Integration of Flow Assurance & Production Chemistry Benefits All: Fact or Fiction?

By Colin Smith, Senior Production Chemist
Maxoil Solutions Ltd
What is Flow Assurance?

Å History î Guarantee the Flow / DeepStar Project

Å Meaning can be broad or narrow
   î Ensuring successful & economical flow of hydrocarbon streams from reservoir to the point of sale
   î Multiphase hydrocarbon fluid transportability

Å Simulation/Modeling of topics such as
   î Thermo - hydraulic analyses
   î Operability Characteristics
   î PVT & Rheology
   î Slugging / Flow Regime
   î Fouling / Blockages / Restrictions to Flow
   î Mechanical Integrity
   î System performance î reliability / availability
   î Mitigation, e.g. Hydrate inhibitors
Flow Assurance – Deepwater Projects

DeepStar Project Focus
## FA Modelling / Simulation Options

### Flow Assurance
- HYSYS
- AspenTech AspenONE
- Pro II
- PVTSim
- Multiflash
- Pipesim
- Prosper/GAP
- Pipeline Studio
- OLGA
- PIPEFLO
- Flowmaster

### Production Chemistry
- ScaleChem / Studio Analyser
- Multiscale / MEGScale
- ScaleSoftPitzer / OK Scale
- Multiflash
- dbrSOLIDS
- PVTSim & DepoWax
- Wax (Msi)
- FloWax (Infochem)
- MWP
- TUWAX
- OLGA
- Cassandra / Norsok
- SourSim RL / REVEAL
**What is Production Chemistry?**

*Production Chemistry* is the management of the chemical properties of fluids that can impact production, product value, asset integrity or environmental/HSE compliance.

<table>
<thead>
<tr>
<th>Impact</th>
<th>Gas</th>
<th>Water</th>
<th>Liquid Hydrocarbons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Production</td>
<td>Hydrates</td>
<td>Emulsions, Scale, Sand/fines</td>
<td>Wax, Asphaltenes, Naphthenates, Foaming</td>
</tr>
<tr>
<td>Product Value</td>
<td>H₂S, CO₂, DMS, Mercaptans, Mercury</td>
<td>Desalination, SRP, PWRI, Reuse, Unconventional</td>
<td>BS&amp;W, Sulphur, Mercury, Organic chloride</td>
</tr>
<tr>
<td>Asset Integrity</td>
<td>H₂S, CO₂, chemicals, Corrosion</td>
<td>Chloride, Bacteria, Sand, Corrosion</td>
<td>Organic acids</td>
</tr>
<tr>
<td>Environmental / HSE Compliance</td>
<td>Flaring / Emissions</td>
<td>Oil in water, WSOs, Contaminants, NORM/LSA Scale</td>
<td>Oil in water, Organic Mercury</td>
</tr>
</tbody>
</table>
What is Production Chemistry?

Å Understanding production fluids interactions
  • Fluids response to changes in P/T/water cut from reservoir to subsea to surface

Å Risk assessing production problems
  • Fouling
  • Physical properties of fluids
  • Plant integrity related
  • Environmental / economic

Å Influencing production system designs & operation

Å Solving production problems • prevention versus cure
  • Facilities design
  • Operational practices
  • Treatment chemicals (deployment practises)
Flow Assurance & Production Chemistry

Quotes

Flow assurance has come to mean the coupling of multiphase flow & production chemistry to manage the interface between the reservoir and topsides processing. Before, a Flow Assurance evaluation would have discussed hydrates, wax, scale, asphaltenes & corrosion, it now includes network modeling and transient multiphase simulation to determine the operability of the designed facility.

Jeff Creek, Senior Flow Assurance Advisor, Chevron (Offshore magazine, 2012).

Flow Assurance is the technical discipline that guarantees achievement of a lifting and transport system's lifetime production targets: from the near wellbore to offloading tanks by predicting, preventing and solving problems originated by the behaviour of the transported substances (i.e., gases, liquids and solids either separated or in multiphase conditions).

Alberto Di Lullo, Flow Assurance Senior Advisor, Eni E&P
Production Chemistry Issues & Solutions

- Wax
- Asphaltenes
- Inorganic Scales
- Naphthenates / Soaps
- Gas Hydrates
- Sand
- Foaming
- Emulsions/Separation/Viscosity
- Corrosion
- Microbiology & Sourcing
- Produced Water / WI
- Contaminants
- Ice
- Chemicals Application

Chemical Solutions

- Inhibitors
- Dispersants
- Dissolvers
- Defoamers
- Demulsifiers
- Deoilors
- Scavengers / Biomodifiers
- Biocides
- DRAs / GTOs

Mechanical Solutions

Design out / minimise impacts
Insulation / DEH
Separator sizing / internals
Cooling/Heating/Electrostatics
Pigging / Hydrate slurry flow
CRAs / pipe coatings
FA / PC Issues - 1
FA / PC Issues - 2
Production Chemistry – Where Issues Occur!

- Wax
- Asphaltenes
- Foam
- Emulsions
- Hydrates
- Scale
- H₂S
- Corrosion
- CO₂
- Foam
- Scale
- Contaminants
- Corrosion
- CaN
- Microbiology
- CO₂

Processes include:
- Production Wellhead
- Choke Valve
- Injection Wellhead
- Injection Valve
- Separator
- Heat Exchanger
- Scrubber / Dehydration
- Compressor
- Storage Tank
- Export Pump
- Corrosion
- Microbiology
- Filtration
- Deaerator
- Ocean / River / Evaporation Pond / Aquifer
- Export Pipeline

Maxoil Process Solutions
## FA & PC During the VAR Process

**Opportunity Realisation Process. Example case, subsea tieback to existing CPF**

<table>
<thead>
<tr>
<th>Appraise / Assess</th>
<th>Concept Select</th>
<th>Define</th>
<th>Execute</th>
<th>Operate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fluid sampling, DST / Downhole / Test Sepr</td>
<td>FA Modelling Thermo hydraulic</td>
<td>FEED Flowline sizing Field layout AFEs to POs</td>
<td>POs Commissioning plan</td>
<td>Start-up / Shutdown Troubleshooting</td>
</tr>
<tr>
<td>PVT analysis, oil assay, Lab experimental (wax, asphaltenes, emulsions, scaling)</td>
<td>Lab analysis. Hydrate curves Fluids compatibility</td>
<td>Start up / shutdown strategies PEP BoD</td>
<td>Operating procedures Handover ownership to asset</td>
<td>Optimisation of operation, chemicals etc.</td>
</tr>
<tr>
<td>Formation water composition</td>
<td>FDP, WFSs, BfD</td>
<td>Chemical injection design CRR</td>
<td>Chemical contract &amp; supply chain</td>
<td>Chemical supply / logistics</td>
</tr>
<tr>
<td>Oil &amp; Water Geochemistry Feasibility report</td>
<td>CSR, prelim CRR Mitigation strategies</td>
<td>Chemicals qualification Materials selection</td>
<td>Sampling &amp; analysis plan Monitoring prog CMS</td>
<td>Demulsifier bottle testing Confirm oil / water / gas</td>
</tr>
</tbody>
</table>
PC/FA Risk Assessments - Asphaltenes

- Laboratory experimental testing (STO / Live oil)
  - SARA, P Value
  - Asphaltene Flocculation Point
  - Live oil ADE / APE
  - Asphaltene deposition rates

- Properties correlations
  - De Boer plots, Colloidal Instability Index (CII)

- Thermodynamic modelling
  - Model flocc points / onsets, amounts
  - Limitations on kinetics, stickability of asphaltenes, regional asphaltene behaviour

- Asphaltene Deposition Simulator (OTC23347, 2012)

- Deposition models (tuned) predict where it occurs

- Tests/models give risk; actual outcome may be benign!
PC/FA Risk Assessments - Asphaltenes

Reservoir fluid P/T pathway

Asphaltene Envelope

Pressure

Temperature

End of precipitation
Bubble point
Precipitation onset

CII = \frac{S + As}{R + Ar}

If CII > 1 then risk of precipitation

<table>
<thead>
<tr>
<th>Component (wt%)</th>
<th>Oil No. 1 (Light)</th>
<th>Oil No. 2 (Intermediate)</th>
<th>Oil No. 3 (Heavy)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Saturates</td>
<td>65</td>
<td>44</td>
<td>14</td>
</tr>
<tr>
<td>Aromatics</td>
<td>31</td>
<td>40</td>
<td>54</td>
</tr>
<tr>
<td>Resins</td>
<td>2.3</td>
<td>9.2</td>
<td>14</td>
</tr>
<tr>
<td>Asphaltenes</td>
<td>1.7</td>
<td>6.8</td>
<td>16</td>
</tr>
<tr>
<td>CII</td>
<td>2.02</td>
<td>1.03</td>
<td>0.44</td>
</tr>
</tbody>
</table>

Asphaltene Problems

Y  N  N

Colloidal Instability Index (CII) Predictive Tool

Colloidal Instability Index (CII) Predictive Tool

maxoil
PROCESS SOLUTIONS
PC/FA Risk Assessments - Asphaltenes

- Screening Tools: De Boer Plot
  - Allows screening based purely on PVT data
  - Shows that light, undersaturated oils give the highest asphaltene risk

- Also an approximate tool, but useful when combined with other screening tests based on SARA analysis
PC/FA Risk Assessments - Asphaltenes

Asphaltene Flocculation Point Test

RealView Deposition Cell (Schlumberger)
PC/FA Risk Assessments - Wax

Â Thermo - hydraulic calculations ï Fluid Arrival Temperatures wrt Wax Appearance Temperature (WAT)
Â Laboratory testing ï rheology & wax properties (WAT, viscosity profiles, gelation T/PP, WDT, HTGC, restart P)
Â Wax modeling
  ï Thermodynamic models ï WAT, wax amount
  ï Wax deposition profiles / rate of build up
Â Experimental data used to tune models
Â Assess the wax risks ï interpretation for solutions
Â Apply operational experience, use analogues
Â Wax Management Strategy development
PC/FA Risk Assessments - Hydrates

- Assessments dominated by modeling
- Lab tests mainly to screen inhibitors (LDHIs)
- Thermodynamic model \(\text{\text{ï}}\) hydrate curves (Multiflash)
- Phase equilibrium prediction program
- Degree of subcooling \(\text{\text{ï}}\) rate of hydrate formation

- Thermodynamic models are used to accurately calculate the hydrate equilibrium and disassociation to within \(\pm 1\text{K}\)
- This predicts a temperature, at a given pressure, above which hydrates will not form
- A nucleation model predicts where hydrates will definitely form
- In between the two boundaries is the region of hydrate risk
Hydrates Modelling

Hydrate Curves for Mixes of Injected Seawater and Formation Water

Typical modelling output showing depression of the hydrate disassociation boundary as greater concentration of methanol is added.
Hydrates Testing

Gas Hydrates Flow Loop Plant

Commercially Available Autoclave and Rocking Cells (PSL Systemtechnik)
PC/FA Risk Assessments - Hydrates

- Thermodynamic modeling - hydrate curves
- Laboratory testing - standardised methods
- Experimental data can be used to tune models
- Assess the hydrates risks - interpretation for solutions
- Models can be used to assess solutions
  - By Design - Artificial Insulation, e.g. pipe-in-pipe, heating, heat tracing, dual production lines, minimise restrictions etc.
  - Use of salts & inhibitors (THIs, LDHIs (KHIs, AAs))
- Remediation measures if a hydrate plug forms
- Shutdown / start-up / ramp up etc.
- Apply operational experience, use analogues
- Hydrates Management Strategy development
PC Assessment & FA Modelling Integration

- Representative fluid samples required
- Sample testing provides experimental data (wax, asphaltenes, hydrates etc.)
- FA modelling provides risk assessments for different scenarios & helps decision making on the overall concept
- Comparison of lab test data & FA models output – tune and validate the models
- Apply operational experience
- Use analogues knowledge
- Apply lessons learned
- Co-operation is key to yielding representative results
Flow Assurance & Production Chemistry Scenarios

- Steady state flow operation
- Transient flow operation
- Start-up operations
  - Initial, Cold, Warm, Interrupted
- Shutdown operations
  - Planned, unplanned, extended
- Line pigging
- Valve testing, well testing
- Slugging & its impacts
- Turndown
- LoF
  - Production rates & water cut variation

Integrated Strategies lead to Fit for Purpose Systems
Reasons for When Simulations / Testing goes Wrong

Â Poor sample quality ï garbage in garbage out!
Â Check on reservoir heterogeneity (compartments)
  ï Collaborate with subsurface engineers
Â FA Simulations - Base data used selectively / not verified
Â Single model used ï no crossï comparison
Â Model simulations output versus reality
Â Test methods used not representative
Â Chemical qualification protocols not robust
Â Operability studies ï reality checks not applied
Â Lessons learned from other projects not applied
Benefits of PC / FA Integrated Approach

- Stronger influence on design team decisions
  - Number of subsea umbilicals for chemicals
  - Umbilical spares
  - Experimental testing programs requests

- Robust risk assessments make fit for purpose systems that are easier to operate

- Minimise nasty surprises, e.g. flow line blockages

- Minimise risk of umbilical blockages

- Robust start-up / shutdown designs / procedures / strategies

- Brainstorm issues!

- Integrated / holistic solutions that are cost-effective

- PC link to existing operations - useful interface
Lack of PC / FA Integration

This can contribute to and has lead to

- Subsea lines being blocked by hydrate plugs
- Subsea lines with wax deposit restrictions
- Production wells with asphaltene deposit restrictions
- Wells / flow lines with scale deposit restrictions
- Composite deposit restrictions subsea
- Loss of system Integrity due to corrosion
- Wells that are difficult to produce / lift
- Chemical, design or operational solutions that solve one problem but create another problem
- Avoidable lost oil / production losses
- Nasty unwanted surprises!

maxoil
PROCESS SOLUTIONS
Case where it has Gone Wrong!

• Unexpected wax deposition in a subsea line, ΔP Inc.
  - No provision for line pigging
  - Wax inhibitor / dispersant not identified

• Wax deposition modelling done in isolation using a single model

• No departmental collaboration / integration — silos!

• Revisited work
  - New oil sample tested — WAT, PP, Viscosity curve, WDT changed
  - New wax deposition modelling — different results

• Rapid identification of wax dispersant

• Problem solved but lack of integrated approach created a production problem that should not have been!
Example Case History – Hydrates, Wax & Scale

- HPHT Gas Condensate field tieback to existing platform
- WGRs of 2 – 10 stb/mmscf
- Fluids commingling in topsides separator
- High drawdown wells to limit sand production
- High salinity brine FW (TDS > 330,000 mg/l)
- CRA flow line selected (not carbon steel + CI injection)
- Hydrates risk controlled by intermittent MeOH use
- Scale risk controlled by SI injection u/s wellheads
- Halite risk controlled by wash water injection
- Wax deposition risk controlled by WI injection subsea
- Umbilical supplies chemicals, hydraulic and electrical power and wash water to the wells
Example Case History – Hydrates, Wax & Scale

â Issue with cold start up of production wells
â Design includes use of umbilicals for continuous wellhead Scale Inhibitor injection & manifold Wax Inhibitor injection
â Cold fluid start-up scenario across subsea choke
â Halite scale formation risk assessed, i.e. where, how much, stickability risk with other mineral scales risk simulated "Potential Problem!"
â Impact of MeOH injection alone for short period on halite risk assessed, plus impact of wash water on halite & scaling modeled
â Operability study on halite removal by delayed (post start-up) wash water use with lessons learned applied from other assets
â Halite masses formed & likelihood to form deposits & locations fully assessed partly based on experiences elsewhere
â Design team went for same umbilical core used for methanol and wash water. All problems could be mitigated successfully!
â Design included bullhead of wells with wash water & dissolver use
â Integrated FA/PC approach applied successfully
Integration of Flow Assurance & Production Chemistry Benefits All:

Fact or Fiction?

FACT!
Acknowledgements

Thanks to
Maxoil Solutions Ltd

SPE
Jane Rodger, Sankesh Sundareshwar

Sponsors
Shell
Archer
The Well Company

maxoil
PROCESS SOLUTIONS