

CO₂ EOR - What's Working, What's Under Evaluation

An Existing Technology Overview

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The Two Lenses with Which to View CO₂ EOR

The Past

- Oil Pays for Everything
(Capture, Processing, Compression, Transportation, Injection)
- Oil Prices (\$10-30/bbl)
- An Emerging Technology

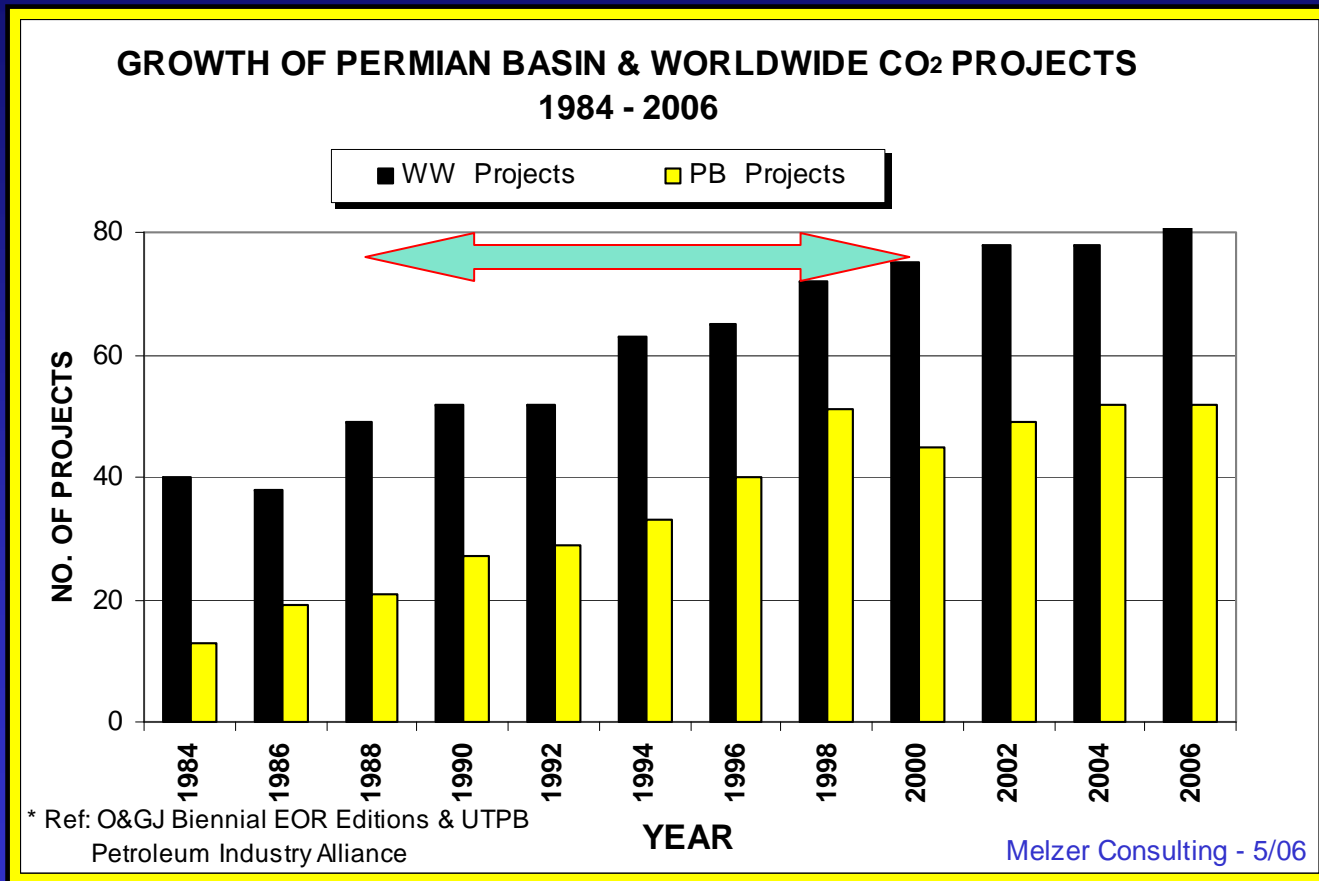
The Future?

- CO₂ Source Capture Pays for Part of the Front End
(Capture, Processing, Compression, Transportation)
- Oil Prices (\$70-110/bbl)
- A Maturing Technology



BACKGROUND (The Past)

CO₂ EOR PROJECT GROWTH*



CO₂ EOR

An Existing Technology Overview

- CO₂ 'Handling'
 - Capture/Separation
 - Processing
 - Compression
 - CO₂ Transportation
 - CO₂ Injection

- CO₂ Operations

- CO₂ Reservoir

CO₂ 'Handling'

(What We Won't be Covering Today)

- Capture and Separation
 - Nat'l Gas, Syngas, Nat'l Sources
- Processing (Recycle, Dehy, BGFs, NGLs, Desulfurization)
- Compression
- Transportation

THE AGENDA FOR THE DAY

- **Next Generation Technologies for CO₂ EOR**
- **Reservoir Sweep**
 - **Conformance Control**
 - **Reservoir Characterization**
- **Industry Experience (Panel)**
- **Breakout Sessions and Identifying the Needs**

CO₂ EOR

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CO₂ Operations Technology: Needs (*Partial List?*)

- Old Well Reentry, Remediation
- Corrosion
- Cementing
- Pattern Balancing
- Monitoring/Surveillance Tools
- Others?



Denbury Resources Inc

West Mallalieu, Mississippi Flood Performance and Wellbore Re-entry Methodology

By: Barry Schneider and Lonnie Ashley

10th Annual CO₂ Flooding Conference
Midland, Texas
December 10, 2004



Re-Drill or Tie-back?

- **Over 22 Patterns Would Be Needed**
- **Drilling Would be More Conventional and “Comfortable”**
- **Tie-backs Would Be “New Territory” for us**
- ***So We Tried Both***

Taken From “West Mallalieu, Mississippi Flood Performance and Wellbore Re-entry Methodology,” Schneider, B & Ashley, L., Denbury Resources, Presented at the 2004 CO₂ Flooding Conference, Midland, Tx, Dec '04

Initial Evaluation

- **In the First 12 Months, 14 New Wells Were Drilled for an Average Cost of \$690,000**
- **9 Wells Were Tied-Back for an Average Cost of \$559,000**
- **Decision Was Made to Continue Tie-backs Whenever Possible**

Taken From "West Mallalieu, Mississippi Flood Performance and Wellbore Re-entry Methodology," Schneider, B & Ashley, L., Denbury Resources, Presented at the 2004 CO₂ Flooding Conference, Midland, Tx, Dec '04

Advantages to Tie-backs vs. Re-Drilling

- ◆ Use Existing Wellbores (185 “Opportunities” Existed)
- ◆ Fewer New Locations
- ◆ Reduce the Possibility of Poorly Plugged Wells Failing During the Life of the Flood
- ◆ Sometimes ROWs, Locations, Etc. Are Still There
- ◆ Already Have E-Log on the Well

Taken From “West Mallalieu, Mississippi Flood Performance and Wellbore Re-entry Methodology,” Schneider, B & Ashley, L., Denbury Resources, Presented at the 2004 CO₂ Flooding Conference, Midland, Tx, Dec '04



Challenges of Modernizing a Century Old Oilfield for CO₂ Flooding

Ken Hendricks
Anadarko Petroleum Corp.

Presented at the 13th Annual CO₂ Flooding Conference

December 6-7, 2007

Midland, Texas

Salt Creek – Overview

History

- Discovered in 1908 with over 4,000 wells drilled.
- 1.7 Bbbl of OOIP w/ 0.7 Bbbl cum. production
- 10 producing horizons
- Oil has been produced from depths of 22' to 4,500', Second Wall Creek ~ 1,800'
- Waterflooding commenced in mid-1960s & is ongoing today
- 1st CO₂ injection Jan 04, first CO₂ production May 04.
- Over 90% of the field on Federal (BLM) acreage.

Current Rates

- 6,000 bopd from CO₂, (8500 bopd total)
- 270 MMSCFD CO₂ injection
- CO₂ EOR Cumulative > 4 MMBO



Salt Creek Oil Field, early 1920s.

Required Credit: AMOCO Refining Co. Collection, Casper College Library.

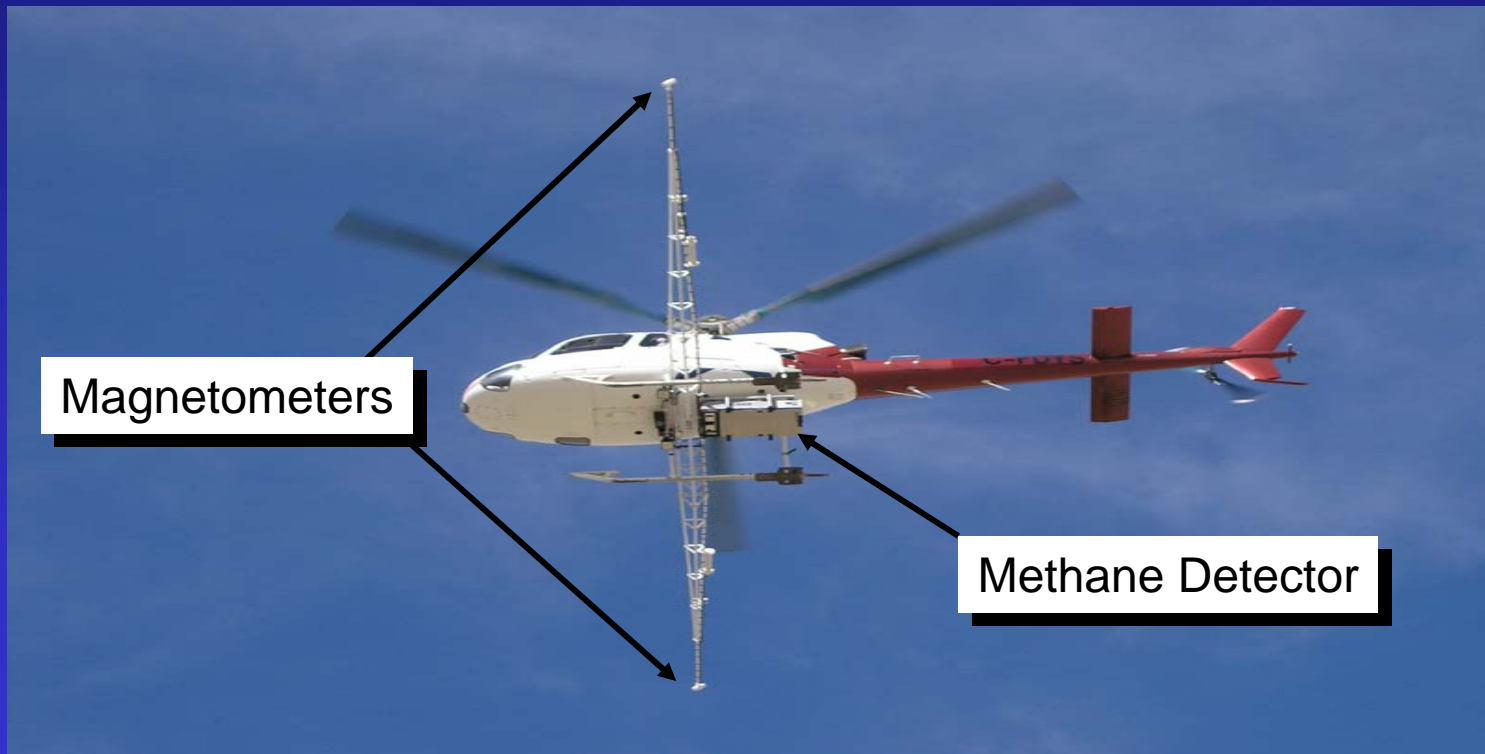
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Taken From "Challenges of Modernizing a Century Old Oilfield for CO₂ Flooding," Hendricks, K., Anadarko Petroleum Corp., Presented at the 2007 CO₂ Flooding Conference, Midland, Tx, Dec '07

Well Challenges

- Identification of all existing wellbores
 - Records searches, conventional & unconventional. Difficult because of limited or nonexistent records for numerous wells
 - Magnetic surveys, both aerial and ground



Taken From "Challenges of Modernizing a Century Old Oilfield for CO₂ Flooding," Hendricks, K., Anadarko Petroleum Corp., Presented at the 2007 CO₂ Flooding Conference, Midland, Tx, Dec '07

Benefits

- Salt Creek Development Viewed Positively by State and Federal Agencies
 - To date >350 wells have been re-plugged, ensuring proper plugging quality & reducing federal liability
 - Improving viewshed & more aggressive field reclamation
 - New flowlines reduce leak frequency, minimizing spills
 - CO₂ sequestration viewed very positively in the regulatory community
- Salt Creek's Brownfield Development Assists the BLM in Meeting its Stated Multiple Use Objective, While Minimizing New Disturbance

Taken From "Challenges of Modernizing a Century Old Oilfield for CO₂ Flooding," Hendricks, K., Anadarko Petroleum Corp., Presented at the 2007 CO₂ Flooding Conference, Midland, Tx, Dec '07

CO₂ Operations Technology: Needs (Partial List?)

<u>Area of Interest</u>	<u>Idea</u>
• Old Well Reentry, Remediation	
• Corrosion	Carbonate buffering?
• Cementing	Passivity?
• Pattern Balancing	new tools?
• Monitoring/Surveillance Tools	remote downhole transducers?
• Others?	?

CO₂ EOR

An Existing Technology Overview

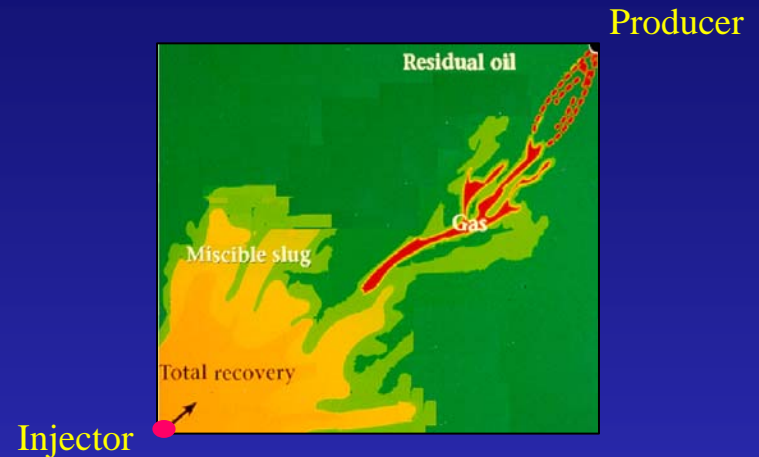
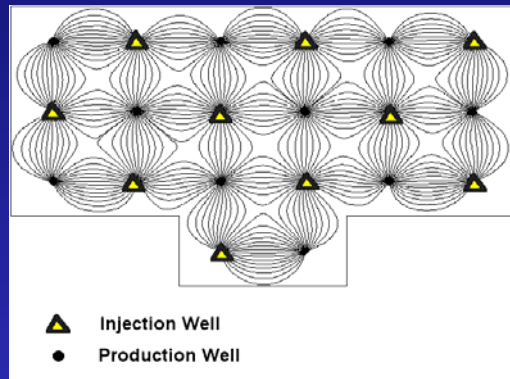
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CO₂ Reservoir Technology: Needs (*Partial List?*)

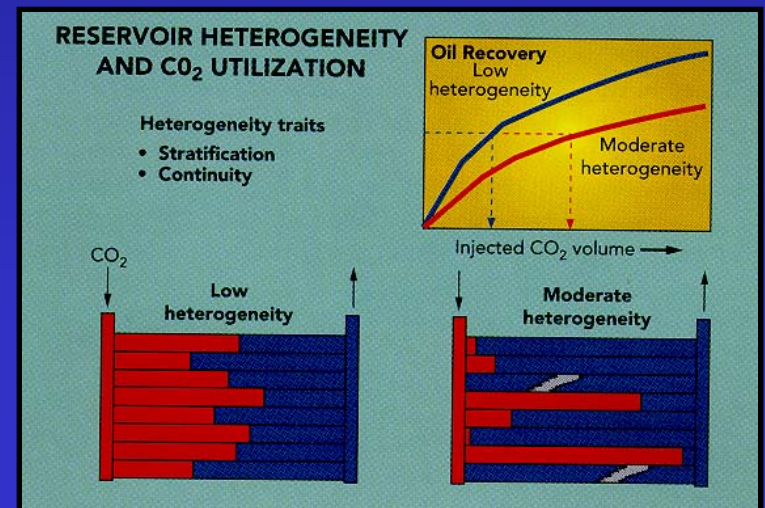
- Conformance Control
- Volumetric Sweep Efficiency
- Reservoir Characterization
- Increasing Targets for EOR and CCS
 - Liquid CO₂ Flooding?
 - Near-Miscible Project Research
 - Vertical Flooding
 - Repressuring with CO₂
 - Transition and Residual Oil Zones
- Others?

POOR RESERVOIR SWEEP

- AREALLY SPEAKING



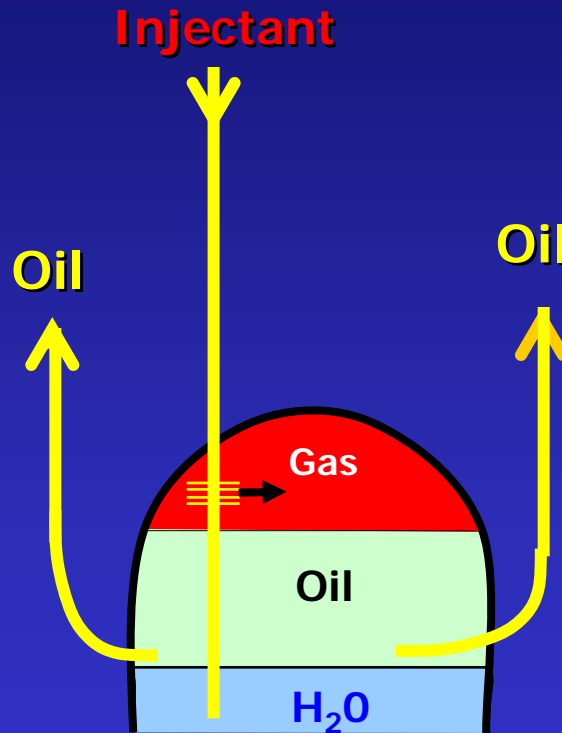
- VERTICALLY SPEAKING



Adapted From "CO₂ EOR and Carbon Capture; Some Issues to Consider," Bradley, T., KinderMorgan CO₂ Company., Presented at the 2006 EOR Carbon Management Workshop, Houston, Tx, Dec '06

Vertical Flooding

(as per Apache Canada at Zama*)



* Adapted from Apache Canada's Zama Presentation at the 2006 CO₂ Flooding Conference, Dec 2006

INTEGRATING CO₂ AND CCS*

* Source: Advanced Resources International

