DOE/BC/14958--2

QUARTERLY TECHNICAL PROGRESS REPORT
GREEN RIVER FORMATION WATER FLOOD DEMONSTRATION PROJECT
UINTA BASIN, UTAH

~~DE-PS22-92BC14804~~ FC22-93BC14958

Lomax Exploration Company
Salt Lake City, Utah

Award Date: October 21, 1992
Anticipated Completion: October 1, 1995

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Reporting Period: January 1 - March 31, 1993

OBJECTIVE

The project concerns itself with increasing recoverable petroleum resources in the United States. The Green River Formation in Utah's Uinta Basin contains abundant hydrocarbons that are not easily recovered by primary means. The successful Lomax **Monument Butte Unit** water flood will be evaluated under this contract, and based on this information, water floods will be initiated in nearby **Travis** and **Boundary** units. In 1987, Lomax Exploration Company started a successful water flood on their Monument Butte Unit. This is a low-energy, geologically heterogeneous reservoir producing a waxy crude oil. Primary production yielded about 5% of the OOIP, while the water flood will yield an estimated recovery of 20% OOIP.

SUMMARY OF TECHNICAL PROGRESS

The drilling and completion of two of the wells, one in the Monument Butte unit (10-34) and the other in the Travis (14A-28) unit, were related in the last report (December 31, 1992). The use of novel logging techniques (Formation Microimaging and Magnetic Resonance Imaging) along with the compositions of the oils and gases from the Monument Butte unit were also discussed.

To update the progress of the above two wells, the Monument Butte 10-34 (11/27/92 first production) has produced 4,953 barrels of oil and 4,039 Mcf of gas and the Travis 14A-28 (1/1/93 first production) has produced 6,187 barrels of oil and 7,829 Mcf of gas from inception through March 31, 1993. Due to the success of the Travis 14A-28 completion, we recompleted the behind pipe "D" zone in the Travis 14-28 on March 8, 1993. The 14-28 has produced 2,411 barrels of oil through March 31, 1993 or 105 barrels per day.

Water injection was resumed in the Travis 15-28 in mid March. The average daily rate was 263 barrels per day. Lomax and the Department of Chemical and Fuels Engineering agreed to a slower injection rate in the 15-28 due to the fractures found in the logging and coring of the 14A-28 well. At this date, tubing pressure of the 15-28 is at 90 psi and casing pressure is at 480 psi.

Due to weather restraints, the Boundary 10-20 location was not approved by the BLM until April of 1993. The Boundary 10-20 well was spudded in April. The tentative completion date is estimated to be the first half of May. The 10-20 is the first of two wells committed to be drilled in the Boundary unit in 1993 as part of the water flood development. The main oil objectives in the 10-20 well are the lower Douglas Creek and the "D" sand members of the Green River formation.

A full diameter core was collected from 5550 ft to 5646 ft in the lower Douglas Creek interval of well 14A-28. The core was photographed and described in detail. The sandstone of the lower Douglas Creek in well 14A-28 is comprised of thick packages of planar-laminated, fine-grained sandstone exhibiting various degrees of dewatering and soft-sediment deformation, that are separated by thinner disrupted or massive very fine-grained sandstone and siltstone beds. The planar-laminated sandstones occur in 15 ft thick packages with an intraclast-rich base and a dewatered top. The sandstones are interpreted as moderate to low-density turbidite channel deposits. Two deformed planar-laminated sandstone units occur, from 5632.7 ft. to 5623.5 ft. and from 5605.5 ft to 5588 ft. Both of these units are strongly oil-stained.

The most strongly oil-stained sandstones are those facies that are planar-laminated, whether or not they are disrupted or undeformed. Presumably, these laminated facies are also the best reservoir units. Moderately stained sandstones of the lower turbidite channel sequence have oil saturations that range from 49.6 to 40.5%, horizontal permeabilities in the .46 to .77 Md range and vertical permeabilities in the .50 to .99 Md range. The plug from 5638 ft had the highest vertical permeability of any of the measured samples, because the laminations are steeply inclined at this depth. Porosities in this facies range from 9 to 11.7%. Strongly oil-stained planar-laminated sandstones in the upper turbidite unit are 67 to 70.7% oil saturated. Horizontal permeabilities in this sandstone unit are much higher than those of the lower turbidite unit and range from 2.5 to 13 Md. Porosities range from 14.8 to 16.6%.

The core from the lower Douglas Creek interval is moderately fractured. There is some lithologic control on the formation of fractures. In general, fractures are developed in cemented sandstone beds rather than in more ductile finer grained lithologies. In the upper portion of the

core, fractures are present in carbonate-cemented sandstone beds at 5570-5572', 5582' and at 5589-5590'. In these beds, the fractures are open, subvertical and planar. Fractures in the upper and lower turbidite sandstone units are more irregular. At 5608-5611' and 5625-5627', open fractures are subvertical but tend to mimic the orientation and geometry of dewatering pipes in the laminated sandstones and are nonplanar. In general, the open, natural fractures have dips greater than 60°. The dewatering pipes exhibit similar dips and are commonly subvertical.

A tracer test is being planned to take place within the Monument Butte unit. At the present time, the test is expected to consist of inserting one tracer into one injection well. However, the possibility of tagging more than one well is being examined with respect to the budget. Injection and production waters from several of the wells in this unit have been subjected to a comprehensive inorganic analysis. The analyses revealed unexpectedly high levels of nitrate, which was the tracer that we had planned to use. We are currently looking at iodide and/or bromide as alternate tracers. To plan the tracer test, we will need estimates of dilution and travel time. These will be obtained from the reservoir simulation currently being run at the Department of Chemical and Fuels Engineering.

Procedures for gas-chromatography based, high-temperature simulated distillation of crude oils have been developed, validated, and used to develop a more accurate description of the composition of the oils in the reservoirs. The method measures the fraction of the crude oils for carbon numbers up to 90. This correlates to a boiling point of about 1300°F. The use of an internal standard allows accurate calculation of the fraction of material above C_{90}.

The live oil PVT - Core Flooding System has been completed. The system is nominally rated to a pressure of 5000 psi and a temperature of 250°F. The equipment is currently being used to perform experiments and to measure the various properties of the reservoir fluids. A schematic of the system is shown in Figure 1, and the details of the core holder are shown in Figure 2. This equipment is designed to measure the thermodynamic properties of the reservoir fluids of interest. It will also be used to quantitatively evaluate the rock-fluid interactions in the reservoir, using reservoir fluids and cores, at the conditions prevailing in the reservoir.

The measured oil and gas compositions for the fluids from the Monument Butte unit have been used to calculate PVT properties. For a GOR of 230, at the reservoir composition and temperature, the bubble point was calculated to be 2017 psi. The thermodynamic model utilizes the Peng-Robinson equation of state for the calculations. The initial field GOR was greater than 230, but there is some uncertainty in the actual initial values. There is also some uncertainty in the model predictions due to the manner in which the oil components obtained using simulated distillation are lumped into psuedocomponents and the critical properties that are assigned to the psuedocomponents. More work is being done on the predictive models and the models will eventually be validated by comparison with the properties measured in the system described above.

Reservoir simulation work was begun during this quarter. A preliminary model for Monument Butte has been constructed, using a state-of-the-art black oil simulator developed by the Computer Modelling Group. The model uses the gas and oil compositions in the reservoir, and it features the major features of the reservoir, including the separate B and D sands.

Major geologic features of the D and the B sands have been represented in the model using a variable depth, variable thickness option. The model includes 20 wells in the Monument Butte unit and keeps track of times of completion, water injection schedule and other pertinent reservoir data. For accurate history matching and future waterflood behavior predictions, the model needs thermodynamic information about the oil and gas originally in place (PVT properties), reservoir geologic parameters and geometry, and rock-fluid interactions (relative permeabilities). The preliminary model incorporated realistic reservoir geologic features, PVT properties believed appropriate for the oil and gas of Monument Butte, and typical relative permeabilities for a water wet sandstone. These input parameters to the simulator will be updated as more geologic information becomes available and as property measurements are completed in the PVT - Core Flooding System. Nevertheless, the preliminary model does provide a basic understanding about primary production and the nature of water flooding in the unit.

In primary production, the reservoir behaves in a manner similar to reservoirs containing fluids with analogous thermodynamic behavior. The average pressure in the reservoir drops below the bubble point pressure in a matter of months, resulting in large increases in the production GOR and in free gas saturation in the reservoir. With continued production, the reservoir pressure declines to a point where oil production is no longer economical. The model shows a primary recovery of about 5% to 6% OOIP, which is considered typical for these type of reservoirs. The free gas in the reservoir is recompressed by the water flood and the oil production rate is dramatically increased.

For a quantitative match of production from each of the wells in the unit, a careful fine-tuning of the model geologic features will be required. Even so, the model predictions from this preliminary model are reasonably close to the field results. For example, the model predicts a production rate of 88 barrels/day in May 1992 for Well 10-35, the most productive well in the unit, while the actual field rate was 100 barrels/day. The oil saturation contour plot for D sands at the end of May 1992 has been presented in Figure 3. The plot shows a mature water flood and identifies zones of high oil saturation in the field.

TECHNOLOGY TRANSFER

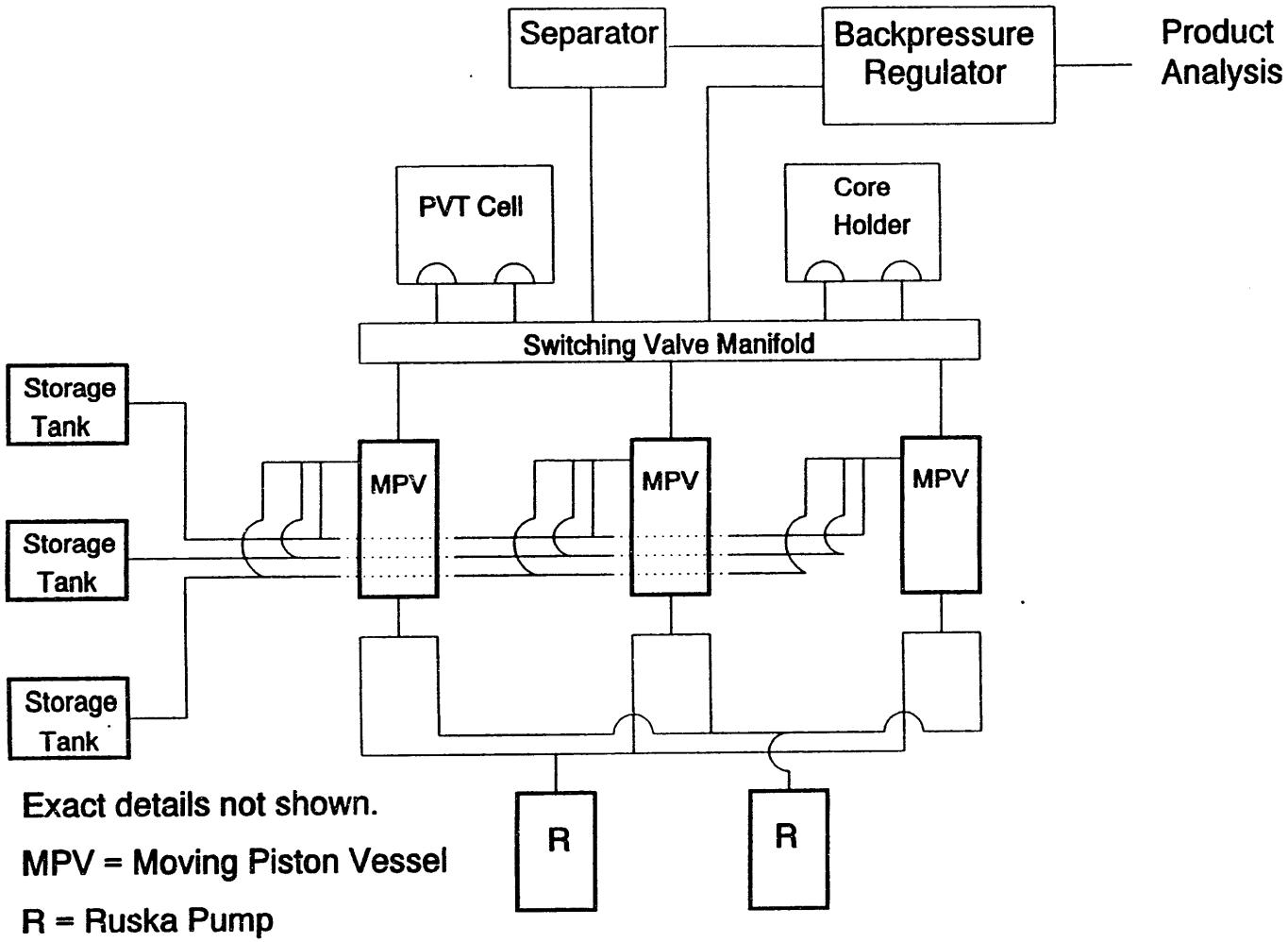
The success of the Monument Butte unit has influenced the start and the development of the Jonah water flood unit by Equitable Resources Energy Company ("Equitable"). Equitable received approval from the State of Utah and the BLM to commence water injection in section 6 of Township 9 South, Range 17 East of Duchesne county, Utah. Equitable plans to expand the water flood unit to cover 4,240 acres. The proposed unit is within 1 mile of the Monument Butte unit.

REFERENCES/ PUBLICATIONS

"Waterflood Project in the Monument Butte Field, Uinta Basin," presented by John Lomax, Annual meeting of the **Interstate Oil and Gas Compact Commission**, December 6-8, 1992, Salt Lake City, Utah

"Waterflood Project in the Uinta Basin", presented by Milind D. Deo, Monthly meeting of the Salt Lake section of the **Society of Petroleum Engineers**, February 16, 1993, Salt Lake City, Utah

"Potential of Waterflooding in the Uinta Basin," presented by Milind D. Deo, Monthly meeting of the Uinta Basin section of the **Society of Petroleum Engineers**, March 25, 1993, Vernal, Utah


Separator
Backpressure Regulator
Product Analysis
PVT Cell
Core Holder
Switching Valve Manifold
Storage Tank
Storage Tank
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MPV
MPV
MPV
R
R
Exact details not shown.
MPV = Moving Piston Vessel
R = Ruska Pump

FIGURE 1

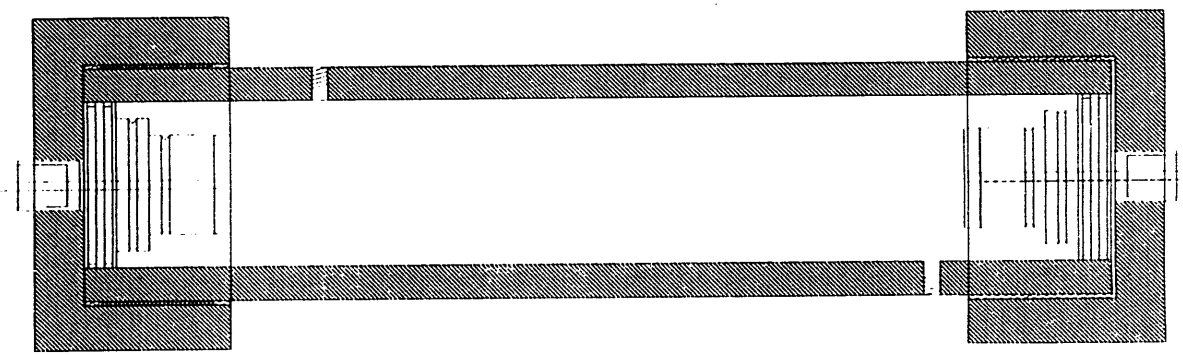

FIGURE 2

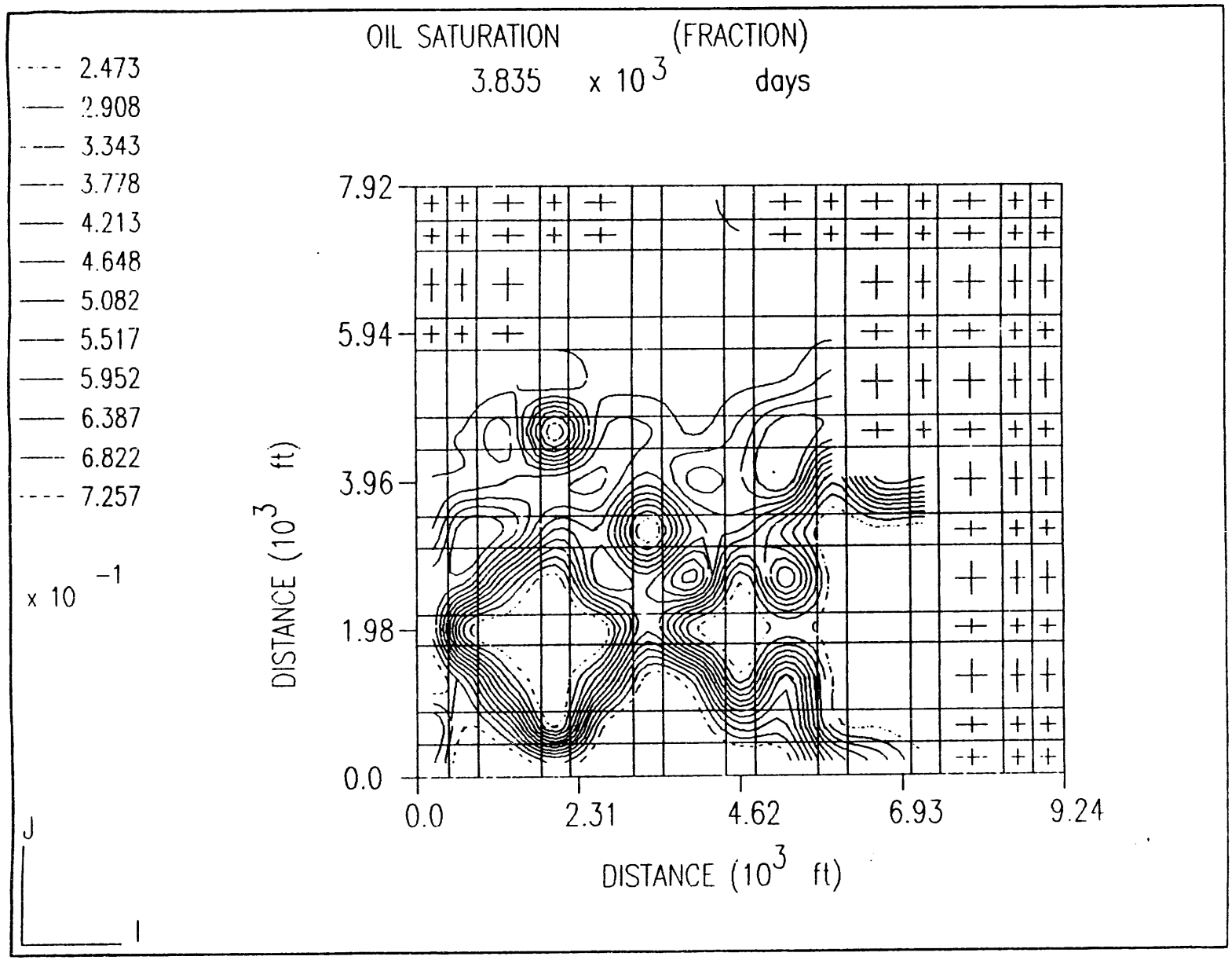
OIL SATURATION (FRACTION)
3.835 x 10^3 days
2.473
2.908
3.343
3.778
4.213
4.648
5.082
5.517
5.952
6.387
6.822
7.257
x 10^-1
7.92
5.94
3.96
1.98
0.0
DISTANCE (10^3 ft)
0.0
2.31
4.62
6.93
9.24
DISTANCE (10^3 ft)
J
I

FIGURE 3

END

DATE
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