Study Of The Effects Of The Casing Of A Heat Pump On Its Thermal Capacity And Emitted Noise

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ABSTRACT

The purpose is to measure the sound attenuation performed by an insulating casing in which the outside unit of a single house air to water heat pump is put. The casing is composed of three volumes joined up together: the central volume contains the heat pump, the other two allow each by an opening, one the air inlet and the other one the air outlet. The casing is made of a bad weather-proof mix of wood and cement. The inside of the casing is covered with mineral wool. Without the casing, the air to water heat pump provides a 7.1 kW cooling capacity and a 68.9 dB(A) sound power at 35°C outdoors. The casing is designed for an inside air speed less than 1 m/s in order to strongly minimize the pressure loss and to help its sound attenuation skill. Laboratory measurements show that in both heating and cooling modes, thermal capacity and COP of the heat pump once put in the casing are not changed. The global attenuation due to the casing on the heat pump sound power is 33 dB(A). On the air inlet side, the attenuation is 40 dB(A). On the outlet air side, the attenuation is 34 dB(A). The interest is to achieve such an attenuation with a casing which does not use any specific sound reducing component.

INTRODUCTION

The main part of an air to water heat pump intended for the heating and the air conditioning of a single house is its outside unit. This one can generate unpleasant noises for the user and his neighbourhoods. The purpose of this work is the design and the experimental study of an insulating casing in which the unit is put. The casing is designed in order to achieve a strong sound insulation and no effect on the unit thermal performances. No specific sound reducing component is used.

TESTED EQUIPMENT

Heat pump features:

The outside unit used for the casing tests is one of a reversible air to water heat pump. Its main features are:
- Dimensions: height = 1050 mm, length = 1306 mm, width = 485 mm;
- Refrigerant: R22;
- Fan air flow: 2800 m³/h at a working pressure of 0 Pa, 2250 m³/h at a working pressure of 15 Pa;
- Standardized thermal performances given by the manufacturer:

<table>
<thead>
<tr>
<th>Operating temperatures</th>
<th>Cooling mode</th>
<th>Heating mode</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inlet air: 35 °C</td>
<td>Inlet air: 7 °C dry bulb; 6 °C wet bulb</td>
<td></td>
</tr>
<tr>
<td>Inlet water: 12 °C</td>
<td>Inlet water: 40 °C</td>
<td></td>
</tr>
<tr>
<td>Outlet water: 7 °C</td>
<td>Outlet water: 45 °C</td>
<td></td>
</tr>
</tbody>
</table>

Capacity 7.10 kW 9.08 kW

EER/COP 2.37 2.96

Table 1: standardised thermal performances of the heat pump

Casing design:

The casing is composed of three volumes joined up together. The biggest one, called the central volume, contains the outside unit of the heat pump. The inlet volume, located on the top of the central volume, has two rectangular openings: one of them is intended to supply the air from outdoor and the other is linked to the central volume. The third part, called the outlet volume, located beside the central volume, has two openings: one of them is circular and connected on the outlet side fan of the unit put in the central volume. The other opening is rectangular and intended to discharge the air towards outdoor.

Based on a unit air flow at 2250 m³/h, the casing is designed in order to limit the inside air speed to 1 m/s. The purpose is to strongly minimize the pressure losses and thus to avoid the downgrade of the air flow unit. Another goal is to help the sound attenuation.

The material of the casing boards is a mix of wood and cement frequently employed by the building trade. It is a strong, dense (1350 kg/m³), rot proof, heat resistant, and bad weather-proof material which contains no unhealthy component. The thickness of the casing boards is 22 mm. Inside the casing, all the boards are covered with 100 mm of mineral wool in order to increase the sound absorption.

The tightness between each board and between the boards and the floor is achieved by adhesive air seals. The link between the unit and the outlet volume is also airtight. Its tightness is achieved by a short flexible conduct and two branches covered with foam air seals.

The backside of the central volume is easy to open in order to access to the unit.

This casing can be used in two real configurations. In the first configuration, the unit is installed in the garden so that the whole casing is outside the house. In the second configuration, the unit is installed inside the house, near a wall, in a storeroom or a garage for example ; in that case, the fan unit blows the air through the wall towards the outlet volume which is outside the house, the central and inlet volumes are inside the house ; in this configuration, a rectangular opening has to be designed in the wall for the inlet volume air supplying.

Figures 1 to 3 show different views of the casing and its dimensions.
Figure 1: casing plan (side view)

Figure 2: casing plan (top view)

Figure 3: casing plan (3D view)
**EXPERIMENTAL SET UP**

Climatic test chamber:

The casing is tested in a double climatic chamber divided by a wall which affords a large opening. For the building of the experimental casing, this opening is closed by a cement-wood double board filled up with mineral wool. The central and inlet volumes are located on one side of the wall (hereafter *indoor side*) of the climatic chamber and the outlet volume is located on the other side (hereafter *outdoor side*). Therefore, this test bench represents the real configuration whereby the unit is installed outside the house.

Main experimental steps:

1. **Measurements of the thermal and acoustic performances of the unit without the casing:**

   A cooling test and an heating test are carried out. The sound power of the unit is measured during the cooling operation. This sound test is performed by the intensity measurement method. For each thermal test, the fan revolutions are also measured.

2. **Measurements of the thermal performances of the unit installed in the casing:**

   The purpose is to compare the thermal performances of the unit installed in the casing to the performances measured without the casing. The fan revolutions are also compared to the previous measurements in order to evaluate the impact of the casing on the air flow. One more heating test is carried out while the inlet and outlet openings of the casing are fitted with grates in order to evaluate their possible impact on the unit working.

3. **Measurements of the sound attenuation due to the casing tested with an high power artificial source of sound:**

   The purpose is to measure the sound attenuation due to the casing. Because the background noise in the laboratory seems to be more important than the noise emitted by the casing containing the unit, the casing sound insulation is tested with an high power artificial source of sound which spectrum features are perfectly well known. The sound test is performed by the intensity measurement method. On the outdoor side, 265 sound measures are carried out all over the casing boards. On the other side, the noise emitted by the boards is too low and cannot be measured by the sensors ; thus, only the noise emitted by the two openings is measured.

4. **Calculation of the noise emitted by the casing containing the unit and calculation of the sound attenuation due to the casing:**

   The sound attenuation spectrum due to the casing and the sound spectrum of the unit allow to calculate the noise emitted by the casing containing the unit. The noise emitted is calculated considering first the outdoor side only, then the indoor side only and finally the two sides simultaneously that is to say the whole casing.

   Figures 4 to 7 show the experimental casing in the laboratory.
Figure 4: indoor side of the opened casing and the artificial source of sound

Figure 5: central volume of the opened casing containing the unit

Figure 6: outdoor side of the casing

Figure 7: indoor side of the closed casing
The main results of the experimental study are shown in the tables 2 and 3, and the figures 8 and 9.

<table>
<thead>
<tr>
<th>Mode</th>
<th>Unit outside/inside the casing</th>
<th>Cooling Outside</th>
<th>Heating Outside</th>
<th>Heating Inside</th>
<th>Heating Inside</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Casing with/without grates</td>
<td>Without</td>
<td>Without</td>
<td>Without</td>
<td>With</td>
</tr>
<tr>
<td>Inlet air temperature °C</td>
<td>35.0</td>
<td>34.9</td>
<td>15.0</td>
<td>15.5</td>
<td>15.4</td>
</tr>
<tr>
<td>Inlet air dew temperature °C</td>
<td>-</td>
<td>-</td>
<td>9.7</td>
<td>9.4</td>
<td>9.9</td>
</tr>
<tr>
<td>Inlet water temperature °C</td>
<td>12.0</td>
<td>12.0</td>
<td>35.0</td>
<td>35.1</td>
<td>35.0</td>
</tr>
<tr>
<td>Outlet water temperature °C</td>
<td>6.9</td>
<td>7.1</td>
<td>40.1</td>
<td>40.1</td>
<td>40.0</td>
</tr>
<tr>
<td>Air flow m³/h</td>
<td>-</td>
<td>2391</td>
<td>-</td>
<td>2283</td>
<td>-</td>
</tr>
<tr>
<td>Water flow kg/s</td>
<td>0.336</td>
<td>0.335</td>
<td>0.497</td>
<td>0.503</td>
<td>0.503</td>
</tr>
<tr>
<td>Fan revolutions min⁻¹</td>
<td>713</td>
<td>716</td>
<td>685</td>
<td>701</td>
<td>701</td>
</tr>
<tr>
<td>Capacity kW</td>
<td>7.1</td>
<td>7.0</td>
<td>10.4</td>
<td>10.6</td>
<td>10.6</td>
</tr>
<tr>
<td>EER/COP</td>
<td>2.2</td>
<td>2.2</td>
<td>3.7</td>
<td>3.8</td>
<td>3.8</td>
</tr>
<tr>
<td>Sound power dB(A)</td>
<td>68.9</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Table 2: results of the thermal and acoustic tests on the unit installed outside and inside the casing

<table>
<thead>
<tr>
<th></th>
<th>Outdoor side (air side)</th>
<th>Indoor side (unit side)</th>
<th>Whole casing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sound power of the casing containing the unit (cooling mode)</td>
<td>29 dB(A)</td>
<td>35 dB(A)</td>
<td>36 dB(A)</td>
</tr>
<tr>
<td>Global sound attenuation on the unit due to the casing</td>
<td>40 dB(A)</td>
<td>34 dB(A)</td>
<td>33 dB(A)</td>
</tr>
</tbody>
</table>

Table 3: calculation of the sound attenuation on the unit due to the casing
Table 2 shows that the casing does not modify the performances of the unit. Indeed, when the unit is inside the casing, its thermal performances and fan revolutions remain the same in both the cooling and heating modes.

The additional heating test shows that the grates on the inlet and outlet openings do not modify the unit working at all. It means that the pressure loss due to possible grates are too low to reduce the air flow considering the fan performance curve.

Figure 9 allows an analysis of the spectrum of the noise emitted by the casing containing the unit. For frequencies under 1000 Hz, the emitted noise is mainly due to the indoor side. Above 1000 Hz, the emitted noise is mainly due to the inlet and outlet openings on the outdoor side. Because of the decreasing slope of the spectrums, the low frequencies, that is to say the noise emitted by the indoor side, are responsible for the global sound power.

The sound attenuation achieved by the casing on the unit is quite high: 33 dB(A) for the whole casing, 40 dB(A) on the outdoor side (air inlet/outlet side) and 34 dB(A) on the indoor side (unit side).

CONCLUSION

A casing properly designed can strongly reduce the noise emitted by the outside unit of a low power heat pump intended for the heating and the cooling of a single house. This casing does not use any specific sound reducing component. It is made of materials and equipment available in ordinary do-it-yourself stores. It does not modify the thermal performances of the heat pump. It can be built completely outside the house if the unit is installed in the garden. Another solution is to install the unit inside the house, against a wall, in the storeroom or the garage, and to build the casing on both sides of the wall.

The main factors responsible for the strong sound attenuation are:
- the increasing air path thanks to the three volumes of the casing,
- an air speed limited to 1 m/s inside the casing,
- a dense material used for the casing boards,
- the covering of the internal side of the casing boards with mineral wool.

Yet it remains to test the casing used for a long time in a real case. The main risk is the decomposition of the mineral wool into fibres which can slowly clog up the fan and the exchanger of the unit. An internal adapted coating may solve this problem but it would certainly slightly modify the sound attenuation skill.

ACKNOWLEDGMENTS

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