Design and Operational Challenges of ESP-DST Heavy Oil Well Testing

Yakov Shumakov, Graham Cox, Graham Hetherington, Schlumberger
Outline

- North Sea Heavy Oil overview
- The Bentley and Kraken heavy oil fields
- Past well test operational experience
- Heavy oil ESP-DST well tests, operational planning and execution
- Conclusions
Heavy Oil in the North Sea is attracting increased interest:
- 9 billion barrels of estimated heavy oil resources in-place \(^{(1)}\)
- Higher oil prices plus new technologies

**Reserves type** | **STOIIP, MMstb** \(^{(1)}\)
--- | ---
Under production | >2100 | >18 API°
Appraisal | 2700 | \(<18\) API°
Other discoveries | 2400 | 
Total of prospects | 2000 | 
TOTAL | >9200 | 

\(^{(1)}\) Source: based on SPE 54623 Jayasekera 1999
(2) Source: article in OilEdge, 26 September 2010
The biggest HO fields in the North Sea — 160 km East of Shetland Isles
Bentley and Kraken fields discovered in 1977 and 1985 respectively
2003 license for block 9/2b awarded to Nautical Petroleum, block 9/3b to Xcite Energy
— 5 further appraisal wells, including one horizontal and multilateral wells drilled in the Bentley field
— 5 appraisal wells drilled, including horizontal side track in the Kraken field

<table>
<thead>
<tr>
<th></th>
<th>Kraken</th>
<th>Bressay</th>
<th>Bentley</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water depth</td>
<td>386ft</td>
<td>360ft</td>
<td>360ft</td>
</tr>
<tr>
<td>API°</td>
<td>15</td>
<td>10.7</td>
<td>10-12</td>
</tr>
<tr>
<td>Porosity</td>
<td>38%</td>
<td>28-33%</td>
<td>32%</td>
</tr>
<tr>
<td>Reservoir pressure</td>
<td>1740psi</td>
<td>1567psi</td>
<td>1690psi</td>
</tr>
<tr>
<td>Reservoir temperature</td>
<td>34°C</td>
<td>35°C</td>
<td>37.5°C</td>
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<tr>
<td>Oil viscosity</td>
<td>161cP</td>
<td>550cP</td>
<td>1518cP</td>
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Well Testing Challenges in Heavy Oil Environment

- Integration of DST with artificial lift methods
- Fluid handling with conventional equipment:
  - Complex due to pressure drop and extra heat requirements
  - Density of oil ≈ density of water. Gravity separation does not work effectively
  - Viscous fluid leads to higher retention time (Gas Trapped)
  - Emulsion or/and Foam requiring chemical treatment
- Metering complexities
- Fluid disposal
- Solids production

Is it possible to overcome these challenges?
Evolution of ESP-DST Well Testing in the North Sea

2008, Bentley
Conventional ESP-DST well test, producing first Bentley crude to surface.

2010, Bentley and Kraken
Application of novel ESP-DST well test concept. Introduction of POD, real-time and Vx MPFM. Achieved economical flow rate at surface of 2,900 bopd on Bentley field.

2011, Kraken
Horizontal well with gravel pack completion. Proven commercial flow rate, achieved maximum stabilized flow rate of 4,550 bopd. Burned 6,000 stb of reservoir crude.

2012, Bentley
Extended ESP-DST well test on multilateral well, produced ≈150,000 stb of reservoir crude.
Test mainly designed to produce Bentley crude to surface

- Conventional ESP arrangement with DST string (no downhole samples)
- “Slug flow” production regime symptomatically caused by free gas in pump intake
- Inaccurate flow rate measurements by liquid level monitoring in gauge tank
- Additional constraint to fluid handling from low well head temperature

**Fundamental changes in ESP-DST well testing needed**

ESP-DST Well Test Components

- Sand prevention
- Fluid handling
- Application of AL method
- Flow Metering
- Real-Time Collaboration

Integrated Workflow
ESP Design and Sizing

- Wide operation range by combination compression stages and VSD
- Supplying heat to production fluid

ESP Components

<table>
<thead>
<tr>
<th>Pump Description</th>
<th>Protector Description</th>
<th>Motor Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>116 Stages SR 8500 538 Series ARZ-SS</td>
<td>2x BPBSL HL 540/540 Series Modular</td>
<td>562 Series 760.5 HP</td>
</tr>
</tbody>
</table>

ESP design: heat retention

Pressure vs. depth

Fluid temperature vs. depth

- Integration of lower permanent sand screen completion with ESP-DST string
- Maintaining dual barrier all the time
- Allowing to collect bottom hole PVT samples below ESP

Separated fluid handling and metering
Maintaining constant well head pressure ≈ bubble point pressure
Application of adjustable choke
Surface well test package\(^{(4)}\)
- 2 Steam generators (8.5 MMBTU/hr)
- Steam exchanger
- Heating coils in knockout separator, diesel and surge tanks
- Plate heater / STX
- Lagging and steam tracing of pipework

Three data headers and additional sensors
- Total 65 data acquisition channels

Reference: SPE 167798, Y. Shumakov, et al., 2014
Flow Rate Measurements

- No moving parts - ideal metering solution for HO testing
- Accurate measurements of BSW allowing monitoring of well clean-up
- Required input of PVT data

Real-time Collaboration Process

Data exchange

Screen Sharing

24/7 conference call facility

Artificial Lift Surveillance Center

- 24/7 Surveillance of ESP in Eur & Africa
- Satellite / SCADA based system
- KPI (well uptime, critical event intervention)

Real-time collaboration

- Entire data acquisition network
- Single data visualization software
- Unified KPI

Testing Services OSC

- More than 100 RT welltests YTD
- Web based data storage
- KPI (rig time, test objectives)
Conclusions

- Accurate operational planning is the key
- Real-time collaboration process is essential
- Application of multiphase flow meter is crucial for:
  - Monitoring the progress of well clean-up
  - ESP monitoring and optimization
  - Accurate measurement of flow rates
- High well head pressure and temperature assists fluid handling
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