HSLU Hochschule Luzern

Technik & Architektur
Competence Center Thermal Energy Systems and Process Engineering
Research Group Energy Integration and Optimization

Master's Thesis – Master of Science in Engineering, Energy and Environment

Optimization of a Low-Lift Propane Heat Pump

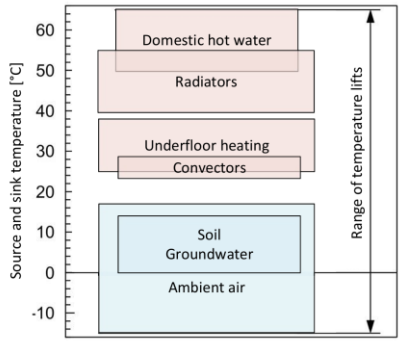

Figure 1: Heat sources and sinks with their Temperatures.

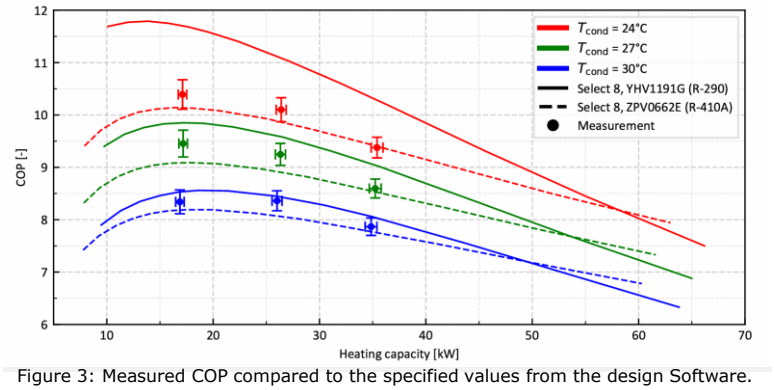

Figure 3: Measured COP compared to the specified values from the design Software.

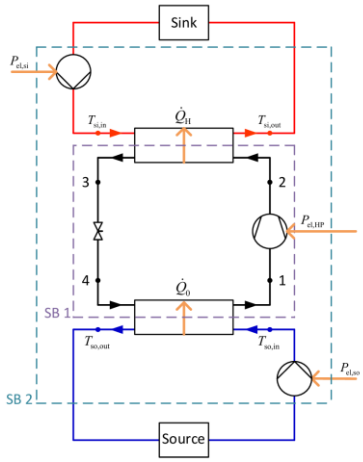

Figure 2: Simplified process flow diagram of the HP system consisting of HP, source and sink pumps.

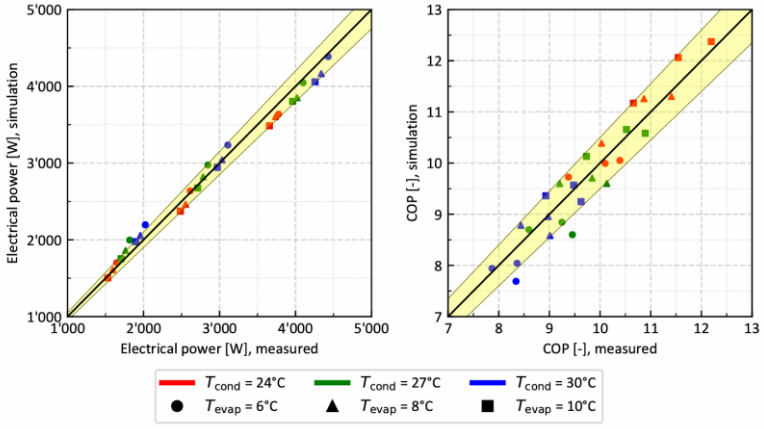

Figure 4: Results of the simulation regarding the electrical power and COP compared with the measured values. The yellow area marks a deviation of +/- 5%.

Background and Motivation

To achieve the target of net-zero greenhouse gas emissions by 2050, the decarbonization of heating systems and improvements in energy efficiency are required. Today efficient heating is done with low-lift heat pump (HP) systems in combination with efficient building heating concepts. A low outer temperature lift (temperature difference between the source and sink) of 15 to 20 K can be achieved, choosing the soil/ groundwater as a source in combination with modern low-temperature air conditioning units as a heating system. To fully exploit the potential of the low outer temperature lift, systems that are specifically designed for this operating regime are required, i.e., low-lift HPs.
In the context of the ongoing phase-down of fluorinated greenhouse gases, natural refrigerants such as R-290 (propane) are considered the most viable long-term solution.
Therefore, efficient low-lift HPs with natural refrigerants are needed to be developed.

Task and Procedure

This work aims to support the development of a low-lift propane HP and to optimize the overall system and its operation conditions. As part of the results, concrete proposals for the construction and operation of efficient low-lift HP systems are presented. A prototype of a low-lift propane HP is installed in the laboratory. Measurements are carried out to determine the efficiency and operating characteristics of the HP. Furthermore, a simulation model of the prototype is built in Modelica with the Thermodynamic Interaction Library (TIL). The simulation model is validated against measurement data. Based on the measurements and the simulations, recommendations for the design and the operation of such systems are derived.

Results and Recommendations

The measurement showed, that the design of the prototype cannot fully exploit the potential of the low outer temperature lift. The design of the heat exchangers have to be optimized, that the temperature approach in the evaporator and condenser between the refrigerant and the source and sink is smaller. The efficiency of the R-290 compressor is similar to the current used compressor, but up to 14% lower as specified by the design software.
A new design for the condenser and a two-stage evaporation concept is recommended. Since the optimal operation point is highly influenced by the design of the HP, these optimizations need first to be implemented, before the optimal operation point can be investigated.

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