An Overview of the Carbon Dioxide Pilot Test in the Hall Gurney Field in Russell County, Kansas

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To The Stars Through Difficulties
Outline of Presentation

- Background
- Scope of Project
- Objectives
- Results to Date
- What We Have Learned
- Remaining Challenges
Field Demonstration of CO₂ Miscible Flooding in the Lansing-Kansas City Formation, Central Kansas

Project Began March 8, 2000

Class II Revisited  DE-AC26-00BC15124

Murfin and WI Partners

KINDERMORGAN
Project Funding-DOE Class Revisited Program

- **Budget Period 1**: Reservoir Characterization and Advanced Recovery Analysis
  March 2000-February 2004 (DOE Cost Share 45%)
- **Budget Period 2**: Field Demonstration and Analysis: February 2004-December 2008
  (DOE Cost Share 35%)
- **Budget Period 3**: Monitoring and Post Flood Analysis: January 2009-March 2010
  (DOE Cost Share 10%)
Pilot Site Located in Largest LKC Field: Hall-Gurney

55 MMBO

19 MMBO

Koudelle and Dubois, 1999
Murfin Colliver and Carter Leases - LKC C Zone

**COLLIVER**
- OOIP = 4238 MSTB
- P&S = 2383 MSTB (56%)
- REM = 1855 MSTB

**CARTER**
- OOIP = 1974 MSTB
- P&S = 852 MSTB (43%)
- REM = 1122 MSTB

- Waterflood ended ~1984
- Lease owned by GE, MV Energy
- Operated by Murfin
• **Colliver No. 18**  
  L-KC “C” divided into 6 Layers-three flooding cycles

• **General Properties***  
  - C1: 8 md, 18.8%  
  - C2: 150 md, 25.8%  
  - C3: 40 md, 22.0%  
  - C4: 6 md, 19.4%  
  - C5: 2 md, 14.7%  
  - C6: 0.3 md, 12.0%

* - Colliver No. 18 injector exhibits better properties than average for site
Remaining Oil: 44-57% of Original Oil in Place
$S_{orw} \sim 30\%$

Carter-Colliver
CO2 I-1  2894.2

Lansing Kansas City Reservoir Rock C-Zone
Lansing Kansas City C Zone

- Waterflooded successfully from 1965-1984
- Average reservoir pressures during water flood at least 1400 psi.
- Wells in good condition
- Average porosity=25%
- Interstitial water saturation=23%
- Estimated waterflood residual oil saturation=30%
- Effective thickness ~8 feet
Requirements for Carbon Dioxide Miscible Flooding

• Must be possible to re-pressure reservoir to reach minimum miscibility pressure (MMP) during the displacement process
• Carbon dioxide must be available at a price that will make the process economic
• Demonstrate sufficient field performance (oil in the tank) to verify technical and economic viability
Minimum Miscibility Pressure in Hall-Gurney LKC

API = 37.5°-38.4°
Scope of Project

• Determine the technical and economic feasibility of using CO$_2$ miscible flooding to recover residual and bypassed oil in LKC shallow shelf carbonates.

• Develop reservoir data for the LKC and Hall-Gurney for other floods

• Develop operating costs and operating experience for CO$_2$ miscible flooding in Lansing-Kansas City reservoirs

• **Produce oil in tank with sufficient information to expand to commercial scale**
Murfin and WI CO2 Project

- 70 acre lease
- ~10 acre half of five spot
- One CO2 injector
- Two Producers
- Two Containment Injectors
- 0.290 BCF CO2 injected
- 4.6 year operating life
Location of Ethanol Plant & CO2 EOR Site

Kansas Geological Survey
CO2 Injection Facilities
Aplex A-50 Portable Storage Tank
Corken Charge Pump
Data Acquisition Control System
Portable Storage Tank
Control Valve
Flowmeters
P
T
P
Vent
Summary of CO2 Injection

Continuous Injection December 2, 2003-Present
• Cumulative Injected-September 2004
  – 72.73 MMSCF
• CO2 Available for Project
  – 290 MMSCF
• % Injected
  – 25.1
• % Surface Losses
  – 16.34 of amount injected
• PPV Injected
  – 22%
• CO2 Loss to North and Out of Zone
  – 29-39%
What We Learned

• Injectivity of carbon dioxide in CO2I-1 is more than required for minimum PPV rate to complete project in 4.6 years.

• Rapid breakthrough of carbon dioxide did not occur even though estimated permeability distribution in CO2I-1 has a high perm streak in upper two feet of the formation that was thought to be continuous between wells.

• Pulsation of pumps on metering skid affected measurement of rates. Cumulative volume of carbon dioxide injected at flow meter was consistently high.

• Flow meter, temperature and pressure sensors must be installed at CO2I-1 wellhead for management of the project.
What We Learned (continued)

• Triplex oversized for the design injection rate resulting in recycle of 80%. Vent losses became excessive during May and June.
• Injection capacity of triplex reduced by installation of smaller plungers. Vent loss reduced substantially.
• Injection of carbon dioxide is handled as routine field operation.
• Injection water treated to removed oxygen and filtered through 10 micron filters. No evidence of pressure buildup due to particulates that were not removed from the water.
Remaining Challenges

• Permeability restriction identified between CO2I-1 and CO2#13. Revised reservoir description under development

• Maintain adequate pressure in the CO2 bubble by balancing injection into CO2I-1, withdrawal from CO2#12 and CO2#13 and injection rates in the confinement wells.

• Anticipating the arrival of high GORs and conversion to WAG
Project Management

PPV = Processable pore volume
Reservoir volume contacted by carbon dioxide that can be produced from CO2#12 and CO2#13

\[ PPV = V_p \left( 1 - S_{iw} - S_{orCO2} \right) \]

- PPV~170,000 RB
- Must be able to inject at 84.8 RB/D (to account for losses) and produce from PPV at a rate of 14 PPV%/year (65.2 RB/D) to complete demonstration project within the 5 year time window in the DOE project.
- Must maintain pressure in CO2 contacted region to retain miscibility
LKC Pilot Monitor Pressures

Pressure psig

9/1/03 10/31/03 12/30/03 2/28/04 4/28/04 6/27/04 8/26/04 10/25/04

CO2 12 Monitor Point
CO2 13 Monitor Point
CO2 I-1
CO2 10
CO2 18
Managing Injection/Withdrawal

• Loses to north were included in design of pilot. Estimates based on reservoir simulation.

• Must be restrained within values that do not add large uncertainty to extrapolation of pilot results to larger, confined regions.

• Requires estimation of:
  – Losses to north
  – Percentage of production from CO2#12 and #13 that is produced from PPV.

• Maintenance of specified carbon dioxide monthly injection volumes.
Based on 30% Loss to the North
Loss to North at 30%
Remaining in PPV Region

Cumulative CO2 Injected, Fraction of PPV
Summary

- Project implemented, operational problems identified and resolved
- Field activities considered within the range of normal oil field operations
- Project management requires monitoring of average pressure and injection/withdrawal ratio from PPV
- Waiting for the oil bank to arrive