Heat pumps in buildings with low energy demand - comparisons with a current test standard

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How does a traditional heat pump system operate in a house with a low heating demand? In what way does a smart grid connection affect the heat pump? Will the operational parameters differ from those that heat pumps of today are optimized for? And how? These questions are relevant as nearly zero energy buildings (nZEBs) soon will be standard for new-built throughout Europe due to the Energy performance of buildings directive. The results from this recent research indicate that the standard for testing of heat pumps should be revised.

Introduction

In a few years' time, in 2021, all new buildings in Europe are supposed to be nearly zero energy buildings (nZEB). The low energy demand in these houses give rise to other usage profiles for space heating and domestic hot water (DHW) than the profile encountered in more traditional houses. This, in turn, might lead to a need for adjustment of heat pump optimization. It might also give opportunities for new designs of the entire heating and ventilation systems.

Two different systems including heat pumps have been tested and evaluated in two new-built one-family nZEBs, in order to find out how to design and optimize systems for the future. This has been done under the HPT TCP Annex 49 by RISE, Research Institutes of Sweden. The research is a continuation of the work carried out under Annex 40. The national project is financed by the Swedish Energy Agency via the research program Effsys Expand and by the project partners Danfoss Heat Pumps AB, Bosch Thermoteknik AB, NIBE AB, Skanska, and TMF.

Setup, results, and discussion

The two houses (See Figures 1a and 1b) can be described as sister villas, as they share many important characteristics:

- Final energy use around 20 kWh/(m^2 · yr)
- Balanced ventilation with heat recovery
- Ground source heat pump
- Sensors for climate, heating etc.
- Further, they are the same size and both have photo-voltaic power generation.

But they also differ in some aspects. The residents in house A belong to a fictive family, where activities are modelled on expected behaviour for a family. In house B there is an actual family living. More importantly, in house A a 4.5 kW on-off heat pump is installed, and is connected to an accumulation tank. In house B, the 6 kW heat pump operates at variable speed leading to variable capacity in the system, due to existing preconditions. Also, house A only has a floor heating system, whereas house B has both floor heating and radiators. Thus, there is information on real-life operating parameters for both heat pump types, possibly for both medium- and low-temperature systems.

The setup of the project will make it possible for the researchers to gain increased knowledge on heating demand and heat pump operation in real-life nZEB buildings. It is also possible to compare some of the

Figure 1. House A (to the left) and House B (to the right).

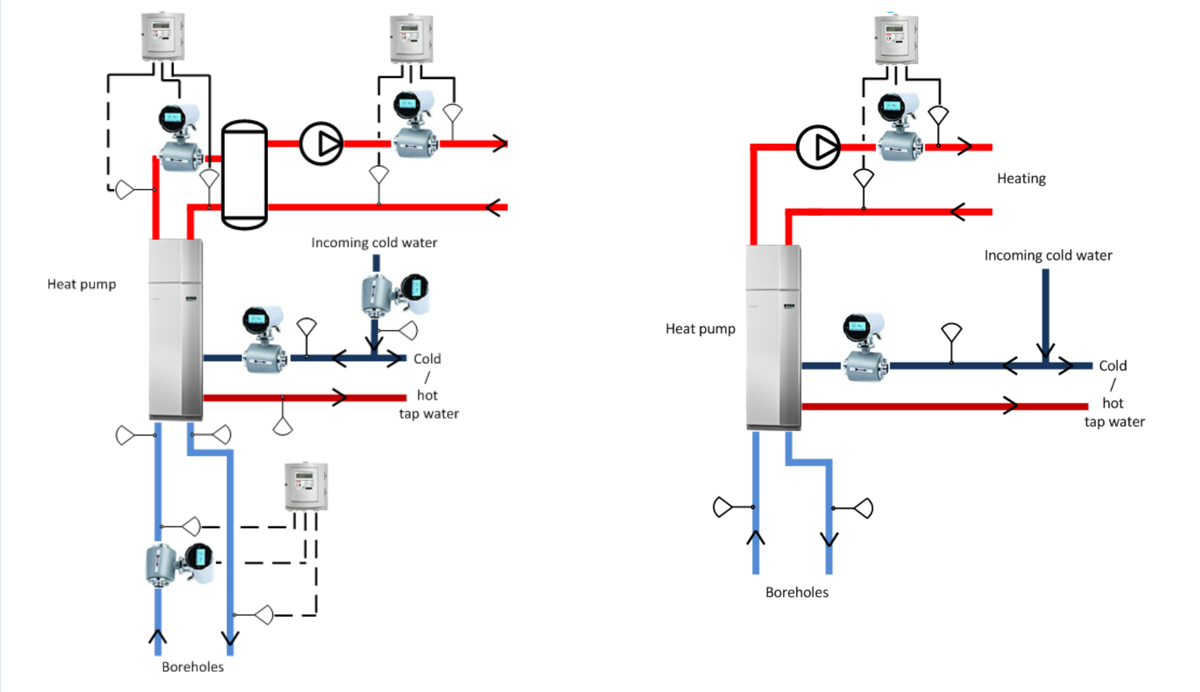

Figure 2. Schematics of the measurement equipment in the two heating systems. To the left, the system in house A with an on/off heat pump and an extra storage tank is shown. On the right, the system in house B with the inverter controlled heat pump is shown.

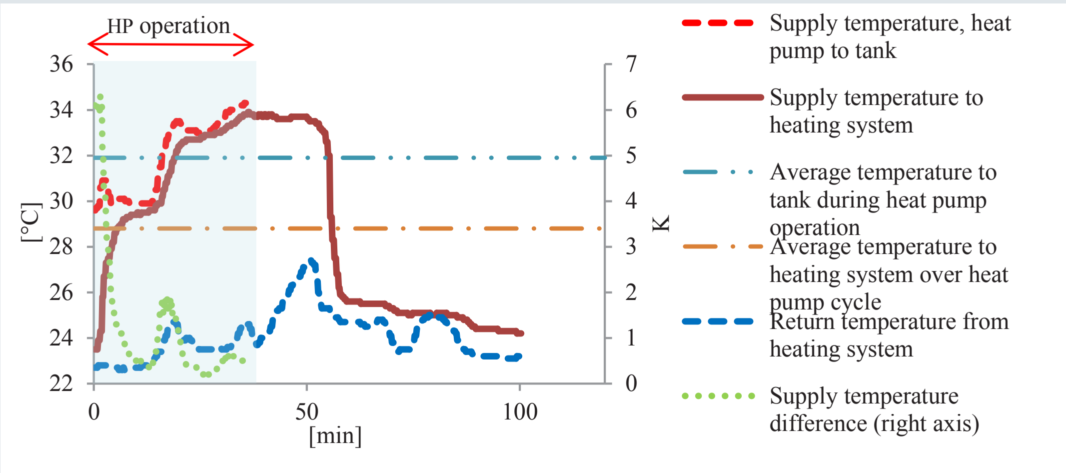

Figure 3. Supply (and return) temperatures to the tank and to the heating system during an on-off cycle in villa A during a period with an outdoor temperature of 2 °C.

results with the parameters for testing heat pumps, as determined in the standard EN14825, which is the standard that the Eco-design and Energy label regulations for heat pumps refer to.

As can be seen in Figure 2, in house A, an accumulation tank is introduced into the system to increase the cycle time of the heat pump, and it is investigated how the operating parameters are affected. This is also relevant for testing the behaviour of the heat pump for future smart grid integration. Results show that the on/off heat pump on average operates with at 1.0-1.5 K higher condensation temperature due to the extra storage tank. In addition, there is an efficiency loss due to the fact that the heat pump is operating on/off, not continuously. Both the on/off control and the tank result in a temperature increase of more than 3 K, representing an efficiency loss of around 8 %.

The brine temperature is also of great importance for the efficiency of the heat pump. In EN 14825 heat pumps are tested at an inlet temperature of 0 °C and, as can

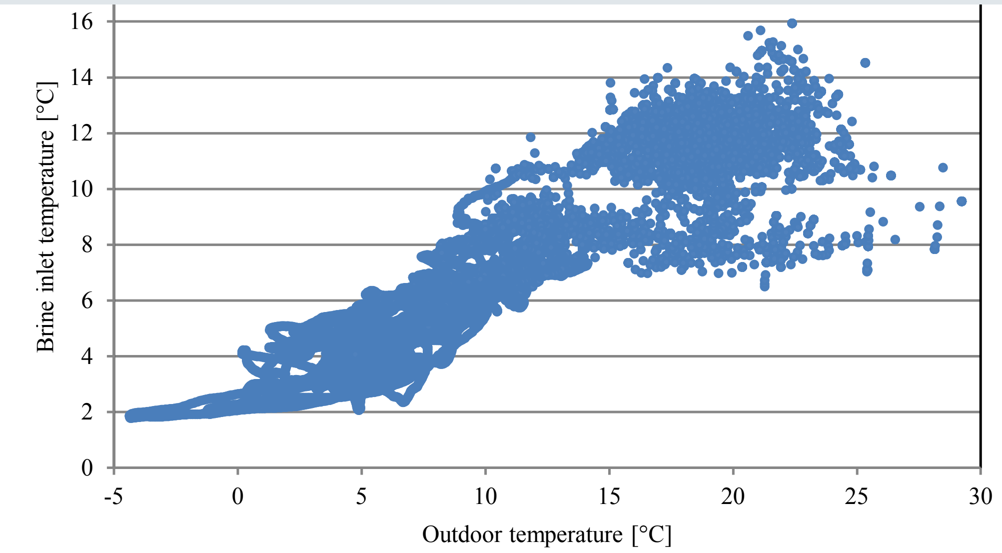

Figure 4. Brine inlet temperatures during on-periods of the operation cycle in villa B as a function of daily averaged outdoor temperature. Data from March 2016 to February 2017.

be seen in Figure 4, such a low temperature was never measured during the whole year. These results suggest that the standard should be revised.

The results indicate that, for nZEB houses, the heating curves of the standard EN14825 coincide well with the measurements except for occasions with low heating demand in House B. The reason is probably that the heat pump system has a variable liquid flow operation and the heating curve of the standard assumes constant liquid flow.

Another finding from the project relates to the control of the heating system. In both houses, the floor heating system is separate in the sense that it has its own thermostats. There is a lack of communication between that system and the heat pump system, causing some problems with temperature regulation. Hence, the efficiency of the heating system is not as good as it could have been with a better control strategy.

In the future part of the project the researchers will investigate how the heat pump should be optimized in an nZEB concerning space heating versus DHW production. Since the heating demand is so low, the ratio between heating and DHW differs from that of an older house. In order to obtain an ideally performing heat pump, this ratio needs to be investigated. Finally, the research team will look into how the operating parameters are affected if the heat pump system is integrated with a ventilation and heat recovery system, and how such integration could be done.

Conclusions

This project has made it possible to relate the preconditions stated for testing heat pumps in the EN14825 standard with real-life conditions. The actual brine temperature to the system is higher than the temperatures stated in the standard. Since the testing temperatures are crucial in determining the SCOP for a heat pump, these results suggest that the standard should be revised. It is important to notice, though, that further real-life testing is needed in order to draw a final conclusion.

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