Application of RESMAN's intelligent inflow tracers in long horizontal sand screen wells across Maersk Oil UK assets

By Hope Okhuoya
Senior Production Technologist • Maersk Oil UK

and Erlend Schou Faevelen
Senior Well Technology Engineer • RESMAN UK
Outline

• Monitoring requirements for Maersk Oil subsea assets
  – Data requirements, challenges, alternatives, solution

• RESMAN inflow tracer technology – how does it work
  – Project cycle and Technology fundamentals
  – Maersk UK applications: Tracer system design and Installation

• Maersk – RESMAN case studies
  – Confirmation of oil contribution
  – Determining shut in cross flow
  – Detection of gas and water producing zones
  – Onsite clean-up verification
  – Quantitative inflow distribution

• Application of acquired tracer data in asset management
Monitoring Requirements

Challenges
• Subsea – wet tree
• Long horizontal wells
• Cost constraints
• Commingled wells
• Flowline tieback

Monitoring Requirements
• Interventionless
• Cost effective
• No added risk
• Long monitoring life
• Capabilities:
  – Detecting oil and water production
  – Verifiction of clean-up
  – Inflow distribution along the wells
RESMAN Technology

HOW IT WORKS
How it works – Project cycle

- **Design and manufacturing**
- **System integration**
- **Well completion**
- **Sampling**

...up to 10 years!

- Polymer Matrix
- 70 oil & 70 water unique signatures
How it works – Technology basics

(Patented)
Tracer system design and Installation

MAERSK UK – RESMAN TRACER DESIGN AND INSTALLATION
Tracer system design

Long life tracer systems:
- Several oil and water tracers ordered
  - Flexibility to adjust deployment to needs
- Reservoir temperature of 65 – 85°C
- 36 months oil marking life
- 12 months water marking life after WBT
- Commingled sampling at up to 15,000bopd and 15,000bwpd

Rig-site tracer systems:
- Designed for same temperature and rates
- Shorter life (clean-up); detectable at rig-site by mobile lab
# Tracer Carrier Screens

- **Oil and Water activated tracer rods installed into drainage layer of sand screens**

<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
<th>Diagram</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Baker Excluder (SAS)</strong></td>
<td>Perforated base pipe</td>
<td>![Diagram 1]</td>
</tr>
<tr>
<td><strong>Baker Equalizer (ICD)</strong></td>
<td>Blank base pipe, ICD nozzles</td>
<td>![Diagram 2]</td>
</tr>
<tr>
<td><strong>Baker Blank Screen (Rig-site)</strong></td>
<td>Blank base pipe, annular flow</td>
<td>![Diagram 3]</td>
</tr>
</tbody>
</table>

**RESMAN Oil (ROS) and Water (RWS) Systems**

**Rig-site system**
Completion Configurations

<table>
<thead>
<tr>
<th>Well #</th>
<th>Completion schematic</th>
</tr>
</thead>
<tbody>
<tr>
<td>1: ICD / SAS</td>
<td>OS-4 OS-3 OS-2 OS-1</td>
</tr>
<tr>
<td>2: All ICD</td>
<td>OS-4 OS-3 OS-2 OS-1</td>
</tr>
<tr>
<td>3: SAS*</td>
<td>OS-3 OS-2 OS-1/Rig-site</td>
</tr>
<tr>
<td>4: SAS*</td>
<td>OS-4 OS-3 OS-2 OS-1/Rig-site</td>
</tr>
</tbody>
</table>
Intelligent Tracer Applications

MAERSK OIL UK – RESMAN MONITORING CASE STUDIES
Confirmation of Oil Contribution

Well 1: Assess oil productivity
- Good sands choked back by ICD
- Tracers OS-1 and 2 in SAS to assess productivity from uncertain, lower sands and shale
- Clean-up to rig and re-starts to FPSO analysed
Confirmation of Oil Contribution

Clean-up

>80% of total production

Re-starts

80-90% of oil production

5-10% of oil production. Potential gas and cross flow

<20% of total production

Little or no contribution to oil production

5-10% of oil production.

SAS

ICD
Determining Shut-in Cross Flow

Well 1: Tracers show dynamic shut-in conditions

- Double, smeared peak for OS-3
- Overlapping arrivals and trend for OS-1 and OS-2
- Stagnant around OS-4: high peak, continuous flush-out
- Shut-in migration from upstream OS-1 into formation by OS-3
Gas Breakthrough Detection

Well 1: Increased gas production

- Tripled GOR corresponding with drop in OS-3 – reduced oil contact
- OS-3 response reduction recovered to some degree, but remains low compared to OS-4 (reference)
- Gas production indicated by tracers.
- Supported by 4D seismic.
Rig-site Clean-up Verification

Wells 3 & 4: Verifying toe contribution with analysis on the rig

- Analysed on the rig with 2-4 hours turn-around time for results
- Similar timing for long life (OS-1) and rig-site tracer (offshore and onshore lab for Well 4)
  - Slow displacement of rig-site tracer pointing towards collapsed annulus

Wells 3 & 4: Verifying toe contribution with analysis on the rig

- Analysed on the rig with 2-4 hours turn-around time for results
- Similar timing for long life (OS-1) and rig-site tracer (offshore and onshore lab for Well 4)
  - Slow displacement of rig-site tracer pointing towards collapsed annulus

← Long life and rig-site systems installed on the same joint. Similar timing but different response trends due to tracer system design and flow displacement mechanism (ICD flush-out vs. annular flow driven)
Rig-site Clean-up Verification

Wells 3 & 4: Verifying toe contribution with analysis on the rig

• Pilot version (2014): Bespoke tracer systems, analysis equipment set up in mud lab
  – Limited number of unique tracers (typically focus on toe)
  – Proof of concept and logistics

• Commercial version (2015): Use long life systems, analysis container on rig or beach
  – Multiple tracers available for full coverage of the well clean-up
  – Container lab available for North Sea assets
Quantitative Inflow Distribution

Well 2: Inflow distribution across multiple sands in an ICD well

- **OS-4** monitoring Sand 5
- **OS-3** monitoring Shale between Sands 5 and 6
- Blanked off above Sand 6
- **OS-2** monitoring Sand 6
- No tracer in Sand 7
- Interpolating OS-1 and 2
- **OS-1** monitoring Sand 8
Quantitative Inflow Distribution

$k = \text{relative ICD performance factor}$

<table>
<thead>
<tr>
<th>Clean-up (rig)</th>
<th>Re-start 1 (FPSO)</th>
<th>Re-start 2 (FPSO)</th>
</tr>
</thead>
<tbody>
<tr>
<td>OS-3</td>
<td>OS-3</td>
<td>OS-3</td>
</tr>
<tr>
<td>$k = 1.0$</td>
<td>$k = 1.00$</td>
<td>$k = 0.52$</td>
</tr>
<tr>
<td>OS-2</td>
<td>OS-2</td>
<td>OS-2</td>
</tr>
<tr>
<td>$k = 0.8$</td>
<td>$k = 0.17$</td>
<td>$k = 0.05$</td>
</tr>
<tr>
<td>OS-1</td>
<td>OS-1</td>
<td>OS-1</td>
</tr>
<tr>
<td>$k = 0.9$</td>
<td>$k = 0.40$ (improving)</td>
<td>$k = 1.00$</td>
</tr>
<tr>
<td>OS-4</td>
<td>OS-4</td>
<td>OS-4</td>
</tr>
<tr>
<td>$k = 0.67$</td>
<td>$k = 0.25$ (improving)</td>
<td>$k = 0.59$</td>
</tr>
</tbody>
</table>

Initially strongest. Reduced relative performance in Re-start 2

Initially strong. Depleting rapidly.

Seeing prolonged clean-up effects, ending up as strongest zone.

Seeing prolonged clean-up effects, ending up as 2nd strongest zone.
Quantitative Inflow Distribution

- **Background**: LCM pumped during completion.
- **Observation**: Prolonged clean-up.
  - Noise in tracer responses and dynamic inflow distribution
- **Conclusions**: Mainly invasion or damage to Sands 6 to 8
  - Longer time required to clean up.
  - Prolific sands once LCM is displaced.
Water Producing Zones

Well 2: Water inflow detection in an ICD well

- Steady state water samples analysed around WC increase
- Early responses seen prior to WC increase (MPFM)

Indicator of emerging water production from WS-2 (sand 6) and WS-4 (sand 5)

Significant response from all water systems at WC increase – Balanced water ingress?
- Strongest for Sand 6 and above
  - In line with early indicator from WS-2 and WS-4
- Potential liquid loading creating response from WS-3 (well trajectory)

Continued sampling and analysis ongoing to further assess water production.
Application of RESMAN data

**RESMAN RESULTS USED IN ASSET MANAGEMENT**
Asset Management – Well 1

- **Drilling Injectites.**
  - **Question:** Should we bother completing zone 1 (≈10ft of sand) separated by ≈1500ft of shale?
- With the tracers we were able to convince management that we will be able to confirm flow from the toe if we completed it.
- Toe tracer (WIT 1) confirmed to produce ≈5-10% of production
  - Production from this zone has paid for entire lower completion!
- Tracer Data also enabled us to make quality decisions in planning intervention.
• Tracer Data confirmed completion is operating as designed.
• Tracer in shale confirmed shale is collapsed and/or packers are holding.
• Well recently has had water breakthrough:
  – Initial analysis (2 samples) of steady state water samples show potential in Sand 6.
  – Water loading in sump causing response from downstream tracers? (Sand 5 and Shale?).
• ‘Transient’ sampling planned to determine water production zone
Conclusions

- Intelligent inflow tracers were successfully installed in the wells at relatively low cost, without adding risk or rig-time.
- Monitoring campaigns provided insight into:
  - Qualitative verification of contribution
  - Quantified inflow distribution (alignment of models and log data)
- Campaigns conducted provided information on:
  - Individual well performance development
  - Completions design
  - Reservoir performance
- Continued monitoring of wells where RESMAN tracers are installed.
  - PLT on Demand!