CO$_2$ Compression Options for CCUS

Presented at Carbon Management Technology Conference
July 18, 2019

Ray McKaskle, P.E.
Trimeric Corporation
Presentation Overview

- What CCUS CO$_2$ compression looks like
- How compression works (in simplest terms)
- Important factors in compressor selection
- Pros and cons of common compressor types for CCUS projects (by project size)
- Emerging technology
- CCUS CO$_2$ compression vs. liquefaction & pumping
- Takeaways
What CCUS CO$_2$ Compression Looks Like (1 of 3)

- This is NOT what CCUS CO$_2$ Compression looks like:

  ![Diagram 1](CO$_2$ Capture to CO$_2$ Transport)

- This is NOT what CCUS CO$_2$ Compression looks like:

  ![Diagram 2](Compressed CO$_2$ Capture to CO$_2$ Transport)
What CCUS CO$_2$ Compression Looks Like (2 of 3)

- This is what CCUS CO$_2$ Compression looks like:

Chaparral Coffeyville 50 MMscfd / 1 MM tonne/yr
19,500 hp (14.5 MW) CO$_2$ Compression and Dehydration Facility
This is what CCUS CO$_2$ Compression looks like:
How Compression Works (In Simplest Terms) 1 of 3

- Positive displacement (PD) machines like reciprocating and screw compressors reduce the volume of the gas, which increases pressure.
Centrifugal blowers, compressors and pumps use one or more impellers to speed up, then carefully slow down the fluid, which converts the kinetic energy to pressure.

https://www.turbomachinerymag.com/types-of-centrifugal-compressor-configurations/
Most often, multiple stages of compression and cooling are required.
Important Factors in Compressor Selection (1 of 2)

- Money! – Capital costs, operating costs (power)
- Project duration
- Mass flow rate
- Suction pressure – impacts actual volumetric flow rate
- Discharge pressure
- Turndown and sparing requirements
- Driver options – electricity, steam, gas engine
Important Factors in Compressor Selection (2 of 2)

- Actual suction volumetric flow rate and discharge pressure impact compressor selection.

Used with Permission from GPSA Engineering Data Book.
Multistage Centrifugal Blowers

- Common in ethanol and fertilizer CCUS applications
- Simple, low cost way to double low suction pressure
- Cuts downstream volumetric flow rate in half
- No oil in contact with process gas
- Controls needed to maintain sufficient flow and discharge pressure

ADM Decatur / MGSC 400,000 tonne/yr CCS Plant
1,250 hp (933 kW), 4-Stage, Centrifugal Blower
Screw Compressors (1 of 2)

- Workhorse of food / beverage CO₂ and frozen food industries
- Lower capital cost than reciprocating and centrifugal compressors
- Great turndown with slide valve even without VFD
- Low noise and vibration compared to other PD compressors
- Oil mixes with process gas - Important to separate properly after compression
- Must manage water dew point carefully to prevent water condensation

Photograph courtesy of GEA FES
Screw Compressors (2 of 2)

Image Courtesy of York Process Systems
Animation Courtesy of Howden Compressors
Reciprocating Compressors (1 of 2)

- Workhorse of CO$_2$ Enhanced Oil Recovery industry
- Several turndown options without VFD – head unloader, variable volume clearance pocket
- Economic to spare compared to large centrifugal compressors
- Vibration requires piping support and thick foundations
- Lots of piping and moving parts
- Cylinder lubrication oil gets into process gas

ADM Decatur / MGSC 400,000 tonne/year CCS Plant
3,250 hp (2,425 kW), 4-Stage, Reciprocating Compressors (x 2)
Reciprocating Compressors (2 of 2)

- Chaparral Coffeyville Compressor Building
- Approaching a point at this scale where higher capacity centrifugal compressors make more sense
- But, this plant had to run at 50% turndown for first year, which requires recycle with centrifugal machines

Image courtesy of Willbros Engineering
Single Shaft / Barrel Style Centrifugal Compressors

- Very high capacity and reliability
- Fewer moving parts (vs. recips)
- No oil in contact with process gas
- Same speed for all impellers
- Limited options for interstage cooling and dehydration pressure
- Limited turndown
- Long lead time (~ 2 X recips)
- More expensive to spare
- Controls needed to maintain sufficient flow and discharge pressure

Image courtesy of Siemens
Integral Gear Centrifugal Compressors (1 of 2)

- State of the Art for Largest CCUS projects – Petra Nova, Air Products Port Arthur, Dakota Gasification
- Very high capacity and reliability
- Highest efficiency
- Optimal speed for each set of impellers
- No oil in contact with process gas
- Most options for interstage cooling and dehydration pressure
- Limited turndown
- Long lead time (~ 2 X recips)
- More expensive to spare
- Controls needed to maintain sufficient flow and discharge pressure

8-Stage, 15 MW Wet CO₂ Compressor
Image courtesy of MAN Energy Solutions
Integral Gear Centrifugal Compressors (2 of 2)

Images courtesy of MAN Energy Solutions
Multistage Centrifugal Pumps

- Common for CO₂ pipeline booster stations
- Very low equipment costs
- Very low power requirements
- Affordable to equip with VFD for wide turndown range
- These pumps can take swings in pipeline / injection well pressure and let more expensive upstream compressors run at their “sweet spots”
- Controls needed to maintain sufficient density, flow, and discharge pressure.
Emerging Technology – Shockwave Compression

- Development work by Dresser-Rand / Siemens continues (see DOE FE0026727)
  - Low Pressure machine from atmospheric pressure to 200 psi in one stage
  - High Pressure machine from 200 to 2,000 psi in one stage

- Expected Benefits
  - Smaller footprint, less piping, fewer coolers
  - Discharge temperatures exceeding 550°F (290°C) creates better waste heat recovery opportunities

- Challenges / Remaining Work
  - Move from lab to plant environment
  - Integrating with dehydration pressure (typ. ~ 550 psi)
  - Slightly less efficient than some other compressors
  - Finding heat integration opportunities to increase overall system efficiency relative to other CCS approaches
Compression vs. Liquefaction & Pumping

- Have to evaluate on case-by-case basis
  - Important factors include CO₂ mass flow rate, project duration, power costs, pipeline length, and water content in feed stream

- Factors that make liquefaction & pumping more attractive
  - CO₂ is available at pressure needed for liquefaction (> 300 psi)
  - CO₂ liquefaction is required for purification (e.g., oxygen removal)

- Trimeric hypothetical comparison for ethanol plant CO₂ showed 38% more power required with liquefaction & pumping
Conclusions

- There are many options for CCUS CO₂ compression.
- Careful analysis for each project considering CO₂ source, capital costs, operating costs, project duration, product requirements, and other factors is needed to select optimal compression approach.
- Mass flow rate, suction pressure / actual volumetric flow rate, discharge pressure, and other factors impact compressor selection.
- Integral gear centrifugal compressors are state of the art for the largest CCUS projects.