Steam-producing pentane-based heat pump in megawatt scale



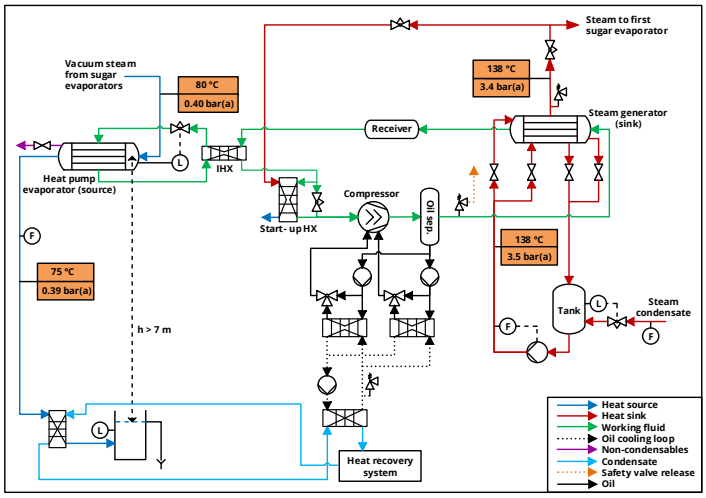


Figure 1: The compressor machine room (left) and process flow diagram of the heat pump system (right).

Summary of demonstration case

This demonstration case is one of the three demonstration cases in the SPIRIT project founded under the Horizon Europe framework. The aim of the case is to generate steam at temperatures up to 140 °C, utilizing a heat source consisting of 75 °C vacuum steam, and using pentane as refrigerant. The expected heat output is 4 MW.

The high-temperature heat pump is developed by GEA, and is integrated into an energy intensive sugar refining process, in which the sugar from the sugar beets is dissolved in water, after which the water is evaporated in several evaporator steps in order to end up with solid sugar crystals as the end product. The sugar factory is operated by Tiense Suiker, and is located in Tienen, Belgium. The heat pump will provide up to 6 % of the total heat demand for steam in the sugar factory.

The heat pump is based on a single screw compressor with a double shaft seal. It is driven by a 1.4 MW electrical motor with a frequency drive. It uses an internal heat exchanger to provide superheating of the suction gas, which is especially important when using pentane. Another heat exchanger is also included which during start-up shortly creates the possibility of also superheating the suction gas with heat from the steam system. The heat from the oil cooling is recovered with an intermediate water circuit. See figure 1 (right) for an overall process diagram of the heat pump.

The evaporator and condenser are large shell-and-tube heat exchangers in stainless steel, which creates the possibility for the operator to be able to clean the steam side of the exchangers, if necessary, which was a requirement in this case. In other applications the GEA heat pumps can be made with alternative heat exchanger types.

Operating experiences

The sugar is produced during two main production campaigns. The beet campaign from September to January and thick juice campaign from March to May. As a part of the commissioning, the first operation in part load with the heat pump was carried out at the end of the thick juice campaign in 2025.

After the first experience with testing the heat pump, the time towards the production campaign in the fall 2025 has been utilized for making several improvements and investigations, such as making oil analyses, re-installing a repaired bypass valve in the discharge line, installing a motorized valve in the oil rectifier line, and adding more trace heating to selected places. On the steam side of the

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Figure 2: Heat pump building.

system the number of plates in the heat exchanger for the water side of the oil cooling loop has been increased, and preventative measures has been taken to avoid air or condensed water being trapped in the vacuum steam line for the heat source of the heat pump.

After the modifications has been done the compressor has been able to run at 100 % capacity, and pinch temperatures down to 2 K has been seen in the evaporator and condenser.

Special learnings

Throughout the project there has been a high focus on safe design, and hence safe operation of the heat pump. Several Atex aspects have been handled which for instance includes the installation of several gas detection sensors, advanced ventilation system, and an anti-static floor in the machine room.

FACTS ABOUT THE CASE

Installation year: 2025
Operating hours: In commissioning phase
Working fluid used: R-601 (n-Pentane)
Compressor technology: Screw
System manufacturer: GEA Heating & Refrigeration Technologies, Germany
Sector: Food (sugar production)
Performance:

- **Heat source:** 75 °C vacuum steam (condensation)
- **Heat sink:** 138 °C steam (evaporation)
- **Heat supply capacity:** Up to 4 MW
- **$COP_{Heating}$:** Pending more testing for validation

Investment cost: n/a
Savings: n/a
Estimated annual CO_2 savings: ~3500 t/a
Links:
https://spirit-heat.eu/demo_sites/sugar-production/
https://www.youtube.com/watch?v=6opq5-K5fRE

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SPIRIT

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