The Characteristics of High Temperature In-situ Combustion Mode In Intensive Heterogeneous Reservoir - A Case Study in Block HQ of Xinjiang Oilfield

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PIRED, CNPC

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1 Background

- **Process of ISC**

- The reservoir is ignited by igniter in the injector, the air is continuously injected to reservoir and combustion front moves towards the producer.

- The oil is driven into the producer by a combination of gas drive, steam flooding, hot water flooding and high temperature distilling, cracking mechanisms.
1 Background

- **Application in China**

<table>
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<tr>
<th>Projects</th>
<th>Started Time</th>
<th>Introduction</th>
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<tr>
<td>D-66, Liaohe Oilfield</td>
<td>Jun.2005</td>
<td>Steam injected heavy oil reservoir; 200 nine-spot patterns and 600 producers; oil rate 5000 bbl/d.</td>
</tr>
<tr>
<td>G-3618, Liaohe Oilfield,</td>
<td>May.2008</td>
<td>Steam injected heavy oil reservoir with depth of 1500 m; 14 injectors, 92 producers; oil rate 1306 bbl/d.</td>
</tr>
<tr>
<td>H-1 Pilot, Xinjiang Oilfield</td>
<td>Dec.2009</td>
<td>Heavy oil reservoir after steam stimulation and steamflood; 7 injectors and 49 producers, oil rate 251 bbl/d.</td>
</tr>
<tr>
<td>Fengcheng Pilot, Xinjiang Oilfield</td>
<td>Sept.2014</td>
<td>Initial heavy oil reservoir, 4 injectors and 4 horizontal wells, 300 bbl/d</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>Oil rate 6557 bbl/d</td>
</tr>
</tbody>
</table>
1 Background

• H-1 ISC Pilot Test

➢ Reservoir Characteristics

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td><strong>Depth</strong></td>
<td>1805ft</td>
</tr>
<tr>
<td><strong>Thickness of pay zone</strong></td>
<td>26.9ft</td>
</tr>
<tr>
<td><strong>Initial pressure and temperature</strong></td>
<td>929 psi; 68F</td>
</tr>
<tr>
<td><strong>Average porosity</strong></td>
<td>25.4 %</td>
</tr>
<tr>
<td><strong>Average horizontal permeability</strong></td>
<td>582 mD</td>
</tr>
<tr>
<td><strong>Dead oil viscosity at 122F</strong></td>
<td>500~1200 cp</td>
</tr>
<tr>
<td><strong>Initial oil saturation</strong></td>
<td>67 %</td>
</tr>
</tbody>
</table>
1 Background

• H-1 ISC Pilot Test

➢ Development history

<table>
<thead>
<tr>
<th>MODE</th>
<th>Well number</th>
<th>Steam injection (MMbbl)</th>
<th>Oil production (MMbbl)</th>
<th>Water cut</th>
<th>SOR</th>
<th>ER</th>
</tr>
</thead>
<tbody>
<tr>
<td>CSS</td>
<td>141</td>
<td>6.76</td>
<td>2.40</td>
<td>80.5%</td>
<td>2.85</td>
<td>26.5%</td>
</tr>
</tbody>
</table>
1 Background

• H-1 ISC Pilot Test

Development history

Steam injection vertical profile

Production vertical profile
1 Background

**H-1 ISC Pilot Test**

- Water cut: 99%-65%
- AOR: 57,000-11,400 scf/bbl
- NO combustion front breakthrough
- Cumulative oil of ISC is already near to that of steam injection
- RF: 26%
There are same characteristics for single well.
2 The Characteristics Of High Temperature In-situ Combustion Mode
The temperature of combustion front is more than 930°F.
High CO₂ content and low H/C Ratio

CO₂ content: 15%
H/C Ratio: 1.4

Limited\( (C_nH_{2n+2}) \) H/C is = 2.0;
The cracked heavy oil components were burned.
*Upgrade in oil composition*

<table>
<thead>
<tr>
<th>well</th>
<th>Sample</th>
<th>Saturate /%</th>
<th>Aromatic /%</th>
<th>Resin &amp; Asphaltene /%</th>
<th>Vis, cp</th>
</tr>
</thead>
<tbody>
<tr>
<td>h2107A</td>
<td>2009/3/10</td>
<td>45.43</td>
<td>24.51</td>
<td>30.06</td>
<td>11000</td>
</tr>
<tr>
<td></td>
<td>2010/2/10</td>
<td>55.47</td>
<td>18.42</td>
<td>26.11</td>
<td>1041</td>
</tr>
</tbody>
</table>
Higher sweep oil efficiency and vertical sweep efficiency

Oil displacement efficiency: >95%
Combustion vertical sweep efficiency: >95%

Drilling core after in-situ combustion
Drilling core before in-situ combustion
Higher sweep oil efficiency and vertical sweep efficiency
3 The Facilitating Key Factors Of High Temperature In-situ Combustion Mode
Evaluating of combustion conditions

- **Te**: Environment
  - (68~248°F)
- **Ti**: Ignition
  - (590~698°F)
- **Tb**: Combustion Front
  - (>752°F)
- **Tm**: Cut off Temperature
  - (716~752°F)

Coal fuel combustion conditions

- **T**: Temperature
- **q**: Rate of heat generation
- **A**: Low temperature oxidation
- **M**: Dynamic combustion
- **B**: Diffusion combustion (high temperature combustion)
Keep high temperature of igniter

When temperature is more than 470°C (870°F), H1 oil sample can be ignited by a high temperature mode.
Keep a reasonable air flux

Temperature profile Air flux: 10m³/(m².h)

Temperature profile Air flux: 30m³/(m².h)
Keep a reasonable air flux

Reasonable air flux: 0.15-0.3 m³/(m².h)
Minimum air flux: 0.05 m³/(m².h)
4 Conclusion
Conclusion

- Good production performance is gained in post-steam heavy reservoir.
- High temperature in-situ combustion mode features high Temperature of Combustion front, high $\text{CO}_2$ content and low H/C Ratio, upgrade oil composition, high sweep oil efficiency and high recovery factor.
- Keep a higher igniter temperature and reasonable air flux can facilitate a high temperate in-situ combustion.
Acknowledgment

• Collaborators – Professor Guan Wenlong, Master Wangting and Doctor Tang Junshi, Senior Geologist Wu Jiang
• Staff in H1 Block ISC Pilot Test in Xinjiang Oilfield Company, PetroChina
Thank you/Questions