Encouraging EOR Projects in the North Sea

Jonathan Thomas, UK Oil & Gas Authority

14th April 2015 - EAGE 18th European Symposium on Improved Oil Recovery
Why we need more EOR

UK oil & gas production

![Graph showing UK oil and gas production from 2000 to 2014. The graph indicates a decrease in production over the years, with a predominant decrease in liquids and a minor decrease in gas. The source is Oil & Gas UK.](Image)
The “window-of-opportunity” is closing
What is “PILOT”?

- Government and industry cooperation
- Ensure full economic recovery of our hydrocarbon resources
Encouraging EOR Projects in the United Kingdom
PILOT EOR Workgroup

OBJECTIVE (set in 2012)

- To be a catalyst for the development of new EOR Projects in the UKCS
- Facilitate cross-industry collaboration in EOR
PILOT EOR Workgroup

ASSESSMENT

- Lack of **CONFIDENCE** in EOR
- Many operators are not yet at the **SCREENING** stage
- **URGENCY** - cycle time from screening to implementation has to be accelerated
Move through “Pyramid-of-Proof” …..more quickly

Developing Proof

Typical Costs
- Deploy: 10 - 100s $m
- Inter Well Trials: 1 - 10 $m
- Multiple Single Well Chemical Tracer Tests: 100s $k
- Multiple Corefloods: 100 - 200 $k
Phase-1: Estimating the “Size-of-the-Prize” for EOR
## "SENOR" EOR Screening Tool

![Image of the SENER screening tool]

<table>
<thead>
<tr>
<th>TECHNICAL PARAMETERS</th>
<th>FIELD MATURITY</th>
<th>Incremental Oil (MMstb)</th>
</tr>
</thead>
<tbody>
<tr>
<td>STOIIP (MMstb)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Depth (ft)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pressure (psia)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Permeability (mD)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oil Viscosity (cP)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Temperature (degC)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Acid number (mg KOH/g)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Arndt-Haven Wetting index</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Frac Clays</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heterogeneity (0, none; 1, lot)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Injection water salinity</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Result</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RF to date</td>
<td></td>
<td></td>
</tr>
<tr>
<td>EURF</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Field Maturity</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Result</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- **Input Data**: 470.3 MMstb, 5123 ft, 2572 psia, 9336 mD, 8.4 cP, 60 degC, 0.1 mg KOH/g, 0.8 Arndt-Haven Wetting index, 0.015 Frac Clays, 0.85 Heterogeneity, 36000 Injection water salinity

### Maximum Incremental Recovery
- 25.5 MMstb

### Table Results

<table>
<thead>
<tr>
<th>Hydrocarbon miscible</th>
<th>Nitrogen and flue gas</th>
<th>CO2 miscible</th>
<th>Surfactant/polymer</th>
<th>Polymer</th>
<th>Alkaline</th>
<th>In situ combustion</th>
<th>Steam drive</th>
<th>Bright Water (strong gel)</th>
<th>Low salinity</th>
<th>CDG/LPS (weak gel)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Green</td>
<td>Red</td>
<td>Green</td>
<td>Green</td>
<td>Red</td>
<td>Green</td>
<td>Red</td>
<td>Red</td>
<td>Green</td>
<td>Green</td>
<td>Green</td>
</tr>
</tbody>
</table>

### Recommendations

I. Results shared with individual field Operators
II. Feedback on incremental recovery volumes and EOR process
III. Inventory of EOR Opportunities on the UKCS

---

Encouraging EOR Projects in the United Kingdom
Phase 1 – Estimate the Size of the EOR Prize

UKCS wide EOR screening performed by DECC

<table>
<thead>
<tr>
<th>EOR Process</th>
<th>Estimated Recovery (mmstb)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Miscible Hydrocarbon flood</td>
<td>5400</td>
</tr>
<tr>
<td>N2 &amp; Flue gas</td>
<td>500</td>
</tr>
<tr>
<td>Miscible CO2</td>
<td>5700</td>
</tr>
<tr>
<td>Surfactant/Polymer</td>
<td>4800</td>
</tr>
<tr>
<td>Polymer</td>
<td>2100</td>
</tr>
<tr>
<td>In-situ combustion</td>
<td>700</td>
</tr>
<tr>
<td>Steam drive</td>
<td>600</td>
</tr>
<tr>
<td>Brightwater</td>
<td>3100</td>
</tr>
<tr>
<td>Low salinity</td>
<td>2000</td>
</tr>
<tr>
<td>Colloid Dispersal Gel (CDG)</td>
<td>3100</td>
</tr>
</tbody>
</table>
EOR "Size-of-the-Prize" Bubble Maps

Figure 8: An example "Bubble-Map" of the Distribution of EOR Potential in the Central North Sea (the diameter of each circle is proportional to EOR potential).
Phase-2: Raising Awareness of EOR Opportunities
Phase 2 – Raising Industry Awareness of EOR Opportunities

3 separate PILOT EOR Work-streams needed:

• **Low Salinity Waterflood**
• **Chemical EOR (polymer / surfactant)**
• **Miscible Gas (hydrocarbon/CO2)**

For each technology we want to build understanding and knowledge sharing.
Low Salinity EOR Activities
Low Salinity EOR UKCS Exemplar – Clair Ridge
PM gives go-ahead for £4.5bn UK oil and gas project

Thursday 13 October 2011

Clair Ridge project will create hundreds of jobs over the next five years and produce a vital source of domestic oil until around 2050
Phase Low Salinity EOR Workgroup Achievements

- 12 operators have participated in a low Salinity EOR collaboration programme
- Established common standards for core testing
- Identified options for brownfield implementation on North Sea platforms
Low Salinity EOR “Clusters”

<table>
<thead>
<tr>
<th>Cluster Name</th>
<th>Lead Operator</th>
</tr>
</thead>
<tbody>
<tr>
<td>NNS Cluster</td>
<td>TAQA</td>
</tr>
<tr>
<td>DECC Estimated Cluster EOR Potential = ~350 MMSTB</td>
<td></td>
</tr>
<tr>
<td>CNS Tertiary Cluster</td>
<td>BP</td>
</tr>
<tr>
<td>DECC Estimated Cluster EOR Potential = ~120 MMSTB</td>
<td></td>
</tr>
<tr>
<td>Moray Firth Cluster</td>
<td>Nexen</td>
</tr>
<tr>
<td>DECC Estimated Cluster EOR Potential = ~270 MMSTB</td>
<td></td>
</tr>
</tbody>
</table>
Low Salinity Core Test “Protocol”

Low Salinity Coreflooding: Key requirements for reliable Measurement:

- Core sample preparation
- Initial water saturation
- Use of representative reservoir oil
- Injection water
- Core flood injection rate
Low Salinity Core Test “Protocol”

Low Salinity Coreflooding: Key requirements for reliable measurement

Objectives:
The following key issues to be addressed when designing a core flood to evaluate low salinity flooding have been developed from observations reported in the open literature and from cumulative experience. Mostly these are what might be considered to be good practice to ensure core is representative of the reservoir state and, hence, the low salinity increment that can be characterized as a recovery change will also be representative.

There are exceptions where these suggestions may not be necessary but they are important for most of the laboratory tests carried out.

Core sample preparation: The EOR increment is only seen in cores containing active grains. Core samples should be prepared in such a way as to minimize disturbance to any grains. Using the core or spall cleaning method which can only cores prior to core flooding should be avoided. Using preserved (and/or restored) cores to obtain a representative cutting made both have merits and potential drawbacks. These options would need to be considered on a case-by-case basis but it is important to avoid obtaining an unrepresentative strongly water-wet core.

Initial water saturation: Representative core-scale water saturation with the correct composition needs to be uniformly distributed in the core. The EOR increment is dependent on the initial deoxygenation composition being less than the “residual” brine and if no ice is in place early tests showed that no salinity EOR increment was observed.

Use of representative reservoir oil: If core floods are carried out with reconstituted oil containing no polar compounds, no incremental oil is seen. Therefore, reservoir crude oil should be used. Using dead crude oil often results in “aerobic” biodegradation over time, and, could, if EOR increment is low, result in no oil bank formation. Ideally, live reservoir oil in equilibrium with the water should be used. Using live reservoir oil would also help to ensure the correct oil is obtained during ageing and flooding.

Injection water: The EOR increment is dependent on the injectant salinity being below a threshold value and on the divalent cation concentration being less than the “residual” brine. The EOR increment decreases as salinity is reduced so maximum benefits will be obtained with the lowest salinity possible without stimulating gas trapping. The “operating range” should be determined by measuring permeability change with varying water composition (swelling tests). These tests and the core used to calibrate EOR benefits should be carried out using combinations of the potential sources waters that might be needed to explain the low salinity water.

Measuring single-phase permeability of the core sample after the core flood is useful to confirm any permeability change under more reservoir realistic conditions than estimated from the swelling tests.

There is no convincing evidence that the differences in sea water and common North Sea reservoir brines will significantly affect the relative permeability in the secondary flood. However, given that the low salinity effect is dependent on the changes in brine composition during flooding, using representative water for the secondary flood prior to a last low salinity flood is preferable.

Core flood injection rate: Unrepresentative flow rates should be avoided. For tertiary tests, during the high salinity flood period that might result in an unrealistic low remaining oil saturation and hence lower EOR benefits. The degree of experimental methodology and test interpretation would result in an inaccurate estimate of the low salinity EOR benefits but if these the key requirements are not met, any measurement will almost certainly be incorrect. Failing a secondary and tertiary baseline flood provides data that can be a good consistency check.

Further Guidance: (added August 2014)

When carrying out low salinity coreflood tests it is common to carry out a “bump” or preflushes in few rates at the end of the test to produce any oil retained by one-side capillary pressure and effects due to the discontinuity of the core cutout. If the “bumps” that are unrepresentative of deep reservoir flow rates, are carried out before the low salinity tertiary step, the immobile oil that could have been the EOR target as well as the post-effect retained oil may have already been produced. Therefore, “bumps” should be carried out after the tertiary low salinity flood. This means that the effect of capillary and adsorption is taken into account.

A first estimate of EOR benefit can be obtained by comparing secondary high salinity and tertiary low salinity saturation data from the first portion of the core that will be less or not significantly affected by the capillary discontinuity at the outlet core boundary. A better estimate can be made by simulation history-matching the coreflood test. This will require an estimate of capillary pressures either through a separate measurement or estimated from “bumps” post-secondary low salinity flood.
Low Salinity EOR Workgroup Achievements

- More than half a dozen fields have been screened to date
- Collaborative studies on Brent Sand low salinity response (Liverpool University) and brown field facilities
Brownfield Facilities for Low Salinity EOR

ITF Database of Contacts (1000’s) → Specific ITF Contacts (100’s) → Targeted Research of Contacts (~80) → 11 EOI’s → 4 proposals under review

ITF is the internationally recognised champion for facilitating collaborative development of innovative technologies within oil & gas and related energy industries.
For more detail see:

SPE 172017

Maximising Enhanced Oil Recovery Opportunities in UKCS Through Collaboration

Copyright 2014, Society of Petroleum Engineers
Miscible Gas Injection EOR Activities
Miscible Gas EOR UKCS Exemplar – Magnus
Miscible Gas EOR Workgroup Achievements

• Industry workshop to discuss main issues
• Looked at potential sources of hydrocarbon gas for EOR
• Looking to link the UK CCS Programme with CO2-EOR opportunities in the Central North Sea
Need Joined-Up CCS Policy & CO2-EOR
Encouraging EOR Projects in the United Kingdom
A Conceptual CO2 EOR “Core Area”
Chemical EOR UKCS Exemplar – Captain
The Polymer Operating Envelope has greatly improved

figure provided by SNF
Quad-9 Heavy Oil Fields

Encouraging EOR Projects in the United Kingdom
Infrastructure issues

Press releases

- Impact of chemical enhanced oil recovery on water management - IFPEN launches Dolphin™, an experimental research project with industry

17 March 2014
The Wood Review and the OGA
EOR has a vital role

The “Wood Review” stressed the importance of EOR

“industry should be encouraged more in EOR schemes to avoid leaving significant value behind”

24 February 2014
The formation of the OGA

Economic challenges intensified since Wood Review

Three key priorities for the OGA

1. People and skills
2. Trust and relationships
3. Focussed delivery

All parties must now deliver
OGA Delivery Plan

Thorough review, clear actions

One integrated plan

Opportunity to create focus and drive delivery

Encouraging EOR Projects in the United Kingdom
Phase-3 : More Detailed Engagement
### Summary of PILOT EOR Workgroup Progress

<table>
<thead>
<tr>
<th>Phase</th>
<th>Objectives</th>
<th>Status</th>
</tr>
</thead>
</table>
| 1. Engagement of Industry & Screening of UKCS fields for EOR potential | • To develop a sense of urgency and energise activity in EOR/IOR projects in the UK oil industry & create a forum for the dissemination of knowledge and experience to other operators and third parties.  
• To identify specific barriers to EOR/IOR implementation on these candidate EOR/IOR projects. | • Basin wide EOR screening complete.  
• EOR workshops held for Low Salinity, Chemical & Miscible Gas techniques. |
| 2. Scoping synergies between fields by geography & EOR technology   | • To identify collaboration opportunities and synergies in the industry, both in subsurface, and in facilities. | • Cluster approach in operation for Low Salinity (NNS & Moray Firth).  
• Chemical EOR Alliance engagement session held. |
| 3. Initiate major options with operators / suppliers                  | • To pinpoint candidate EOR/IOR projects in a timely manner.  
• To generate solutions to the challenges associated with retrofitting a tertiary EOR/IOR scheme, and initiate the necessary developments in subsurface and facilities technology. | • Proposal for EOR assists on top 14 candidate fields.  
• Proposal for Brownfield Low Salinity facilities JIP underway.  
• Engagement between DECC / OCCS on CO₂ EOR potential. |

Encouraging EOR Projects in the United Kingdom
PILOT EOR – Next Steps

- Operators should now be more aware of EOR opportunities in their portfolio
- However, few EOR developments are coming forward
- EOR has a limited window-of-opportunity and more needs to be done
The DECC “EOR Reviews”

• A structured discussion of the current field status & future options – including EOR
• Based on SPE 109555 “RTL” Process
• Identify barriers to EOR deployment and how to overcome
The DECC “EOR Reviews”

- A forum for discussion between DECC and operators to promote more EOR activity
- Identify what we both need to do & by when to make EOR happen
Impact of Low Oil Price

- Interest in EOR has dropped down the agenda
- EOR teams have been reduced in size
- Operators are generally more risk-adverse
Response to Low Oil Price

- Increase emphasis on larger new developments
- Ensure development plan commitments on EOR are honoured
- Closer engagement with operators to progress EOR options and tackle barriers to progression
- Strengthen OGA EOR capability and seek out new technological solutions
For further information, contact:

Jonathan Thomas
Senior Reservoir Engineer – EOR & Carbon Storage
The Oil and Gas Authority
Kings Buildings, 16 Smith Square, London SW1P 3HQ, UK
E: Jonathan.Thomas@oga.gsi.gov.uk   T: 0300 068 6065
Follow us on Twitter.com/ OGAAuthority