Optimization of a Mature CO2 Flood

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Presented at the 16th Annual CO2 Flooding Conference
December 9-10, 2010
Midland, Texas
Field Data
Field Overview

- Discovered in February 1950
- Developed with 75 wells by 1952
- Unitized for pressure maintenance in late 1971; peripheral water injection below original oil-water contact
- Initial 20-acre infill well drilled in 1984
- Final 20-acre infill well completed in 1992
- Initiated CO2 injection in January 1998
Geology

- 4 Sequences
  - 100, 200, 300 and 400
  - Transgressive facies
- 3 Producing intervals
  - 50 to 100 ft thick
- South Dome ~ 1Mi^2
- Limestone 80 % reservoir
  - PHI 11%
  - K 165 mD
- Dolomite 20 % reservoir
  - PHI 8.3%
  - K 894 mD
- Shale < 1%
  - Vertical barrier
Issues vs. Opportunities
Gravity Stable CO2 Flooding

Original design basis:
- Excellent primary + secondary recovery
- Dome structure fits in gravity stable design

Tertiary results:
- Initial: Good CO2 responses
- Current: Late stage CO2 flood in South Dome
  - High CO2 utilization factor
  - High GOR and high gas production
Design Concept vs. Actual Field Observations

Hypothetical cartoon

NW Area

South Dome

RESIDUAL OIL

CO2 INJECTION

PRESSURE MAINTENANCE
WATER INJECTION

RESIDUAL OIL

Bypassed & Residual oil
CO2 Bypass Indication

- Well response indicated vertical communication b/w zone 1&2
- Earth model indicated dolomite chimney inside South Dome
Field Potential and Challenges

- **Opportunities**
  - Optimize current CO2 flooding area
  - Expand CO2 flooding to water flood area
  - Fully utilize current gas plant capacity & existing CO2 facilities
  - Realize substantial tertiary oil recovery

- **Challenges:**
  - Limited well data
  - Aged wellbores
  - Completion strategies – commingle vs. selective

- **Needs:**
  - Understand current field operation
  - Develop strategies to capture opportunities identified
Reservoir Simulation
Engineering Evaluations Prior to Simulation

- Evaluated water and CO2 flood performances
- Conducted material balance study to confirm OOIP, reservoir pressure, aquifer support
- Identified field potentials by analog study
- Sampled production fluid and reviewed previous PVT & CO2 miscibility tests to understand reservoir fluid behaviors and miscibility requirement
- Recompiled wellbore diagrams to understand field completion history and wellbore integrity
- Analyzed MICP and centrifuge capillary pressure results to identify fluid distribution
3-D Earth Model Structure
Reservoir Simulation Strategies

- Simplified cross-section model
  - High-level history match to understand
    - Local OOIP, water flooding mechanism and residual oil distribution after WF
  - Forward simulation on
    - straight CO2 injection to understand gravity stable design
    - WAG injection to evaluate the flood efficiency and various completion scenarios for completion design
Simulation Results

Results Observations

✓ Continuous CO2 injection with gravity stable design is ineffective in this reservoir due to the existence of the high-perm streaks and high CO2 mobility

✓ WAG could be more efficient because of its mobility modification on injectant

✓ Selective completion – bottom-up is superior to others in terms of recovery
X-section Simulation History Match

Well B

Well C

1 Jan 2007  J=1
Deepen Producer Only – Solvent Saturation

- CO2 couldn’t sweep the lower zones effectively due to high perm channeling.
Impact of High & Low Perm Strikes

- Reservoir quality will affect CO2 sweeping path and efficiency
- Reservoir quality will impact completion strategy
Completion Strategy Comparison – BOPD & Cum

- Bottom-up completion is better than Top-down
- Selective provides better early production than commingle
Completion Strategy Comparison – Solvent Saturation
Conclusions & Recommendations
Summary

Lesson Learned

- The heterogeneity of the reservoir highly compromised the original gravity-stable design.
- It’s critical to understand the impact of vertical communication on CO2 flood efficiency.

Best Practice

- Cross-section reservoir simulation can be used to understand reservoir recovery mechanisms and provide forecasts that allow the selection of the proper injection strategy.

Conclusion

- A bottom-up completion with WAG could be more effective for this reservoir