THE FIRST OFFSHORE STEAM FLOOD IN EUROPE

DEVEEX 2015
May 20th - 21st
OUTLINE

- Steam flooding technology
- Why not offshore?
- Pilot Field
- MER:UK

Remaining Reserves, mmbbls

Total reserves on the chart ≈ 4.2 billion bbls
Nearly 2 million bbls per day of steam enabled production around the world

Chevron, Oxy and Shell are the leaders in steam flood

Exxonmobil (Imperial) and PDVSA are the top companies in cyclic steam stimulation

Cenovus, Suncor, CNRL, Lukoil, Devon, CNOOC (Nexen), Husky and MEG are the pioneers of SAGD

Shell and Wintershall are steam flooding the Schoonebeek/Emlichheim field on the Dutch/German border in Europe’s biggest steam flood

2013 production data from Oil & Gas Journal 2014 EOR review, except Canada (Alberta Energy Regulator & company data) and Middle East (project specific estimates)
Kern River Field, California

- Steamflood
- 87,000 BOPD
- 230,000 BSPD
- 9,000 wells
- Recovery will approach 80%
- Increases reserves by a factor of 2 – 10 times compared to primary heavy oil recovery.
- Production is both incremental and accelerated.

<table>
<thead>
<tr>
<th>Mechanism</th>
<th>Heavy Oil Recovery</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary</td>
<td>5 - 15%</td>
</tr>
<tr>
<td>Steam Flood</td>
<td>50 - 80%</td>
</tr>
</tbody>
</table>

Pre-Steaming

Oil Saturation Averages 55%

Post-Steaming

Oil Saturation Averages 8%

Typical oil saturated core in Duri Field, Indonesia

**RECOVERY FACTOR POTENTIAL**

Chevron Corporation
OIL VISCOSITY

As a function of API gravity and temperature

Viscosity correlation derived from the Excel Macro PVTProps.xla based upon the Petroleum Fluids Pack developed by Hewlett Packard for use in their HP-41 series programmable handheld calculators. GOR = 100 scf/bbl, Pressure = 1500 psi, bubble point = 1500 psi
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STEAM FLOODING IS THE “PRIME” WAY TO PRODUCE HEAVY OIL...
# STEAM FLOOD SCREENING

From The Petroleum Engineering Handbook

<table>
<thead>
<tr>
<th>TABLE 15.1—SEOR PROJECT SCREENING CRITERIA&lt;sup&gt;23&lt;/sup&gt;</th>
<th>Pilot</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reference</td>
<td></td>
</tr>
<tr>
<td>Depth, ft</td>
<td>&lt;3,000</td>
</tr>
<tr>
<td>Net thickness, h, ft</td>
<td>&gt;20</td>
</tr>
<tr>
<td>Porosity, φ</td>
<td>&gt;0.2</td>
</tr>
<tr>
<td>Oil saturation, S&lt;sub&gt;i&lt;/sub&gt;</td>
<td>&gt;0.1</td>
</tr>
<tr>
<td>φ x S&lt;sub&gt;i&lt;/sub&gt;</td>
<td></td>
</tr>
<tr>
<td>Oil gravity, API</td>
<td>10-34</td>
</tr>
<tr>
<td>Permeability, k, md</td>
<td>&gt;250</td>
</tr>
<tr>
<td>Oil viscosity, μ, cp</td>
<td>&lt;15,000</td>
</tr>
<tr>
<td>Transmissibility, hk/μ, md-ft/μ</td>
<td>&gt;5</td>
</tr>
<tr>
<td>Initial pressure, psia</td>
<td>&lt;1,500</td>
</tr>
<tr>
<td>Pattern size, acre</td>
<td>&lt;10</td>
</tr>
</tbody>
</table>

WHY DEPTH MATTERS?
DEEPER STEAMFLOODS IMPLY HIGHER TEMPERATURES...

...AND LESS LATENT HEAT
OUTLINE

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OFFSHORE STEAM

“We did not investigate steamflooding because North Sea reservoirs are too deep and above the pressure limits for successful application.” Department of Petroleum and Geosystems Engineering, University of Texas at Austin; EOR Field Data Literature Search, Prepared for: Danish Energy Agency & Mærsk Olie og Gas AS, 2008

“No, too much heat loss in riser to ocean water”, National Petroleum Council, Global Oil & Gas Study, Topic Paper #22 Heavy Oil; Table IV.4b. page 13, 2007

“Potential for heated injection fluid processes are limited in cold or deep water by heat losses in transit…. Even with equipment advances such as vacuum-insulated tubulars, heat losses above the mudline could be unacceptably large.” Technical Challenges for Offshore Heavy Oil Field Developments, OTC 15281, 2003

“The problems of providing reasonable steam quality at the Pilot reservoir depth and pressure are significant. The offshore environment and potential for wet trees make the problem nearly insurmountable. [Unnamed consultancy] advise not to consider steam injection.”, Previous Pilot EOR screening study, Unnamed consultancy, 2003
WELLBORE HEAT LOSS

- Initial steam quality of 80%
- At 500 bpd cwe steam quality is reduced to 23.3% at 4,000'
- At 1,000 bpd cwe steam quality is reduced to 51.5% at 4,000'
- Steam condensed is 285 bpd in each case
- So, at 10,000 bpd cwe steam quality would reduce by about 3%

Data for 500, and 1,000 bcwe/day cases, New Advances and a Historical Review of Insulated Steam Injection Tubing - SPE-113981, 4,000' data point calculated by extrapolation
WHAT’S THE REAL PROBLEM?

- **Few candidates**
  - Limited number of candidates that meet the screening criteria
  - Pilot is one of only a few in the North Sea

- **Well densities**
  - Onshore projects have typically been at 2.5 to 10 acre spacings
  - Long (1,000m plus) horizontal wells at 100m to 150m spacings have solved this problem
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The reservoir description is well understood and all the well and seismic data needed has been gathered.

The block is fully covered by the Western Geco Quad 21 3D survey which was reprocessed in 2009 and a new survey by Fugro which completed processing in 2013.

<table>
<thead>
<tr>
<th>WELL</th>
<th>FIELD AREA</th>
<th>TEST RATE (BOPD)</th>
<th>FLUID COLUMNS</th>
<th>API GRAVITY</th>
<th>OIL VISCOSITY (CP)</th>
</tr>
</thead>
<tbody>
<tr>
<td>21/27-1A</td>
<td>Harbour</td>
<td>920</td>
<td>Gas 20 ft</td>
<td>17.0</td>
<td>98</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Oil 29ft</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Water</td>
<td></td>
<td></td>
</tr>
<tr>
<td>21/27-2</td>
<td>Pilot Main</td>
<td>110</td>
<td>Oil 62ft</td>
<td>16.8</td>
<td>159</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Water</td>
<td></td>
<td></td>
</tr>
<tr>
<td>21/27-3</td>
<td>Pilot Main</td>
<td>-</td>
<td>Oil 7ft</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>21/27-4</td>
<td>Pilot South</td>
<td>-</td>
<td>Oil 11ft</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Water</td>
<td></td>
<td></td>
</tr>
<tr>
<td>21/27a-5/5X</td>
<td>Pilot Main</td>
<td>2,000</td>
<td>Gas 19 ft</td>
<td>12.8 - 13.4</td>
<td>600 - 1870</td>
</tr>
<tr>
<td></td>
<td></td>
<td>horiz. well</td>
<td>Oil 29ft</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Water</td>
<td></td>
<td></td>
</tr>
<tr>
<td>21/27a-6</td>
<td>Pilot Main</td>
<td>-</td>
<td>-</td>
<td>15.5</td>
<td>420</td>
</tr>
</tbody>
</table>
POTENTIAL WELL PATTERN

- Target the area with greater than 30’ of net pay
- Alternating producers and injectors, 100m apart (potential to increase spacing)
- Wells between 1000m to 1800m long
- Inflow control devices to achieve conformance control
- 42 alternating producers and injectors
INITIAL SECTOR MODELLING

Top Tay

Hydrocarbon Pore Volume

1870 cP

1870 cP

420 cP

159 cP
INITIAL SECTOR MODELLING

Well #5
1870 cP
66% RF

Well #5x
1870 cP
52% RF

Well #6
420 cP
64% RF

Well #2
159 cP
71% RF
CONFORMANCE CONTROL

Horizontal slice of sector model located at 5x well location

Injector

Producer
CONFORMANCE CONTROL

- Autonomous Inflow Control Valves (AICV®)

- Valve has two flow pathways, one always open (1%-5% of combined flow) one open or closed (95%-99%)

- Status of main flow pathway depends on pressure drop in pilot flow pathway.

- Valve can shut off low viscosity fluids (e.g. steam, gas or water)

- Installed in each joint of sand screen with swellable packers at every fifth joint or so

Illustrated valve is available in a high temperature version from Inflow Control of Norway http://www.inflowcontrol.no
PILOT – RESOURCES

<table>
<thead>
<tr>
<th>Field</th>
<th>STOOIP mmbbls</th>
<th>RF</th>
<th>Recoverable mmbbls</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pilot Main</td>
<td>230</td>
<td>58%</td>
<td>132</td>
</tr>
<tr>
<td>Pilot South</td>
<td>33</td>
<td>30%</td>
<td>10</td>
</tr>
<tr>
<td>Harbour</td>
<td>9</td>
<td>~</td>
<td>~</td>
</tr>
<tr>
<td>Total</td>
<td>272</td>
<td></td>
<td>142</td>
</tr>
</tbody>
</table>

* Recovery factors based upon sector modelling of Pilot Main steam flood. Pilot South and Harbour based upon an assumed recovery factor for water flood
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MER-UK: HEAVY OIL POTENTIAL

The steam prize: ~ 2 billion bbls

Area of bubble is proportional to oil in place, not a complete inventory of all UKCS heavy oilfields.
THE BIGGER PRIZE

- The Pilot project can prove offshore steam and be a test bed for new equipment and technologies.
- Extending the applicable depth for steam flood could unlock almost 2 billion bbls of recoverable reserves in the UKCS.
- The Operator at the forefront of deep steam offshore will have a real competitive advantage both in the UKCS and internationally.
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