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Laboratory Test of New Non-Intrusive Heater-Accumulator Design for Frost-less Heat Pump

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Engineering Science and Technology Division

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Abstract

The frost-less heat pump has the potential to improve thermal comfort with less energy consumption due to the energy efficiency provided by an improved defrosting scheme in which heat is added directly to the accumulator. In previous studies, heat addition was accomplished through use of a modified accumulator. In this study, a new frost-less design concept was evaluated. This new design does not require the costly re-design of the current accumulators in a typical heat pump unit which would make the frost-less retrofitting much easier and more cost effective. Results showed the ability to retard the frost accumulation on the outdoor coil. Past experience has shown that the majority of the heat added to the accumulator would be delivered to the indoors in the form of higher supply air temperature due to the higher suction pressure providing improved thermal comfort.

1. Introduction

The frost-less heat pump is an idea that would not only improve indoor thermal comfort, but also conserve energy because of the energy efficient defrosting scheme. These effects were proven with laboratory tests and field tests (Ref. 1 and 2). These tests showed that when the heater at the bottom of the accumulator was working, the system performed as expected. However, the heaters burned out frequently because moisture seeped toward them and then froze, which broke the thin mica heaters. Also, because a special flat-bottom accumulator was needed for the mica heater, the cost for retrofit would be high. In addition, the heat pump manufacturers were reluctant to make any changes to their design of the accumulator. Based on the above considerations, a new concept was needed. This was achieved with a non-intrusive accumulator-heater design described in the following section.

2. New Non-Intrusive Accumulator-Heater Design

Figures 1 and 2 show the new non-intrusive accumulator-heater design. The advantages of the new concept are the following:

- It is not necessary to change the heat pump manufacturing process.
- The frost-less feature is an add-on part. Accumulator change is no longer required.
- The heater is rugged and can handle moisture freezing and frequent on/off operation.
- It is much easier to replace the heater in case it burns out.
- Retrofitting the heat pumps will be much easier than with the old design.

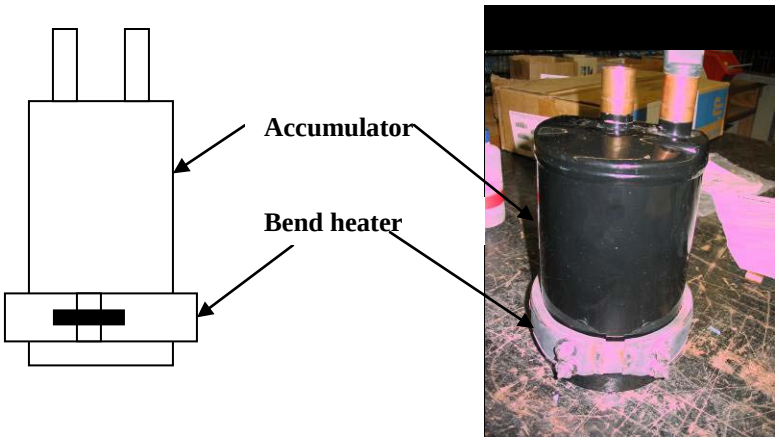

Fig. 1. New non-intrusive accumulator-heater design.

Fig. 2. Accumulator heater installed inside the heat pump.

3. Laboratory Test of Newly Designed Frost-less Heat Pump

The tests were performed on a 2-ton split heat pump with the outdoor coil equipped with an orifice plate expansion valve. The laboratory test of the frost-less heat pump with the new design was divided into three steps, with the ASHRAE's frost-accumulation test outdoor conditions of 35°F Dry Bulb (DB) and 33°F Web Bulb (WB) temperatures (ANSI/ARI 1998):

A. Baseline test at 90-minute defrosting schedule,
B. unit tests with the accumulator heater on, and
C. coil defrost test with only the accumulator heater on and the indoor fan off.

Step A was to establish the heat pump baseline performance, and Step B was to study whether the heat pump frost accumulation was delayed with the accumulator heater on, and Step C was to study the effectiveness of the defrost scheme with the accumulator heater only.

4. Test Results and Discussion

4A. Baseline Test

Figures 3a to 3j show the baseline frost accumulation test. The pictures were taken every 10 minutes, with Fig. 3a at 0 minutes (heat pump had just started operating):

Fig. 3a. 0 minutes.

Fig. 3b. 10 minutes.

Fig. 3c. 20 minutes.

Fig. 3d. 30 minutes.

Fig 3e. 40 minutes.

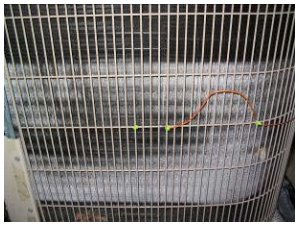

Fig. 3f. 50 minutes.

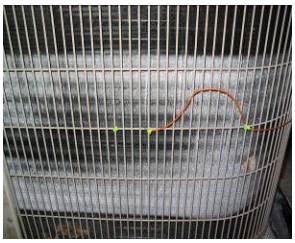

Fig. 3g. 60 minutes.

Fig. 3h. 70 minutes.

Fig. 3i. 80 minutes.

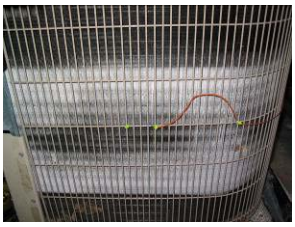

Fig. 3j. 90 minutes.

The photos clearly show gradual frost accumulation over 90 minutes of continuous heat pump operation.

4B. Heat Pump Operation Test With Accumulator Heater On

Figures 4a to 4i show the delay in frost accumulation with accumulator heater energized during the heat pump operation. These pictures were again taken every 10 minutes. The 0 minute was not recorded as it would be the same as Fig. 3a (no frost on the coil).

Fig. 4a. 10 minutes.

Fig. 4b. 20 minutes.

Fig. 4c. 30 minutes.

Fig. 4d. 40 minutes.

Fig. 4e. 50 minutes.

Fig. 4f. 60 minutes.

Fig. 4g. 70 minutes.

Fig. 4h. 80 minutes.

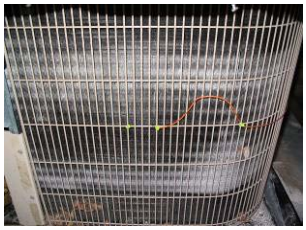

Fig. 4i. 90 minutes.

By comparing Figures 3 and 4, it became clear that much less frost was accumulated when the accumulator heater was energized. It should be noted that the test was performed at the ASHRAE frost-accumulation test condition, where the frost was most likely to form on the coil. Away from the test point, the frost accumulation would be less. These tests proved that the frost-less heat pump would reduce the frost accumulation on the coil.

4C. Defrosting Test With the Accumulator Heater Only

In the new defrosting scheme, the heater around the accumulator was energized and both the indoor and outdoor fans were turned off during defrosting. However, the four-way valve reamained switched to cooling mode. Liquid refrigerant flowed through the indoor expansion device, and two-phase refrigerant flowed through the indoor coil (without

evaporation) to the accumulator. The accumulator, because of the heater, acted as the evaporator.

The tests were performed at the ASHRAE frost accumulation test condition with outdoor conditions at 35°F DB and 33°F WB. The heat pump was operated continuously for over two hours, until a solid layer of ice was formed on the coil as shown in Fig. 5a. Typically the frost would not be so thick under normal heat pump heating operation. If we compare Figs. 3j and 5a, it is clear that Fig. 5a has much more solid frost on the outdoor coil than Fig. 3j. Pictures were taken every minute for the first 10 minutes, and then every 2 minutes for the rest of the defrost cycle. After 12 minutes, the coil was almost frost free, with only a trace remaining on the coil. Again, the frost accumulated on the coil for this test was much heavier than it would be for normal operation. While a normal defrosting cycle would last 6 to 10 minutes, depending on the amount of frost accumulated on the coil, the new scheme should be compatible with the conventional scheme. The pictures proved that the new scheme worked very well.

Fig. 5a. Defrost started .

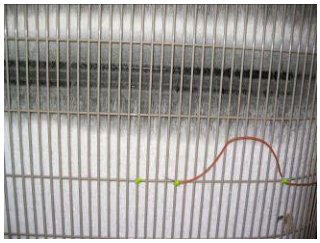

Fig. 5b. 1 minute.

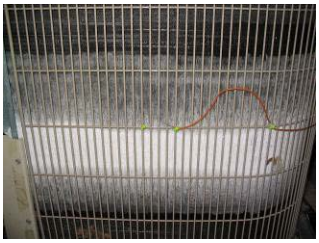

Fig. 5c. 2 minutes.

Fig. 5d. 3 minutes.

Fig. 5e. 4 minutes.

Fig. 5f. 5 minutes.

Fig. 5g. 6 minutes.

Fig. 5h. 7 minutes.

Fig. 5i. 8 minutes.

Fig. 5j. 9 minutes.

Fig. 5k. 10 minutes.

Fig. 5m. 12 minutes.

5. Conclusions

The new frost-less design is more rugged and easier to install, and most importantly, it does not require a change to the specially made accumulator as did the old design. The new design retards the frost accumulation on the outdoor coil, as shown in Figs. 4a to 4i. Past experience indicates that the majority of the heat added to the accumulator is delivered to the indoors in the form of higher supply air temperature due to the higher suction pressure. Also, the new design was able to provide sufficient heat for defrosting, as shown in Figs. 5a to 5m. The new design is more cost effective and easier to maintain and makes the frost-less retrofitting easier and more cost effective.

6. References

1. Mei, V.C., et al., "A Frost-Less Heat Pump", ASHRAE Transactions 2002, Vol. 108, Pt. 1, AC-02-5-2.
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