Asphaltene Management: Structured Approach For Production Maximization
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- Pre-Development asphaltene management philosophy
- Enhanced Structured Approach to Maximize Production
- Results
Field Background

- Field located in a remote area offshore

- Horizontal Subsea wells with dual ESP, and wire wrapped screens. 5 ½ inch tubing, production rates \( \approx 15,000 - 1,500 \) bopd. TVD approx. 7500 ft. distance wellhead to platform approx. 400 mts 6 inch pipeline

- Limited pressure support from pair injectors, compartmentalized reservoir.

- PVT gradient with depth, Asphaltene content weight of \( \approx 4\% \) top structure – \( \approx 12\% \) lower structure

- \( \approx 27-22 \) API, low to mid viscosity \( \approx 5-10 \) cp, Low GOR \( \approx 120 \) scf/sbls. Normally pressured reservoir avg 3600 psia

- Workover cost \( \approx £20-40 \) MM- only summer window (approx. May-August) for ESP string deployment.
Field Background

Asphaltenes

- Dissolved solids part of the heavy ends fraction of crude oil. (Ostlund, J. et al. 2001)
- No real understanding of its equilibrium and how they come out of solution and flocculate.
- Generally a very subtle balance in the oil and small changes in pressure, gas pocket temperature could create a instability resulting in bulk sticky solids.
- Asphaltenes have been extensively studied, but there has been disagreement over its fundamental chemical and physical properties.
- The oils that contain high % of aromatics and resins maintain asphaltene stability.
- % of saturates -methane, ethane and propane when present in significant quantities act to destabilise asphaltene.

Asphaltene deposition: can severely affect the development
High economic impacts for horizontal well remediation. Increase in number of workovers, downtime and replacement parts (a killer for subsea developments).

Asphaltenes deposition evidence during well clean up- that was ran without asphalthen inhibitor.

Therefore an important consideration in the development stages of the field. Conservative approach was adopted to minimize remediation cost / downtime while searching for a solution.
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Pre-Development asphaltene management philosophy

Asphaltene Trend in the field.

**Exploration/appraisal wells**

- Well 4 Average (DST)
- Well 5z Average (DST)
- Well 7 Average (MDT)
- Well 3 DST 2 Average (DST)
- Well 3 DST1a Average (DST)
- Well 4 Range
- Well 5z Range
- Well 7 Range
- Well 3 DST2 Range
- Well 3 DST1a Range
- Well 3 Iatroscan

* Analogue well for development well 1
** Analogue well for development well 2
Pre-Development asphaltene management philosophy

RFT densities

Density values found in the lab were converted to downhole conditions using Dake's equation:

\[
\rho_0 = \frac{(\rho_{ss} \times 5.615) + (\rho_s \times \rho_{ss})}{B_o \times 5.615} = \frac{(52.8 \times 5.615) + (352 \times 0.0511)}{1.182 \times 5.615} = 47.37 \text{ lb/cu ft}
\]

and the liquid oil gradient is 47.37/144 = 0.329 psi/ft.

In-situ fluid density from RFT and densities derived from samples match for Wells 4 and 7.

Clear discrepancy between in-situ gradient from RFT and densities derived from samples.
Pre-Development asphaltene management philosophy

Well 5z Compositional Data

- Plots taken from Core Labs Partial Reservoir Fluid Study – RFLA 930103
- The Heptanes+ fraction molecular weight verses weight percent asphaltene would suggest that asphaltene / heavy end dropout has occurred and that the sample is artificially light.
- From literature, the heavy ends of crude oil that are liable to dropping out are waxes or asphaltenes.
Pre-Development asphaltene management philosophy

5z well test

- There is a concern that the fluid sampling taken at the end of the test may be unrepresentative due to asphaltene deposition in formation.

- Both natural flow periods drawdown and flow rate are similar. The lack of change in mobility over a short flow period may be real as the effects of reduced permeability and reduced fluid viscosity cancel each other out.
Pre-Development asphaltene management philosophy

5z history match

**Workflow:**

- A proxy PVT was generated in PVTi which has an in-situ density of that of both Wells 5z and gradient of ~ 0.389 psi/ft.
  - Ideal Solution Principles were used to derive the required molecular weight of each component of the pseudo PVT which matches the RFD density.
- It was taken to reservoir conditions using the Vasquez and Beggs correlation.
- The new PVT data was then input into PVTi to obtain the compositional model.
- A simplified box model was used and the E100 and E300 simulations were initially matched without the asphaltene options.
- The asphaltene option was then used to induce asphaltene deposition and permeability reduction around the near-well bore to obtain a better match.

**Tartan Grid Box Model:**

- FAULT1 is 180ft from 5z with Multfl = 0.0
- FAULT2 is 100ft from 5z with Multfl = 0.1 for best match
- Horizontal Perm = 130mD
- Vertical Perm = 75mD
- End Point Rel Perm multiplier of 0.64
- Net sand as per full field model
Pre-Development asphaltene management philosophy

• The is strong evidence that the 5z samples are not representative of the in-situ fluids.

• To match the in-situ fluid density an estimated 24% weight of asphaltene / heavy ends is required. This would suggest a drop-out of 12% occurred during the nitrogen lift period.

• A better match was obtained by inducing permeability damage / asphaltene damage during the nitrogen lift period of well 5z test.

• Due care must be taken on development wells to maintain flowing BHP above the asphaltene onset pressure AOP, and THP above bubble point. Note: There is still uncertainty as to the asphaltene envelope and how much it varies with depth / fluid composition.

AOP + -Reservoir Compartmentalization -Poor pressure support =

• BHP constrain set to avoid Asphaltene deposition
• Production constrain
Pre-Development asphaltene management philosophy
Basis of design and data acquisition program

- **Asphaltene:**
  - Asphaltenes were detected using detailed SARA analysis.
  - Asphaltenes content in the Jurassic samples taken higher up in the formation 4 %wt and those lower down 12.0 %wt. Unclear is difference are due to oil properties graduation within the reservoir and/or compartmentalisation.

- **The risk of asphaltenes deposition exists**
  - Asphaltene downhole injection.
  - Pre-installed tanks and pumps for Asphaltene Solvent were also included in the facilities for bull heading.
  - Bypass tool on ESP design for reservoir access.

- **Design Basis:**
  - Chemical injection rates are for normal Asphaltene Inhibitor rates of 50 to 150 ppmv (expressed as a fraction of oil volume) with a peak rate capability of 300 ppmv for semi-remedial purposes.
  - Tank storage based on 100 ppmv average.
  - Asphaltene Solvent can also be fed to the wellheads for flowline or downhole remediation.
## Pre-Development asphaltene management philosophy

### Asphaltenene Risk/ Mitigation

<table>
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<tr>
<th>Section</th>
<th>Risk</th>
<th>Mitigation</th>
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| **Reservoir**  | - Any deposition then to be near wellbore affecting PI  
- Inhibition within reservoir is not possible on a continuous basis  
- Remediation by bull heading solvents via subsea pipeline/tree unlikely to be fully effective in horizontal wells. | - Average Reservoir pressure to be kept >> the Asphaltene Onset Pressure by dradown management and water injection  
- Connection point on the tree and from the flow lines for solvent injection |
| **Artificial Lift** | - Asphaltene can deposit if Pump intake pressure goes below onset pressure  
- Hot surfaces, such as ESP motor, could destabilize asphaltene.  
- Shear forces, typical in an ESP, could separate resins and accelerate asphaltene destabilization | - Asphaltene inhibitor mandrel located below ESP motors with permanent Al injection.  
- Solvent injection (high risk => protectors with metal bellow sensible to changes in temperature-solvent to be low rate or heated/ both detrimental for remediation  
- Advance downhole Instrumentation for Temp and pressures, intake/Discharge-combine with vibration/current leakage and torque (topside) |
| **Tubing Wellhead** | - Asphaltene destabilize below the AOP with maximum precipitation close to the bubble point. | - Install well head chokes to be able to control WHP > bubble point.  
- Connection point on the tree and from the flow lines for solvent injection |
| **Flow Lines**  | - Due to sep pressure to be < BP, pipeline will operate outside of the safe Asphaltene deposition envelop | - Topside flow choke installed to maintain high landing pressure in the event of Asphaltene destabilization.  
- Connection point for solvent injection |
| **Facilities**  | - As the platform oil system pressure is low (max 5 bara / 75 psia), the topsides will operate well below the lower boundary of the Asphaltene Phase Envelope | - Utility Connections and onto the Vane Pack by the spray connection on sep.lines for solvent injection |
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Enhanced Structured Approach to Maximize Production

- Data Analysis, Studies
- Value Case,
- Risk Assessment
- Implementation

- Surveillance
- Basis of Design
- PVT analysis
- Strategy for sampling
- Research (i.e. SPE 103137 Screening for Potential Asphaltene problems) => ASIST
- WI Pump in series to increment pressure

- Prod Eng

- Production Profiles
- History match for anomalies.
- PVT gradient and time progression of Asphaltene content
- Economics - Size of the price

- Reservoir Eng

- Solvent Bull heading operation program.
- ESP studies for asphaltene fouling and health increase that could potentially induce an Electrical Failure

- Prod Chem

- AI test for Field crude
- Solvent wash selection for quick and optimal arrangement for Bull heading operation

- Surveillances
- Basis of Design
- PVT analysis – SARA Analysis
- ASIST modelling
- AI efficiency

- Wells

- External
Enhanced Structured Approach to Maximize Production

- Constrain on the production wells
  - BHP to be kept > AOP - Inability to drawdown the well further – low rate – outside operative envelop
  - THP to be kept > BP - Inability to flow the well further if ESP fail

On top of this, compartmentalized reservoir, pressure support from injection to be improved.

Benefit:
- Production increase from 1,100 bopd instead of 2,400
- Stop cycling well risking ESP electrical components leading to a potential catastrophic failure.

- ACTIONS:
  - Revisit of the previous method to determine AOP using PVT EOS models
  - Revisit of the risk for having an AOP using a novel technique called ASIST.
  - Create a Surveillance workflow and risk assess for remediation
  - Improve WI performance by installing pump in series.
**ASIST: Understanding the theory**
- Asphaltenes represent the most polar components in the oil
- They are not compatible with the non-polar components in the oil, such as n-alkanes
- For example, if we add n-C7 to a stock tank oil (STO), it could trigger asphaltene precipitation
Enhanced Structured Approach to Maximize Production

- **ASIST: Understanding the theory**
  - Analogous to n-C7 making asphaltene precipitate, the light ends in the live oil can make asphaltene precipitate

Then the Essence of the Asphaltene Instability Tredn (ASIST) is to see if the amount of the light ends in the live oil is enough to trigger asphaltene precipitation at different pressures.
Enhanced Structured Approach to Maximize Production

- **ASIST: Understanding the theory**
  - ASIST uses the refractive index
    - Refractive index is an important parameter to gauge asphaltene solubility in the oil
  - The refractive index experiments at the onset of asphaltene precipitation (PRI) tells us when asphaltene will precipitate

![ASIST Plot - Sample 205/26A - 4](image)

**Figure 1:** ASIST plot for Well 205/26/A-4
ASIST Understanding the theory
- ASIST uses the refractive index
  - Refractive index is an important parameter to gauge asphaltene solubility in the oil
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![Graph showing PRI curve and refractive index variations with pressure.](image1)

**Figure 1:** ASIST plot for Well 205/26/A-4
Enhanced Structured Approach to Maximize Production

- Results from ASIST
- Well 4-Well P1 low asphaltene content 4%
- Well 5= High Asphaltene content 12%
- High GOR effect
- Mud Content

Figure 3: ASIST plot on the impact of mud for Well 4

Figure 5: Impact of GOR for the Solan Well 4 sample.

Figure 8: ASIST plot for P1 in comparison with Well 4 and Well 5
Enhanced Structured Approach to Maximize Production

- ESP benefit to operate inside operative envelope and reduction of start and stops

More than 2 start every 10 days can reduce the Avg Run life by 80%

Running below the recommended Operative Envelop cause down thrust-elevated temp which could affect ESP run life.
Enhanced Structured Approach to Maximize Production

- Water Injection to Frac or overcome back pressure

- Ability to Frac the wells
- Increase II
- Increase Sweep
- Increase reservoir pressure

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<thead>
<tr>
<th>Single Pump Injecting into Water Injectors @ 66.5 Hz pump (A or B or C)</th>
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Approximate gain due to pump in series: 30.2 m³/hr, 4545.1 bpd
Enhanced Structured Approach to Maximize Production

- **Reduction of BHP below AOP**

Documentation Studies

- ASIST modelling no AOP
- Multiflash modelling 84 barg AOP

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**BHP Reduction**

**Process**

- Well Performance Prosper-Eclipse

**Data**

- PIP Oil
- Pseudogradient
- Lab oil density AI/doses

**Instructions**

- Reduce PIP further 2 to 5 barg, establish targets, update WOP

**Decision**

- Is PIP > 43 barg?
  - **Y**: Document benefits/lessons learnt
  - **N**: Hold further changes, revert back to previous healthy indicator.
  - e-Evaluate well performance state cause of change and decide remediation action if required

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- Pump in Series
- Implementation of PIP reduction

Pressure [psig]

Oil rate (stbld)

1,100 bopd cyclic ESP period

2,400 bopd
Results

▪ An average production increase from 1,100 bopd to 2,400 bopd (1,300 bopd gain) with a cumulative incremental estimated to be in the order of 400,000 barrels of oil including plant performance improvement (from June 2017 to date)

▪ ESP stop/starts required to manage pressure cycles were reduced from 1 a month to 0, hence a reduction of 12 starts per annum previously required for reservoir / well performance management have been removed.

▪ No well performance deterioration has been experienced since commencement of the PIP reduction process started (currently operating 30barg below original asphaltene onset pressure); this has been backed up by reservoir and well models, and surveillance methods shown to be working. Well performance remains steady with PI stable at circa 1.4 stb /psi.