ETN Webinar Series

February 2021

Baker Hughes

sCO2flex

# Technology Innovation in $sCO_2$ power cycles

*This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 764690*

Presenter: Fulvio Bellobuono

# About myself

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Baker Hughes

**Senior Aerodynamics Engineer**

Lead Aero Engineer for CC & GT

## Background

PhD in Aerospace Engineering @ University of Naples

Master *MEDEA* @ ENI



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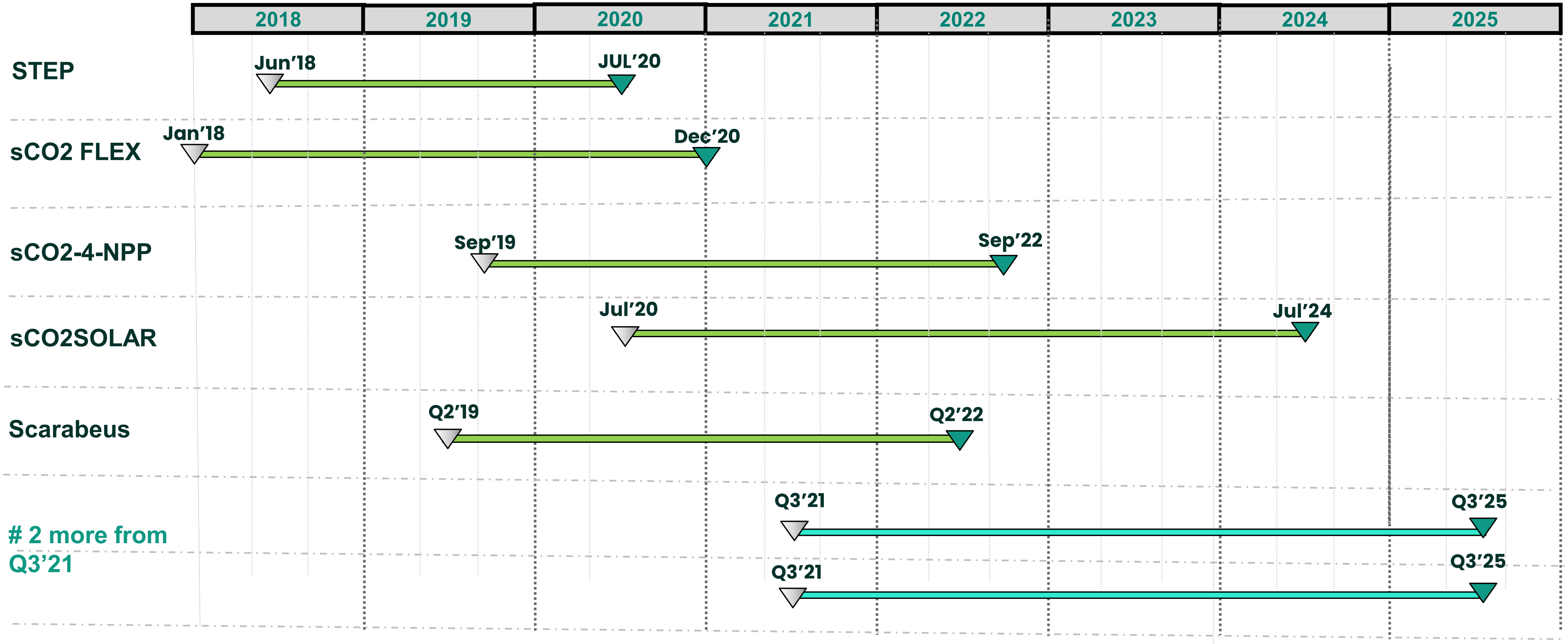
# $sCO_2$ Programs in Baker Hughes, timeline

Horizon 2020
European Union Funding
for Research & Innovation



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# $sCO_2$-Flex: Baker Hughes Deliverables

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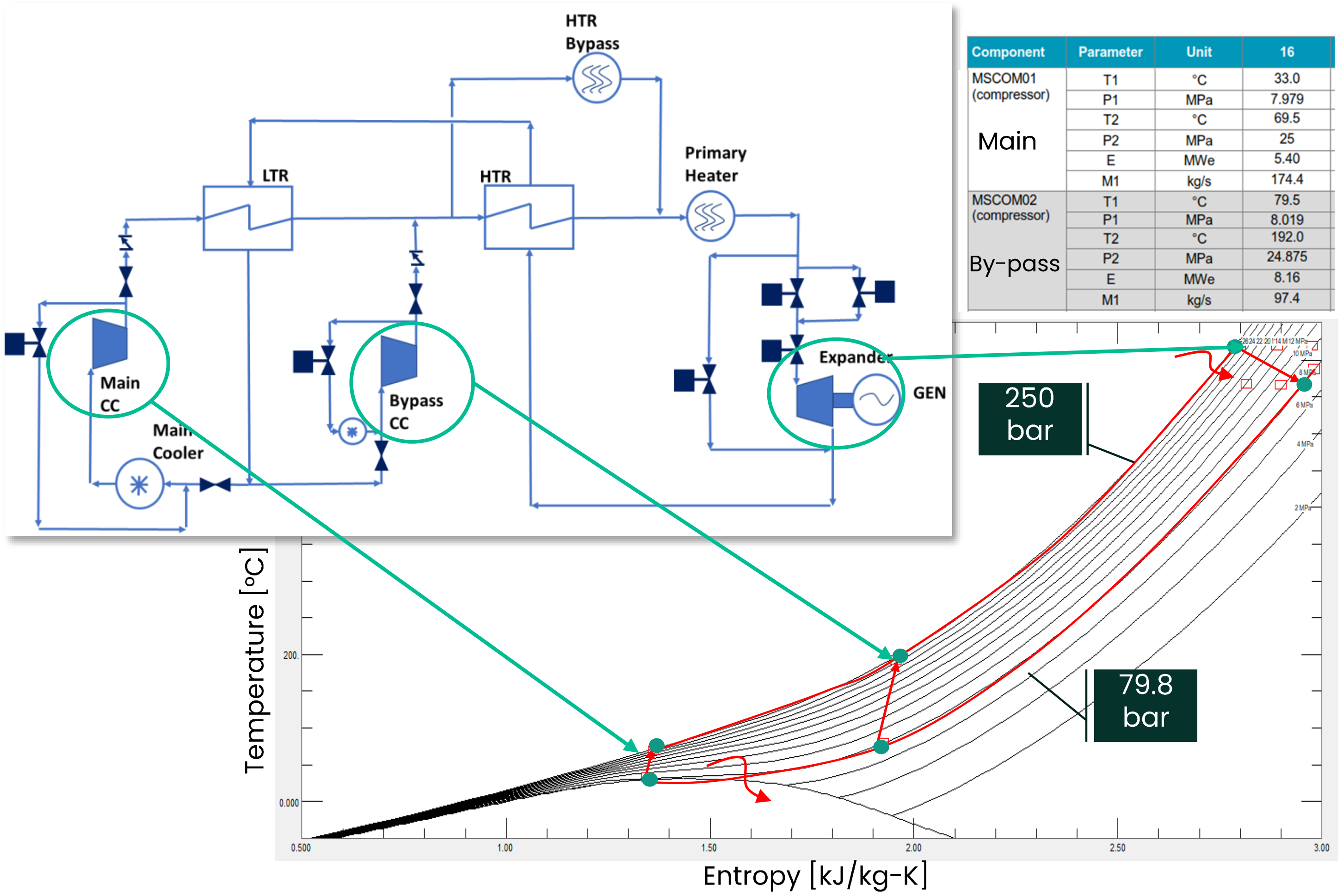
- Design of two centrifugal compressors (BCL252/B and BCL303/B ) and one turbine expander
- Test of prototype compressor working close to $CO_2$ critical point
- Material selection and relevant tests
- Plant simulation in design and off-design condition
- Scale-up of the system to 100MWe




| Component | Parameter | Unit | 16 |
|---|---|---|---|
| MSCOM01 (compressor) Main | T1 | °C | 33.0 |
| | P1 | MPa | 7.979 |
| | T2 | °C | 69.5 |
| | P2 | MPa | 25 |
| | E | MWe | 5.40 |
| | M1 | kg/s | 174.4 |
| MSCOM02 (compressor) By-pass | T1 | °C | 79.5 |
| | P1 | MPa | 8.019 |
| | T2 | °C | 192.0 |
| | P2 | MPa | 24.875 |
| | E | MWe | 8.16 |
| | M1 | kg/s | 97.4 |

**Project Partners**
EDF, BH, JUV, Rina, CVR, Fives, Politecnico Milano, University Duisburg/Essen, University Stuttgart



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# $sCO_2$-Flex Compressors

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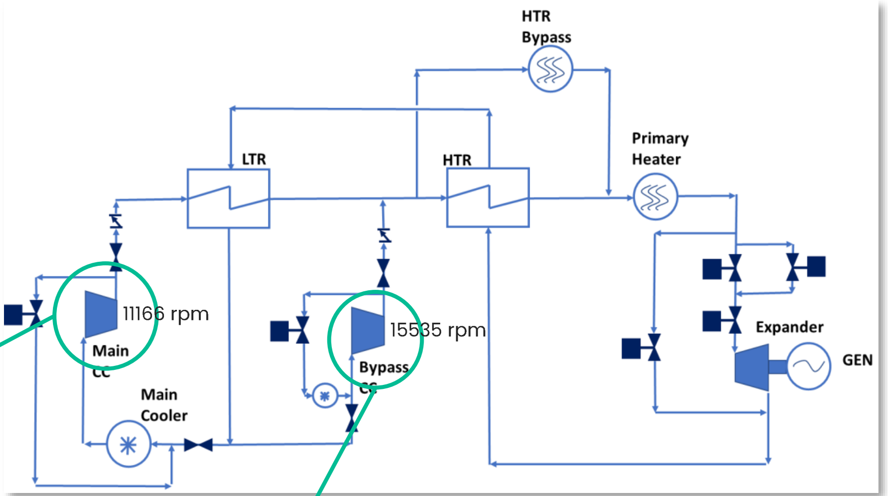
**Main CC - Prototype**

Prototype provided with special internal instrumentation to monitor compressor behavior




| | MSCOM01 | MSCOM02 |
|---|---|---|
| Compressor Model | BCL252/B | BCL303/B |
| bearing span [mm] | 1127 | 1059 |
| 1st Impeller [mm] | 255 | 255 |
| 2nd Impeller [mm] | 255 | 255 |
| 3rd Impeller [mm] | - | 255 |
| Rotating speed [rpm] | 11166 | 15535 |
| JB diameter [mm] | 90 | 80 |
| IGV blade number | 20 | 20 |
| Rotor weight [kg] | 150 | 130 |
| Bundle weight [kg] | 1400 | 1800 |
| Inlet flange size | 8” | 10” |
| Outlet Flange size | 8” | 8” |

- Suction condition far from CO2 critical point
- Standard impeller design
- Variable IGV at compressor suction

## Design Challenges

- ✓ Main compressor **suction condition close to $CO_2$ critical point**: large gradients of thermodynamic quantities
- ✓ Turndown requirements **20%-100%**
- ✓ Critical DGS system: possible **phase change** during operation

## Design Features

- ✓ Main compressor first impeller design ad hoc (**splitter impeller**)
- ✓ **Variable IGV** at compressor suction for each compressor
- ✓ VFD EM driver for each compressor
- ✓ Modification to the standard DGS system arrangement (psv…..)



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# $sCO_2$-Flex Expander

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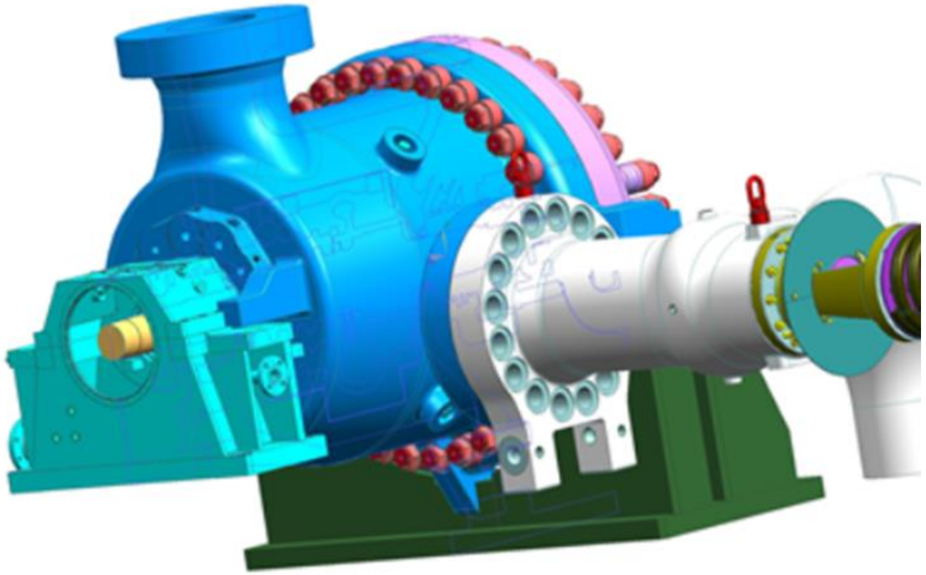
## Design Challenges

- **Thermal stresses** very critical due to the fluid properties.
- DGS needed for cycle performance: necessary **DGS cooling** to limit the temperatures. Developed a **conjugate convective heat transfer model** to have the best predictions: cooling effect obtained by minimizing thermal stresses and cooling flow.
- **Material selection** : needed a tradeoff among corrosion strength, mechanical properties and costs.
- **Extreme power density** (power to inertia ratio): rotor design must be suitable for the high speed reached in case of load rejection.

| | | | |
|---|---|---|---|
| Expander | T suction | [°C] | **620** |
| | p suction | [bar] | **245.5** |
| | T disch | [°C] | **490** |
| | p disch | [bar] | **81** |
| | Power | [MWe] | 38.61 |
| | Mass flow | [kg/s] | 271.8 |
| | Speed | [rpm] | 9000 |

## Design Features

- Expander casing **barrel type**
- Inner casing with **shrink rings**
- Rotor with **n°5 axial stages** having 50% reaction degree.
- **Nickel based alloys** for rotor and inner casing, stainless steel for external casing and valve body.





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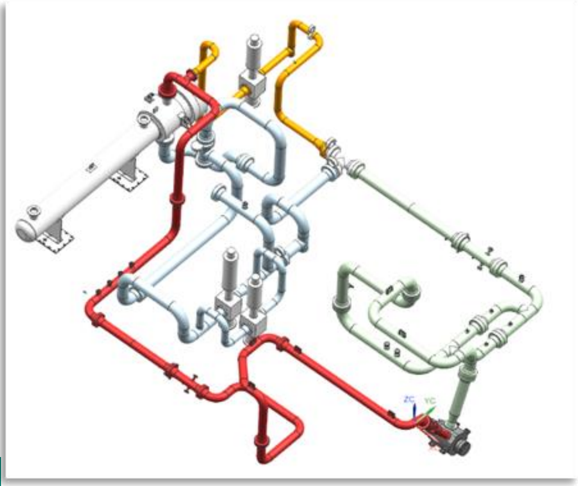
# $sCO_2$-Flex Main Compressor Test

## Test Challenges

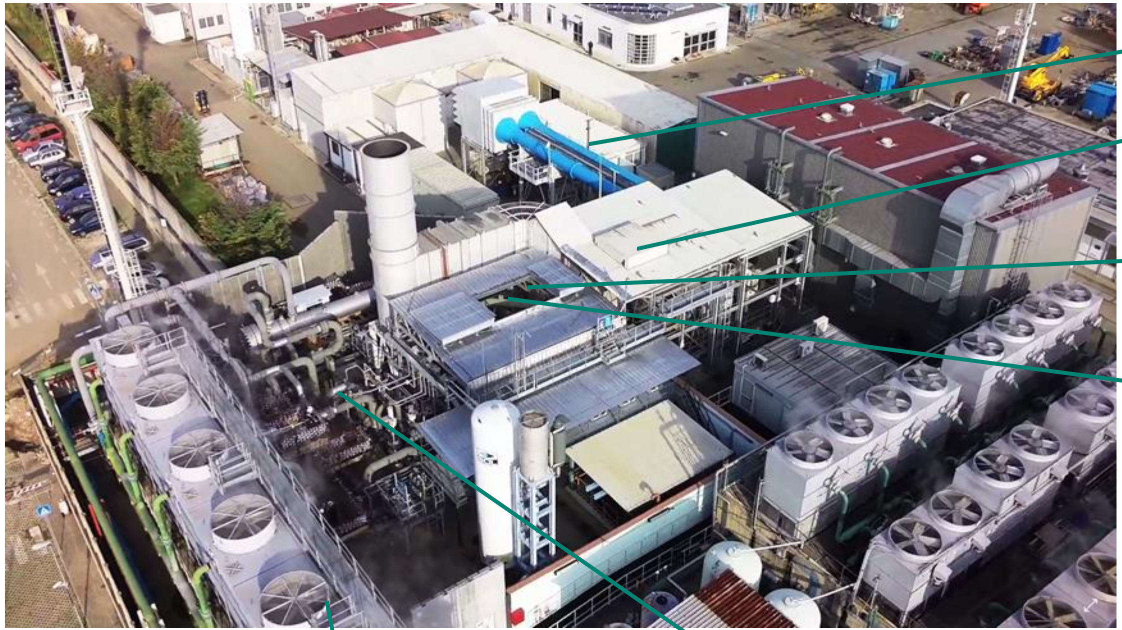
- Main compressor **suction condition close to $CO_2$ critical point… suction control temperature is critical**
- Possible **$CO_2$ phase change** in transient conditions, off-design, pressurized stops
- High $\rho \cdot v^2$, critical piping and material design

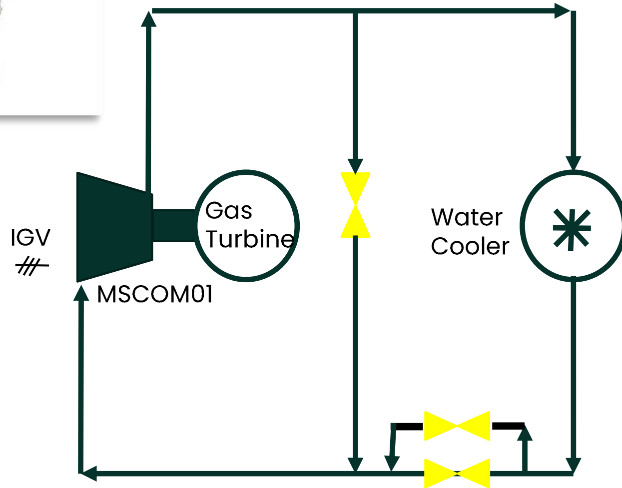
## Test Objectives

- Validate compressor performance predictability
- Explore off-design conditions (low/high temperature)



Test arrangement to $sCO_2$ CC prototype



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# $sCO_2$–Flex Highlights

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- High $CO_2$ density allows to reduce significantly turbomachinery size. This high power to inertia ratio would require innovative solutions and selection of special materials
- Turbomachinery design has been carried out in line with project requirements (Plant electrical load flexibility, capability to operate close to $CO_2$ critical point).
- Both turbomachinery layouts equipped with DGS sealing system
- BH finalized design and manufacturing of $sCO_2$ 5MW prototype compressor operating close to $CO_2$ critical point. Test scheduled for Q1 ‘21