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Compression Machinery and Processes for CO2 Capture

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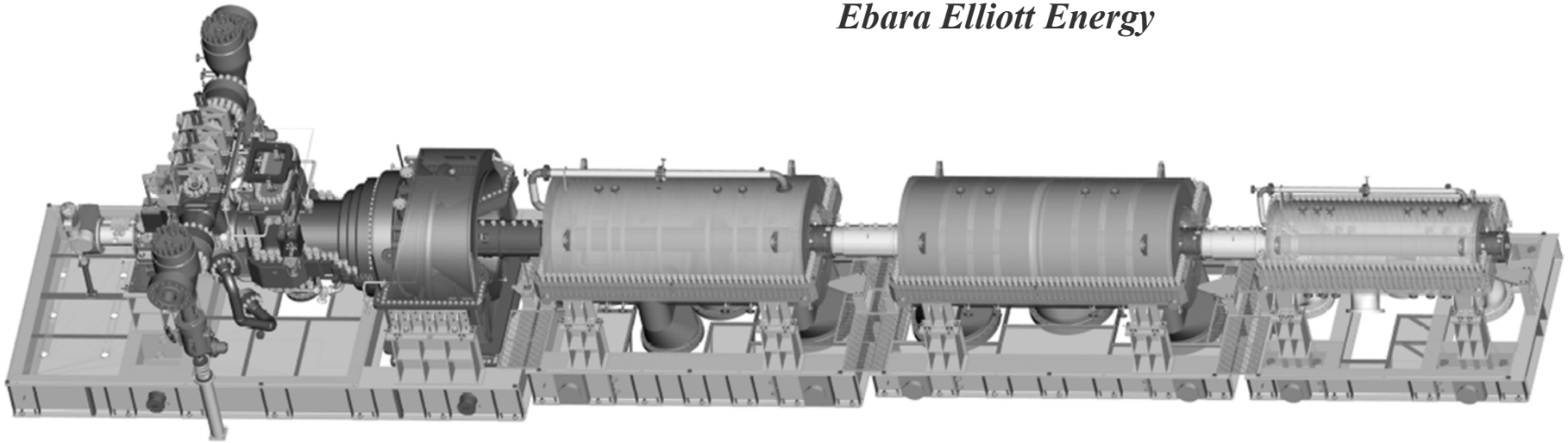

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Compression Options For CCS

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Carbon Capture

- Pre-Combustion
- Post Combustion
- Direct Air Capture
- Industrial Processes

Atmospheric pressure
Can be water-saturated

CO_2 Compression Value Chain

Export Compressor

- High Pressure Ratio
- Low to Medium Flow
- In: Wet CO_2
  Out: Dry CO_2

Injection Compressor

- High Discharge Pressure and Ratio
- High Flow
- Dry CO_2

Pipeline Compressor

- Low Pressure Ratio
- High Flow
- Dry CO_2

Storage

- Enhanced Oil Recovery
- Permanent Sequestration

Very high pressure
Can be supercritical

Challenges Associated with Turbomachinery Design

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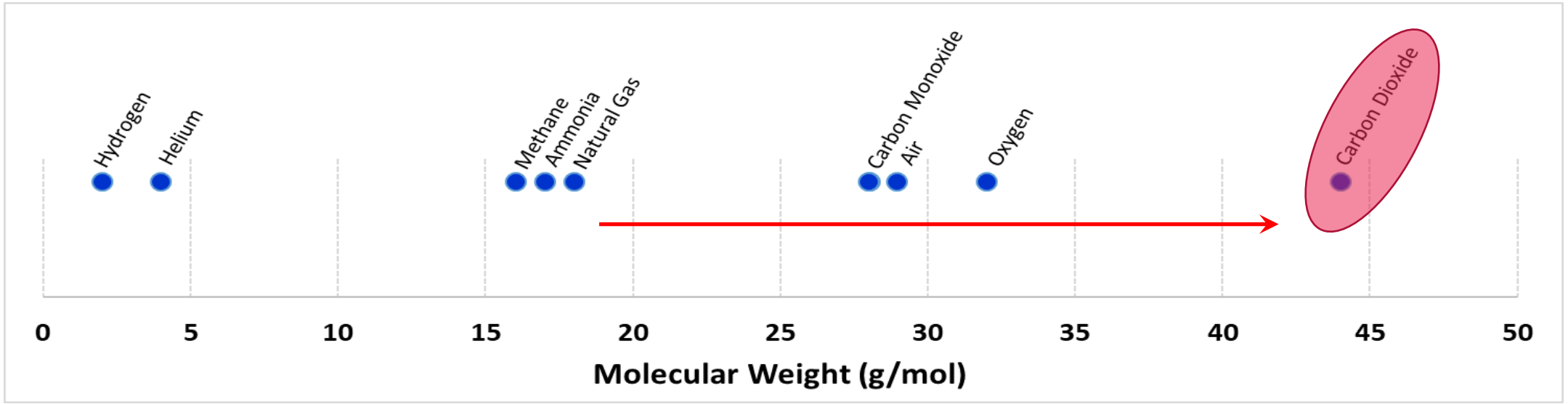

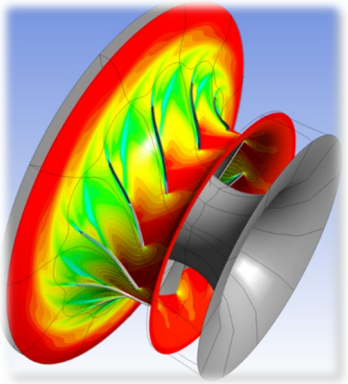

P Ratio:

$$\frac{P_2}{P_1} = \left(1 + \frac{\eta}{c_p T_1} \cdot H\right)^{\frac{\gamma}{\gamma - 1}}$$

T Ratio:

$$\frac{T_{Cold}}{T_{Hot}} = \left(\frac{P_{Hot}}{P_{Cold}}\right)^{\frac{1-\gamma}{\gamma}}$$

- ✓ Specific Heat of CO2 is low
  - Natural gas – 2.3 kJ/kgK
  - Carbon Dioxide – 0.8 kJ/kgK
- ✓ ***High Volume Reduction***
- ✓ ***High Temperature Rise***

CO2 Compression Path Dependence

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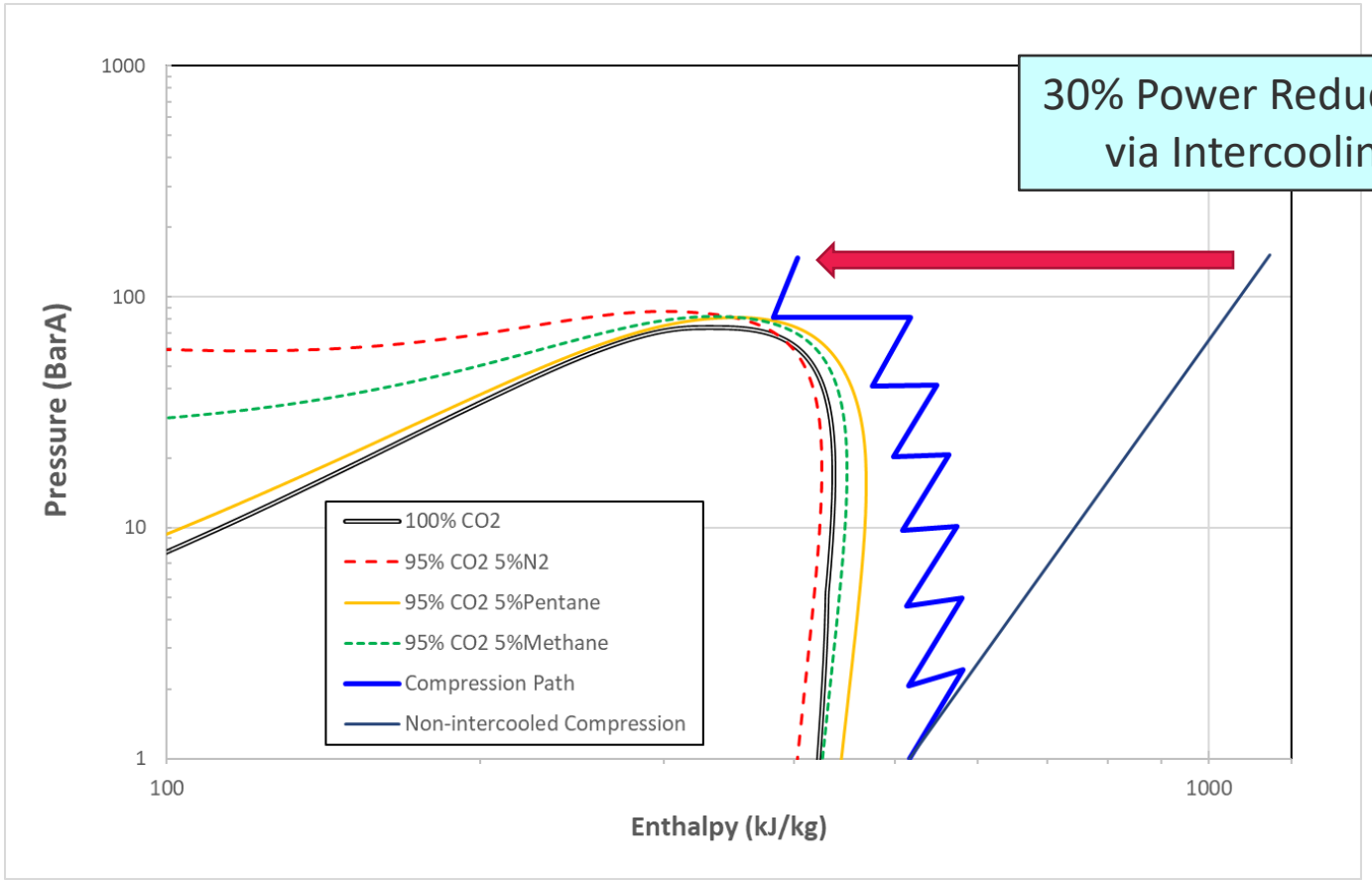
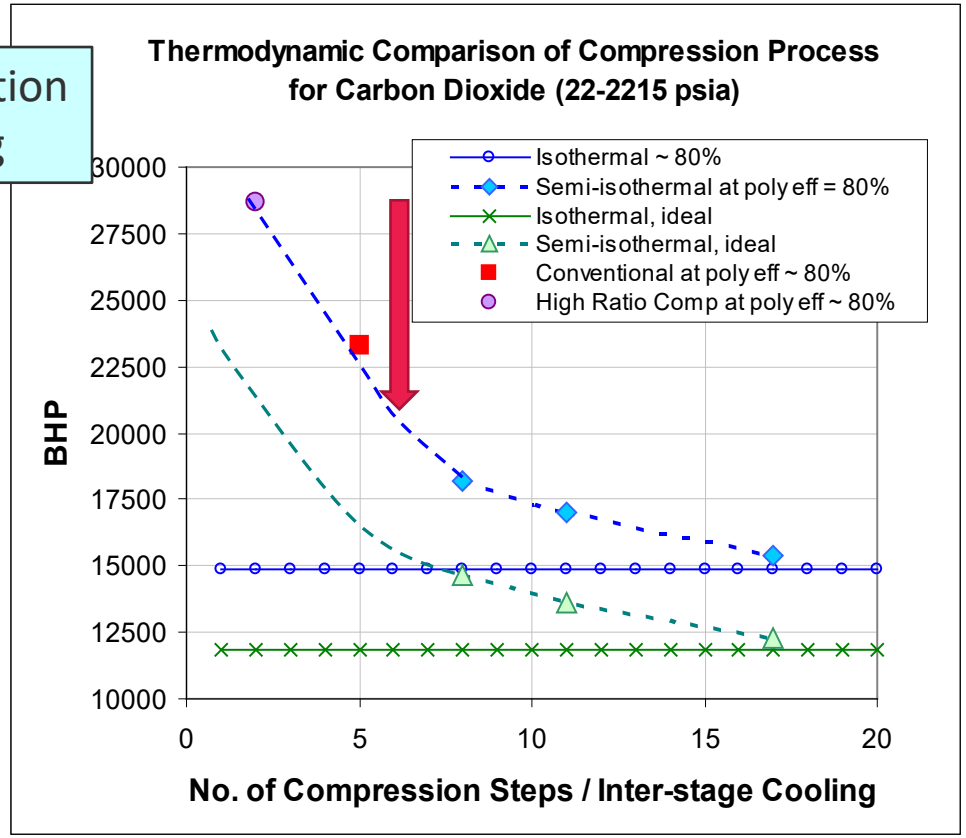
- ✓ Intercooling dramatically reduces power consumption
- ✓ This pushes stage inlets near the saturation line
- ✓ Care must be taken to avoid multi-phase flow is there is uncertainty in the gas composition





Courtesy SwRI and DOE [Moore et al.]

CO_2 Compressor Design Challenges

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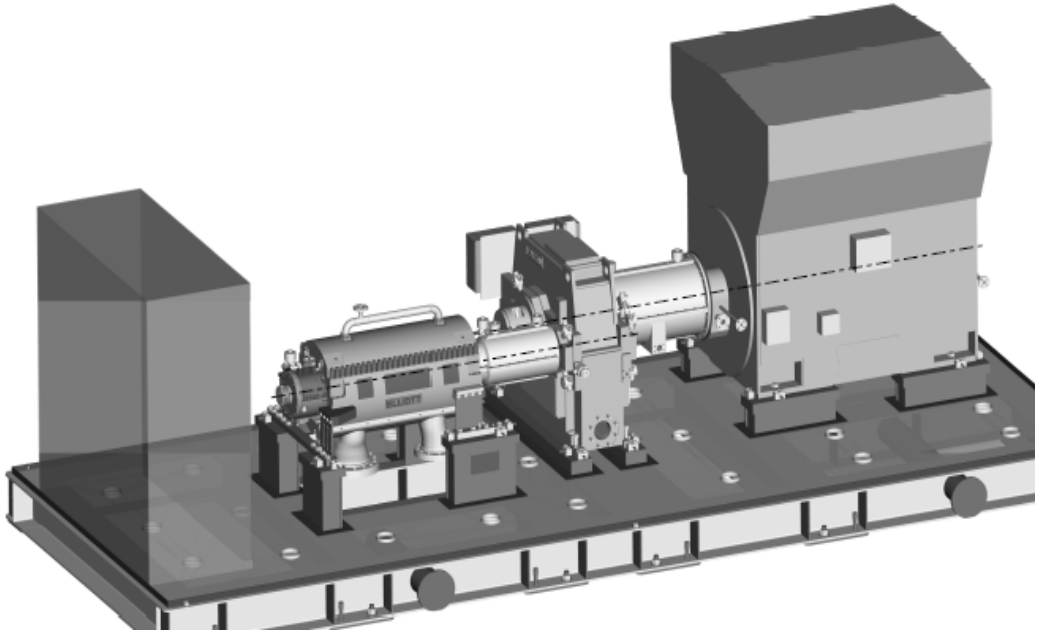
- High compression ratios and large volume changes result in substantial change in optimal stage size requiring multiple casings and gearboxes
- Wide required operating range to match plant operation
- Low sonic speed near the critical point can reduce operating range
- Large variation in gas properties with impurities
- High density amplifies rotordynamic and impeller-dynamic forces
- Multi-phase behavior (pumping versus compression)
- Carbonic acid formation in presence of water (corrosion)
- Solubility in elastomeric materials (seals, flexible ducting, packings, valves)
- Liquid/ice formation when rapidly expanded (Joule-Thomson) at shaft seals
- Selectively leeches certain elements from common metals (materials, coatings)



Elliott 15 MW CO2 Recycle Compressor

Turbomachinery Architecture for CO2 Compression

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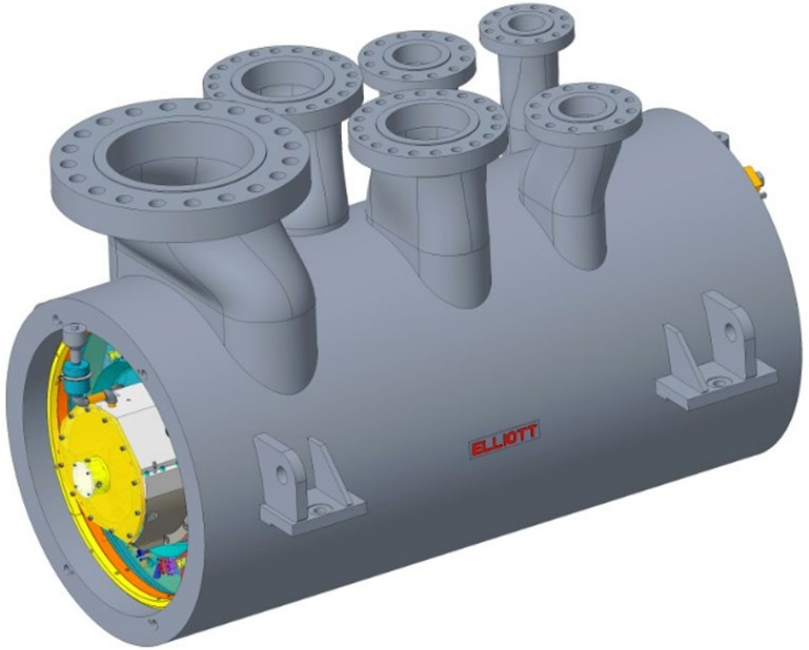
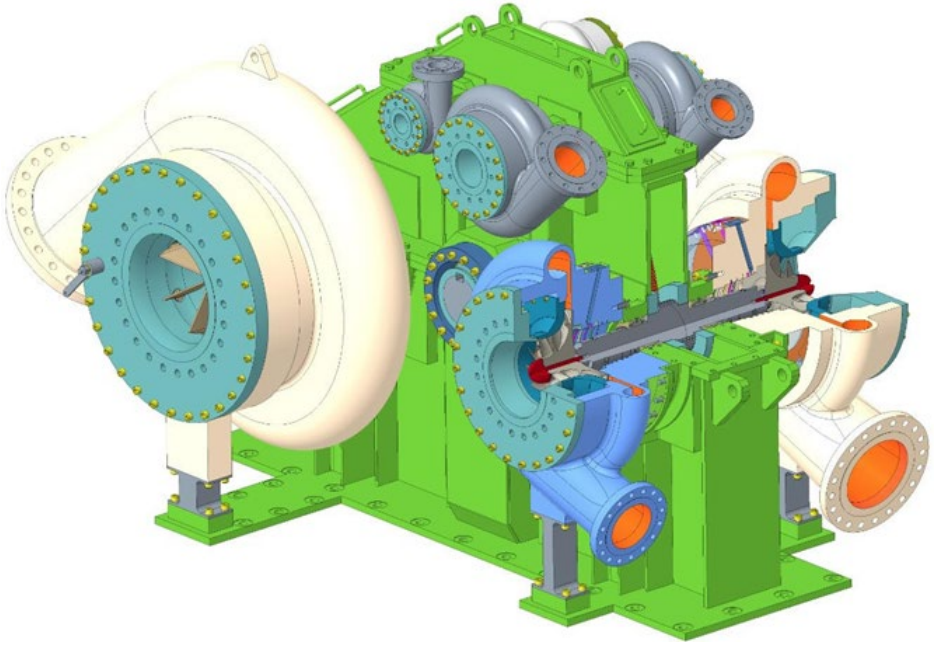


Beam Style Compressors

- 2 seals & bearings per casing
- All stages operate at the same speed
- Intercooling is difficult
- Last stages can drop to very low flow coefficients and efficiency
- Can manage higher pressures



Integrally Geared Compressors

- Individual pinions run at different speeds
- Improved aerodynamics
- Easier intercooling
- More seals and bearings
- More complex package

Machinery Options

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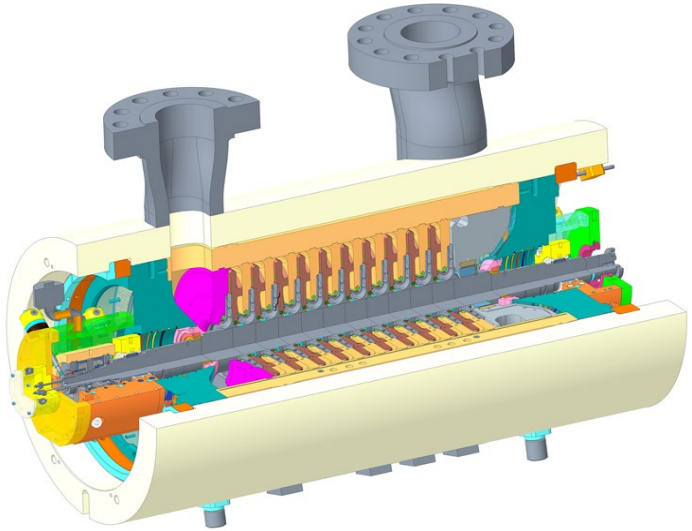
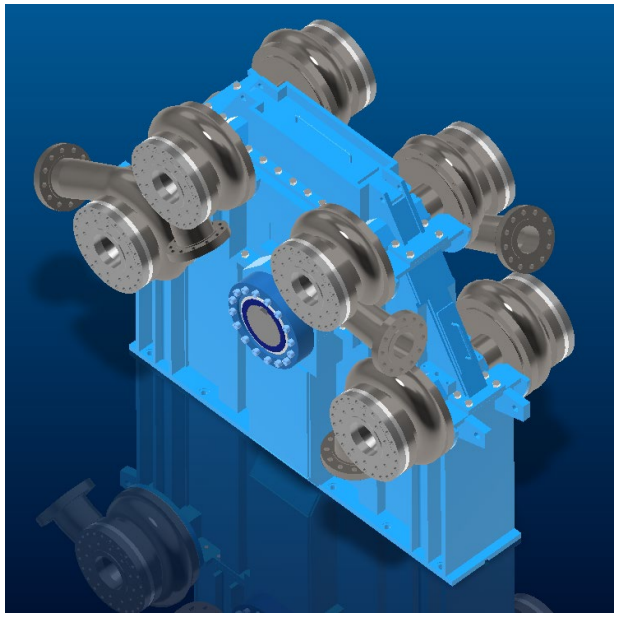
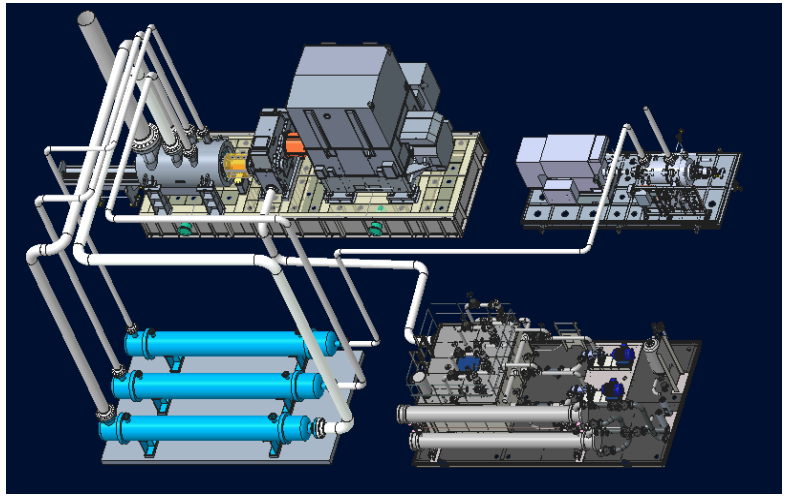


Conventional High Speed
In-Line Centrifugal Compressors



Integrally Geared Conventional and
High Speed Centrifugal Compressors



Blend of Compressors & inline
pump/compressors

Pressure Ratio: *1.2* *1.5* *4.0* *30* *90* *120* *200* *300* *500* *700*

Blower ***Pipeline Transport*** ***Pipeline Header*** ***Production*** ***Storage***