Repurposing of Existing Pipelines for CCUS Service

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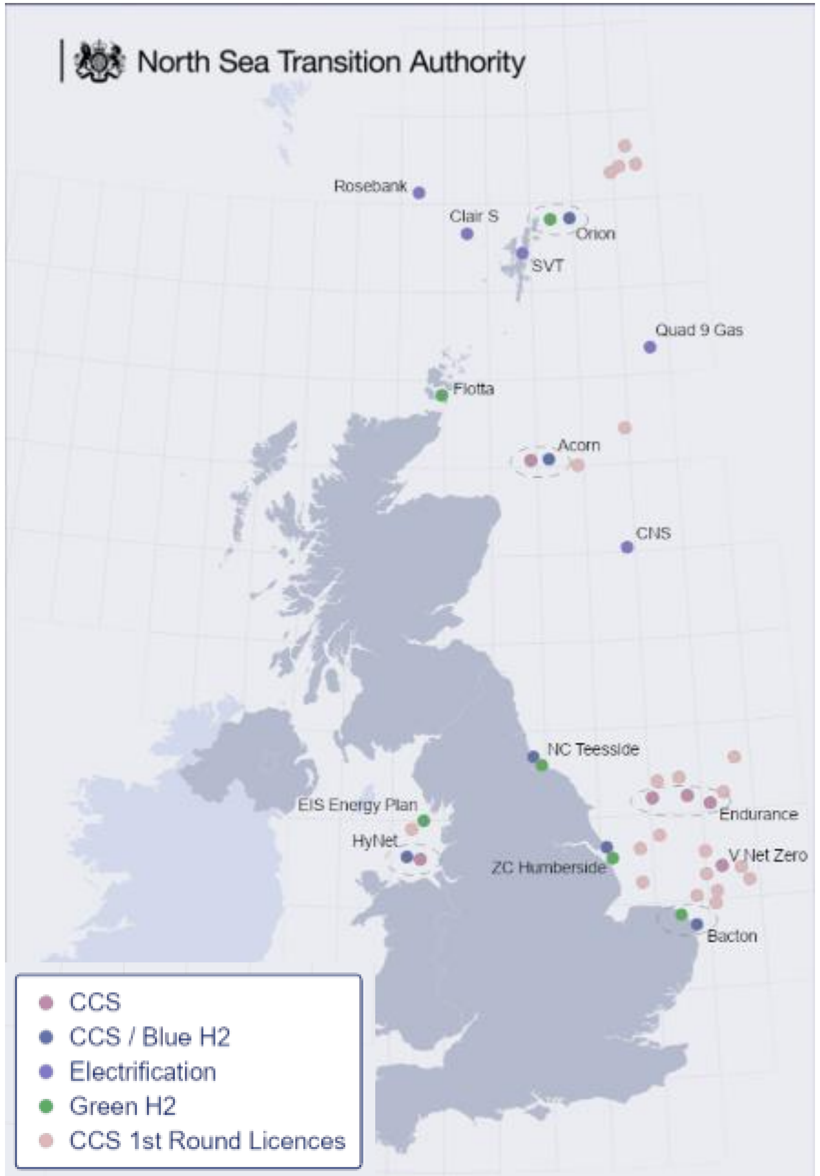
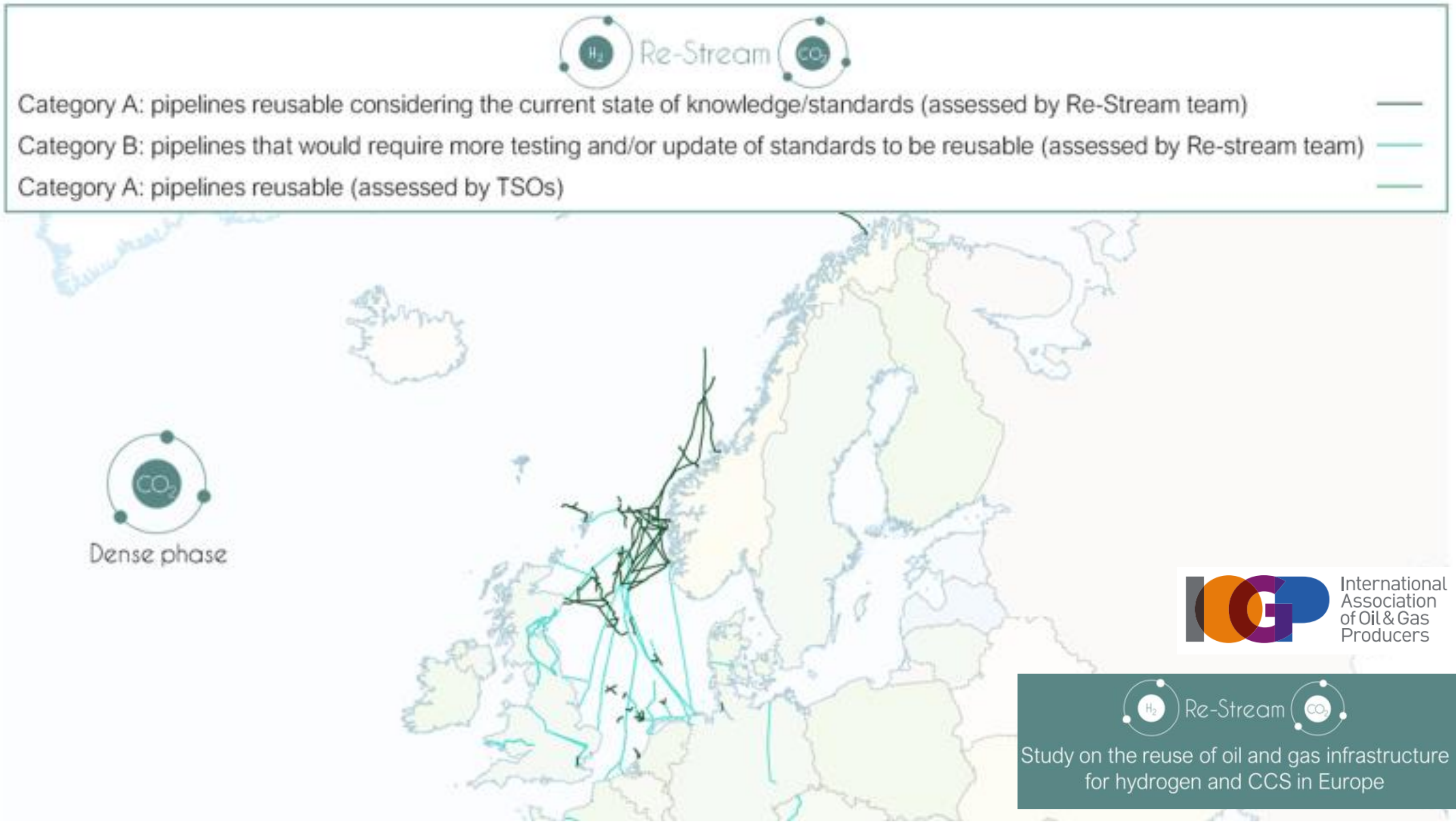
Potential for Repurposing





70% of the existing offshore pipeline length may be suitable for CO_2 transport

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Why Repurpose and What are the Challenges?

Project enabler
especially when connected to depleted gas reservoirs

Reduced CAPEX
– up to £2M/km

Reduced project lead times

Reduced environmental impacts

Meet NTSA stewardship expectation 11

- Does pipeline have sufficient capacity for gaseous/dense phase CO_2 transportation and pressure rating for dense phase?
- Is current condition and cleanliness of pipeline adequate?
- Are materials and design suitable for repurposing?
- Does pipeline comply with contemporary design codes?
- Are risk profiles in CO_2 service acceptable?
- Does pipeline have sufficient remaining life?
- What are requirements for confirmatory hydrotest and pipeline drying?

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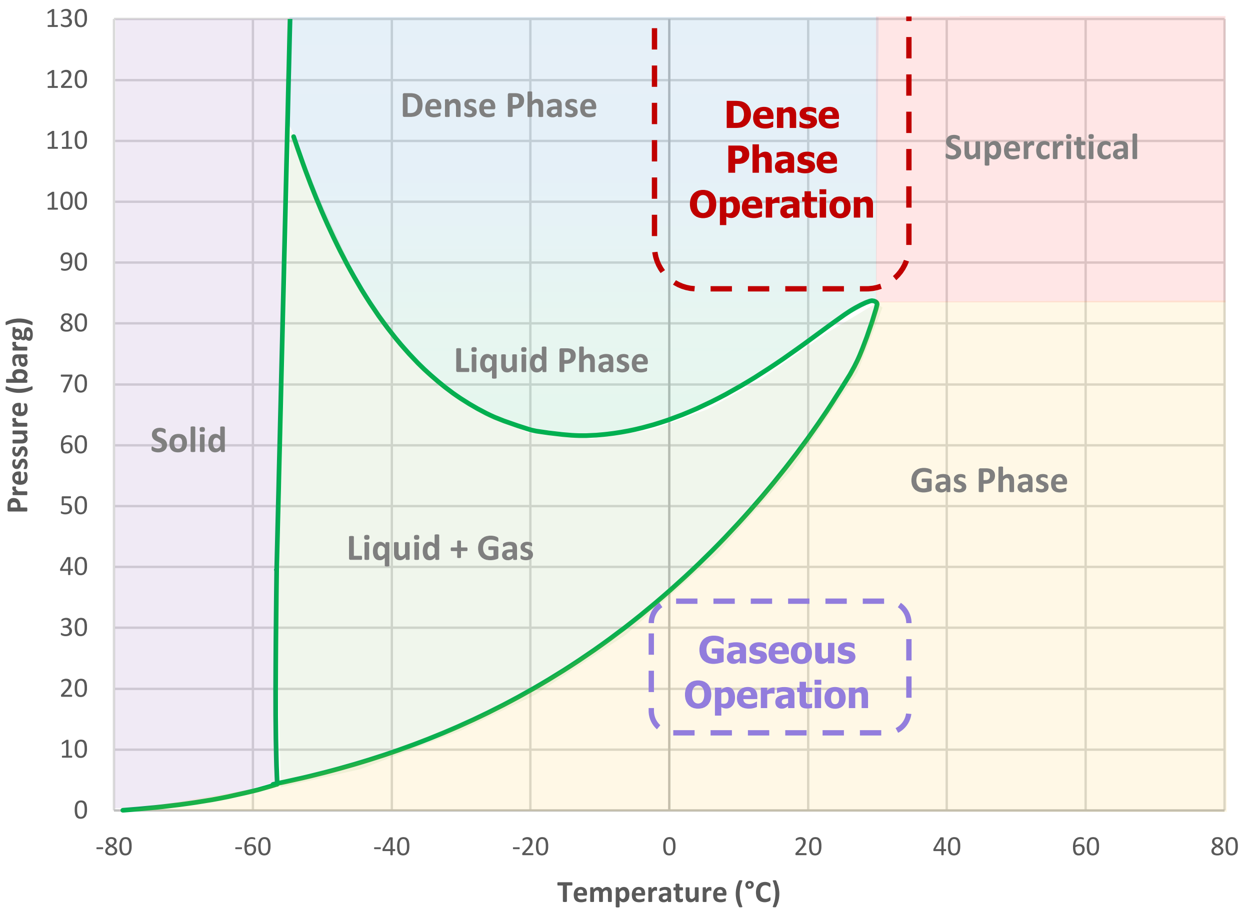
Dense vs. Gaseous Phase Operation

- Need to avoid unstable multiphase flow in pipeline
- Dense phase required to meet target rates/capacity for CCS clusters
- Repurposing challenges are much more severe for dense phase than gaseous phase
- Offshore, high pressure, gas pipelines are most suitable candidates for repurposing for dense phase CO_2



Industry Guidance for Repurposing for CCUS

PD8010 and DNV ST-F101 give some guidance for CO_2 pipelines, with further guidance in:

- BS ISO 27913
- DNV RP-F104

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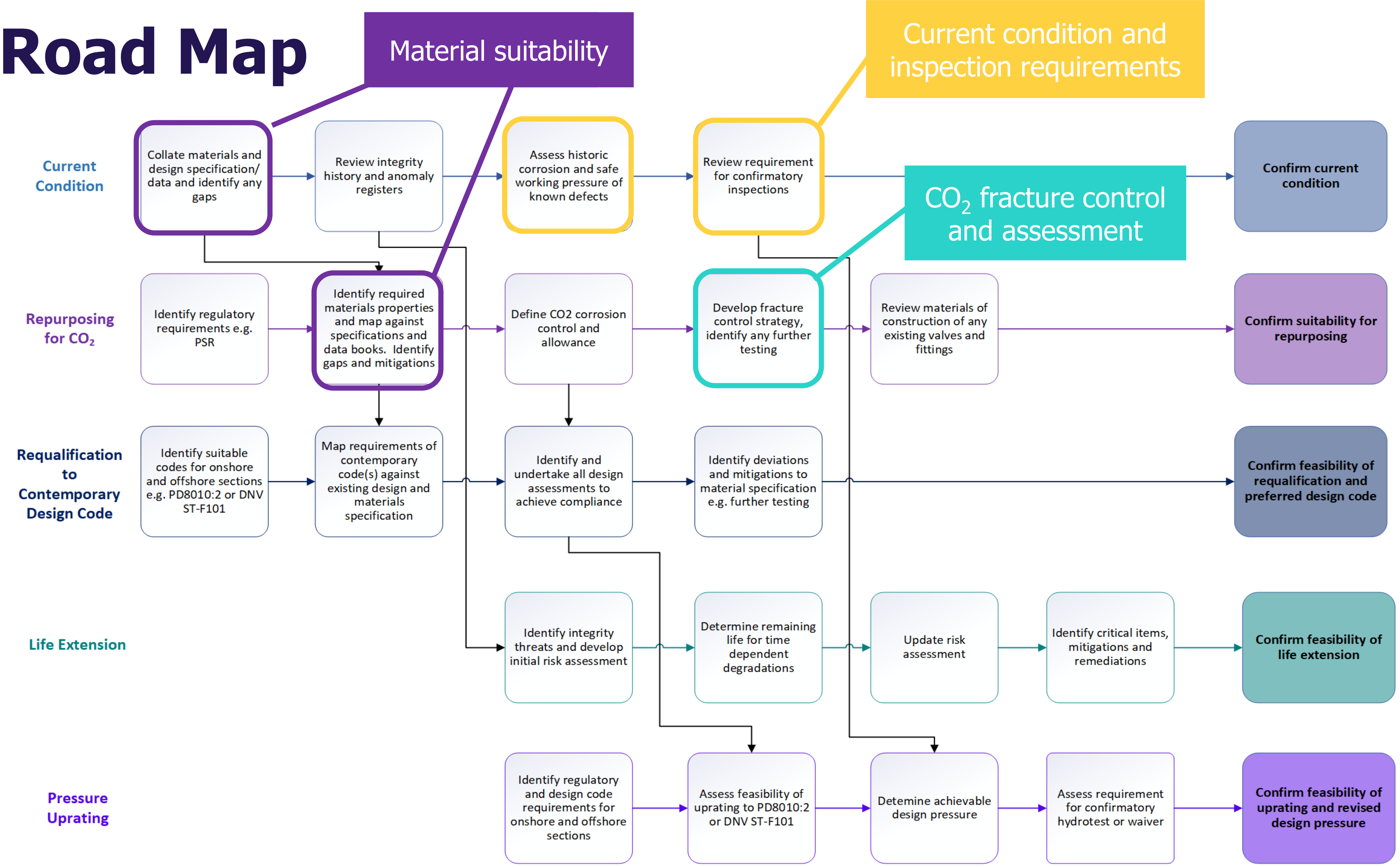
Road Map



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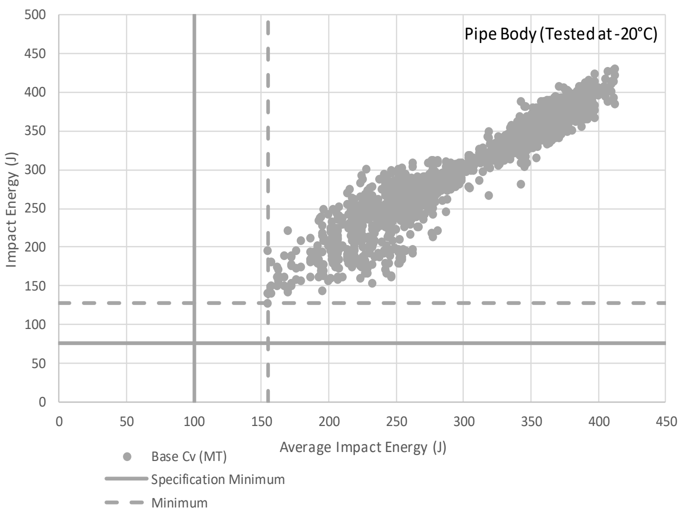
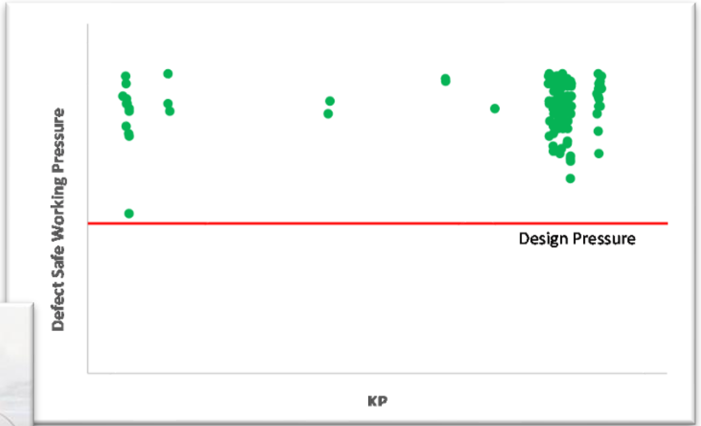
Material Suitability and Current Condition

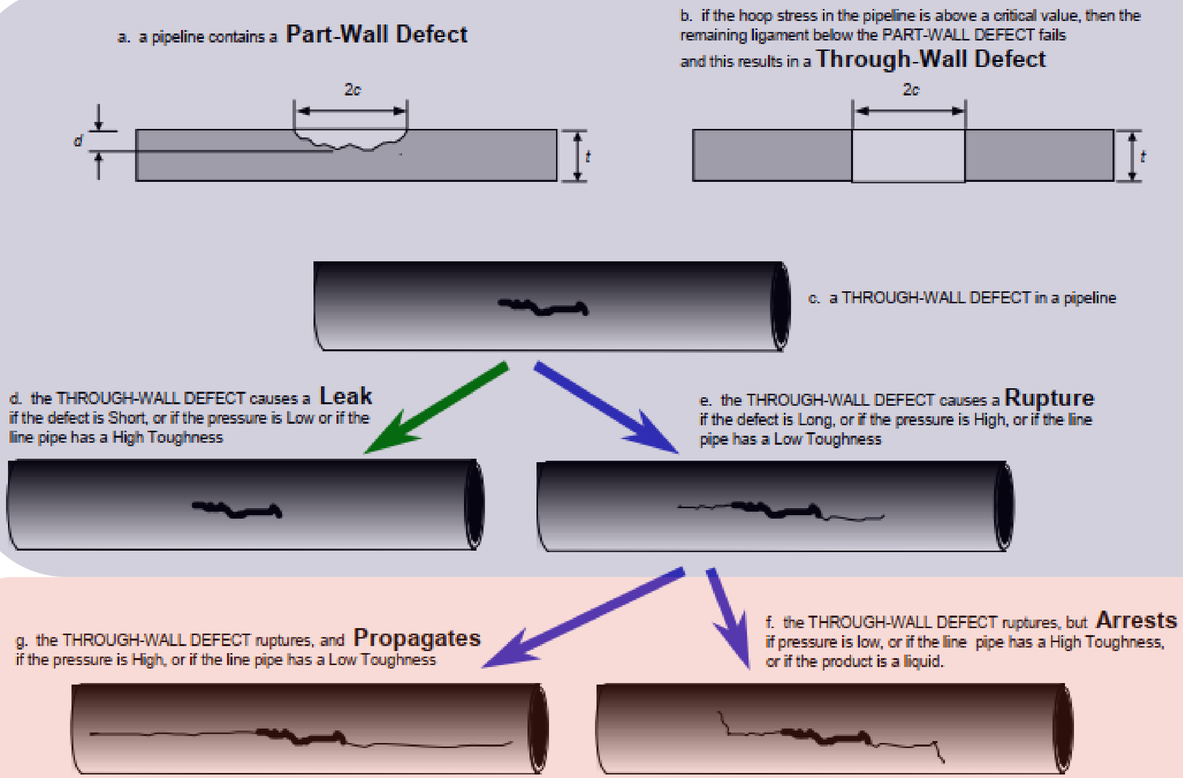
- Desirable material properties for dense phase CO_2
  - Low carbon equivalent (CE), good ductility, avoidance of high Y/T
  - Low minimum design temperature
  - Good fracture toughness at low temperature
  - Avoidance of high hardness, sour service rating (ideally)
  - Control of inherent defects
- Confirm achieved properties by review of linepipe and welding specifications, data books, WPQR



- Consider historical corrosion and damage mechanisms (general loss, pitting, cracking etc.)
- Assess safe working pressure of known defects (e.g. ASME B31G, DNV RP-F101)
- Review resistance to future CO_2 damage mechanisms
- Identify requirements for any confirmatory inspections
- Identify debris risk to downstream filters and wells



Fracture Control of CO_2 Pipelines



Fracture Initiation Control

i) Initial source of defects can be:

- independent of fluid e.g. 3rd party interaction, or
- fluid dependent e.g. internal corrosion

ii) Critical Defect Length (leak vs. rupture) is independent of fluid

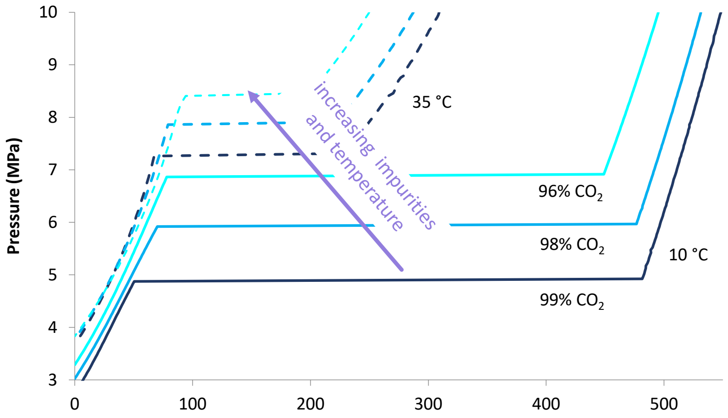
- however, CO_2 pin-hole leaks may result in very low temperatures with risk of brittle failure

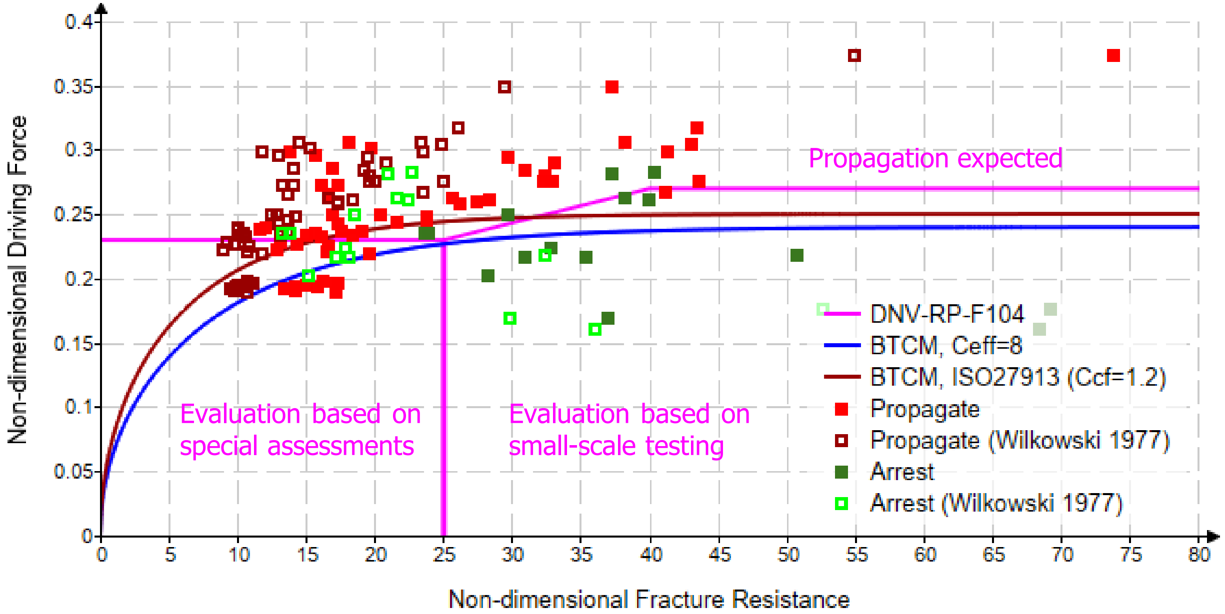
Fracture Propagation Control

iii) Dense phase CO_2 requires significantly higher toughness to arrest a running ductile fracture (c.f. natural gas)

CO_2 Running Ductile Fracture Methodology

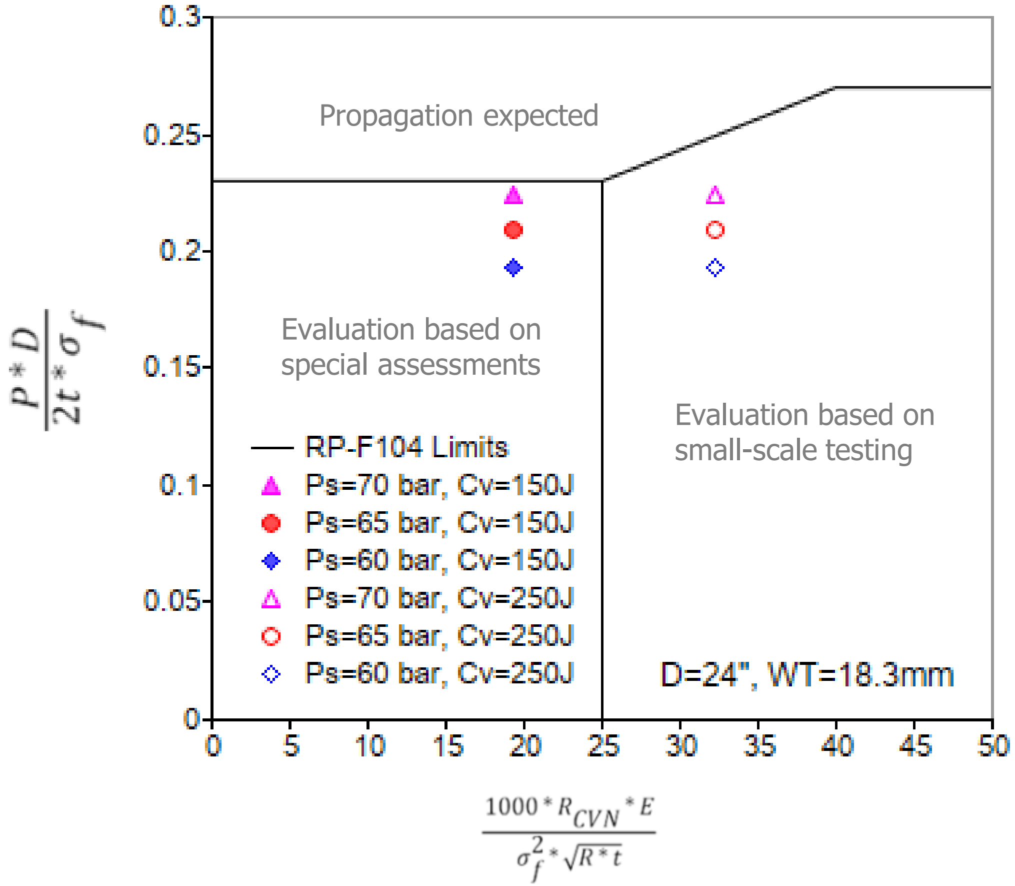
- Dense phase CO_2 experiences a long decompression plateau along liquid-vapour line - *saturation pressure, P_s*
- Resistance is increased by wall thickness, grade and toughness - *arrest pressure, P_a*
- Running ductile fracture arrests when $P_a > P_s$
- Assessed using Battelle Two-Curve Model
  - Correction factors for CO_2 and high toughness
  - Potentially non-conservative
- Recent re-evaluations of dataset of full-scale CO_2 tests:
  - DNV-RP-F104 (2021): empirical model from CO2Safe-Arrest JIP with applicability limited by test dataset
  - Cosham et al. (2022): modified BTCM with effective crack length of 8 and Wilkowski (1977) correction
- Remains an ongoing research area
- Project specific testing may be required



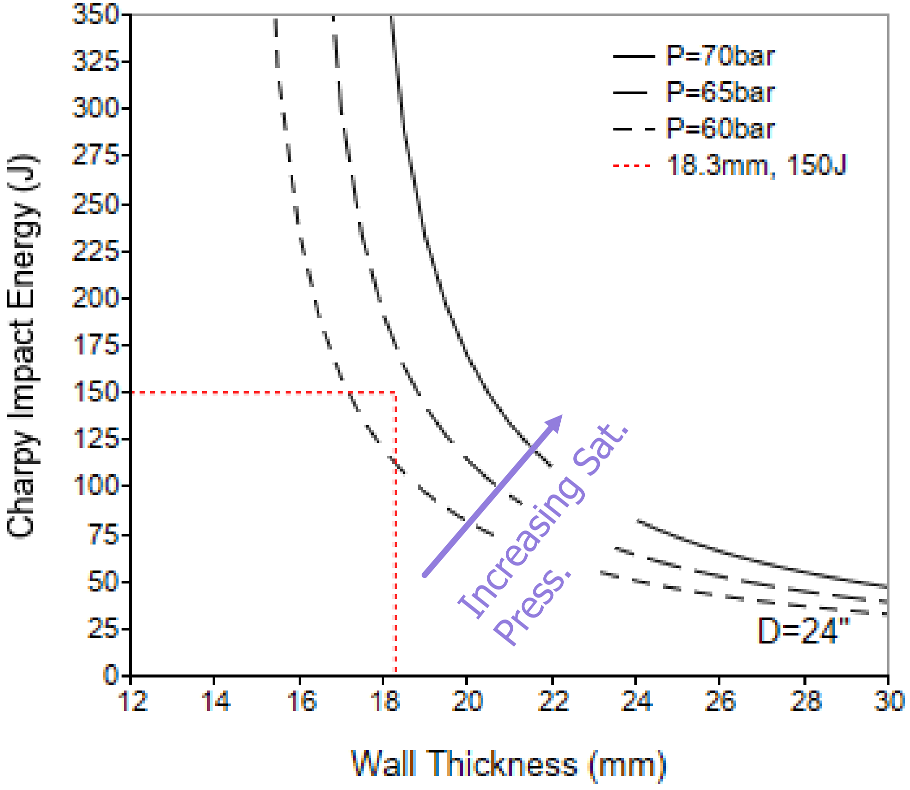


CO_2 Running Ductile Fracture Assessment

DNV RP-F104 (2021)
Repurposed pipelines may be outside limits of applicability, and may fall in "Evaluation based on special assessments" due to insufficient toughness



BTCM with Ceff = 8 and Wilkowski 77 correction
Wider applicability but not fully validated



Summary

Challenges

- Current condition
- Suitability of materials
- Fracture control and arrest
- Requalification
- Life extension
- Pressure rating

Benefits

- Project enabler
- Reduced CAPEX
- Lower environmental impacts
- Reduced project lead time
- Meeting stewardship expectations

THANK YOU

Contact

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