Northwest McGregor Field CO_2 Huff 'n' Puff: *A Case Study of the Application of Field Monitoring and Modeling Techniques for CO_2 Prediction and Accounting*

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The Williston Basin Phase II validation test is being conducted in the Northwest McGregor oil field in the North Dakota portion of the Williston Basin. The basic principle of this test is to inject CO_2 into a single well, allow it to "soak" for a number of days, and then resume oil production. This procedure is commonly referred to in the oil and gas industry as a "huff 'n' puff" operation and can be an effective means of evaluating the response of a reservoir to CO_2, both with respect to EOR and CO_2 storage.

Goal

The goal of this investigation is to evaluate the feasibility of simultaneous CO_2 sequestration and enhanced oil recovery (EOR) in a deep (>8000 ft) carbonate oil reservoir. Concurrent objectives will be to:

- Determine the effectiveness of the CO_2 huff 'n' puff approach to stimulate oil recovery.
- Evaluate the effects and fate of CO_2 injected into the oil-producing horizon.
- Develop a regional technology implementation strategy for CO_2 storage in deep carbonate oil fields.

Geologic Setting

The geologic setting of this test makes this huff 'n' puff operation unique in several ways:

- Few CO_2-based "huff 'n' puff" projects have been in carbonate reservoirs.
- Previous projects that have targeted carbonate reservoirs are at significantly shallower depths. At a depth of 8050 ft, this test will be the deepest by over 2000 ft.
- In-situ pressures near 3000 psig and temperatures of approximately 200°F are among the highest of a huff 'n' puff operation.
- The test provides the opportunity to investigate the use of state-of-the-art downhole logging techniques (reservoir saturation tool [RST] and vertical seismic profile [VSP]) in high-pressure and -temperature environments and in an older existing well.

Reservoir and Well Characteristics

Reservoir	Well
Lithology: Primarily limestone	NDIC Well No.: 3392
Average Pay Thickness: 14 ft	Date Drilled: 7/31/1963
Porosity: 15%	Perfs: 8052 to 8062 ft Madison
Depth to Pay: 8050 ft	Tubing Inside Diameter: 2 3/8 in.
Average Temperature: 216°F	Casing Inside Diameter: 5 ½ in.
Initial Reservoir Pressure: 3127 psig	Packer Set at: 7788 ft
Cumulative Oil Production: 2.2 Mbo	

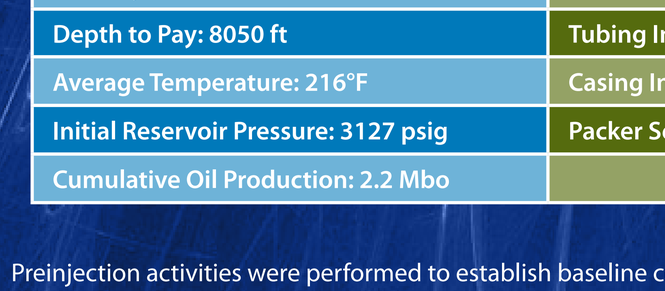
Preinjection activities were performed to establish baseline conditions:

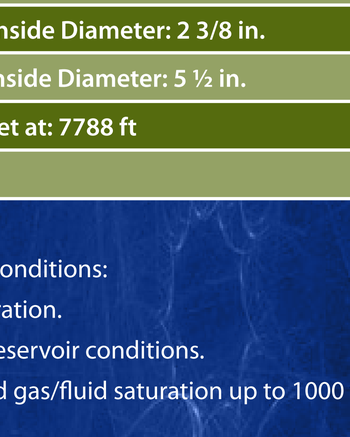
- Ran RST to provide data on near-wellbore gas/fluid saturation.
- Collected and analyzed downhole fluid samples under reservoir conditions.
- Created a vertical seismic profile to provide lithology and gas/fluid saturation up to 1000 ft away from the wellbore (depending on conditions).
- Set pressure "bombs" to collect reservoir temperature and pressure data.

CO_2 Injection (the huff)

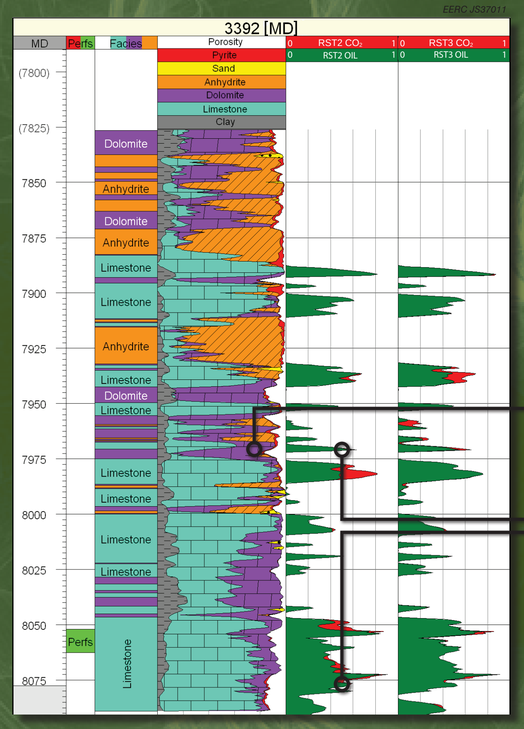
CO_2 was purchased from Praxair and delivered to North Dakota via rail. It was then shipped to the injection site by truck. Over a 36-hour period, 440 tons of CO_2 was injected into the target horizon. The well was then shut in for a 2-week soak period.

Production Period (the puff)





Postproduction Activities



The RST is being used to identify residual CO_2 in the reservoir. By comparing the preinjection and postproduction saturation profiles, along with information obtained in the VSP survey, insight into the CO_2 storage potential of the reservoir will be obtained.

- Collect and analyze downhole fluid samples.
- Run a suite of downhole logging tools to collect data for comparison of preinjection, postinjection, and postproduction reservoir conditions.
- Pull tubing to evaluate any changes in casing and cement.

Additional Monitoring

Sampling and analysis of water supply wells in the vicinity of the study area were conducted to provide verification that there was no out-of-zone migration of the injected CO_2. The standard downhole equipment was also inspected for evidence of corrosion following contact with the CO_2-rich environment.

Monitoring ran through November of 2009, and geologic models were revised based on newly acquired data.

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