Field Demonstration of CO$_2$ Miscible Flooding in the Lansing-Kansas City Formation, Central Kansas

April 7, 2005
Sixteenth Oil Recovery Conference
Wichita, KS
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Class II Revisited DE-AC26-00BC15124

Murfin and WI Partners

KINDERMORGEN

T.O.R.P.
Purpose of Demonstration

• Determine the technical and economic feasibility of using CO₂ 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 an understanding of operating costs and operating experience for CO₂ miscible flooding in Lansing-Kansas City reservoirs

• Oil in tank and provide sufficient information to expand to commercial scale
Type Log
CO2#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%

- *- CO2#18 exhibits better properties than average for site
Murfin Colliver 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
Overview

- **Budget Period 1 (March 2000-January 2004)**
  - Drill water supply well and recomplete production and water injection wells (2003).
  - Prestartup Activities (August – November 2003)
  - Continuous CO2 Injection (December - 2003)

- **Budget Period 2 (February 2004-December 2008) - Implementation**

- **Budget Period 3 (January 2009-March 2010)**
  - Post CO2 flood monitoring
Project Management

PPV = Processable pore volume contacted by carbon dioxide that is produced by pattern production wells

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

- 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).
- Adequate productivity in CO2# 12 and 13 to complete demonstration project within the 5 year time window in the DOE project.
Project Management

• Control injection rates into CO2I-1, CO2#10 and CO2#18 to maintain minimum miscibility pressure (~1200 psi) in most of the PPV to ensure miscible displacement and control CO2 loss to the north.

• Monitor production rates and balance with CO2 injection
  – ~29% of the production from CO2#12 is from the PPV
  – ~87% of the production from CO2#13 is from the PPV

• Control Injection/Withdrawal Ratio from PPV to 1 after allowance for carbon dioxide losses to the north.
Prestartup Activities

• Demonstrate connectivity between CO2I-1 and CO2#13
• Demonstrate that the estimated pattern volume can be processed within the time frame of the project (5 years)
• Installation of CO2 injection equipment
• Pressurization of pilot area
• Establish withdrawal rates at CO2#12 and #13
Injection Skid
Aplex A-50 Triplex
Flowmeter at CO2I-1
Vent Loss from Portable Storage Tank

Replace Plungers in Aplex A-50
Estimated Reservoir Pressure Distribution

LKC-C Pressure 3-2-05
Summary of CO2 Injected
February 2005

- Cumulative Injected
  - 112.25 MMSCF
- CO2 Available for Project
  - 290 MMSCF
- % Injected
  - 38.7
- % Surface Losses
  - 11.4% of amount injected
- PPV Injected
  - 33.5%
- CO2 Loss to North and Out of Zone
  - 29-39%
CO2 Injectivity Test
CO2 I-1
January 27, 2005

- 14% in C1/Upper C2
- 0% in Middle C2 zone
- 34% in Lower C2/Upper C3
- 52% in C3

- Middle C2 zone-shingle with limited lateral extent??
- 86% of injection is into low permeability intervals of C2/C3 zone
- Production response will be delayed
Transition in Permeability

CO2I#1

Higher Permeability
100’s md

Moderate Permeability
10’s md

Low k contact

Moderate Permeability
10’s md

Higher Permeability
100’s md

Gonzalez & Eberli (1997)

Ripples on Channel Floor
Base Level
Tidal Channel
Sand Wave
Spillover Lobe
Ripples on Top of
Sand Bars
Prograding Foresets

Murfin Colliver

Gonzalez & Eberli (1997)
Treated CO2#13 with Two tanks of CO2 12-9-04 and SI for 26 days.
Summary

- Oil and carbon dioxide production rates differ from West Texas experience.
  - Oil rate increases before substantial amount of CO2 is produced.
  - CO2 rate and GOR are relatively constant.
  - Do not know if this is related to reservoir heterogeneity, saturation distributions or the pore structure.
- CO2 production rate still within acceptable values.
  - WAG not needed yet to control CO2 yet.
- Carbon dioxide injection rate has exceeded and fell behind the fluid withdrawal rate from the PPV. Need to provide better control in the field.
Summary

• Injected CO2 is confined to the C zone
• Primary oil bank generated by CO2 injection has not arrived at either CO2#12 or CO2#13
• GOR is relatively constant at ~4000-little CO2 channeling
• Late arrival of oil bank appears to be due to more complex areal reservoir heterogeneity in the pattern
• CO2#13 responded to CO2 stimulation-cannot determine if increased oil production is due to stimulation or connection with the oil bank
Replace Pump CO2#12

Vent CO2#12 Annulus to Atmosphere