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Case study

High-Temperature Heat Pump for Sugar Production

Pentane heat pump at Tiense Suikerraffinaderij, Tienen, Belgium

Photo credit: GEA

At the Tiense Suikerraffinaderij in Belgium, a 4 MW heat pump from GEA Refrigeration Germany GmbH uses the natural refrigerant pentane to recover waste heat from the sugar production process and generate steam at temperatures of up to around 139 °C. The system reduces the consumption of fossil fuels and is expected to cut CO_2 emissions by around 3,000 to 3,500 tonnes per year. Inaugurated in February 2025, the installation is a full-scale demonstration plant in the EU-funded SPIRIT project.

Key information

Client: Tiense Suikerraffinaderij / Raffinerie Tirlemontoise, part of Südzucker Group, Tienen, Belgium

Supplier: GEA Refrigeration Germany GmbH

Type of facility: Industrial heat recovery and process steam generation in beet sugar production

Refrigerant: n-Pentane (R601)

System start-up: 2025

Requirements

Sugar production is highly energy-intensive. After washing, slicing, diffusion and juice purification, large quantities of water must be evaporated before crystallisation. These process steps require significant amounts of steam and have traditionally relied on fossil-fuel boiler systems. For the Tienen site, the challenge was to make available waste heat useful at a temperature level high enough for industrial steam generation with a high coefficient of performance (COP).

While many industrial heat pumps in the 500 kW to 10 MW range have historically been limited to lower supply temperatures, the sugar process requires substantially higher temperature levels.

Solution

As part of the EU-funded SPIRIT project which demonstrates sustainable heat upgrade technologies for the food and beverage and the pulp and paper industries aimed at decarbonising industrial processes in the food and paper industries, GEA Refrigeration Germany GmbH and Tiense Suikerraffinaderij N.V. jointly realised a full-scale heat pump system. The heat pump system is integrated into the heart of the sugar production process and uses vacuum steam from the evaporation plants as its heat source. The system uses pentane R601 as a refrigerant – a natural hydrocarbon that is particularly suitable for heat pumps operating in the high-temperature range.

The refrigerant absorbs heat from the vacuum steam. A GEA screw compressor then compresses the pentane to a higher temperature level, and a shell-and-tube condenser / steam generator converts condensate into usable process steam – thereby replacing some of the steam that would otherwise be generated from fossil fuels.

Technical concept

Figure 1 shows the layout of the heat pump installation. The numbers 1 to 8 mark the main components of the refrigerant circuit and correspond to the same numbers in the flow diagram in Figure 2:

1 – Screw compressor & electric motor
2 – Oil separator
3 – Steam generator (heat sink): shell-and-tube condenser raising process steam
4 – Internal heat exchanger (IHX)
5 – Level-controlled expansion valve
6 – Heat pump evaporator (heat source)
7 – Oil cooling circuit
8 – Steam condensate tank with feed pump

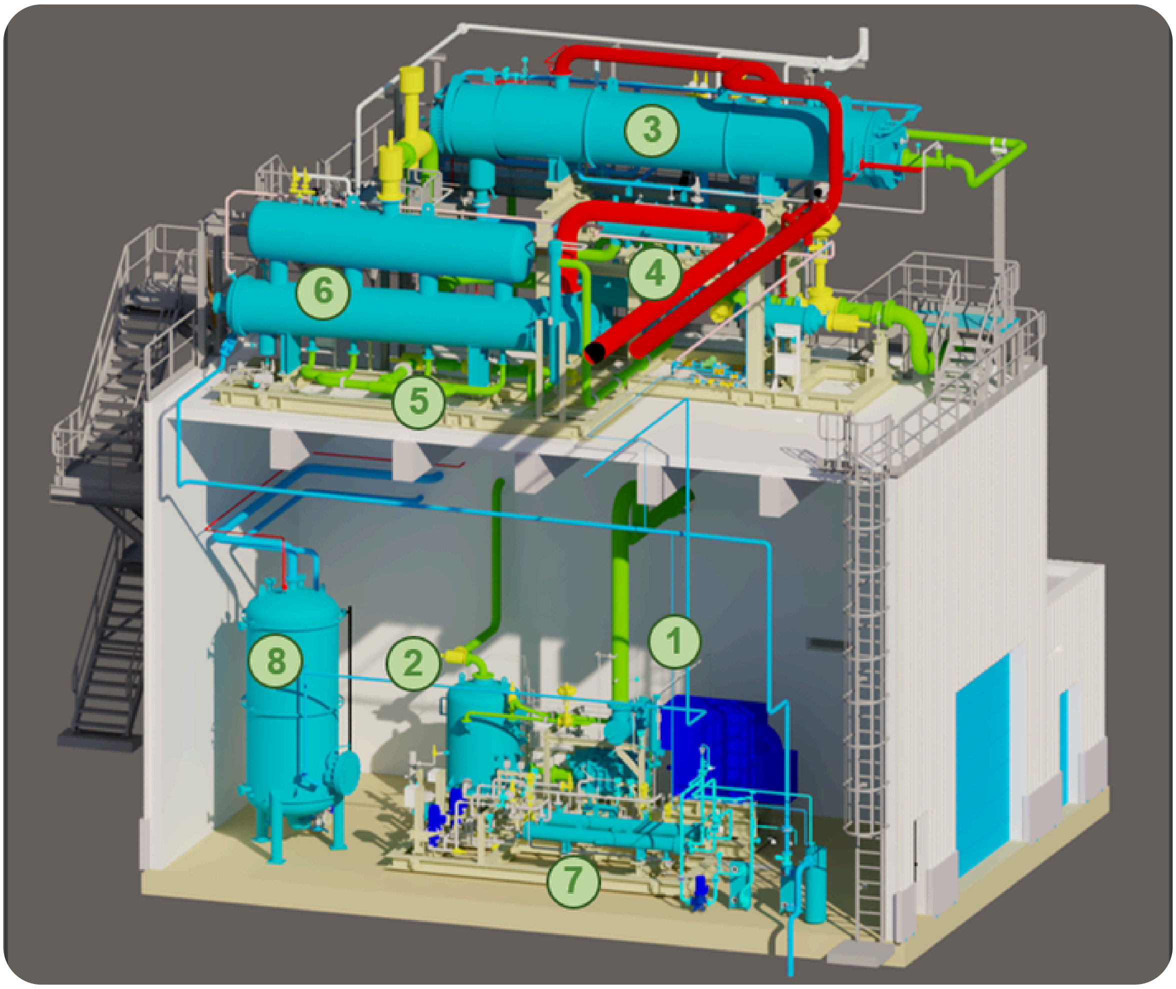

Figure 1: Layout of the heat pump installation at Tiense Suikerraffinaderij, Credit: Tiense Suikerraffinaderij

Figure 2 shows the design of the heat pump system. In addition to the standard components of a refrigerant circuit – expansion valve, evaporator, compressor and condenser – an internal heat exchanger (IHX) is installed. It superheats the suction gas and at the same time sub-cools the pentane condensate.

The heat pump is designed for a heating capacity of approximately 3.5–4 MW. Energy from vacuum steam, which is process waste heat at a temperature of approximately 75–92 °C, is used to upgrade process steam from condensate.

During the main sugar beet campaign, the process steam temperature is around 138–139 °C; during the secondary campaign for thick juice production, the required steam temperature is around 114 °C.

The project also covers long-term operation as well as data logging for process optimisation and performance validation. A digital process simulation supports the optimisation of the systems.

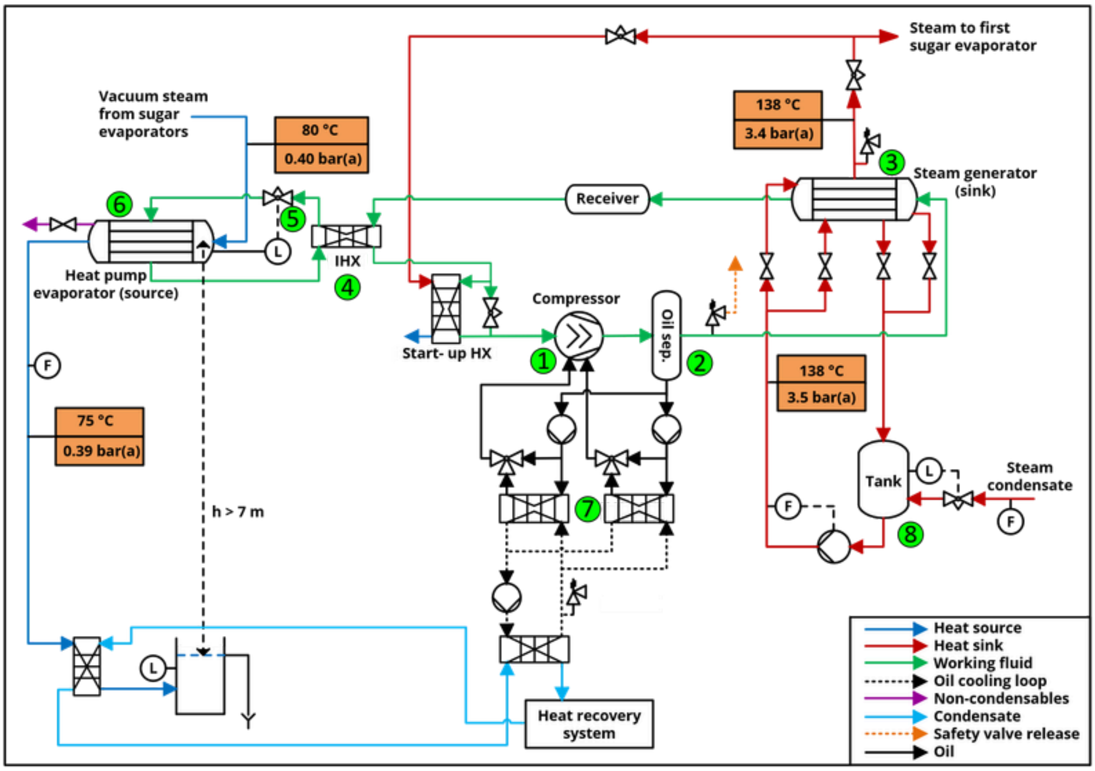

Figure 2: Flow diagram of the heat pump system at Tiense Suikerraffinaderij N.V. Credit: Danish Technological Institute

Key benefits and features

- **CO_2 reduction:** around 3,000 to 3,500 tonnes of CO_2 avoided per year at full seasonal capacity.
- **Fossil fuel replacement:** the heat pump covers around 5 % of the factory's process heat demand and displaces fossil gas in the evaporation stages.
- **High-temperature capability:** process steam at up to around 139 °C, generated from waste heat at 75–92 °C.
- **Natural refrigerant:** n-pentane (R601) is a natural hydrocarbon with zero ozone depletion potential and negligible global warming potential.
- **Proven at scale:** a full-scale 4 MW installation integrated into a running production process.
- **Validated performance:** continuous data logging and digital process simulation for performance validation and optimisation.

Pentane enables high-temperature heat pumps to operate without the use of synthetic refrigerants. For industries with available waste heat and a demand for high-temperature steam, heat pumps using natural refrigerants offer a pathway to electrification, reduced dependence on fossil fuels and a smaller environmental impact. This makes the Tienen installation an important signal for the food and beverage industry as well as for other process industries.

Outlook

The heat pump at Tiense Suikerraffinaderij is part of a wider industrial transition: replacing fossil-fuel-based process heat with electrically driven heat pump technology wherever suitable waste heat sources are available. SPIRIT – Implementation of sustainable heat upgrade technologies for industry – runs until 2027 under the Horizon Europe programme and demonstrates heat upgrade technologies for the food and beverage and the pulp and paper sectors. The long-term goal is to support the potential future full electrification and decarbonisation of production processes. The operational data from Tienen can help to scale up similar high-temperature heat pump applications in the food, paper, chemical and other energy-intensive industries.

Technical data

Heat source: Vacuum steam from the evaporation plant, approx. 70-92 °C; around 72 °C as representative operating point

Heat sink: Process steam up to approx. 138-141 °C during the beet campaign; approx. 114 °C during the secondary thick-juice campaign

Main components:

- Screw compressor & electric motor
- Oil separator
- Steam generator (heat sink): shell-and-tube condenser raising process steam
- Internal heat exchanger (IHX)
- Level-controlled expansion valve
- Heat pump evaporator (heat source)
- Oil cooling circuit
- 8 – Steam condensate tank with feed pump

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