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

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Outline of Presentation

• Carbon Dioxide Flooding
• Background
• The Central Kansas Initiative
• Field Demonstration Project Hall-Gurney Field
• A Vision for the Future
Carbon Dioxide Flooding

CO₂/water injection

production well

to separator

isolated oil at Sorw
Minimum Miscibility Pressure in Hall-Gurney LKC

API = 37.5°-38.4°
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
Mobil Oil Company Postle Field-1995
Central Kansas Initiative

- **Carbon Dioxide Flooding in Central Kansas Reservoirs--1998**
  - A Cooperative Program Involving Shell CO$_2$ Ltd, Energy Research Center at University of Kansas (TORP, KGS)

- **KTEC-1998-1999**
  - Expanded study including Arbuckle and Lansing Kansas City reservoirs
  - Identified potential field demonstrate sites
  - Critical element: Demonstrate sufficient field performance (oil in the tank) to justify the development of a carbon dioxide pipeline into Central Kansas
DOE Class Program Revisited

Program for Field Demonstration Projects
Announced-Proposals Due May 1999

- Phase 1-Reservoir Characterization
  (45% DOE Match/55% Project)
- Phase 2-Field Demonstration
  (35% DOE Match/65% Project)
- Phase 3-Monitoring
  (10% DOE Match/90% Project)
Pilot Site Located in Largest LKC Field: Hall-Gurney

Structure on Lansing
State of Kansas

Lansing & Kansas City Oil Production

Hall-Gurney

Pilot Site

55 MMBO

19 MMBO

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

**Colliver**
- OOIP = 4238 MSTB
- P&S = 2383 MSTB
- REM = 1855 MSTB

**Carter**
- OOIP = 1974 MSTB
- P&S = 852 MSTB
- REM = 1122 MSTB

- Waterflood ended ~1984
- Lease owned by GE, MV Energy
- Operated by Murfin
• **Colliver No.18 CO₂ Injector**

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*
DOE Class Program Revisited

Central Kansas CO$_2$ Demonstration Project
Proposal Submitted and Accepted in 1999

• Phase 1-Reservoir Characterization (1 Year)
  (March 8, 2000-March 7, 2001--45% DOE)
• Phase 2-Field Demonstration (4 years)
  (March 8, 2001-March 7, 2005--35% DOE)
• Phase 3-Monitoring (1 year)
  (March 8, 2005-March 7, 2006--10% DOE)
Project Costs/Funding

• **Total Project** – $5.4 million
  – $2.0M – CO₂ Purchase, transport, recycling
  – $1.5M – Research, Technology Transfer
  – $1.1M – Capital Costs (wells, etc.)
  – $0.8M – Operations (6 years)

• **Funding**
  – $2.4M Shell CO₂ Co. and Murfin Drilling Company
  – $1.9M U.S. Department of Energy
  – $1.0M KGS and TORP
  – $0.1M Kansas Department of Commerce
Pilot Pattern #1

40 Acre

- New Injection Well
- Five existing production wells
- Four injection wells to increase pressure in the pattern and to confine flood
- Produced carbon dioxide not recycled
- Carbon dioxide to be trucked from the Guymon, Oklahoma pipeline terminus
Pilot Pattern #2

- 40 acre, seven-spot
- 2 CO\(_2\) injectors
- 5 Producers
- 5 Containment Water Injectors
- 0.843 BCF CO\(_2\) injected-WAG
- 4.6 year operating life
- 75,300 BO estimated recovery
- 18,300 BO in 3 years after DOE Project
Project Activity 2000

• DOE Contract began March 8, 2000
• Workover on Colliver #18 (May 2000) not successful cannot be used for carbon dioxide injection
• Reservoir simulation indicated CO2#1 should be drilled on Colliver lease, north of Colliver #18
• Colliver Carter CO2#1 drilled and completed October 2000
Pilot Pattern #3

- 55 acre, nine-spot
- 2 CO₂ injectors
- 7 Producers
- 5 Containment Water Injectors
- 0.843 BCF CO₂ injected-WAG
- 4.6 year operating life
- >80,000 BO estimated recovery during DOE
- >20,000 BO in 3 years after DOE Project
Pilot Pattern #4

- 40 acre, five-spot
- 2 CO₂ injectors
- 4 Producers
- 3 Containment Water Injectors
Shell CO2 sold to Kinder Morgan CO2-early 2000

2000 Kinder Morgan Evaluation

• Not enough resource in LKC to justify pipeline (November 2000)
• No cash from Kinder Morgan CO2-only CO2 in kind (short ~$350,000 for 40 acre pilot)
• Must demonstrate Arbuckle potential to keep Kinder Morgan CO2 commitment to LKC pilot
Carbon Dioxide Supply (Late 2000)

- ICM (U.S. Energy Partners, LLC) announces ethanol plant to be constructed in Russell (February 5, 2001)
- On stream ~November 1, 2001
- CO2 production 3.4 MMCFD (wet at atmospheric pressure)
- 8.5 miles from CO2 demonstration project
Location of Ethanol Plant & CO2 EOR Site

ICM Ethanol Plant Site

Colliver-Carter CO2 Site

Scale in Miles

Kansas Geological Survey
2001 → Re-evaluate Project Economics

• Examine economics of expanding pilot from 40 acres to ~60 acres to operate profitably within Kinder Morgan contribution

• New ethanol plant constructed in Russell becomes potential source of carbon dioxide

• Proposal developed and submitted to DOE - expands project cost to $7.56 million.

• Length of project expands to 8 years
Pilot Pattern #5
(One of Several)

- 60 acre
- 2 CO₂ injectors
- 6 Producers
- 6 Containment Water Injectors
- 0.85 BCF CO₂ injected-WAG
- 8 year operating life
- >96,000 BO estimated recovery
Expanded Project Economics

• Total Project – $7.56 million
  – $2.34 M – CO₂ Purchase, transport, recycling
  – $2.21 M – Research, Technology Transfer
  – $1.33 M – Capital Costs (wells, etc.)
  – $1.68 M – Operations (8 years)

• Funding
  – $2.03 M MV Energy
  – $0.52 M Kinder-Morgan CO₂ Co. LP
  – $0.97 M ICM
  – $2.77 M U.S. Department of Energy
  – $1.17 M KGS and TORP
  – $0.10 M Kansas Department of Commerce
Expanded Pilot Project

• Kinder Morgan reduced financial support
• CO2 available from ICM plant in Russell
• Pilot size increased to provide acceptable economic and technical risk to MV Energy, ICM and Kinder Morgan
• Budget Period 1 extended to March 2002
• Additional funding obtained from DOE effective October 1, 2001
• Project extended to 2008
• ICM/Kinder Morgan to provide CO2
Expanded Project (2001)

- (November 2001) GE declines to invest in expanded project when AFE is submitted to drill second injection well.
- Must use original CO2 injection well if project is to proceed.
- Evaluate half of a five spot pattern (~15 acres) using existing wells.
Redesign Pilot Project-2001

• Goal--conduct a pilot that minimized loss but provide sufficient information to expand to commercial scale if warranted.

• Evaluation and economics developed for reduced scale pilot and submitted to MV Energy.

• Extensive reservoir simulation
  – Effects of reservoir heterogeneity
  – Gravity segregation
  – Residual oil saturation to carbon dioxide

• Economic analysis
Pattern #6

15 acre half of five spot

- One CO2 injector
- Three Producers
- Two Containment Injectors
- 0.271 BCF CO2 injected
- 4.6 year operating life
- 27,784 BO estimated recovery
2002 Progress

• Risk too high for Murfin Drilling to cover $298K shortfall in the initial capital investment required to initiate the project.

• Department of Commerce (KTEC) provides $88K additional commitment, reducing the shortfall in capital investment to $210K in addition to leasehold costs.

• Decision made to seek working interest partners and purchase lease in pilot region
Working Interest Proposal

• Purchase lease (70 acres)
• Share risk of capital loss if project does not reach full development
• Field work planned to minimize investment as uncertainties in reservoir properties are evaluated in pre-flood injection testing and well recompletions
• Working Interest Partners
  – Murfin Drilling
  – White Eagle Resources
  – J.O. Farmer, Inc.
• Completed and lease purchased-2002
Pattern #6

- ~15 acre half of five spot
- One CO2 injector
- Three Producers
- Two Containment Injectors
- 0.271 BCF CO2 injected
- 4.6 year operating life
- 27,784 BO estimated recovery
Anticipated 15 Acre Pilot Response
~20% PPV

Cumulative Oil 27,784 STB

Oil, STB

Repressure Pilot

Time, years

0 1 2 3 4 5 6

CO2 Injection
Carbon Dioxide/ Water Injection
271,360 MMSCF

Time, years

CO2 Injected, MMSCF

CO2/Water Injection

Water Injection
Project Funding-DOE Class Revisited Program

- Budget Period 1: Reservoir Characterization and Advanced Recovery Analysis
  March 2000-March 2003 (DOE Cost Share 45%)
- Budget Period 2: Field Demonstration and Analysis: April 2003- March 2008
  (DOE Cost Share 35%)
- Budget Period 3: Monitoring and Post Flood Analysis: March 2008-March 2009
  (DOE Cost Share 10%)
## Summary of Costs - 2002 Design (15 Acre)

<table>
<thead>
<tr>
<th>Category</th>
<th>Cost</th>
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<tbody>
<tr>
<td>Facilities</td>
<td>$918,215</td>
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<tr>
<td>Flood Operations</td>
<td>$928,658</td>
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<tr>
<td>CO2 Supply</td>
<td>$870,000</td>
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<tr>
<td>Research, Data, Tech Transfer, Administration</td>
<td>$1,698,168</td>
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<tr>
<td><strong>Total</strong></td>
<td><strong>$4,415,041</strong></td>
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# Summary of Revenue Sources- 2002 Design (15 Acre)

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<thead>
<tr>
<th>Source</th>
<th>In-Kind</th>
<th>Cash</th>
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<tbody>
<tr>
<td>DOE</td>
<td>$1,702,242</td>
<td>$2,848,082</td>
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<tr>
<td>Murfin and WI</td>
<td>$1,566,958</td>
<td>$1,001,458</td>
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<tr>
<td>Kinder-Morgan</td>
<td>$188,500</td>
<td>$54,716</td>
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<tr>
<td>U.S. Energy Partners</td>
<td>$377,000</td>
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<tr>
<td>KUCR(TORP,KGS)</td>
<td>$1,001,458</td>
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<tr>
<td>State of Kansas- DOC</td>
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<td>$188,000</td>
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<tr>
<td>Totals</td>
<td>$1,566,958</td>
<td>$2,848,082</td>
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## Summary of Partner Contributions

<table>
<thead>
<tr>
<th>Contribution</th>
<th>Cost</th>
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<tbody>
<tr>
<td>Kinder-Morgan CO2 in-kind</td>
<td>$176,384</td>
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<tr>
<td>US Energy Partners CO2 trucked to site($1.05/MCF from DOE funds)</td>
<td>$284,928</td>
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<tr>
<td>USDOE 45% Startup Costs</td>
<td>$284,928</td>
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<tr>
<td>USDOE 35% of LOE</td>
<td>$125,867</td>
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<tr>
<td>State of Kansas KDOCH</td>
<td>$88,000</td>
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<tr>
<td>Murfin and WI Partners 55% of Startup Costs</td>
<td>331,277</td>
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<tr>
<td>65% of LOE except CO2 Costs</td>
<td>$233,753</td>
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<tr>
<td>Total</td>
<td>$1,525,162</td>
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</tbody>
</table>
Carbon Dioxide Supply

• U.S. Energy Partners
  – Will commit sufficient CO2 to run pilot project at $1.05/MCF delivered to field as liquid CO2 (0°F at 300 psig).
  – Plans to expand ethanol capacity of plant

• Kinder Morgan
  – Will supply carbon dioxide in-kind at one of its locations as needed in project
  – Negotiations in progress to trade KM carbon dioxide for carbon dioxide injection facilities during the life of the pilot flood
Field Demonstration of CO₂ Miscible Flooding in the L-KC, Central Kansas Project Extension

March 12, 2003

Class II Revisited  DE-AC26-00BC15124
CO₂ Pilot Project Team

- Kansas Geological Survey
  - Alan P. Byrnes
  - Marty Dubois
  - W. Lynn Watney
  - Timothy R. Carr
  - Willard J. Guy
  - John Doveton
  - Dana Adkins-Heljeson
  - Kenneth Stalder

- Kinder-Morgan CO₂ Co. LP
  - Russell Martin
  - Paul Nunley
  - William Flanders (consultant)
  - Don Schnacke (consultant)

- U.S. Department of Energy
  - Edith C. Allison (Prgrm Mngr)
  - Paul West (Project Mngr)

- State of Kansas (Dept. of Commerce)

- Tertiary Oil Recovery Project
  - G. Paul Willhite
  - Don W. Green
  - Jyun-Syung Tsau
  - Richard Pancake
  - Rodney Reynolds
  - Rajesh Kunjithaya
  - Ed Clark

- Murfin Drilling
  - Dave Murfin
  - Jim Daniels
  - Tom Nichols
  - Stan Froetschner

- Working Interest Partners
  - White Eagles Resources
  - J.O. Farmer, Inc.

- ICM, Inc. Dave Vander Griend
A Vision for the Future
AD ASTRA PER ASPERA

To The Stars Through Difficulties