Introduction of Enhanced oil recovery technology

V-petrotek, LLC
Enhanced oil recovery technology

Conventional water flooding
- High water cut stage reservoir
- Complex fault block oil reservoir
- Low permeability reservoir

Chemical flooding
- I, II, III, V and Offshore oil reservoir
- I, II and polymer flooding reservoir
- IV and polymer flooding reservoir
- IV and polymer flooding reservoir

Steam flooding
- Conventional water flooding of heavy oil reservoir
- After stimulation of heavy oil reservoir

Microbial flooding
- After high ooze water flooding and polymer flooding reservoir

Vector well pattern adjustment
- Three-dimensional development of complex fault block
- Small well spacing waterflood development
- CO2 miscible displacement

Sand body pattern perfect
- Development of the top horizontal well
- Streamline pattern modification

Polymer flooding technology
- Binary compound flooding
- Foam combination flooding
- Heterogeneous composite flooding
- Conventional steam flooding
- Chemical steam drive
- Microbial enhanced oil recovery

Enhanced oil recovery technology

Sand body pattern perfect
- Sand body pattern perfect

Streamline pattern modification
- Streamline pattern modification

Enhanced oil recovery technology
- Enhanced oil recovery technology

CO2 miscible displacement
- CO2 miscible displacement

Enhanced oil recovery technology
- Enhanced oil recovery technology

Streamline pattern modification
- Streamline pattern modification

Enhanced oil recovery technology
- Enhanced oil recovery technology

Sand body pattern perfect
- Sand body pattern perfect
一、Conventional waterflood enhanced recovery technology

1、high water cut stage reservoir

1、Vector well pattern adjustment

“Tenth Five-Year” the mid to late

**cognition**

lit-by-lit high water
well-by-well high water

integrated regulation
Downsizing
Reperforating
changing layer
Strengthen extract

Well network of layer is destroyed

Since the "twelfth five-year"

theoretical guidance

layer recombination
Vector well pattern adjustm ent

deepen understanding of potential

play weak drive layer potential

enhance plane weak drive layer potential
(1) 9-10 layer recombination, Vector well pattern adjustment

10 sands group 5 sublayer a layer, Proposed differential resistance 3.7
- vacuate well pattern: 300*260m-380*300m;
- change flowline: 35-40°
- extract: 70t↑150t
- recovery ratio: 41→45%

9 sands group 2 sublayer a layer, Proposed differential resistance 2.1
- well pattern: 300*260m-200*250m;
- change flowline: 30-45°
- extract: 22t↑50t
- recovery ratio: 28→36%

geologic reserve: $355 \times 10^4$ t
- water content: 96.2%
- degree of reserve recovery: 32.2%
- Proposed differential flow resistance: 45

- daily oil production, t: decrease from 14.4% to 6.2%, degree of reserve recovery improve 5.7 percent
一、Conventional waterflood enhanced recovery technology

(2) 8 layer system plane vector well pattern adjustment

High permeability, extraction zone → big well pattern → Changing the flow direction → Improve multiple of injection, displacement pressure gradient

Low permeability, extraction zone → Small well pattern

Optimize injection parameters

Geologic reserve: 1280万吨; water content: 97.9%; degree of reserve recovery: 46.4%

Original well spacing: 400m

Big well pattern 450–600m, small well pattern 200–300m

Scheme recovery ratio improve from 48.4% to 52.85%, Improved 4.45 percentage points
（3）1-3 Layer well network restructuring

**Conventional waterflood enhanced recovery technology**

Expected to increase recoverable reserves 191万吨，Recovery rate increased by 5.1%
Conventional waterflood enhanced recovery technology

1. high water cut stage reservoir
   (1) multilayer layer system: Strata subdivision, old well upper layer, new well down layer (Streamline change 90°)

   Subdivided into two strata, the upper level is the use of old wells network development wells, down level drilling new wells form 250 * 250m ranks well pattern (90° change streamline)

   Being further optimization program, ready to implement

   geologic reserve: 430 million tons; water content: 95.2%; degree of reserve recovery: 37.8%
一、Conventional waterflood enhanced recovery technology

（2）Single-layer system：Converting some oil wells and water wells, changing the flow direction

Changing the flow direction of 60 degrees

Well turn injection wells
Transfer pumping wells
Conventional waterflood enhanced recovery technology

1. high water cut stage reservoir

xx Oilfield overall water content ratio > 92%, the main sand body injection patterns better, small sand with low level of well network control.

Statistics of utilized small oil sands condition

<table>
<thead>
<tr>
<th>分类</th>
<th>砂体个数</th>
<th>地质储量 10^4t</th>
<th>采出程度%</th>
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<tbody>
<tr>
<td>砂体动用状况≤0.02</td>
<td>13</td>
<td>8.67</td>
<td>15.25</td>
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<tr>
<td>砂体动用状况0.02-0.04</td>
<td>22</td>
<td>40.44</td>
<td>20.84</td>
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<tr>
<td>砂体动用状况0.04-0.1</td>
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<td>32.12</td>
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<tr>
<td>合计</td>
<td>44</td>
<td>81.23</td>
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xx Oil sands unused small tables sands

<table>
<thead>
<tr>
<th>分类</th>
<th>≤1.0×10^4t</th>
<th>1.0-2.0×10^4t</th>
<th>2.0-5.0×10^4t</th>
<th>&gt;5.0×10^4t</th>
<th>小计</th>
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<tbody>
<tr>
<td>个数</td>
<td>个数</td>
<td>个数</td>
<td>个数</td>
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<tr>
<td>面积≤0.02km^2的砂体</td>
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<td>合计</td>
<td>279</td>
<td>109.9</td>
<td>36</td>
<td>51.6</td>
<td>23</td>
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</tbody>
</table>

To 2010, drilled 13, put into production 11, old well turn injection wells 6, enhanced oil recovery of 15.7%.
一、Conventional waterflood enhanced recovery technology

1. high water cut stage reservoir

4. Thick oil layer at the top horizontal wells tapping technique

After the operation has accumulated oil production 22,200 tons.
一、Conventional waterflood enhanced recovery technology

2、complex fault block oil reservoir  Three-dimensional adjustment techniques

Geological reserves of 4.39 million tons, 92.3% water cut; degree of recovery of 38.2%, 42.5% recovery

Ⅰ class. Thick layer of simple block:
The degree of recovery of 48.8%, 97.8% water cut, open wells 2, state is basically technology abandoned.

Class Ⅱ. Multiple thin simple block  The degree of recovery of 30.1%, water content 89.8%, the obvious contradiction between layers.

Ⅲ class. Complex fault block
The degree of recovery of 27.9%, 78.6% water cut, open wells 2, many small non-well control.

Between layers, the inter-block potential overall analysis, three-dimensional optimization
Conventional waterflood enhanced recovery technology

(1) Class I thick layer of simple block - horizontal wells near fault + high strength injection wells

horizontal wells near fault - put into production from the spray 24 tons/d, 12.2% water content

Day 13 tons of oil production, water content 36%, has accumulated 8,777 tons of oil
Conventional waterflood enhanced recovery technology

(2) II class multiple thin layers—layer recombination, vector network of wells

Three segments: Layer recombination, selective mining, separate injection, variable density perforation

- Old Well based
- New Well based
- Selective mining
- Separate injection
- Variable density perforation
一、Conventional waterflood enhanced recovery technology

（2）Ⅱ class multiple thin layers- layer recombination，vector network of wells

vector network of wells

I class layers injection well spacing 280m.
Ⅱ class layers injection well spacing 200m

Consider permeability, formation dip, to determine the specific well spacing.
一、Conventional waterflood enhanced recovery technology

（3）Ⅲ class Complex fault block - use a combination development of multi-target multi-block

Horizontal wells across the block

Oil drilling 317m. Initial daily oil production 60t / d, excluding water. The current production of AB segment, 12.4 tons daily oil production, water 82.9%, has accumulated 15,295 tons of crude oil.

Initial daily output of 10t / d, water 3.9%. Currently oil production 3.0t / d, 85% of water, tired produced 7,625 tons of crude oil.
The overall effect of the test area

Daily oil production increased from 18t to 192t, water rate from 92.3% down to 65.1%. Has accumulated increase of oil 118,000 tons, recovery from the 42.5% increase to 53%.
1、Conventional waterflood enhanced recovery technology

3、low permeability reservoir

Under the guidance of low permeability reservoir percolation mechanism established technology critical spacing plates.

Low permeability reservoir flow state distribution area

To determine the reasonable well spacing to achieve cost-effective development of the reservoir to provide theoretical guidance.
Recovery increased from 17.7% to 24.5%, 6.8%, enhanced oil recovery
一、Conventional waterflood enhanced recovery technology

3、low permeability reservoir

2、horizontal well fractured completions waterflooding

Using a horizontal well fracturing by fragment oil well completion, matching small well spacing injection supplement energy wells network mode

Xxblock Well network deployment diagram

Cumulative oil production 1.38万t。

4 horizontal wells into production, cumulative oil production 4030 tons of single well, injection wells injecting normal recovery reached 26%.
一、Conventional waterflood enhanced recovery technology

3、low permeability reservoir

Xx well array well location map

含油面积: 0.7km²
地质储量: 50.6×10⁴t
空气渗透率: 4.7mD

Expected recovery from 8.9% to 26.1%, improved by 17.2%.

3、CO2 miscible flooding pilot test

Injection test stage

20,400 tons of accumulated injection. Injection pressure 6MPa, day water injection 63.6 tons; meters depending on the suction index 1.55t / (d · MPa · m)

Gas injection phase

Well Group 4 gas injection wells, as the current total amount of 31,300 tons injection

Xx Well group gas injection basic statistics

<table>
<thead>
<tr>
<th>井号</th>
<th>初期注入压力 (MPa)</th>
<th>目前日注 (t)</th>
<th>累注 (t)</th>
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<td>高89-4</td>
<td>3</td>
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<td>23076</td>
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<td></td>
<td>7.6</td>
<td>15.9</td>
<td></td>
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<td>高89-16</td>
<td>12</td>
<td>16.6</td>
<td>2150</td>
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<td>7</td>
<td>30.3</td>
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<td>高89-5</td>
<td>12</td>
<td>16.6</td>
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<td>高89-17</td>
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<td>29</td>
<td>3386</td>
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<td></td>
<td>17.1</td>
<td>35.8</td>
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</tr>
<tr>
<td>小计</td>
<td>目前</td>
<td>31307</td>
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</table>
Well Group cumulative incremental oil 7430 tons. Peripheral production wells yield showed a decreasing trend.

Conventional waterflood enhanced recovery technology.
### Chemical flooding Resource Evaluation Criteria

<table>
<thead>
<tr>
<th>类别</th>
<th>空气渗透率 $10^{-3} , \mu m^2$</th>
<th>原始地层温度 $^\circ C$</th>
<th>目前地层水矿化度mg/L</th>
<th>Ca$^{2+}$+Mg$^{2+}$mg/L</th>
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<td>$&lt;95$</td>
<td>$&lt;100000$</td>
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<td>IV类</td>
<td>大孔道严重</td>
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</tr>
<tr>
<td>V类</td>
<td>温度：95-120°C；渗透率：50～100×$10^{-3} , \mu m^2$</td>
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海上：海上油田
Different types of reservoirs suitable for chemical flooding methods

<table>
<thead>
<tr>
<th>Reservoir classification</th>
<th>polymer flooding</th>
<th>dualistic flooding</th>
<th>Heterogeneous combination flooding</th>
<th>foam flooding</th>
<th>notes</th>
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<td>✓</td>
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<td>III</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
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<td></td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td></td>
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<tr>
<td>V Special high temperature (95-120°C)</td>
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<td></td>
<td>✓</td>
<td>reserve</td>
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<td></td>
<td>Low permeability (50-100md)</td>
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<td>Maritime</td>
<td>✓</td>
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<td>✓</td>
<td>pilot tracey</td>
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<tr>
<td>After polymer flooding</td>
<td></td>
<td></td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
</tbody>
</table>
(一) Polymer flooding technology

Class I reservoir: the effect of the implementation of polymer flooding

XX Well deployment diagram

XX Production curve

- Area: 1.8 km², Reservoir storage: 1185 million tons
- Temperature: 70.5 °C, Salinity: 5797 mg/L
- Original viscosity: 85 mPa·s
- Injection well: 38, Production well: 90
- Injection well spacing: 250 m
- Cumulative increase: 120.6 million tons
- Oil recovery rate: 10.2%
- Oil recovery rate: 84.6 t/t
- Recovery rate: 59.4%
Polymer flooding technology

Class II reservoir high temperature and salinity polymer flooding pilot test

- Geologic reserve: $1.089 \times 10^4$ t
- Injection wells: 32, Production wells: 58
- Formation temperature: 80°C
- Formation water salinity: 21000 mg/L
- Calcium and magnesium content: 311 mg/L
The recovery ratio has been increased by 7.4% (OOIP), tons of poly oil increase by 101 t/t, which is expected eventually can be achieved 109 t/t.

production curve of central well in pilot site
2.2 The binary system flooding technology

- The pilot test of surfactant/polymer (SP) flooding

- Well location map of pilot site

- Reservoir Profile

- Reservoir temperature: 68°C
- Reservoir water salinity: 8207 mg/L
- Ca²⁺ + Mg²⁺: 231 mg/L
- Geologic reserve: 277 0 kiloton
- Injection well: 10, producing well: 16
- Injection producer distance: 300 m

- The composite water cut before combination flooding: 98.0%
- The degree of reserve recovery before combination flooding: 35.2%
2.2 The binary system flooding technology implementation effect

(2) Production performance - The daily oil production is improved and water content is lower

- The recovery ratio has been increased by 16.8%
2.3 The Foam Flooding Technology

It enhanced oil recovery of class IV high capacity channel and class I and II reservoir (after polymer flooding)

Diagram of chemical resources in Shengli Oilfield

Development feature
- Composite water cut: >95%
- Water injection multiple: >2PV
- Cumulative water/oil ratio: >7

Reservoir feature
- Reservoir temperature: 60-80 °C
- Total salinity: 6000-20000mg/L
- Ca and Mg content: 100-400mg/L
2.3 The Foam Flooding Technology

1. The pilot test of reservoir enhanced foam flooding after polymer flooding

The injection curve of polymer

The production curve of XX well
The obvious of decreasing water and increasing oil are achieved.

6 wells are response producer, and the total increased oil production is 11,000 tons.
2.3 The Foam Flooding Technology

The pilot test of enhanced foam flooding in class IV reservoir

The well location map of the enhanced foam flooding in XX site

- Reserves of pilot site: $119 \times 10^4$ t
- Injection well: 4
- Producing well: 15
- Reserves of central well region: $42 \times 10^4$ t
- Central well: 3

Reservoir profile in XX site

- Composite water cut: 97.1%
- Water injection rate: 0.3PV/a
- Degree of reserve recovery: 40%
- Cumulative water-injected multiple: 2.8 PV

Typical representative of IV reservoir
The injection curve of injection well

The injection pressure

The main slug pressure has increased significantly, proved that the shut off capacity is stronger than polymer.
2.3 The Foam Flooding Technology

◆ The resistance coefficient is larger significantly.

- Hall curve in pilot site
  - RF=4.86
    - \(y = 0.068x + 13.202\)
    - \(R^2 = 0.9977\)
    - \(y = 0.2193x - 29.947\)
    - \(R^2 = 0.9989\)
    - \(y = 0.3326x - 64.471\)
    - \(R^2 = 0.9923\)

- Hall curve in XX polymer-flooding block
  - RF=2.2
    - \(y = 0.0151x - 5.3503\)
    - \(R^2 = 0.9993\)
    - \(y = 0.025x - 10.345\)
    - \(R^2 = 0.9992\)
    - \(y = 0.0332x - 15.932\)
    - \(R^2 = 0.999\)

- It is significantly higher than the resistance coefficient of polymer, the filtrational resistance of the enhanced foam system is greater and has stronger shut off capacity.
2.3 The Foam Flooding Technology

- The obvious of decreasing water and increasing oil achieved in pilot site.

- The daily oil production is 5.2 times before injection.
- The total increased oil production is 19,000 tons.
- The oil recovery has been enhanced by 4.5%.
- The forecast oil recovery will be enhanced by 12.7%.
2.4 The heterogenous flooding technology

◆ After polymer flooding by “well network adjusted heterogeneous flooding” to improve oil recovery

feature

The remaining oil
Become more dispersed
But widespread distribution

Heterogeneity is more prominent
And the remaining oil is local enrichment

strategy

Changes in flow lines

Well pattern adjustment

Strong washing

method

heterogenous flooding

Substantial increase recovery after polymer flooding
2.4 The heterogenous flooding technology

Carry out pilot test of heterogenous flooding by well pattern adjustment after polymer flooding in class I reservoir.

Further enhanced oil recovery after exploring polymer flooding

well location map in pilot site

Oil area: 0.54 km²
Geologic reserve: 221×10⁴t
Reservoir temperature: 70°C
Water salinity: 7373mg/L
Divalent ion content: 92mg/L
Injection well: 15
Production well: 10
The composite water cut before water injection: 98.3%
Degree of reserve recovery: 52.3%
The forecast enhanced recovery is 8.5%
2.4 The heterogenous flooding technology

◆ The effect of pilot test

- Significant effect in mine application

The filtrational resistance is significantly increased.

### The comparison of resistance coefficient with different chemical flooding

<table>
<thead>
<tr>
<th>Block</th>
<th>Resistance coefficient</th>
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<tbody>
<tr>
<td>Polymer flooding</td>
<td>1.43</td>
</tr>
<tr>
<td>Binary flooding</td>
<td>1.79</td>
</tr>
<tr>
<td>heterogenous flooding</td>
<td>2.20</td>
</tr>
</tbody>
</table>

The Hall curve in XX well:

\[
y = 902.23x - 71409 \\
R^2 = 0.9977
\]

\[
y = 329.79x + 8036.6 \\
R^2 = 0.9992
\]

RF = 2.7
2.4 The heterogenous flooding technology

● Significant effect in mine application—the significant effect of decreasing water and increasing oil in oil well

The production data in central test area

The dimensionless daily oil comparison with different chemical flooding

- 10 central well has increased oil 38,600 tons, and has been enhanced recovery by 3.14%
- The daily oil production of central well by the 4.5 t/d increased to 78.5 t/d
- The composite water cut from the 97.5% drop to 80.6%, a decrease of 16.9%
2.4 The heterogenous flooding technology

Form the reservoir after polymer flooding and improve the recovery supporting technology

Heterogenous flooding by well pattern adjustment after polymer flooding reservoir

- Compound design
- Reservoir engineering
- Numerical Simulation and Optimization
- producing characteristic evaluation
- Produced liquid processing
- Comprehensive Evaluation of the effect

- Oil displacement agent optimization
- Architectural design
- Laboratory physical simulation
- Reservoir description
- Well pattern optimization
- Layer system optimization
- Scheme optimization
- Software development
- Performance matching
- Exploitation features
- The effect of factors
- Efficient oil separator
- Integrated processing design
- Economic evaluation
- Technical evaluation
3. The steam flooding technology

The heavy oil classification standard in Shengli Oilfield

<table>
<thead>
<tr>
<th>Type</th>
<th>surface viscosity mPa.s</th>
<th>Suitable methods</th>
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<tbody>
<tr>
<td>I ordinary heavy oil</td>
<td>100～3000</td>
<td>conversion development ways after waterflooding</td>
</tr>
<tr>
<td>II ordinary heavy oil</td>
<td>3000～10000</td>
<td>thermal recovery by steam injection</td>
</tr>
<tr>
<td>Extra heavy oil</td>
<td>10000～50000</td>
<td>thermal recovery by steam injection</td>
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<tr>
<td>Super heavy oil</td>
<td>&gt;50000</td>
<td>improved thermal recovery technology</td>
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</table>
3.1 The stream flooding technique of conventional heavy oil

1. The mine application shows that the enhanced recovery of steam flood is about 20% higher than huff flooding.

Key technique

- Improve steam ratio
- Decrease borehole heat loss
- Effectively reduce the formation pressure

The effect comparison of steam flooding after cyclic steam stimulation

<table>
<thead>
<tr>
<th>type</th>
<th>block</th>
<th>well spacing m</th>
<th>reserves $10^4$ t</th>
<th>oil viscosity mPa.s</th>
<th>steam stimulation recovery %</th>
<th>steam flood recovery %</th>
<th>Increase rate %</th>
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<tbody>
<tr>
<td>domestic</td>
<td>Le’an Oilfield</td>
<td>141×200</td>
<td>151</td>
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<td>32.3</td>
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<tr>
<td></td>
<td>Region 9 of Gudong Oilfield</td>
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<td>4000</td>
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<td>36.5</td>
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<td>51.0</td>
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2. Forming a series of steam flooding technology

- The steam flooding reservoir screening technique
- The steam flooding reservoir engineering technique
- The steam flooding economic evaluation technique
- The steam flooding supporting technology

- The remaining oil description technique
- The numerical simulation techniques of thermal recovery
- The scheme optimization and preparation technique
- The dynamic tracking evaluation techniques
- The injection parameter adjustment technique
3.1 The stream flooding technique of conventional heavy oil

3. Application results

(1) active edge and bottom water glutenite extra-viscous oil reservoir

- The pilot test of stream flooding

The stream flooding effect Statistics table

<table>
<thead>
<tr>
<th>well group</th>
<th>well spacing m</th>
<th>beginning time a.mon</th>
<th>huff and puff recovery percent %</th>
<th>stream flooding recovery percent</th>
<th>total recovery percent</th>
<th>notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>test well group</td>
<td>200×141</td>
<td>93.8</td>
<td>19.3</td>
<td>35.04</td>
<td>54.34</td>
<td>2002.2停驱</td>
</tr>
<tr>
<td>test well group</td>
<td>200×283</td>
<td>93.1</td>
<td>13.4</td>
<td>28.09</td>
<td>41.49</td>
<td>2002.4停驱</td>
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<tr>
<td>Expanding test well group</td>
<td>200×283</td>
<td>94.5</td>
<td>16.76</td>
<td>11.74</td>
<td>28.5</td>
<td>00.3停驱</td>
</tr>
<tr>
<td>Expanding test well group</td>
<td>200×283</td>
<td>94.5</td>
<td>19.85</td>
<td>19.02</td>
<td>38.87</td>
<td>02.5停驱</td>
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<tr>
<td>the well of transfer to stream flooding</td>
<td>200×283</td>
<td>95.8</td>
<td>8.89</td>
<td>7.21</td>
<td>16.1</td>
<td>99.2停驱</td>
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<tr>
<td>the well of transfer to stream flooding</td>
<td>200×283</td>
<td>97.5</td>
<td>9.77</td>
<td>2.5</td>
<td>12.27</td>
<td>01.9停驱</td>
</tr>
<tr>
<td>the well of transfer to stream flooding</td>
<td>200×283</td>
<td>97.5</td>
<td>20.36</td>
<td>5.95</td>
<td>26.31</td>
<td>99.12停驱</td>
</tr>
</tbody>
</table>

Active edge and bottom thickness: 12~20m
Viscosity: 20000~30000mPa.s

The area of well group is 1.0km², reserve is 219×10⁴t, there are 1 small well group and 6 big well group, the stream flooding, the stream flooding enhance recovery of 16.6%; And the degree of recovery of small well group reached 54.34%
3.1 The stream flooding technique of conventional heavy oil

3. Application results

（1）active edge and bottom water glutenite extra-viscous oil reservoir

- the stream flooding evaluation of area I and II

It has active edge and bottom water and the thickness is 10-15m, Viscosity is 20000~40000mPa.s

Reserves: $151 \times 10^4 t$

**Area I**
Well spacing: $141 \times 200m$
Well group: 9

Reserves: $312 \times 10^4 t$

**Area II**
Well spacing: $200 \times 283m$
Well group: 10个
3.1 The stream flooding technique of conventional heavy oil

(1) active edge and bottom water glutenite extra-viscous oil reservoir

- the stream flooding evaluation of area I and II

**Evaluation the area I : the development curves**

In area I, the steam injection is $123.6 \times 10^4$ t, oil increment is $20.8 \times 10^4$ t, cumulative oil steam ratio is 0.17 t/t, the recovery of huff and puff and stream flooding is 51.7%, the enhanced recovery is 19.4%. In area II, the enhanced recovery is 3.2%, cumulative oil steam ratio is 0.16 t/t.
3.1 The stream flooding technique of conventional heavy oil

3. Application results

(2) The thin edge water common heavy oil sandstone reservoir.

The stream flooding well group location of west block in XX site

The histogram of heavy oil-producing over the years

Stable 8 years

Area: 2km², reserves: 375 × 10⁴ t
reservoir depth: 1320~1400m
crude viscosity: 2000~5000 mPa.s
Thickness: 11~18 m
permeability: 2000 × 10⁻³ μm²
Oil/water volume ratio: <1.5

The 5 well groups are intermittent stream flooding, the cumulative oil/stream is 0.77 t/t. The recovery of huff and puff and stream flooding is 36.5%, the stream flooding improved 20.9%.
3.2 The heavy oil chemical stream flooding technique

- the technique of heavy oil chemical stream flooding to improve recovery

After years of research and deepen scientific research, it has made a breakthrough.
3.2 The heavy oil chemical stream flooding technique

The pilot test of heavy oil chemical stream flooding

Well spacing: $141 \times 200m / 100 \times 141m$

Reservers: $184 \times 10^4 t$

formation of interest : Ng53

effective thickness : 10.2m

The recovery has been improved by 18.1%;

Which: big well group improved by 6.2%

small well group improved by 21.8%

2009.10

Improve well network、huff and putt decompression

Well groups with small spacing

well groups turned to stream flooding

Two wells in the first round turned to chemical stream flooding

xx well group turn in the first round

xxx well group turn in the second round

Well groups with big spacing

4 well groups turned to stream flooding

xx well in the first round turned to chemical stream flooding

xxx well group turn in the second round

xxx well group turn in the first round
3.2 The heavy oil chemical stream flooding technique

◆ The overall effect of the test area was significantly

The production curve of well groups with small spacing

The production curve of well groups with big spacing

production is from 20.2 t/d increased to 104 t/d, and currently is 70 t/d.
Cumulative oil production: 65,500 tons
Cumulative incremental oil: 58,500 tons (the degree of recovery is improved of 9.3%)
Oil/stream ration: 0.17 t/t

The production is from 68 t/d increased to 113 t/d, and currently is 80 t/d.
Cumulative oil production: 66,000 tons
Cumulative incremental oil: 38,000 tons (the degree of recovery is improved of 3.1%)
Oil/stream ration: 0.16 t/t
Microbial Enhanced Oil Recovery

Refers to the use of a variety of microorganisms (mainly bacteria) and its metabolites to increase oil production and recovery.

Existing processes

- Single-well Microbial Soak
- Microbial Waxing Control
- Microbial oil displacement
- Microbial plugging
4. The Microbial Enhanced Oil Recovery technology

The mechanism of microbial enhanced oil recovery

- bacterial cell
- metabolic product

- metabolism
- biomembrane: extracellular polysaccharides, surface active substance, organic solvent, biogas

- Degradation of crude oil
- plugging and profile control of high permeability zones
- Improved crude liquidity
# 4. The Microbial Enhanced Oil Recovery technology

## Range of application

### Adaptation reservoir conditions

<table>
<thead>
<tr>
<th>Guideline</th>
<th>Exogenous microbial enhanced oil recovery</th>
<th>Endogenous microbial enhanced oil recovery</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reservoir Temperature (°C)</td>
<td>Range of application &lt; 80</td>
<td>Optimum range &lt; 65</td>
</tr>
<tr>
<td>Water salinity (mg/L)</td>
<td>&lt; 100, 000</td>
<td>&lt; 50, 000</td>
</tr>
<tr>
<td>Reservoir permeability ($10^{-3} \mu m^2$)</td>
<td>&gt; 100</td>
<td>&gt; 200</td>
</tr>
<tr>
<td>Crude oil surface viscosity (mPa.s)</td>
<td>&lt; 3000</td>
<td>&lt; 1000</td>
</tr>
</tbody>
</table>

### Remarks

The well network is basically completeness, the correspondence between the oil and water wells is clear, and the block has stable production.
The positioning of the microbial enhanced oil recovery technology

- permeability > $100 \times 10^{-3} \mu m^2$
- temperature < 75°C
- salinity < 5万 mg/L

Range of application:
- Mid high permeability fault block reservoir
- Integrity reservoir after water flooding
- Reservoir after chemical flooding
4. The Microbial Enhanced Oil Recovery technology

Mine implementation effect

The development curve

Water flooding
Anaerobe flooding
Aerobe flooding
Natural energy development phase
Regulation of endogenous microbial
4. The Microbial Enhanced Oil Recovery technology

- Improve development effectiveness

Actual production forecast recovery: 38.67%

Elastic recovery : 18.5%

Water flooding recovery: 28.5%

Through microbial enhanced oil recovery, the ultimately forecast improved water flooding recovery is 10.17%, recoverable reserves are increased 29.6×10⁴t.
Thank you