CO_2 Transport via Pipeline and Ship

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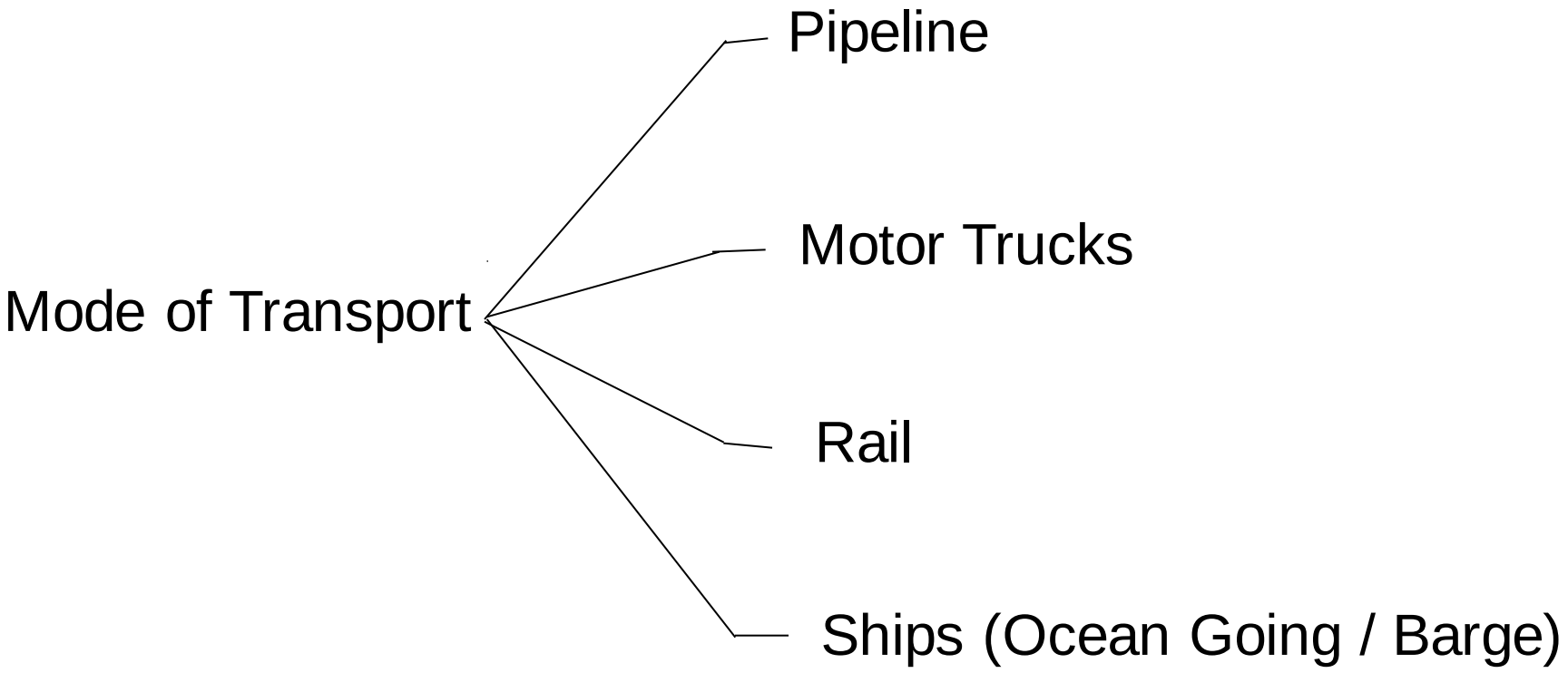
CO_2 Transport



3

CO_2 Transport – Important Notes

- ***Technology is available and mature***
  - For example: USA – about 2000 miles of CO_2 pipeline.
- ***Economic Consideration is the main driver on the choice of CO_2 transport technology options.***
  - Demand and Capacity Utilisation
  - Economy of Scale
  - Flexibility of Ship transport
- ***Operating pressure and temperature defined by the chosen transport technology option.***
- ***CO_2 processing could be an integral part of the CO_2 transport***

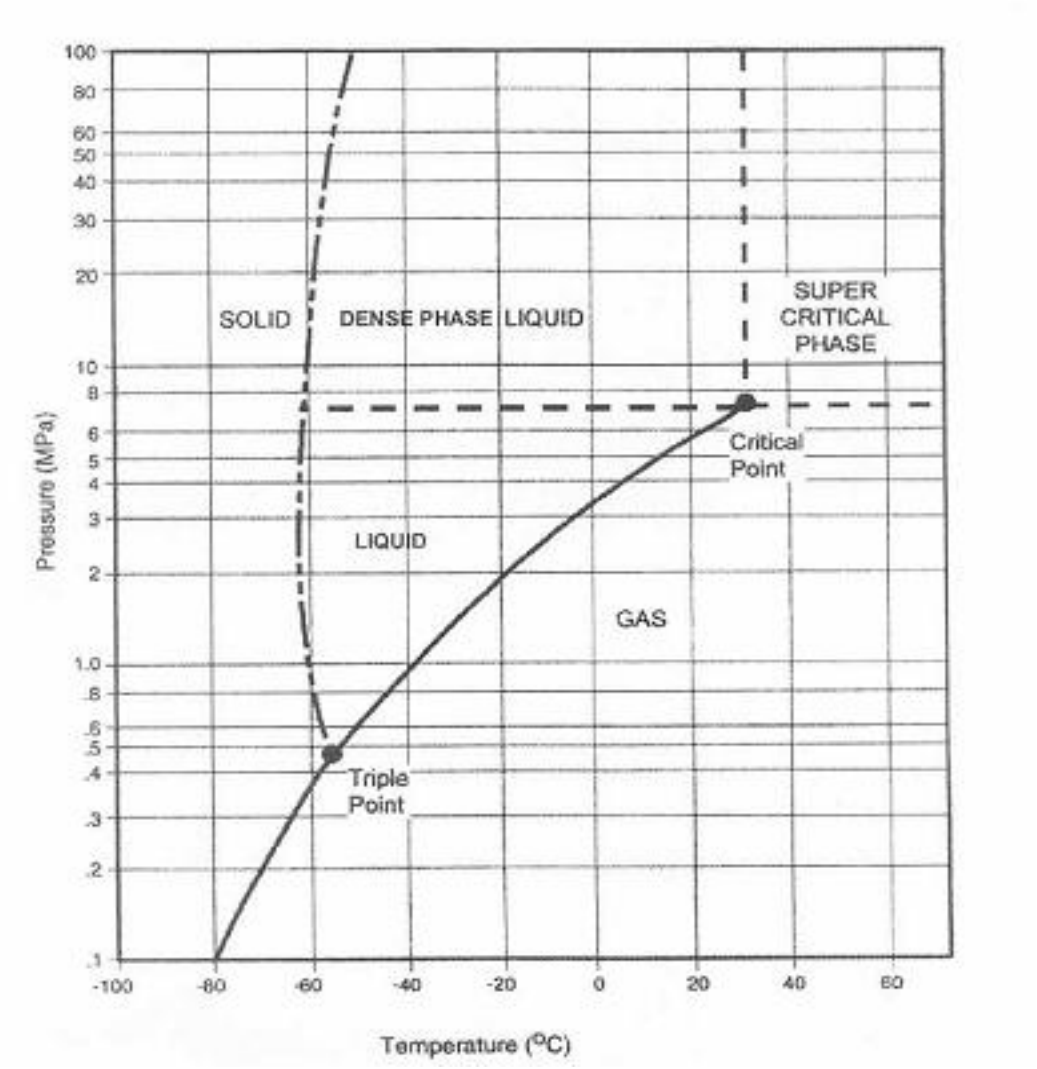
Pipeline Transport

- ***CO_2 compression and pumping***
  - With or without booster station?
  - Liquid, Gaseous or Dense Phase operation?
- ***CO_2 pipeline operation***
  - CO_2 metering
  - Pipeline inspection
- ***CO_2 health and safety***
  - Pipeline design safety consideration (i.e. Crack arrester)
  - Corrosion issues
  - Hydrate formation

CO_2 Compression

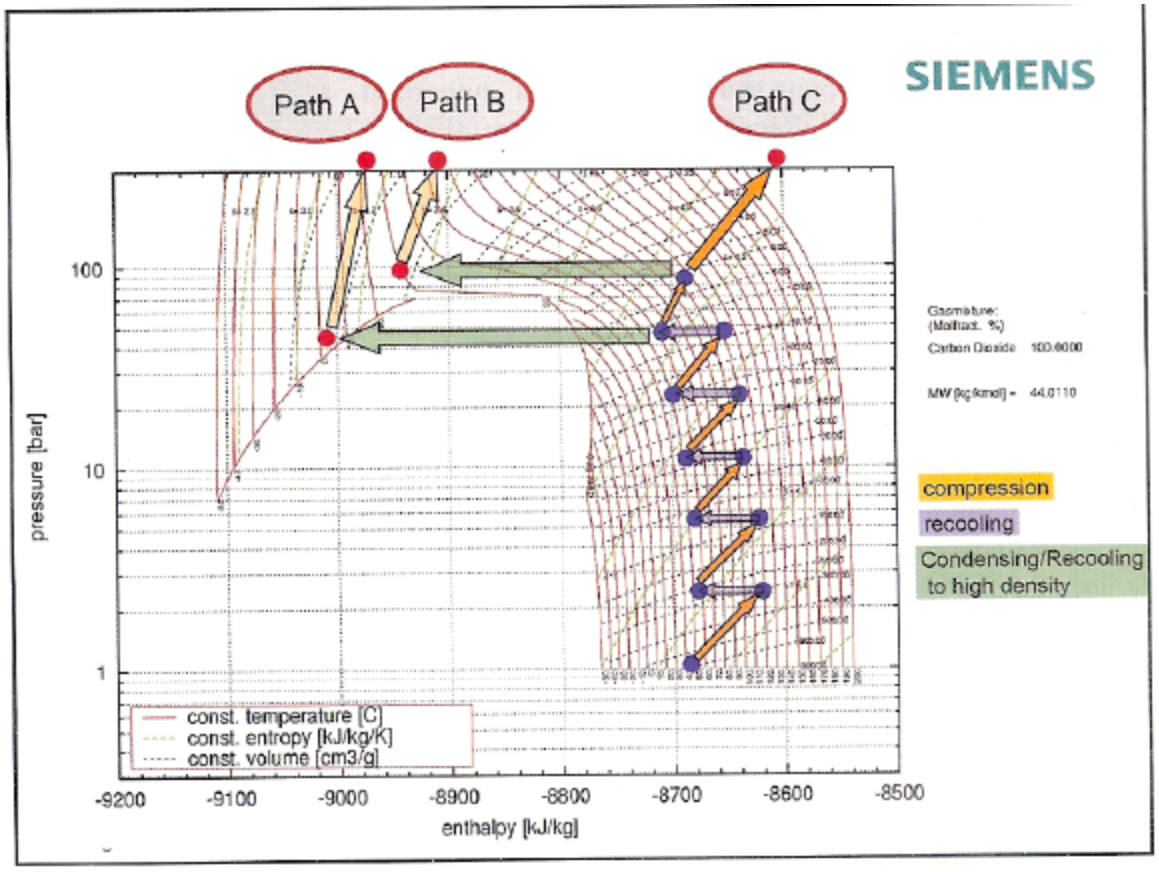
- ***CO_2 compression uses mature technologies typically found in large scale fertilizers manufacturing plant (ie. production of Urea).***
- ***Similar compression technology is also used in natural gas pipeline transport worldwide.***
- ***Centrifugal compressors are preferred for large volume applications.***
- ***The main additional operating issues for CO_2 are avoiding corrosion and hydrate formation.***

Phase Diagram of CO_2



10

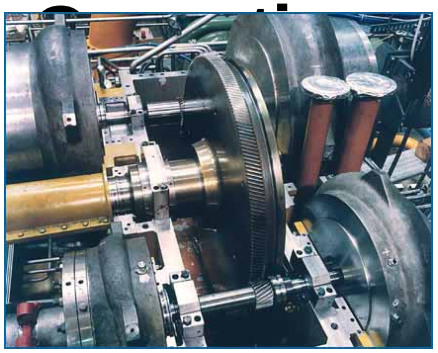
Enthalpy Diagram



Three main compression paths with a reference target pressure of 200 bar

11

CO_2 Compression in a Commercial

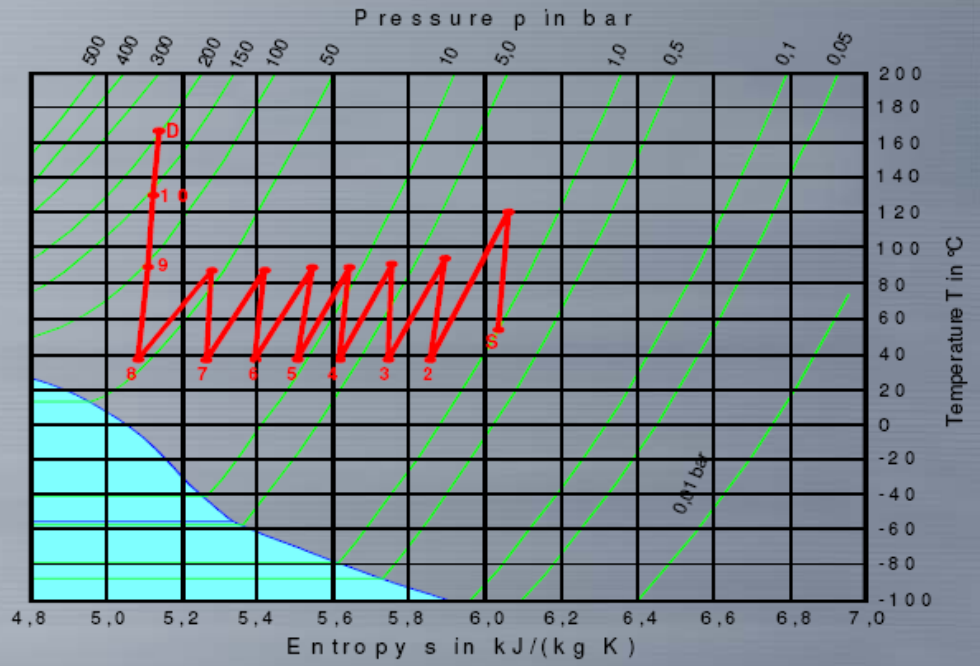


MAN TURBO AG

CO_2 COMPRESSION UPDATE
T / S Diagram NOVAZOT UREA Plant

MAN

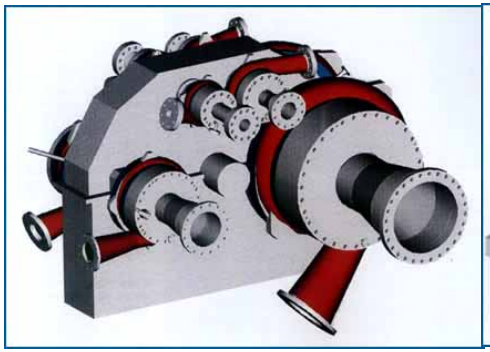
Compression Characteristic

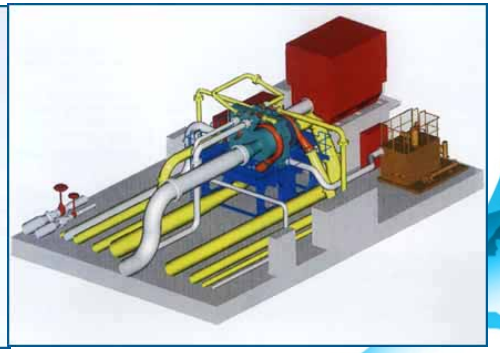


12

CO_2 Compression in a Commercial Operation (Dakota Gasification Plant – CO_2 to Weyburn EOR)

- ***Operation Profile***
  - MAN Turbo RV 042/07
  - Motor Driven (~19500 HP)
  - Mass Flow: 125 000 kg/hr
  - Inlet Pressure: 1 Bar
  - Discharge Pressure: 190 Bar
  - 2 units started operation in 2000 (each unit transporting ~55 mmSCFD)
  - 3rd units started operation in June 2006





14

Pipeline Design

- ***Pipeline pressures: 10-20 MPa (existing pipelines)***
- ***CO_2 is a "dense phase" fluid (about 0.8 t/m^3)***
- ***Moisture below 10 ppm level is now expected as a pre-requisite.***
- ***Retrofit of existing Hydrocarbon or NG pipeline is possible.***
- ***Special steels are not required***

17

Operational Issues

- ***Pipeline Inspection – an important part of CO_2 transport operation which would require extensive review during design and implementation.***
  - i.e. Pipeline Pigging Exercise
- ***CO_2 metering – this is an important aspect to provide accountability between CO_2 capture and storage.***
  - i.e. Orifice and venturi meters
- ***Start up and shut down***
  - Drying procedure during start up
  - Depressurisation procedure during shut down

Pipeline Safety

- ***CO_2 is not flammable or explosive***
- ***CO_2 is an asphyxiant and is heavier than air***
- ***Leaking CO_2 may accumulate in low-lying places***
- ***The number of incidents is similar for existing CO_2 and natural gas pipelines***
- ***No deaths from CO_2 pipeline accidents***
- ***Existing pipelines are mostly is sparsely populated regions***
- ***Existing pipelines pass through some small built-up areas***
- ***Further work is needed to assess potential hazards in some circumstances, e.g. for offshore EOR***

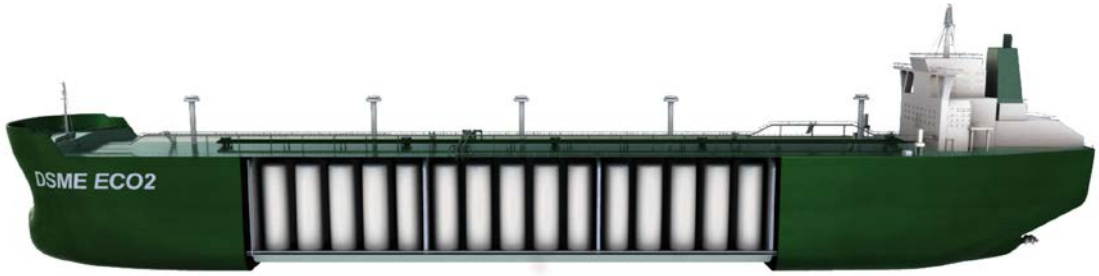
Ship Transport

- ***Ship transport could make the economics consideration of CO_2 transport more flexible. (Mix and Match with pipeline transport)***
- ***Transport of CO_2 by ship in smaller volume (i.e. <1500 m^3) is currently practiced in the industry***
- ***Shipping at lower pressure is preferred.***
- ***However, operating at higher pressure should not be a major problem, as tankers currently used for shipping liquefied petroleum gas (LPG) can be used for CO_2***

CO_2 Ships Transport

CO_2 is transported for the food, drink and chemical industries

Coral Carbonic 1250 m^3 CO_2



Larger ships would be needed for CCS

Daewoo's proposed 100k m^3 CO_2 ship

River barge transport

- ***Barges have been used to transport liquefied gases for many decades***
- ***Barges may have cost and regulatory advantages over CO_2 pipelines in some circumstances***

Thank you

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