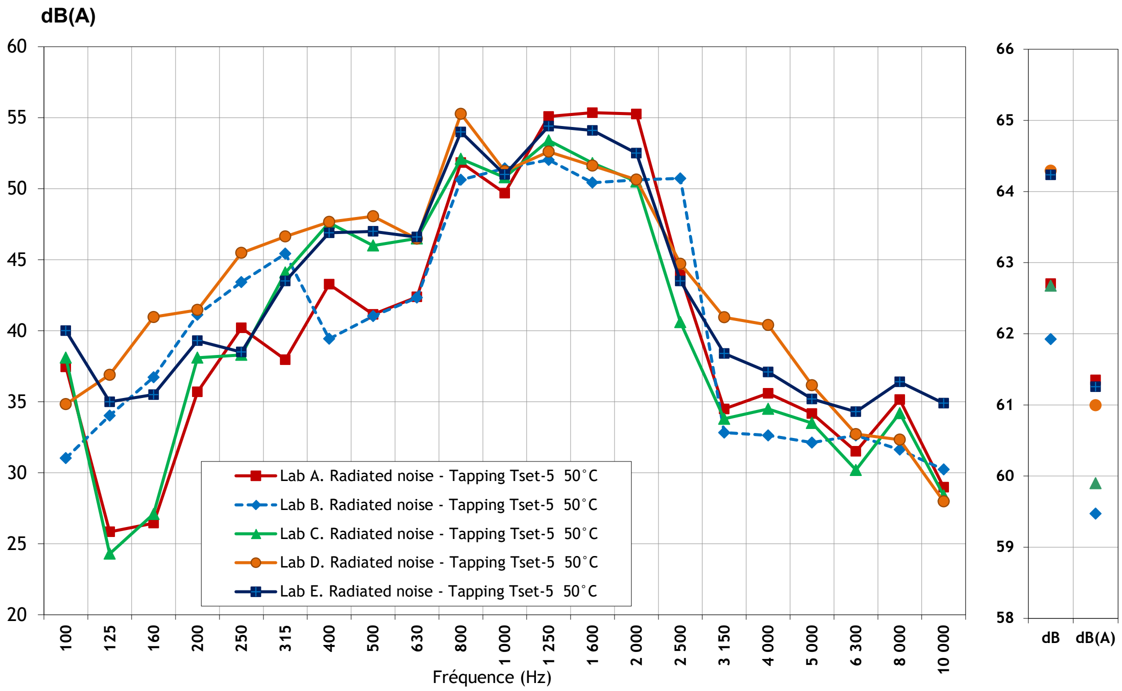


Figure 28 : radiated noise levels at Thw = 50 °C

For the warmest water temperature of test (T_{hw} = 50 °C), the shapes of the spectrums are similar, but local differences lead to big overall differences. One can mention labs A and C which again are close but lab A measured higher levels around 1600 Hz, and lower around 400 Hz. Lab E and B are consistent with lab C.

The levels measured at medium frequency has a great influence on the overall dB(A) value. Due to differences up to 5 dB between 800 and 2000 Hz, the overall values can be different of 2 dB(A).

These first 3 results for radiated noise demonstrate that the overall dB(A) value is a very simple indicator which can hide big differences in spectrums.

It can be concluded that measurements of radiated noise have to be done according to the project standard prEN 12102-2, with airflow rate of 150 m³/h airflow rate under 100 Pa. Results are very scattered. The water temperature in the tank is easy to measure for such laboratories, with small tappings. Perhaps the management of the airflow and the pressure on air side can be the cause of these differences.

The conditions of operation of the heat pump itself are unknown as the water flowrate and temperatures on the condenser side are not accessible, which limits the possible comparison in the results from different laboratories. With the compactness of the unit, it is not possible to measure the rotation speeds of fan or compressor, which are also essential parameters in comparing acoustic results.

3.2.2 Inlet noise

Inlet noise has been measured by 3 laboratories. This noise characteristic is the noise "available" at the inlet opening of the unit; it is then used to calculate the sound power level in the different rooms in the house, taking into account the ductwork characteristics.

Specificity of inlet measurement is that the measurement has to be corrected by the duct end correction and the elbow correction.

- Duct end correction allows to calculate the sound power level inside the duct from the one radiated by the duct outlet. It takes into account the change of acoustic impedance at the end of the duct
- The elbow leads to impedance change, and then sound reduction, when measuring at the duct outlet. The elbow correction allows calculating the in-duct sound power level at the outlet of the unit itself, represented by ⑥ on Figure 23.

One proposal for the installation is presented in Figure 29. The inlet noise is measured in the left side acoustic room. The unit is ducted at its outlet section to an auxiliary fan to manage the pressure drop and to compensate the pressure drop of the circuit to the airflow measuring device.

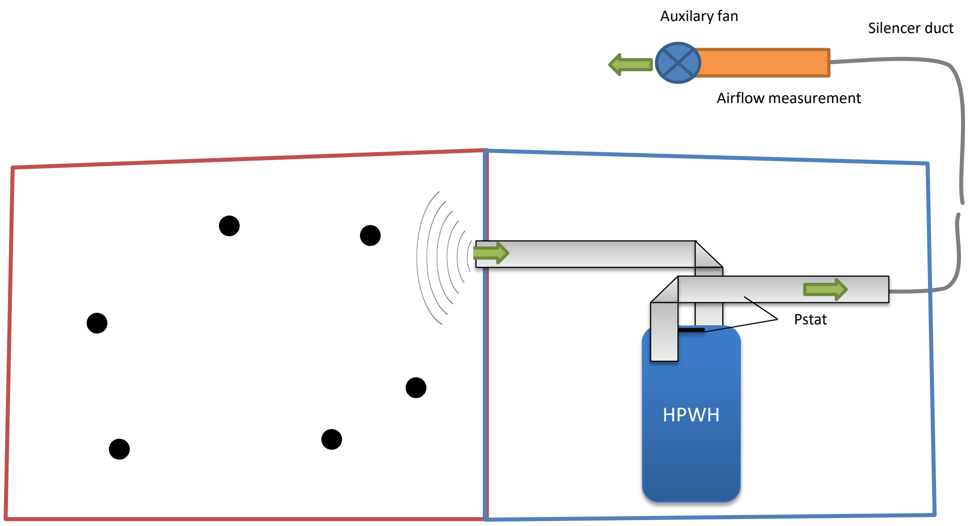


Figure 29 : proposal for the installation of HPWH to measure the inlet noise

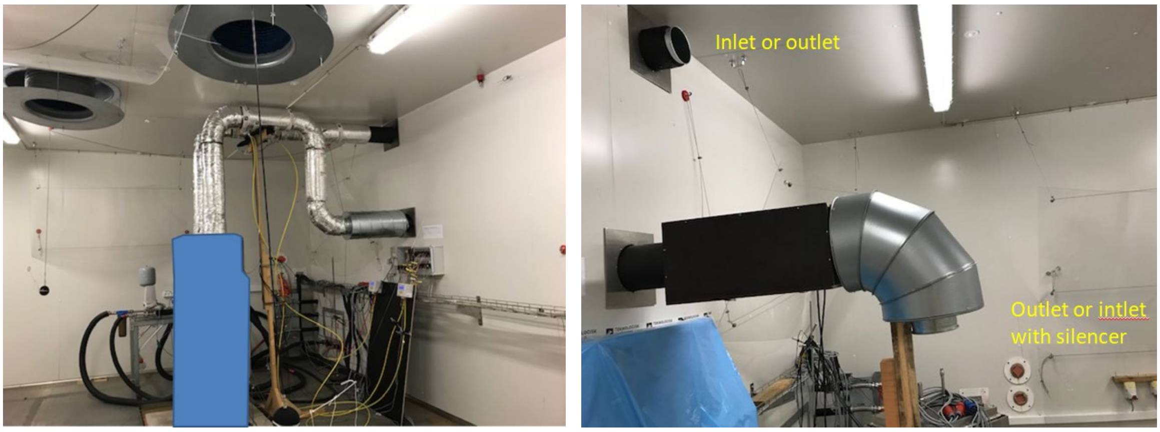


Figure 30 : installation in one lab

Figure 31 : installation in another lab

One laboratory used a configuration close of the "radiated by casing", with a silencer on the "not under test" duct. The other one used a secondary circuit outside the room to suck the exhaust air.

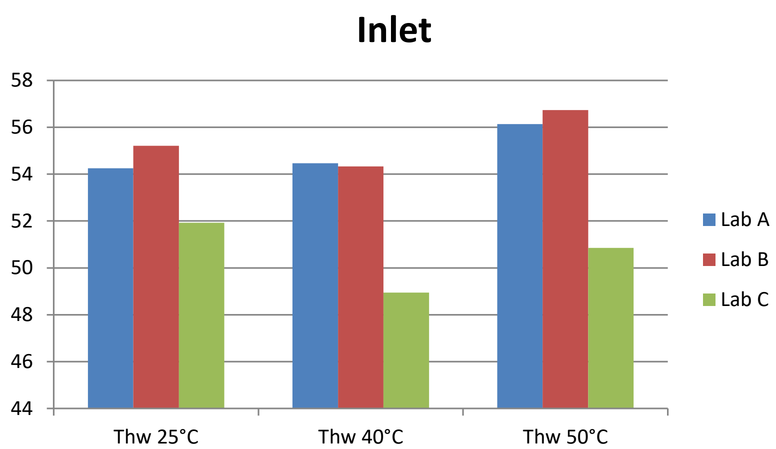


Figure 32 : overall dB(A) inlet sound power level for the 3 target T_{hw} temperatures

For this inlet noise, labs A and B are very close, but Lab C has lower values, between 2 and 5 dB(A), not linked to T_{hw} temperatures, for which usually, the hotter water tank temperature leads to higher sound value. Nevertheless, the spectrums exhibit quite similar shapes with an offset. It can be questioned if it is due to the duct end correction reflection and/or the elbow, applied with the wrong sign. .

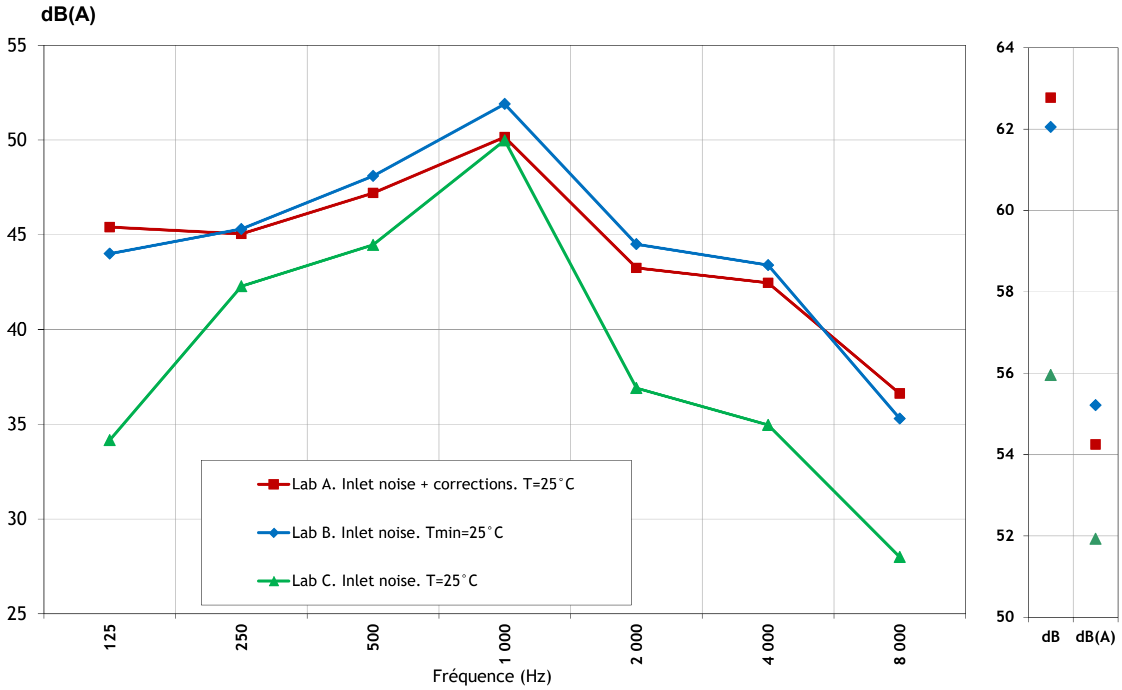


Figure 33 : overall dB(A) inlet sound power level for the 3 target T_{hw} temperatures (oct. bands)

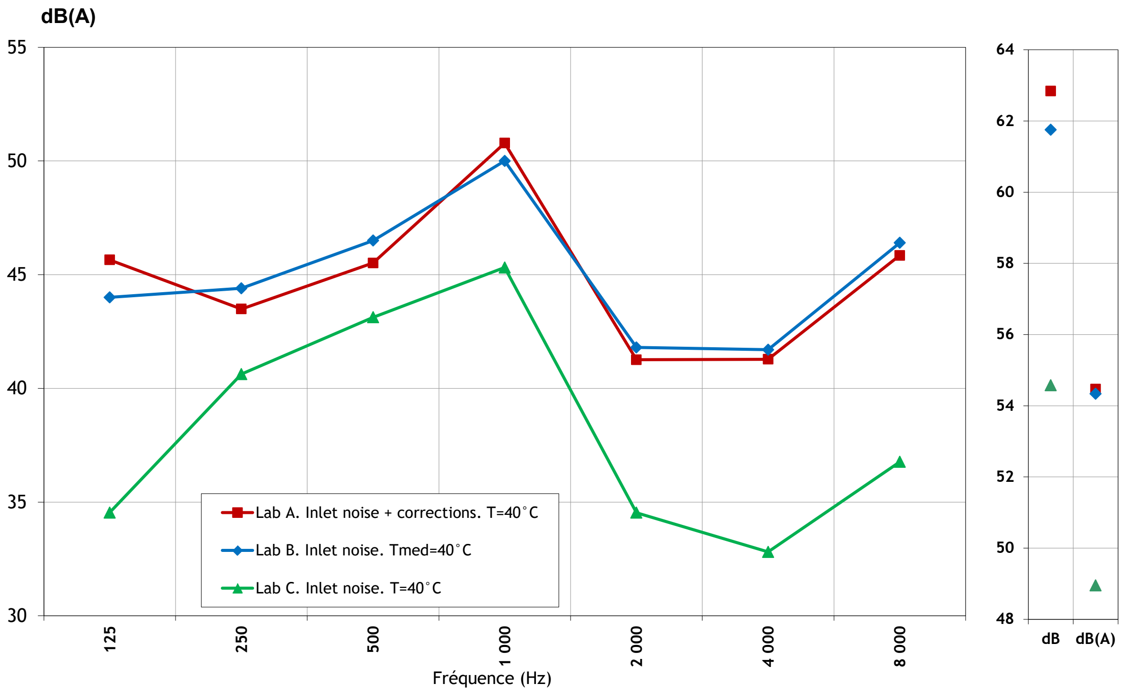


Figure 34 : overall dB(A) inlet sound power level for the 3 target T_{hw} temperatures (oct. bands)

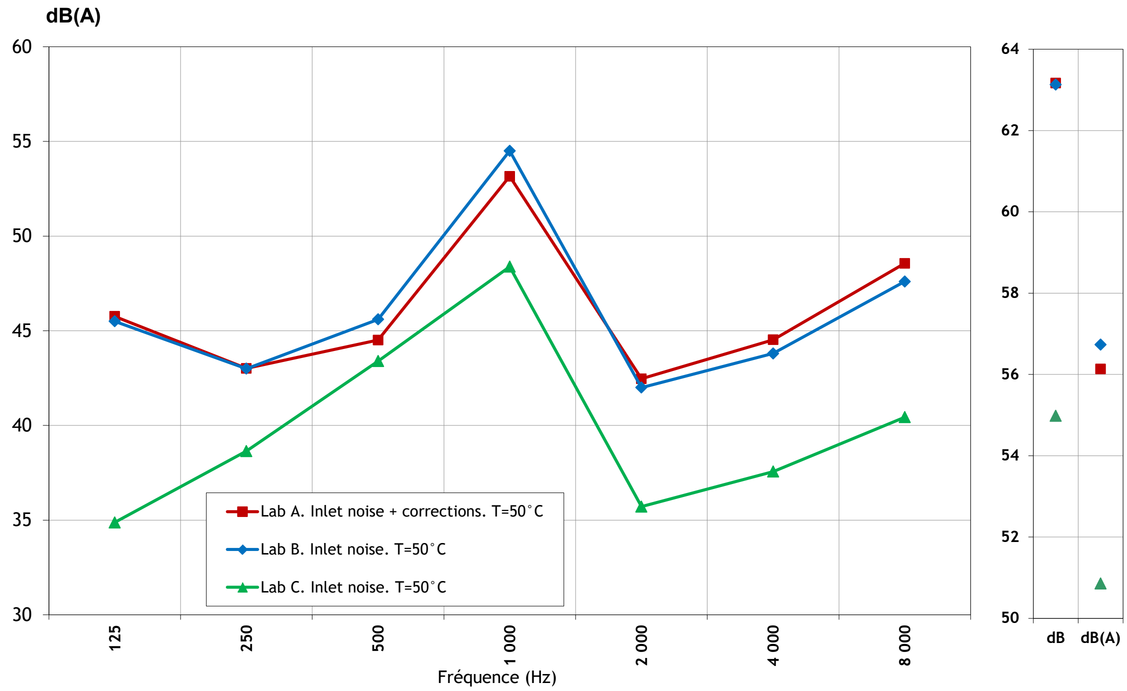


Figure 35 : overall dB(A) inlet sound power level for the 3 target T_{hw} temperatures (oct. bands)

3.2.3 Outlet noise

The outlet noise is determined for the neighborhood. It is measured at the ending of the outlet duct, and duct end correction is not necessary, because the expected noise is directly the sound heard by the neighborhood, not the one traveling inside the duct.

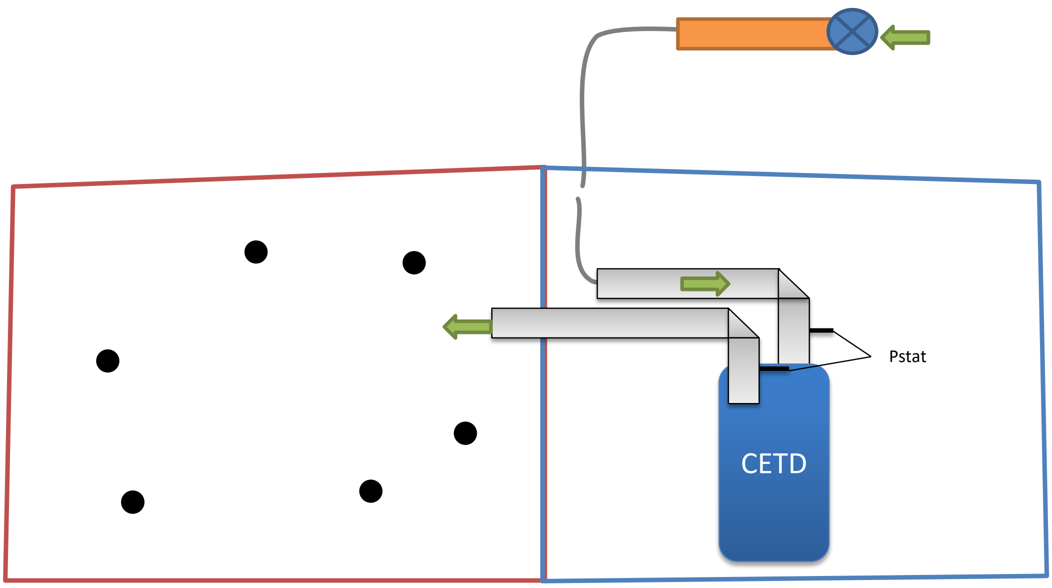


Figure 36 : proposal for the installation of HPWH to measure the outlet noise

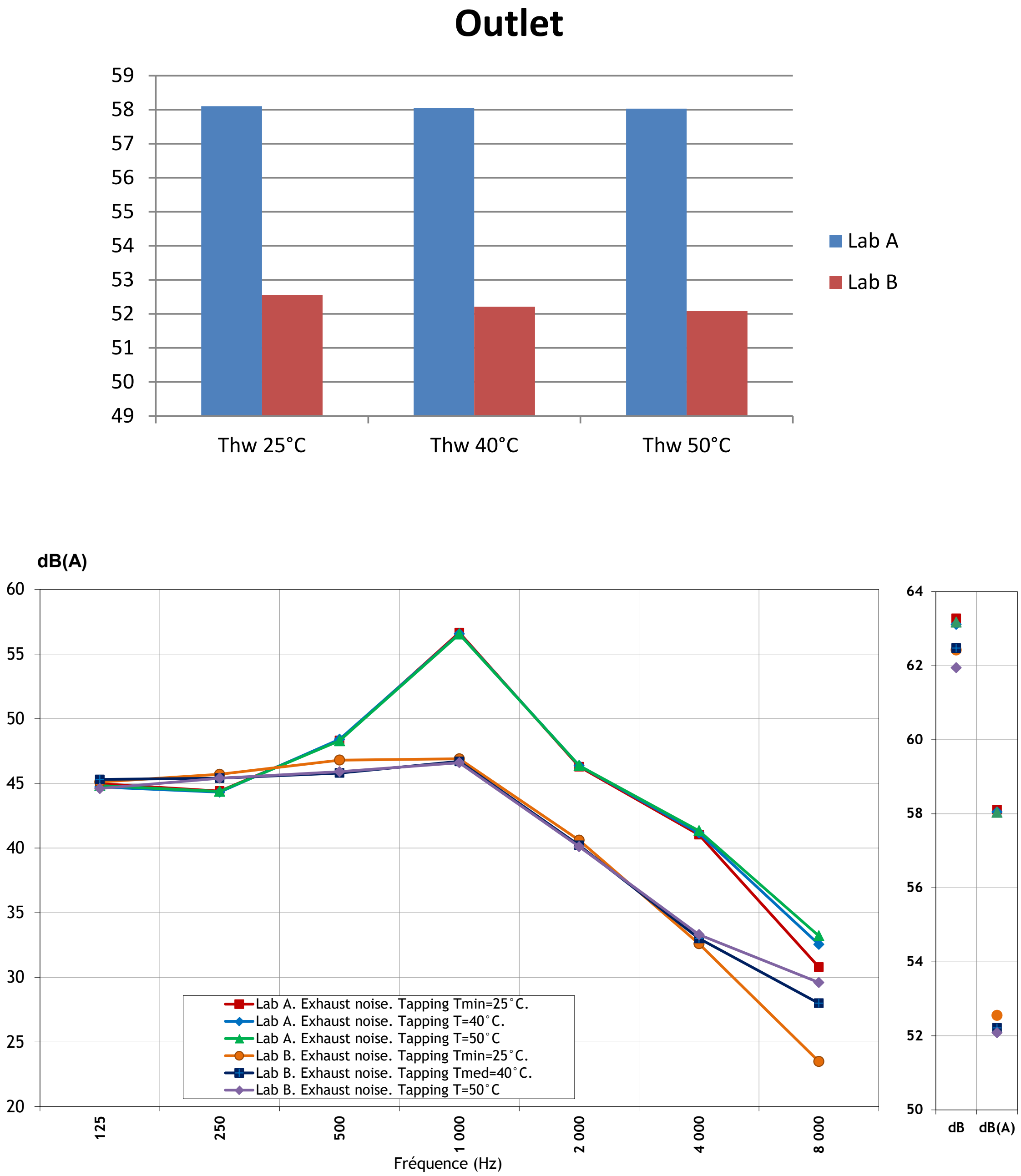


Figure 37 : spectrum for labs A and B for outlet sound power levels

Results presented in Figure 37 clearly show that they are not influenced by the operating condition (or water tank temperature) as all spectrums are exactly the same for each laboratory. This means that the fan noise is the only source, without any contribution of the compressor noise.

Nevertheless, the two laboratories found very different results, lab A observing a strong peak at 800/1000 Hz, where lab B has a flat spectrum.

These results are very surprising, after the high consistency of results for inlet noise for these two laboratories. No direct explanation can be done.

4 CONCLUSIONS

Tests have been done on two types of heat pumps, an air-to-water split heat pump for space heating and a heat pump water heater.

4.1 RRT1: air to water heat pump

The tests performed on the air to water heat pump were aimed at comparing the measurement results between laboratories, at investigating the sound levels generated under other climatic conditions (especially conditions with partial load operation of the heat pump) for steady state operation of the unit, but also for unsteady behavior, e.g. during frosting and defrosting cycles, with a time sampling around one or two seconds.

The list of almost 9 test conditions has been partially or fully implemented by laboratories, during which sound power level has been measured. Design of the acoustic means in the different laboratories did not allow all of them to perform all tests.

The comparison begins by a quite positive result for the condition (#1) EN 14511, 7(6)°C on air side and 30-35 on water side. This operating condition is very common and familiar to the laboratories. Acoustic results from all laboratories compare well, with an overall dB(A) in an 1.5 dB(A) range, and consistent spectrum shapes. This is encouraging to see that so various environments of laboratories (reverberant room, climatic chamber used as reverberant room, climatic chamber with absorbing material to give free field) and diversity of acoustic methods (from laboratory class to control class) can give comparable results.

For other operating conditions, the results are more scattered and, to sum up, it is very difficult to give an explanation to these differences because back investigations are not really possible in this framework. Differences may be due to operating conditions (conditions difficult to reach), or difficulties to implement the acoustic measurements in cold or very cold conditions. No data about rotation speed of fan or compressor being available, it is again difficult to explain and understand the observed differences without deeper investigation in the operational behavior of the heat pump and test implementation by the laboratories.

The frosting/defrosting cycles observed according to time at positive outdoor air temperatures, show that the frosting gradually increases the sound level by ~2 dB(A) (while the capacity decreases). Then the defrosting cycle, during which many (acoustic) events occur, lead to an average sound level approximatively 20 dB(A) lower than the sound level at the end of frosting.

A psychoacoustic study could perhaps demonstrate that for the end-user, the perceived difference is less or more than 20 dB(A) because of the many events that occur, but for the sound level, we just have to consider these 20 dB(A).

For negative outdoor air temperatures, the gradual increase of sound level during the frosting period is not observed.

From these measurements, a "Seasonal Sound Power Level" is proposed and its calculation is described in the Report 2.3.

4.2 RRT4: heat pump water heater

The circulation between the laboratories of a ducted heat pump water heater highlighted again some difficulties of measurement for this "challenging to implement" unit, with an unusual standard method prEN 12102-2.

As for the sound power level of the outdoor unit of the air-to-water heat pump (RRT1) the results are mixed, the results are very close and sometimes very far, with a real difficulty to analyze the origin of these discrepancies, due to the "black box" configuration of such heat pump water heater. It is clear that the ducted nature of the unit generates some difficulties, for the installation and for the management of the aerodynamic part. Some laboratories, which are not equipped for these configurations, only measured the sound power level radiated by the casing.

Anyway, the specific approach with the small tappings to know the water temperature inside the tank seems to be well implemented by the labs. The airflow & pressure setting and measurement are probably more difficult to manage.

5 ANNEX1: Short description of the laboratories

The description of the laboratories is given in this Annex. This is a short description, from which it appears that most of the laboratories chose implementing acoustics in a climatic chamber, with a class 2 *engineering* acoustic measurement. The sheet metal nature of wall allows having reflecting walls, then diffuse field; the ISO 3743-1 is suitable for this kind of environment.

ISO 3743-1 "Determination of sound power levels and sound energy levels of noise sources using sound pressure — Engineering methods for small movable sources in reverberant fields — Part 1: Comparison method for a hard-walled test room".

The measurement is done by comparing the sound pressure level produced by the unit to the sound pressure level of a reference sound source, its sound power level being known by calibration.

Some issues that can frequently arise with climatic chambers:

- The background noise level is usually not very low, because the walls are light compared to 30 cm thick concrete of a reverberation room. This may not be a problem, depending on the noise of the unit and the noise in the other parts of the laboratory.
- The dimensions of the rooms. Physics (and ISO 3741) requests specific ratios of height/length and width/length to avoid entire or remarkable ratios, and then redundant resonance modes. Climatic chamber designers are usually not aware of these recommendations, leading to cubic volumes. Strong modes may appear at low frequencies, because of small size of rooms, and of coincidence between room modes and tonal bands radiated by unit.

DTI applied the acoustic recommendation in its climatic rooms, so does CETIAT which performed tests in true reverberant rooms. AIT built a kind of hemi-anechoic room in its climatic chamber by adding 100 mm foam on the walls.

Laboratory	Room 1 dimension (LWH) (m)	Room 2 dimensions (LWH) (m)	Type of room Material	Typical background noise - without activity - during HP testing	Acoustic Standard used	Capacity (kW)
Fraunhofer IBP ISE	4 x 8 x 4 128 m³	If necessary, room 1 is split in 2 rooms 4 x 3.9 x 4	Climatic chamber used as hard wall reverberant room	30 dB(A)	ISO 3743-1	2 x 50 or 100
Polimi	5.5 x 4.2 x 4.4 101 m³	5.5 x 4.2 x 4.4 101 m³	Climatic chamber used as hard wall reverberant room	23 dB(A) 29 dB(A)	ISO 3743-1	50
DTI	5.3 x 6.8 x 3 143 m³	5.3 x 6.8 x 3 143 m³	Climatic chamber used as hard wall reverberant room	18 dB(A)	ISO 3743-1	30
CETIAT	8.1 x 6 x 4.8 230 m³ non parallel walls	7,2 x 6 x 4.8 205 m³ Non parallel walls	Reverberant rooms Concrete walls, ceiling, floor	17 dB(A) 22 dB(A)	ISO 3741	50
AIT	5 x 5 x 5 125 m³		Climatic chamber used as hemi-anechoic room 100 mm absorbing material on walls	32 dB 52 dB	ISO 9614-2 ISO 3746	20

Remarks: most of the climatic chambers used as reverberant rooms do not fulfil the basic recommendations of acoustic rooms, such as non-remarkable dimensions ratios, the worth being the cube. ISO 3743-1 has no direct requirement about the room dimensions, but a cubic room can lead to hard modes and difficulties in the qualification.

Fraunhofer IBP-ISE (Germany)

- Use of climatic chambers, acting as reverberant rooms
- The walls are almost entirely made out of metal, the two sides featuring perforated panels to allow for A/C flow. (cf pictures)
- Room dimensions: (L,W,H) = 4 x 8 x 4 m (128 m³)

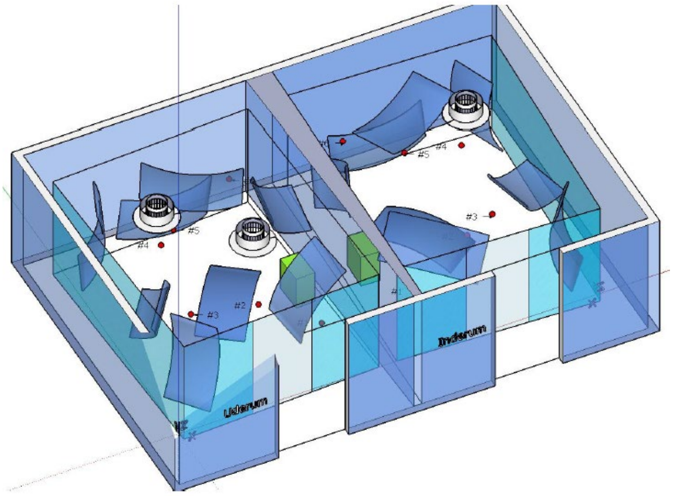
- RRT1 : the indoor unit is installed outside the chamber, whereas the outdoor unit is in the climatic chamber, used as hard wall room for ISO 3743-1 measurement.
- RRT4 : the chamber was separated in two equal rooms, each measuring 4 x 3.9 x 4 m (62.4 m³)

Polimi (Italy)

- Type of rooms: climatic chamber used as reverberant room, hard wall method ISO 3743-1
- Type of wall: stainless steel composite panels comprised of two sheets - one of stainless steel (internal surface into the room) – In the middle a solid core of polyurethane foam. The separating wall and the doors instead consist in sandwich panel made with polyurethane foam and painted metal plates
- Main dimensions: the 2 rooms have the same dimensions (LxWxH) : 5.5 x 4.2 x 4.4 m (101 m³)
- The cooling capacity is around 50 kW for each chamber
- For RRT4, 6 microphones used alternatively: first for indoor sound measurement; then for outdoor sound measurement.
- For RRT1, 6 microphones in the “outdoor” room and 4 microphones in the indoor room were used.

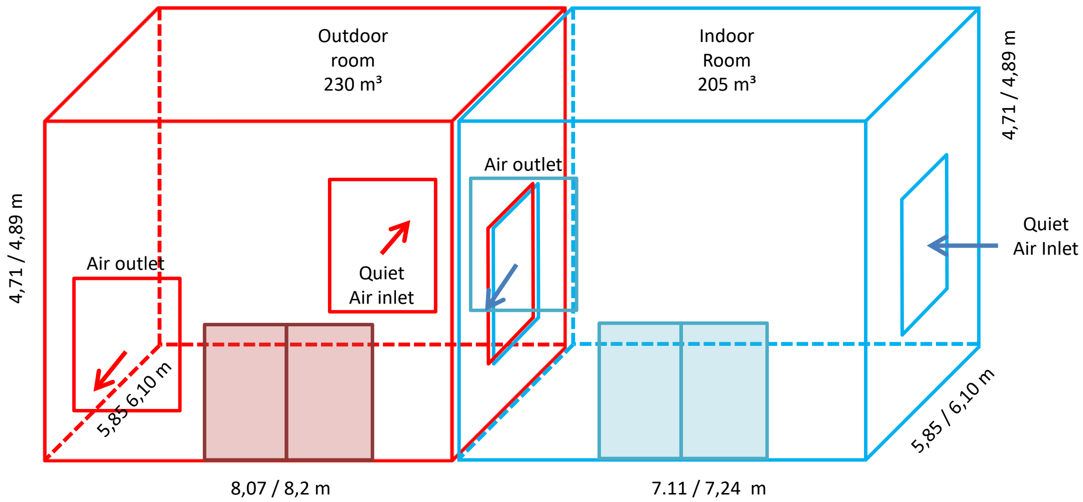
DTI (Denmark)

- Type of rooms: two identical joined climatic rooms designed in respect of acoustic rules of ISO 3741
- Type of wall: core of heat-insulating foam covered with thin steel plate, giving a low absorbing behavior for sound waves. The floor has the same construction, with an extra top layer of welded robust steel plate, which can carry pallet lifters under heat pump installation
- Main dimensions (inside) width 5.25 m, length 6.75 m and height 3 m for a volume of 106 m³



The acoustic measurement method used is EN ISO 3743-1, with comparison with reference sound source.

CETIAT (France)



- type of room: joined reverberant rooms , box in the box construction with external enclosure with 40 cm concrete, and 30 cm for the internal rooms, mounted on anti-vibrations mounts.
- material of walls, floor, ceiling: concrete, thickness 30 cm for the walls and ceiling
- main dimensions (L, W, H) : 8.1 x 6 x 4.8 m for outdoor side (230 m³), 7,2 x 6 x 4.8 m for indoor side (205 m³). The wall are not parallel, as well as the ceiling
- acoustic method: ISO 3741 (laboratory class 1)
- max cooling/heating capacity : 50 kW
- typical background noise spectrum when testing heat pumps: 18 dB(A)

AIT

- type of room: climatic room used as semi-anechoic
- material of walls, floor, ceiling: floor = stainless steel, walls/ceiling = 10 cm Basotect absorbing material
- main dimensions (L, W, H) : approx. 5 x 5 x 5 m (125 m^3)
- acoustic method: Intensity ISO 9614-2 (class 2), with an "acoustic dome" = ISO 3746 (class survey)
- max cooling/heating capacity : 20 kW
- typical background noise spectrum when testing heat pumps:

6 ANNEX 2: Protocol given for RRT1

Working Document
IEA HPT ANNEX 51 - Task 2: Testing of heat pumps - RRT1

CETIAT

Date: 03/05/2018

From: Michèle Mondot - François Bessac

To: Annex 51 partners

Working Document

IEA HPT ANNEX 51 - Task 2

Testing of heat pumps - RRT1

1. INTRODUCTION

In Task 2 of Annex 51, the partners have identified 3 types of heat pumps representing the major shares of market in the different EU Member States.
The aim is to perform round robin tests (RRT) on these 3 types of heat pumps with the following objectives:

- Evaluate and compare the different acoustic test methods when testing according to reference standards
- Assess the influence of the behaviour of the unit (frequency, frosting/defrosting,...)
- Possibly identify new indicator(s) for the sound power level of heat pumps, based either on a "maximum" sound power level and/or on sound power level measured at different part load conditions.

The RRT1 is to be performed on an air-to-water heat pump, split type for heating only, provided by Atlantic (France).

This document is describing the different tests to be performed, according to the test facilities of the different labs.

2. UNIT UNDER TEST

The RRT1 unit is an air-to-water heat pump Extensa 10 from ATLANTIC.
The heat pump is a split unit and includes :

- Indoor unit
- Outdoor unit

- Refrigerant lines of 7.5 m
- R410A charge

The unit shall be shipped to the next lab with no refrigerant but charged with nitrogen.
Each lab, except the first one, shall fill in the unit with the mass of refrigerant as indicated by the manufacturer on the nameplate.

The unit is delivered with the following notices:

- Installation
- Settings for all test points of this protocol
- Product fiche according to ErP regulation

3. STANDARDS AND TEST METHODS

The basic document for testing is EN 12102-1:2017 which specifies the different acoustic methods that can be applied and describes how to install the heat pump for acoustic measurements.
The manufacturer will provide all necessary information for installation of the unit and all settings for conducting the different tests.
The standard allows different generic acoustic test methods.
If the test lab has the possibility (test facilities / time / budget) to perform the same tests using different acoustic measurement methods, it will allow evaluating the equivalence of the different techniques.

With each set of performance data, the test lab. shall clearly state which acoustic measurement technique(s)/standard(s) was(were) used.

4. TEST CONDITIONS

4.1. Standard rating conditions

The sound power level of the unit shall be measured in the standard rating conditions as specified in EN 14511. These are:

- Outdoor air : 7(6)°C
- Inlet/outlet water temperatures : 30-35°C

With the settings as specified by the manufacturer.

4.2. *ErP sound power level*

The sound power level of the unit shall be measured as requested for ErP declaration, i.e. as described in Annex A.4 of EN 12102-1.
The temperature conditions are the standard rating conditions of EN 14511 with the settings to obtain the same heating capacity as during Part load test C of EN 14825.

4.3. *Part load conditions*

Part load conditions as defined in EN 14825 Table 8 for:

- average climate (A)
- Variable outlet water temperature

shall be used.

These conditions will be set based on the instructions from the manufacturer and the sound power level will be measured at each part load condition.
Depending on the capabilities of the test facilities and/or acoustic test methods used, all test conditions cannot necessarily be achieved. Each test lab. shall try to perform the maximum of the proposed part load conditions.

Table 8 — Part load conditions for air-to-water units in low temperature application for the reference heating seasons "A" = average, "W" = warmer and "C" = colder

Condition	Part Load Ratio in %				Outdoor heat exchanger		Indoor heat exchanger			
					Inlet dry (wet) bulb temperature °C		Fixed outlet °C	Variable outlet[d] °C		
	Formula	A	W	C	Outdoor air	Exhaust air	All climates	A	W	C
A	$(-7 - 16) / (T_{designh} - 16)$	88	n/a	61	−7(−8)	20(12)	[a] / 35	[a] / 34	n/a	[a] / 30
B	$(+2 - 16) / (T_{designh} - 16)$	54	100	37	2(1)	20(12)	[a] / 35	[a] / 30	[a] / 35	[a] / 27
C	$(+7 - 16) / (T_{designh} - 16)$	35	64	24	7(6)	20(12)	[a] / 35	[a] / 27	[a] / 31	[a] / 25
D	$(+12 - 16) / (T_{designh} - 16)$	15	29	11	12(11)	20(12)	[a] / 35	[a] / 24	[a] / 26	[a] / 24
E	$(TOL - 16) / (T_{designh} - 16)$				TOL	20(12)	[a] / 35	[a] / [b]	[a] / [b]	[a] / [b]
F	$(T_{bivalent} - 16) / (T_{designh} - 16)$				$T_{bivalent}$	20(12)	[a] / 35	[a] / [c]	[a] / [c]	[a] / [c]
G	$(-15 - 16) / (T_{designh} - 16)$	n/a	n/a	82	−15	20(12)	[a] / 35	n/a	n/a	[a] / 32

[a] With the water flow rate as determined at the standard rating conditions given in EN 14511–2 at 30/35 conditions for units with a fixed water flow rate, and with a fixed delta T of 5 K for units with a variable flow rate. If the resulting flow rate is below the minimum flow rate then this minimum flow rate is used with the outlet temperature.

[b] Variable outlet shall be calculated by interpolation from $T_{designh}$ and the temperature which is closest to the TOL.

[c] Variable outlet shall be calculated by interpolation between the upper and lower temperatures which are closest to the bivalent temperature.

[d] If the variable outlet temperature is below the minimum of the operation range of the unit, this minimum should be considered.

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4.4. *Maximum sound power level*

The aim is to assess if a maximum sound power level can be measured. The test will be performed in 2 operating conditions:

- In the standard rating conditions of EN 14511, with the maximum frequency as specified by the manufacturer
- At the part load condition F of EN 14825 (Tbiv) and the maximum frequency as specified by the manufacturer.

5. ACOUSTIC MEASUREMENTS

When the behaviour of the unit is steady, the sound power level shall be identified by one spectrum in one-third octave bands.
When the behaviour of the unit is in non-stationary (case of frosting for example), the sound power level should be determined in continuous measurement at least 30 seconds steps, to get the evolution of sound related to other parameters.

6. TEST RESULTS

For each test, the test laboratory shall a test report including the following general information:

- The outdoor air temperatures dry bulb (wet bulb)
- The inlet/outlet water temperatures
- The water flowrate
- The pressure drop/external static pressure
- The measured power input and effective power input
- The measured capacity
- The sound power level spectrum in one-third octave bands (dB) and overall dB(A)
- All individual measurement uncertainties
- Uncertainty on measured capacity
- Uncertainty on measured on sound power level

In addition for each test, all data during the acoustic measurement acquisition period shall be reported at the time period (10 or 15 or 30 s) in Excel files for allowing further data treatment and analysis.

Photos of installation are also required, showing the installation and the acoustic means.
The methodology of sound power level uncertainty assessment shall be shortly described.

7 ANNEX 3: Protocol given for RRT4

Working Document
IEA HPT ANNEX 51 - Task 2 : Testing of heat pumps – RRT4

Date: 03/05/2018

From: Michèle Mondot - François Bessac

To: Annex 51 partners

Working Document

IEA HPT ANNEX 51 - Task 2
Testing of heat pumps - RRT4

1. INTRODUCTION

In Task 2 of Annex 51, the partners have identified 3 types of heat pumps representing the major shares of market in the different EU Member States.
The aim is to perform round robin tests (RRT) on these 3 types of heat pumps with the following objectives:

- Evaluate and compare the different acoustic test methods when testing according to reference standards
- Possibly identify new indicator(s) for the sound power level of heat pumps, based either on a "maximum" sound power level and/or on sound power level measured at different part load conditions.

The RRT4 is to be performed on an exhaust air heat pump water heater (HPWH) provided by De Dietrich (France).

This document is describing the test protocol applicable to RRT4. As the standard for the sound power level measurement of HPWH is still a draft standard, the main objective of RRT4 is to experiment the correct understanding of the standard and the reproducibility of the proposed test method.

2. STANDARDS AND TEST METHODS

The reference document for testing is pr EN 12102-2 (doc. N XX) which describes:

- The test installation according to the type of HPWH

- The sound power levels to be measured according to the type of HPWH
- The test method
- The acoustic measurement techniques that can be used.

The manufacturer will provide all necessary information for installation of the unit and all settings for conducting the tests.

The standard allows different generic acoustic test methods.
If the test lab has the possibility (test facilities / time / budget) to perform the same tests using different acoustic measurement methods, it will allow evaluating the equivalence of the different techniques.

With each set of performance data, the test lab. shall clearly state which acoustic measurement technique(s)/standard(s) was(were) used.

3. TEST CONDITIONS

Only one single test is performed at the test conditions defined in the standard prEN 12102-2 (Doc. N XX).

4. ACOUSTIC MEASUREMENTS

One part of the test is the assessment of the sound power level measurements at the three temperatures as described in the new draft prEN 12102-2.

If possible, a measurement shall be done with a continuous measurement on 30 seconds step during a complete heating, with a starting water temperature in the tank at xx °C.

5. TEST RESULTS

For each test, the test laboratory shall a test report including the following general information :

- The outdoor air temperatures dry bulb (wet bulb)
- The inlet/outlet water temperatures
- The water flowrate
- The pressure drop/external static pressure
- The measured power input
- The effective power input

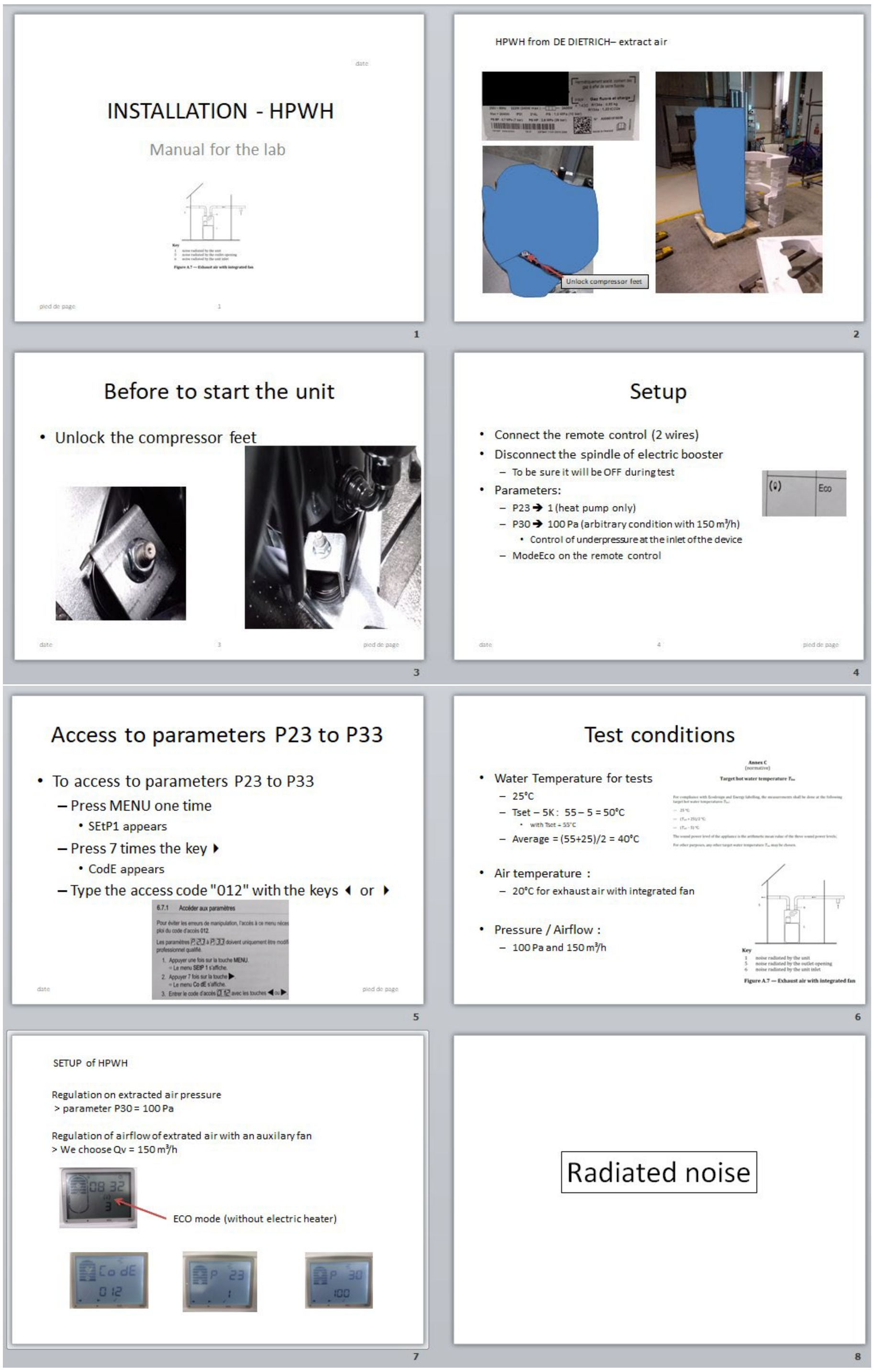
- The measured capacity
- The sound power level spectrum in one-third octave bands (dB) and overall dB(A)
- All individual measurement uncertainties
- Uncertainty on measured capacity
- Uncertainty on measured on sound power level

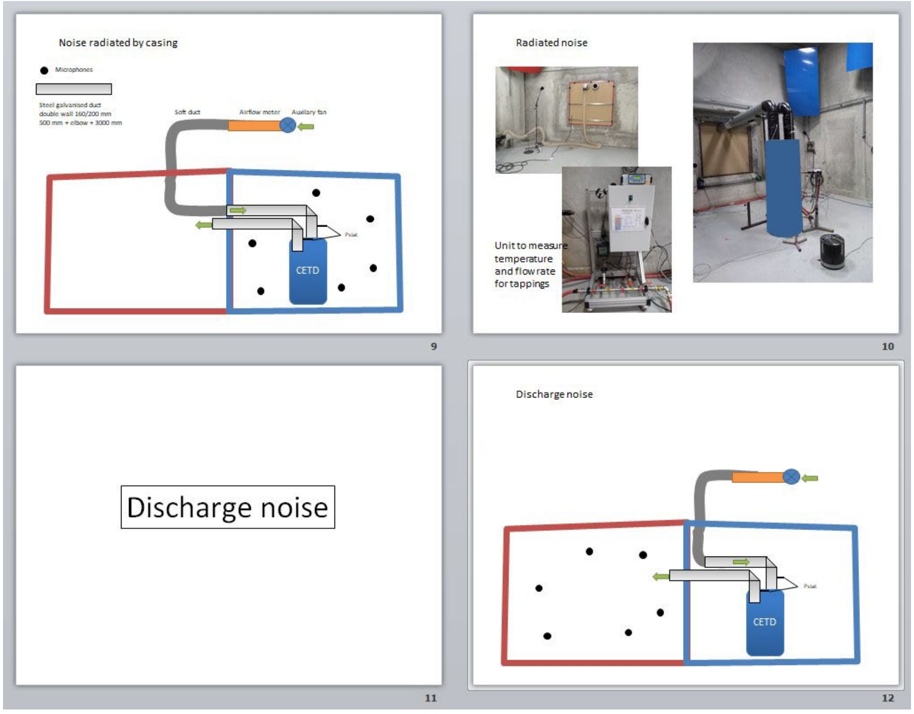
In addition for each test, all data during the acoustic measurement acquisition period shall be reported at the time period (10, 15 or 30 s) in Excel files for allowing further data treatment and analysis.

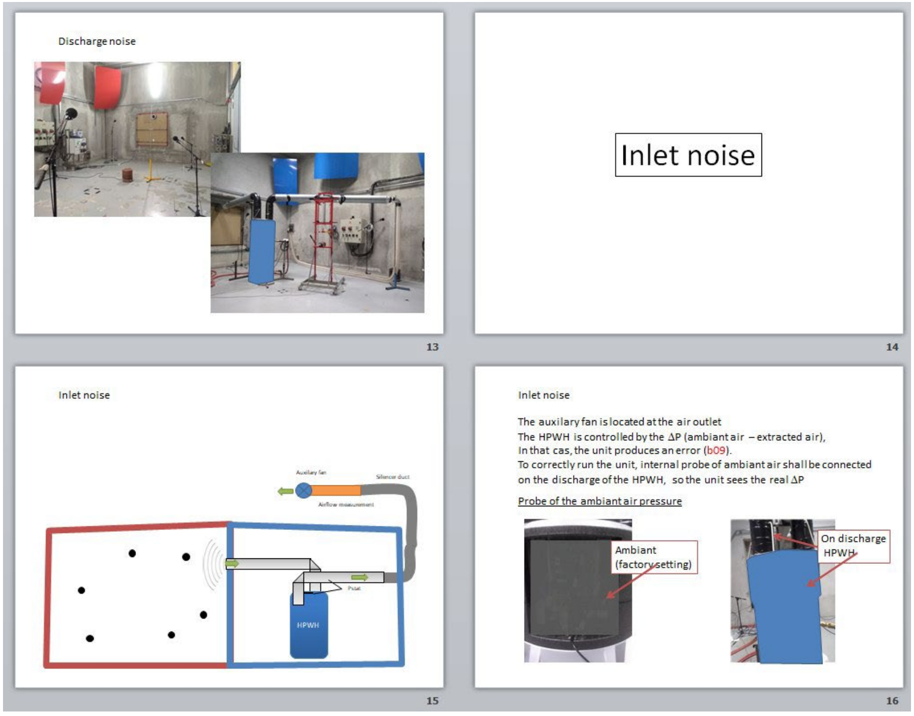
Photos of installation are also required, showing the installation and the acoustic means.

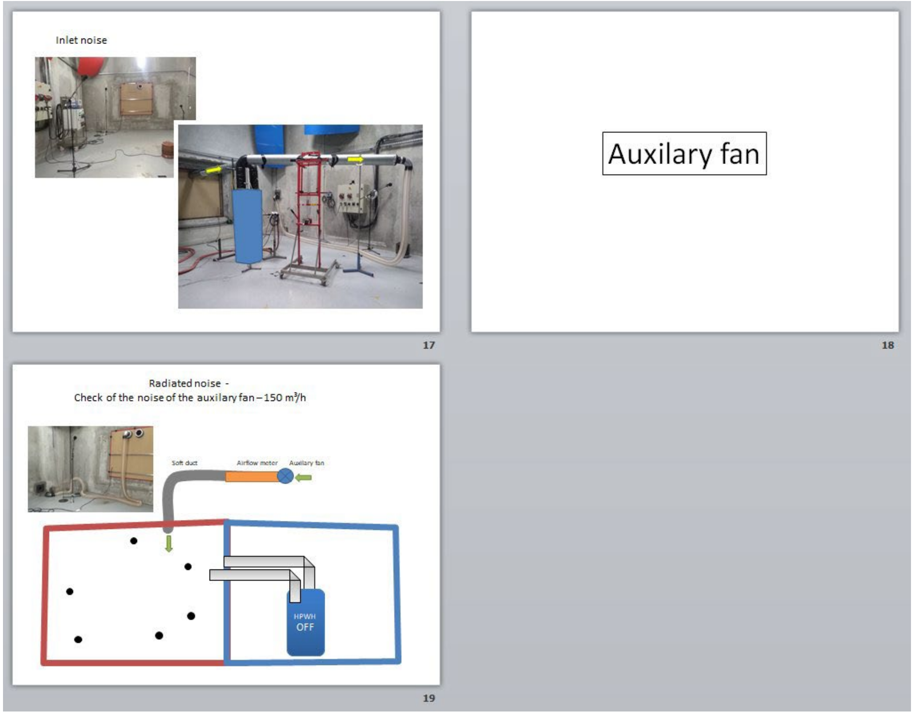
The methodology of sound power level uncertainty assessment shall be shortly described.

Practical protocol to run the HPWH unit




Noise radiated by casing
Microphones
Steel galvanised duct
double wall 160/200 mm
500 mm + elbow + 3000 mm
Soft duct
Airflow meter
Auxilary fan
Pstat
CETD
9
Radiated noise
Unit to measure temperature and flow rate for tappings
10
Discharge noise
11
Discharge noise
Pstat
CETD
12


Discharge noise
13
Inlet noise
14
Inlet noise
Auxiliary fan
Silencer duct
Airflow measurement
Pstat
HPWH
15
Inlet noise
The auxilary fan is located at the air outlet
The HPWH is controlled by the ΔP (ambiant air – extracted air),
In that cas, the unit produces an error (b09).
To correctly run the unit, internal probe of ambiant air shall be connected on the discharge of the HPWH, so the unit sees the real ΔP
Probe of the ambiant air pressure
Ambiant (factory setting)
On discharge HPWH
16


Inlet noise
17
Auxilary fan
18
Radiated noise -
Check of the noise of the auxilary fan – 150 m³/h
Soft duct
Airflow meter
Auxilary fan
HPWH
OFF
19

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