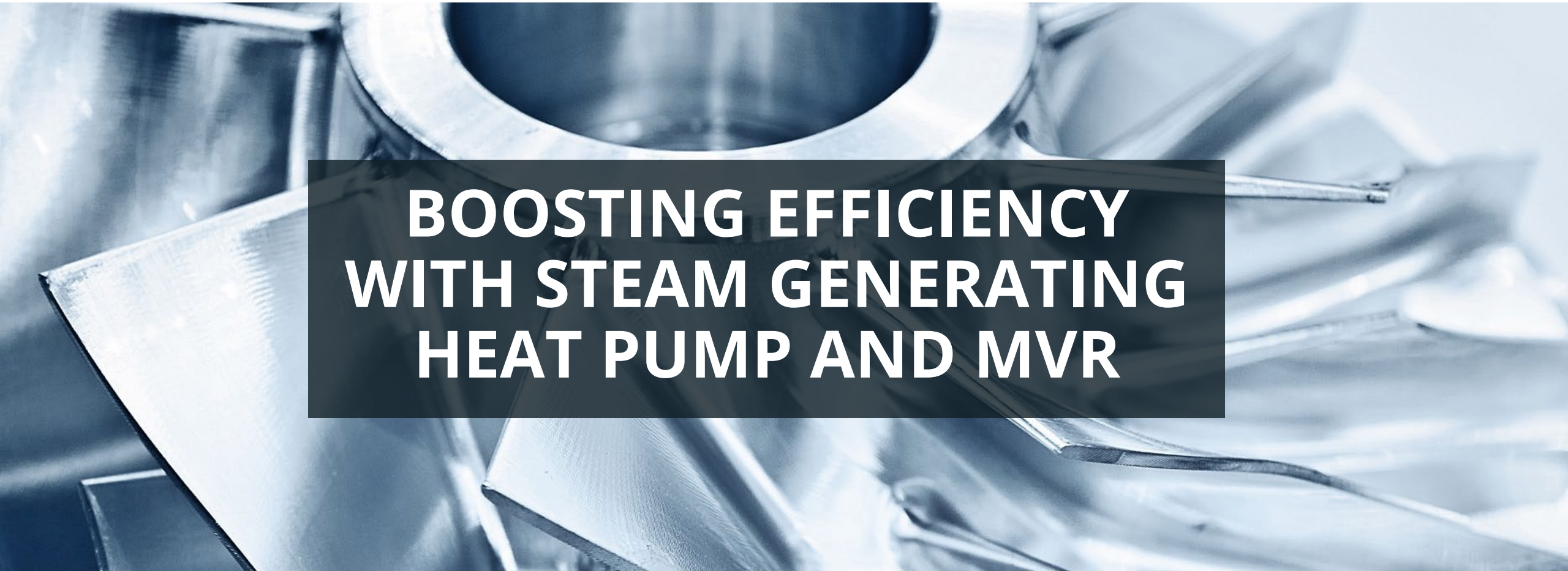




BOOSTING EFFICIENCY WITH STEAM GENERATING HEAT PUMP AND MVR

Davide Rizzi – Application Engineer

Turboden S.p.A.

A Group Company of  **MITSUBISHI HEAVY INDUSTRIES**

AGENDA

- **TURBODEN COMPANY INTRODUCTION**
- **TURBODEN HEAT ELECTRIFICATION PORTFOLIO**
- **TURBODEN STEAM COMPRESSOR PORTFOLIO**
- **STEAM GENERATING HEAT PUMP REFERENCE**



TURBODEN COMPANY INTRODUCTION

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A Group Company of **MITSUBISHI HEAVY INDUSTRIES**

GLOBAL AND PROVEN EXPERIENCE

Worldwide presence in
50+ countries

Around
460 plants



HEAT GENERATION

2 units, 18 MWth



HIGH TEMPERATURE
POWER GENERATION*
+ COGEN

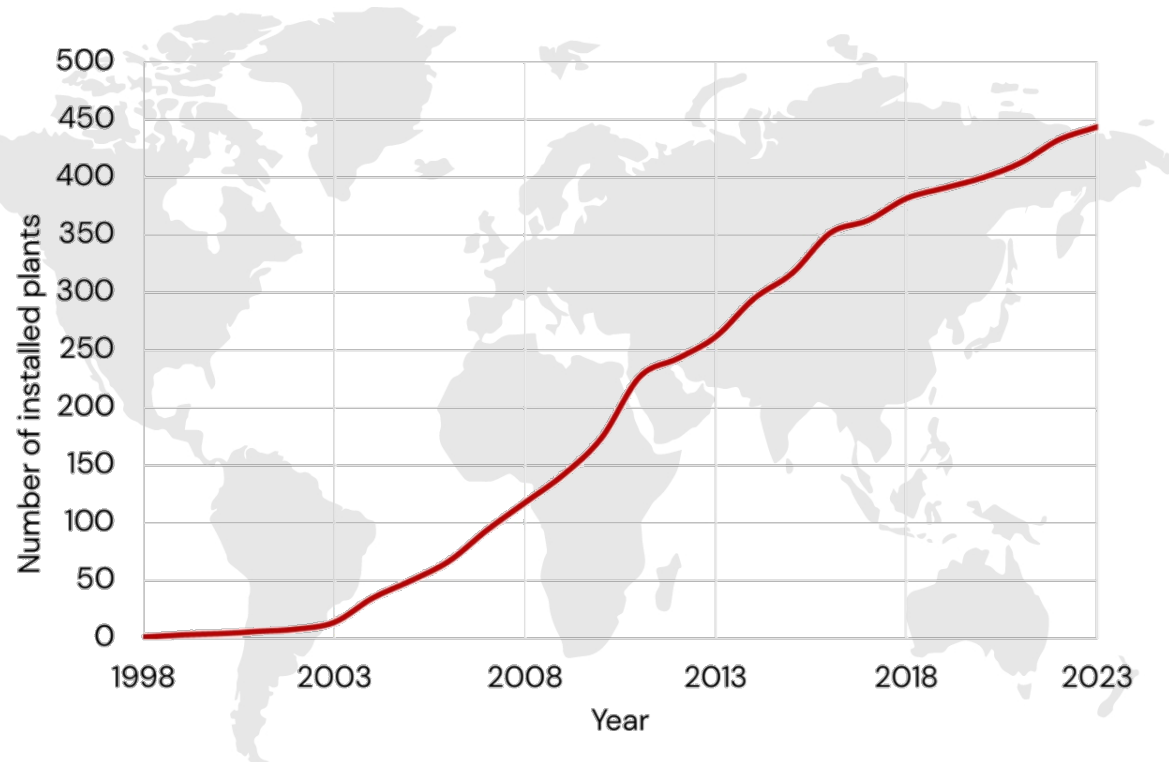
442 units, 810 MWe



GEOHERMAL
POWER GENERATION

20 units, 247 MWe

Last update: August 2024
* ORC and gas expanders included.



Largest plant
in operation
29 MWe



Largest plant
under construction
120 MWe



Overall capacity
installed
1,050 MWe

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MHI AT A GLANCE



FOUNDATION

1884

over 130 years of history



EMPLOYEES

77,768

(Consolidated)



GROUP COMPANIES

259

(Consolidated)



SALES

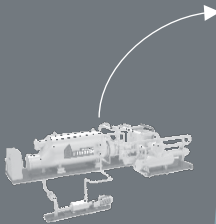
¥5TN (\$33.6BN*)

(FY2024, consolidated)



*On the FY2022 average JPY/USD exchange rate.

DIVERSE PRODUCTS



GX (GREEN
TRANSFORMATION)
SOLUTIONS



PLANTS &
INFRASTRUCTURE
SYSTEMS



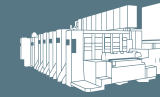
LOGISTICS,
THERMAL &
DRIVE SYSTEMS



NUCLEAR
ENERGY
SYSTEMS



MACHINERY
SYSTEMS



INTEGRATED
DEFENSE &
SPACE SYSTEMS



COMMERCIAL
AVIATION
SYSTEMS



ENERGY
SYSTEMS



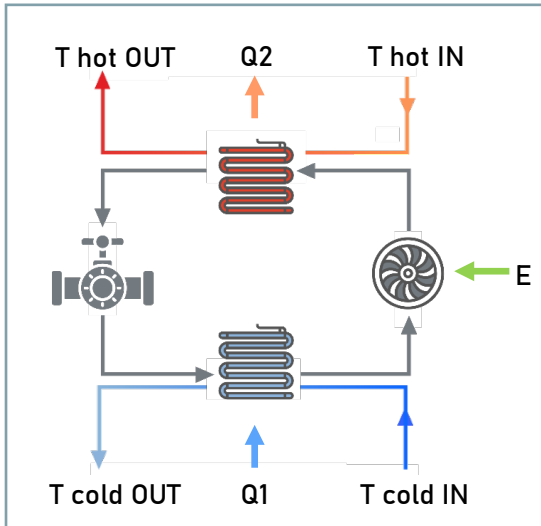


TURBODEN HEAT ELECTRIFICATION PORTFOLIO

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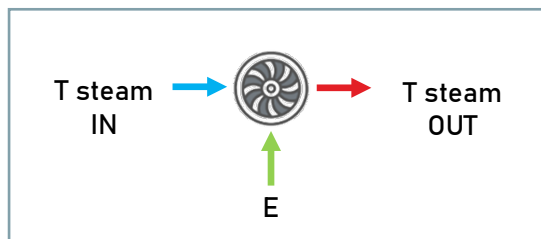
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A FULL-FLEDGED PORTFOLIO TO COVER LARGE SIZES AND HIGH TEMPERATURES



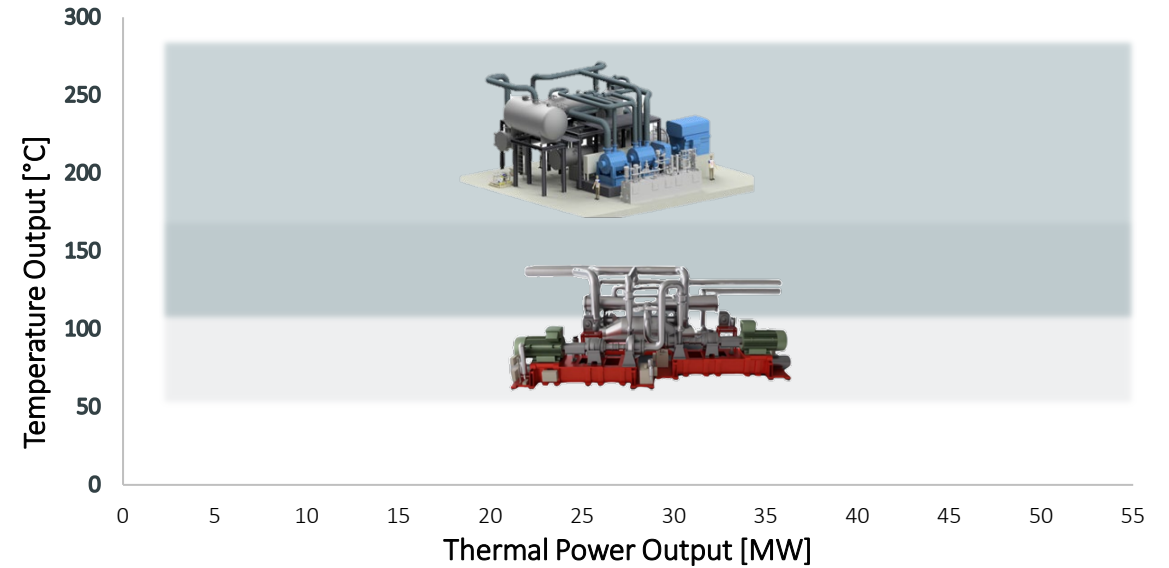
LHP

Large Heat Pumps (LHP) are utility-scale heating plant, designed to transfer large quantities of heat from a lower temperature source to a higher temperature heat user, such as district heating grid or industrial process.



MVR

Mechanical vapor recompression (MVR) system, acting as an open cycle water heat pump, increases both the temperature and the pressure of a water stream, to generate steam at specific conditions needed.



NOTE: capability to operate at high lift and at high output temperature, thanks to optimised solutions.



Large-scale (thermal power output from 5 MWth)



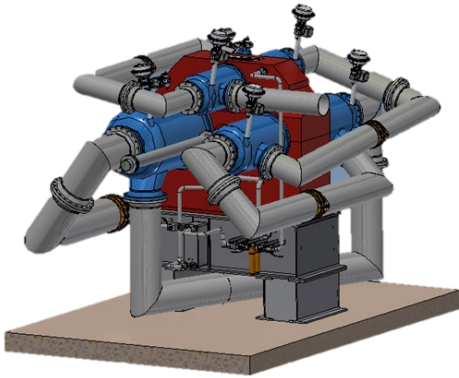
High temperature (output temperature beyond 200°C, including steam generation)

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TURBODEN COMPRESSOR PORTFOLIO

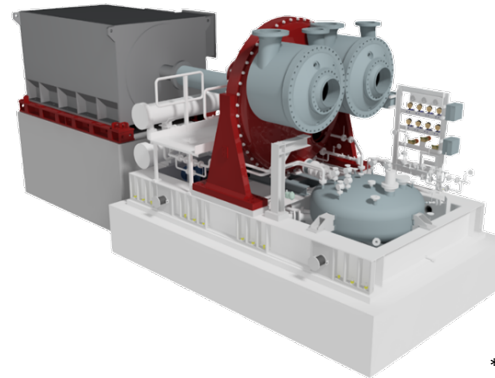
TURBODEN MECHANICAL VAPOUR RECOMPRESSOR (MVR) LINE



*Patent pending

- Multi-stage integrally geared system
- Compact solution for high compression ratio
- Power range: 150 kWe – 10MWe
- Minimum Design: inlet 65°C – 0,2 bara
- Max Design : up to 30 barg
- Number of stages per gear: 6
- Pinion speed range: up to 90000 rpm

TURBODEN LHP HERMETIC COMPRESSOR LINE*



*Patent pending

- Heavy duty machine designed for continuous operation with reduced maintenance
- Power range: 300 – 18,000 kW
- Impeller diameter up to 1,500 mm
- Enhanced flexibility for optimal part load operation and quick process adaptation
- Optimized design for HC refrigerants
- Maximum safety with no harmful fugitive emissions

MITSUBISHI HEAVY INDUSTRIES COMPRESSOR

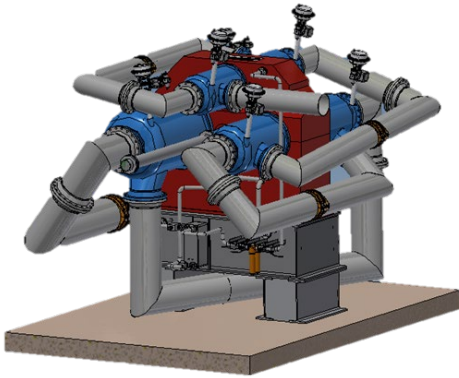


API617 beam type compressors

- Special Purpose API centrifugal compressor designed for critical process operation
- Power up to 50+ MW
- Impellers diameter up to 1,700 mm
- High reliability and availability
- Heavy duty and process industry suitability
- DGS sealing system with leakage recovery system

TURBODEN COMPRESSOR PORTFOLIO

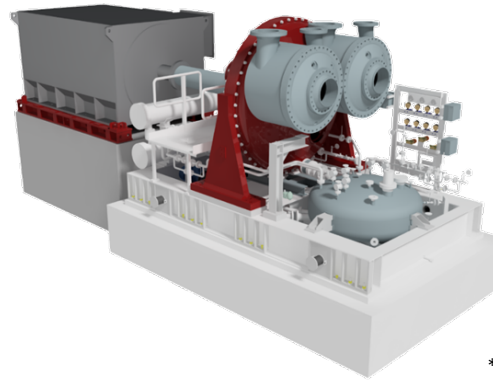
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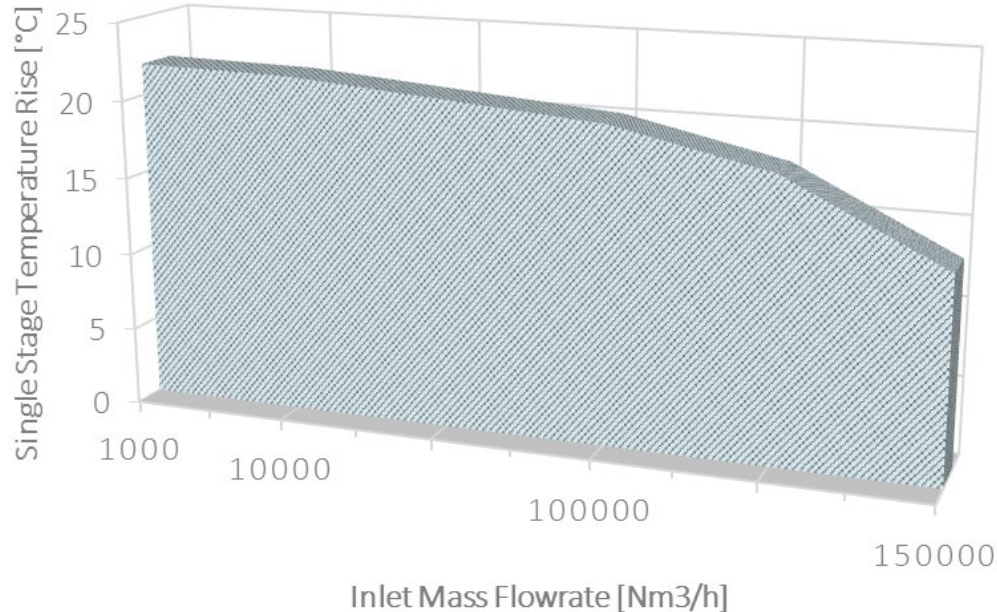


TURBODEN STEAM COMPRESSORS PORTFOLIO

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TURBODEN STEAM COMPRESSOR

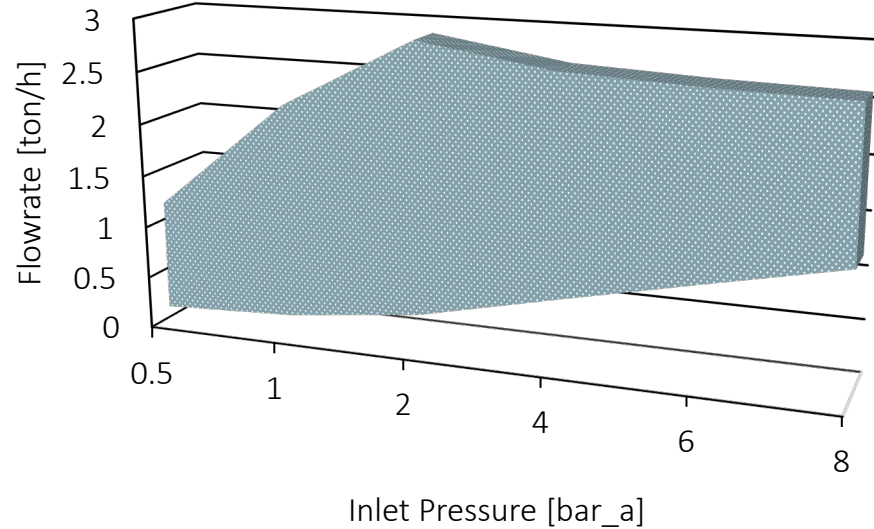
Turboden Steam Compressor solutions are based on integrally geared centrifugal compressors, which are designed with reduced number of very high head stages. This technology allows high compression ratios in a single unit with superior efficiency and a very compact layout. Turboden steam compressors are heavy duty machines characterized by

- Single or Multi-stage design with optimized speed for each impeller;
- Three dimensional impellers specifically designed for steam compression using state of art tools
- IGV (Inlet Guide Vanes) and VFD for precise modulation and control;
- Integrated piping and condensate separators for minimal footprint
- Compact package with built on lubrication system
- Corrosion resistant materials for the most severe harsh conditions

Other than the rotating machine, Turboden also offers complete package (design and construction) composed by **steam compressor and evaporator heat exchanger and piping**, generally mentioned as **MVR**.

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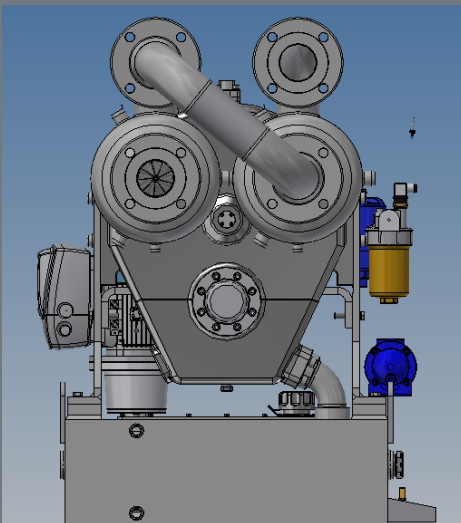


INNOVATIVE COMPACT STEAM COMPRESSOR

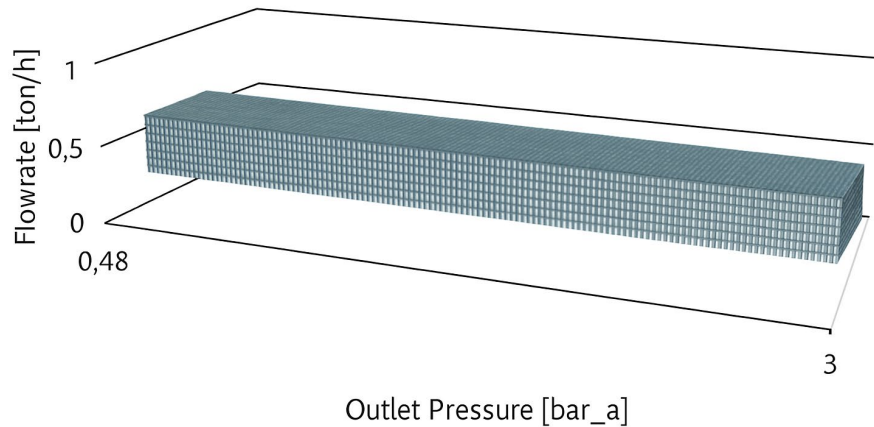
Turboden Compact Steam Compressor is a new development derived from the larger frame architecture. This solution is designed to address applications with low steam flow rates.

Key Features:

- **Platform approach**
- **Modular configuration** allows multiple units to operate in parallel, enabling scalability for higher inlet flow capacities.
- **Constant single-stage temperature lift** maintained across different unit sizes and configurations.
- **Integrated auxiliaries and piping** reduce installation complexity and minimize system footprint. **Evaporator heat exchanger** included in the scope of supply, meaning **complete MVR package**.
- **High aerodynamic efficiency** through advanced impeller design tailored for steam compression.
- Flexible control enabled by **Inlet Guide Vanes (IGV)** and **Variable Frequency Drives (VFD)** for precise performance modulation
- **Pilot test expected in Q1 2026**



MHI SGHP

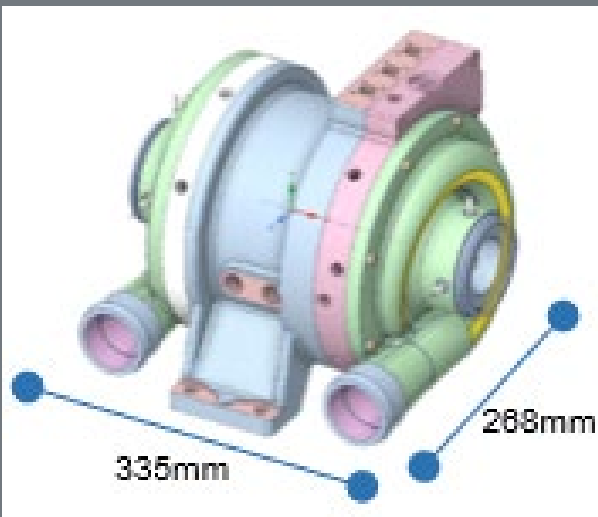


MITSUBISHI SGHP

Mitsubishi SGHP (Steam Generating Heat Pump) technology is derived from advanced automotive turbomachinery concepts, integrating high-speed rotors and compact mechanical architecture.

Key Features:

- **Automotive-derived design**, leveraging high-speed rotating machinery for compact and efficient performance.
- **High-speed rotor architecture**, enabling significant compression ratios with minimal footprint.
- **Integrated system layout**, including lubrication, piping, and control components within a single compact package.
- **Compactness**, ideal for installations with space constraints.
- **Simplicity**, reducing auxiliary systems and streamlining operation and maintenance.



TURBODEN COMPRESSORS TEST BENCH FACILITY FACILITY

TURBODEN CENTRIFUGAL COMPRESSOR



Compressor general characteristics

- Heavy duty machine designed for continuous operation with reduced maintenance
- Power range: 300 – 18,000 kWe
- Impeller diameter up to 1,500 mm
- Enhanced flexibility for optimal part load operation and quick process adaptation
- Maximum safety with no harmful fugitive emissions - Hermetic
- Suitable for both steam and hydrocarbons compressors

Features of the compressor currently on the test bench

Technical features:

- semi-hermetic design
- 2 stage overhung per pinion
- 3 pinions
- mechanical oil seal on LS shaft
- 12,000 kWe design

Next test scheduled:

- Steam compressor Q1 2026



MVR APPLICATION FIELDS

- **Chemical / Petrochemical Industry:** solvent recovery, crystallization, and concentration of chemical solutions.
- **Food and Beverage Industry:** concentration of fruit juices, dairy products, sugar mills and other liquid foods.
- **Pharmaceutical Industry:** concentration and purification.
- **Pulp and Paper Industry:** topping heat pump for steam compression, black liquor evaporation and other concentration processes.
- **Wastewater Treatment:** wastewater treatment facilities for concentrating sludge and recovering water from the wastewater.
- **CHP plants :** enhance existing CHP plants by generating process steam through the cooling of engine jacket water.

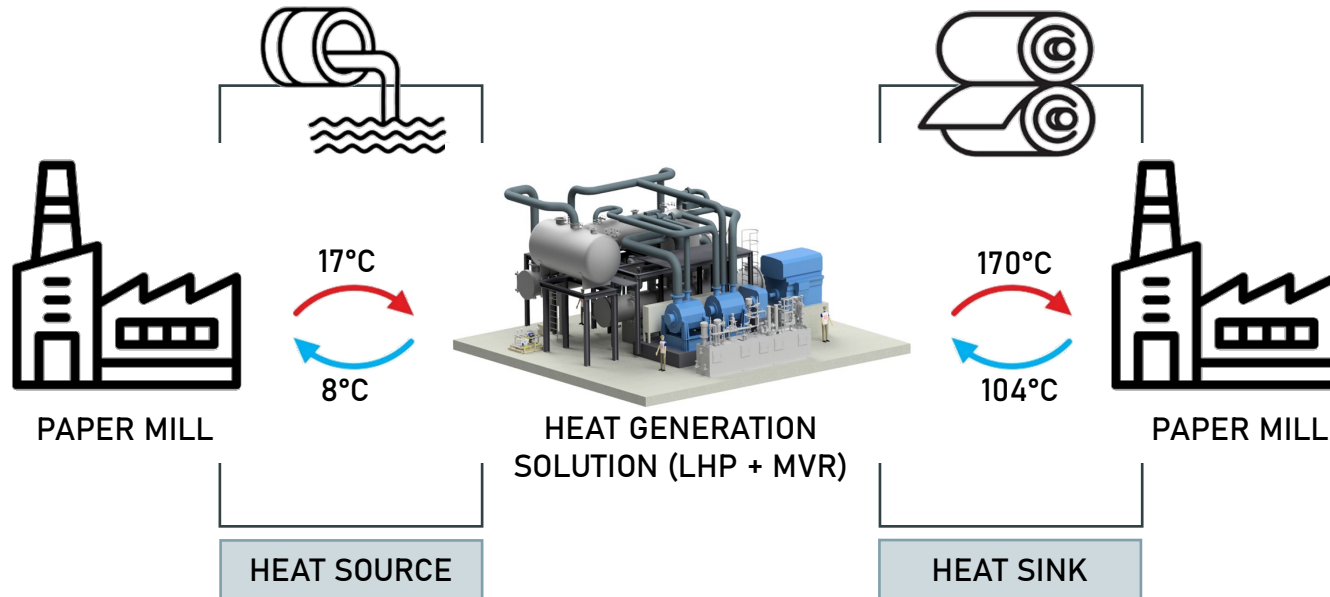


STEAM GENERATING HEAT PUMP REFERENCE CASE

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REFERENCE PLANT: STEAM GENERATING HEAT PUMP FOR PAPER MILL



The customer valorized the low-temperature waste water from the paper mill by installing an innovative heat-upgrade solution, a LHP together with an MVR, to produce valuable steam for the paper mill itself.

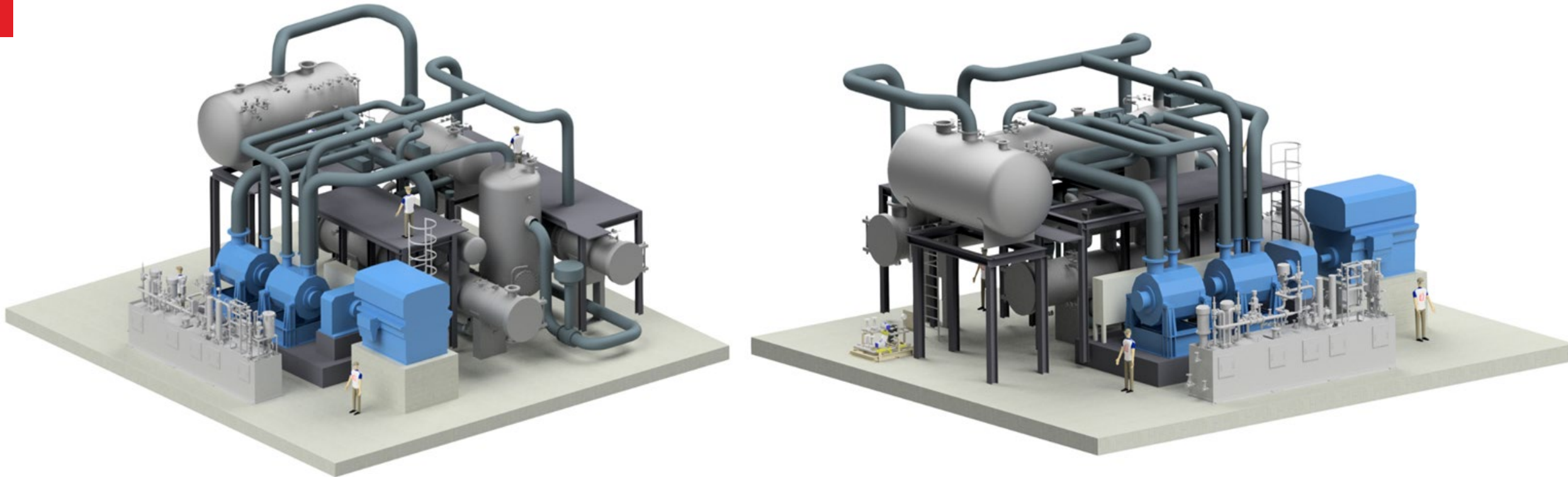
PROJECT FEATURES

- Country: Northern Europe, under construction
- Thermal Power : 12 MW (20 ton/h steam)
- Exploitation of paper mill waste heat to generate steam for the process
- Output: **superheated steam at 170°C** delivered to the paper mill

TECHNICAL FEATURES

- Integration of **Steam Generating Heat Pump** with Steam Compressor to provide high-temperature steam at high efficiency;
- Overall **COP: 2 avg**
- Heat Pump compressor: MCO- Centrifugal compressor 6H line
- LHP working fluid: **Isobutane**

CASE HISTORY: PULP & PAPER INDUSTRY



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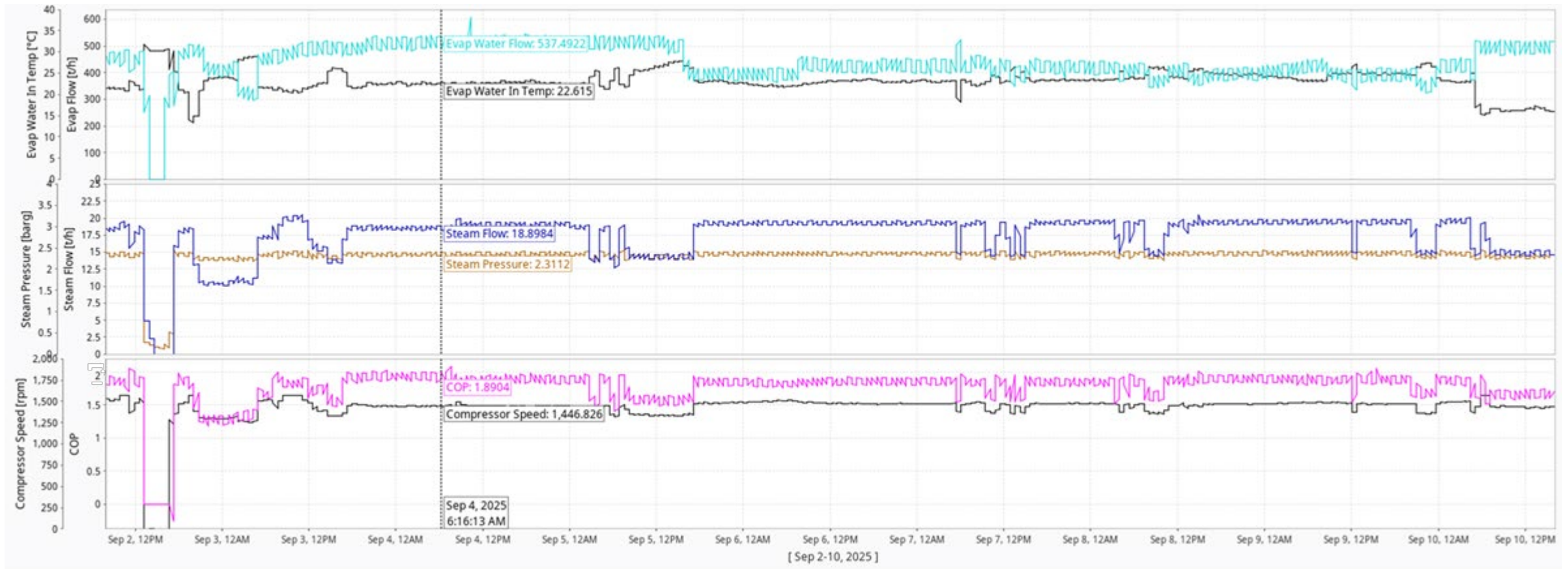


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CASE HISTORY: PULP & PAPER INDUSTRY



THANKS FOR THE ATTENTION



Davide Rizzi – Application Engineer

Turboden S.p.A.

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Steam-generating heat pumps, OST Webinar, 21 October 2025