



Carbon Dioxide Compression

DOE – EPRI – NIST

Large CO_2 Compression Workshop

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CO_2 Compression Applications

- CO_2 pipeline transmission
- CO_2 production
- CO_2 injection - enhanced oil recovery
- Feedstock for urea & fertilizer plants
- Food & beverage processing
- Refrigerant, propellant, fire extinguishers
- *Greenhouse gas sequestration*

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CO_2 Miscible Flooding

- CO_2 Injection for EOR has a four-fold benefit
  - Lowers viscosity of the oil in place
  - Provides a measure of pressure drive
  - Can penetrate more types of rocks better than other enhancing agents
  - Leaves a cleaner well

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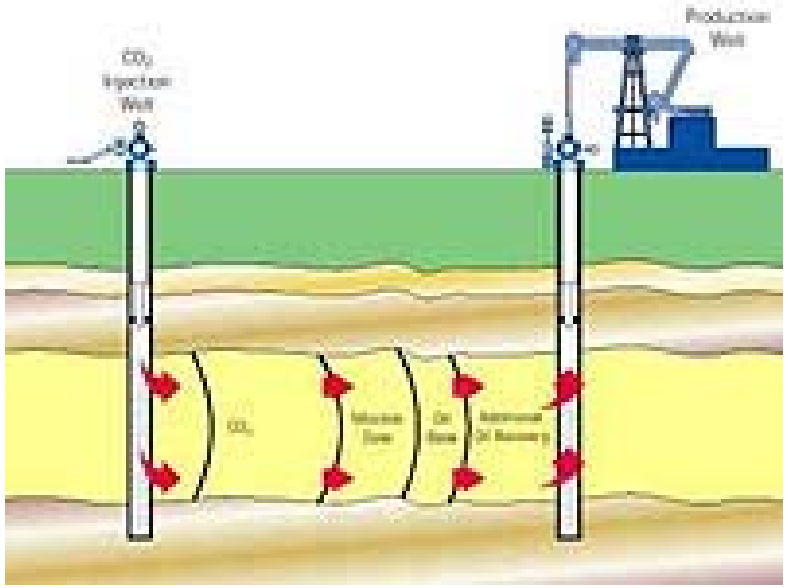
CO_2 Miscible Flooding

continued…

- CO_2 injection proven to be one of the most efficient EOR methods since its introduction in the early 70's.



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CO_2 Compression Experience

- Centrifugal
  - More than 100 units, first shipped in 1948, most recent 2009
  - Max discharge pressure;
    - more than 2,500psia (175 bar) operating
    - more than 4,400psia (300 bar) - delivery 200
  - Installed in 16 different countries
  - Max inlet flow greater than 48,000 acfm (82,000 m3/hr)
  - Max power greater than 15,000 bhp (11,000 kW)
  - Total installed power > 400,000 bhp (>300MW)

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D20R4S CO_2 Booster Rotor & Internal Flowpath

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CO_2 EOR Recycle Unit - Canada

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Sleipner CO_2 Injection Compressor

- First CO_2 re-injection project for the purpose of mitigating greenhouse emissions
- 9 million tons CO_2 injected

Harald Underbakke

STATOIL

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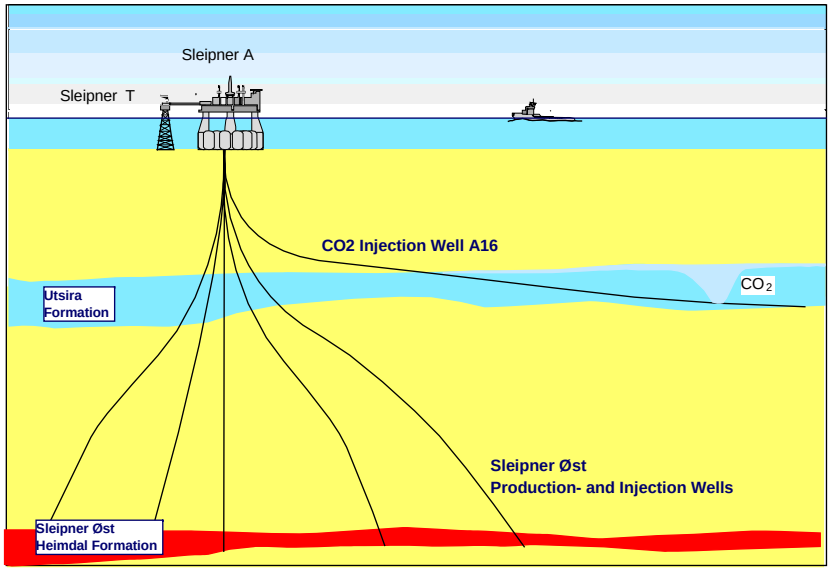
Sleipner CO_2 Injection Compressor

continued…

- Objective: reduce the CO_2 content from 9% to 2.5% (sale spec.)
- Capture the CO_2 by an amin plant
- CO_2 storage in an aquifer
- Start up: Aug 1996
- Injection: ~ 1 mill ton CO_2/yr
- Regularity: 98-99%



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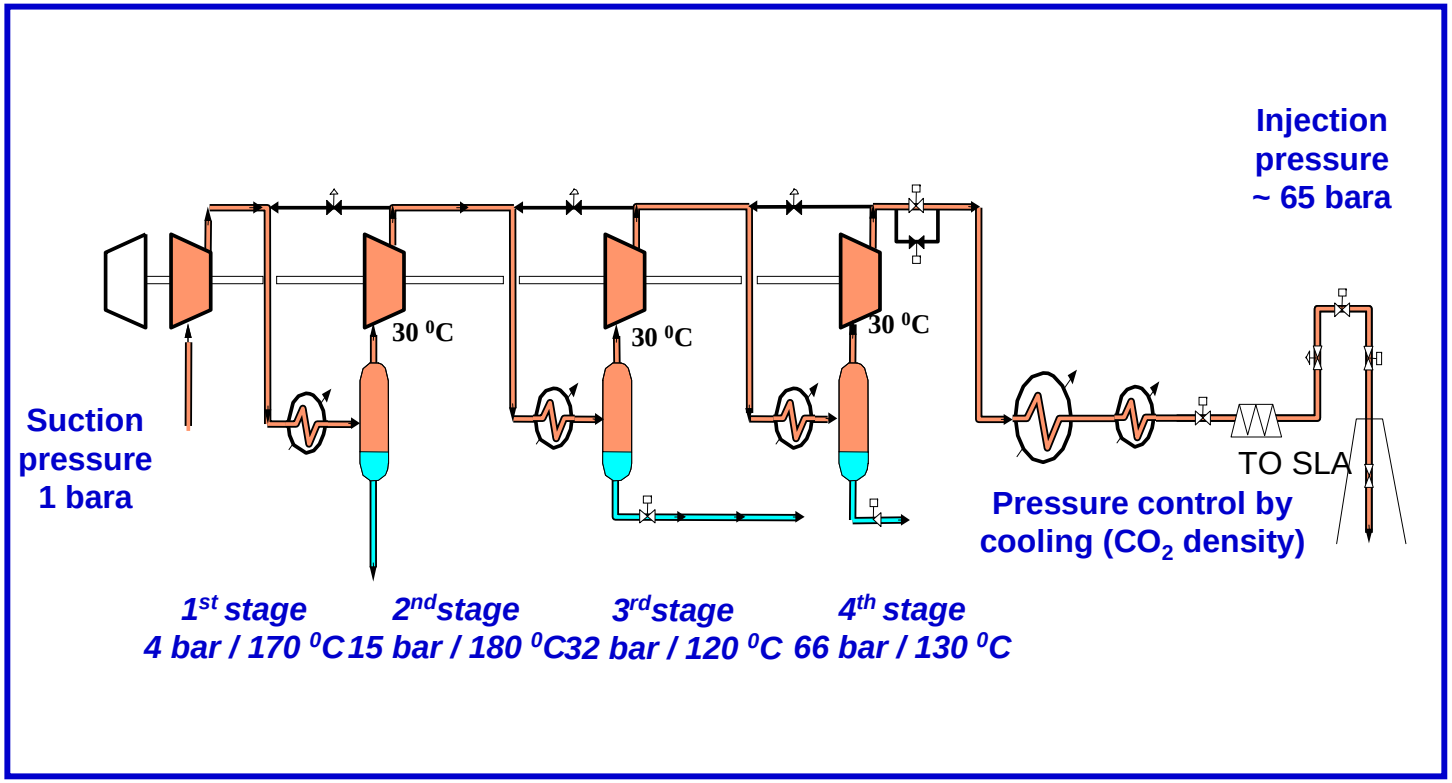
CO_2 Compression and Injection Systems



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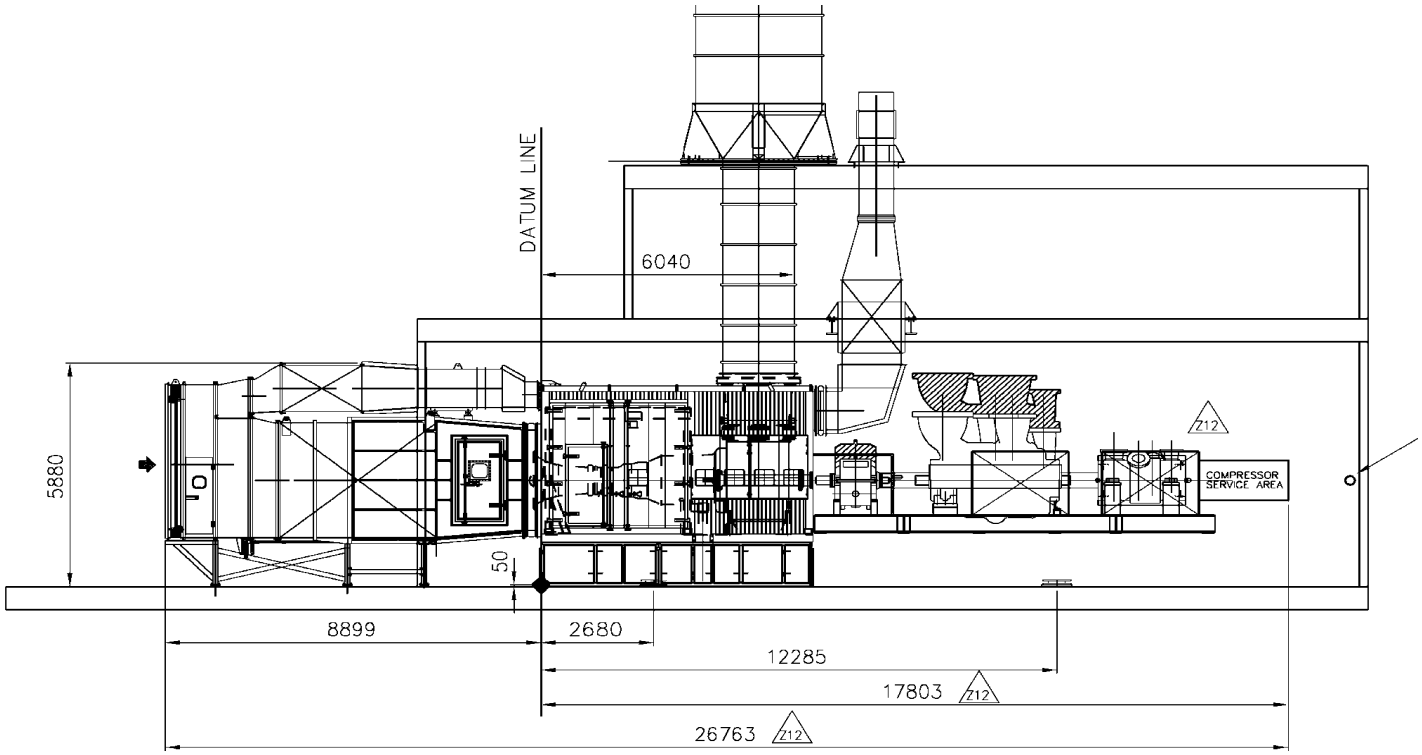
Compressor General Arrangement



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Platform and Injection Module

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1st and 2nd Stage Compressor

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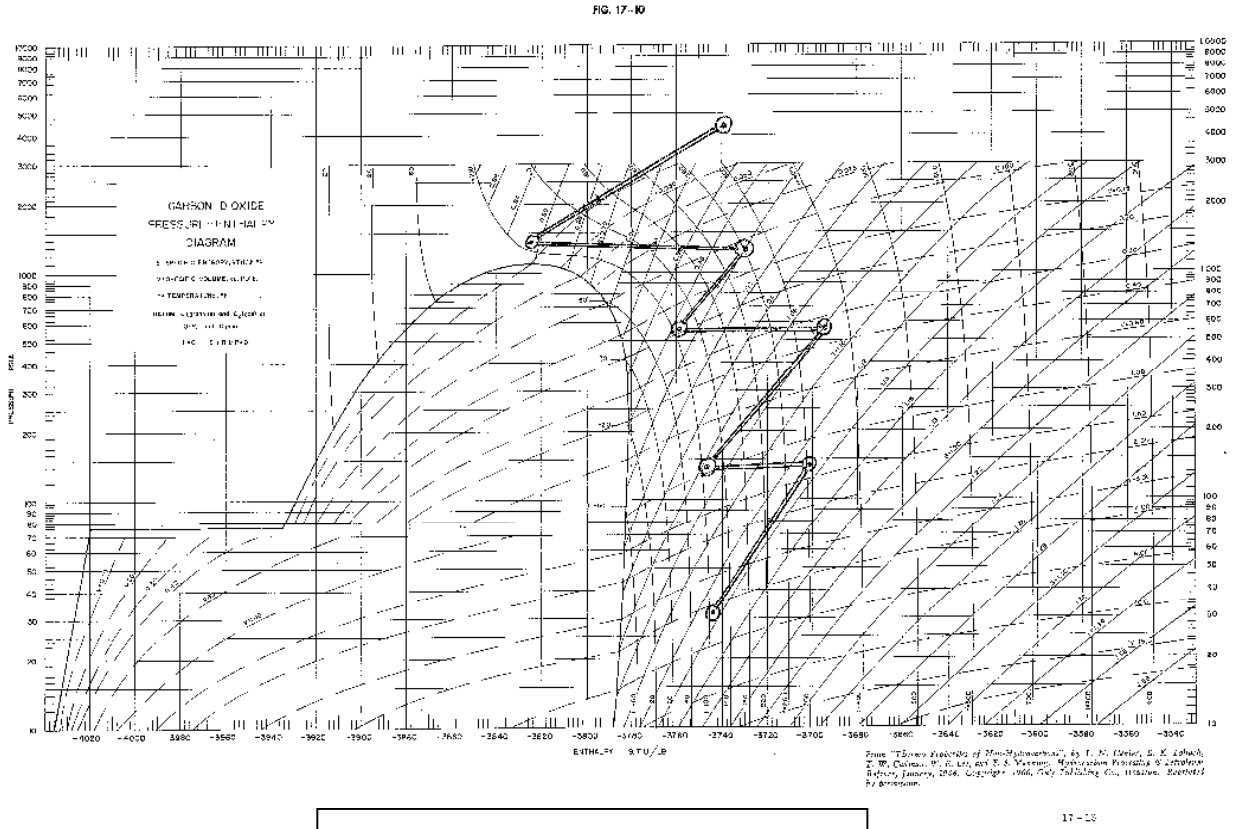
D-R High Pressure CO_2 Application



4472 psia final pressure

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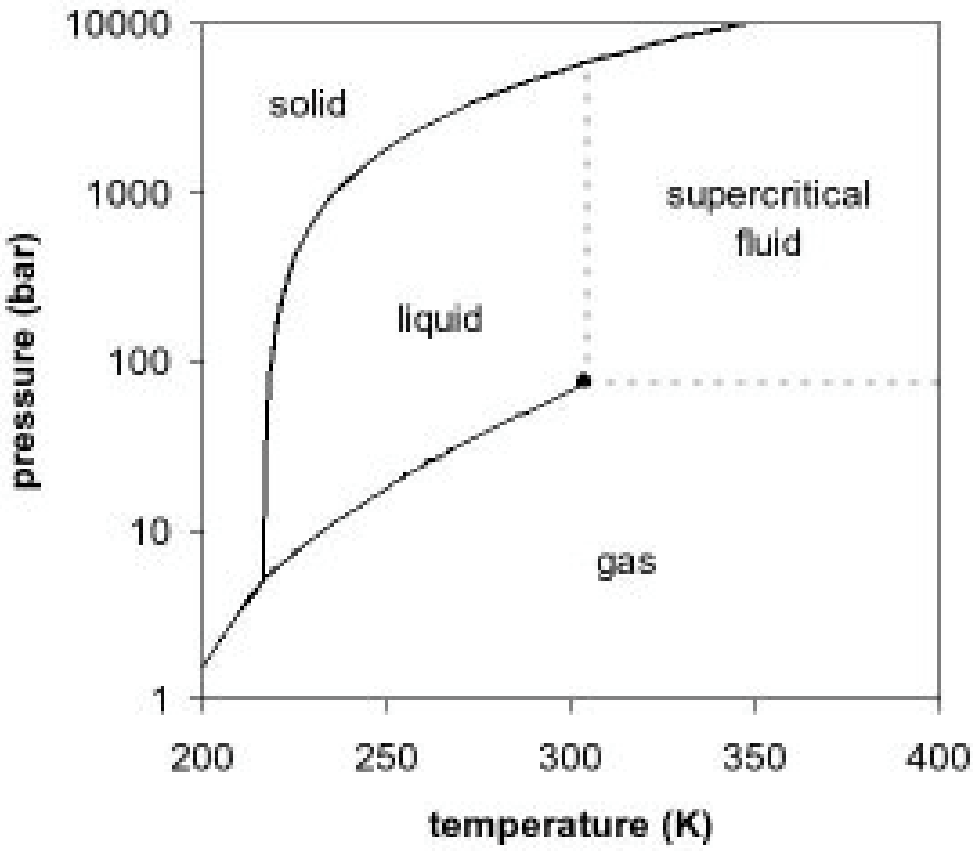
CO_2 Phase Diagram



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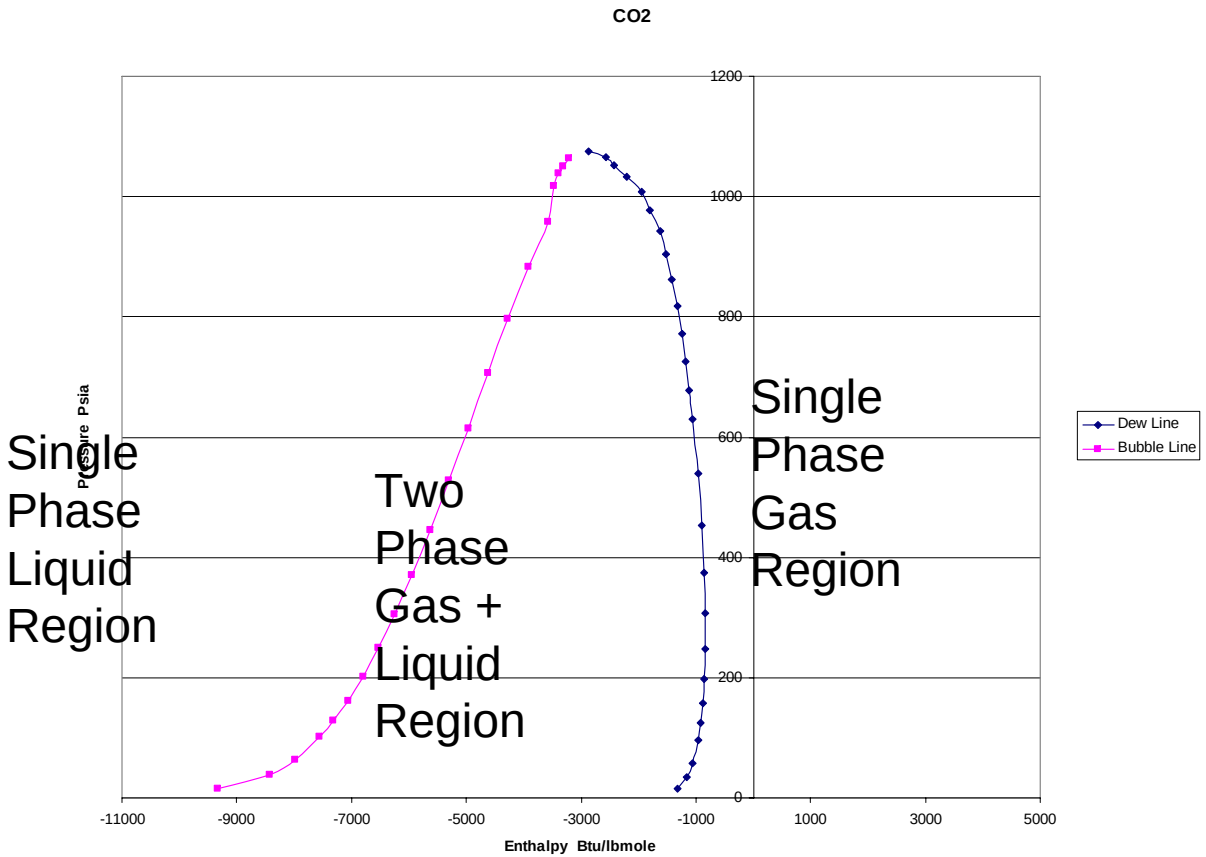
CO_2 Sealing Gas Phase Map



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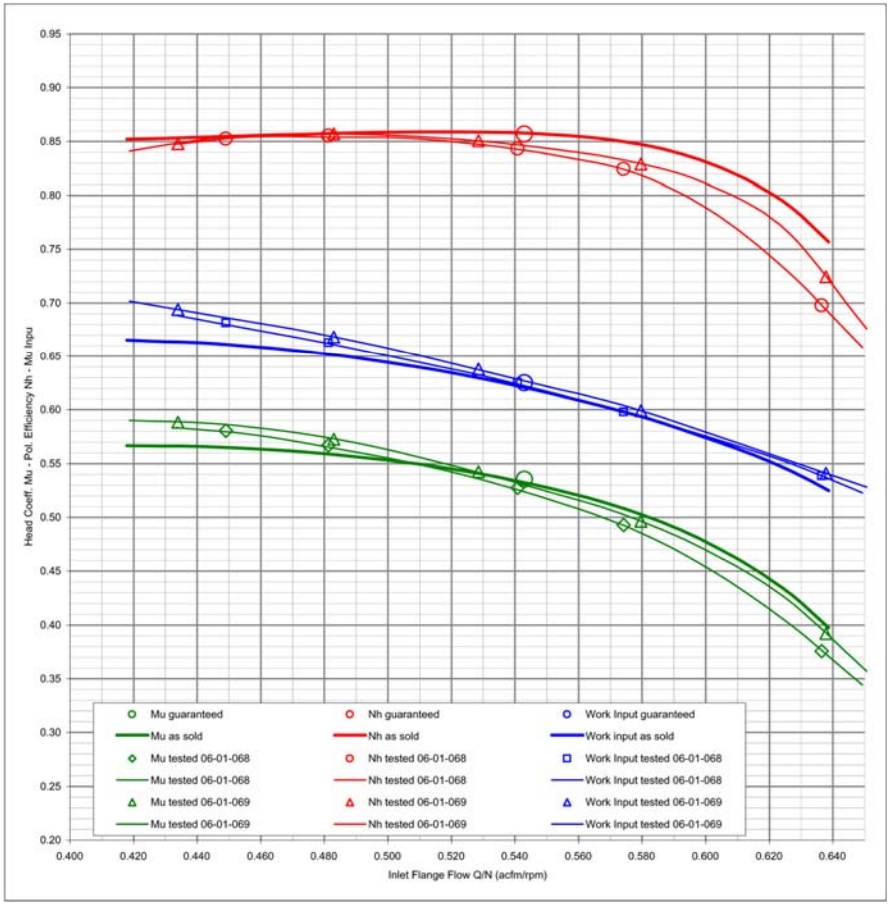
DATUM CO_2 Predicted vs. Actual Performance



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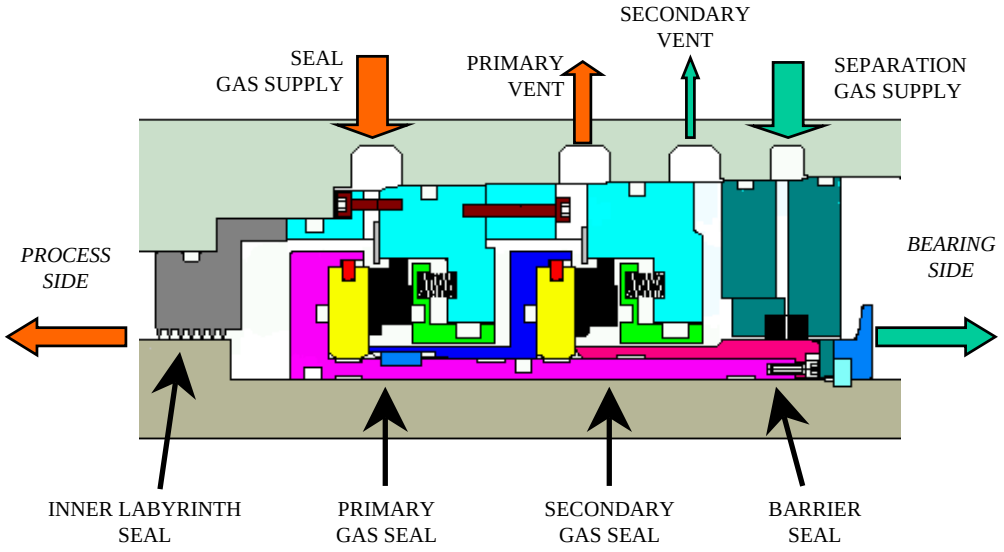
D-R Shaft End Seals - Dry Gas Seals

- Minimum leakage - approx. 1 scfm
- Requires seal gas supply
  - Normally comes from compressor discharge
  - Alternate supply source is usually required for start-up
- D-R manufactures their own high-quality gas seals



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CO_2 Compression Experience

- Reciprocating
  - more than 200 units, first shipped in 1928, most recent 2007
  - Max discharge pressure - more than 6000 psig (425 bar)
  - Max inlet flow - more than 4000 acfm (7,000 m3/hr)
  - Max power - greater than 5,000 bhp (4,000 kW)
  - Total installed power > 530,000 bhp (>395MW)

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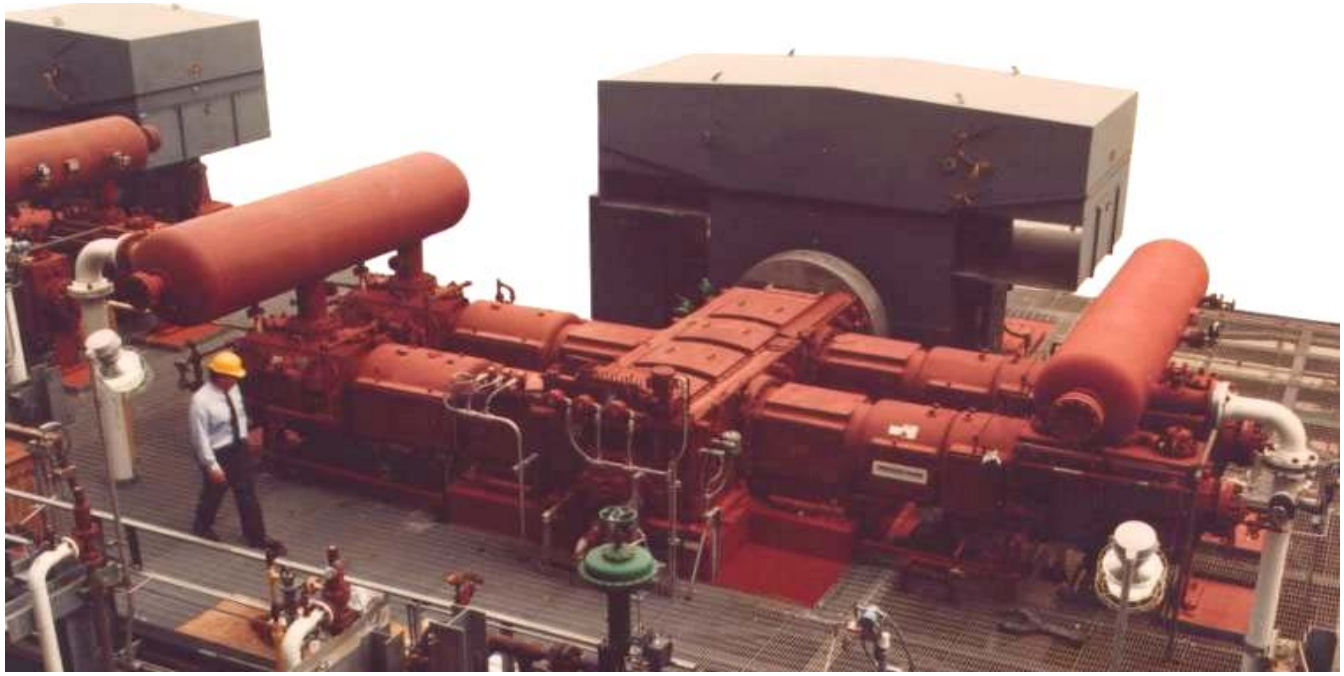
Process Reciprocating Compressor



5,500 HP HHE-VL Process Reciprocating Compressor on Hydrogen Makeup Service in USA Gulf Coast Refinery

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Challenges with CO_2 Compression

- The presence of water together with CO_2 creates carbonic acid which is corrosive to carbon steels. The use of stainless steel for any components in contact with wet CO_2 eliminates the problem.
- Similarly, the presence of water with CO creates iron carbonyl upon contact with carbon steel. Again, the use of stainless steels for solves the problem.
- Special O-ring materials required to resist explosive decompression due to entrapped CO_2.

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Toxic Effects of H_2S

- 1 PPM smell
- 10 PPM 8 hr. TWA
- 100 PPM loss of smell
- 300 PPM loss of consciousness with time (~ 30 min.)
- 1000 PPM immediate respiratory arrest, loss of consciousness, followed by death

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Future Considerations...

- Increasing the amount of inter-stage cooling will reduce the overall power required for CO_2 compression.
- Advanced inter-stage cooling concepts are being investigated to improve the effectiveness of existing water-cooled stationary diaphragms.
- D-R working with SwRI on DOE-NETL funded project to develop advanced inter-stage cooling for traditional multi-stage inline centrifugal compressors.
- D-R supporting RAMGEN supersonic compression development.

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High Capacity and High Power Compressor Experience

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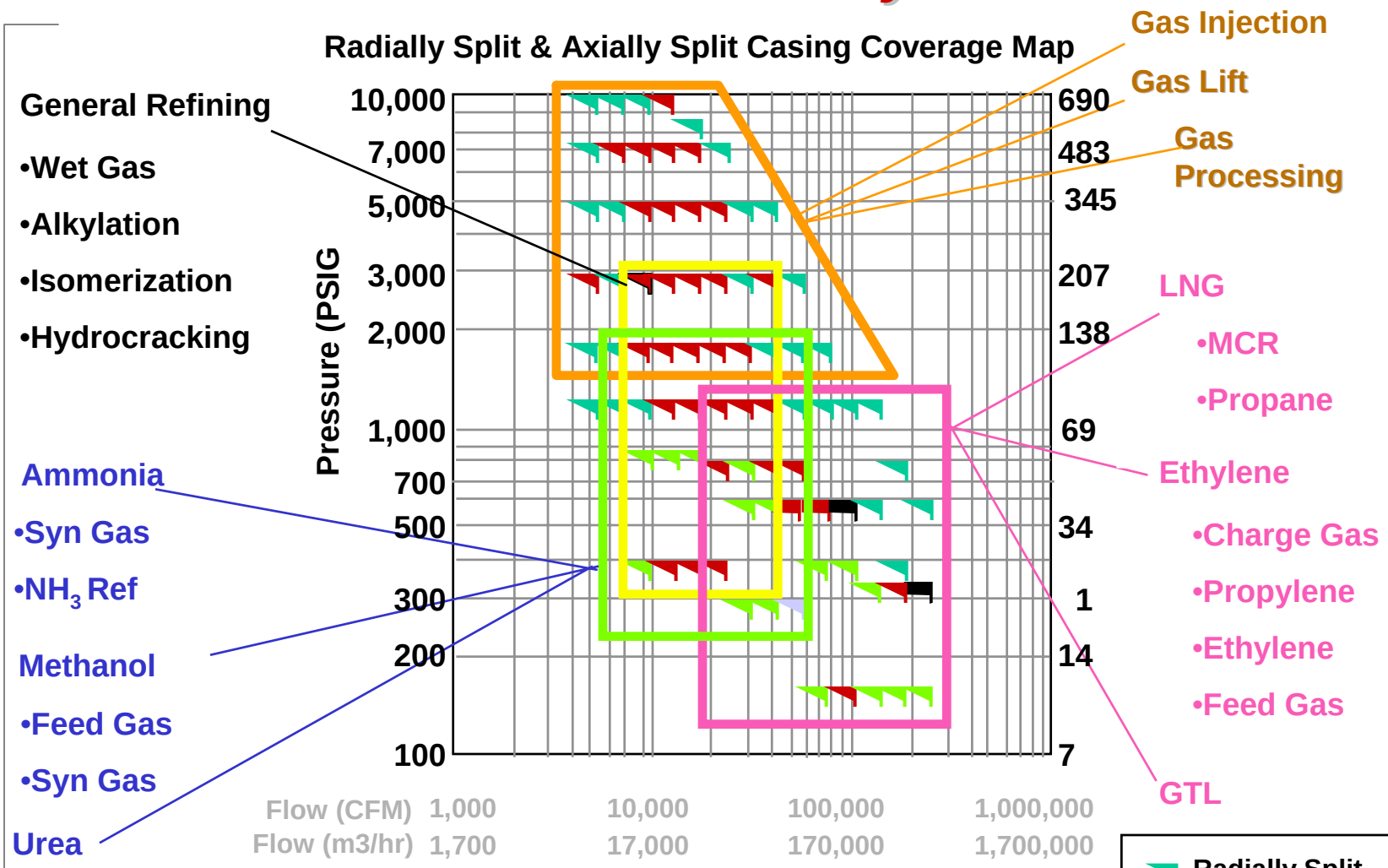
DATUM Product Flexibility



- •Gas Mole Wt 2 - 44+
- •Horsepower 500 - 120,000+
- •Speed 2,000 - 35,000 RPM
- •14 Frame Sizes

- •5 Imp. Famlies / Frame
- •Impeller Dia 9” - 66”
- •Case ID 17” - 123”

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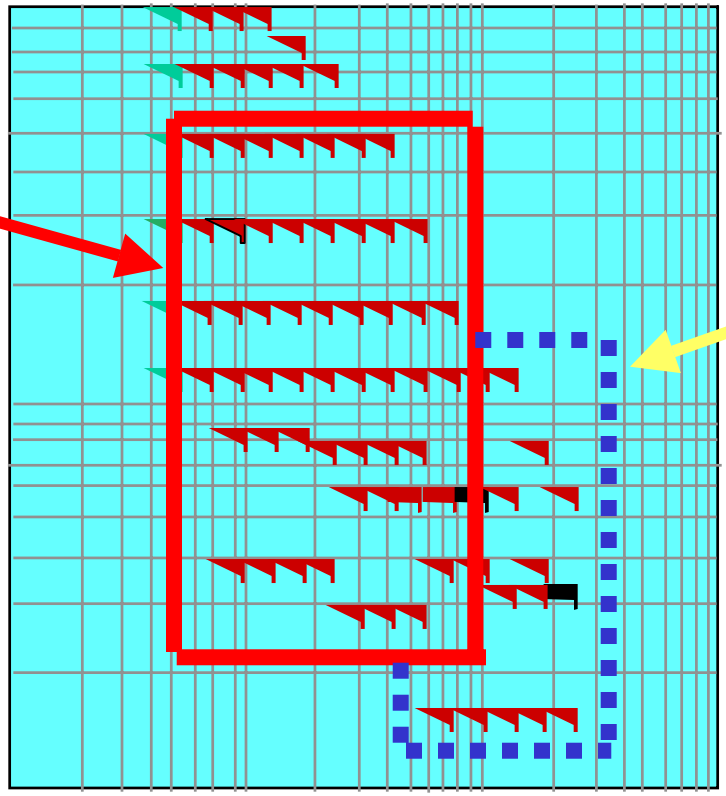
DATUM Product Flexibility

Radially Split & Axially Split Casing Coverage Map

CO_2 Experience To Date



Future Full-Size IGCC, Oxy-Coal, & PC CCS Applications

Flow (CFM)	1,000	10,000	100,000	1,000,000
Flow (m3/hr)	1,700	17,000	170,000	1,700,000

- •Gas Mole Wt 2 - 44+
- •Horsepower 500 - 120,000+
- •Speed 2,000 - 35,000 RPM
- •14 Frame Sizes

- •5 Imp. Famlies / Frame
- •Impeller Dia 9” - 66”
- •Case ID 17” - 123”

Radially Split
Axially Split
Radially & Axially Supplied

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LNG Liquefaction Compressors
Large Trains = Large Casings

Over (100) Dresser-Rand compressors are in liquefaction services. Nine (9) of these very large Dresser-Rand vertically split compressors are operating in propane refrigeration service.

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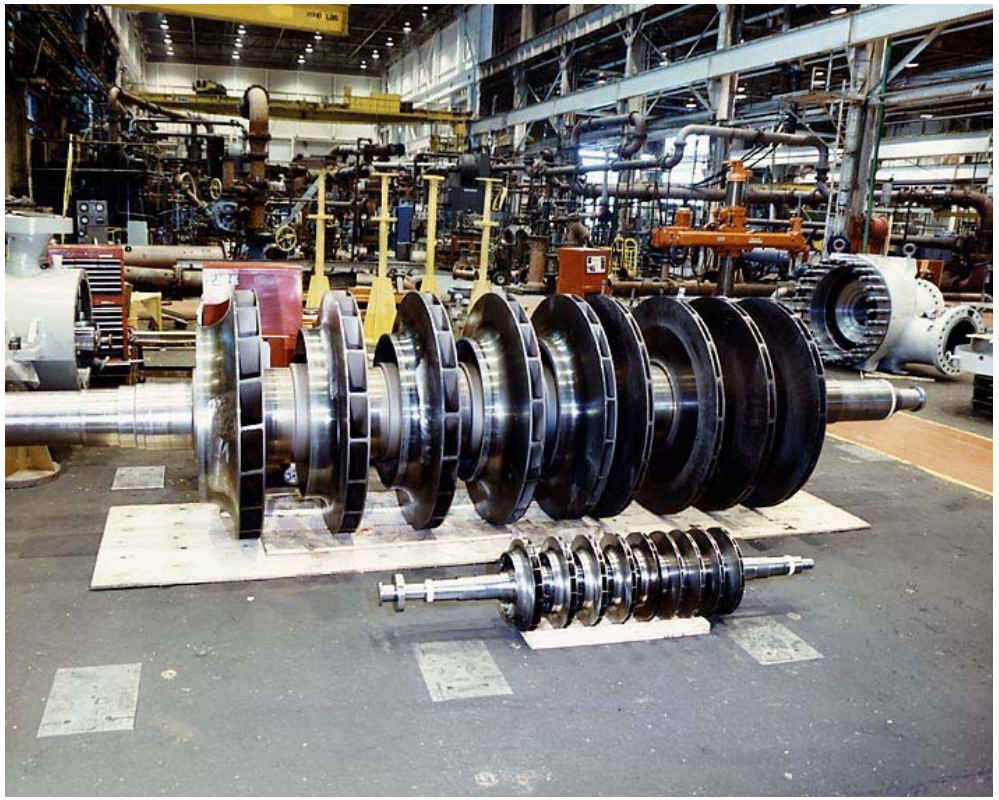
DATUM D26R9B Rotor (background) + D10R9B Rotor (foreground)



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DATUM D26R9B

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DATUM & RR Trent on Test
52 MW Rating at ISO Conditions

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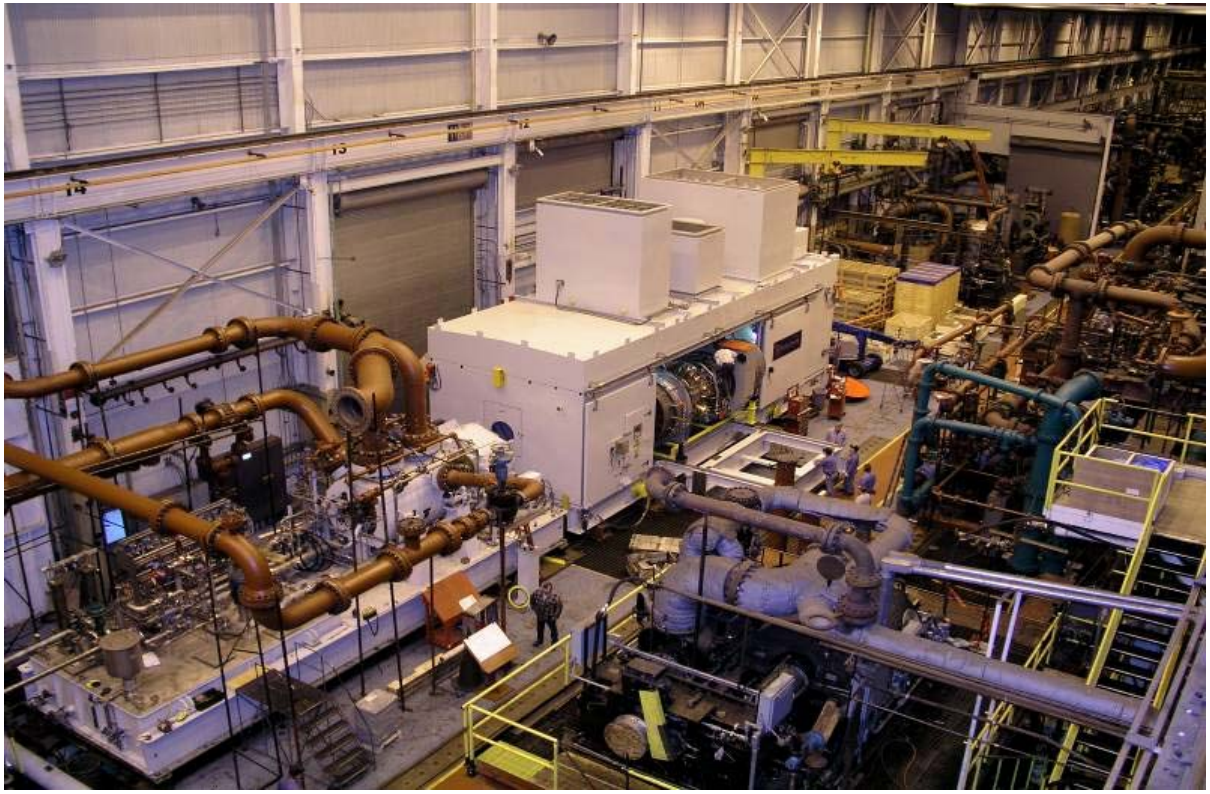
DATUM - Trent Train on Test
52 MW Rating at ISO Conditions



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DATUM - Trent Installed at Site

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RR Trent Enclosure

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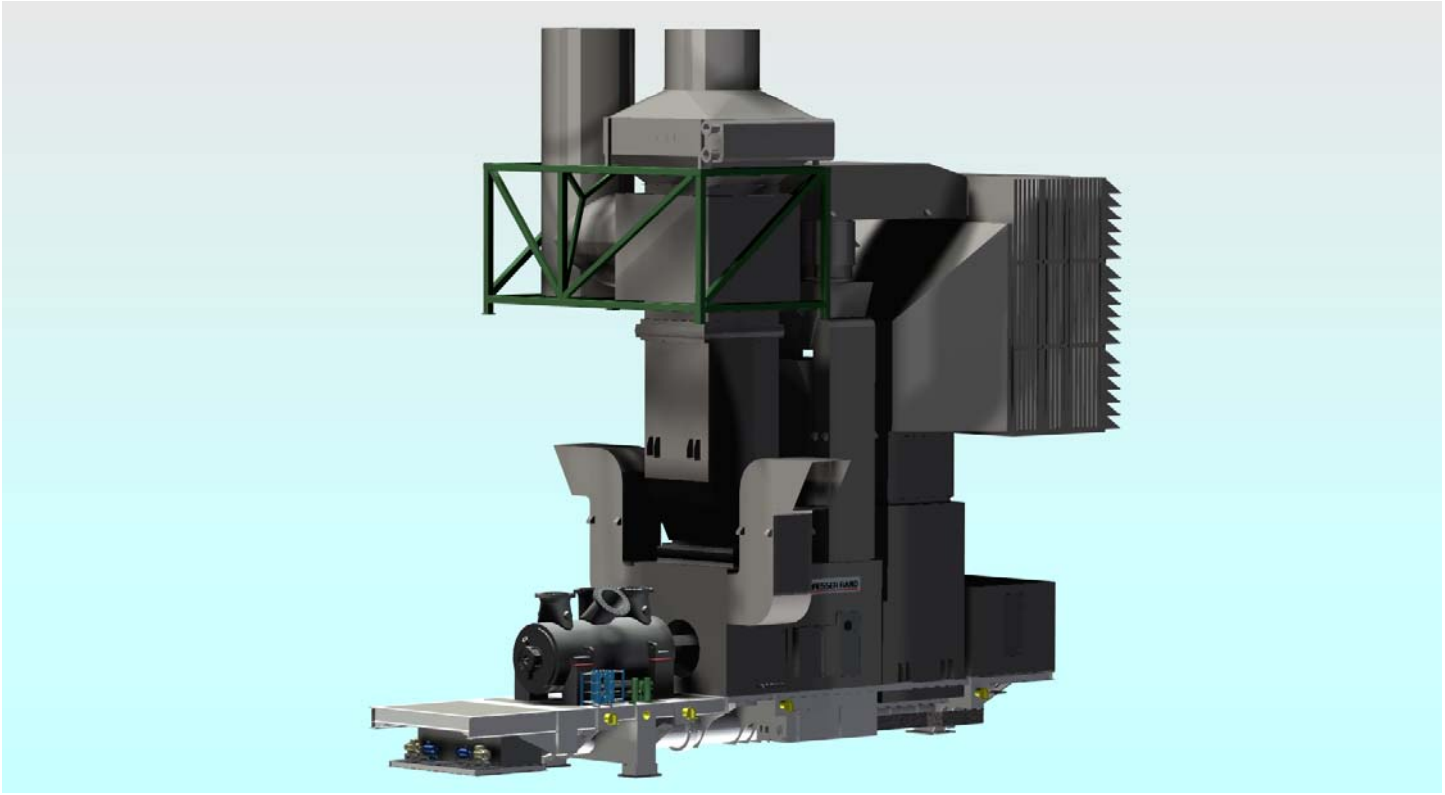
DATUM D22R7S + GE LM6000



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D-R Compressor Driven by 42MW VFD Motor

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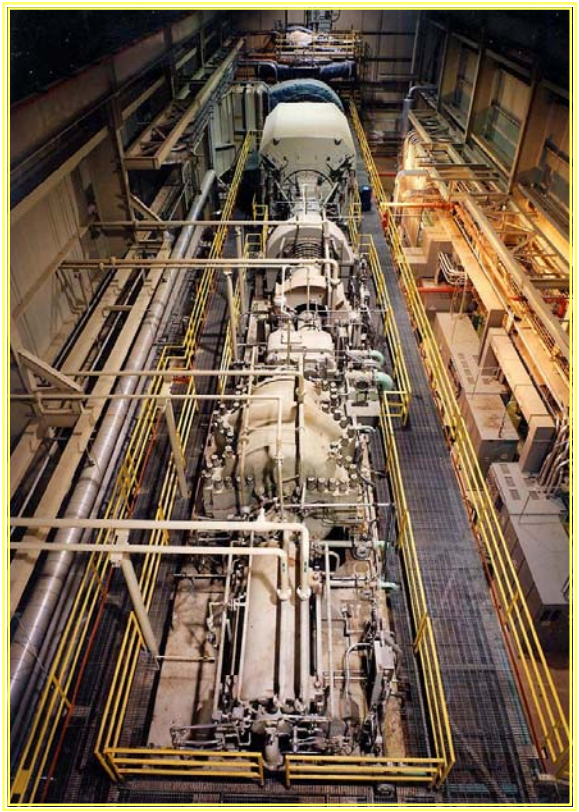
110MW McIntosh CAES Installation



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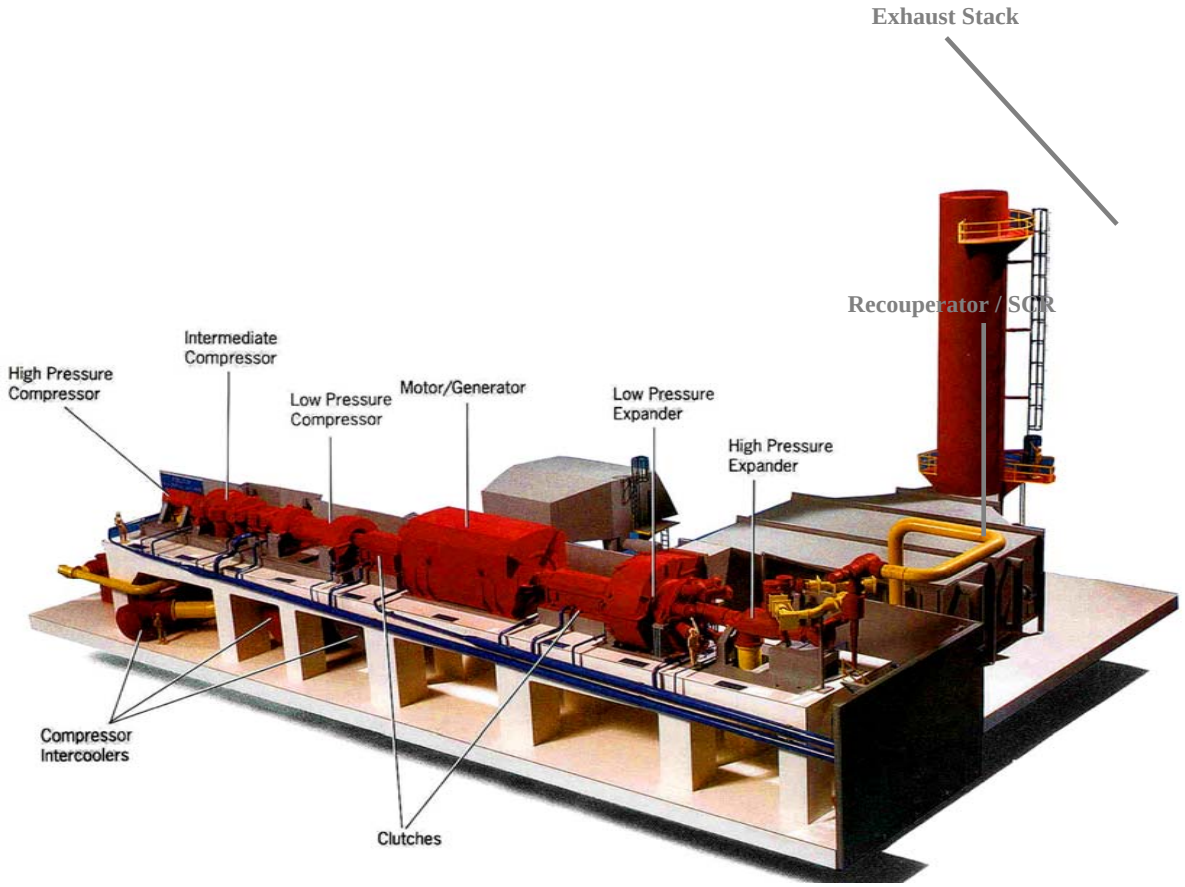
D-R CAES Single Train Arrangement



Couplings

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D-R High Power Driver Experience

- GE Frame 7
- GE Frame 6
- GE LM6000
- RR Trent
- ABB Electric Motor
- EM (Converteam) Electric Motor/Generator
- Steam Turbines up to 70,000 bhp

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Thank You !

Questions?

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