Flow assurance from oil and gas to CO2 transport and injection

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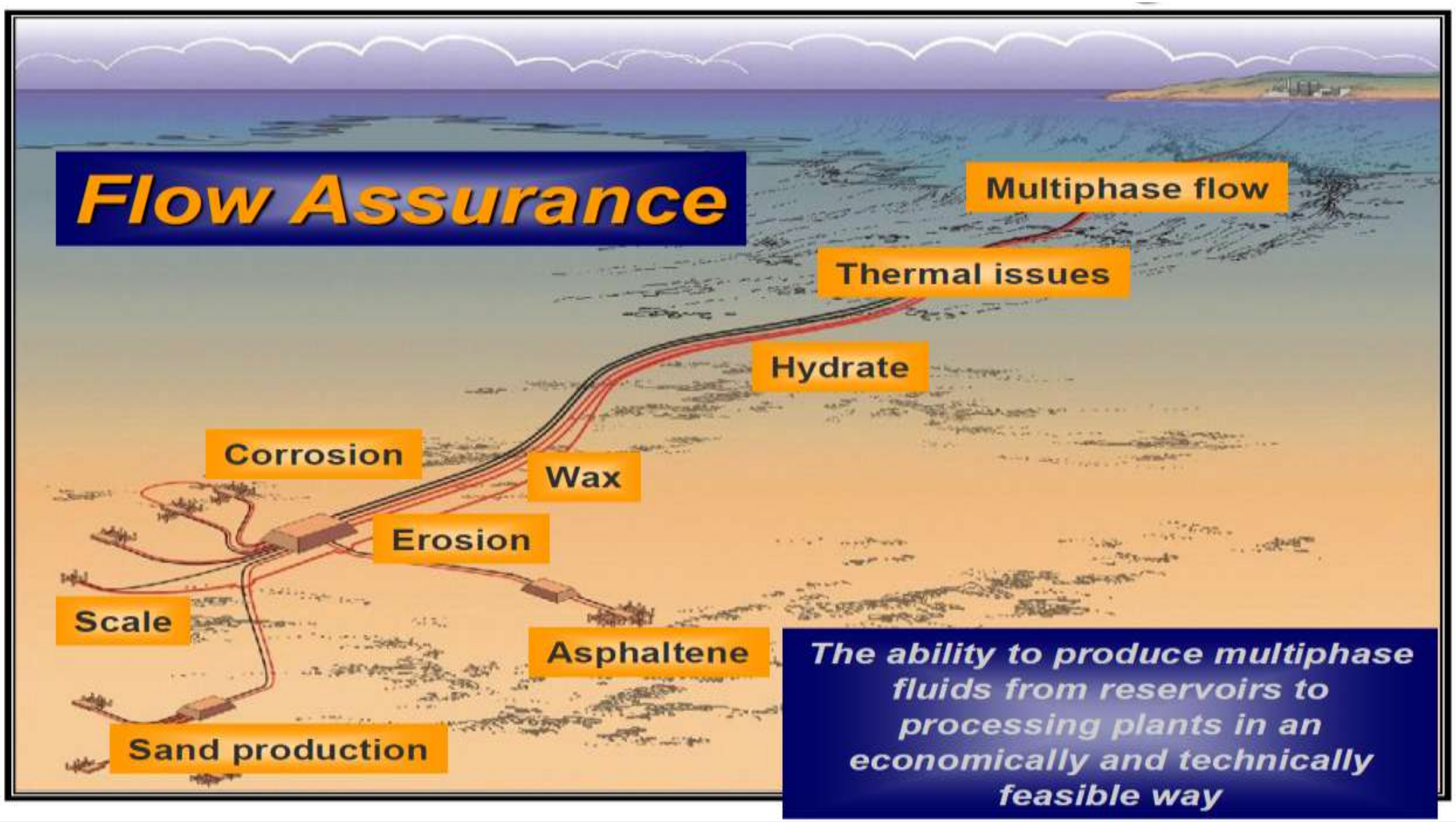
Outline

- Introduction to flow assurance
- State-of-art of commercial software for flow assurance of oil & gas transport and production
- Challenges of CO_2 transport and injection
- Research programme of CO_2 FACT JIP
- Summary

Flow assurance in oil & gas



Open

State-of-The-Art Flow Assurance Tools

- Address flow dynamics (multiphase flow) & thermal process primarily
- Provide inputs (P, T, u, fluid contents, etc) to other flow assurance studies
  - Hydrate, wax, corrosion, erosion, etc.
- Major physical phenomena:
  - Steady-state process:
    - P, T, and flow regimes
  - Transient operations
    - Ready-for-operation (RFO)
    - Shut-in and restart
    - Ramp-up production
    - Slugging, etc
  - Depressurization processes:
    - blow-out, leakage
- PVT package: input to flow assurance tool (PVTsim, MultiFlash, etc.)

Software Name	No of Phases	Physical processes
OLGA	2 & 3	Steady-state and transient
LedaFlow	2 & 3	Steady-state and transient
PIPESIM	2	Steady-state
Prosper & Gap	2	Steady-state
FlowManager	2	Steady-state and transient

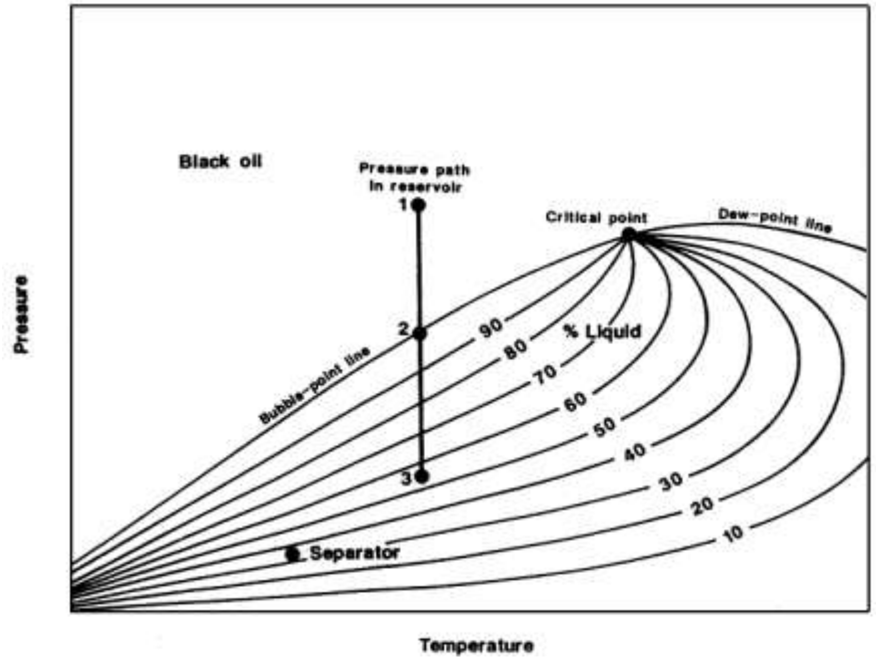
Similarities between CO_2 and oil&gas system

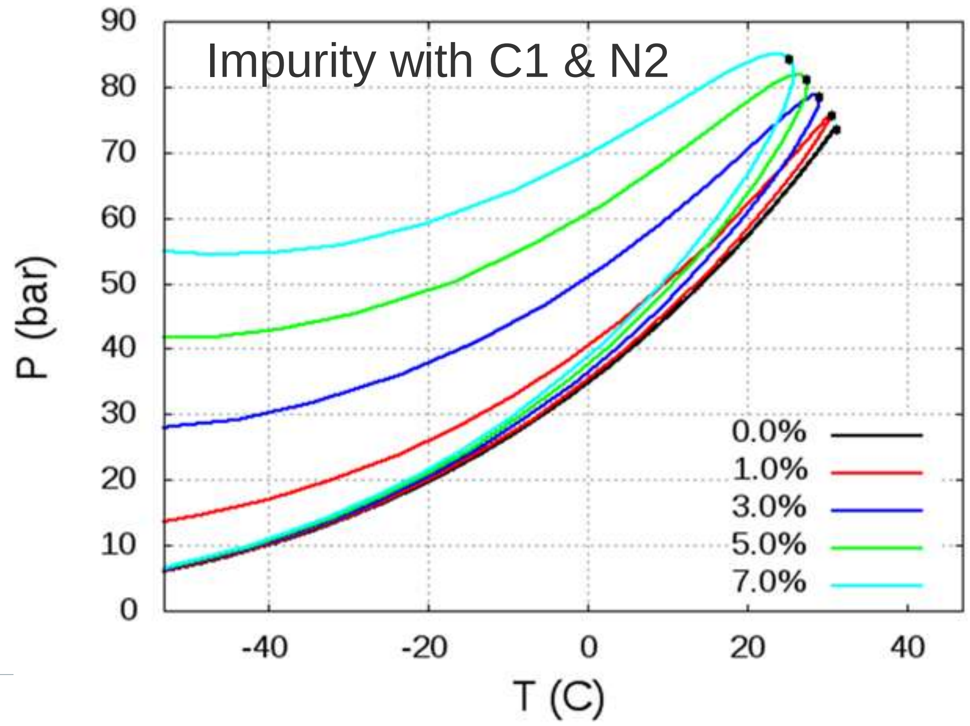
- Steady-state fully-developed flow – base model in all flow assurance software
  - Physical model developed based on lab data

Parameters	Existing lab data	Oil production system	CO2 system
Fluid system	N2-Exssol, N2-Naphta, SF6-Exssol, gas condensate	Light crude oils	Pure CO2 and CO2 with impurities
Pipe diameter, m	0.078, 0.1, 0.19	Up to 16 inches	Up to 16 inches
System pressure, bar	4 – 90	From around 10 bar to reservoir condition	Up to reservoir condition
Gas density, kg/m3	20 - 100	Depends on system pressure and fluid system	Up to 250 for two-phase condition
Liquid density, kg/m3	550 - 820	>750	550 – 700 for two-phase condition
Liquid viscosity, cP	0.3 – 1.7	>1	0.1 – 0.15 for pure CO2
Gas viscosity, cP	0.01 – 0.015	~0.1	0.02 – 0.1
Interfacial tension, mN/m	8 – 28	Up to 30	N/A

Challenges of CO_2 flow assurance

- PVT package: accurate physical properties crucial for the flow model
    - Effect of impurities
- Dynamic process in two-phase region
    - Strong coupling between hydro- and thermo-dynamics
- Strong Joule-Thomson effect
- Poor understanding of flow behavior in supercritical condition, in particular in the area close to critical point
- Triple point and solids are not addressed in any of the existing commercial flow assurance tools



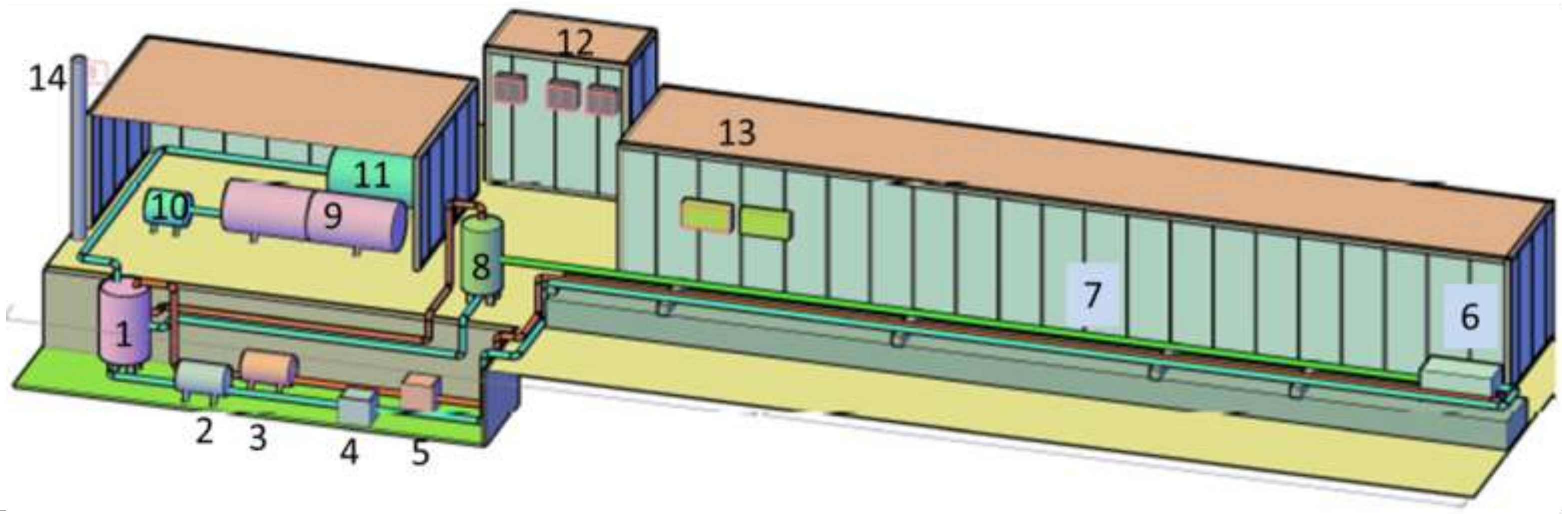


Research program – CO2 FACT JIP (co-funded by Gassnova through the CLIMIT-Demo Program)
CO_2 Flow Assurance for Cost-effective Transport

- **Objectives**
  - Establish the best practice of the existing flow assurance software for CO2 pipeline transport and injection system by comparing with lab and field data
  - Reduce the uncertainty of these software for the design and operation of CO2 systems
- **Scope of work**
  - WP1: In-kind contribution from oil industry on field data and thermodynamics
  - WP2: Experimental study from laboratories via sub-contractor
  - WP3: Software update and best practices
- **Deliverables**
  - Operational experience & data from Snøhvit field
  - Thermodynamics model for CO2 with impurities
  - Beta release of software & best practices
- **Schedule**
  - Nov.2018 – Dec.2019: Pure CO2 system
  - Oct.2019 – Mar.2021: CO2 system with impurities

CO2 FACT JIP
- Lab study at IFE: Pure CO2 and CO2 with impurities

1. Fully-developed flow: both single and two-phase gas-liquid
   - 1.1:Steady state single-phase
   - 1.2: Steady state two-phase flow
2. Steady-state and developing flow
   - 2.1: Phase change process along the pipe
   - 2.2: Flow with choke
3. Transient process:
   - 3.1: Shut-in type experiments
     - 3.1.a :Fluid hammering;
     - 3.1.b: Shut in at two-phase conditions
     - 3.1.c: Shut-in at conditions near critical point
   - 3.2: Re-start experiments
   - 3.3: Depressurisation experiments



Summary

- Extensive experience of multiphase flow assurance from oil and gas industry can be transferred to the flow assurance for CO_2 transport and injection system
- Most of the functionalities and physical models in the existing commercial flow assurance tools for oil & gas are still applicable to CO_2 systems, however, their verification and validation need to be conducted with dedicated lab tests with CO_2 fluids and relevant field operational data
- The on-going research program – CO_2 FACT JIP (funded by Gassnova and partners) shall provide important data to quantify the uncertainty of commercial flow assurance tools
- Significant efforts are needed to mature the existing tools for CO_2 transport and injection

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TOTAL

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