QUARTERLY TECHNICAL PROGRESS REPORT
FOR THE PERIOD ENDING MARCH 31, 2003

TITLE: FIELD DEMONSTRATION OF CARBON DIOXIDE MISCIBLE FLOODING IN THE LANSING-KANSAS CITY FORMATION, CENTRAL KANSAS

DOE Contract No. DE-AC26-00BC15124

Contractor: University of Kansas Center for Research, Inc.
2385 Irving Hill Road
Lawrence, KS 66044

DOE Program: Class II Revisited - Field Demonstrations

Award Date: March 8, 2000

Total Project Budget: $5,388,683

DOE Cost Amount: $1,892,094

Program Period: March 8, 2000 – March 7, 2009 (BP1 03/00-10/03, BP2 10/03-03/08, BP3 03/08-03/09)

Reporting Period: January 1, 2003 – March 31, 2003

DOE Project Manager: Paul West, NPTO Tulsa, Oklahoma

Contractor Contact: Alan P. Byrnes
Kansas Geological Survey
1930 Constant Ave., Lawrence, Kansas 66047
email: abyrnes@kgs.ukans.edu
phone: 785-864-2177

Principal Investigators: Alan Byrnes (Program Manager Budget Period 1)
G. Paul Willhite (Program Manager Budget Periods 2&3)
Don Green, Martin Dubois, Richard Pancake, Timothy Carr, W. Lynn Watney, John Doveton, Willard Guy, Rodney Reynolds, Rajesh Kunjithaya, Dave Murfin, James Daniels, Niall Avison, Russell Martin, William Flanders, Dave Vander Griend, Eric Mork, Paul Cantrell

DISCLAIMER:

ABSTRACT:

Progress is reported for the period from January 1, 2003 to March 31, 2003. A water supply well was permitted, drilled, and completed in the shallow, fresh-water, Dakota Sandstone. The pumphouse has been put in place and the long-term injection equipment is being set-up. Although the short-term injectivity test was cut short by power failure following an ice storm, results indicate the well exhibits sufficient injectivity to proceed with the long-term injectivity test, which will start in the beginning of the second quarter. The CO2 Project #10 and #12 wells were reworked and the Lansing-Kansas City (LKC) "C" interval in both wells isolated. The CO2 Project #16 well was drilled deeper, cored in the LKC "C" and "G" zones, and cased to the "C" zone and will be perforated and stimulated in the beginning of second quarter. Initial wireline log analysis and examination of the core indicate that the porosity of the "C" zone in this location may be lower than in other parts of the pattern by 3-5 porosity units. Log analysis indicates water saturations are near 60% consistent with predicted residual oil saturation to waterflood modeling. Lower porosities may indicate lower permeability may also be present. Core analysis is being conducted and results will be available in the first week of the second quarter. A draft letter agreement has been presented to FLOCO2 Company for supply of CO2 storage and injection pump equipment. Presentations of the project status were made at the 15th Oil Recovery Conference in Wichita on March 12-13.

TABLE OF CONTENTS

LIST OF FIGURES

INTRODUCTION

Objectives - The objective of this Class II Revisited project is to demonstrate the viability of carbon dioxide miscible flooding in the Lansing-Kansas City formation on the Central Kansas Uplift and to obtain data concerning reservoir properties, flood performance, and operating costs and methods to aid operators in future floods. The project addresses the producibility problem that these Class II shallow-shelf carbonate reservoirs have been depleted by effective waterflooding leaving significant trapped oil reserves. The objective is to be addressed by performing a CO_2 miscible flood in a 10-acre (4.05 ha) pilot in a representative oomoldic limestone reservoir in the Hall-Gurney Field, Russell County, Kansas. At the demonstration site, the Kansas team will characterize the reservoir geologic and engineering properties, model the flood using reservoir simulation, design and construct facilities and remediate existing wells, implement the planned flood, and monitor the flood process. The results of this project will be disseminated through various technology transfer activities.

Project Task Overview -

Activities in Budget Period 1 (03/00-09/03) involve reservoir characterization, modeling, and assessment:

- Task 1.1- Acquisition and consolidation of data into a web-based accessible database
- Task 1.2 - Geologic, petrophysical, and engineering reservoir characterization at the proposed demonstration site to understand the reservoir system
- Task 1.3 - Develop descriptive and numerical models of the reservoir
- Task 1.4 - Multiphase numerical flow simulation of oil recovery and prediction of the optimum location for a new injector well based on the numerical reservoir model
- Task 2.1 - Drilling, sponge coring, logging and testing a new CO2 injection well to obtain better reservoir data
- Task 2.2 - Measurement of residual oil and advanced rock properties for improved reservoir characterization and to address decisions concerning the resource base
- Task 2.3 – Remediate and test wells and patterns, re-pressure pilot area by water injection and evaluate inter-well properties, perform initial CO2 injection to test for premature breakthrough
- Task 3.1 - Advanced flow simulation based on the data provided by the improved characterization
- Task 3.2 - Assessment of the condition of existing wellbores, and evaluation of the economics of carbon dioxide flooding based on the improved reservoir characterization, advanced flow simulation, and engineering analyses
- Task 4.1 – Review of Budget Period 1 activities and assessment of flood implementation

Activities in Budget Period 2 (09/03-03/08) involve implementation and monitoring of the flood:

- Task 5.4 - Implement CO_2 flood operations
- Task 5.5 - Analyze CO_2 flooding progress - carbon dioxide injection will be terminated at the end of Budget Period 2 and the project will be converted to continuous water injection.

Activities in Budget Period 3 (03/08-03/09) will involve post-CO2 flood monitoring:

- Task 6.1 – Collection and analysis of post-CO2 production and injection data

Activities that occur over all budget periods include:

- Task 7.0 – Management of geologic, engineering, and operations activities
- Task 8.0 – Technology transfer and fulfillment of reporting requirements

EXECUTIVE SUMMARY:

Progress is reported for the period from January 1, 2003 to March 31, 2003. A water supply well was permitted, drilled, and completed in the shallow, fresh-water, Dakota Sandstone. The pumphouse has been put in place and the long-term injection equipment is being set-up. Although the short-term injectivity test was cut short by power failure in an ice storm, results indicate the well exhibits sufficient injectivity to proceed with the long-term injectivity test. The CO2 Project #10 and #12 wells were reworked and the Lansing-Kansas City (LKC) "C" interval in both wells isolated. The CO2 Project #16 well was drilled deeper, cored in the LKC "C" and "G" zones, and cased to the "C" zone and will be perforated and stimulated in the beginning of second quarter. Initial wireline log analysis and examination of the core indicate that the porosity of the "C" zone in this location may be lower than in other parts of the pattern by 3-5 porosity units. Log analysis indicates water saturations are near 60% consistent with predicted residual oil saturation to waterflood modeling. Lower porosities may indicate lower permeability may also be present. Core analysis is being conducted and results will be available in the first week of the second quarter. A draft letter agreement has been presented to FLOCO2 Company for supply of CO2 storage and injection pump equipment. Presentations of the project status were made at the 15th Oil Recovery Conference in Wichita on March 12-13.

RESULTS AND DISCUSSION:

TASK 2.3. Remediate and Test Wells and Pattern

2.3.1 Drill, Complete, and Equip Water Supply Well - An onsite water supply well was drilled and completed in the shallow (245 ft; 74.7 m) fresh-water Dakota aquifer on 3/27/02. Supply water total dissolved solids was measured by Pace Laboratories to be 4,920 milligrams per liter. A submersible pump is to be run in the well the first week of April. A water injection station located near the Colliver lease tank battery (near CO2 Project #10, formerly Colliver #10) comprising a 200 bbl (31.8 m^3) fiberglass tank, triplex pump, filter cartridges, metering, valves, etc. is being fabricated and installed. The site has been graded and the pumphouse put in place. The injection equipment has already been used for short-term injection and will be relocated into the pumphouse for long-term use. A fiberglass injection line is to be laid to CO2 I#1 before 4/7/03 in preparation for long-term injection starting when the CO2 Project #16 (formerly Colliver #16) is completed.

2.3.2 Workover and Test Producing Wells in Pilot Area –
CO2 Project #12 - A workover on the CO2 Project #12 well (formerly Colliver #12) was completed 3/6/03. For this well, the LKC G was plugged back with cement and a 4-1/2" welded liner was cemented to surface across all shallow zones leaving only the LKC C open with open-hole completion (Figure 1).

Figure 1. Workover of the CO2 Project #12 well in late February-early March 2003.

Wireline logs were obtained since this well was not previously logged. Porosity and distribution of depositional cycles in the CO2 Project #12 are similar to the CO2I #1 (Figure 2).

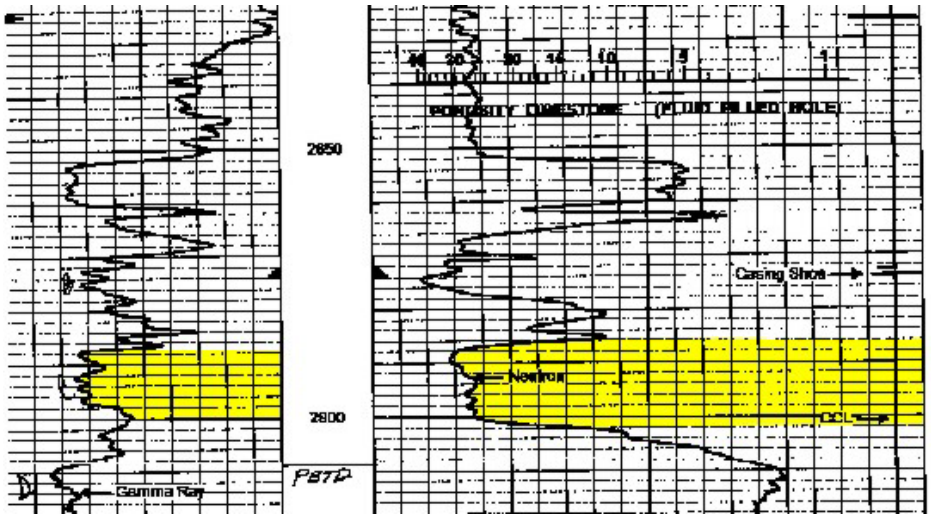

Figure 2. Wireline neutron log of the CO2 Project #12 logged in March 2003. High porosity in upper cycle and lower porosity in lower cycle are similar to the CO2I#1.

CO2 Project #16 - The CO2 Project #16 is the northeast producer of the CO2 pilot. The well was formerly a shut-in Indian Cave shallow gas producer. The well's slotted liner was successfully removed in January (Figure 3).

Figure 3. Liner removed from the CO2 Project #16 well in January in preparation for drilling deeper to the LKC C interval.

The well was drilled deeper beginning 3/27/03. Cores were cut in the LKC "C" zone (2877-2905 ft; 876.9-885.4 m) and the LKC "G" zone (2936-2966 ft; 894.9-904.0 m) with 100% recovery. The cores were laid out on the catwalk, photographed, packed in dry ice and transported to Core Laboratories, Midland, TX for on-going analysis. The upper LKC "C" interval (2882-2888 ft; 878.4-880.3 m) exhibits good oomoldic porosity and cross-bedding (Figure 4). The lower LKC "C" interval has lower porosity and less dense oomold packing. Wireline logs indicate the upper LKC "C" zone exhibits porosities of 23-26%, about 3-5 porosity units less than in the CO2I#1, with water saturations of approximately 60%, consistent with water saturations in the CO2I#1 and with predicted residual oil saturations (Figure 5). The lower porosities may result in lower permeability in this area, which will be determined by the core analysis. As of 4/1/03, the well was drilled to 3253 ft (991.5 m), open-hole logged, and 4-1/2 inch (0.114 m) casing cemented to surface. The well is presently shut-in pending completion into the LKC "C", which is to start the week of 4/7/03.

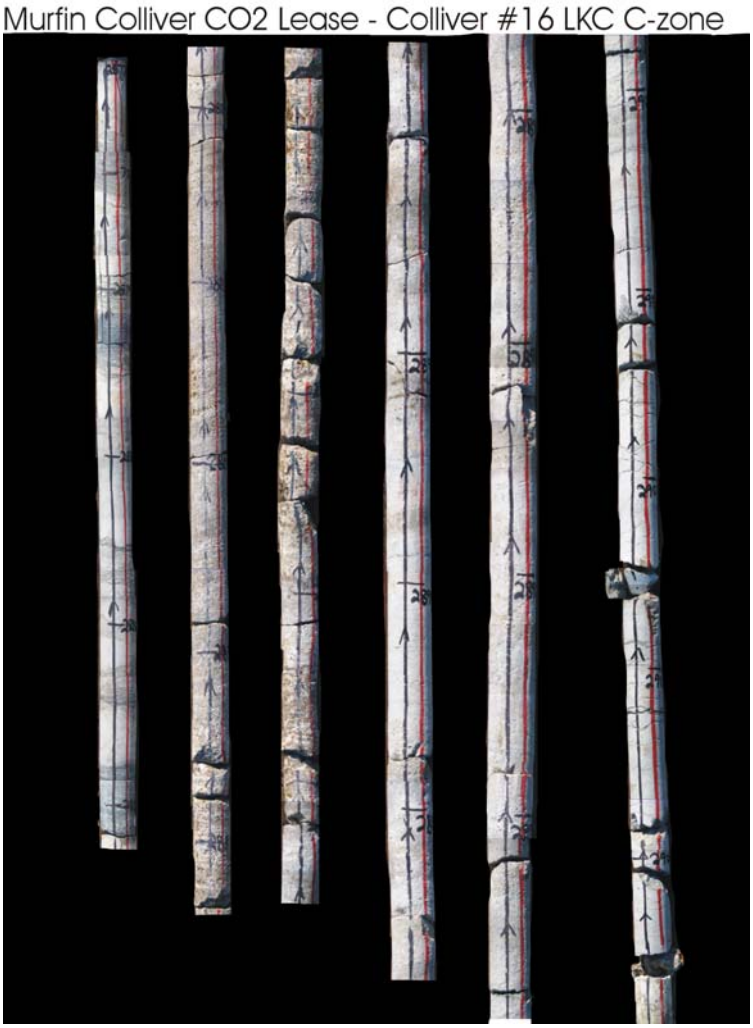

Figure 4. Core obtained from the CO2 Project #16 LKC "C" interval (2877-2905 feet; 876.9-885.4 m). The interval from 2877-2882 ft (876.9-878.4 m) is overlying dense limestone. Upper "C" zone interval from 2882-2888 ft (878.4-880.3 m) exhibits the highest visual porosity and 23-26% porosity on neutron log.

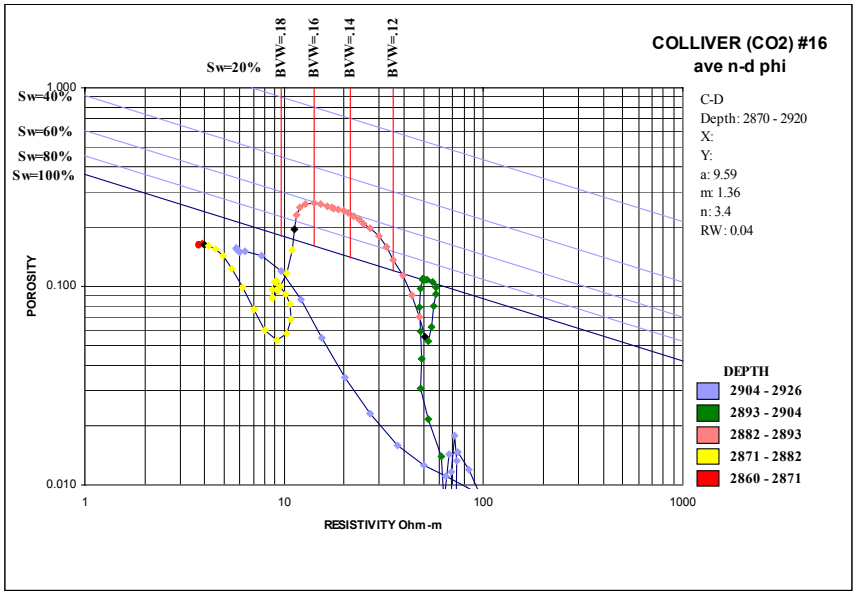

Figure 5. Pfeffer Pickett plot of the CO2 Project #16 "C" interval (2882-2893 feet; 876.9-881.8 m) exhibits porosities of 23-26% and water saturations of ~60%. Note water saturations for all intervals were calculated using LKC-C zone Archie cementation and saturation exponents of m=1.36, a=9.39, n=3.4. Intervals above and below exhibit Sw=100% for m=2, a=1,n=2.

2.3.3 Workover Containment Water Injection Wells in Pilot Area – Workover of the CO2 Project #10 (formerly Colliver #10) was performed between 3/5/03 and 3/10/03 (Figure 6). Previously, the Colliver #10 had been stimulated in February 1960 with Dowell Duo-Frac 17,000 pound sand/15,000 gallons Dowell 3% "slick-acid" in the "C" and "G" zones and the Topeka. Well rework in 2001 cemented the "C" and "G" zones. The Colliver #10 was used as an injection well in the shallower Topeka and Plattsmouth intervals. The CO2 Project #10 was prepared for injection in only the LKC "C" zone by: 1) drilling out the cement plug to +/-2925, 2) perforating the LKC "C" from 2898-2910 ft (883.3-887.0 m), 3) running a dual packer assembly across the Topeka and Plattsmouth perforations (for isolation), and 4) acidizing the LKC "C" with 500 gallons (1893 L), 15% MCA at ¼ bpm (barrels per minute; 2.38 m^3/h) with an injection surface pressure not exceeding 500 psig (pounds per square inch gauge, 3448 kPa). Flushed acid to perfs and swabbed back acid volume and two load volumes.

Figure 6. Workover rig on the CO2 Project #10 water injection containment well in early March 2003.

2.3.4 Injection Well Testing and Analysis – A short-term injectivity test in CO2I#1 was performed on 2/5/03-2/6/03 to confirm adequate injectivity. A longer-term test was planned but the test was cut short by transformer failure following an ice storm. Injection began on vacuum and caught pressure after 40 barrels (6.4 m^3) injected. Injection rates at the end of the test at 36 hours were 170 BPD (barrels per day; 27 m^3/d) at 60 psig (414 kPa) surface pressure (Figure 7). Extrapolation of these rates to long-term injection conditions indicated that the well has sufficient injectivity for the demonstration and to move forward with the long-term injectivity test without additional stimulation at the present time.

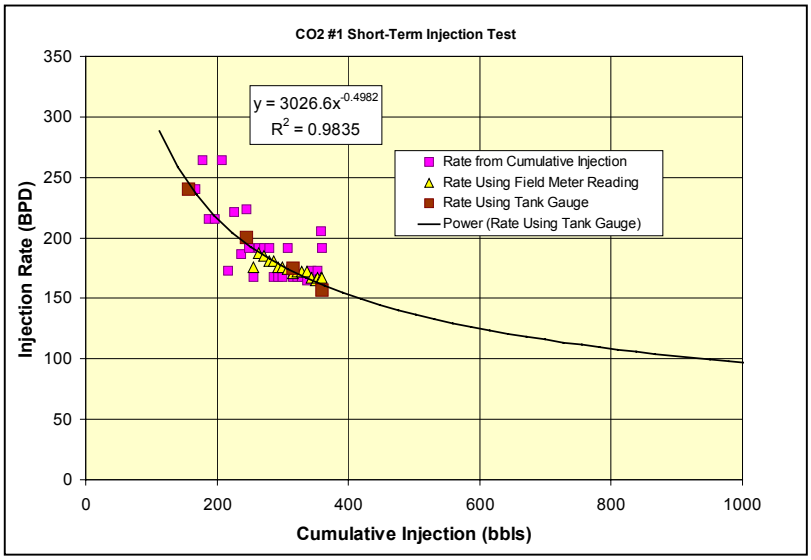

Figure 7. Injection rate versus cumulative injection for the CO2I#1 during short-term injectivity test.

2.3.5 Construct Surface Facilities – A water injection station located near the Colliver lease tank battery (near CO2 Project #10) comprising a 200 bbl (31.8 m^3) fiberglass tank, triplex pump, filter cartridges, metering, valves, etc. is being fabricated and installed. A fiberglass injection line is to be laid to CO2 I#1.

2.3.6 Pattern Repressurization and Analysis – Beginning on 3/7/03 the CO2 Project #18 injection well was shut-in and a program of measuring fluid levels every Monday, Wednesday, and Friday was initiated on the #18, #12, CO2I#1, and #10 (beginning on 3/19/03) to obtain bottom hole pressures (BHP, Figure 8). Bottom-hole pressures are calculated from the fluid levels. The pressures indicate that the reservoir is stabilizing and that all wells are in communication. Injection into CO2 I#1 is planned to begin when the CO2 Project #16 is completed and the well has stabilized after stimulation. Following confirmation of pattern connectivity from the CO2I #1 to surrounding wells, the CO2 Project #13 well will be reworked.

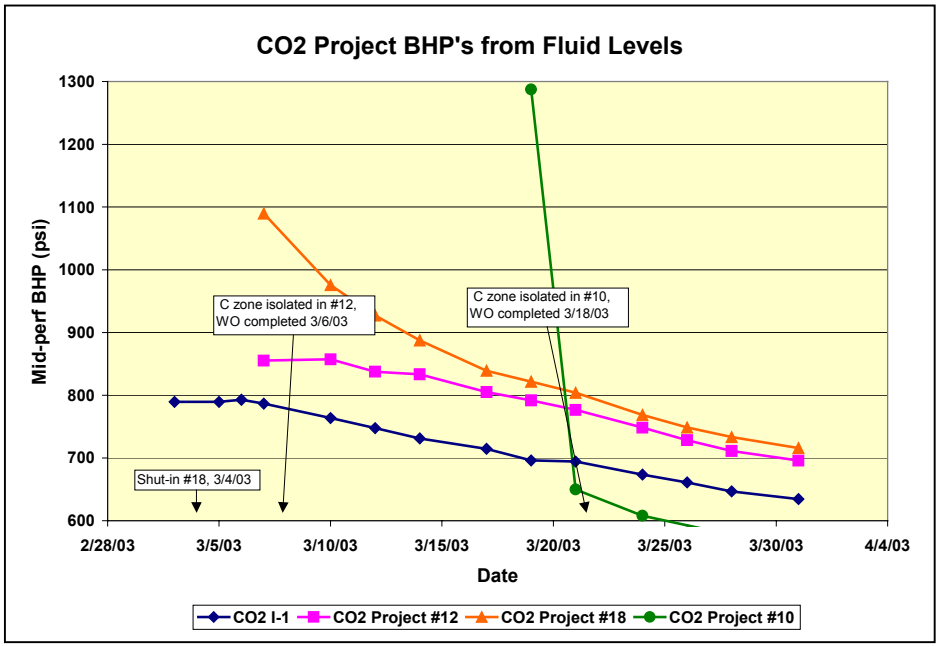

Figure 8. Calculated bottom-hole pressures through time showing decline of reservoir pressures following shut-in of the CO2 Project #18 well and CO2 I#1 well.

TASK 3.1. Reservoir Simulation (Phase 2)
The existing and alternate models are being adjusted to be consistent with measured data and predict response of the long-term injection test.

TASK 3.2 Economic and Recovery Analysis of Pilot
3.2.1 Determine CO2 Source for Pilot – A draft letter agreement has been sent by Murfin Drilling to FLOCO2 Company outlining equipment to be supplied and CO2 to be provided by Kinder-Morgan CO2 Company. The letter agreement is being reviewed by FLOCO2.

U.S. Energy Partners is ready to provide liquid CO2 from the Russell ethanol plant when needed. Specifications for how EPCO liquid CO2 trucks will hook up to and transfer CO2 to the on-site storage tank are being discussed.

3.2.3 Design Facilities for Pilot and Monitoring – Pilot surface facilities design have been reviewed. Specifications for CO2 transfer and injection have been reviewed.

TASK 7.0 PROJECT MANAGEMENT

Beyond daily email exchanges over specific technical or business issues, Kansas CO2 Team conference calls were held on January 14, February 24, and March 24, 2003. The following personnel were present by phone for most calls: Murfin Drilling) James Daniels; Stan Froetschner, Kevin Axelson, Tom Nichols; Tertiary Oil Recovery Project) Paul Willhite, Richard Pancake; Kansas Geological Survey) Alan Byrnes, Martin Dubois; Kinder-Morgan) William Flanders, Don Schnacke. Topics covered have included: 1) Water Supply, 2) Well completion procedures and results, 3) Rework scheduling and preparation, 4) CO2 supply, storage and injection facilities, and 5) Project management.

TASK 8.0 TECHNOLOGY TRANSFER

Two talks were presented at the Tertiary Oil Recovery Project (TORP) and Northern Midcontinent Petroleum Technology Transfer Council (PTTC) 15th Oil Recovery Conference in Wichita, March 12-13, 2003. Titles of the talks were:

- "Overview of the CO2 pilot test in the Hall-Gurney field in Russell County, Kansas" by G. Paul Willhite
- "Reducing risk in the implementation of the CO2 pilot test in the Hall-Gurney field in Russell County, Kansas" by G. Paul Willhite

CONCLUSIONS

Well rework and testing is proceeding on budget and generally on-time. Minor delays have been encountered due to inclement winter weather. The wells exhibit properties consistent with the present understanding of reservoir properties though questions exist about the CO2 Project #16 well, which is presently being analyzed. Completion of the #16 and beginning of the long-term injectivity test will start at the beginning of the second quarter and will address connectivity questions. The CO2 Project #13 will also be reworked next quarter. Results of testing will provide the data needed to ascertain reservoir properties and evaluate the site for effective miscible flooding.