INTEGRATED MANAGEMENT OF OIL AND GAS CONDENSATE FIELDS’ DEVELOPMENT: BEST PRACTICES

Development Technologies for Oil Deposits below the Gas Cap in Lamadian of Daqing
Outline

- Introduction to Lamadian Oilfield
- Development Principles
- Development Technologies
- Oil-gas Buffer Zone Development Technologies
- Summary
Introduction to Lamadian Oilfield

- Oil-bearing area: 100km²
- Gas-bearing area: 32.3km²
- OOIP: $8.2 \times 10^8$ t
- OGIP: $99.6 \times 10^8$ m³
Oil, gas and water distribute in circularity zones

- 5 zones: pure gas, oil-gas transition, pure oil, oil-water transition and water
♦ Height of the gas cap: 90m
♦ Height of the oil reservoirs: 280m
♦ Depth of oil-gas interface: -770m
♦ Depth of oil-water interface: -1050m

Section drawing of the gas and the oil reservoirs
Reservoir type: river-delta deposit

- 3 layer series
- 8 layer groups
- 37 sandstone groups
- 97 sub layers
- 115 sedimentation units
By the end of 2016

- Total number of production wells: 9770
- Total number of injection wells: 4315
- Cumulative oil production: $3.36 \times 10^8$ t
- Recovery of geological reserves: 41.18%
- Recovery of recoverable reserves: 96.07%
- Residual recoverable reserves: $1374.0 \times 10^4$ t
- Cumulative water injection: $32.48 \times 10^8$ m$^3$
- Cumulative injection-production ratio: 1.08

Develop well position map
Development Principles

♦ Development strategy: keep oil-gas interface steady
♦ General Principle: two-step development
  • Step 1: oil reservoirs development in priority
  • Step 2: gas cap development when needed
Development Technologies

♦ Establishment of a buffer zone between oil and gas zones

• 450m-600m

• Reserves: $3117 \times 10^4$ t

A diagram of the buffer zone

Section drawing of L7-163
♦ Research on rational oil and gas zone pressure difference

• Early calculation results by electrical network analogy method

\[ P_{oil} - P_{gas} > +0.5\text{MPa}: \text{oil breakthrough} \]
\[ P_{oil} - P_{gas} < -0.5\text{MPa}: \text{gas breakthrough} \]
Oil and gas zone pressure differences in some sub layers when gas breakthrough (MPa)

- Computer simulation results

\[ P_{\text{oil}} - P_{\text{gas}} = \pm 0.5\text{MPa} \]
Proper well-point arrangement for monitoring

- Total number of monitoring wells: 246 (oil zone 50, gas zone 50, produced GOR 64, oil-gas interface 82)
- 2 times per year

Well logging interpretation (L7-232)
Control of oil and gas zone pressure system

- **Adjustment basis**
  - Pressure difference
  - Neutron-neutron logging
  - Associated gas in production wells

- **Adjustment methods**
  - Oil breakthrough: production ↗, i-p ratio ↘, oil zone pressure ↘
  - Gas breakthrough: production ↘, i-p ratio ↗, oil zone pressure ↗

Oil-gas interfaces of different layers in the north block
Oil-gas Buffer Zone Development Technologies

Basic information

- Target layer: Sa II2+3
- Buffer zone area: 2.9km²
- Buffer zone reserves: 179.8 x 10⁴ t
- Well pattern: 150m five-spot
- Number of wells: 163 (34 polymer barrier wells, 45 polymer injection wells, 84 oil production wells)
- Start of injection of polymer barrier wells: Sep, 2007
- Start of production in buffer zone: May, 2008
- Start of subsequent waterflooding: Jan, 2017
**Establishment of barrier**

- Using high-concentration polymer (2000mg/L)
- Parameter optimization
  - Distance between polymer injection barrier wells and oil-gas boundary: 100m
  - Polymer injection barrier well spacing: 75m
- Interval well-opening and alternating injection
- Establishing a monitoring system
  - Logging, microseismic, testing, calculation…
♦ Development of the buffer zone

• Well pattern: 150m five-spot

<table>
<thead>
<tr>
<th>Well pattern</th>
<th>Recovery by water flooding (%)</th>
<th>EOR by polymer flooding (%)</th>
<th>Ultimate recovery (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Five-spot</td>
<td>42.0</td>
<td>13.1</td>
<td>57.8</td>
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<tr>
<td>Seven-spot</td>
<td>41.5</td>
<td>12.3</td>
<td>56.2</td>
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<tr>
<td>Inverted nine-spot</td>
<td>41.2</td>
<td>11.6</td>
<td>54.8</td>
</tr>
</tbody>
</table>

• High-concentration polymer flooding
  - Lab experiment and numerical simulation
  - Direct polymer injection
  - Polymer concentration: 2000mg/L
3-zone pressure regulating and control

- **Gas cap**
  - Control the injection rate in polymer barrier wells

- **Buffer zone**
  - Control injection-production ratio
  - Control production parameters of the wells outside the gas cap

- **Oil zone**
  - Control injection rates in the target layers
Development effect

- Cumulative polymer injection pore volume: 1.33PV
- Cumulative stage oil production: 78.3 × 10^4 t
- Enhanced stage recovery: 26.71%
- Recovery of reserves: 66.47%
Summary

♦ DEVELOP a set of technologies for development of oil reservoirs below the gas cap, especially for efficient control of oil-gas interface

♦ EXPLORE efficient development methods for buffer zone

♦ CREATE 14-year stable production \((1000 \times 10^4 \text{t/a})\) record, even \(400 \times 10^4 \text{t/a}\) for now
Thank you!