Experimental analysis of heat recovery systems in reverse Brayton cycle configuration

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High-Temperature Heat Pump Symposium

Introduction

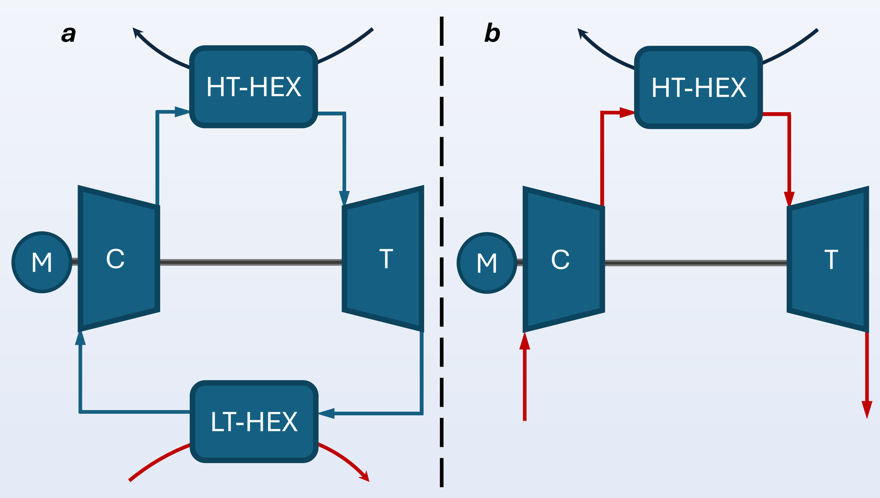
The integration of renewable energy sources and the electrification of thermal users are essential to **achieve decarbonization** and reduce dependence on fossil fuels.

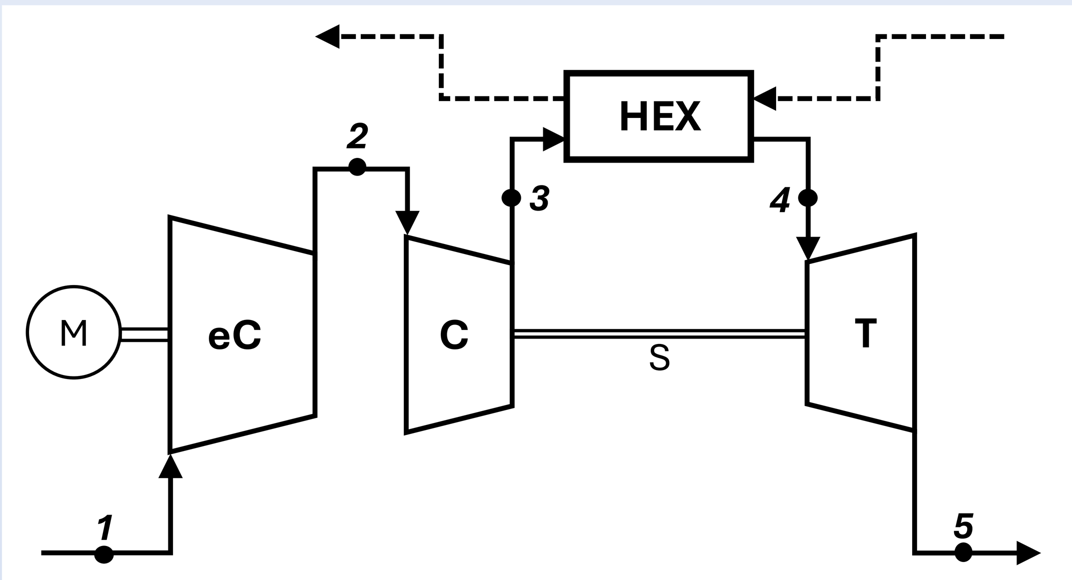
High-temperature heat pumps, capable of delivering heat above 160 °C, are a key technology for industrial applications requiring heat in the range of 150-250 °C.

Innovative Heat Pump Concept

This work investigates an **open reverse Brayton cycle** operated as a high-temperature heat pump. Developed and recently patented by SIT Technologies, a spin-off of the University of Genoa. The concept is quite straightforward: the novelty lies in the direct utilisation of waste-stream gases as the working fluid, a configuration that has been investigated only by the University of Genoa.

Closed reverse Brayton cycle (a) compared to open reverse Brayton cycle (b)

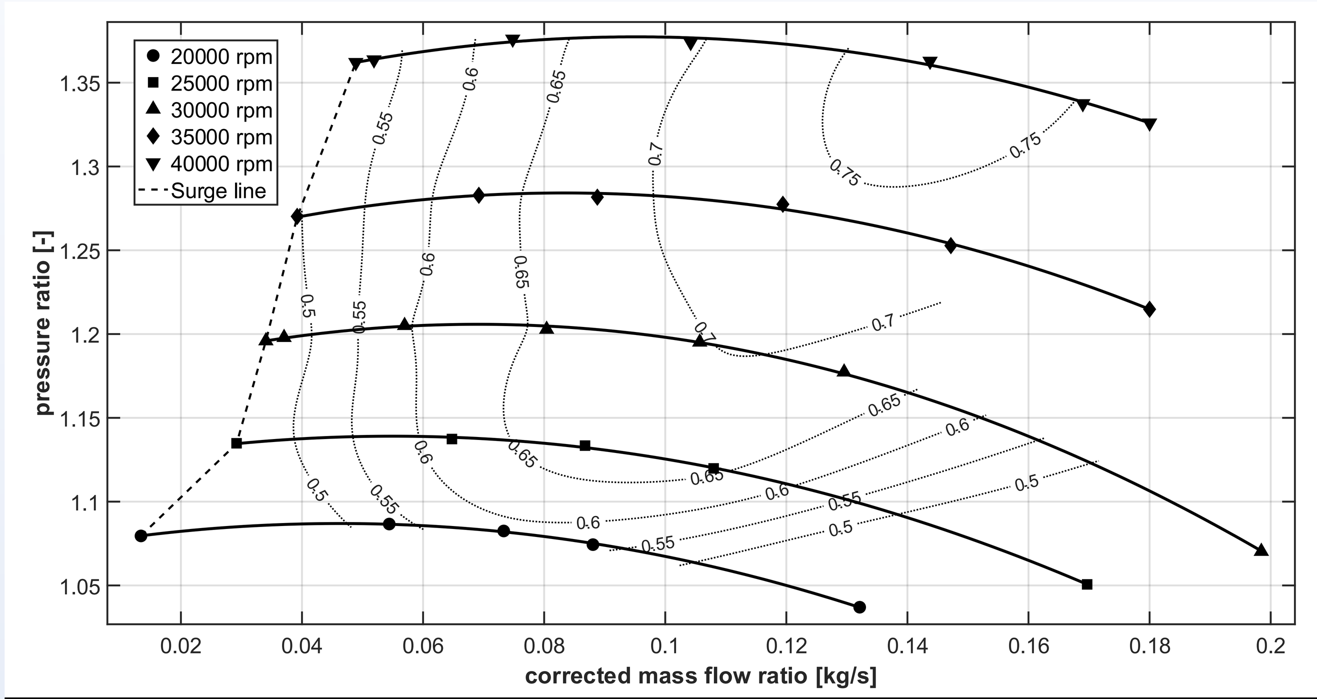




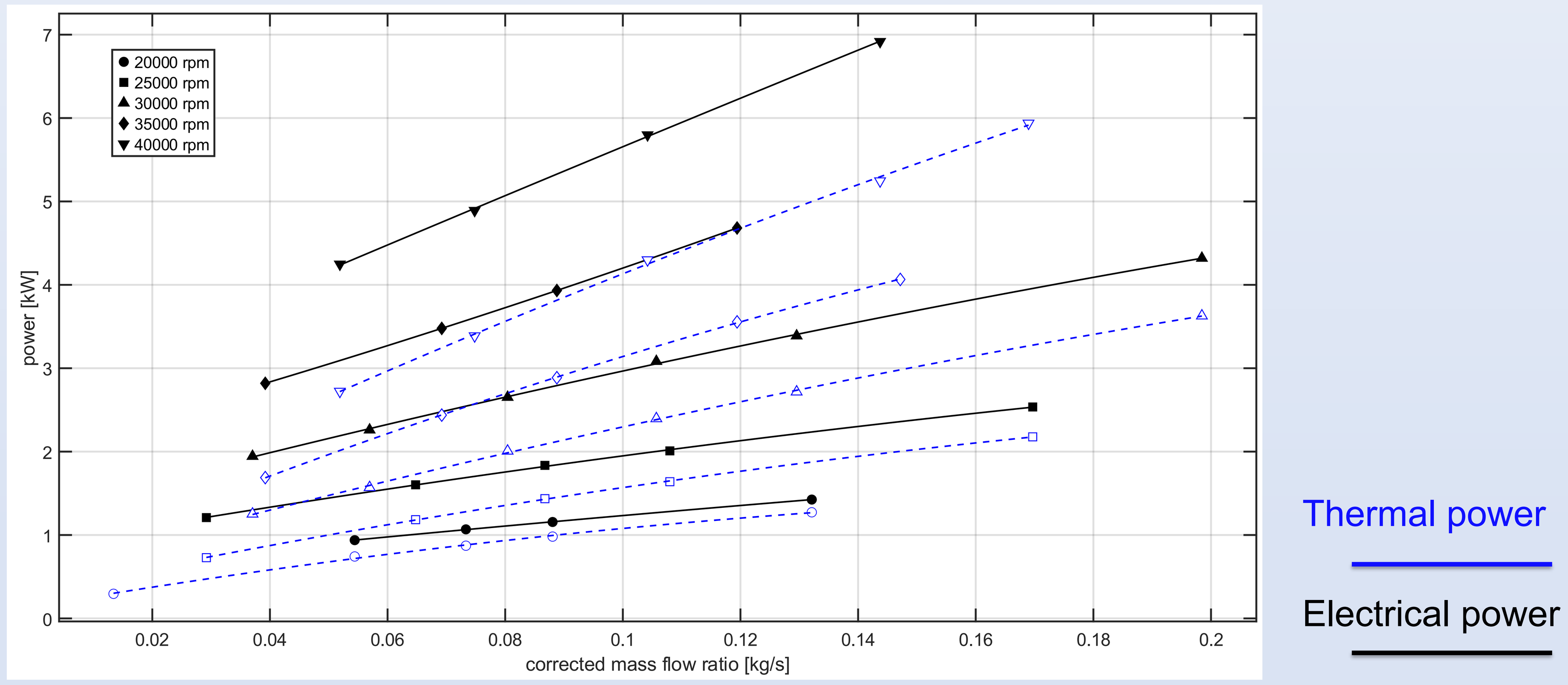
Simplified schematic of the investigated system

E-compressor Characterization

The first experimental campaign focused on the standalone characterization of the e-compressor over a wide range of rotational speeds and operating points. The measured performance maps show a stable and repeatable behavior under steady-state conditions, with consistent trends in pressure ratio and temperature rise.



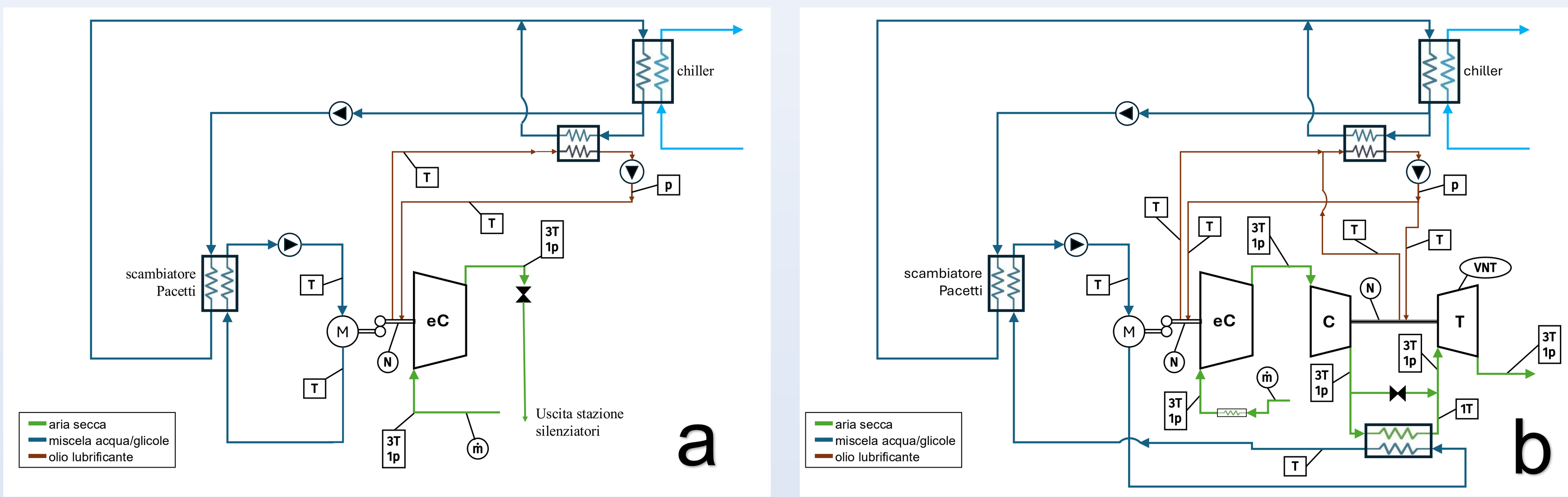
A nearly constant power offset along each isospeed line reflects the electromechanical efficiency.



Reverse Brayton Cycle, Experimental Layouts

Two different experimental layouts were implemented to progressively investigate the system behavior:

- The first layout (**a**) focuses on the **e-compressor operating under controlled steady-flow conditions**, allowing an accurate characterization of its thermodynamic and mechanical performance.
- The second layout (**b**) integrates the e-compressor with the turbine, forming the **complete open reverse Brayton cycle**. This configuration allows system-level performance assessment under realistic operating conditions.

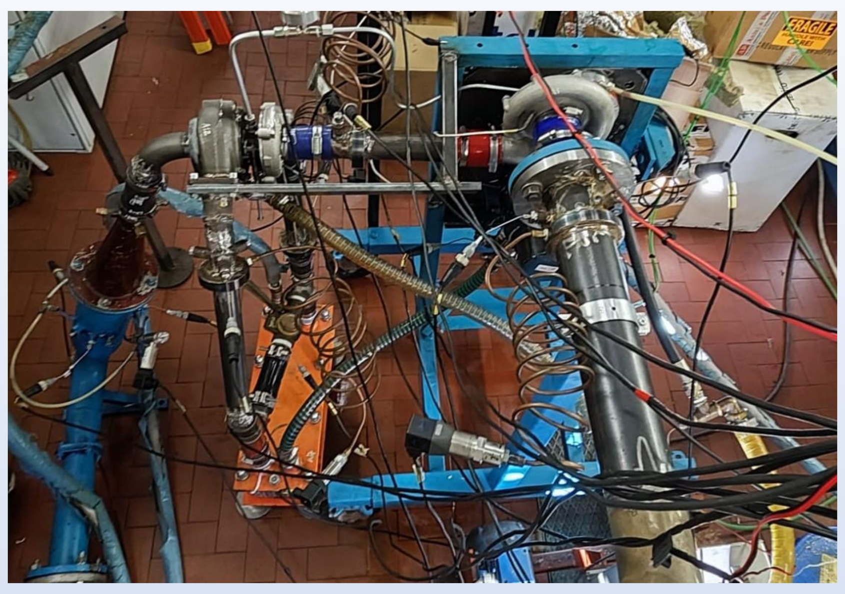


Both layouts ensure reliable measurements, operational flexibility, and safe operation over a wide range of conditions.

Objective & Experimental Methodology

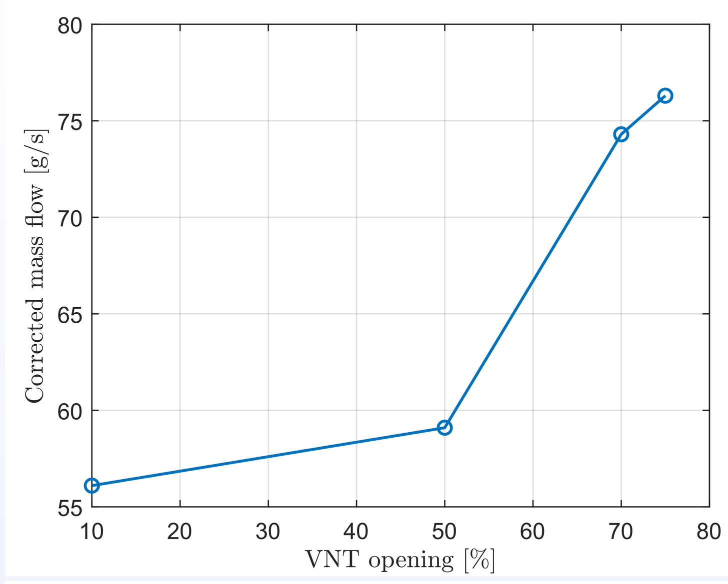
Assess the performance of the open reverse Brayton cycle under **real operating conditions**

- Inlet temperature fixed at **120 °C**
- Controlled inlet pressure at **1 bar**
- Steady-state tests at fixed rotational speeds
- Thermal equilibrium reached before data acquisition
- Identification of operating range and system limits
- Data averaged over multiple acquisitions per operating point
- Experimental data post-processing and validation

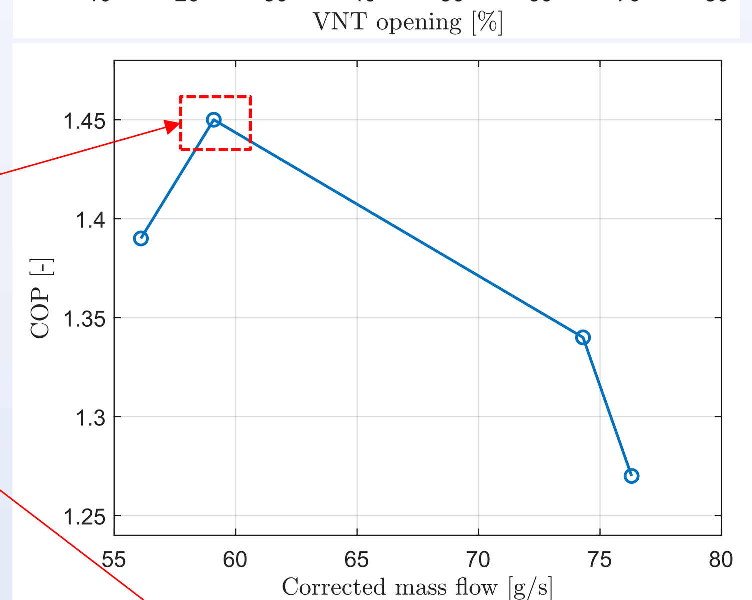


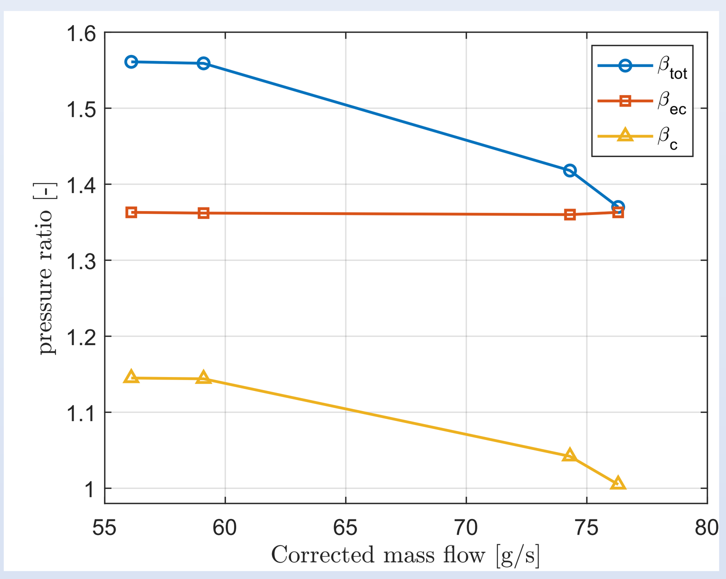
Integrated Cycle Experimental Performance

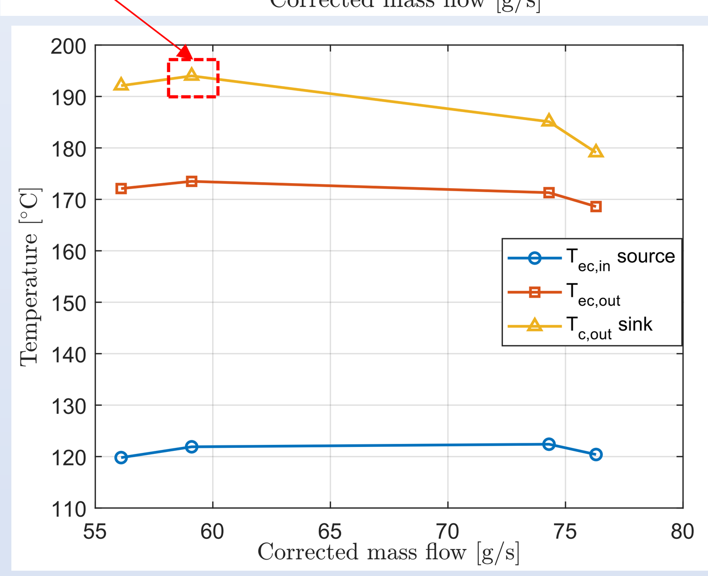
During the second experimental campaign, the system mass flow rate was controlled by adjusting the **turbine variable nozzle** (VNT) opening. This approach allowed the investigation of the integrated cycle behavior over different operating points while maintaining stable operating conditions.



The **maximum COP** reaches 1.45, while the **highest sink outlet temperature** attains 194 °C, with a corresponding temperature lift of **70 °C**.







Conclusions

- This work presents the **first experimental investigation of an open reverse Brayton cycle** operated as a high-temperature heat pump.
- Experimental results confirm the technical feasibility of the proposed concept and its stable operation under steady-state conditions.
- The experimental campaigns provide a solid basis for component- and system-level understanding and further development.

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