Maximising Multiphase Production From Offshore Pipelines

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• Introduction.
• Flow Assurance Challenges.
• Flow Assurance Solution Options.
• Technologies- GTLA.
• Design Process Through an Integrated System Approach.
• Summary
Production (Q) = function of \((P_{res} - P_{Hbt} - \text{Losses})\) is always positive
“The ability to produce fluids economically from the reservoir to a production facility, over the life of field in any environment “Deepstar.

“The term Garantia de Fluxo” Coined by Petrobras in the early 1990’s, and translates literally as Guarantee the Flow.
To produce and transport fluids from the pore throat of reservoir to the host facility:
- Throughout life cycle of field
- Under all operating conditions
- In a cost-effective way

“A structural engineering analysis process that utilizes the in-depth knowledge of fluid properties and thermal hydraulic analysis of the system to develop strategies for control of solids such as hydrates, waxes, asphaltenes and scale”

OTC #13123

Costly and conservative
FA Engineers – Trouble makers

Keep the flow path open!

Goals:
- Reduce risk of lost or reduced production
- Enhance production rate
FA strategies must be integrated into overall systems design and field operations

Typical Subsea Engineer

The broadest link throughout the production system
- Cross-Functional, Cross-Team Discipline
- From Project Conception to Operations

Forget flow assurance
Industry needs performance assurance
Flow Assurance Challenges

- Gas Hydrates
- Emulsion / Foam
- Paraffin / Ashphaltenes
- Scales
- Liquid Slugging
- Low Temperatures
- Corrosion
- Sand / Erosion

Flow Assurance

Blockages

Operational

Integrity
Gas Hydrates: Formation & Structure

- Solid Ice-like crystal
- Hydrocarbon molecules trapped inside water “cages”
- Hydrate Formation occurs when
  - Water + light HC
- Formation temperature (higher than freezing) depends on pressure, can form > 15 °C
- Approximately 85% water, 15% HC
- Gas volume – 150-200 scf/ft³ hydrates
What Problems Can Hydrates Cause?

- Blockage of pipeline and flowline
  - Block line completely
  - Plugs up to 6 miles
  - Plugs in up to 40” pipe
- Production downtime
- Time and cost of remediation
- Serious safety issues
- During drilling or completion
  - Plug blow out preventers
  - Collapse tubing and casing
- Worsens as water depth increases
- Spans life cycle of field

Courtesy of Petrobras
Pipeline / Riser System during Shut Down

Oil/Wat

Gas

Oii/Wat
Hydrate Curves for Pipeline Shut Down (GOR=3000scf/stb)

- 29 Barg Shutdown
- 95 Barg Shutdown
- 95 Barg Flowing
Cool down at Riser Mid Point

- Time (Hrs)
- Temp. (°C)

Reservoir Composition
Shut in Composition

(bopd)
- 24788
- 30709
- 36491
- 42131
- 47632
- 52991
- 58210
- 63289
• Normally Based on Hydrate Dissociation Curve

• Reservoir Composition is usually used.

• However the composition varies with Shut Down

• Compositional Tracking of Benefit
  • Increased cool down time
  • Reduced Insulation Requirements
  • Precious additional time prior to hydrates
Pipeline & Riser Slugging

Insufficient gas velocity in riser
Liquids accumulate at bottom of riser

Upstream pressure builds sufficiently to overcome hydrostatic head in riser Slug of liquid is expelled, followed by gas which has packed behind blockage

Liquid accumulation at riser base seals off gas flow Flow out of riser stops

Slugging Types:
• Hydro-dynamic
• Terrain
• Riser induced

Liquid continues to accumulate at the riser base
Riser begins to fill with liquid Pressure builds upstream of the blockage
Liquid Hold-up Profiles.

- Horizontal: Increase.
- 30deg. Up: Increase.
- 45deg. Up: Constant.
- Vertical: Lowest.
- 30deg. Down: Increase.
- Vertical Down: Increase.
FA – Consequences of Slugging

- Safety to personnel and equipment
- Unstable production
- Equipment trips
- Total field shutdown
- Loss of revenue
- e.g. 100mbpd field shutdown: loss of $5m /day @ $50/bbl & $10m @ $100/bbl

Slug Characteristics

Flow Rate (bbl/d)

Frequency (1/Hr)
Length (m)
Volume (m³)
- Stable in presence of resins
- Resins diluted by gas release and injection
- Flocculate in wells and topside equipment
- Prediction via SARA analysis
- Saturates, Aromatics, Resins and Asphaltene fluid property analysis.
- Asphaltene content: amount of material insoluble in n-heptane (or n-pentane) but soluble in toluene
- Precipitation is induced by pressure decrease and/or changes in the solvency of crude oil (by low MW n-paraffins, CO2, acids, etc)
- Minimum solubility at bubble point
- Component in crude at C20+
- Solubility measured by Wax Appearance Temperature (WAT) or Cloud Point (CP)
- Wax appearance and deposition requires integrated wax phase behaviour with thermo-hydraulic analysis.
where,

\( M \) = Wax mass transfer rate per unit time.

\( m_{tr} \) = Wax mass transfer coefficient and is a function of the Reynolds and Schmidt numbers.

\( P_{SA} \) = Pipe surface area of consideration.

\( W_{FC} \) = Concentration of wax content in the fluid.

\( W_{RW} \) = Concentration of wax content at the pipe wall.
OPERATING:
• Tight emulsion between water and oil causes inversion viscosity
• High pressure drop in pipelines
• Separation efficiency impaired

SHUT DOWN:
• Shut-in conditions can cause rheology change to Non-Newtonian behaviour
• High yield stress at low shear rates require very high pressure to start up pipeline.

- Newtonian
- Non-Newtonian

Shear Stress

Shear Rate

Viscosity at Low Shear Rate (cPoise)

Newtonian

Non-Newtonian

Shear Stress

Shear Rate

0 10 20

S⁻¹

5 100 10,000
FA – Sand Erosion

Consequences:

• Material Loss
• Pipeline leaks
• Separator Efficiency
• Erosion Velocity Limits
• Requirement for CRA materials / Q Reduction.
Issues:

- Development of Anti-Corrosion Strategies
- Integrating Multi-Phase Flow
- De-Ward Milliums
Low Temperatures – Well Start-Up

Issues:

- Prod. Hydrates S/U
- Material Integrity
- Prod. Loss
- System S/D
- Safety

Mitigation:

- Flowline Insulation
- Operational
Operational Limits.

Production
Flow Assurance – Solution Options

- Fluids Handling
- Mix Chemicals – Thermodynamic, Kinetic, THI, AA
- Heat Retention – Insulation (Passive)
- Provide Heating: Fluids / Circulation, Electrical, Other
- Active Methods
- Remove Heat – Change Rheology (Cold Pipe Slurry)
- Separate Fluids
- Re-Combine Fluids – Subsea GTLA
- Others
Consequences of Ignoring FA

• Incorrect designs
• Operating Problems
• Flow Path Blockages
• Production Shut down
• Revenue Loss
• Loss of Asset.
• Subsea Processing
• Separation
• Multiphase Pumping
• Metering
• Subsea Gas Compression

• Pipeline Thermal Management
• Raw Sea Water Injection
• Gas to Liquids Conversion
• Gas to Liquids Absorption
• Other Emerging Technologies
Technology - FA Cost Vs Benefit Map

- Low Cost Insulation
- Draining Systems
- Pigging
- Slurry Transport
- Intelligent Slug Control
- Chemicals
- Active Heating
- Electrical Induction
- Subsea Processing
- PIP
- Multiphase Pumping
- Liquid Boosting
- G-T-L-A
- Subsea
- Benefit
- Risk
- Simplicity
- Capex / Opex / Intervention
What is GTLA?

- Gas to Liquid Absorption.
- Process of Gas Absorption of $C_1$-$C_3$, $CO_2$, $H_2S$ by high gas solubility liquids.
- Fluids Phase Equilibrium Change.
- Recovery of Oil Light End Components ($C_3$-$C_8$).
- Multiphase to Liquid Only Transport.
- Considerable Benefits (Capex / Opex).
- Innovation / Value.
What is GTLA?

3 Components to GTLA:

• Subsea Architecture & Absorption.
• Transportation.
• Host Facilities Processing.
• System configurations – Reservoir fluids characteristics.
Marginal Field Development GTLA

- **Power/Umbilical**
- **G-T-L-A Absorber**
- **Liquid Pump**
- **No Manifold**
- **No Well to Manifold lines**
- **No PIP / insulation**
- **Single Production Line**

**Water Injection**
Hydrate Risks

Production Rates

Years

Gas

Oil

Water

GTLA

Conventional
Impact of GTLA Technology on Hydrate Dissociation.

Hydrate Envelopes

Temperature (C)

Pressure (Bara)

Normal
GTLA

Water Temperature 2000m - Angola
**Technical**

- No Slugging
- No Hydrates or Wax
- Reduced Corrosion
- Reduced Scale
- Reduced pipe wt, expansion & stress, upheaval buckling, expansion joints and burial.
- Reduced Riser fatigue
- Increased Safety, Availability, Reliability & Recovery
- Pressure Boosting via Liquid Pumps.

**Economic**

- One Production Pipeline
- No Pipeline Insulation
- No Manifold
- 60% Pipeline Capex reduction (no insulation and use of CS rather than CRA)
- Use of SCR’s
- Smaller Umbilical Size
- No Hydrate or Wax inhibitors
- Reduced Interventions.
Field Options

- Which Technology (Gas lift, ESP's, M/P's, Separation)?
- Flow Assurance Risks?
- Best Reservoir Recovery Option?
- Lowest Cost Option?
Sizing of Subsea Infrastructure:
System Data:
• Reservoir Pressure = 200bara & Host Pressure = 15bara.
• Reservoir temperature = 60deg.C.
• Well Tubing = 5” & 1500m length.
• Sea bed and sea surface temps. = 5 & 15deg.C.
• Oil API = 15, 20 & 30 degrees.
• Water Depth =100-2000m
• Tie-back Distance = 10-50km.

Constraints:
• Erosion Limit = C factor of 150 carbon steel pipe.
• Hydraulic Limit = Based on max Well Head pressure (150bara)
<table>
<thead>
<tr>
<th>Water Depth (m)</th>
<th>Tie-Back Distance (km)</th>
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<tbody>
<tr>
<td>100</td>
<td>0</td>
</tr>
<tr>
<td>2000</td>
<td>0</td>
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- GOR=100 API=30
- GOR=100 API=20
- GOR=100 API=15
- GOR=500 API=30
- GOR=500 API=20
- GOR=500 API=15
- GOR=1000 API=30
- GOR=1000 API=20
- GOR=1000 API=15
- GOR=1500 API=30
- GOR=1500 API=20
- GOR=1500 API=15
- GOR=2000 API=30
- GOR=2000 API=20
- GOR=2000 API=15

8" Multiphase
Maximising Multiphase Production & Flow Assurance Requires:

- Innovative Flow Assurance Solutions
- Better use of existing & New Technologies
- Overcoming Fear to Change
- Offer Value Added Benefits
- Low Risks

Beware:
Operators are queuing up to be 2\textsuperscript{nd} or 3\textsuperscript{rd} to use new technology.
Further Information

New Flow Assurance Book
Thank You
I would be happy to answer questions