The Captain Polymer EOR Pilot

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Outline

- Captain Background
- Why Polymer?
- Chemical Selection
- Injectivity Test & Pilot Plans
- Facilities Re-Instatement
- Logistics
- Forward Plans
Captain Field Location

Location:
Block 13/22a, UK North Sea.

First Oil 1997:
13 years production history

Current gross oil production:
40,000 bbls/ day.

Equity:
85%
15%
Captain Development

- Discovered 1977
- Early development challenges
  - Multiple platforms and over 300 vertical wells
- Early 1990s technology advances
  - Horizontal drilling and ESP development
- Successful EWT – 1993
- 1997 installed WPP & FPSO, first oil
- 2000 expansion project: BLP and subsea Area B template installed
- 2006 Captain Area C - further 2 subsea well development 4km east of Area B template
- Polymer injection facilities installed as part of original development
Captain Infrastructure
Captain Waterflood Performance

- **Volumetric sweep**
  - Injection water slumps down, under-running oil column
  - Water cones up to producers from OWC or under-running water
  - Significant hydrocarbon volumes by-passed

- **Microscopic sweep**
  - Poor SCAL data (unconsolidated rock)
  - Large uncertainty in ROS and Sorw
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Captain Long Term Development Project

- EOR
  - Alkali
  - Surfactant
  - Polymer
- ASP/SAP/PAS
- Huff & Puff
- "Fizzy Water"
- WAG
- "Area 51", Devonian, Southern Terrace, Massive infill drilling
- Hot
- Waterflood
- WAG
- Fibre Optics - DPT
- Voidage
- Produced Water
- Water Management
- Reservoir Management
- DDP – 2nd Contact displacement
- LoSaI
- Microbial
- Vibroseis
- 3rd Party Business
  - Phoenix
  - West Wick
- Other?
Long Term Development Sub-Projects – Chemical EOR

- **Positives**
  - Exceptionally high permeability
  - Low temperature, moderate salinity
  - Medium to high oil acidity

- **Challenges**
  - Heavy/viscous oil
  - High hardness (Ca, Mg ions in formation water)
  - Offshore (impact on facilities, brown field modifications)

- **Key Issues**
  - Incremental sweep
  - Chemical compatibility and chemical performance
  - Offshore space/weight/POB constraints
  - Existing equipment suitability/conditions
Impact on Life of Field

Polymer Flood EOR Potential for Upper Captain Sand

Oil Production (Mbopd)

EOR likely to extend Captain field life

UCS MAIN

POLYMER FLK

ADDITIONAL DEVELOPMENT & EXPANSION

EOR Strategy

- Evaluate suitable chemicals (polymer and ASP) for Captain
- Implement pilot polymer flood project using existing equipment on the Captain facilities
  - Follow by ASP flood if viable
- Develop reliable forecasting tools and evaluate full field implementation
- Implement EOR scheme on Captain
Pilot Objectives

- Demonstrate polymer flood technical feasibility in Captain field
- Provide data to evaluate economic viability for further expansion
- Reduce range on key uncertainties
  - Ability to ship, mix, and inject polymer offshore
  - Well injectivity
  - Increase in sweep efficiency
  - Chemical usage
  - Impact on production efficiency
  - Operability of facility
- Meet above objectives within desired timeframe
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# Laboratory Screening of Commercial Polymers

<table>
<thead>
<tr>
<th>Form</th>
<th>Polymer</th>
<th>Status</th>
<th>Issues and Concerns</th>
</tr>
</thead>
<tbody>
<tr>
<td>Powder</td>
<td></td>
<td>Pass</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Fail</td>
<td>Functional polymer surfactant (FPS), proprietary chemical (has not been field tested) and did not pass the filtration ratio test.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Fail</td>
<td>Viscosity not sufficient, required high polymer concentration and not economically feasible.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Fail</td>
<td>Viscosity not sufficient with increasing calcium concentration exhibits sharp decline, precipitation observed in samples &gt;600 ppm calcium ions.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Fail</td>
<td>Viscosity not sufficient with increasing calcium concentration, precipitation observed in samples &gt;600 ppm calcium ions.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Fail</td>
<td>Precipitation evident at low concentration of calcium, below Captain injected brine level (&gt;600 ppm calcium ions).</td>
</tr>
<tr>
<td>Emulsion</td>
<td></td>
<td>Pass</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Fail</td>
<td>Viscosity not sufficient, required high polymer concentration and not economically feasible.</td>
</tr>
</tbody>
</table>

![Graph showing viscosity vs polymer concentration](image)

- Produced Captain Brine
- Synthetic Captain Brine
- Polymer = EM 533
- Shear rate = 10 sec⁻¹
- Temperature = 87 deg F
Core Flood Set Up
Chemical/Thermal Stability of Polymer

- Comprehensive test of polymer stability in synthetic Captain brine, field brine, and production chemicals
- Results showed that polymer is sensitive to Fe and Oxygen in the brine with some loss of viscosity
- Polymer vendor customized the polymer emulsion with embedded protection package
- With the protection package, polymer would maintain initial viscosity with slight increase with time due to hydrolysis
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Pilot Area

- Southern Upper Captain Sand
- Existing producer plus new injector
- Injector location dictated by water flood reserves recovery, but modified for polymer use
  - Downhole gauge
  - Materials selection
  - Pilot response time
Sequence of Events

- Water flood Baseline (6-8 months)
- Polymer Injectivity Test (1-2 weeks)
- Polymer Pilot (12-18 months)
Injectivity Test Objectives

1. Establish ability to inject desired injection rates
   - No continuous pressure build-up at a constant rate indicative of well-plugging

2. Determine maximum polymer injection rate
   - Achieve steady BHP at various injection rates
   - Validate laboratory rheological properties/constitutive model of injected polymer solution

3. Demonstrate the ability to prepare high-quality polymer solution on site
   - Polymer content, viscosity yield and filterability as specified
   - Sufficient mixing/hydration: no microgels or fish eyes causing plugging
   - Ability to deliver polymer solution at specified viscosity to the wellhead
   - Ability to monitor/measure TDS, hardness, pH, iron, oxygen, viscosity and polymer filtration ratio, on site

4. Demonstrate proficient polymer supply (to FPSO)
   - Compliance with all Regulations & HSE
   - Validation of logistics with cost-effective, timely and uninterrupted supply of polymer

5. Demonstrate that QA, risk assessment, data acquisition and mitigation plans work with minimal or no impact on base operation
Injectivity Test Preparation

- Field scale mixing test of static mixers for inline mixing and hydration of polymer at vendor’s manufacturing site
- Prepare Injectivity Test procedure for predetermined step rates and polymer concentrations
- Establish polymer QA/QC plan (from manufacturer to wellhead) to ensure polymer quality
- Establish sampling and analysis plan (frequency of sampling and analysis) to monitor polymer system performance
- Facility and Operations – re-commissioning of existing polymer facilities (3” subsea line,…), equipment additions, and modifications
Field Scale Polymer Mixing Test
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Facilities Constraints/Issues

- Existing storage tanks on FPSO
- Polymer injection pump/power supply
-Existing 3” subsea polymer line FPSO to WPPA
- Static mixers; space in well bay area
- Logistics
  - transporting polymer via road and rail from France to Aberdeen, supply vessel to Captain, offloading to FPSO.
- Polymer QC
  - Long chain molecules break down under shear
  - No water or oxygen ingress
- Test separator
  - Previously, only used for clean-up
Injection Facilities
Production Test Facilities
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Polymer Transportation & QC

Vendor Central France
- Bulk Viscosity
- Viscosity Yield
- Non volatile solids
- Free Acrylamide
- Filtration Ratio

Antwerp

Aberdeen
- Bulk Viscosity
- Viscosity Yield
- Filtration Ratio

Captain Supply Boat

Captain FPSO (ex ISO’s)
- Bulk Viscosity
- Viscosity Yield
- Filtration Ratio

Captain WPPA
- Bulk Viscosity
- Viscosity Yield
- Filtration Ratio
New Transportation/Offloading Facilities

- Polymer transfer pumps skid for supply boat
  - Mono pump duty/stand-by
  - Diesel hydraulic drive
  - Control system
- 2x5x25,000 litre isotank frames & pipe manifold
- Self sealing coupled hoses
- New hose reel on FPSO
Five 25,000 Litre Isotanks on Frame
Isotank Frame
Polymer Transportation Offshore
Polymer Transportation Offshore
Polymer Offloading to FPSO
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Forward Plans

- Injectivity Test Completion
- 1st Polymer Pilot (SUCS)
- 2nd Polymer Pilot (Aquifer)
- ASP Pilot?
- Expansion Decision
- Field Wide EOR Implementation