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IGU

Captured CO2 Treating and Transportation Challenges and Lessons Learned

Noora Al-Derham, Facilities Development Planning Specialist

Qatargas Operating Company Limited

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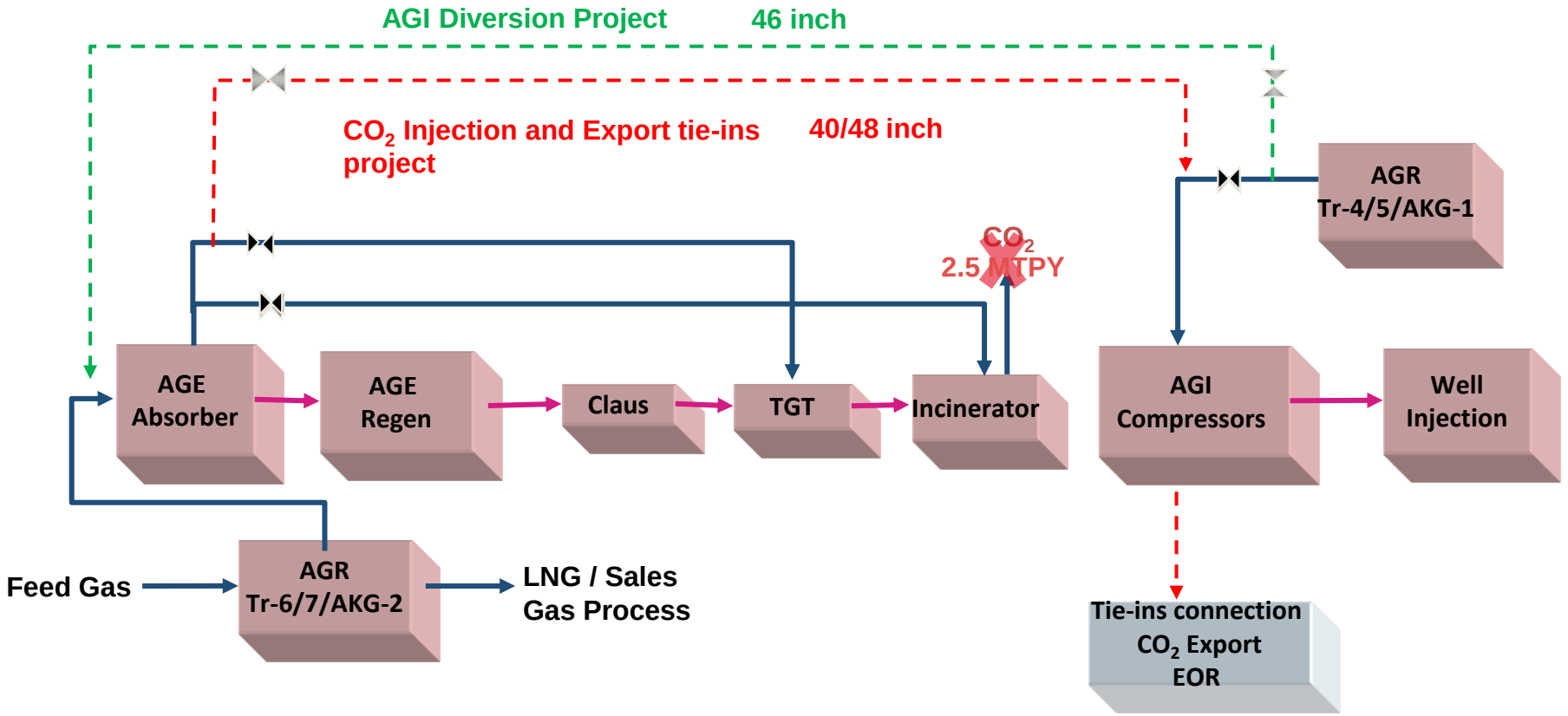
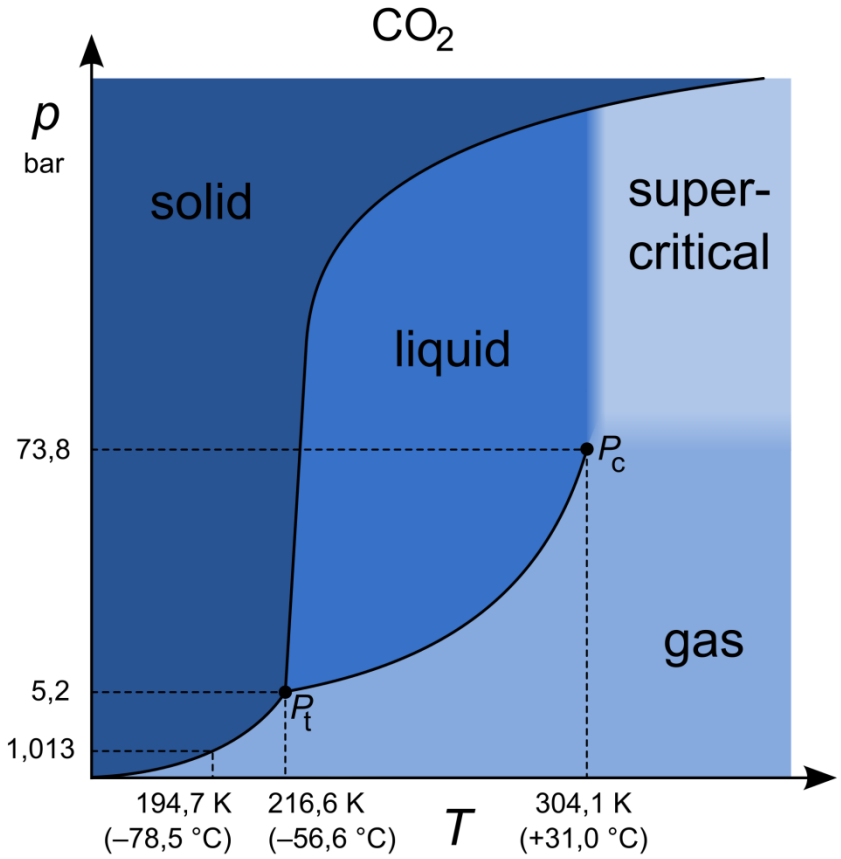
CO2 Capture Overview



Supercritical Fluids - Definition

- Supercritical or Dense phase is a fourth (Solid, Liquid, Gas, Dense) phase that cannot be described by the senses.
- It is found when the fluid is above its Critical pressure and temperature.
- Dense phase is a highly compressible fluid that demonstrates properties of both liquid and gas.
- The dense phase has a viscosity similar to that of a gas, but a density closer to that of a liquid.



Supercritical Fluids - Application

Pure compounds in the dense phase or supercritical fluid state normally have better dissolving ability than do the same substances in the liquid state.

Because of its unique properties, dense phase has become attractive for transportation of:

- CO2 and natural gas
- CO2 for Enhanced oil recovery
- Food processing and pharmaceutical processing products.

Design and Operational considerations

Dehydration

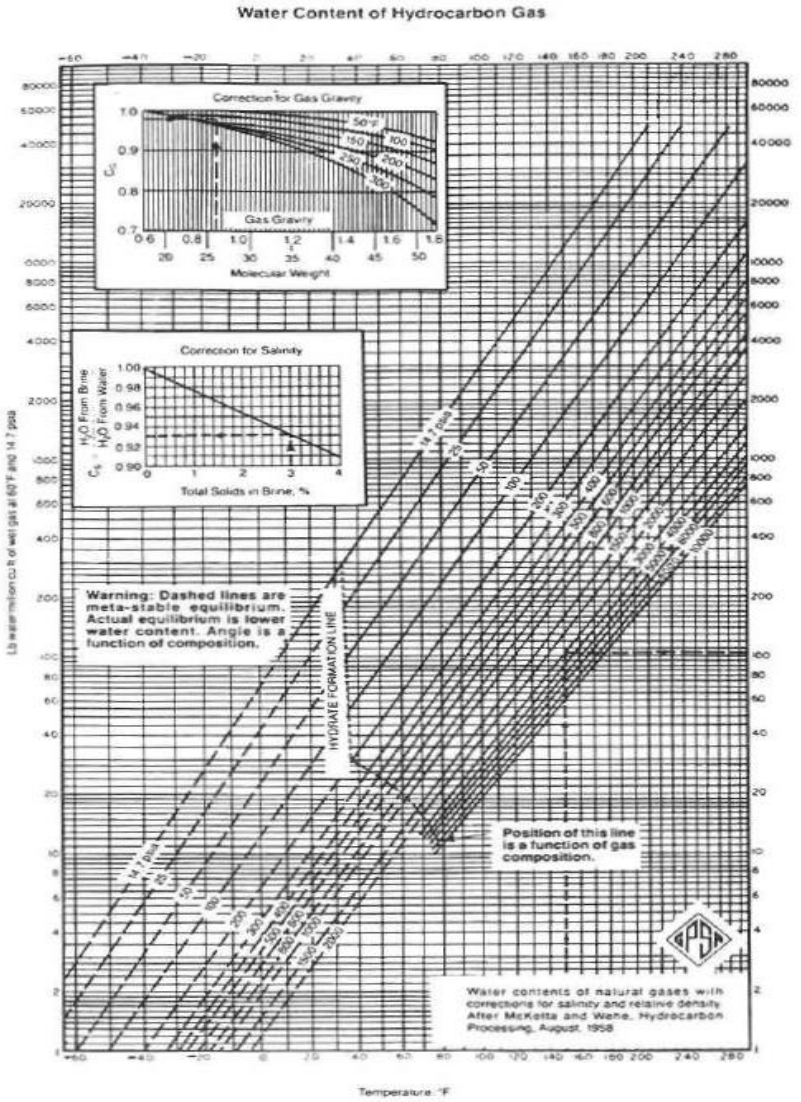
Why dehydrate?

Free water is leading to:

- Corrosion ($CO_2 + H_2O \leftrightarrow H_2CO_3 \leftrightarrow H^+ + HCO_3^-$)
- Hydrate formation

How much?

- For Sales Gas, typical maximum water in sales gas at 4 to 7 lb/MMscf
- For this particular CO2 stream composition and the operating conditions, the maximum water content 60 lbs/MMSCF.



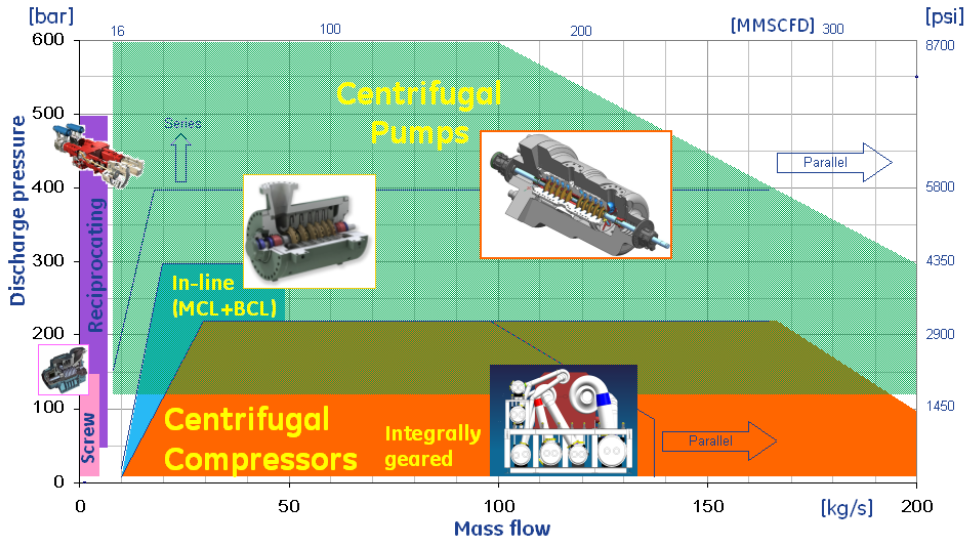
Design and Operational considerations

Transportation Devices

In terms of transport properties supercritical phase behaves more like a liquid than a gas:

- Extremely high density (up to 800 kg/m3)
- Low compressibility factor

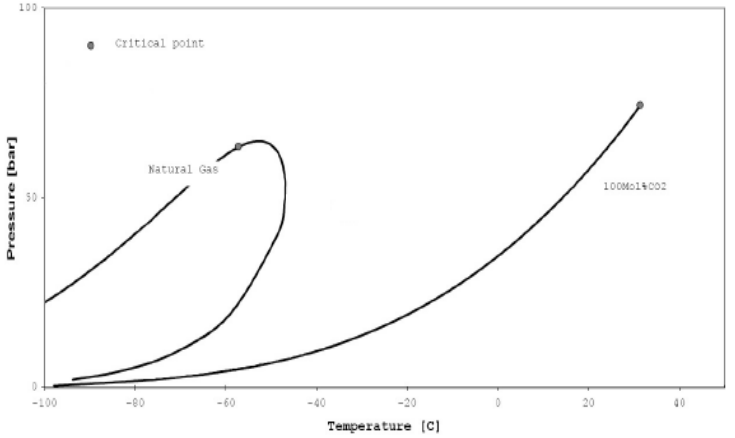
Industry experience shows that both compressors and pumps can be used for CO2 transportation

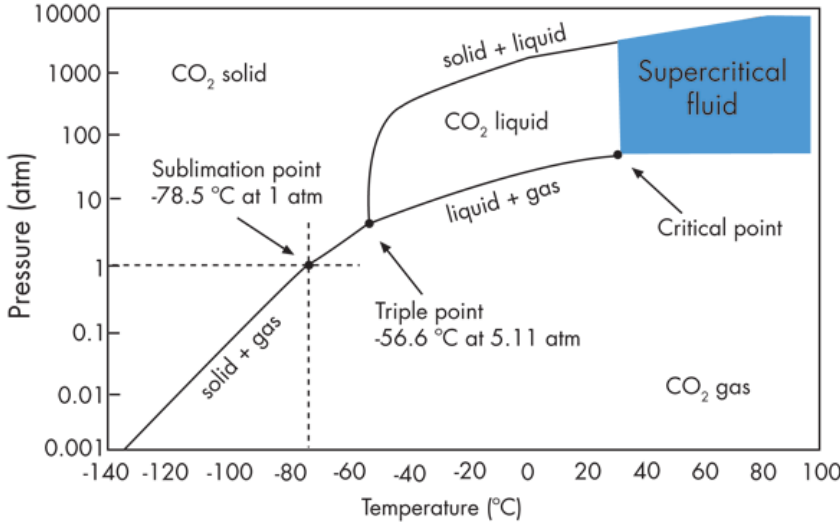


Design and Operational considerations

Depressurisation

- The thermodynamic behavior of CO2 drastically differ from Natural Gas
- CO2 cools dramatically during decompression, leading to potential multiple phase changes.
- Controlled depressurisation is recommended to avoid liquid/solid formation.
- Controlled depressurisation avoids reaching very low temperatures causing pipeline steel walls become brittle.
- CO2 in dense phase has significant mass, therefore its release at high pressure will produce high noise.





Design and Operational considerations

Pipeline Integrity

The following aspects need to be considered when designing a CO2-service pipeline;

- **Internal Corrosion**
  - ✓Dewatering at the inlet of the pipeline
  - ✓Internal corrosion allowance
- **Materials**
  - ✓Depressurisation can cause low temperature (minimum design temperature and proper material selection)
  - ✓CO2 can be a highly effective solvent; Materials in contact should be carefully selected
- **Coatings**
- **Cathodic Protection**

Design and Operational considerations

Measurement

- Volumetric flow rate measurement devices requires accurate knowledge of the density
- Density of dense CO2 has nonlinear dependence on the pressure and temperature. Hence, it is not easy to measure accurately with standard flow meters
- The general preference for this condition calls for **mass measurement**
- Coriolis meters can provide mass measurement directly

Conclusions

- Supercritical or Dense phase is another state of the matter (Solid, Liquid, Gas, Dense).
- At that phase, CO2 exhibits properties of both a liquid and a gas, making it exponentially difficult to control.
- Dense phase CO2 being extensively use in the Food processing, pharmaceutical processing products, and for enhanced oil recovery.

Thank you