

CO2 compression capabilities

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GE imagination at work

Enabling technologies

l a n d • o f f s h o r e • s u b s e a



Agenda

- CO₂ compression
- Experience

CO₂ Re-injection

Equation of State

- GE has used the BWRS EOS for the last 30 years: up to 300 bar on regular basis and up to 540 bar with CO₂ + HC gas mixture in specific cases also in the supercritical region

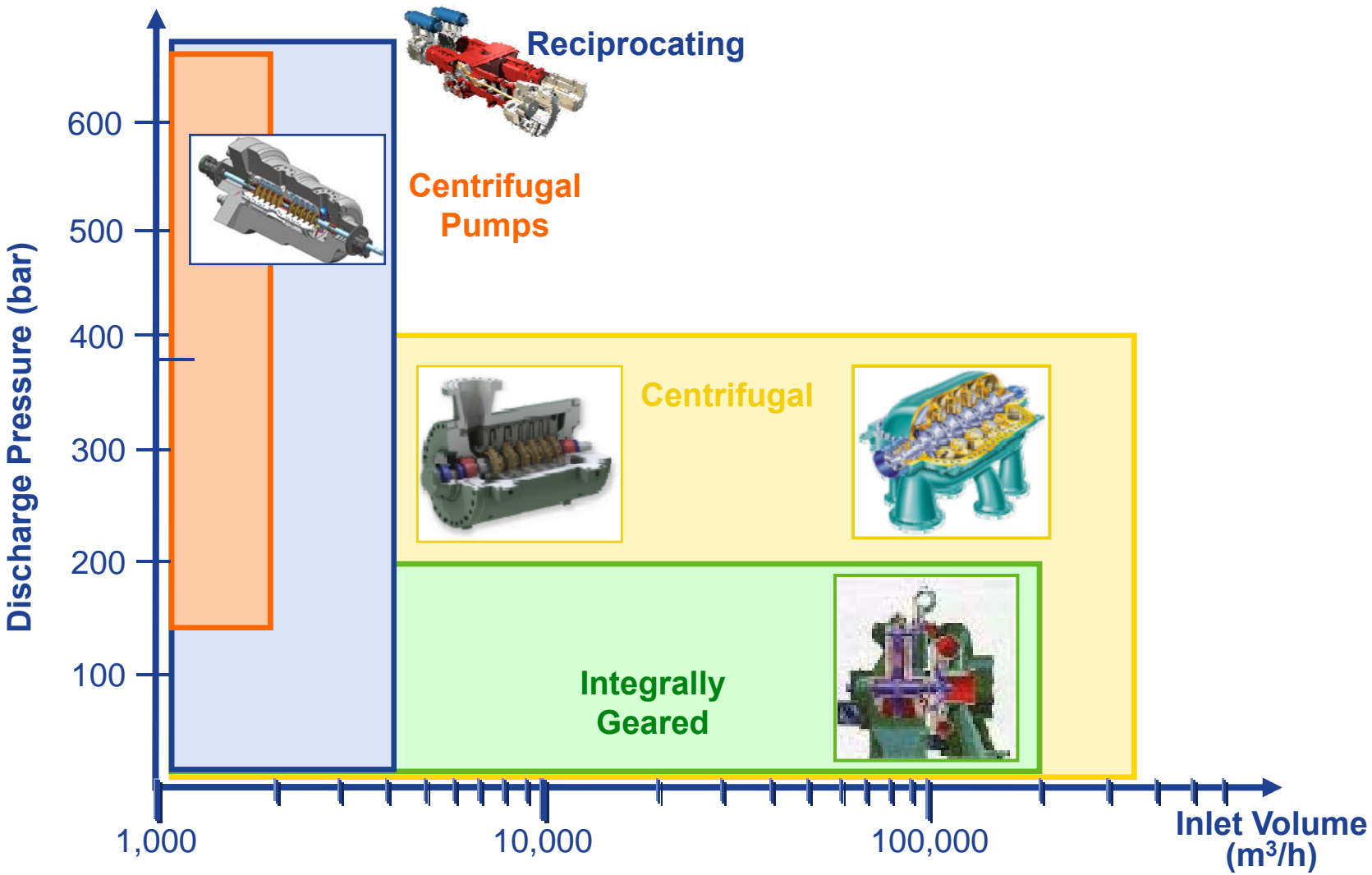
$$P = RTD + (BoRT - Ao - Co/T^2 + Do/T^3 - + Eo/T^4)D^2 + (bRT - a - d/T)D^3 + \alpha(a + d/T)D^6 + c/T^2)(1 + \gamma D^2)D^3 e^{-\gamma D^2}$$

BWRS Equation

BWRS above 480 bar requires careful verification of literature data and is not suitable for liquid-vapour equilibrium calculations

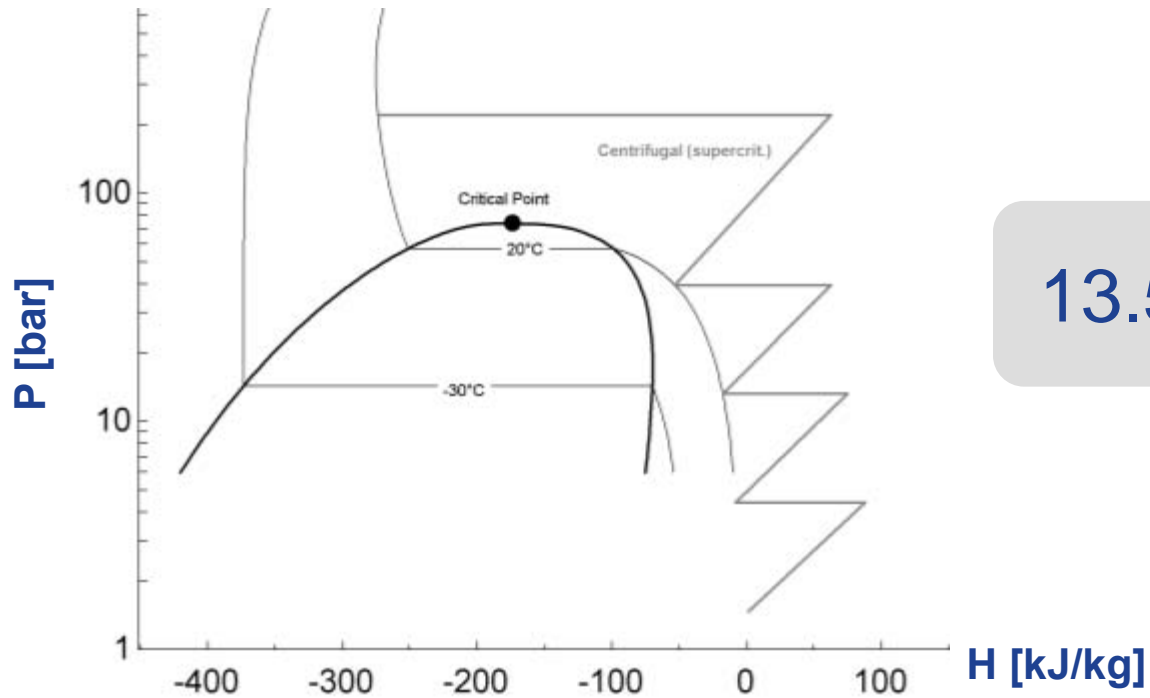
- Many existing CO₂ EOS are optimized for pure CO₂ but not for mixtures
- To allow for regions not adequately covered by current EOS, GE is introducing a new thermodynamic model to improve predictability

Product Lines for CO₂ Compression



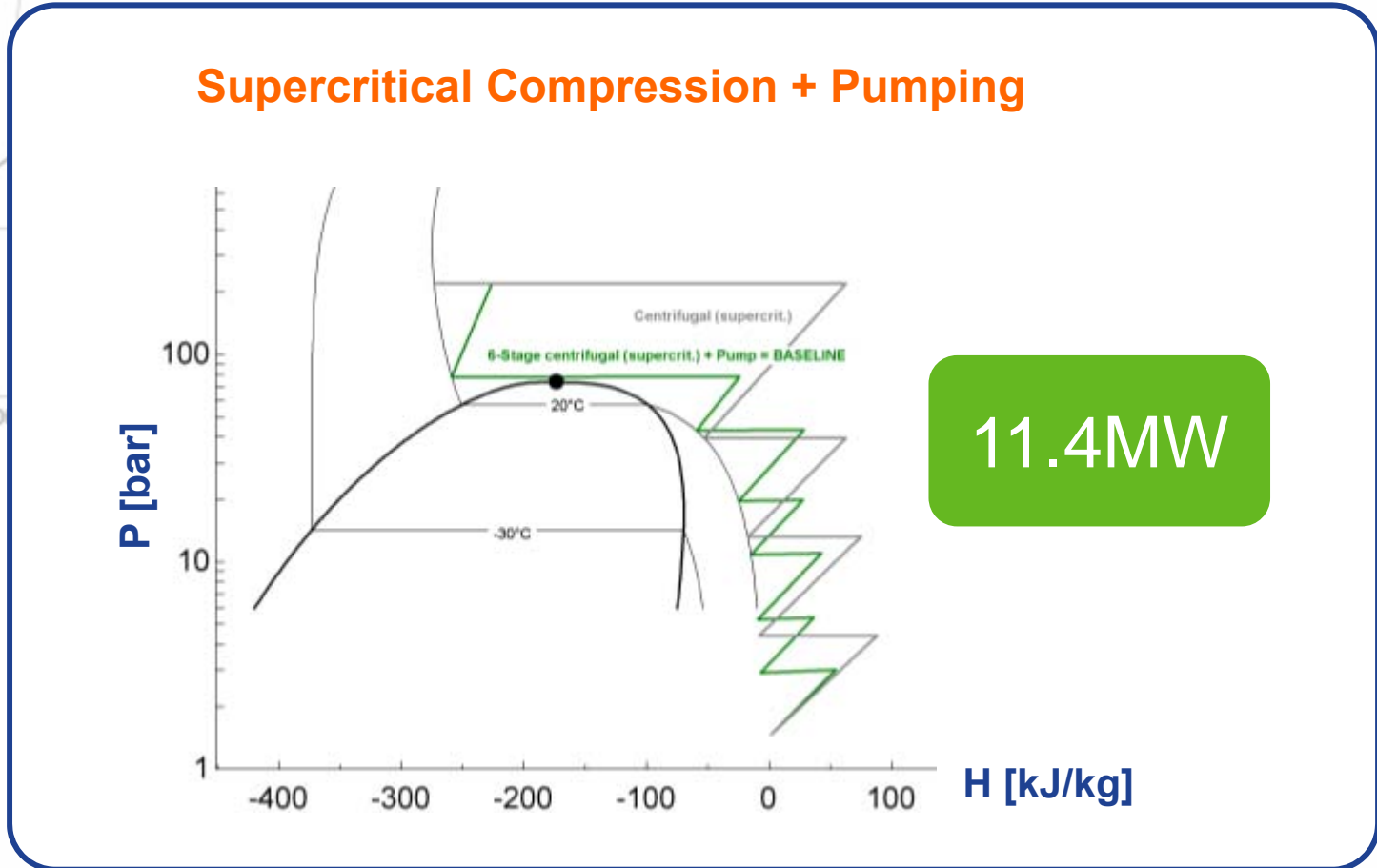
Compression + Pumping Optimization

Compression from 1.5 bar up to approx. 220 bar



Compression + Pumping Optimization

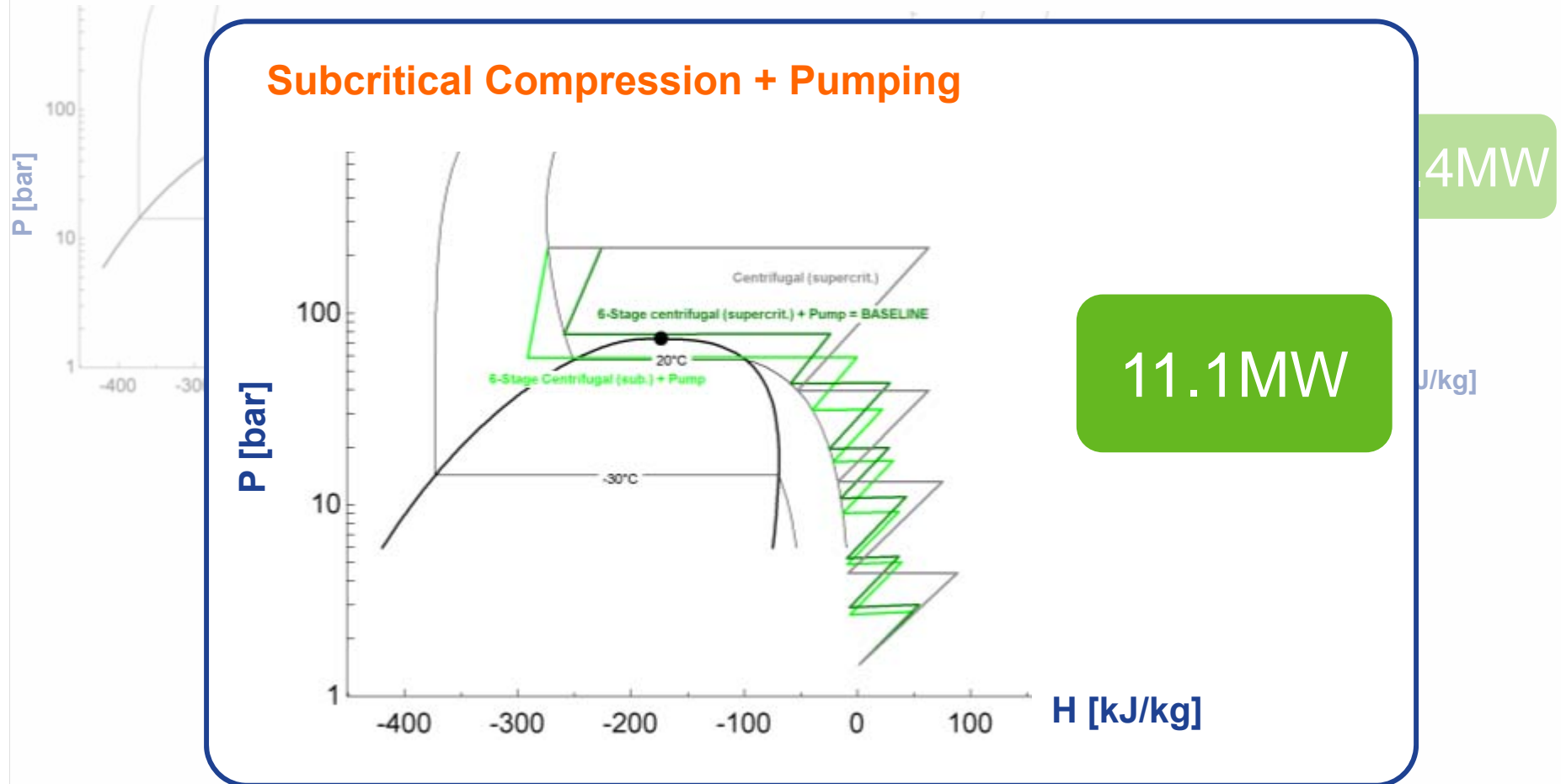
Compression from 1.5 bar up to approx. 220 bar



Compression + Pumping Optimization

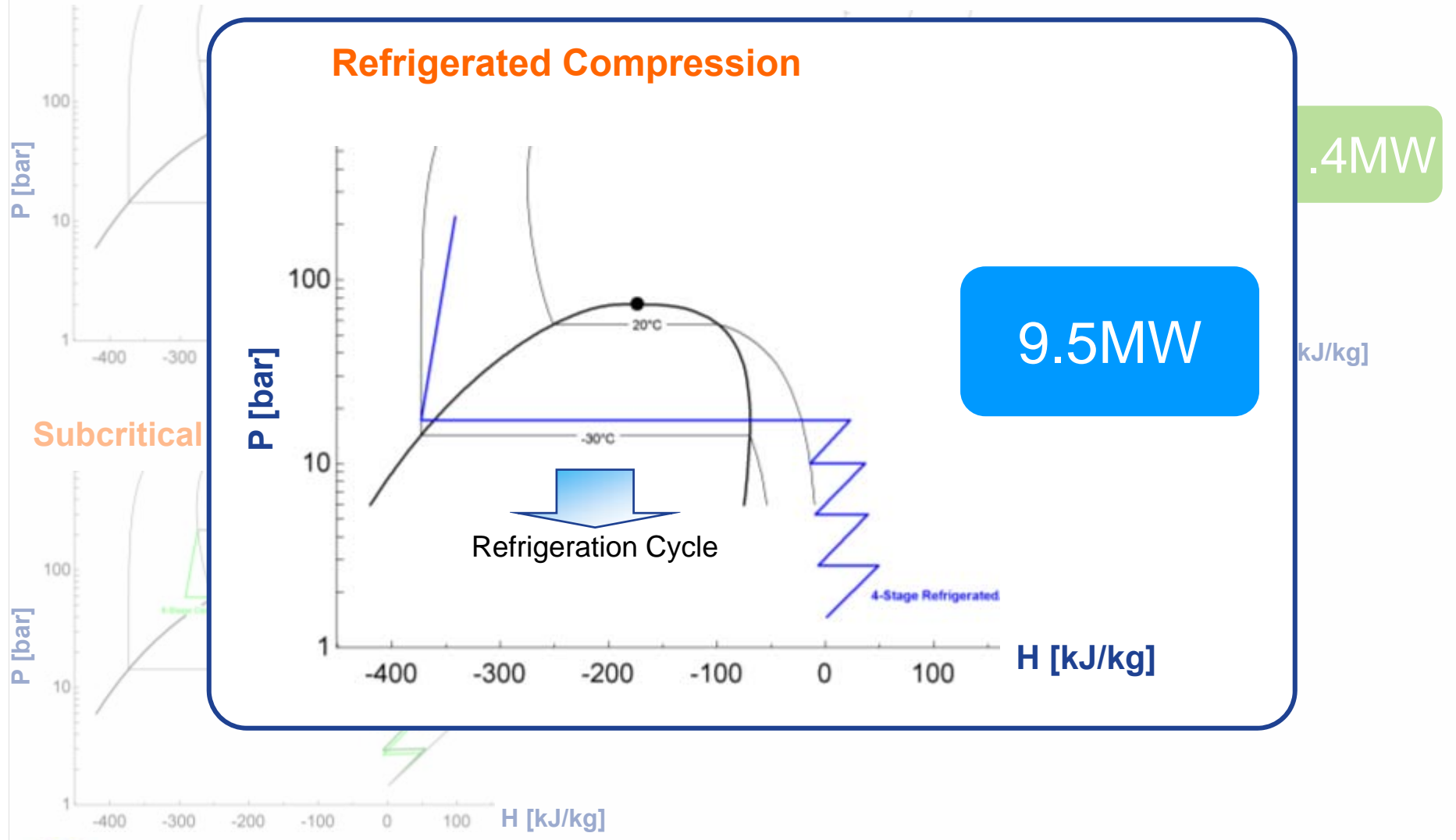
Compression from 1.5 bar up to approx. 220 bar Supercritical Compression + Pumping

Subcritical Compression + Pumping



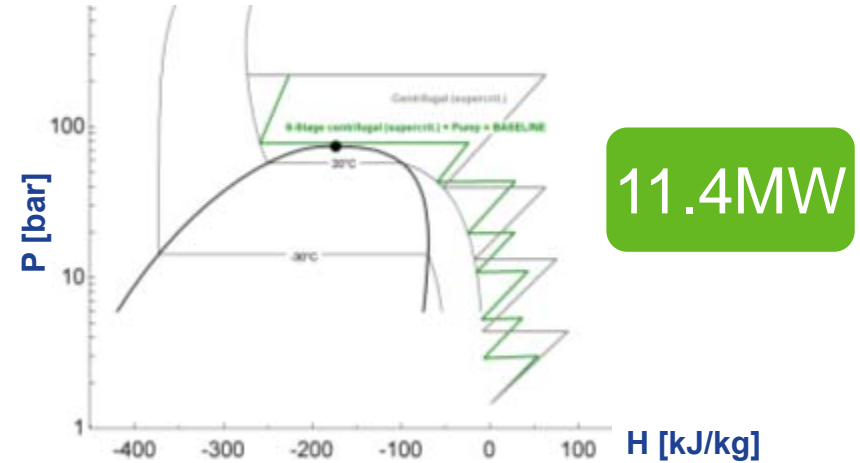
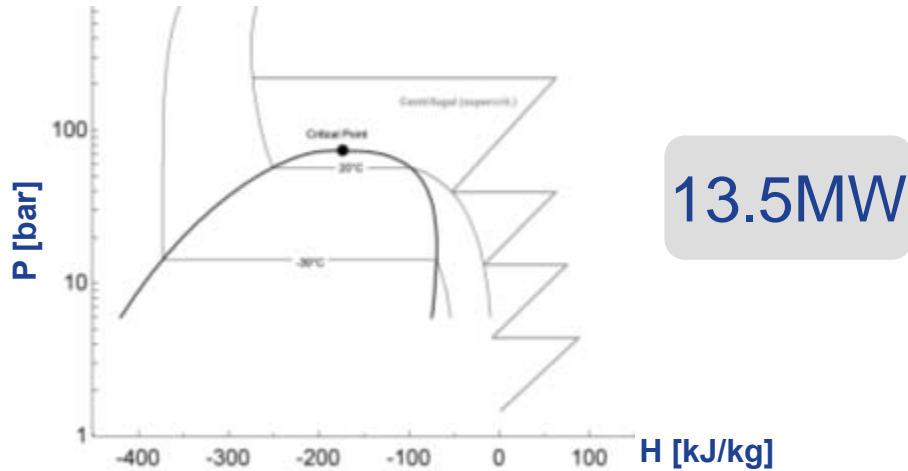
Compression + Pumping Optimization

Compression from 1.5 bar up to approx. 220 bar Supercritical Compression + Pumping

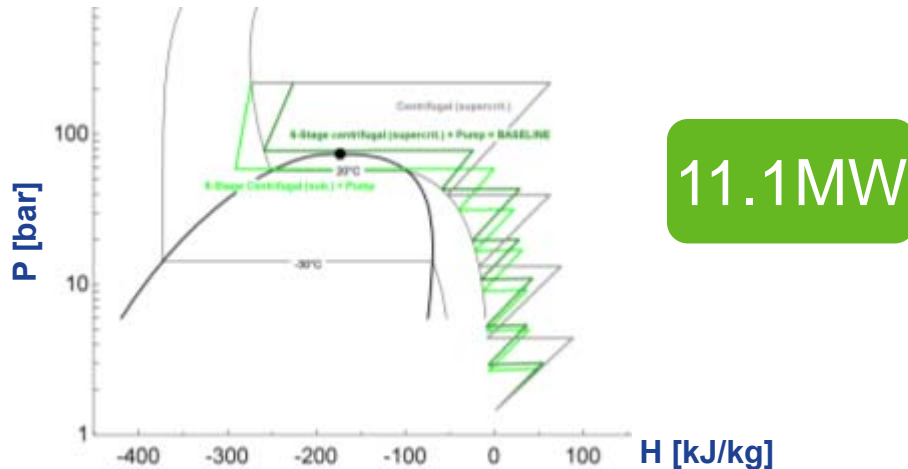


Compression + Pumping Optimization

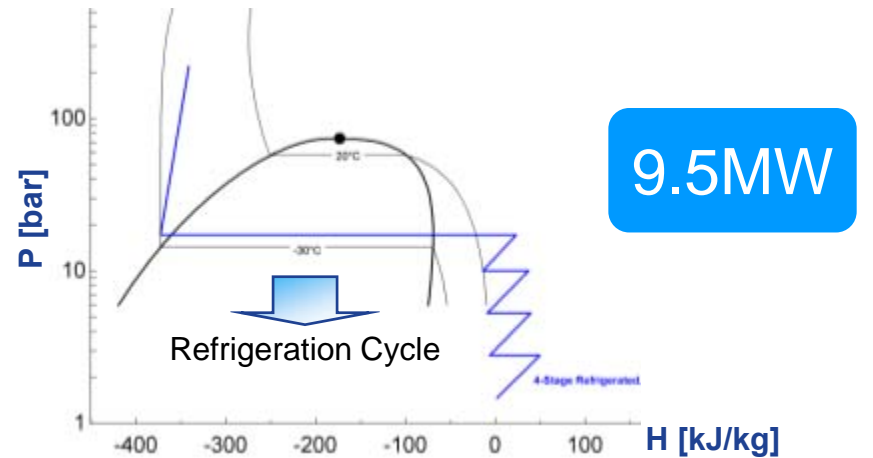
Compression from 1.5 bar up to approx. 220 bar Supercritical Compression + Pumping



Subcritical Compression + Pumping

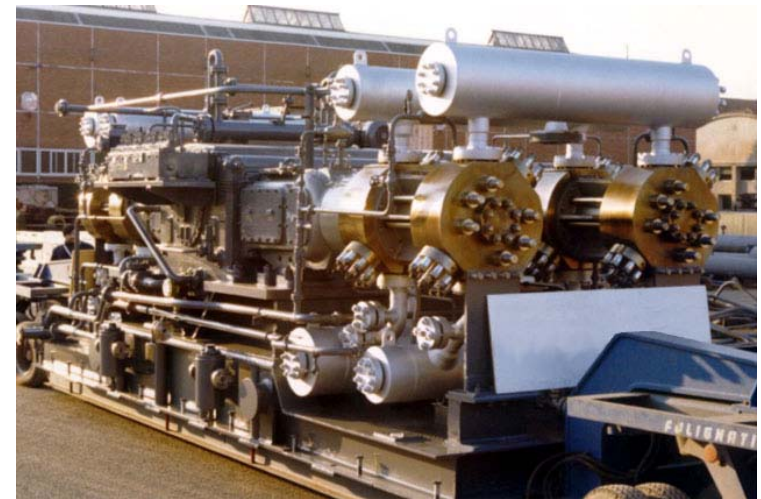
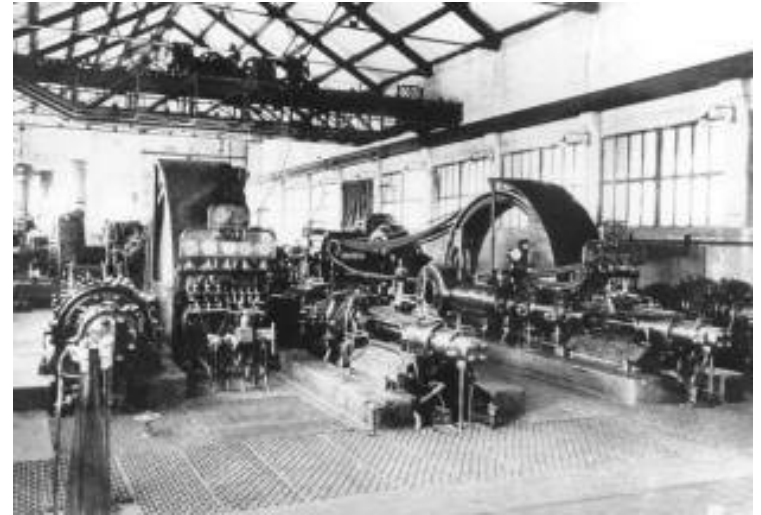


Refrigerated Compression



CO₂ Reciprocating Compressor Experience

- Many years of experience ... started with fertilizers plants
- 180+ machines in operation processing CO₂ or gases containing CO₂, H₂ and H₂S
- Up to 750 bara disch. pressure ... 19,000 Nm³/h max requested capacity
- Most recent major experience CO₂+H₂S reinjection ... 55,000 Nm³/h @ 486 bara max. discharge pressure
- From small to large compressor sizes (HG frame)



CO₂ Centrifugal Compressor Experience



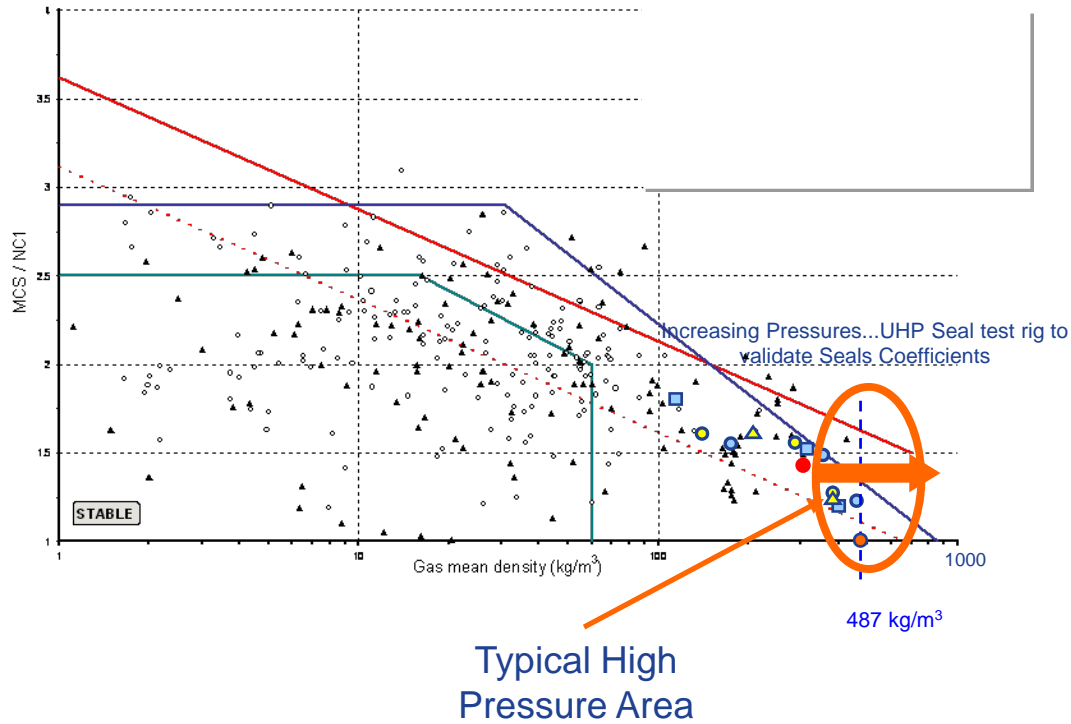
References

- 200+ units installed since 1968
- Discharge pressure up to 280 bar/a
- Compressor power ... up to 18 MW
- Inlet flow ... 2,000 to 300,000 Nm³/h
- World's Largest Single Train capacity (3450 t/d QAFCO Qatar)
- 90+ Urea Plants ... 13 Million Operating hours

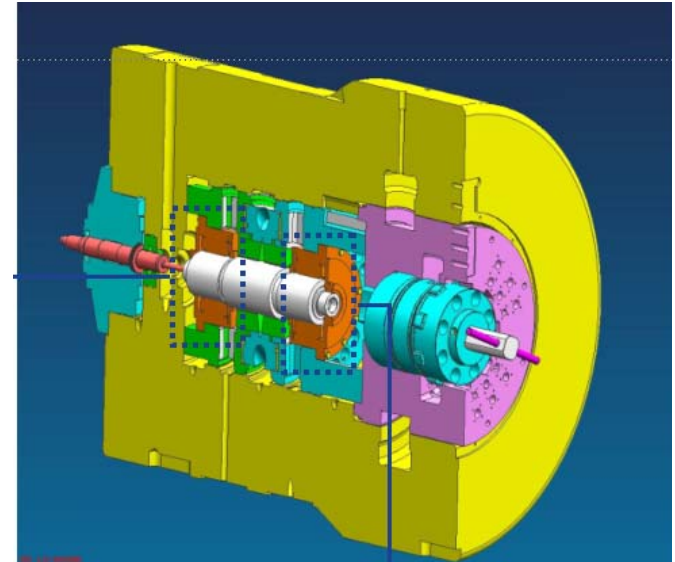
Technical design challenges

- Aerodynamics
 - Very high pressure ratio and compressibility
 - Wide range of flow coefficient stages
- Rotor Dynamics
 - Very high density and destabilizing effects
 - Predictability of compressor seal dynamic coefficients

CO₂ compression ... Rotordynamics



Experimental validation of seals



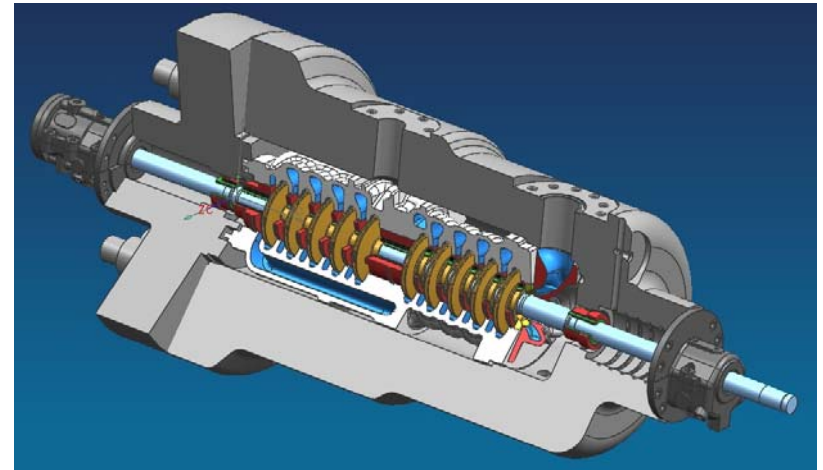
- Operating pressure : up to 400 bar
- Rotational speed: up to 18000 rpm
- Test gas: N₂, CO₂
- Design Pressure: 500 Bara

**Extensive Experience in High Density Applications ...
Record discharge press with centrifugal
compressor: 915 bar... UHP Seal Test Rig to move
the boundaries**

CO₂ Pumping Experience

Brazil HP pilot project

- Custom designed mechanical seal qualification process
- Rotor dynamic stability assessment
- Physical properties of supercritical gas mixture tested by SWRI
 - Suction pressure 300 bar
 - Discharge pressure 540 bar
 - Design pressure 670 bar (API 6A 10000)
 - Flowrate 10 kg/s
 - Four pumps in series
 - Installation on FPSO
 - Triple mechanical seal configuration
 - Job delivery date: 31/12/2009



First reference for this service



CO₂ Compression Summary

- Both compressor and pump technology in-house
- Compression + pumping thermodynamic optimization
- Many years of experience in CO₂ compression ... centrifugals and reciprocating
- Leverage experience in HP re-injection compression
 - Rotordynamics
 - Seals
 - Low flow stage aerodynamics
- Validation activities in place ... Gas properties and UHP test rig

Questions