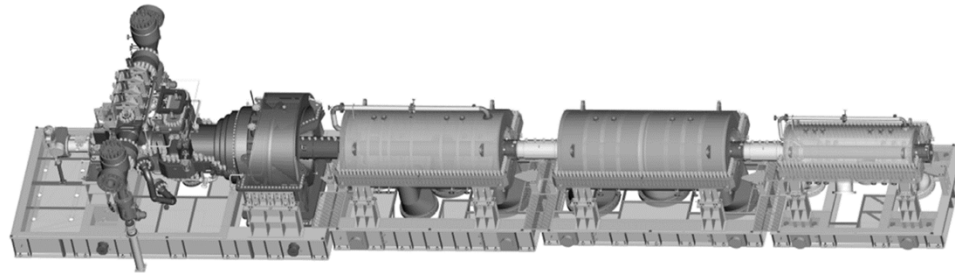




# *Carbon Dioxide Compression*



Klaus Brun, Ph.D., Elliot Group





- Headquartered in Jeannette, Pennsylvania, USA
- Revenue: ~ US\$ 1.5 billion
- About 2,600 employees
- 38 locations in 15 countries



- 110 Acre Campus
- 802,000 Sq. Ft Factory Area

**Jeannette, PA**

Businesses:

- Engineered Products (EP)
- Industrial Products (IP)
- Global Service (GS)
- Cryodynamic Products (CP)



- 41 Acre Campus
- 371,000 Sq. Ft Factory Area

**Sodegaura, JPN**

## Engineered Products

- Centrifugal Compressors
- Axial Gas Expanders
- Axial Compressors
- Steam Turbines (API 612)
- High Speed Balance
- Packaged Solutions



## Cryodynamic Products

- Cryogenic Pumps
- Cryogenic Expanders



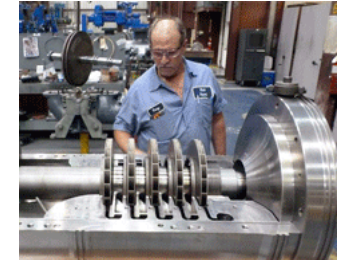
## Industrial Products

- Single Stage Steam Turbines (API 611)
- Multi Stage Steam Turbines (API 611)
- Steam Turbine Generators



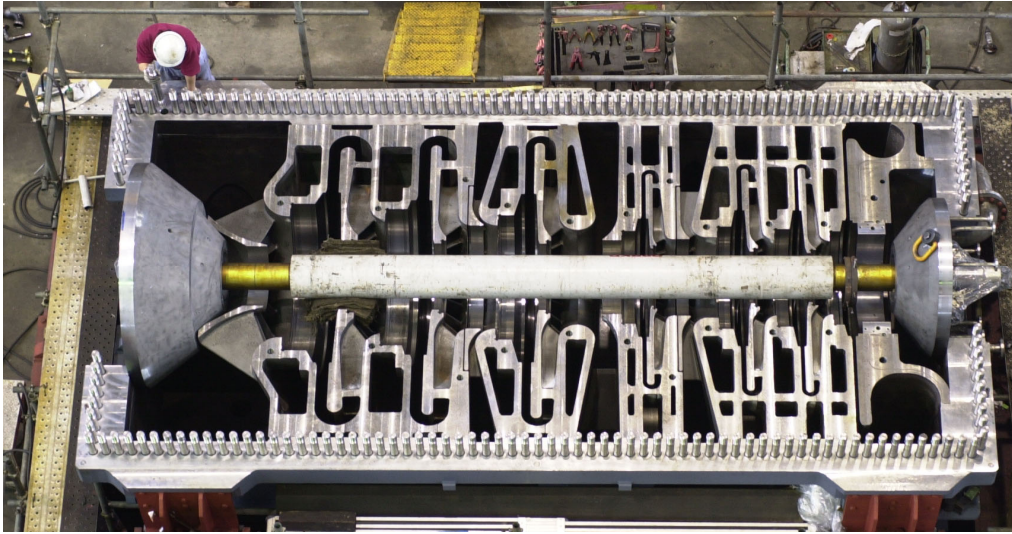
## Global Services

- Service Parts
- Field Services
- Repair Operations
- Re-rate Engineering
- Product Upgrades
- Technical & Training Services
- Engineered Support Systems





# Elliott Centrifugal Compressors



**Small To  
Large**



**All kinds  
of fluids**

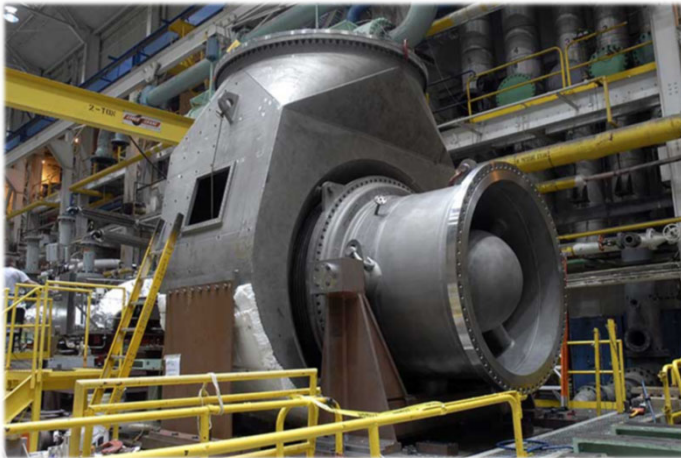
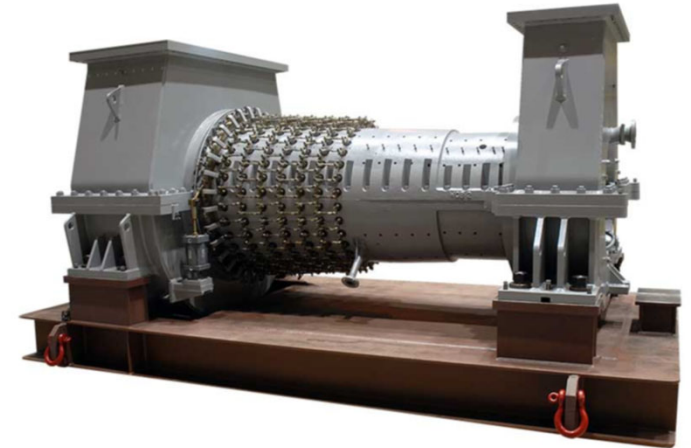




# Elliott Axial Compressors and Expanders



**Mechanical  
Drives and  
Power  
Generation**





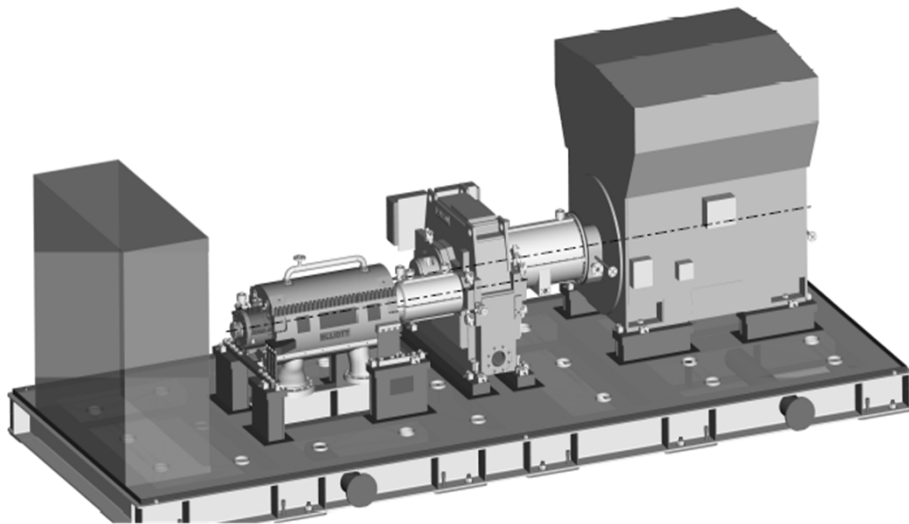
# Carbon Dioxide Compression



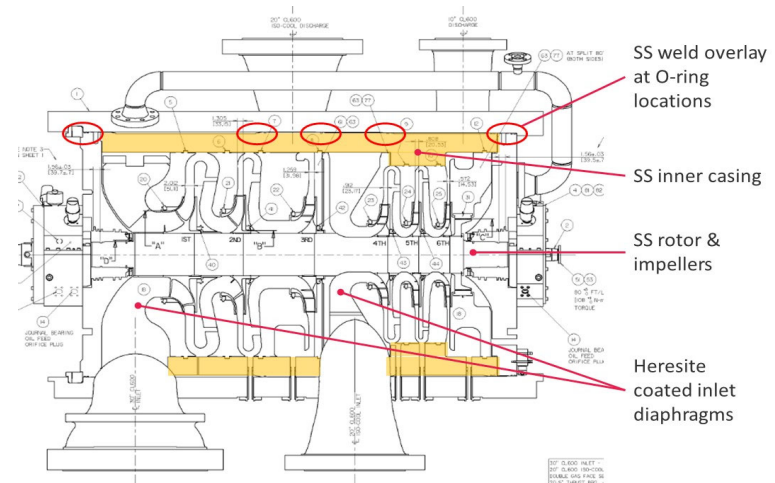
# CO<sub>2</sub> Compressors

## Applications:

- Pipeline header injection and re-compression transport
- Sequestration storage geological reservoir injection
- Various CO<sub>2</sub> separation processes
  - membranes
  - distillation
  - chemical (reformer, catalytic)
- Power plant cycle compressor (Oxy and sCO<sub>2</sub> cycles)



*Elliott 15 MW CO<sub>2</sub> Recycle Compressor*



*Elliott 5 MW  
Acid Gas  
Compressor*

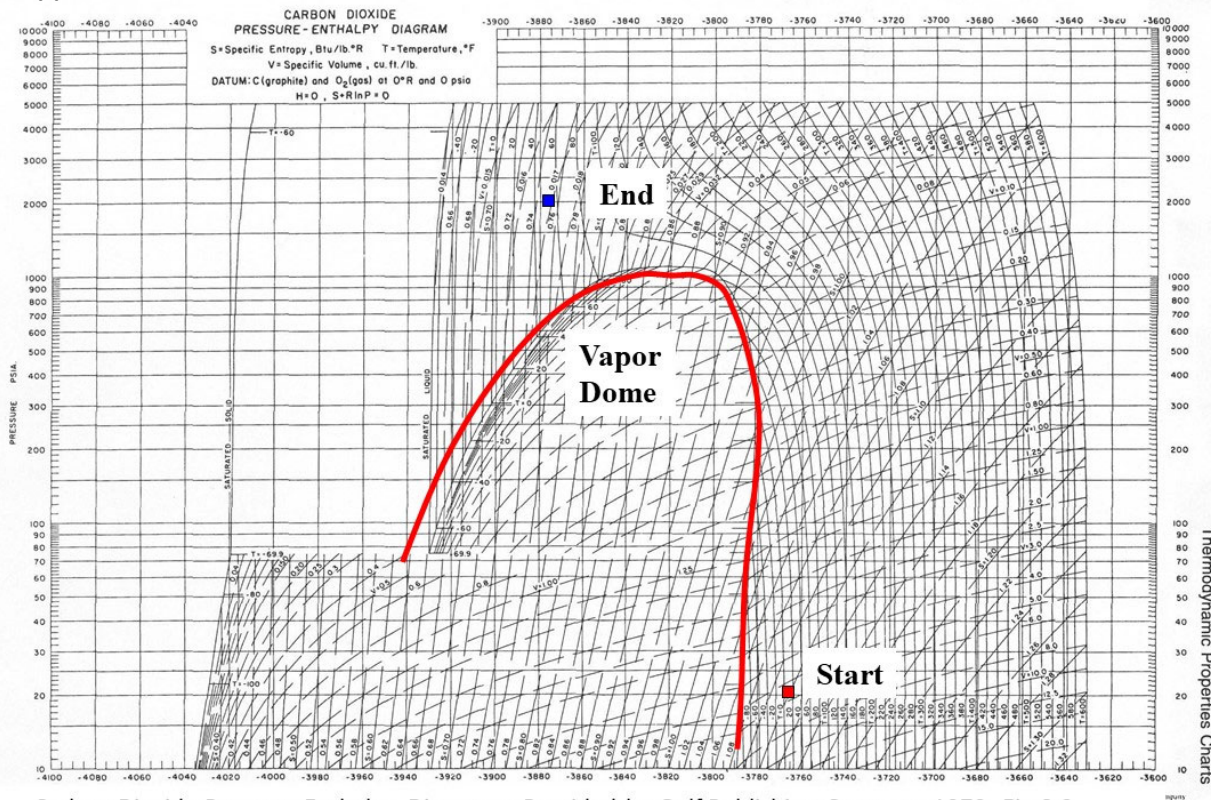
## Design Challenges:

- Equation of state for CO<sub>2</sub> (high pressure, high temperature, mixtures)
- High compression ratios (large volume changes, long compression trains, gear boxes, mechanical reliability, usually requires intercooling)
- **High density (amplifies rotordynamic and impeller-dynamic forces)**
- Wide required operating range (function of plant load)
- Strong thermodynamic path dependence (isentropic versus isothermal)
- **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**
- **Low sonic speed (higher shock losses and reduced operating range)**
- **Selectively leeches certain elements from common metals (materials, coatings)**
- Very low viscosity



# Carbon Dioxide Compression versus Pumping

## Typical CCS Start/End Points



Carbon Dioxide Pressure-Enthalpy Diagram – Provided by Gulf Publishing Company-1972, Fig.8.2

## Issues:

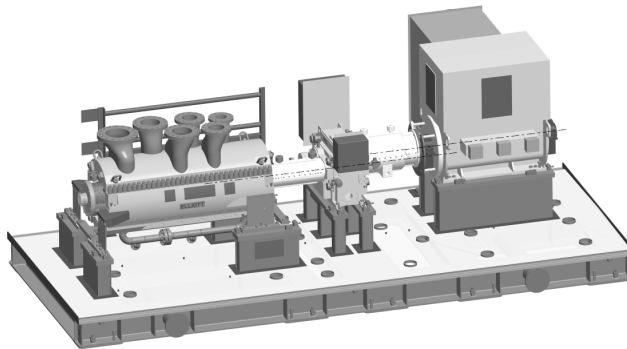
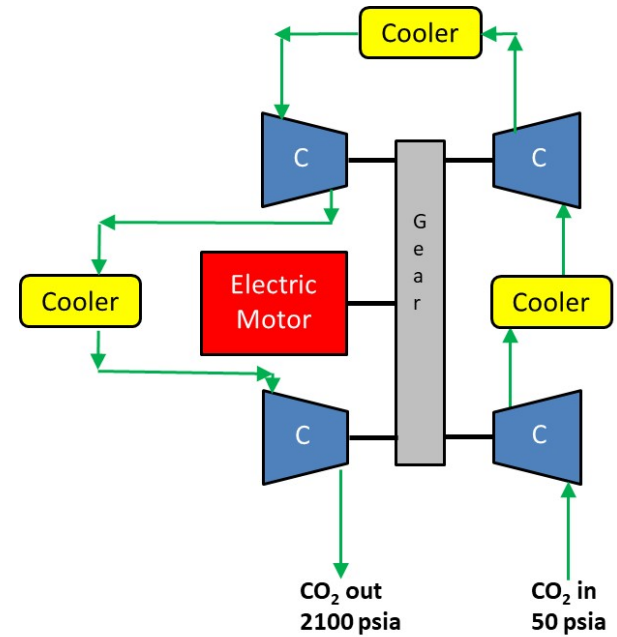
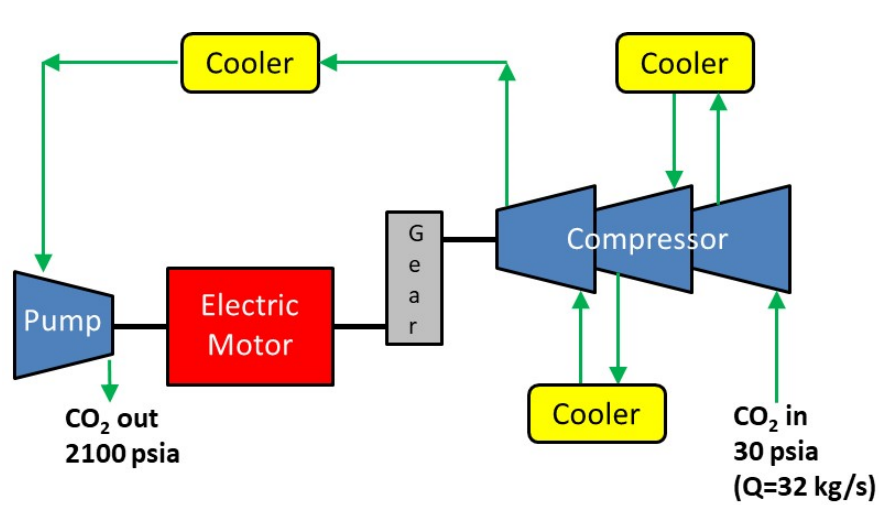
- CO<sub>2</sub> available from separation at low (near atmospheric pressures (<100 psi). Header station is always compressor.
- Conventional assumption is that CO<sub>2</sub> is transported (“pumped”) at supercritical pressures (2100 psi).
  - Requires very high pressure ratio compressors with intercooling
  - Large volume reduction
  - Multiple compression path options

## Pipeline operating pressure:

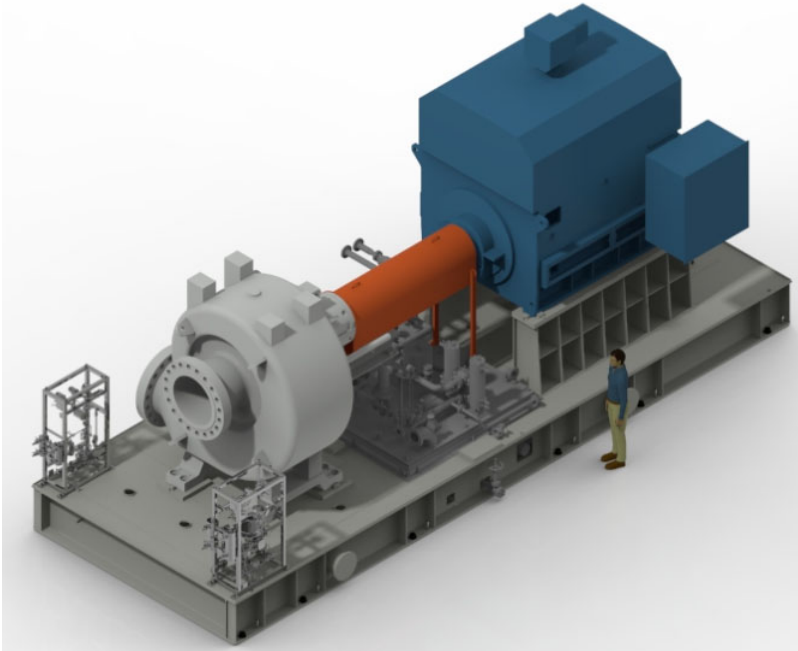
- **Not necessarily supercritical**
- Depends on transport distance, starting pressure and delivery pressure.
- Injection pressure is not always supercritical (1150 psi per km of depth)



# Barrel Versus Integrally Geared (CCS)

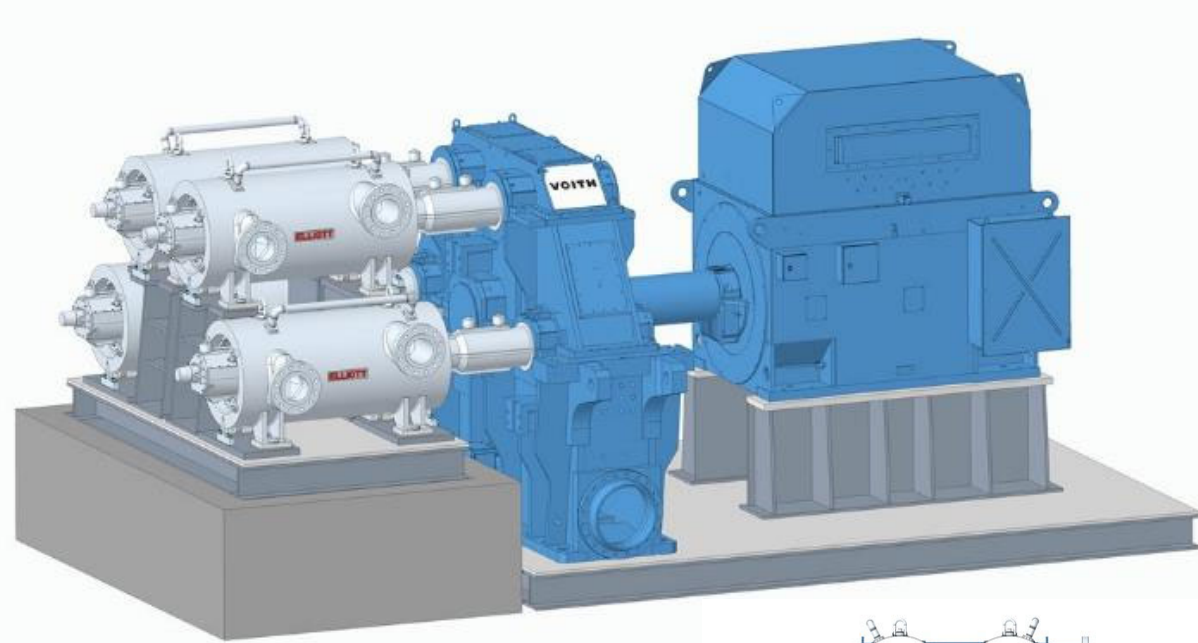
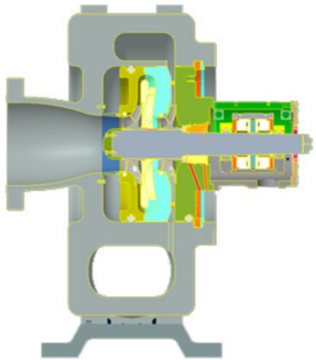


# New Products for CO<sub>2</sub> Compression



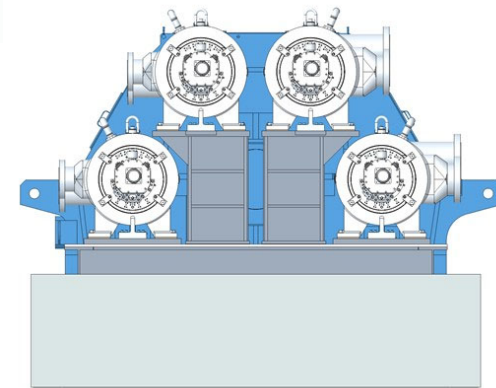
**Elliott THM140**

Low Pressure Ratio  
Application



**Elliott Flex-Op**

High Pressure Ratio and Wide Range  
Application





**Elliott has built CO<sub>2</sub> compressors for over 50 years.**

Thank you!  
Questions?

