Novel Technique for Addressing Gas Hydrate and Flow Assurance: Coldflow & HYDRAFLOW

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Outlines

• Background
  – Gas Hydrates: What are they?
  – Hydrate problems, current solutions, limitations

• What is ‘Cold Flow’?

• The ‘Hydraflow’ Concept

• Laboratory results

• Future development
What are gas hydrates?

Gas hydrates are:

• Ice-like crystalline compounds
• Composed of water + gas (e.g. methane, CO₂)
• Formed under low temperatures and elevated pressures
• Stable well above the ice-point of water
Gas Hydrates Problem

• Hydrate blockages are major flow assurance problem in offshore and Arctic operations

• Economic and safety hazard

• Hydrates can form:
  – In subsea long tiebacks / transfer lines
  – At high pipeline residence times
  – Across gas expansion valves (cooling)
  – During drilling following a gas kick

Gas hydrates removed from a subsea transfer line (Courtesy of Petrobras)
Current Approaches & Limitations:

Avoiding hydrate formation:

• **Dehydration (Water removal)**
  - Requires costly/complex subsea separation units

• **Active heating and/or insulation**
  - Very high PAPEX/OPEX
  - Failure of insulation during shut-in
  - Shorter lines only

• **Thermodynamic inhibition (e.g. methanol, glycols)**
  - High dosage often required (> 50 wt%)
  - High water-cut = huge volumes
  - Can encourage salting-out
  - Loss to/ contamination of hydrocarbons
  - Need for regeneration = large/costly topside
Current Approaches & Limitations:

• Low Dosage Hydrate Inhibitors (LDHIs):
  - Kinetic Hydrate inhibitors (KHI)
    - Emerging technology / not fully understood
    - Limited subcooling (~ 12 °C) and pressure
    - Lack of means for regeneration
  
  - Anti-Agglomerants (AA)
    - Emerging technology / lack of knowledge
    - Best suited to oil/condensate system
    - Limited to low water-cuts (< 60%)

Prevent growth for ‘induction time’

Stop hydrate agglomeration/plugging
Cold Flow: An Alternative Approach?

What is Cold Flow?

- No active heating or insulation
- Minimal (or no) chemical additives
- Allowing / inducing hydrate formation, but preventing agglomeration / plugging
- Transporting gas/water as hydrate slurries
- Several institutes working on Cold Flow
  - SINTEF/BP, NTNU, CSIRO/IFP, Shell, Petrobras…
The **HYDRAFLOW** Concept

- Convert all or most of gas to hydrates
  - Add water (e.g. seawater) if necessary
  - Transport as hydrate/water/oil slurry to processing facilities

- Prevent hydrate blockage using AAs and/or natural crude AA properties

- At platform / processing facilities:
  - Dissociate hydrate to recover gas or transfer gas in the form of hydrate slurry
  - Separate phases for export
  - Loop concept: Recycle some fluids / AA

- Patented concept
**HYDRAFLOW ‘Loop’ Concept**

- Loop connects producing wells
  - Liquid (water) acts as ‘carrier’ fluid

- Gas/water from wells form hydrate slurry with oil
  - Transported via loop to facilities
  - AA / natural inhibitor prevent blockage

- At processing facilities
  - Hydrate, oil and some water Separated
  - Suitable fluid mixture +AA re-circulated
HYDRAFLOW: Potential Benefits

• Reduce / eliminate
  – Gas hydrate risks
  – slugging and wax / pigging(?)

• Lower pipeline
  – No heating/insulation
  – No need for subsea and/or multi-phase

• Reduce chemical costs
  – Only little (or no) AA required
  – All or part of AAs (and other chemicals) could be re-circulated (loop concept)

• Environment
  – Reduce/eliminate chemical use / discharge
  – Green/bio-degradable AAs
Hydraflow Progress to date

• Measured viscosity / transportability of:
  – Water/oil emulsions
  – Hydrate/water/oil slurries

• For various systems…
  – Low to high GOR oil systems (350 to 4200 SCF/B)
  – Gas systems
  – High water cuts (e.g. mature fields…)

• Effect of:
  – AAs (type, concentration, partitioning, biodegradable)
  – Salts
  – Subzero conditions (cold environments, e.g. Siberia, Alaska)

• Various production scenarios (e.g. shut-in and start-up…)

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**Hydraflow Laboratory Proof of Concept**

- **Materials:**
  - North Sea natural gas
  - Various real crudes
  - Commercial AAs

- **Equipment:**
  - 5(+) autoclave cells
  - Various impeller types
  - V = 300 to 2000 cc
  - Max P = 410 bar (6000 psi)
  - Calibrated to 4000 cp
Results: Hydrate Slurry Viscosities

Rheological behaviour of hydrate/water/oil slurries with 1 mass% AA and 5 mass% MeOH
Results: Hydrate Slurry Viscosities

Effect of salt and AAs on the rheological behaviour of the water-oil-natural gas system as a function of temperature.
Results: Hydrate Slurry Images

Effect of AA on the hydrate particle size in a water – oil – natural gas – salt system
Results: Hydrate Formation Rate

Initial hydrate formation rate for low and high GOR oil systems at similar conditions.

Parameters affecting hydrate formation rate and their values in the first and second run respectively:

- **Subcooling**: 6 & 12°C
- **Cooling rate**: 1.7 & 4.8°C/hr
- **Mixing rate**: 350 & 550 rpm
- **Cooling rate**: 1.7 & 4.6°C/hr
- **Mixing rate**: 250 & 550 rpm

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HYDRAFLOW: Future Visions

- **Hydraflow Cell lab studies**
  - Variable volume autoclave
  - Visual capabilities
  - Capability for simulating choke condition

- **Upscaling: Small (autoclave) to large scale (flow loop) studies**
  - 2.5 cm / 1” diameter
  - 40 m / 130 ft length
  - 200 bar / 2900 psi pressure
  - -15 to +20 °C temperature range
  - Moineau pump system
  - Interchangeable ‘test section’

- **Joint Industry Funded Project (JIP)**
  - 5 confirmed sponsors

- **Design criteria and preparation for initial field trails**

*HYDRAFLOW* is a project under the Centre for Flow Assurance Research (C-FAR) at Heriot-Watt University, focused on developing future visions for offshore oil and gas operations. The Hydraflow Cell lab studies aim to simulate real-world conditions using a variable volume autoclave with visual capabilities and the ability to simulate choke conditions. Upscaling efforts will transition from small-scale autoclaves to large-scale flow loops, incorporating parameters such as 2.5 cm diameter, 40 m length, 200 bar pressure, and a -15 to +20 °C temperature range. The project is jointly funded by industry partners and is designed to prepare for initial field trials, ensuring technological advancements are tested under real-world conditions.
Thank you