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Process Safety Challenges of Carbon Dioxide Sequestration

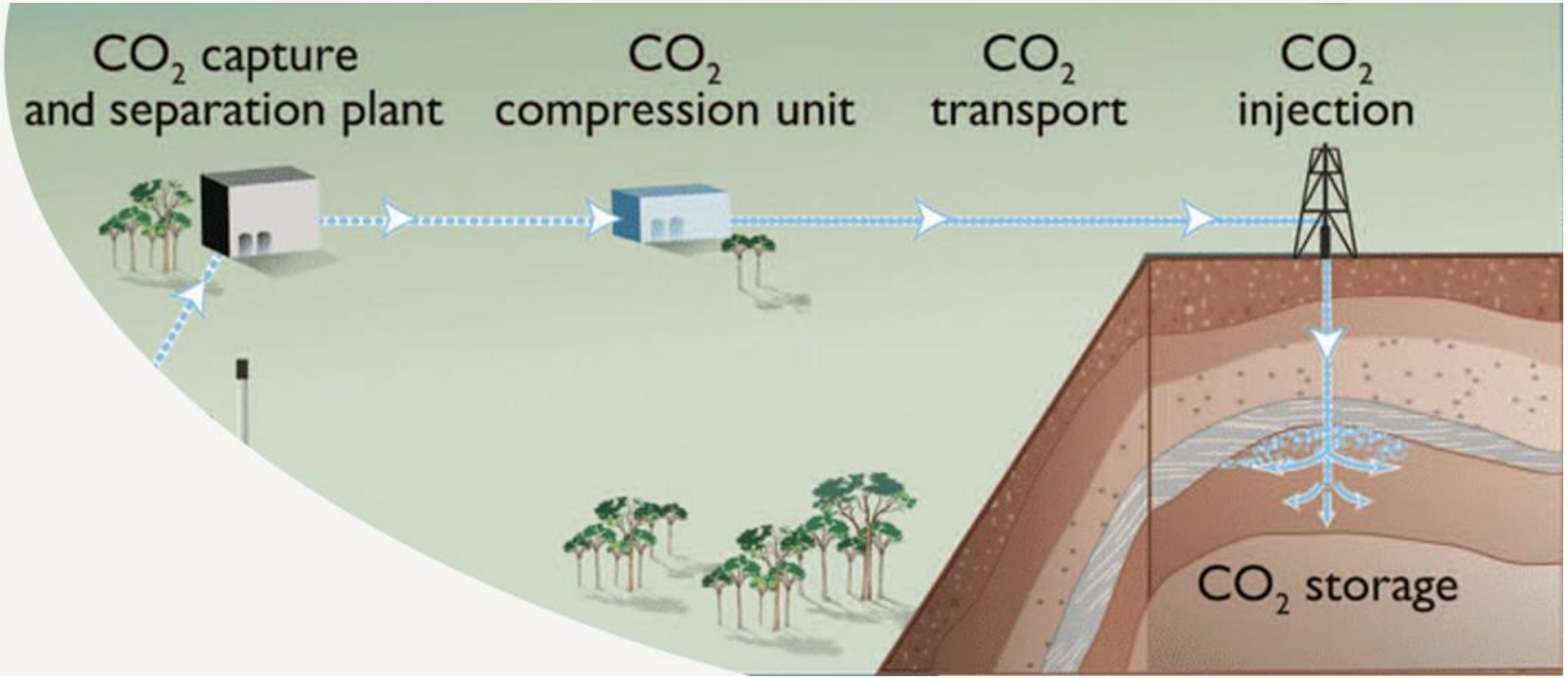
Scope of Presentation

Included - CO_2 removed from natural gas and reinjected underground.

Excluded – Recovery of CO_2 from exhaust/flue gases

Main Themes:

- Corrosion
- Phase Envelope



Corrosion in CO_2 Systems

When CO_2 is removed from natural gas, e.g. by an Amine system, it is typically wet and often saturated with water

Liquid water forms Carbonic Acid in the presence of CO_2 and the resultant corrosion rate is proportional to the partial pressure of CO_2, which is very high

The water is not consumed in the reaction, so the amount of liquid water present doesn't matter

Unfortunately, moisture analysers do not have a reputation as the most reliable instruments

Reaction with Iron in a Water Mediated System

$$CO_2(g) + H_2O(l) \leftrightarrow H_2CO_3(aq)$$
$$H_2CO_3 \leftrightarrow H^+ + HCO_3^-$$
$$HCO_3^- \leftrightarrow H^+ + CO_3^{2-}$$

Cathodic reactions may occur either by the direct reduction of hydrogen ions, or via carbonates:

$$2H^+ + 2e^- \rightarrow H_2$$
$$H_2CO_3 + e^- \rightarrow HCO_3^- + \tfrac{1}{2} H_2$$
$$HCO_3^- \rightarrow CO_3^{2-} + \tfrac{1}{2} H_2$$

The anodic reaction occurs simply via the oxidation of iron:

$$Fe \rightarrow Fe^{2+} + 2e^-$$

Oxides may form either via a one-stage reaction with carbonates, or via a two-stage reaction with bicarbonates:

$Fe^{2+} + CO_3^{2-} \rightarrow FeCO_3$	or	$Fe_2+ + 2HCO_3^- \rightarrow Fe(HCO_3)_2$ $Fe(HCO_3)_2 \rightarrow FeCO_3 + CO_2 + H_2O$

Source: “Corrosion of pipelines used for CO2 transport in CCS: is it a real problem?” (2011) I.S. Cole et al.

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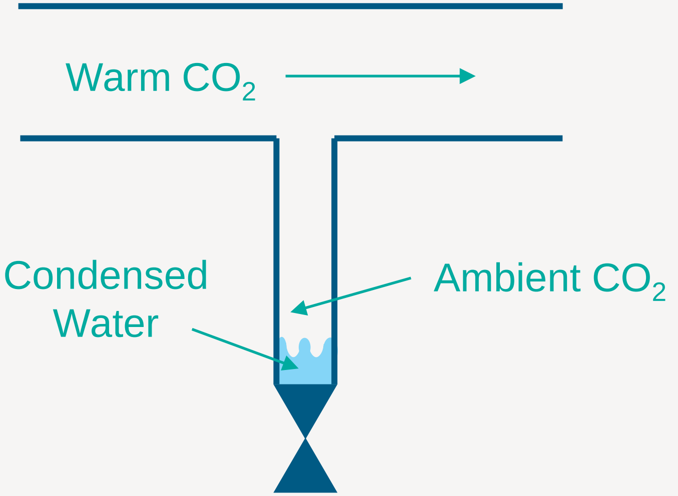
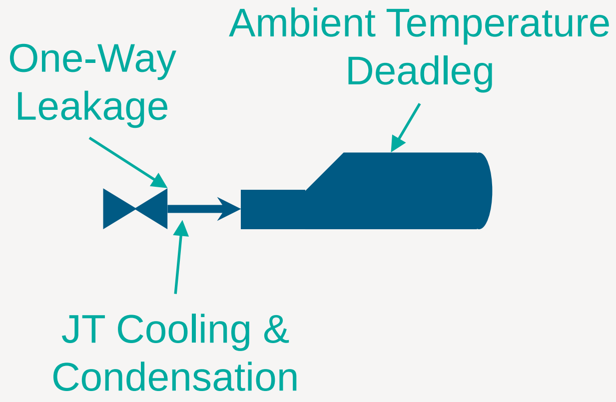
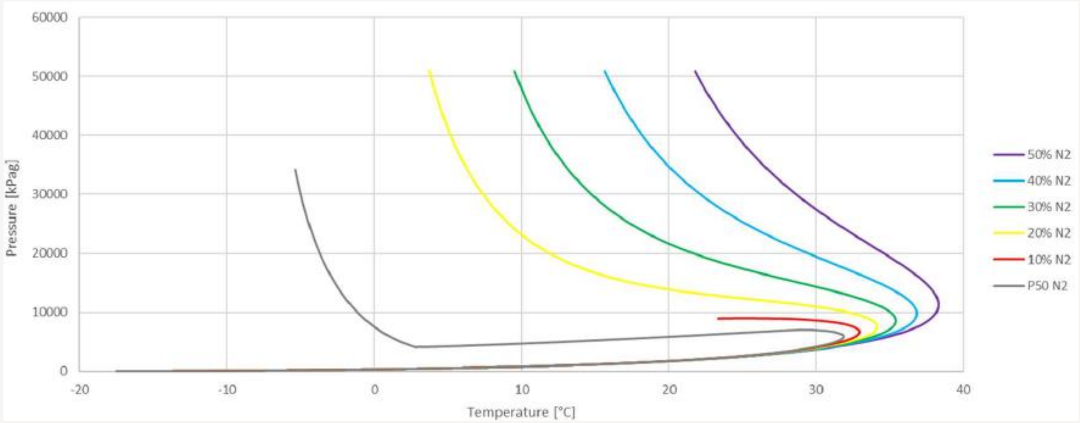
CO_2 Corrosion Weak Points

CO_2 corrosion is a hazard for carbon steel components wherever liquid water occurs. This typically, but not always, occurs where there is a pressure drop resulting in JT cooling:

- Low points in drainage systems
- Valve leakage
- Pipeline pressurisation



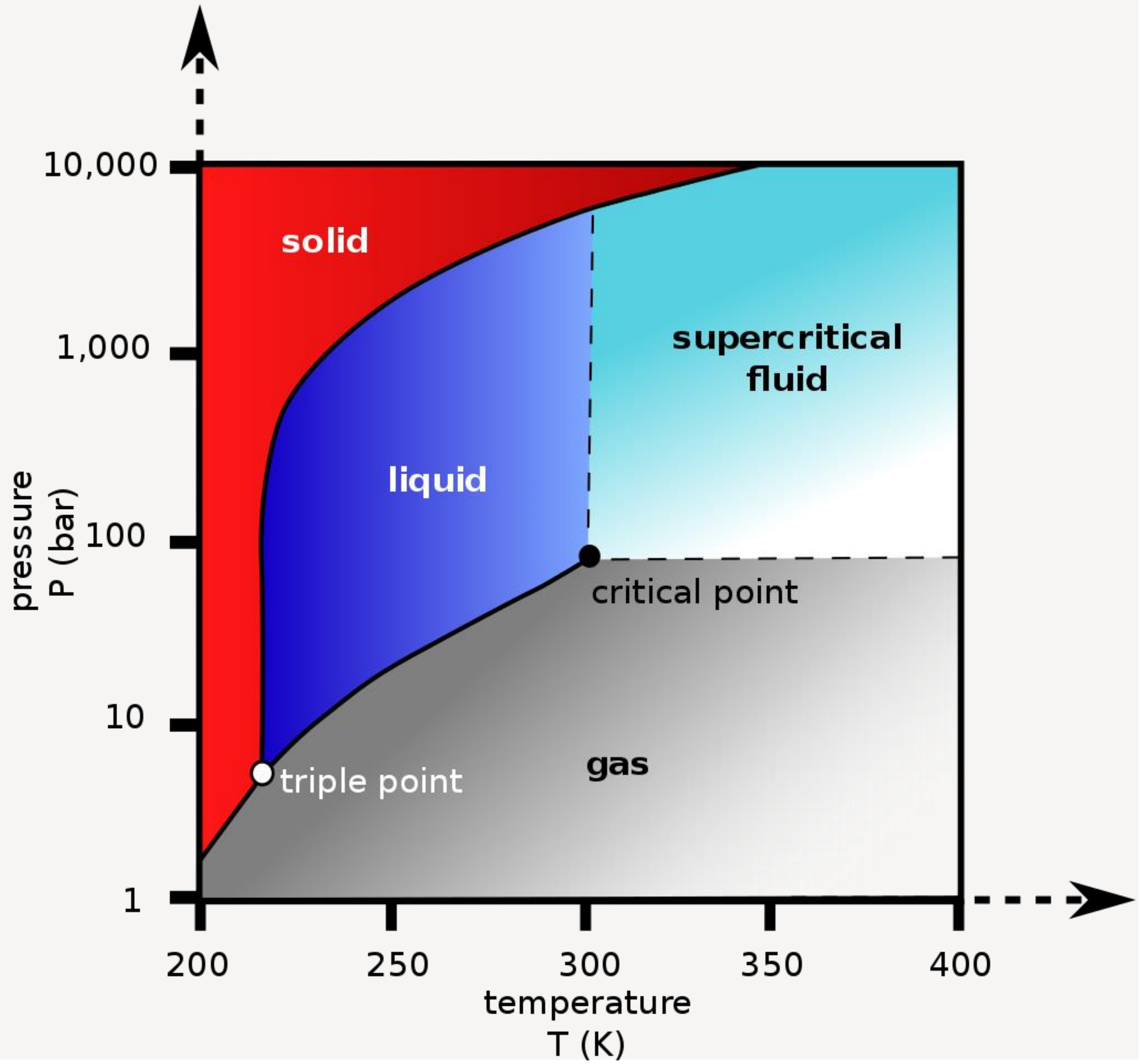




CO_2 Phase Envelope

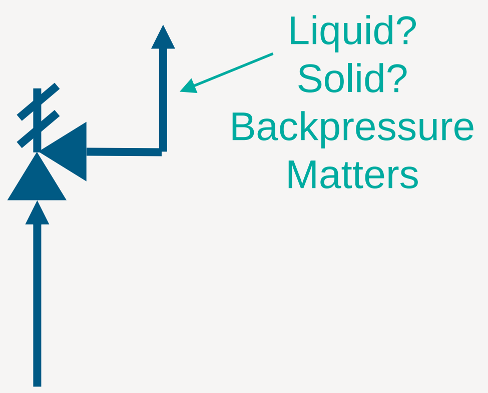
The high pressures required for sequestration create the opportunity for solid, liquid, gaseous or dense phase CO_2. The phase must be checked for all upset conditions.

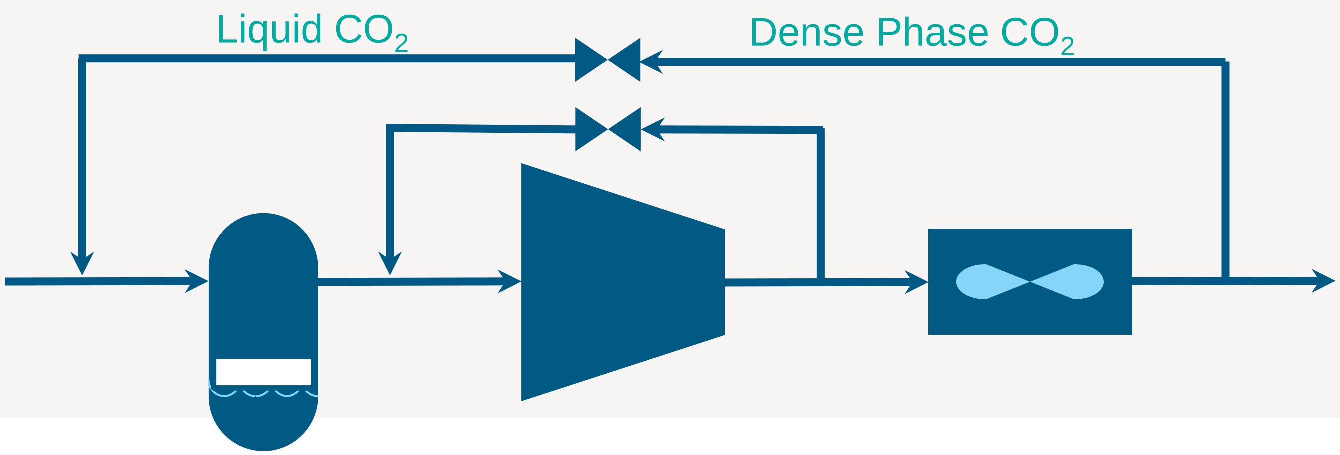
There are particular areas to investigate.

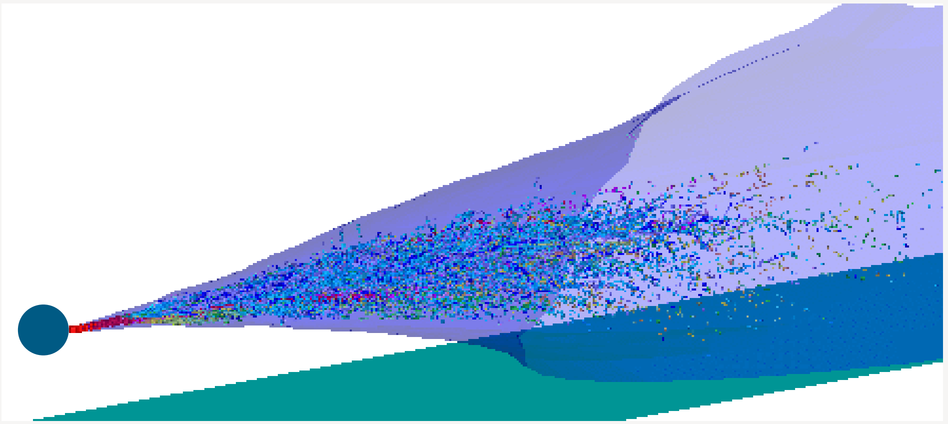


CO_2 Phase Envelope Hazards

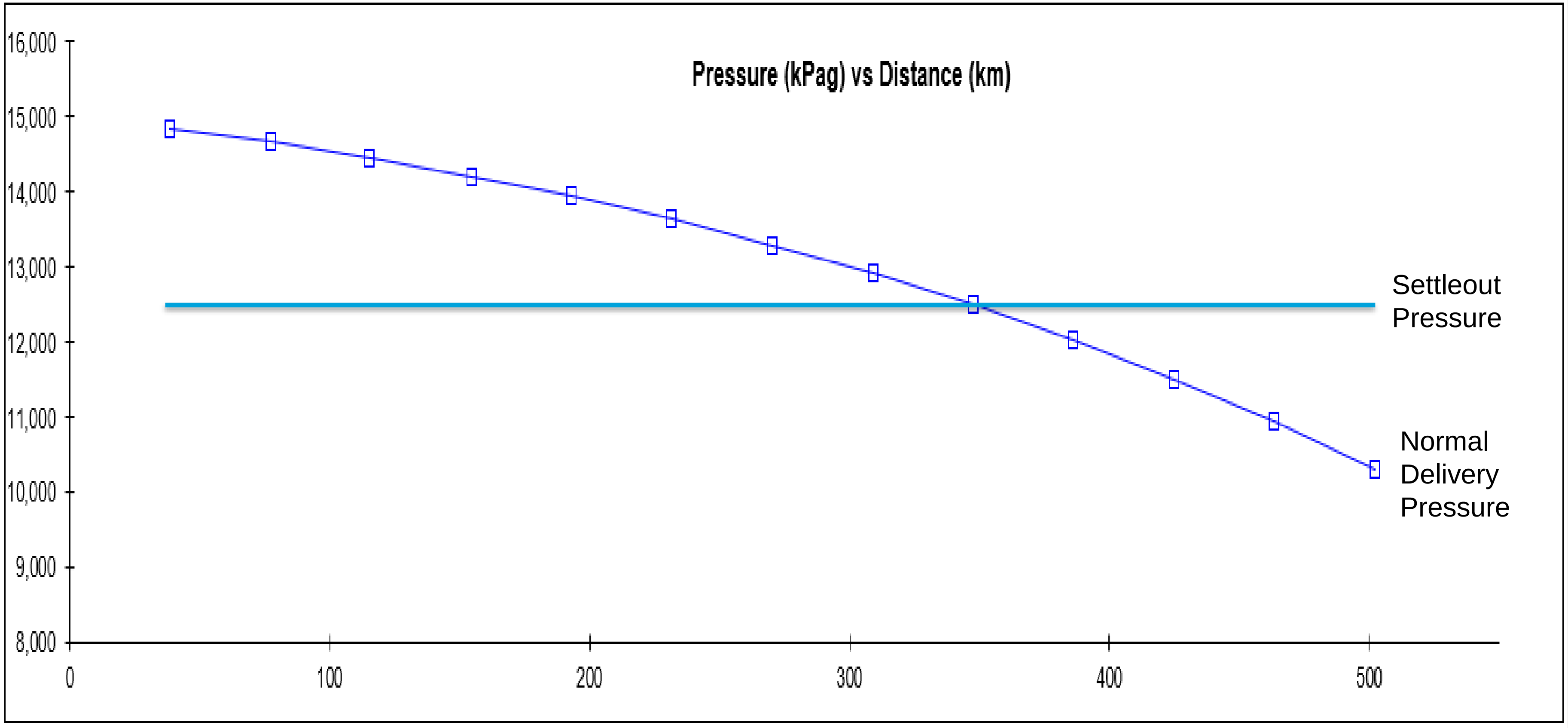
- PSV or BDV tailpipes
- Recycle on the compressor
- Dry gas seals
- Cryogenic protection of structural steel







CO_2 Phase Envelope Hazards

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Thank You!