HTHP SYMPOSIUM 2026

CoBra - A High-Temperature, Load-Flexible Brayton-Cycle Heat Pump Demonstrator

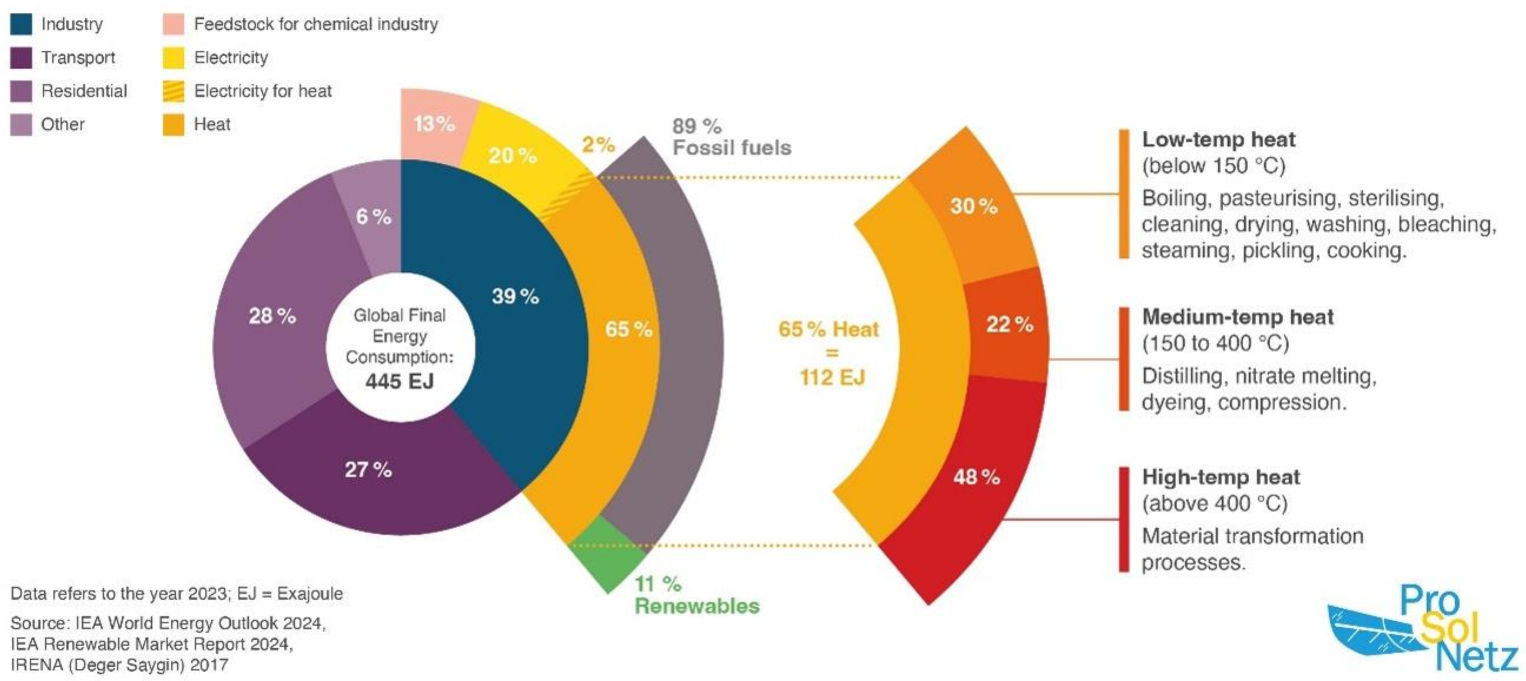
Phong Tran, Johannes Oehler, Fatma Cansu Yücel, Panagiotis Stathopoulos

Why we need an air cycle heat pump

CoBra: A reverse Brayton-Joule cycle heat pump.

Why Brayton?

- Natural refrigerant (air)
- High temperatures
- Large temperature glides
- Flexible in design and operation



Source: Solar Payback, Solrico (2025)
www.solar-payback.com

CoBra: Reaching 260 °C with air

- Heat delivery: 60 kW
  - Heating up air from ambient to 260 °C
  - Ambient heat source
- Compressor discharge: up to 280 °C
- Turbine discharge: down to -40 °C
- Turndown ratio: ~40 % (min-to-max)

2019-2022
Design

2022-2024
Commissioning

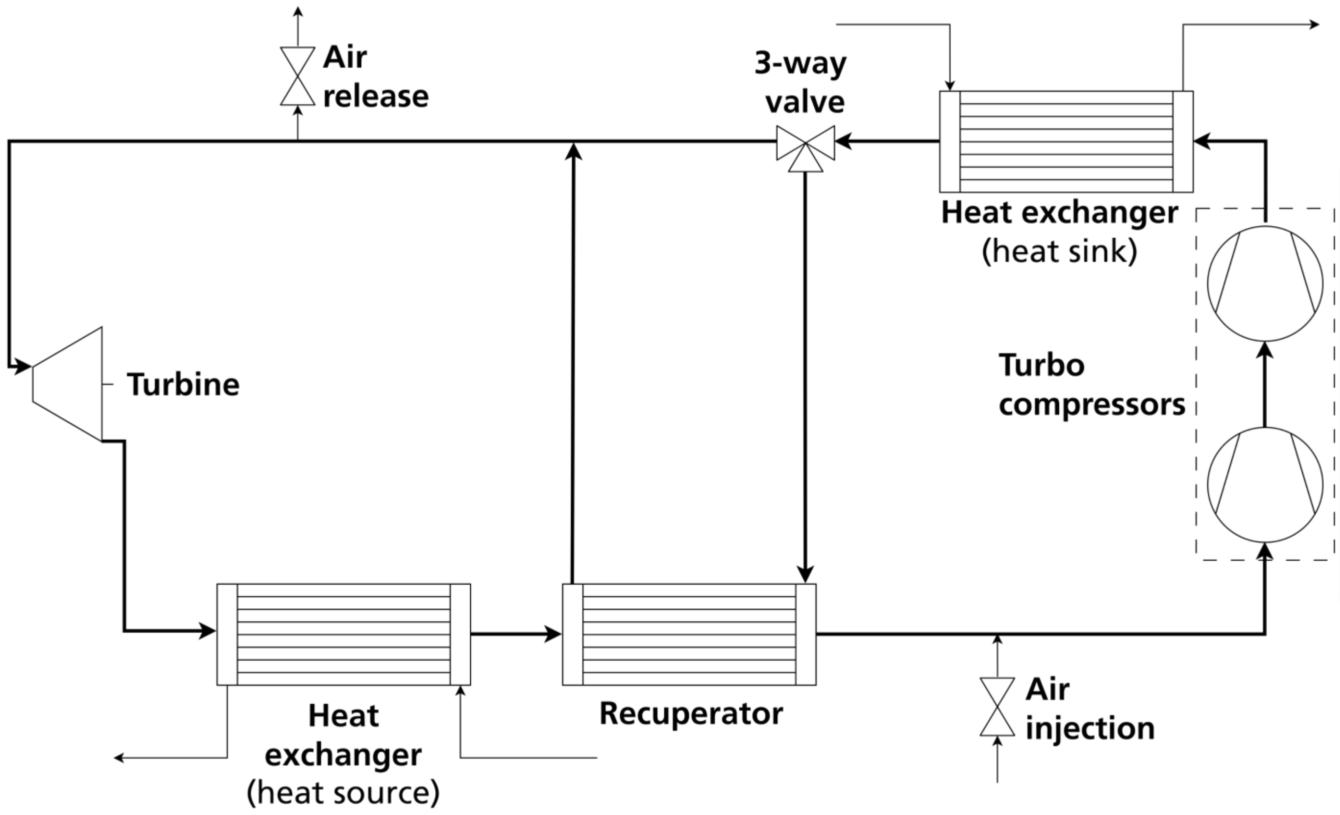
2024-
Closed-cycle operation

The reverse Brayton-Joule Cycle

Refrigerant: Dry air
- Buffer tanks for air resupply
- Dehumidification system

Heat exchangers
- Three shell-and-tube HX
- Low pressure losses
- Large heat capacity

Turbine
- Axial turbine
- Connected to generator
- Discharge temperature: down to -40 °C
- Isentropic efficiency: ~80 %



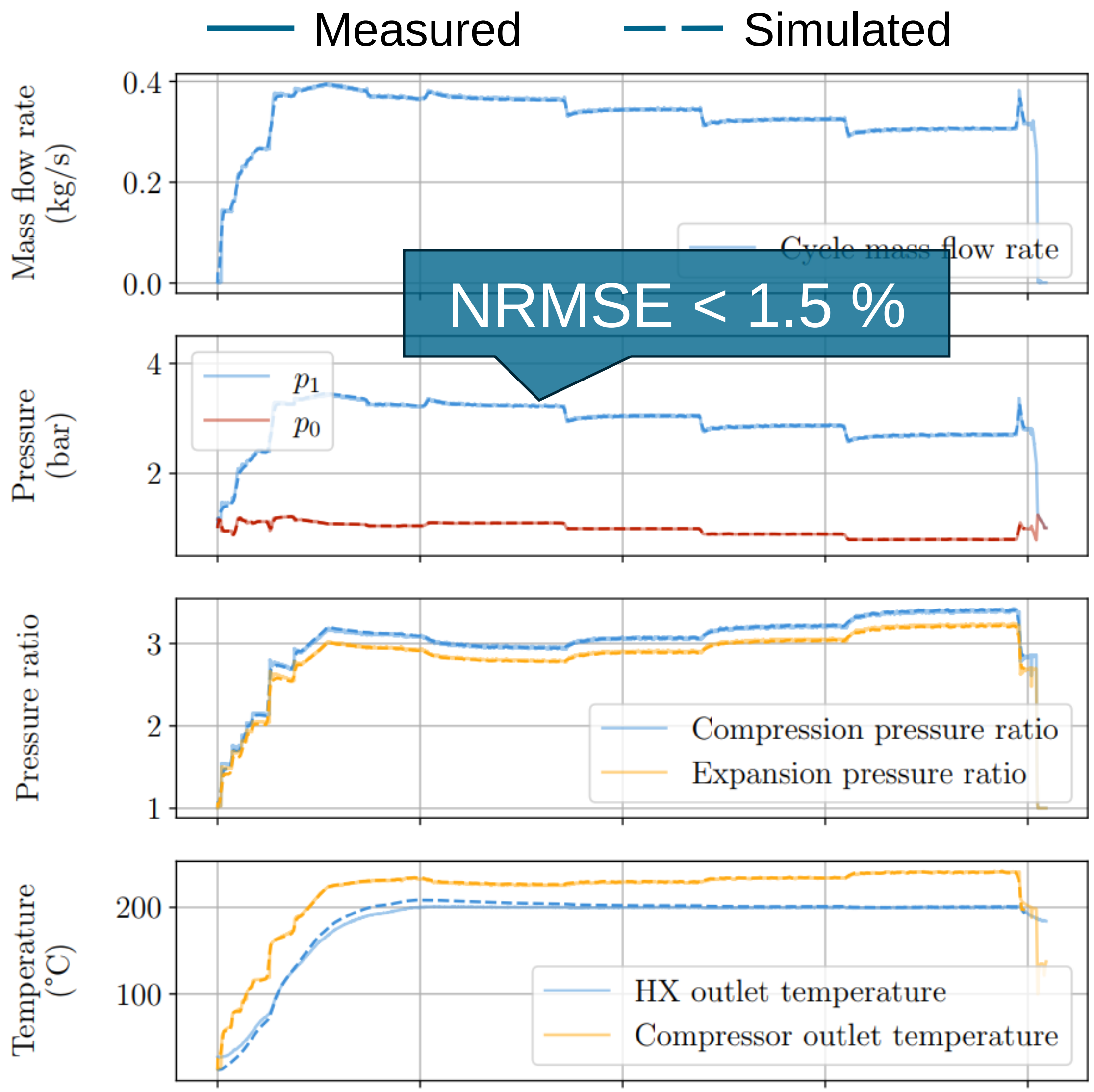
Turbo compressors
- Two radial compressors in series
- Derived from turbocharger
- Pressure ratios: up to 3.5 each
- Discharge temperatures: up to 280 °C
- Isentropic efficiency: ~75 %

Dynamic model: a virtual testbed

- Dynamic simulation using Dymola/Modelica
  - Main thermodynamic phenomena
  - System dynamics
- Calibrated using experimental data: Errors < 1.5 % (NRMSE)

Model is used as a **virtual testbed.**

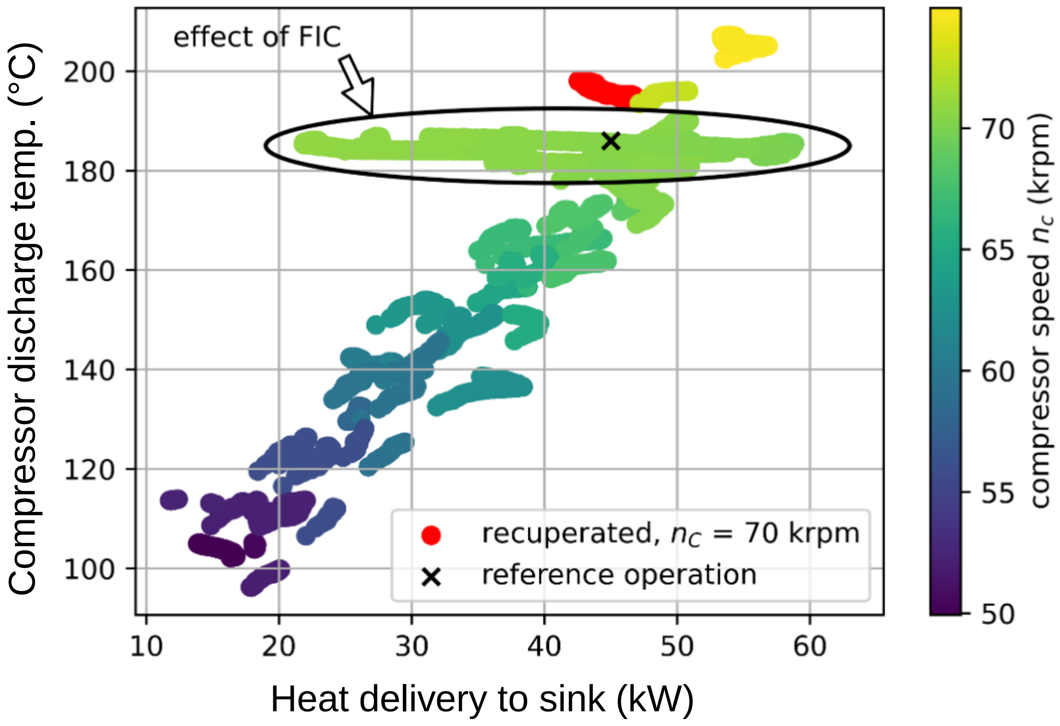
(control design, component sizing, etc.)



Part-load operation

CoBra has **two main control parameters**:

1. Compressor speed
   - Affects pressure ratio, temperatures and mass flow rate
   - Subject to compressor map
2. Fluid inventory
   - Affects amount of working fluid, pressure levels and mass flow rate



Part-load operation

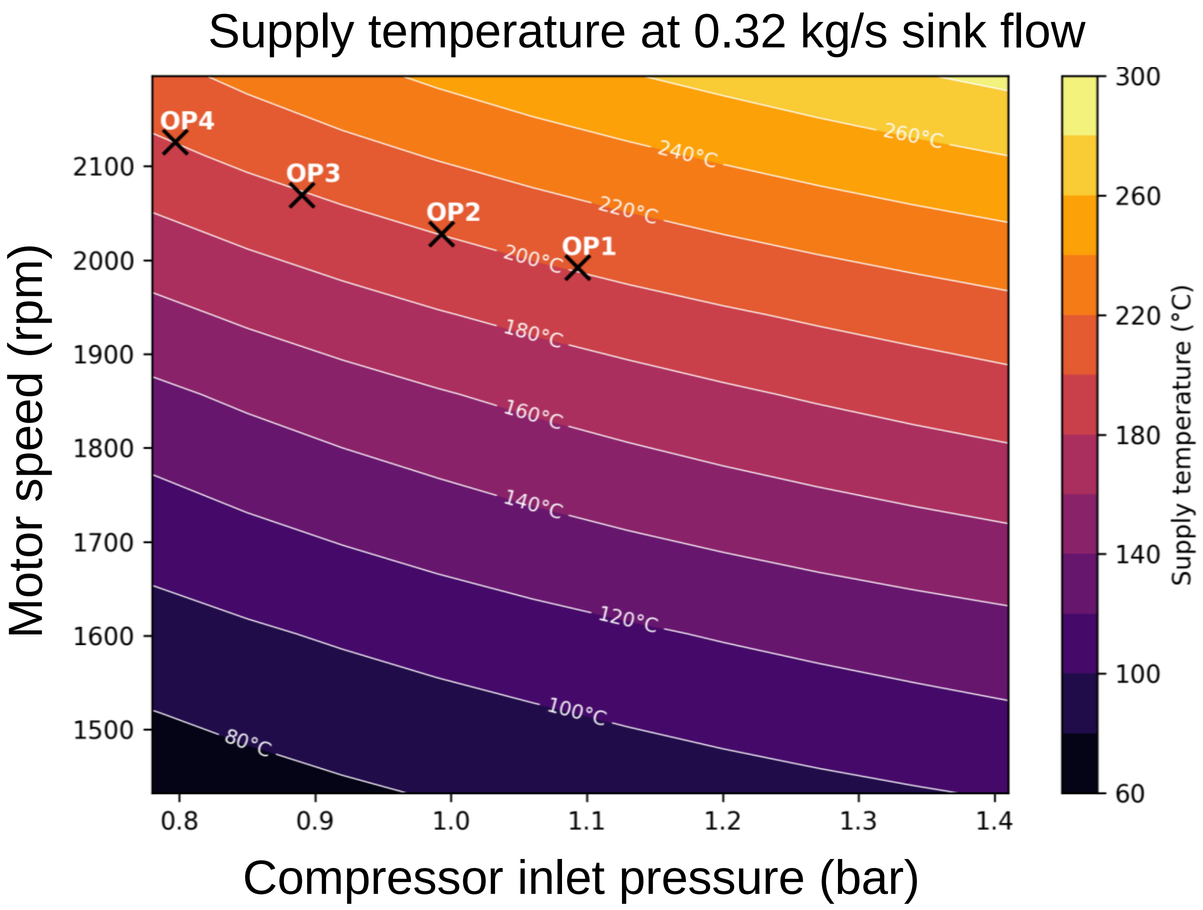
When to use which?

Compressor speed:

- For temperature control

Fluid inventory:

- Measured by compressor inlet pressure
- Flow rate scales linearly with pressure, temperatures remain constant
- Suitable for load changes with constant temperatures



Control

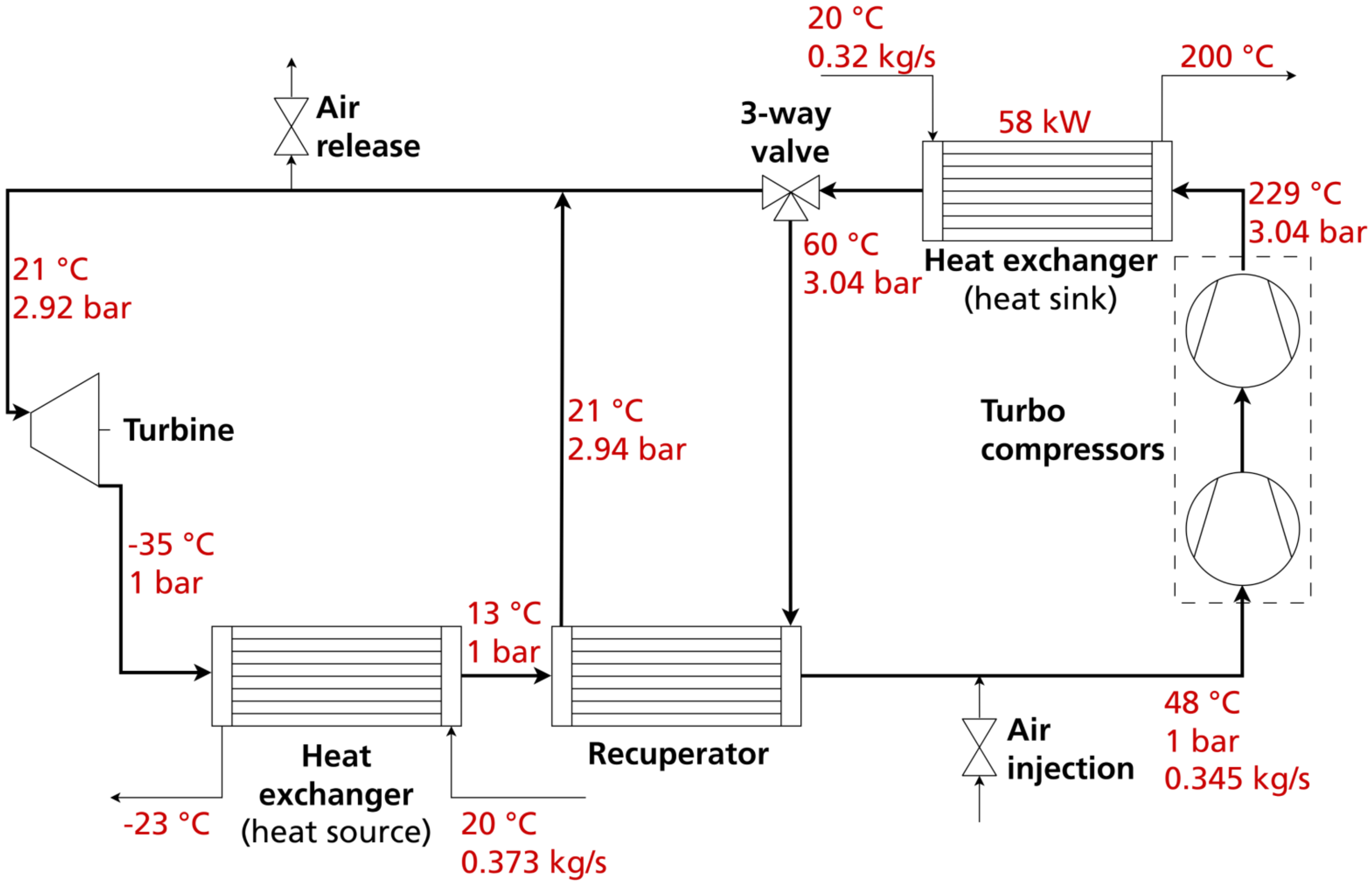
The challenges:

- Mitigate thermal stresses by differential thermal expansion in HX
- Avoid vibrations (natural frequencies)
- Avoid compressor surge

CoBra thermal load control:

- Compressor speed: Used for supply temperature control (two PI controllers)
- Fluid inventory: Used for **COP maximization**
- Recuperation: Always activated

Operating point with 200 °C
Steady-state measurement from 25.02.2025



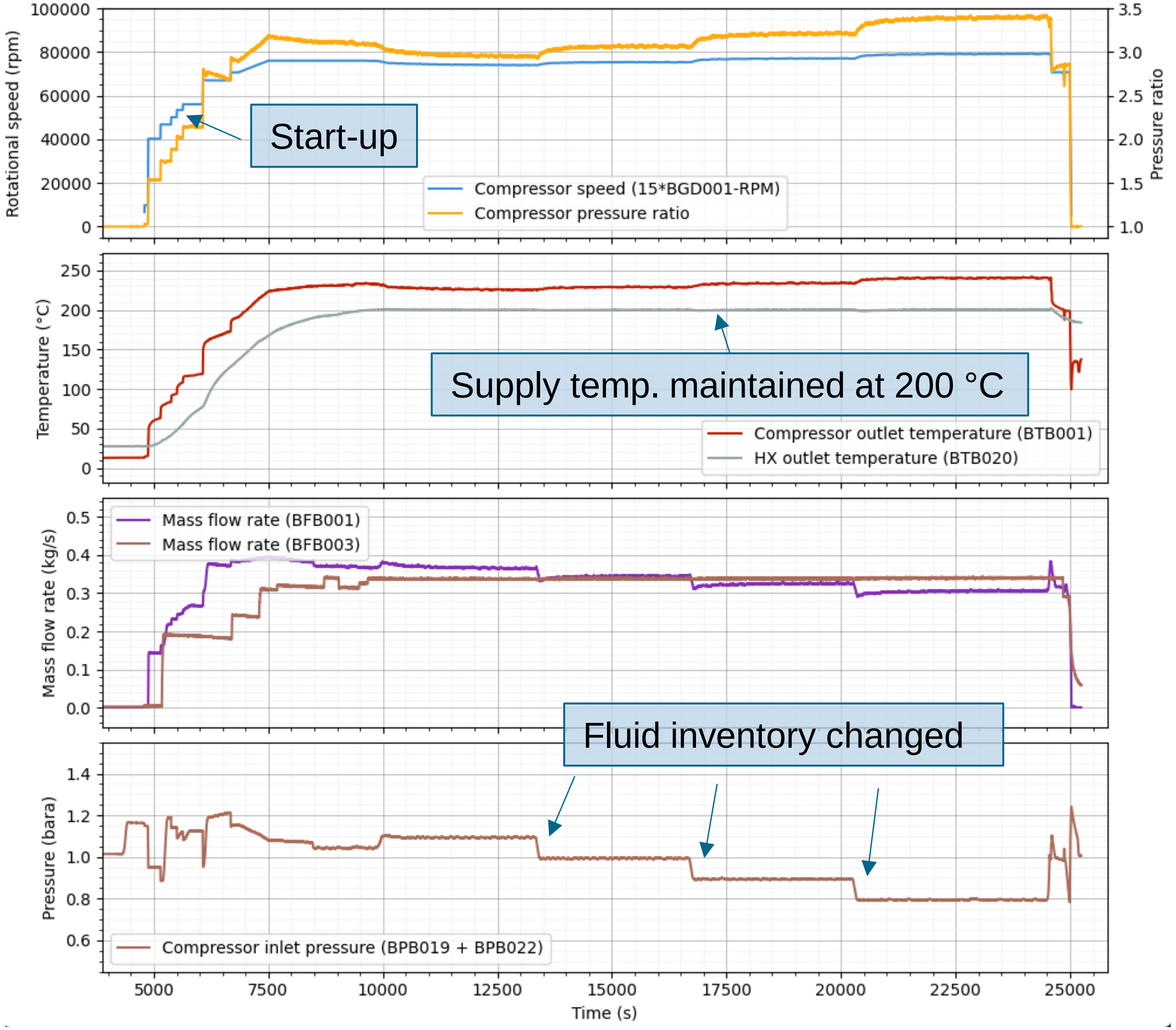
COP: 1.34
(37 % Lorenz COP)

Experimental results

- Cold start to 200 °C achieved in ~1.5 hours (thermal inertia)
- Control system maintains stable temp. of 200 °C
- Multiple speed and fluid inventory combinations can achieve the same thermal load

→ Ongoing research: Optimal control.

Measurement on 25.02.2025



Public availability of experimental data

DLR

- Measurements from June 2024 to February 2025 are publicly available in an **open-access repository**
  - Measurement data (1 Hz)
  - Experiment protocols
  - P&ID diagrams
- Future test data will be published 1 year after the test

Published September 29, 2025 | Version 1.0.0 Dataset Open

CoBra High Temperature Heat Pump Demonstrator - Experimental Dataset 2024-2025

German Aerospace Center

Contributors

Data collector: Naumann, Jonas[1]

Data curator: Oehler, Johannes[1]

Project leaders: Yücel, Fatma Cansu[1]; Stathopoulos, Panagiotis[1]

Project members:

Tran, Phong[1]; Uddin, Nur[1]; Setzepfand, Nico[1]; Tannert, Mario[1]; Herbrich, Justus[1]

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Summary

CoBra: A **demonstrator** and **research platform** for heat pumps.

- **Feasibility** of closed-loop Brayton cycle for heat pumps confirmed
- **Thermal performance:** Achieved stable temperatures of 200 °C at 58 kW, recorded maximum of 260 °C
- **Rapid power reduction** in <60 seconds via fluid inventory control

Get the CoBra measurement data: