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RESIDUAL OIL SATURATION TECHNOLOGY TEST
BELL CREEK FIELD, MONTANA

Final Report

MASTER

Work Performed for the Department of Energy
Under Contract No. DE-AC03-78ET12366

Date Published—June 1981

Gary Energy Corporation
Englewood, Colorado

U. S. DEPARTMENT OF ENERGY

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**RESIDUAL OIL SATURATION TECHNOLOGY TEST
BELL CREEK FIELD, MONTANA**

Final Report

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ABSTRACT

Gary Energy Corporation has conducted a field test of the technology available to measure residual oil saturation following waterflood secondary oil recovery processes. The test was conducted in a new well drilled solely for that purpose, located immediately northwest of the Bell Creek Micellar Polymer Pilot. The area where the test was conducted was originally drilled during 1968, produced by primary until late 1970, and was under line drive waterflood secondary recovery until early 1976, when the area was shut in at waterflood depletion.

This report presents the results of tests conducted to determine waterflood residual oil saturation in the Muddy Sandstone reservoir. The engineering techniques used to determine the magnitude and distribution of the remaining oil saturation included both pressure and sidewall cores, conventional well logs (Dual Laterolog - Micro Spherically Focused Log, Dual Induction Log - Spherically Focused Log, Borehole Compensated Sonic Log, Formation Compensated Density-Compensated Neutron Log), Carbon-Oxygen Logs, Dielectric Logs, Nuclear Magnetism Log, Thermal Decay Time Logs, and a Partitioning Tracer Test.

Prepared for DOE under Contract No. DE-AC03-78ET12366

INTRODUCTION

Gary Energy Corporation has completed for the U.S. Department of Energy, Contract No. DE-AC03-78ET12366, an evaluation of current residual oil saturation measurement technology. The purpose of this test was to demonstrate the capability of different techniques to measure residual oil saturation, in situ, in a semi-consolidated sandstone reservoir, post waterflood, and to serve as a basis for selection of appropriate methods to determine residual oil saturation at tertiary recovery test sites.

Residual oil saturation is the overriding parameter in determining the potential for economic success for enhanced oil recovery projects. To determine residual oil saturation using the indirect techniques, one needs to measure: i) the portion of the reservoir occupied by sandstone, and that occupied by shale; ii) the porosity, ϕ ; and iii) the water saturation, S_w . The majority of residual oil saturation evaluation techniques available utilize indirect methods to arrive at residual oil saturation. Three techniques, however, involve direct determination of residual oil saturation.

The test well, drilled solely for this purpose, is immediately north of the Bell Creek Micellar Polymer Oil Recovery Demonstration Project being conducted jointly by the Bell Creek Working Interest Owners and the U.S. Department of Energy, Contract No. DE-AC03-78SF01802. The area where the test has been conducted was originally developed during 1968, produced by primary until late 1970, and was under line drive waterflood secondary recovery until early 1976, when the area was shut in at waterflood depletion.

SUMMARY

Gary Energy Corporation has completed a residual oil saturation evaluation in the semi-consolidated Muddy Sandstone reservoir in the Bell Creek Field, Montana.

Figure 1 illustrates the sequence of residual oil saturation testing operations. The test well, SOR Well No. 1, located in C SE $\frac{1}{4}$ Section 1, T8S, R54E, Figure 2, was drilled to the casing point in the Muddy Silt at 4632 feet depth, referenced to Kelly bushing elevation (KB), approximately 18 feet above the top of the Muddy Sandstone pay. The well was logged to the surface with the Borehole Compensated Sonic - Gamma Ray tool and 10-3/4 inch diameter casing was run to total depth and cemented. The well was then unsuccessfully pressure cored from 4646 feet KB to 4660 feet KB. However, sidewall core coverage was obtained through the zone of interest to provide a general check on porosity and permeability through the Muddy Sandstone interval. Following reaming to 7 inches diameter, the open hole log suite, consisting of the following logs was obtained: the Dual Laterolog - Micro Spherically Focused log, Dual Induction - Spherically Focused log, Formation Compensated Density-Compensated Neutron with Gamma Ray log, Borehole Compensated Sonic with Gamma Ray log, Nuclear Magnetism log, Electromagnetic Propagation log, the Carbon-Oxygen log and the Dielectric Constant log. Following completion of open hole logging, the hole was reamed to 9 $\frac{1}{2}$ inches diameter and an 8-5/8 inch diameter fiberglass liner was cemented in place from total depth to tie back to the production casing at 4550 feet KB. Four abrasijet holes per foot were then cut in the fiberglass liner over the zone of interest. The Formation Compensated Density Compensated Neutron log was conducted a second time to determine if near well porosity was altered during installation of the liner and/or during abrasijet perforation. Following installation of the fiberglass liner, the Carbon-Oxygen log, Spectralog and Thermal Decay Time logs were run to determine waterflood residual oil saturation. To complete the waterflood residual oil saturation measurements, a Partitioning Tracer Test, in conjunction with a drift test, was undertaken. Sand production problems that manifested themselves during the Partitioning Tracer Test precluded any post-tertiary process oil saturation measurements, thus terminating the project as a Waterflood Residual Oil Saturation Technology Test in a Semi-Consolidated Sandstone Reservoir.

Table 1 presents a summary of the saturation measurement techniques that utilize knowledge of the secondary properties of the rock-fluid system to indirectly obtain residual oil saturation. The resistivity devices depend upon a knowledge of porosity, clay content, saturation exponent, cementation exponent, water resistivity and the clay conductance to indirectly obtain residual oil saturation. The dielectric devices depend upon a knowledge of porosity and the dielectric permittivity of the rock matrix and formation fluids to indirectly obtain residual oil saturation. The pulsed neutron capture logs depend upon a knowledge of porosity and the capture cross section of two waters of contrasting salinity to indirectly obtain residual oil saturation. Lastly, the partitioning tracer test depends upon a knowledge of the rate at which an injected chemically reactive tracer is absorbed into the oil in the formation. When the injected fluid is produced back into the wellbore, the tracer components will return at different times, because the tracer components, one preferentially absorbed by the immobile residual oil and the other by mobile formation water, travel at different velocities. The formation, with its residual oil, acts as a chromatographic column, and the separation between the component concentration curves can be related, through numerical simulation and with a knowledge of formation porosity, to residual oil saturation.

Table 2 presents a summary of the oil saturation measurement techniques that directly determine residual oil saturation. Pressure retained cores, cut with minimal drilling fluid invasion, result in a sealed sample of the formation and its contained fluids at reservoir conditions. The nuclear magnetism device, when utilized in conjunction with porosity information and with the injection of water containing paramagnetic ions to dampen the formation water signal, results in a direct determination of residual oil saturation. The carbon-oxygen devices determine, by means of spectrographic analysis, the carbon, oxygen, silicon, and calcium content of the formation. Since crude oil is composed of carbon molecules, a measure of the carbon content provides a direct evaluation of the oil content.

Table 3 presents a summary of the remaining oil saturations determined from the near wellbore devices. The conventional "near wellbore" devices, the Spherically Focused log and the Micro Spherically Focused log, indicated average residual oil saturations of 30.2% and 28.1%, respectively. The Spherically Focused log and the Micro

Spherically Focused log must be run open hole and require knowledge of the mud filtrate resistivity for determination of flushed zone water saturation and the resultant residual oil saturation.

The two dielectric devices, the Electromagnetic Propagation log and the Dielectric Constant log, indicated residual oil saturations of 25.4% and 31.9%, respectively. The dielectric devices determine flushed zone water saturation independent of a knowledge of formation water resistivity. However, due to a lack of complete understanding at this time of the interrelationship between dielectric measurements and quantitative values of fluid mixtures in various rock matrices, the dielectric devices are considered experimental.

The Nuclear Magnetism log indicated an erroneously high average residual oil saturation of 47.8% due, in large part, to incomplete invasion into the area of investigation by the paramagnetic material required to kill the formation water signal. The Nuclear Magnetism log is the only in situ measurement device that directly measures residual oil saturation. This log holds much promise when deep invasion of the paramagnetic material can be achieved.

The Carbon-Oxygen logs, run both open hole and following installation of the fiberglass liner, indicated average residual oil saturations of 34.2% and 33.6%, respectively. Once sufficient stability and repeatability with the Carbon-Oxygen log are obtained, this tool will have a major advantage for measuring residual oil, since it can be used in either open hole, fiberglass cased, or steel cased holes.

Log-inject-log indicated an average residual oil saturation of 31.6%. This is in very good agreement with the aforementioned conventional near wellbore devices, dielectric logs, and Carbon-Oxygen logs. The log-inject-log measurement technique can be used in either open hole or through steel or fiberglass cased holes.

Table 4 presents a summary of the remaining oil saturations determined using the deep investigation devices. The Dual Induction log and the Dual Laterolog, deep investigation resistivity devices, indicated average residual oil saturations of 39.2% and 43.5%, respectively. Both devices require a knowledge of formation water resistivity to determine water saturation and the

resultant residual oil saturation. Differences in the remaining oil saturation indicated by these measurement techniques are, in large part, a result of the method in which each device treats the thin beds.

The partitioning tracer test is a deep investigation device that uses a chemical tracer whose components separate and react at different rates with the oil and formation water. The partitioning tracer indicated erroneously low average residual oil saturation of 15%. The partitioning tracer results are dependent in their entirety on the permeability profile, and the oil saturation determined is the average oil saturation in the volume contacted by the injected tracer bank. The low oil saturation indicated herein is the result of inability to clearly define both the partitioning coefficient, and subzone injection and withdrawal rates, along with sand production, which caused steadily increasing porosity during the production cycle, and, in turn, resulted in high dispersion of the partitioning tracer components.

CONCLUSIONS

The following conclusions can be drawn with respect to the various techniques evaluated while undertaking a determination of waterflood residual oil saturation in the Muddy Sandstone reservoir, Bell Creek Field, Montana.

1. The near wellbore devices, Table 3, indicated average residual oil saturations within several inches of the wellbore to be approximately 30% PV. The Nuclear Magnetism log, which is the exception, indicated a residual oil saturation of 47.8%. Nuclear Magnetism log results are believed to be in error, as discussed in Conclusion 10.
2. The deep investigation devices, Table 4, indicated residual oil saturation at distances several feet from the wellbore to be approximately 41% PV. The exception is the Partitioning Tracer Test, which indicated a residual oil saturation of 15% in the zones accepting fluid. The Partitioning Tracer Test results are believed to be in error as discussed in Conclusion 15.
3. A comparison of Tables 3 and 4 indicates significant tertiary target oil remaining following waterflood depletion.
4. The conventional open hole porosity logs can be used to accurately determine porosity.
5. Sidewall core coverage also serves as a check on the porosity devices and provides a general picture of the permeability when no full hole core can be obtained. No evaluation of oil saturation is possible in the sidewall cores except in a very qualitative way.
6. The Spherically Focused log and the Micro Spherically Focused log provide reasonable values of flushed zone residual oil saturation.
7. The Dual Induction log provided oil saturation values inconsistent with what would be expected in a waterflood depleted reservoir, and with the swab test results following completion. This could be the result of a combination of factors, i.e., thin bed effects, borehole effects, the proximity of the casing shoe and casing string to the logged interval and/or resistivity anisotropy within the formation.

8. The Dual Laterolog oil saturation values are not consistent with saturations that would be expected in a waterflood depleted reservoir, or with swab test results. This could be a result of a combination of one or more of the following factors, i.e., thin bed effects, borehole effects, the proximity of the casing string to the logged interval, and/or resistivity anisotropy within the formation.
9. The Electromagnetic Propagation log and the Dielectric Constant log provided flushed zone saturation measurements consistent with their respective depths of investigation, without the knowledge of formation water resistivity, and with respect to this particular well, correlatable (see Table 3) with the conventional near wellbore devices.
10. The Nuclear Magnetism log failed to yield results consistent with the other saturation measurement techniques. This resulted from either one or a combination of the following reasons: incomplete displacement of the formation water by mud filtrate containing paramagnetic ions, the presence of the magnetic mineral Siderite within the Muddy Sandstone, or significant change in the magnetic field with depth due to the presence of the 10-3/4 inch diameter steel casing landed 23 feet above the top of the Muddy Sandstone pay interval.
11. The Carbon-Oxygen log surveys conducted both open hole and through a fiberglass liner yielded results consistent, both with each other and, with respect to this well, they are correlatable with the conventional near wellbore devices.
12. Spectralog surveys of the Muddy Sandstone interval correlate satisfactorily with the X-ray diffraction analysis of sidewall core samples, and indicate increased shaliness toward the base of the Muddy Sandstone.
13. Log-inject-log testing results are correlatable (see Table 3) with the results from the conventional near wellbore devices and are consistent with their depth of investigation.
14. The partitioning tracer test is weighted according to the brine permeability of the formation, and consequently measures the lower limit for oil saturation in the reservoir because the tracer material in the injected fluid partitions into residual oil only in that portion of the formation accepting injection fluid.

15. The partitioning coefficient determined for the Bell Creek crude oil may be in considerable error due to the formation of a stable emulsion between the crude oil, flood water, and propyl formate tracer. Consequently, the resulting residual oil saturation is suspect.
16. Each reservoir is a unique entity. When measurement techniques are selected to evaluate residual oil saturation in a candidate reservoir, they must be tailored to the individual reservoir rock-fluid system.

OPERATIONAL RECOMMENDATIONS

As a result of conducting a comparison of various residual oil saturation measurement techniques in the Bell Creek Field, Montana, the following recommendations are presented to allow future investigators to minimize expenditures and maximize the quality of information obtained during testing to determine residual oil saturation in a waterflood depleted reservoir.

1. Pressure core with a drilling rig equipped to handle normal drilling operations, not with a service unit and assembled components. Rig crews are normally familiar with their own equipment. Rental equipment malfunction results in much lost time when personnel unfamiliar with the equipment are required to perform repairs.
2. All contractors should be required to stock spare parts or backup equipment on site for hard usage items.
3. Pressure coring operations in a semi-consolidated sand should incorporate the improved pressure core barrel design with the non-invading drilling fluid, and should also utilize the polycrystalline cutter bit to maximize penetration rate and minimize flushing and disintegration of the core.
4. Pressure coring operations should be conducted under moderate weather conditions, not under conditions of extreme cold, which result in much less efficient operation of both men and equipment.
5. Several sidewall core samples should be obtained within each one foot interval to minimize the effects of heterogeneity within the formation interval being investigated.
6. The Nuclear Magnetism log requires that paramagnetic ions be introduced into the mobile formation water in the near well area to kill the formation water signal to allow the Nuclear Magnetism log to directly determine residual oil saturation. This should be accomplished by spotting the required volume of water containing paramagnetic ions in the drill pipe and across the zone of interest, and then squeezing the material directly into the formation by shutting in the annulus between the drill pipe and the casing, and displacing the water containing paramagnetic ions down the drill pipe with drilling fluid.

7. Perforation of fiberglass liners should be accomplished using only abrasijet techniques to minimize the chances of damage to the liner.
8. The partitioning tracer technique requires that a clear value be derived for the partitioning coefficient, K , between the oil and the water. Should problems with formation of stable emulsions between the crude oil, water, and the propyl formate or other tracer material be indicated, the partitioning tracer technique should not be undertaken.
9. The partitioning tracer technique requires detailed knowledge of the capability of each subzone within the formation to accept fluid on injection and to return fluid to the wellbore during production. Should the thickness of the subzones be outside the range of definition of the fluid injection and production surveys, the partitioning tracer test should not be undertaken.
10. The capability of the formation to produce sand should be addressed when considering the magnitude of the testing program to be undertaken. Sand control measures should be incorporated in the completion design if the partitioning tracer test is to be undertaken. However, sand control measures such as gravel packing or in situ sand consolidation techniques would preclude the use of log-inject-log techniques, the Carbon-Oxygen log and the Nuclear Magnetism log.

DISCUSSION

SITE SELECTION

Figure 2 shows the location of the test well in C SE $\frac{1}{4}$, Section 1, T8S, R54E, Powder River County, Montana, immediately to the north of the Bell Creek Micellar Polymer Oil Recovery Demonstration Pilot Project. This location was selected due to the similarity of the formation in this area to the micellar polymer pilot area; but it is still outside the immediate pilot boundaries, so that operations in the test well would not impinge upon operations in the pilot area. However, the adjacent location of the injection facilities at the pilot (see Figure 2) could be used for mixing and blending of chemicals for the tertiary minitest portion of the residual oil saturation determinations had that been possible, and a comparison made with the full pilot.

DRILLING TO THE CASING POINT

During late October 1978, the residual oil saturation technology test well, designated SOR Well No. 1, was drilled to the casing point in the Muddy Silt at 4632 feet KB, approximately 16 feet above the top of the Muddy Sandstone pay. A 20 inch diameter hole was drilled to 325 feet, and 16 inch diameter, 65 lb./ft. H-40 casing was set at 304 feet KB and cemented back to surface with 300 sacks of 50/50 Pozmix A cement and 100 sacks of Class G Regular cement. A 14-3/4 inch diameter hole was then drilled to 4632 feet KB. The hole was then logged from 4632 feet KB to 304 feet KB with the Borehole Compensated Sonic Gamma Ray log for correlation purposes. A 10-3/4 inch diameter, 40.5 lb./ft. to 51.0 lb./ft. long string was then run to 4630 feet KB and cemented with 275 sacks of 50/50 Pozmix A cement containing 2% gel and 10% salt. As it had been decided to pressure core with a service unit following the cementing of the long string, the drilling rig was released.

PRESSURE CORING OPERATIONS

Introduction

To obtain the best possible value of remaining oil saturation for the Bell Creek Muddy Sandstone reservoir to compare with log derived values for remaining oil saturation, it was decided to pressure core the Muddy Sandstone producing interval. Pressure coring provides

a sealed sample of the oil bearing formation which is brought to the surface at reservoir pressure for fluid saturation analysis. Analysis of a core brought to the surface under bottom hole pressure conditions, taken under conditions of minimal drilling fluid invasion, reflects oil, gas and water saturation as closely as currently is possible.

Diamond Oil Well Drilling Company, Midland, Texas, was selected as the pressure coring contractor, due to their extensive experience with pressure coring. Figure 3 illustrates the configuration of the DOWDCO Pressure Core Barrel used at Bell Creek.

Service Unit

Due to the high demand for service units in the Rocky Mountain area, a service unit capable of drilling from 4630 feet KB to the coring point, cutting the pressure core, and drilling to total depth at 4705 feet KB was not obtained until early December 1978. By December extreme winter weather prevailed in southeastern Montana with snow and ambient temperatures, with wind chill, down to -88°F. The service unit selected for pressure coring was a Cooper Model 4210 rated to 12,000 feet with 2-7/8 inch diameter EUE tubing, having a draw works capacity of 250,000 pounds, a 12 foot substructure, and equipped with a power swivel.

Drilling Fluid System

The drilling fluid system selected for pressure coring was a low spurt loss (2-3 cc), low API fluid loss (5-6 cc), fresh water mud. The properties of the drilling fluid system throughout pressure coring operations are presented on Table 5. As the reservoir pressure in the pilot area was estimated to be approximately 1550 psi prior to pressure coring operations and the hydrostatic pressure of the mud column was estimated to be 2220 psi, it was deemed necessary to minimize the overbalance by nitrifying the drilling fluid. Nitrification during pressure coring operations decreased the mud column hydrostatic head by slightly more than 200 psi. Pressure coring operations were then undertaken with an operating overbalance of approximately 400 psi. To ensure that the drilling fluid properties did not vary throughout pressure coring operations, the mud system was equipped with a two-tier shale shaker with 200 mesh screens, a desilter, and a gas buster for removal of nitrogen from the mud returns.

Pressure Core

Preparation for actual pressure coring was completed by December 9, 1978, with the drilling of 8 feet of 9-1/2

inch diameter hole below the casing shoe (4630 feet KB to 4638 feet KB) and 3 feet of 6-1/2 inch diameter pilot hole (4638 feet KB to 4641 feet KB) for the bit on the pressure core barrel. At this time the coring mud was mixed and the hole was displaced with approximately 450 barrels of low spurt loss, low water loss, nitrified coring mud. Table 6 presents a summary of pressure coring operations information for each coring run.

Actual pressure coring operations were initiated on December 12, 1978. Pressure Core Barrel No. 1, a dummy run in the Muddy Silt, was conducted to check systems and procedures prior to actual pressure coring in the Muddy Sandstone. Five feet of silt and shale were recovered between 4641 feet KB and 4646 feet KB. A check of the bottom hole pressure following nitrification with 50 SCF nitrogen per barrel of mud, just prior to the dummy run, indicated that nitrification reduced the bottom hole pressure from 2220 psi to 2015 psi. Pit gain indicated the bottom hole pressure to be reduced from 2220 psi to 2000 psi. Thus, nitrification did assist in minimizing the pressure differential during pressure coring operations.

Pressure Core Barrel No. 2, the first coring run in the Muddy Sandstone, was conducted on December 13, 1978. After one hour of coring at an extremely low penetration rate, coring was terminated and the pressure core barrel surfaced to determine if the core barrel had jammed. Recovery was approximately 1.3 feet of black shale and small sand stringers from 4646 feet KB to 4648 feet KB. Pressure Core Barrel No. 2 was recovered with approximately 1800 psi intact at the surface.

Pressure Core Barrel No. 3, the second coring run in the Muddy Sandstone was conducted on December 14, 1978. Five feet of interval, between 4648 feet KB and 4653 feet KB, was pressure cored. Approximately 3.8 feet of pressure core was obtained with approximately 2000 psi intact. Unfortunately, the cored interval was a thin sand shale sequence in the Muddy Silt immediately above the producing interval.

Pressure Core Barrel No. 4, the third coring run in the Muddy Sandstone, was initiated the evening of December 14, 1978. Circulation was established and nitrification of the mud system was underway for approximately 30 minutes before a valve seat in the mud pump washed out. Following continued problems with the mud pump, it was decided to continue with coring until the pump rate decreased to a point where the pressure core barrel had to be pulled.

When the pump rate had decreased to 25 gpm, it was decided to pull the pressure core barrel. A 7 foot interval between 4653 feet KB and 4660 feet KB was cored and the barrel was recovered with 2200 psi intact at the surface. No core was recovered over the interval of interest. This interval, between 4653 feet KB and 4660 feet KB was indicated, from open hole logs and sidewall cores, to traverse the heart of the Muddy Sandstone pay. Pressure coring operations were terminated at a depth of 4660 feet KB.

We believe that several factors resulted in the inability to recover core through the Muddy Sandstone pay interval. The extreme friability of the Muddy Sandstone in this area is indicated by the need for sand screens to maintain offset wells on production. Sand friability, in conjunction with the extremely slow drilling rate and the inability to circulate at rates sufficient to move cuttings away from the bit face, all are suspected to have contributed to the inability to recover core through the interval of interest.

The following comments are presented as a guideline to others considering pressure coring operations to optimize core recovery and minimize costs: i) Pressure core with a drilling rig equipped to handle normal drilling operations, and not with a service unit and assembled components. Rig crews are normally familiar with their own equipment and stock spare parts on site. Rental equipment breakdown or malfunction results in extra lost time when people, unfamiliar with the equipment, are required to perform repairs. ii) Pressure coring operations, when possible, should be conducted under moderate weather conditions. iii) Require that all contractors stock spare parts and back up equipment for hard usage items such as power tong components, pump valves, seats, springs, plungers and power swivel packing. iv) Future operations in semi-consolidated sands should incorporate the improved pressure core barrel design with the non-invading drilling fluid and the polycrystalline cutter bit which should dramatically improve penetration rate, thus minimizing washing and disintegration of the core.

SIDEWALL CORES

Following completion of pressure coring operations, the 6-1/2 inch diameter hole was reamed to 7 inches diameter and the well was drilled to a total depth of 4705 feet KB (see Figure 4). Following completion of open hole logging operations, sidewall core coverage was obtained over the

Muddy Sandstone interval at one foot intervals from 4648 feet KB to 4664 feet KB. Sidewall core recovery was 100% over the desired interval. Analysis of the sidewall core was carried out by Core Laboratories, Dallas, Texas, and is presented in Table 7.

In all types of coring, the core is subjected to the flushing action of the drilling fluid filtrate. The sidewall core sample is normally flushed to a greater extent than a conventional core sample, since the sidewall core sample represents only 1 inch to 2 inches of the formation, including the mud cake, and any infiltrated mud particles in the sample. This flushing action therefore results in higher water saturation, lower residual oil saturation, and permeabilities lower than true reservoir permeability. Further, some degree of uncertainty in the results obtained from analysis of sidewall core samples is due to procedures and test conditions involved with evaluating friable core samples. Consequently, the sidewall core analysis presented in Table 7 indicates minimum values with respect to residual oil saturation and permeability. Porosity values agree reasonably well with porosities obtained with the Formation Compensated Density Compensated Neutron log.

CONVENTIONAL OPEN HOLE LOGS

Introduction

The conventional open hole logging sequence consisted of the Dual Induction Spherically Focused log, Figure 5; Dual Laterolog Microspherically Focused log, Figure 6; Borehole Compensated Sonic with Gamma Ray log, Figure 7; and the Formation Compensated Density Compensated Neutron log with Gamma Ray, Figure 8.

Measurement of oil saturation with conventional open hole logs depends upon the knowledge of porosity, clay content, cementation exponent, saturation exponent, water resistivity and clay conductance, along with mud properties, formation geometry, and tool response. The accuracy of the resulting calculation depends upon the uncertainties associated with each of these variables. Under the most stringent conditions the uncertainty (one standard deviation) of calculated residual oil saturation is between 5% pore volume and 10% pore volume, and with less favorable conditions, greater than 10% pore volume.^{1,2,6}

The test well is located in a thoroughly waterflooded area where mixed salinity waters predominate within the

various lenses of the Muddy Sandstone interval. Water samples recovered by swabbing, Table 8, following recovery of 542 barrels of water, indicated a formation water resistivity of 1.6 ohm meters at 100°F bottom hole temperature. Log derived formation water resistivity was 0.55 ohm meters, or closely representative of formation water resistivity in the Bell Creek Micellar Polymer Demonstration Project, immediately to the south. Consequently, the Schlumberger open hole logs were analyzed using the formation water resistivity obtained from analysis of the Spontaneous Potential curve, i.e., 0.55 ohm meters.

Porosity values obtained from the Formation Compensated Density Compensated Neutron log, Borehole Compensated Sonic log, and Sidewall Core Analysis, were compared. The formation porosity developed from a crossplot of the Formation Compensated Density log porosity and the Compensated Neutron log porosity agreed reasonably well with the sidewall core porosity, and consequently was used, shale corrected, in the conventional open hole log analysis.

The cementation exponent was developed, Figure 9, using a logarithmic plot of true formation resistivity versus sidewall core porosity. The cementation exponent "m" was calculated to be 1.7, while the cementation constant "a" was calculated to be 1.09 at a formation water resistivity of 0.55 ohm meters at 100°F BHT.

The formation factor "F" can be determined using the following relationship:

$$F = \frac{a}{\phi^m}$$

$$F = \phi_{\text{formation factor}}$$

$$\phi = \text{porosity}$$

$$a = 1.09$$

$$m = 1.7$$

Due to the inability to recover pressure core through the Muddy Sandstone pay interval, it was impossible to determine the saturation exponent "n" in the laboratory. For purposes of this analysis, the saturation exponent "n" was assumed to be 2.0. Formation water saturation S_w was determined using Archie's equation.

$$S_w = \left[\frac{FR_w}{R_t} \right]^{1/n}$$

where: F = formation factor
 R_w = formation water resistivity, ohm-meter
 R_t = true formation resistivity, ohm-meter
n = saturation exponent
 S_w = water saturation, percent pore volume

Flushed zone water saturation, S_{xo} , was determined using the modified form of Archie's equation.

$$S_{xo} = \left[\frac{FR_{mf}}{R_{xo}} \right]^{1/n}$$

where: F = formation factor
 R_{mf} = mud filtrate resistivity, ohm-meter
 R_{xo} = flushed zone resistivity, ohm-meter
n = saturation exponent
 S_{xo} = flushed zone water saturation, percent pore volume

Discussion

The Schlumberger open hole logging sequence was initiated December 19, 1978, and completed, without incident, December 20, 1978. Each survey, conducted from total depth at 4705 feet KB to the base of the 10-3/4 inch diameter long string at 4630 feet KB, was repeated several times to ensure statistically valid information. Figure 4 illustrates the wellbore configuration during logging operations. Table 9 illustrates the results of the open hole log analysis between 4650 feet KB and 4663 feet KB using the Dual Induction Spherically Focused log and the Dual Laterolog Microspherically Focused log in conjunction with porosity developed from the crossplot of data from the Formation Compensated Density Compensated Neutron logs.

Remaining oil saturations using the Dual Induction log and the Dual Laterolog were 39.2% and 43.5%, respectively, through the interval of interest between 4653 feet KB and 4662 feet KB. The difference in saturations determined

using these two devices is attributed to the manner in which the tools are affected by thin beds, borehole effects, proximity to the casing string, and resistivity anisotropy within the formation. Flushed zone residual oil saturation averaged 30.2% for the Spherically Focused log and 28.1% for the Microspherically Focused log through the interval of interest from 4653 feet KB through 4662 feet KB.

ELECTROMAGNETIC PROPAGATION LOG

Introduction

The Electromagnetic Propagation log measures the phase shift and the attenuation time of an electromagnetic wave propagated through the formation at a frequency of 1.1 GHZ and encompassing a radius of investigation within 4 cm of the wellbore. The magnitude of these measurements are determined by the dielectric permittivity of the matrix and formation fluids, and the formation water salinity. Since, under fresh mud conditions, a decrease in dielectric permittivity due to salinity is compensated for by increased conductivity due to the presence of salinity, water saturation can be determined essentially independent of the salinity. Consequently, the Electromagnetic Propagation log is most accurate in fresh formation waters, and becomes slightly less accurate in waters containing very high brine concentrations. Due to the proximity of the log measurements to the wellbore, the water saturation determined is, in essence, S_{xo} , the flushed zone water saturation near the wellbore.

The flushed zone water saturation, S_{xo} , can be determined at the depths of interest using the following relationship:

$$S_{xo} = \frac{(t_{pl} - t_{pma}) + \phi_{ND} (t_{pma} - t_{ph})}{\phi_{ND} (t_{pw} - t_{ph})}$$

where: S_{xo} = flushed zone water saturation, percent pore volume

t_{pl} = propagation time direct from log, nanoseconds/meter

ϕ_{ND} = formation porosity, percent bulk volume

t_{pma} = matrix propagation time, nanoseconds/meter

t_{pw} = water propagation time, nanoseconds/meter

t_{ph} = hydrocarbon propagation time, nanoseconds/meter

The response of the Electromagnetic Propagation log is dependent upon the dielectric constants of the rock and formation fluids, and is frequency dependent. Water has a significantly higher dielectric constant than crude oil and reservoir rock. The Electromagnetic Propagation log, as previously stated, is much less sensitive to salinity change than the resistivity logs, making it potentially valuable for use in mixed salinity environments, such as exist in reservoirs under waterflood. Although the dielectric measurements are strongly dependent upon water saturation, quantitative values of fluid mixtures in different rock matrices are not yet fully understood. Consequently, this tool is considered experimental.^{1,2,4}

Discussion

On December 20, 1978, Schlumberger personnel from Casper, Wyoming conducted an Electromagnetic Propagation log survey in the test well. The surveys were repeated several times to ensure statistically valid information. Figure 10 illustrates the Electromagnetic Propagation log response through the Muddy Sandstone interval. Table 10 presents the porosity from the Formation Compensated Density-Compensated Neutron log and the flushed zone residual oil saturation from 4650 feet KB to 4663 feet KB at one foot intervals. Analysis of the Electromagnetic Propagation log utilized a matrix propagation time, t_{pma} , of 7.2 nanoseconds/meter; a water propagation time, t_{pw} , of 28.2 nanoseconds/meter; and a hydrocarbon propagation time, t_{ph} , of 4.9 nanoseconds/meter. Oil saturation, presented in Table 10, averages 25.4% through the interval of interest from 4653 feet KB through 4662 feet KB.

GEARHART-OWENS DIELECTRIC CONSTANT LOG

Introduction

The dielectric constant device used by Gearhart Owens was developed at the Texaco Research Center, Bellaire, Texas, and is covered by U.S. Patent No. 4107598, dated August 15, 1978. This device measures the formation relative dielectric constant to a depth of investigation of approximately 23 cm. The relative dielectric constant can provide an essentially salinity independent value of water saturation in low salinity formation waters and in waters of mixed salinity, such as result from waterflood secondary recovery operations.

The Gearhart Owens Dielectric Constant tool uses a 30 MHZ electromagnetic wave and determines phase difference in degrees and amplitude ratio at the 30 MHZ frequency. Both the phase and amplitude of the wave are affected by the conductivity and dielectric permittivity of the formation. For a given phase and amplitude, a unique travel time for the wave exists. The travel time is expressed in degrees of phase shift by comparing the sine wave obtained at the two receivers on the tool. The difference in degrees between zero crossings of the sine wave with respect to travel time reflects the combined effect of dielectric permittivity and conductivity of the formation along with the receiver spacing. At a given dielectric permittivity and conductivity, a specific propagation loss exists.

The amplitude of the wave at the two receivers is a function of both the wave attenuation by the formation and the receiver spacing. Since an exponential loss in wave amplitude occurs as a function of distance, the ratio of the wave amplitudes, rather than the difference in amplitudes, is recorded. This results in the phase difference and the amplitude ratio having the same vertical resolution.

The phase difference in degrees and the amplitude ratio can then be plotted on Figure 11 to obtain the dielectric constant, K. Using the following relationship, the propagation time can then be determined at the depths of interest.

$$t_{pl} = (\Sigma_0 \mu_0 K)^{1/2}$$

where: μ_0 = magnetic permeability of free space, henrys/meter

Σ_0 = dielectric permittivity of free space, farads/meter

K = dielectric constant of the formation at a given depth, farads/meter

t_{pl} = propagation time, nanoseconds/meter

The flushed zone water saturation, S_{xo} , can then be determined at the depth of interest using the following relationship.

$$S_{xo} = \frac{(t_{pl} - t_{pma}) + \phi_{ND} (t_{pma} - t_{ph})}{\phi_{ND} (t_{pw} - t_{ph})}$$

where: S_{xo} = flushed zone water saturation, percent pore volume

t_{pl} = propagation time, nanoseconds/meter

ϕ_{ND} = formation porosity, percent bulk volume

t_{pma} = matrix propagation time, nanoseconds/meter

t_{pw} = hydrocarbon propagation time, nanoseconds/meter

The response of the Dielectric Constant log is dependent upon the dielectric constants of the rock and formation fluids, and is frequency dependent. Water has a significantly higher dielectric constant than crude oil and reservoir rock. The Dielectric Constant log is much less sensitive to salinity change than the resistivity logs, making it potentially valuable for use in mixed salinity environments, such as exist in reservoirs under waterflood. Although dielectric measurements are strongly dependent on water saturation, quantitative values of fluid mixtures in different rock matrices are not yet fully understood. Consequently, this tool must be considered experimental.^{1,2,4}

Discussion

On December 20, 1978, Gearhart Owens personnel from Aurora, Colorado, attempted to run the Dielectric Constant log and the Sidewall Neutron Porosity log in the test well. Operations were delayed until December 22, 1978, due to failure of Gearhart Owens' power supply and the inability, because of blizzard conditions, to move a replacement power supply into the field. Operations were completed December 22, 1978, without further incident. Both the Dielectric Constant log and the Sidewall Neutron Porosity log were repeated several times to ensure statistically valid information. Figure 12 illustrates the Dielectric Constant log response through the Muddy Sandston interval. Table 11 presents the results of the Dielectric Constant log interpretation using porosities developed with Schlumberger's Formation Compensated Density Compensated Neutron log rather than Gearhart Owens Sidewall Neutron log, so that one variable parameter could be eliminated when comparing the two dielectric tools. Analysis of the Dielectric Constant log utilized a matrix propagation time, t_{pma} , of 7.2 nanoseconds/meter; a

water propagation time, t_{pw} , of 28.2 nanoseconds/meter; and a hydrocarbon propagation time, t_{ph} , of 4.9 nanoseconds/meter. The residual oil saturation, presented on Table 11, averages 31.9% through the interval of interest between 4653 feet KB and 4662 feet KB.

NUCLEAR MAGNETISM LOG

Introduction

The Nuclear Magnetism log, unlike other logging tools, derives its signal only from the pore fluid. It responds to hydrogen protons in fluid molecules within four inches of the wellbore. The total response is from both the oil and water within the pore space. The oil portion of the response is not greatly influenced by the pore size, whereas the water portion of the response is greatly influenced by pore size and shape. Water molecules in very small pores such as pores associated with clays will not be seen by the NML. Consequently, by suppressing the formation water signal through introduction of paramagnetic ions into the mobile formation water in the area of investigation of the NML tool, the log response will then directly reflect residual oil saturation.

The major advantage of using the Nuclear Magnetism log is that the bulk oil volume (oil saturation x porosity, $S_{or}\phi$) is directly measured. Gas saturation is not mistaken for residual oil as can be the case where residual oil is inferred from measurements of water saturation. This helps make the Nuclear Magnetism log the most valuable field technique for determining residual oil, provided that all water signal is effectively suppressed. The Nuclear Magnetism log must be run either open hole or through a non-conductive liner.^{1,2,5,7}

Discussion

During December 1978, Schlumberger personnel from Casper, Wyoming, assisted by Schlumberger Research personnel from Houston, Texas, conducted a Nuclear Magnetism log in the test well for purposes of determining post-waterflood residual oil saturation. Chevron Oilfield Research personnel monitored the spin lattice relaxation time on the drilling fluid filtrate throughout coring operations to ensure that the spin lattice relaxation time of the drilling fluid filtrate invading the formation was sufficiently low to kill the formation

water signal. This was accomplished using a portable Nuclear Magnetic Resonance apparatus.

Mud Treatment and Log Measurements

To cause the nuclear magnetism signal from mud filtrate to decay much faster than that from residual oil, about 750 pounds of manganese sulfate and 1500 pounds of a two sodium versene EDTA (ethalene-diamine tetraacetic-acid) were mixed into the 750 barrel mud system. The drilling mud, in addition, was treated with 10 gallons/100 barrels of magnetized magnetite particles to suppress the borehole water signal.

Filtrate spin lattice relaxation times were less than 11 milliseconds (ms) through the pressure coring effort and subsequent drilling. Because the portable nuclear magnetic resonance device used to measure the spin lattice relaxation time uses a magnetic field over 2,000 times that of the earth, in situ relaxation times were presumably even shorter. Subsequent laboratory measurements of spin lattice relaxation times, probably more representative of the signal decay downhole, showed that filtrate with similar chemical additives decayed with a time constant of about 3 ms. Subsequent laboratory measurements showed that a signal from the produced oil decayed with a room temperature time constant of about 60 ms. Figure 13 shows the "Multiecho T2" decay of a mixture of 50 percent treated filtrate and 50 percent produced oil from the Muddy Sandstone. The mixture had been mixed thoroughly and heated to 155°F for four days. The water signal portion decayed with a time constant of 4 ms. and the oil signal portion decayed with a time constant of 86 ms. The signal recorded by an NML after the 25 ms. of delay used in the tool would, under these conditions, be a measure of the oil content alone.

The mud weight was intentionally decreased by adding nitrogen, and filtrate loss was controlled to minimize invasion during pressure coring. Thus, there was presumably little filtrate invasion during several days of pressure coring. Following pressure coring operations, the hole through the cored interval was reamed from 6-1/2 inches diameter to 7 inches diameter, mud weight was increased to 9.6 lb./gal., fluid loss (30 minute filtrate loss) was increased to 6.8 cc., and the circulation was increased during the drilling of the hole below the cored interval to total depth at 4705 feet KB. It was presumed that additional mud filtrate invasion would occur at this time.

The Free Fluid Index (FFI) recorded by the NML before reprocessing is shown in Figure 14. Some of many repeat passes of the NML showed high FFI at depths known to correspond to shale. There was, therefore, some question about how much the extraneous signal might influence the actual signal recorded through the sandstone interval.

Log Processing and Display

Along with the averaged FFI and T2 presented on the field log, Figure 14, the Schlumberger NML records on magnetic tape 1024 numbers that represent the actual signal decay with time at a specific depth interval and also records digitally the associated information necessary to relate the signal decay to that experienced in the test pits used for log calibration. These data have been reprocessed using a method to be published⁷ in order to better understand and discern the true and anomalous components of the recorded signal. Figure 15 shows an overlay of two repeat passes of the reprocessed NML. One of the passes had a large component of anomalous signal and the other a small component of anomalous signal. The FFI reported through the Muddy Sandstone section was little changed by the anomalous signal, even though the anomalous signal predominated in the shale section below the Muddy, where there was no real signal.

Figure 16 shows the traces recorded on the Schlumberger log compared to traces processed from the digital data. The processed traces have lower background noise than the traces recorded on the log. They are not smoothed, and thus reflect boundaries more accurately than the field log. They also display the frequency of hydrogen resonance not available on the field log. Nevertheless, the Free Fluid Index measured through the Muddy Sandstone is still much larger than possible from residual oil. Because the scale factor used to compute Free Fluid Index from the signal detected is computed from data also recorded on the digital tape, there seems to be no way that the logged Free Fluid Index could be in error because of panel setting, miscalibration, etc. The scale factor used to determine the Free Fluid Index from the logged signal depends on the frequency of hydrogen magnetism. The frequencies determined from the digital data were somewhat different from the preselected value of 2485 HZ and changed reproducibility with depth. However, this frequency error amounts to less than two percent change

in the logged Free Fluid Index. Therefore, there is no reason to believe that the recorded Free Fluid Index was larger than residual oil because of errors in tool response.

Table 12 presents the oil saturation determination on a foot-by-foot basis through the Muddy Sandstone interval. The residual oil saturation indicated from the Nuclear Magnetism log averaged 47.8% over the pay interval. This is high in comparison with the other methods used in this study to determine residual oil saturation and is believed to be in error.

It would be impossible to determine with certainty all reasons for the very high remaining oil saturations indicated from the Nuclear Magnetism log. The following possible explanations are presented: i) The mud filtrate had not completely displaced formation water from the near well area, about four inches into the formation, at the time of logging with the Nuclear Magnetism log, ii) Magnetic minerals known to be present within the Muddy Sandstone -- e.g., Siderite -- caused both the water and the oil to decay with a single relaxation time of about 25 ms., iii) The magnetic field changed significantly with depth, due possibly to the 10-3/4 inch diameter steel casing landed 23 feet about the top of the Muddy Sandstone pay interval.

Any future use of the Nuclear Magnetism log should use a different method to achieve adequate invasion of the manganous versene. Water containing the required concentration of manganous versene should be mixed on the surface, spotted across the zone of interest, and squeezed into the formation in sufficient volume to ensure that invasion was achieved equivalent to at least three times the depth of investigation of the Nuclear Magnetism log.

FIBERGLASS LINER INSTALLATION AND WELL COMPLETION

After completion of open hole logging, the hole was reamed to 9-1/2 inches diameter to total depth at 4705 feet KB. Due to the extreme friability of the Muddy Sandstone pay interval and plans at that time to run the Nuclear Magnetism log post-tertiary process, it was decided to equip the well with a non-conductive fiberglass liner. An 8-5/8 inch outside diameter, 7 inch inside diameter, 0.88 inch wall thickness, flush joint, fiberglass liner manufactured by Fibercast Company, Sand Springs, Oklahoma,

was selected. A Texas Iron Works 10-3/4 inch by 8-5/8 inch outside diameter liner hanger assembly was selected to tie back the fiberglass liner to the long string. A Texas Iron Works 8-5/8 inch diameter Type A Modified set shoe was selected to land and cement the liner in the well. Figure 17 illustrates the fiberglass liner assembly installed in the well. Figure 18 shows the set shoe, landing assembly, and change over being picked up through the "V" door preparatory to running the bottom stand of liner in the well. Figure 19 illustrates heating the pin end of the connection prior to applying epoxy. The holes in the box end of the connection are for fiberglass reinforcing pins used for added strength at the connection. Figure 20 illustrates the completed connection ready to run in the hole.

Following assembly, the liner was run to 4702 feet KB, with the liner hanger at 4550 feet KB and cemented in place with 35 sacks of Class G Regular Cement containing 0.75 percent CFR2, 0.4 percent Halad 22-A, and 3 percent KCl. Prior to assembly, the fiberglass liner was sandblasted to provide a rough surface to improve the bond between the liner and the cement. Good cement returns were experienced throughout the liner cementing operation. A Cement Bond log undertaken several weeks after liner installation indicated an excellent cement bond over the full length of the liner.

On January 13, 1979, four holes per foot were abrasijetted in the fiberglass liner between 4648 feet KB and 4660 feet KB. The well subsequently swabbed 22 barrels of water per hour, with an operating fluid level 3500 feet from surface. Laboratory analyses indicated that the water recovered on swab test was midway in salinity between Muddy Sandstone formation water and Madison injection water, and similar in composition to water produced at offset wells.

CONTINUOUS CARBON-OXYGEN LOG

Introduction

The Carbon-Oxygen log is designed to allow the measurement of oil saturation directly, either in an open hole or through steel casing, in formations containing waters of unknown salinity. The tool utilizes a 14 Mev neutron source and a gamma ray detector to determine the quantity of carbon, oxygen, silicon, and calcium in the formation. This is accomplished through the measurement of prompt gamma rays resulting from the inelastic

scattering of neutrons by the four aforementioned elements. Since changes in the carbon-oxygen ratio can be caused by lithologic changes, a calcium-silicon ratio is also determined to assist in defining the lithology.

Hydrocarbon saturation is determined using the following relationship.

$$S_o = \frac{C/O(\log) + .4 \text{ Si/Ca}(\log) - I_{wa}}{C/O_{hy} - C/O_w}$$

where: S_o = oil saturation, percent pore volume

$C/O(\log)$ = C/O ratio as recorded on log

$Si/Ca(\log)$ = Si/Ca ratio as recorded on the log

C/O_{hy} = C/O response in a 100% hydrocarbon saturated zone

C/O_w = C/O response in a hydrocarbon free zone. The hydrocarbon free zone can be a 100% water zone or in any lithology which does not contain hydrocarbons.

I_{wa} = a constant determined by such variables as tool response, casing size, and type of fluids in the borehole and formation. This constant is found for any sequence with common conditions by the relationship $I_{wa} = C/O(\log)$ response in a 100% hydrocarbon free zone + .4 Si/Ca(log) response in a 100% hydrocarbon free zone.

The value of $C/O_{hy} - C/O_w$ has been found to be .2 under most logging conditions. This response is primarily porosity insensitive, but if porosity changes drastically, this value needs adjustment.

Problems with stability and repeatability of Carbon-Oxygen log measurements create a large uncertainty with respect to the accuracy of the readings obtained. Once sufficient stability and repeatability can be achieved through improved tool design, this tool will have tremendous advantages for measuring residual oil saturation, since it can be used either open hole or in a cased wellbore. Presently this tool does not offer adequate stability or resolution in most circumstances for accurate determination of residual oil saturation.

Discussion

December 20, 1978, Dresser Atlas personnel from Gillette, Wyoming, conducted a Continuous Carbon-Oxygen log open hole in fresh water mud, in the test well. To provide statistically valid information, surveys were repeated several times. Figure 21 illustrates the typical Continuous Carbon-Oxygen log response open hole, while Table 13 presents the log analysis at one foot intervals from 4650 feet KB to 4662 feet KB. Oil saturation averaged 34.2% through the interval of interest between 4653 feet KB and 4662 feet KB.

On April 26, 1979 a repeat survey was conducted following installation of a fiberglass liner with formation water in the hole. Again, surveys were repeated several times to ensure both statistically valid information, and proper tool operation. Figure 22 illustrates a typical Continuous Carbon-Oxygen log response through the fiberglass liner, while Table 14 presents the log analysis at one foot intervals from 4650 feet KB to 4662 feet KB. Oil saturation averaged 33.6% over the pay interval.

A shift in the carbon-oxygen ratio was noted between the first and second surveys. This shift in carbon-oxygen ratio and the resulting change in oil saturation between the open hole measurement and the one through the fiberglass liner was probably due to fluid movement in the hole as a result of installation of the fiberglass liner, and also to differences in design in the logging tools utilized in the respective surveys. During the time interval between the first and second surveys, Dresser Atlas increased the neutron generator output and decreased the detector size in an effort to improve tool reliability. Experience indicates that no change in interpretation techniques is necessary when comparing Continuous Carbon-Oxygen logs run open hole with those run through fiberglass.

Further, any shift in carbon-oxygen ratio observed between logging runs using different sondes in the same hole are taken into account in the constant, I_{wa} , in the saturation equation.

SPECTRALOG

Introduction

The Dresser Atlas Spectralog was recorded through the Muddy Sandstone interval in an effort to better resolve the lithologic characteristics. The Spectralog provides the

measurements necessary to differentiate naturally occurring radioactivity into the three most commonly occurring radioactive series, i.e. Thorium, Potassium, and Uranium. Each of these, in turn, can be associated with certain identifiable minerals in the lithology. Clay minerals are the most identifiable minerals with respect to the radioactive series. Illite, Glauconite, and Mica clays are associated with the Potassium response. Bauxite, Bentonite, and Montmorillonite are associated with the Thorium response.

Spectralog analysis presents quantitatively Potassium clays, Thorium clays, and the combined Potassium-Thorium clays, or total clays, resulting from primary deposition. The Uranium series presents a method to differentiate between the natural radioactivity associated with lithology, i.e., primary clays, and the radioactivity that is present more as a function of secondary deposition due to migrating formation fluids, i.e., hydrocarbons or ground water.

Discussion

Figure 23 illustrates the Spectralog response through the Muddy Sandstone interval. Table 15 and Figure 24 present the Spectralog Analysis in tabular and graphical form, respectively. These data indicate there is a thin Thorium base clay present from 4645 feet KB to 4649 feet KB which was, previous to drilling the test well, identified as bentonite. The Spectralog also indicates permeable zones from 4650 feet KB to 4653 feet and from 4657 feet KB to 4662 feet KB. These two zones indicate the presence of more radioactive Uranium isotopes than the lithology would warrant. Sidewall core analysis confirms the presence of these two permeable zones. Table 16 presents the X-Ray diffraction analysis carried out by Dresser Atlas of three sidewall core samples taken at 4648 feet KB, 4655 feet KB, and 4662 feet KB, respectively. The X-Ray diffraction analysis also indicates the clay minerals content to be increasing toward the base of the Muddy.

LOG-INJECT-LOG

Introduction

The log-inject-log procedure involved two series of Thermal Neutron Decay Time logs conducted at waterflood depletion. The first series of Thermal Neutron Decay Time logs was conducted following Madison floodwater injection, while the second series of Thermal Neutron Decay Time logs was conducted following injection of

salt water. The change induced by the contrast in salinity between the fresh Madison flood water and the high salinity water provides a means of determining remaining oil saturation post waterflood.

The remaining oil saturation can be determined with the log-inject-log technique using the following relationship:

$$S_{or} = 1 - \frac{\Sigma_{fw} - \Sigma_{ff}}{\phi_{ND}(\Sigma_{ws} - \Sigma_{wf})}$$

where: S_{or} = formation residual oil saturation, percent pore volume

Σ_{fw} = formation capture cross section following salt water injection

Σ_{ff} = formation capture cross section following fresh water injection

Σ_{ws} = salt water capture cross section

Σ_{wf} = fresh water capture cross section

ϕ_{ND} = formation porosity, percent bulk volume

The log-inject-log technique provides a means to determine residual oil saturation behind casing. The injection of two compatible waters having widely varying salinity eliminated the necessity of determining the hydrocarbon capture cross section and the matrix capture cross section, both of which are troublesome to determine. However, special precautions must be taken when employing log-inject-log techniques to insure optimum results. Salinity contrast should be kept at a maximum. Injection rates should be kept low to avoid stripping of oil by viscous forces. Excess fluid injection should be avoided to minimize solubilizing gas in the under-saturated injection fluid. Lastly, surfactants and caustics in the injection fluid should also be avoided so that no water-flood residual oil is mobilized.^{1,2,3}

Discussion

An injection profile was run on May 2, 1979 following injection of 500 barrels of 1050 ppm TDS Madison floodwater to determine the injection fluid distribution prior to initiating log-inject-log operations. The injection

profile, Figure 25, indicated fluid entry distribution through the zone of interest from 4648 feet KB to 4664 feet KB, as would be expected from the permeability profile indicated from the Sidewall Core Analysis, Table 7. In addition, Gearhart Owens 40 Arm Caliper, run May 8, 1979, indicated the abrasijet perforations were open from 4646 feet KB to 4660 feet KB.

The fresh water portion of the log-inject-log sequence was initiated May 12, 1979, following injection of an additional 695 barrels of fresh Madison floodwater. The Schlumberger TDT-K log was run through the Muddy Sandstone interval, Figure 26, from 4648 feet KB to 4664 feet KB. Five passes were made with the TDT-K log to ensure statistically valid information. The TDT-L log was then run from 4648 feet KB to 4664 feet KB, see Table 17, with stationary readings obtained at one foot intervals. Following resolution of electrical problems with both the TDT-L sonde and the panels, logging was completed May 16, 1979. During both the logging and the four day delay, water injection was maintained at 40 BWPD to ensure no counter flow into the well bore. The capture cross section of the 1050 ppm TDS Madison injection water was determined to be 22.2 capture units from laboratory analysis of a one-gallon sample at Schlumberger Research, Houston, Texas.

The salt water portion of the log-inject-log sequence was initiated May 20, 1979, following injection of 450 barrels of 130,000 ppm TDS salt water. The Schlumberger TDT-K log was run through the Muddy Sandstone interval, Figure 27, from 4648 feet KB to 4664 feet KB. Five passes were made with the TDT-K log to ensure statistically valid information. The TDT-L log was then run from 4648 feet KB to 4664 feet KB, see Table 18, with stationary readings obtained at one foot intervals. Logging operations were completed May 22, 1979. The capture cross section of the 130,000 ppm TDS salt water was determined to be 69.3 capture units from laboratory analysis of a one-gallon sample at Schlumberger Research, Houston, Texas. Total fluid injected during the salt water phase was 650 barrels to the end of logging operations.

All fluid injection operations leading up to and including the log-inject-log testing were conducted at rates significantly below 140 BWPD to ensure that no stripping of residual oil occurred in the near well area.

Table 19 illustrates the results of the log-inject-log testing to determine residual oil saturation. A diffusion

correction was determined from the TDT-L log information to be -0.86 capture units. The remaining oil saturation in the interval from 4653 feet KB to 4662 feet KB ranged from 4% to 78% and averaged 31.2%.

PARTITIONING TRACER TEST

Introduction

The Partitioning Tracer Test, conducted and analyzed by Union Oil of California Research personnel, is based upon the theory of partition chromatography. A slug of formation water tagged with the primary tracer, either propyl formate, ethyl formate, or ethyl acetate, is injected into a well. Propyl formate or ethyl formate are the primary tracers used in reservoirs with bottom hole temperatures less than 130°F, because of their fast reaction rates. The ester tagged water is displaced with additional formation water without the primary tracer. All of the injected water is tagged with a nonreactive, material balance tracer, methanol and/or another alcohol. The injection of the nonreacting tracer is necessary for calculating the amount of dilution of the injected water by reservoir water due to either multizone water production and/or high drift and dispersion rates. The injection of tagged water is continued until the ester solution bank has been moved out to the desired distance from the wellbore. The primary ester tracer partitions into the oil and reacts with the water hydrolyzing it to form a product alcohol and acid. The acid is spent on the formation. The ester moves at a velocity that is a fraction of the injection water velocity due to its partitioning into the residual oil. This retarding effect results in the ester being displaced a fraction of the distance the injection water is displaced, thus forming a doughnut of ester around the well.

The test is designed so that most of the reaction occurs during a shut-in period after the chemicals have been displaced to the desired location in the reservoir. The shut-in period is of sufficient duration to allow enough ester to react so that the returning ester and product alcohol are of sufficient concentration to be accurately measured. When producing the injected water, the product alcohol will return to the wellbore more rapidly than the remaining ester, because the ester return is retarded, due to its solubility in the residual oil. The greater the oil saturation, the greater the retardation between the ester and the alcohol formed by hydrolysis. The

peak separation and shape of the alcohol and ester concentration profiles are dependent on the residual oil saturation.

The ability to sample a large volume of the reservoir is the major advantage of the partitioning tracer technique when compared with the near wellbore techniques, such as coring and logging. However, the partitioning tracer test can sample only those zones in a reservoir that will both take fluid on injection and produce fluid into the wellbore. The partitioning tracer measures the average oil saturation in the volume that is contacted by the injected tracer bank. If a region containing high oil saturation is more than a few centimeters away from a zone containing injection water with tracer, the oil will not be seen by the tracer. Thus, the results of the partitioning tracer test depend entirely on the permeability profile to brine in the test interval. Consequently, the partitioning tracer test gives a relatively lower value than other techniques which are not so weighted for residual oil saturation in a given reservoir.^{1,2} Observed differences between this lower value and the results of other procedures for determining residual oil saturation should be reviewed in an overall context to ensure that partitioning tracer test results are representative for the reservoir in question.

Partition Coefficients

So that the residual oil saturation is the only unknown variable in a test, the partitioning coefficient, K_j , and reaction rate, R_i , must be determined by laboratory experiment. The partitioning coefficient, K , is defined by the equation

$$K = C_o / C_w$$

where: C_o = oil phase concentration of tracer

C_w = water phase concentration of tracer

The partitioning coefficient is determined in the laboratory by contacting a sample of the oil with the tracer tagged water at reservoir temperature and pressure in the presence of reservoir rock. This experiment is run at different tracer concentrations to determine the effect of concentration on the partitioning coefficient. The tracer concentration in the water is determined by gas chromatography and the concentration in the oil phase by material balance.

Rate of Hydrolysis Reaction

The rate of reaction is determined in the laboratory by injecting water and ester into a slim tube filled with crushed reservoir rock. The chemicals are back-flushed, and concentrations of ester, and product alcohol are measured daily by gas chromatography. The reaction rate is then approximated by the first order equation

$$C_{\text{ESTER}}(t) = C_{\text{ESTER}}(o) e^{mt}$$

where: $C_{\text{ESTER}}(t)$ = ester concentration in water phase at time t

$C_{\text{ESTER}}(o)$ = ester concentration in water phase at time o

t = time in days at which $C_{\text{ESTER}}(t)$ was measured

m = slope of line from plot of $\log(C_{\text{ESTER}})$ vs. time in days

Field Testing

Concurrently with the laboratory work, tests are conducted with the candidate well to find the drift rate and dilution factors. The test usually involves injecting formation water tagged with methanol and/or tracer into the well. The injection time is from 1/2 to 1 day and shut-in time is from 1 to 2 days. The well is then produced, samples taken, and tracer concentrations are measured in the laboratory. The drift rate, dispersion, and multizone dilution can be approximated by matching the returning tracer concentrations with a computer simulation. The partitioning tracer test is then designed based on information, such as probable injection and production rates, drift rate, dispersion, dilution effects, K_j values, reaction rate, reservoir temperature, porosity-thickness product, and other minor parameters.

Partitioning Tracer Test

The normal partitioning tracer test procedure is to inject enough tracer tagged water so that the ester doughnut is 15 to 25 feet from the wellbore. The first 25% to 50% of the total injected volume contains the ester; the first 50% to 90% contains the methanol tracer;

and the last 50% to 10% contains a second, nonproduct alcohol tracer. The shut-in time is adjusted to allow at least 30% to 70% of the ester to react, after which the well is produced. A mini-partitioning tracer test is conducted prior to the main partitioning tracer test to ensure that all variables defined by the laboratory results and drift test results are consistent and reasonable, and that the main partitioning tracer test design is correct and optimal. The volume of water injected during the mini-test is usually $1/3$ to $1/2$ of the volume designed for the main partitioning tracer test. Water entry and exit profiles are usually run during both the mini and main partitioning tracer tests to ensure that the water is being injected into and produced from the same zones, and to ensure a proper interpretation of the test data.

The four chemical concentration profiles obtained from the field tests are plotted and simulated by a computer program. The data are adjusted for inconsistencies caused by operational problems, well and reservoir performance characteristics, etc. Once the correct parameters are supplied to the computer simulator, only one correct match should be obtained.

Laboratory Experiments

Samples of Battery 12 water and oil from the vicinity of the test well were obtained. Partitioning coefficient and reaction rate experiments were undertaken in the laboratory. The procedure to determine the K value required mixing 79 cc of reservoir oil, 15 cc of reservoir water, and 0.03 to .1 cc of propyl formate in a pressure vessel at a pressure of 500 psi and reservoir temperature of 92°F and 110°F for four hours. Subsequent to the cell's contents reaching equilibrium, the concentration of propyl formate in the water phase was measured by gas chromatography. The concentration of components in the oil phase were then calculated by material balance. A plot of partitioning coefficient, K, versus propyl formate concentration in the water, C_w , is shown in Figure 28.

Temperature had little effect on the partitioning coefficient. It is not certain whether concentration had much effect. During the laboratory work it was discovered that an emulsion was formed when the oil, water and ester were mixed, especially at high oil content. Therefore, the correct K value to use for the simulation is questionable.

When an emulsion breaker was added, the resulting concentration distribution indicated that the partitioning coefficient was 6.0. The formation of emulsion has not been observed in any prior laboratory test. It is not known if, during the partitioning tracer test, an emulsion was formed in the reservoir. In any case, the partitioning coefficient has a direct bearing on the oil saturation measurements. If the partitioning coefficient determined in the laboratory is less than the actual partitioning coefficient, the oil saturation determined by the computer match of the data would be higher than actual and vice versa. In any case, the results of this test indicate oil saturations of less than 15% regardless of the partitioning coefficient used in the computer match.

Additional partitioning coefficient measurements were conducted using other samples of Bell Creek crude oil and Madison injection water. A wide variation in results was obtained due to the formation of emulsions. The best results were obtained by using the Madison injection water collected during the main partitioning tracer test and untreated oil from a well in the vicinity of the test well during the same time period. The best estimate for the K value was found to be 6.0 for propyl formate. Similar K values were calculated for the other tracers as follows:

Ethanol K = .04

Methanol K = .03

Propanol K = .17

The reaction rate for hydrolysis of the ester was determined in the laboratory using samples of Madison injection water. Injection water with 5000 ppm propyl formate was injected into a slim tube filled with crushed Bell Creek Muddy Sandstone. The tube was kept at a constant temperature and a pressure of 100 psig. Reaction rates for ethyl formate and propyl formate were determined at temperatures of 100°F and 110°F. Samples of water were produced from the slim tube daily and the concentration of ester and product alcohol were measured by gas chromatography. The results of the reaction rate experiments are presented in Figure 29. From the curves, the reaction rates were calculated to be

Propyl Formate at 90°F 18%/Day

Ethyl Formate at 90°F 18%/Day.

A 90°F temperature was used because it was assumed that some cooling from 110°F would occur with 70°F injection water. Based upon these results, the shut-in period was planned for four days, so that 50% of the propyl formate would react.

Drift Rate Measurement Tests

Drift Test No. 1. It has proved to be expeditious to measure drift rate, dispersion, and dilution effects on a well prior to moving the expensive field laboratory equipment to the well site. If the drift test confirms that the drift, dispersion, or dilution are so high that meaningful results cannot be obtained with the partitioning tracer test, then the partitioning tracer test would not be conducted. As a matter of precaution, a drift test was conducted in the test well during June of 1979. Figure 30 illustrates that wellbore configuration during the drift rate measurements.

The test was conducted as follows:

1. May 30, 1979

Water was injected at a rate of 575 barrels per day at 135 psia. A methanol tracer was injected at approximately 5400 ppm for the first 280 barrels. Ethanol was injected for the last 13 barrels.

2. May 31, 1979

The water injection was stopped after the injection of 294 barrels of Madison water with methanol and ethanol tracer.

3. June 1, 1979

The well was placed on production after a 24 hour shut-in period, at 690 barrels per day. Production was continued until 685 barrels were produced. The tracer concentrations were measured by gas chromatography in the laboratory.

The tracer tagged water penetrated the formation to an average radial distance of 16 feet. The drift rate and/or dispersion were determined by matching a computer-predicted curve of returning methanol concentration. The results are displayed in Figure 31. The data can be matched by using a drift rate of 2 feet per day, and a dispersion constant of

.09 in a two zone model. The injection water distribution was 12% into the first zone, and 88% into the second zone. This solution is not unique and other matches could be obtained at higher drift rates, and with different fluid injection and production distribution. The results of injection and production radioactive tracer logging, Figure 32, confirmed that the well was not completely open in the producing interval during the first drift test.

Drift Test No. 2. A decision was made to attempt to measure the drift rate a second time due to the uncertainties associated with the previous test. A change in test design was made to confirm or refute the existence of a high drift rate. However, injection and production problems prevented this test from producing any meaningful data.

Drift Test No. 3. A third drift rate test was then planned. Based upon a verbal recommendation from Dr. Harry Deans, propyl acetate was added to the injected water. The addition of propyl acetate was for the purpose of attempting to measure the oil saturation while conducting a drift measurement test.

The third drift test was conducted on the test well from June 23 to June 29, 1979. The test was conducted as follows:

1. June 22, 1979

Water injection was started at 430 BWPD and 50 psi.

2. June 23, 1979

Water injection was continued at 340 BWPD on vacuum and methanol was injected to give a concentration in the injection water of approximately 5000 ppm and propyl acetate of approximately 2300 ppm.

3. June 24, 1979

Water injection was continued at 340 BWPD on vacuum and ethanol injection was begun after 12 hours of methanol and propyl acetate injection. The total volume of water with methanol and propyl acetate concentrations was 170 barrels. Ethanol was injected at a concentration of 4800 ppm.

The injection of water with ethanol was stopped after 12 hours, or 170 barrels. The total water injected was 340 barrels. The radius of invasion by this volume of water was approximately 16 feet. The well remained shut-in for 1 to 1-1/2 days.

4. June 26, 1979

The well was placed on production at 400 BWPD. The returning water was sampled every 20 minutes and tracer concentrations were measured in the laboratory. A total of 1200 barrels were produced. The results of the computer match of the tracer concentration profiles indicated that the entire formation was not in communication with the wellbore. Additionally, multiple zones were accepting and producing water at different percentages. No drift was indicated when a dispersion constant of 0.2 was used in the computer match of the field test results. The results of this analysis are presented in Figure 33.

Based upon these results, it was decided to reperforate the well with two 3 gram jet shots per foot. The well was reperforated on July 8, 1979, and produced very fine sand when returned to production. An attempt was made to begin the partitioning tracer test, but the well pressured up due to sand fill, and the test could not continue. It was decided to clean out the well, squeeze cement the interval, and reperforate. Following this workover, only one string of tubing was placed in the hole. An injection profile after the workover, Figure 34, indicated that the well was most likely open in all zones of interest.

Main Partitioning Tracer Test

The portable laboratory was moved to Bell Creek on July 4, 1979. A production radioactive tracer survey could not be run on the well, because only one string of tubing was placed in the well following the workover. The injection profile indicated the majority of the interval was accepting water. Figure 35 illustrates the wellbore configuration during the main partitioning tracer test. No mini-tracer test was conducted, due to the fragile condition of the well completion. The main partitioning tracer test was initiated August 23, 1979.

The injection rate was reduced during the injection period to prevent build-up of pressure and to ensure that

the cement squeeze on the well remained intact. The production rate was reduced to 400 barrels per day for the same reason. The main test was conducted as follows:

1. August 22, 1979

Water was injected at a rate of 410 BWPD for approximately 24 hours prior to the injection of chemicals.

2. August 23, 1979

Chemical tracer injection was initiated at 5:00 p.m. at a rate of 410 BWPD. The injection water contained approximately 5000 ppm propyl formate, 3260 ppm propanol, and 4300 ppm methanol. After 8 hours on injection, the methanol concentration was increased to 5000 ppm.

3. August 24, 1979

After 24 hours of injection at the above chemical tracer concentrations, the propyl formate injection was stopped and methanol injection continued. The water injection rate remained at 410 BWPD and the injection pressure at 220 psig.

4. August 25, 1979

Methanol injection was discontinued after injection for 48 hours. Ethanol, at 4000 ppm, was injected during the remainder of the injection period as a chemical tag.

5. August 26, 1979

Ethanol injection was stopped after 24 hours. The chemically tagged water was displaced down the hole by Madison injection water to the formation face, at which time the water injection was terminated and the well shut-in for the soak period. The total volume of chemically tagged water was 1230 barrels.

6. August 26 - 29, 1979

The test well remained shut-in for the chemical reaction, hydrolysis between propyl formate and water, to occur in the reservoir.

7. August 30 - September 5, 1979

The test well was placed on production at a reduced rate of 400 BWPD. Returning chemical concentrations were measured. Much sand was produced and sampling was difficult.

The results of the main test injection rate and concentration measurements are in Appendix A and the production rate and concentration measurements in Appendix B. It was very difficult to arrive at a unique solution since the wellbore conditions complicated matters. Initial analysis of the data indicated that a minimum of two zones were present, each producing a different percentage of water than they were accepting. A moderate drift rate and very high dispersion also complicated the analysis. Finally, laboratory studies to determine the partitioning coefficient were hampered by the formation of emulsions as discussed earlier.

The analysis for multiple zones was difficult because production profiles were not run and injection profiles were not sufficiently definitive. Therefore, the production and injection volumes from the various zones had to be determined by trial and error. This required a considerable number of trial and error computer runs. Analysis of the results led to the conclusion that at least three, and probably four, separate zones, each accepting and producing water at different rates, were present in the formation. The description of each zone is presented on Table 20. Once the zones were matched, a partitioning coefficient of 6.0 was chosen because it was an average of the best data obtained in the laboratory and was consistent with the partitioning coefficient determined for propyl formate with other oils.

All indications are that the calculated high dispersion of 1.2 was caused by a higher than expected porosity. This was most likely due to the production of sand from the zone when the well was produced after the additional abrasijet perforating job. This complicated the data analysis, making it difficult to accurately measure the oil saturation and provide enough definitive data. If a fourth zone was added, the computer match would be even closer and the dispersion coefficient much lower than 1.2. However, much additional time would be required to add a fourth zone to the model with little additional benefit. The difference between residual oil saturations in the three zones shows a wide variance and is not sensitive to the matching of the data.

The results of the match of the field data are presented in Figure 36.

A schematic of the reservoir showing chemical invasion is presented in Figure 37.

Figure 38 shows the propanol curve as it varies with residual oil saturation with all else held constant. These analyses indicate that the residual oil saturations in the vicinity of the test well are $5\% \pm 5\%$ for Zone 1, $10\% \pm 5\%$ for Zone 2, and $25\% \pm 10\%$ for Zone 3.

ANALYSIS OF EXPENDITURES

Table 21 presents an analysis of the expenditures for the Bell Creek residual oil saturation measurement program. The total cost for the project, through abandonment of the well, is estimated to be approximately \$1,093,415.

Drilling to Casing Point

Drilling the well to 4632 feet in the Muddy Silt, approximately 18 feet above the Muddy Sandstone pay, and casing with 10-3/4 inch diameter 40.5 lb., 41.5 lb. and 51 lb. per foot casing required expenditures of \$239,910. Major items within this category were \$17,995 for 304 feet of 16 inch diameter surface casing, \$67,434 for 4630 feet of 10-3/4 inch diameter long string, \$55,334 for contract drilling and \$23,000 for the rig move.

Pressure Coring Services

A service unit was used to drill out from under the long string to the coring point at 4646 feet KB, pressure coring from 4646 feet KB to 4660 feet KB, and for drilling to total depth in the Skull Creek shale at 4705 feet KB. The total expenditure required for these operations was \$299,612. Major items within this category were \$95,460 for a service unit, \$46,071 for pressure coring service, \$40,245 for low water loss coring mud, \$12,498 for nitrogen to decrease the drilling fluid hydrostatic head, and \$69,202 in miscellaneous rental equipment and supplies. These expenditures are inordinately high due to operations being conducted under severe winter conditions.

Fiberglass Liner

Installation of a fiberglass liner to maintain the integrity of the open hole interval from 4630 feet KB to

4705 feet KB required an expenditure of \$84,329. Major items within this category were \$39,484 for a service unit, \$5,652 for the fiberglass liner, \$14,444 for the liner hanger, and \$7,163 for abrasijet perforating services.

Sidewall Cores (Schlumberger)

Failure to obtain a pressure core through the Muddy Sandstone pay necessitated obtaining sidewall cores for purposes of obtaining a correlation base with the open hole logs. Sidewall coring operations required an expenditure of \$2,886.

Conventional Open Hole Logs (Schlumberger)

The open hole logging program included the following log suites: Dual Induction Spherically Focused log, Dual Laterolog Microspherically Focused log, Formation Compensated Density Compensated Neutron log with Gamma Ray, and the Borehole Compensated Sonic log with Gamma Ray. The total service, including digital recording, required an expenditure of \$34,777.

Electromagnetic Propagation Log (Schlumberger)

The Electromagnetic Propagation log was, at the time of its use, considered an experimental tool. Consequently, only third party transport charges were incurred. The Electromagnetic Propagation log required an expenditure of \$2,886.

Dielectric Constant Log (Gearhart-Owens)

The Dielectric Constant log program included a Formation Compensated Density Sidewall Neutron log to verify the porosity values from third party open hole logs. The total service, including digital recording, required an expenditure of \$10,591.

Nuclear Magnetism Log (Schlumberger)

The Nuclear Magnetism log for residual oil saturation determination requires the injection of paramagnetic ions into the formation to suppress the formation water signal, and the addition of magnetite to the drilling fluid to kill extraneous borehole signal. Drilling fluid additives were approximately 70% of the \$15,853 expenditure required for the Nuclear Magnetism log.

Carbon-Oxygen Log (Dresser Atlas)

The total expenditure required for the open hole Carbon-Oxygen log was \$8,678. The cased hole application of the Carbon-Oxygen log required an expenditure of \$5,204.

Spectralog (Dresser Atlas)

The total expenditure required to run the Spectralog was \$2,405.

Log-Inject-Log (Schlumberger)

The total expenditure required to run the log-inject-log program to determine residual oil saturation was \$50,673. Major items within this category were \$27,519 for the logging surveys, \$2,944 for an injection profile, \$3,659 for brine related items, and \$4,736 for a service unit.

Partitioning Tracer Test (Union Oil of California)

The total expenditure required for the partitioning tracer test was \$172,859. Major items within this category were \$83,876 for Union Oil Company of California field and laboratory services, \$7,994 for chemicals necessary for the partitioning tracer test, \$18,971 for service unit, \$6,702 for remedial squeeze cementing services and abrasijet perforating services, \$8,936 for production and injection profiles, and \$13,521 for a dual packer.

The Union expenditures were necessitated by the need to confirm fluid drift in the area immediate to the test well, and for numerous trial and error numerical simulation runs required to match the partitioning tracer test field data to determine residual oil saturation. The expenditure for a service unit, squeeze cementing, and abrasijet perforating was necessitated to mitigate sand production that resulted when several feet of Muddy Sandstone interval, at the base of the pay, was jet perforated to insure that the entire productive interval was accepting fluid directly from the wellbore. The costs incurred for injection and production profiles, and for downhole equipment were required to run both the drift test and the partitioning tracer test.

Engineering Services

Engineering services expenditure for test design, field operations and analysis of measurement information (including consultants) was \$89,969.

Travel

Travel expense for engineering personnel through inception, implementation and analysis of the various residual oil saturation measurements was \$11,106.

Administrative Labor and Overhead

Administrative labor, overhead and miscellaneous expense associated with assembling the monthly and quarterly reports, along with the final report was \$14,576.

Well Abandonment and Site Restoration

The expenditures required to plug and abandon the test well and restore the land to Federal Government environmental standards is estimated to be \$25,000.

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TABLE 1

TECHNIQUES USING INDIRECT METHODS
TO DETERMINE RESIDUAL OIL SATURATION

<u>Device</u>	<u>Physical Phenomenon</u>
Dual Laterolog Dual Induction Log Microspherically Focused Log Spherically Focused Log	Electrical Resistivity
Electromagnetic Propagation Log Dielectric Constant Log	Phase shift of electro- magnetic waves at 1.1 GHZ and 30 MHZ, respectively
Thermal Neutron Decay Time Log	Elastic Scattering of Hydrogen Atoms
Propyl Formate Tracers, Lab Analysis; Numerical Simulation; Log, Fluid & Core Data	Partition Chromatography

TABLE 2

TECHNIQUES USING DIRECT METHODS
TO DETERMINE RESIDUAL OIL SATURATION

<u>Device</u>	<u>Physical Phenomenon</u>
Pressure Core Barrel	---
Continuous Carbon Oxygen Log Spectralog	Scattering of Neutrons by Carbon, Oxygen, Calcium, and Silicon Atoms
Nuclear Magnetism Log	Proton Free Precession Following Removal of Induced Magnetism

TABLE 3

SUMMARY
RESIDUAL OIL SATURATION FROM NEAR WELLBORE DEVICES

<u>Technique</u>	<u>Maximum</u>	<u>Minimum</u>	<u>Average</u>
Spherically Focused Log	59%	12%	30.2%
Microspherically Focused Log	49%	12%	28.1%
Electromagnetic Propagation Log	47%	7%	25.4%
Dielectric Constant Log	60%	7%	31.9%
Nuclear Magnetism Log	69%	24%	47.8%
Carbon Oxygen Log			
Open Hole	46%	23%	34.2%
Through Fiberglass	46%	23%	33.6%
Log-Inject-Log	78%	4%	31.2%
Pressure Core	---	---	N/A

TABLE 4

SUMMARY
RESIDUAL OIL SATURATION FROM DEEP INVESTIGATION DEVICES

<u>Technique</u>	<u>Residual Oil Saturation</u>		
	<u>Maximum</u>	<u>Minimum</u>	<u>Average</u>
Dual Induction Log	51%	28%	39.2%
Dual Laterolog	55%	26%	43.5%
Partitioning Tracer	30%	5%	15.0%

TABLE 5

DRILLING FLUID SYSTEM PROPERTIES DURING PRESSURE CORING OPERATIONS

<u>Date</u>	<u>Drilling Fluid Weight (1)</u>	<u>Drilling Fluid Viscosity (2)</u>	<u>Plastic Viscosity</u>	<u>Yield Point</u>	<u>Water Loss cc</u>	<u>Spurt Loss cc</u>	<u>Mud Filtrate Spin Lattice Relaxation Time</u>	<u>Operation</u>
12/12/78	9.4 ppg	46 sec.	21	6	8.6	3.0	11.1	Coring
12/13/78	9.5 ppg	47 sec.	26	3	6.8	1.8	N/A	Coring
12/14/78	9.5 ppg	47 sec.	26	4	6.6	2.6	10.0	Coring
12/15/78	9.5 ppg	60 sec.	32	8	6.4	2.7	10.2	Coring
12/16/78	9.5 ppg	60 sec.	32	8	6.0	2.5	10.2	Coring
12/17/78	9.5 ppg	65 sec.	32	15	6.0	2.5	N/A	Drilling
12/18/78	9.5 ppg	83 sec.	68	29	6.4	N/A	10.8	Drilling
12/19/78	9.5 ppg	83 sec.	68	29	6.4	N/A	8.4 (3)	Logging

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- NOTES:
1. Mud Weight in Pounds per Gallon
 2. Mud Viscosity from Marsh Funnel in Seconds
 3. Spin Lattice Relaxation Time Taken December 19, 1978, was obtained after magnetite was added to the drilling fluid.

TABLE 6

SUMMARY OF PRESSURE CORING OPERATIONS

Core No.	Footage Interval KB Reference Depth	Foot Number	Coring Rate Minutes/Ft.	Bit Data		Nitrogen SCF/Bbl. Mud	Remarks
				WOB	RPM		
1	4641-4642	1	32	10K	60	50	
	4642-4643	2	19	10K	60	50	
	4643-4644	3	22	10K	60	50	
	4644-4645	4	10	10K	60	50	
	4645-4646	5	25	10K	60	50	
Core Recovery Data							
	Drilled:	5 feet					
	Recovered:	5 feet					
	Pressure on Barrel:	800 psi					
2	4646-4746	1	22	10K	60	88	
	4647-4648	2	30	10K	60	88	
Core Recovery Data:							
	Drilled:	2 feet					
	Recovered:	1.3 feet					
	Pressure on Barrel:	1800 psi					
3	4648-4649	1	128	<10K	60	82	Cored two feet very slowly to allow nitrogen rate to stabilize in the returns
	4649-4650	2	197	<10K	60	82	
	4650-4651	3	20	10K	60	82	
	4651-4652	4	48	10K	60	82	
	4652-4653	5	50	10K	60	82	
Core Recovery Data:							
	Drilled:	5 feet					
	Recovered:	3.8 feet					
	Pressure on Barrel:	2000 psi					

TABLE 6
(continued)

Core No.	Footage Interval KB Reference Depth	Foot Number	Coring Rate Minutes/Ft.	Bit Data		Nitrogen SCF/Bbl. Mud	Remarks
				WOB	RPM		
4	4653-4654	1	10	10K	60	0	Mud pump problems occurred causing wide fluctuations in circulating rate. Nitrogen bypassed to the mud pump suction through leaking valve seat causing nitrogenation of drilling mud to be terminated.
	4654-4655	2	147	10K	60	0	
	4655-4656	3	90	10K	60	0	
	4656-4657	4	95	10K	60	0	
	4657-4658	5	95	10K	60	0	
	4658-4659	6	80	10K	60	0	
	4659-4660	7	100	10K	60	0	

Core Recovery Data:

Drilled: 7 feet
Recovered: 0 feet
Pressure on Barrel: 2200 psi

TABLE 7
SIDEWALL CORE ANALYSIS

<u>Depth</u>	<u>Porosity %</u>	<u>Permeability md</u>	<u>Water Saturation %</u>	<u>Oil Saturation %</u>
4652	Shale	Shale	--	--
4653	Altered Core	Altered Core	--	--
4654	28.6	46	56	11
4655	30.4	110	53	14
4656	32.2	800	68	4
4657	22.0	34	60	6
4658	29.4	270	50	19
4659	26.8	240	61	10
4660	27.3	250	63	12
4661	30.9	234	56	14
4662	Shale	Shale	--	--
4663	31.6	735	52	21
4664	Shale	Shale	--	--

NOTE: Sidewall cores were analyzed at zero overburden pressure.

TABLE 8

PRODUCED WATER ANALYSIS

SOR #1
3rd sample taken after
swabbing 542 barrels
1-23-79

<u>CONSTITUENTS</u>	<u>MILLIGRAMS PER LITER</u>
Sodium	959
Calcium	30
Magnesium	7
Sulfate	3
Chloride	1,090
Carbonate	48
Bicarbonate	756
Iron (dissolved)	2.6
Total Dissolved Solids	2,460
Total Solids (calculated)	2,510
Total Hardness as CaCO_3	103
Specific Conductance @ 25°C	4,100 microohms/cm
pH	8.3
Rw	1.6 ohm meters @ 100°F

TABLE 9

CONVENTIONAL OPEN HOLE LOG ANALYSIS

Depth	<u>Porosity, %</u>		<u>Dual Induction-Spherically Focused Log</u>			<u>Dual Laterolog-Microspherically Focused Log</u>		
	ϕ_{DN}	ϕ_T^*	S_w %	S_{xo} %	<u>Flushed Zone</u> <u>Remaining Oil Saturation %</u>	S_w %	S_{xo} %	<u>Flushed Zone</u> <u>Remaining Oil Saturation %</u>
4650	21.8	20.8	100	100		96	100	
4651	20.0	18.0	100	100		89	100	
4652	21.5	20.6	76	83		84	92	
4653	24.5	21.8	71	88	12	74	76	24
4654	27.5	22.6	63	78	22	63	78	22
4655	29.0	20.9	67	84	16	58	88	12
4656	29.5	25.4	55	69	31	53	56	44
4657	29.0	25.8	52	41	59	51	51	49
4658	30.5	25.8	51	63	37	46	65	35
4659	32.0	27.5	49	62	38	45	58	42
4660	30.5	22.6	58	73	27	52	79	21
4661	29.5	18.6	72	86	14	63	86	14
4662	30.5	20.7	70	71	29	60	87	18
4663	26.0	20.0	98	100		79	99	
<u>Average Porosity:</u>			<u>Average Residual Oil Saturation</u>			<u>Average Residual Oil Saturation</u>		
Porosity, DN: 29.2%			Dual Induction Log: 39.2%			Dual Laterolog: 43.5%		
*Porosity, Sh. Cr.: 23.2%			Spherically Focused Log: 30.2%			Microspherically Focused Log: 28.1%		

*shale corrected porosity

TABLE 10

ELECTROMAGNETIC PROPAGATION LOG ANALYSIS

<u>Depth</u>	<u>Porosity, %</u>		<u>Residual Oil Saturation, %</u>
4650	21.5		0
4651	20.0		31
4652	21.5		30
4653	24.5	-TOP MUDDY-	27
4654	27.5		27
4655	29.0		31
4656	29.5		31
4657	29.0		47
4658	30.5		25
4659	32.0		21
4660	30.5		9
4661	29.5		17
4662	30.5	-BASE MUDDY-	19
4663	26.0		7
AVERAGE (PAY)	29.2%		25.4%

TABLE 11

DIELECTRIC CONSTANT LOG ANALYSIS

<u>Depth</u>	<u>Porosity, %</u>		<u>Residual Oil Saturation, %</u>
4650	21.5		--
4651	20.0		--
4652	21.5		14
4653	24.5	-TOP MUDDY-	39
4654	27.5		43
4655	29.0		16
4656	29.5		17
4657	29.0		37
4658	30.5		42
4659	32.0		60
4660	30.5		42
4661	29.5		7
4662	30.5	-BASE MUDDY-	16
4663	26.0		36
AVERAGE (PAY)	29.2%		31.9%

TABLE 12
NUCLEAR MAGNETISM LOG ANALYSIS

<u>Depth</u>	<u>Porosity, %</u>	<u>FFI</u>	<u>ROS, %</u>
4650	21.5	.01	5
4651	20.0	.02	10
4652	21.5	.04	19
4653	24.5	.06 -TOP MUDDY-	24
4654	27.5	.09	33
4655	29.0	.14	48
4656	29.5	.14	47
4657	29.0	.17	59
4658	30.5	.21	69
4659	32.0	.22	69
4660	30.5	.18	59
4661	29.5	.13	44
4662	30.5	.08-BASE MUDDY-	26
4663	26.0	.05	19
4664	21.0	.03	14
AVERAGE (PAY)	29.2%		47.8%

TABLE 13

CARBON-OXYGEN LOG ANALYSISOPEN HOLE: DECEMBER 20, 1978

<u>Depth</u>		<u>Residual Oil Saturation, %</u>
4650		1
4651		0
4652		7
4653	-TOP MUDDY-	23
4654		33
4655		41
4656		21
4657		36
4658		36
4659		46
4660		42
4661		30
4662	-BASE MUDDY-	34
AVERAGE (PAY)		34.2%

TABLE 14

CARBON-OXYGEN LOG ANALYSISFIBERGLASS LINER: APRIL 26, 1979

<u>Depth</u>		<u>Residual Oil Saturation, %</u>
4650		0
4651		12
4652		23
4653	-TOP MUDDY-	23
4654		27
4655		31
4656		22
4657		37
4658		37
4659		46
4660		43
4661		37
4662	-BASE MUDDY-	33
AVERAGE (PAY)		33.6%

TABLE 15

CLAY VOLUMES FROM SPECTRALOG ANALYSIS

<u>Depth</u>	<u>Percentages</u>			
	<u>K</u>	<u>U</u>	<u>TH</u>	<u>K/TH</u>
4645	5.2	5.2	100.0	100.0
4646	3.6	3.6	100.0	100.0
4647	6.7	6.7	100.0	100.0
4648	4.1	4.1	62.9	62.9
4649	6.4	6.4	44.4	44.4
4650	4.8	18.2	12.9	18.2
4651	8.1	12.6	13.4	13.4
4652	11.2	11.2	10.4	11.2
4653	17.9	17.9	9.5	17.9
4654	18.0	19.4	8.3	19.4
4655	18.3	20.6	9.3	20.6
4656	16.4	19.2	0.8	19.2
4657	15.2	25.8	1.0	25.8
4658	11.6	38.5	1.6	38.5
4659	17.0	47.6	0.9	47.6
4660	22.5	59.5	2.3	59.5
4661	33.4	70.1	7.2	70.1
4662	58.0	58.0	11.9	58.0
4663	77.7	77.7	19.7	77.7
4664	100.0	100.0	41.3	100.0

TABLE 16

X-RAY DIFFRACTION ANALYSIS OF SIDEWALL CORES

	<u>4648</u>	<u>4655</u>	<u>4662</u>
Mica	2-5%	10-15%	20-25%
Chlorite	2-5%	10-15%	15-20%
Feldspar	1-2%	2-5%	2-5%
Halite	5-10%	--	--
Hematite	--	--	Trace
Pyrite	--	--	Trace
Quartz	75-80%	60-65%	45-50%

• Indicates sample location on Figures 23 and 24.

TABLE 17

THERMAL DECAY TIME "L" LOG DATA, FRESH WATER PHASE

Depth	τ_{uF}	Gate #1	Gate #2	Gate #3	Gate #4	Gate #5	Gate #6	Gate #7	Gate #8	τ_u	σ
4648	200	21002	15554	13672	12903	12597	12590	12394	74208	211	21.1
4649	200	23882	16743	13953	12761	12497	12275	12397	73046	216	21.1
4650	200	30027	19209	13812	11423	10454	10168	9853	57638	257	17.7
4651	200	30024	19088	13204	10973	9479	9079	8729	51099	268	17.0
4652	200	30018	18339	12243	9743	8168	7724	7239	42373	274	16.6
4653	200	30015	18873	13110	10522	9392	8779	8352	49205	272	16.8
4654	200	30016	18428	12718	10170	9182	8831	8535	49963	252	18.0
4655	200	30016	20179	14194	11987	10303	9959	9428	55685	288	15.8
4656	200	30019	18484	12513	9731	8166	7740	7363	41720	283	16.1
4657	200	30002	19129	12847	9911	8233	7634	7262	41087	297	15.3
4658	200	30038	18477	11934	9189	7811	7005	6628	37696	286	14.9
4659	200	30023	19467	12786	9351	7822	6905	6276	35454	316	14.4
4660	200	30203	19101	12461	8994	7228	6375	5594	30929	324	14.1
4661	150	30030	18515	13342	9438	7353	5861	4947	23982	287	15.8
4662	100	30020	21159	15304	10926	8776	7040	5557	19873	248	18.4
4663	100	30022	20435	14224	10034	8269	6349	5042	19290	229	19.8
4664	100	30019	18039	12048	8488	7095	6199	5383	28246	164	27.2

NOTE: 1. Time (M,N) = $c \times 10^3$ sec.

2. Manual stop.

TABLE 18

THERMAL DECAY TIME "L" LOG DATA, SALT WATER PHASE

Depth	<u>Tau_F</u>	<u>Gate #1</u>	<u>Gate #2</u>	<u>Gate #3</u>	<u>Gate #4</u>	<u>Gate #5</u>	<u>Gate #6</u>	<u>Gate #7</u>	<u>Gate #8</u>	<u>Tau</u>	<u>Sigma</u>
4648	200	15427	12295	10668	10522	10363	10131	10099	59130	283	16.04
4649	100	37681	25557	18706	14851	12118	10354	9292	48440	247	18.4
4650	200	30161	25404	22509	21419	21089	20815	20535	122107	287	15.8
4651	150	30148	20155	15746	13076	11828	11205	10872	60530	239	19.04
4652	150	29154	19817	15763	13637	12902	12555	12110	67572	240	18.96
4653	100	30005	20444	15497	12760	11352	10651	10131	58063	160	28.48
4654	100	30058	20140	14468	11595	9868	9044	8406	47991	164	27.78
4655	100	30018	22596	18347	16443	15203	14510	14241	81779	168	27.12
4656	100	30003	19382	13751	10766	9318	8610	8043	45664	155	29.4
4657	100	30013	21927	17944	16129	14870	14561	14169	82131	154	29.48
4658	100	30007	19503	14082	11150	9502	8670	8080	46384	159	28.70
4659	100	30106	22193	36017	15780	14522	13880	13286	76547	166	27.48
4660	100	30005	22076	18039	15654	14432	14161	13350	78297	164	27.80
4661	100	30006	22328	18615	16272	15334	14701	14388	81916	171	26.66
4662	100	30064	22201	18039	15825	14547	14144	13441	77979	168	27.10
4663	100	30002	23288	19651	18417	17433	17134	16516	97459	158	28.89
4664	100	30004	23483	20150	18620	17998	17955	17187	100981	161	28.30

NOTE: 1. Time (M,N) = 3×10^3 sec.
 2. Manual Stop.

TABLE 19

LOG-INJECT-LOG ANALYSISRESIDUAL OIL SATURATION

<u>Depth</u>	<u>Porosity %</u>		<u>Residual Oil Saturation %</u>
4650	21.5		82
4651	20.0		59
4652	21.5		61
4653	24.5	-TOP MUDDY-	37
4654	27.5		9
4655	29.0		13
4656	29.5		17
4657	29.0		4
4658	30.5		18
4659	32.0		32
4660	30.5		45
4661	29.5		59
4662	30.5	-BASE MUDDY-	78
AVERAGE (PAY): 29.9%			31.2%

TABLE 20

PARTITIONING TRACER ZONE DESCRIPTION
OF RESIDUAL OIL SATURATION

	<u>Zone #1</u>	<u>Zone #2</u>	<u>Zone #3</u>
Porosity - Thickness	1.5	1.5	.6
Residual Oil Saturation	5% $\pm$ 5%	10% $\pm$ 5%	30% $\pm$ 10%
Reaction Rate	.14	.123	.28
Injection (% of Total Volume)	31% (1st day) 42% (2nd&3rd)	44% 49%	5% 2%
Production (% of Total Volume)	32%	47%	20%

TABLE 21

BELL CREEK RESIDUAL OIL SATURATION MEASUREMENTANALYSIS OF EXPENDITURES

<u>CATEGORY</u>	<u>DETAILED COST</u>	<u>TOTAL COST</u>
Drilling to Casing Point		
Land Damages	\$ 1,668	
Road and Location	17,118	
Rig Move	23,000	
Drilling	55,334	
Surface Casing	17,995	
Long String	67,434	
Cementing Services	10,683	
Casing Head	9,069	
Drilling Mud	8,677	
Casing Services	5,522	
Company Labor	12,542	
Miscellaneous Equipment & Supplies	10,868	\$239,910
Pressure Coring		
Service Unit	\$95,460	
DOWDCO Services	46,071	
DOWDCO Diamond Bit	3,886	
Mud Handling Equipment	16,501	
NOWSCO Services	12,498	
Coring Mud	40,245	
Core Analysis	4,912	
Core Transport	1,976	
Company Labor	8,861	
Miscellaneous Equipment & Supplies	69,202	\$299,612
Fiberglass Liner		
Service Unit	\$39,484	
Fiberglass Liner	5,652	
Liner Hanger	14,444	
Cement Bond Log	2,505	
Cementing Services	2,284	
Abrasijet Perforating	7,163	
Tool Rental	5,831	
Company Labor	6,966	\$ 84,329

TABLE 21

(continued)

<u>CATEGORY</u>	<u>DETAILED COST</u>	<u>TOTAL COST</u>
Sidewall Cores		
Field Operations	\$ 2,502	
Core Analysis	384	\$ 2,886
Conventional Open Hole Logs		
Dual Induction-Spherically Focused Log	4,268	
Dual Laterolog-Microspherically Focused Log	3,728	
Formation Compensated Density-Compensated Neutron Log w/Gamma Ray	3,893	
Borehole Compensated Sonic Log w/Gamma Ray	4,672	
Miscellaneous Services	18,216	\$34,777
Electromagnetic Propagation Log		
Electromagnetic Propagation Tool	N.C.	
Miscellaneous Services	\$ 2,886	\$ 2,886
Dielectric Constant Log		
Dielectric Constant Log	\$ 2,064	
Formation Compensated Density-Sidewall Neutron Log w/Gamma Ray	3,293	
Miscellaneous Services	5,234	\$10,591
Nuclear Magnetism Log		
Nuclear Magnetism Log	\$ 3,037	
Drilling Fluid Additives for Water Signal Suppression	11,233	
Miscellaneous Services	1,583	\$15,853
Carbon-Oxygen Log (Open Hole)		
Carbon-Oxygen Log	\$ 6,288	
Miscellaneous Services	2,390	\$ 8,678
Carbon-Oxygen Log (Cased Hole)		
Carbon-Oxygen Log	\$ 4,504	
Mast Truck	138	
Miscellaneous Services	562	\$ 5,204

TABLE 21
(continued)

<u>CATEGORY</u>	<u>DETAILED COST</u>	<u>TOTAL COST</u>
Spectralog		
Spectralog	\$ 1,705	
Mast Truck	138	
Miscellaneous Services	562	\$ 2,405
Log-Inject-Log		
Formation-Compensated Density- Compensated Neutron Log w/Gamma Ray	\$ 3,895	
Thermal Decay Time-K Log (F.W.)	4,517	
Thermal Decay Time-L Log (F.W.)	5,000	
Mast Truck	825	
Miscellaneous Services	2,355	
Thermal Decay Time-K Log (B.W.)	4,517	
Thermal Decay Time-L Log (B.W.)	8,000	
Mast Truck	275	
Miscellaneous Services	490	
Brine Mixing and Storage	3,659	
License Fee (Shell)	625	
Service Unit	4,736	
Injection Profile	2,944	
Miscellaneous Equipment & Supplies	303	
Company Labor	8,532	\$ 50,673
Partitioning Tracer Test		
Union Oil Company Field & Laboratory Services	83,976	
Chemicals	7,994	
Electrical System Construction	4,377	
Production Facilities	7,965	
Injection Facilities	7,580	
Service Unit	18,971	
Cement Squeeze, Abrasijet Service	6,702	
Injection & Production Profiles	8,936	
Dual Packer	13,521	
Tubing Head	2,554	
Wellhead Valves, etc.	3,226	
Miscellaneous Equipment & Supplies	1,412	
Company Labor	5,645	\$172,859
Engineering Services		\$ 89,969
Travel		\$ 11,106
Administrative Labor & Overhead		\$ 14,576
Sub Total		\$1,046,314

TABLE 21

(continued)

<u>CATEGORY</u>	<u>DETAILED COST</u>	<u>TOTAL COST</u>
Well Abandonment & Site Restoration (Estimated)		\$ 25,000
Fee		\$ 10,125
Tank Insulation for Minitest Micellar Components		\$ <u>11,976</u>
TOTAL COST.....		<u>\$1,093,413</u>

FIGURE 1
 FLOW DIAGRAM OF
 RESIDUAL OIL SATURATION TESTING OPERATIONS

RESIDUAL OIL SATURATION EVALUATION AREA

FIGURE 3
SCHEMATIC OF PRESSURE RETAINING CORE BARREL

FIGURE 4

WELLBORE DIAGRAM DURING LOGGING OPERATIONS

NOTE : ALL DEPTHS REFERENCED TO KELLY BUSHING ELEVATION

FIGURE 5

DUAL INDUCTION-SPHERICALLY FOCUSED LOG

GARY ENERGY CORPORATION

SOR #1

SE SE Sec. 1, T8S-R54E

BELL CREEK FIELD

POWDER RIVER COUNTY, MONTANA

Date: 12-19-78

Depth-Driller: 4700

Depth-Logger: 4688

Bottom Logged Interval: 4682

Top Logged Interval: 4629

Casing-Driller: 10 3/4 @ 4631

Casing-Logger: 4629

Type Fluid in Hole: FGM

Density & Viscosity: 9.6 80

pH & Fluid Loss: 8.0 6.8ml

Rm @ Meas. Temp.: 1.91 @ 55°F

Rmf @ Meas. Temp.: 1.42 @ 55°F

Rmc @ Meas. Temp.: 1.20 @ 55°F

Rm @ BHT: 1.10 @ 100°F

Max. Rec. Temp. Deg. F.: 100°

FIGURE 6
SIMULTANEOUS DUAL LATEROLOG
MICRO-SPHERICALLY FOCUSED LOG
GARY ENERGY CORPORATION
SOR #1
 SE SE Sec. 1, T8S-R54E
 BELL CREEK FIELD
 POWDER RIVER COUNTY, MONTANA

Date: 12-19-78
 Depth-Driller: 4700
 Depth-Logger: 4687
 Bottom Logged Interval: 4673
 Top Logged Interval: 4629
 Casing-Driller: 10 3/4 @ 4631
 Casing-Logger: 4629
 Type Fluid in Hole: FGM

Density & Viscosity: 9.6 80
 pH & Fluid Loss: 8.0 6.8 ml
 Rm @ Meas. Temp.: 1.91 @ 55° F
 Rmf @ Meas. Temp.: 1.42 @ 55° F
 Rmc @ Meas. Temp.: 1.20 @ 55° F
 Rm @ BHT: 1.10 @ 100° F
 Max. Rec. Temp. Deg. F.: 100°

FIGURE 7 BOREHOLE COMPENSATED SONIC LOG

GARY ENERGY CORPORATION
SOR #1
SE SE Sec. 1, T8S-R54E
BELL CREEK FIELD
POWDER RIVER COUNTY, MONTANA

Date: 10-25-78
Depth - Driller: 4632
Depth - Logger: 4629
Bottom Logged Interval: 4618
Top Logged Interval: 300
Casing - Driller: 16 @ 304
Casing - Logger: 300
Type Fluid in Hole: FGM

Density & Viscosity: 9.2 63
pH & Fluid Loss: 8.5 13.2ml
Rm @ Meas. Temp.: 6.18 @ 60°F
Rmf @ Meas. Temp.: 3.16 @ 60°F
Rmc @ Meas. Temp.: 4.40 @ 60°F
Rm @ BHT: 3.90 @ 99°F
Max. Rec. Temp. Deg. F.: 99°

FIGURE 8 **FORMATION COMPENSATED DENSITY -** **COMPENSATED NEUTRON LOG** **GARY ENERGY CORPORATION**

SOR #1
SE SE Sec. 1, T8S-R54E
BELL CREEK FIELD
POWDER RIVER COUNTY, MONTANA

Date: 12-19-78

Depth-Driller: 4700

Depth-Logger: 4686

Bottom Logged Interval: 4685FDC 4670CNL Rmf @ Meas. Temp.: 1.42 @ 55°F

Top Logged Interval: 4629

Casing-Driller: 10 3/4 @ 4631

Casing-Logger: 4629

Type Fluid in Hole: FGM

Density & Viscosity: 9.6 80

pH & Fluid Loss: 8.0 6.8ml

Rm @ Meas. Temp.: 1.91 @ 55°F

Rmc @ Meas. Temp.: 1.20 @ 55°F

Rm @ BHT: 1.10 @ 100°F

Max. Rec. Temp. Deg. F.: 100°

FIGURE 9
DETERMINATION OF CEMENTATION EXPONENT

FIGURE 10 ELECTROMAGNETIC PROPAGATION LOG

GARY ENERGY CORPORATION
SOR #1
SE SE Sec. 1, T8S-R54E
BELL CREEK FIELD
POWDER RIVER COUNTY, MONTANA

Date: 12-20-78
Depth-Driller: 4700
Depth-Logger: 4688
Bottom Logged Interval: 4684
Top Logged Interval: 4620
Casing-Driller: 10 3/4 @ 4631
Casing-Logger: 4630
Type Fluid in Hole: FGM

Density & Viscosity: 9.6 80
pH & Fluid Loss: 8.0 6.8ml
Rm @ Meas. Temp.: 1.91 @ 55°F
Rmf @ Meas. Temp.: 1.42 @ 55°F
Rmc @ Meas. Temp.: 1.20 @ 55°F
Rm @ BHT: 1.10 @ 100°F
Max. Rec. Temp. Deg. F.: 100°

FIGURE II
DIELECTRIC CONSTANT LOG INTERPRETATION CROSSPLOT

FIGURE 12

DIELECTRIC CONSTANT LOG

GARY ENERGY CORPORATION
 SOR #1
 SE SE Sec. 1, T8S-R54E
 BELL CREEK FIELD
 POWDER RIVER COUNTY, MONTANA

Date: 12-22-78
 Depth-Driller: 4700
 Depth-Logger: 4691
 Bottom Logged Interval: 4682
 Top Logged Interval: 4631
 Casing-Driller: 10 3/4 @ 4631
 Casing-Logger: 4631
 Type Fluid in Hole: FGM

Density & Viscosity: 9.5 83
 pH & Fluid Loss: 8.0 6.4cc
 Rm @ Meas. Temp.: 1.98 @ 74°F
 Rmf @ Meas. Temp.: 1.94 @ 72°F
 Rmc @ Meas. Temp.: 2.2 @ 72°F
 Rm @ BHT: 1.4 @ 105°F
 Max. Rec. Temp. Deg. F.: 105°

FIGURE 13

MULTIECHO T_2 DECAY OF SIGNAL FROM A MIXTURE
OF HALF CRUDE AND HALF TREATED MUD FILTRATE

FIGURE 14 NUCLEAR MAGNETISM LOG

GARY ENERGY CORPORATION
SOR #1
SE SE Sec. 1, T8S-R54E
BELL CREEK FIELD
POWDER RIVER COUNTY, MONTANA

Date: 12-19-78
Depth-Driller: 4700
Depth-Logger: 4688
Bottom Logged Interval: 4680
Top Logged Interval: 4630
Casing-Driller: 10 3/4 @ 4631
Casing-Logger: 4630
Type Fluid in Hole: FGM

Density & Viscosity: 9.6 80
pH & Fluid Loss: 8.0 6.8 ml
Rm @ Meas. Temp.: 1.91 @ 55° F
Rmf @ Meas. Temp.: 1.42 @ 55° F
Rmc @ Meas. Temp.: 1.20 @ 55° F
Rm @ BHT: 1.10 @ 100° F
Max. Rec. Temp. Deg. F.: 100°

Figure 15 Nuclear Magnetism Log , Processed

Repeat Passes Showing Processed NML Data. Pass Shown as Dashed Line Had Little Noise While Pass Shown as Solid Line Had Considerable Anomalous Signal

FIGURE 16 NUCLEAR MAGNETISM LOG
PROCESSED LOG COMPARED TO FIELD LOG

Note: Frequency Processed Log 2400 Hz - 2800 Hz

FIGURE 17

WELLBORE DIAGRAM FOLLOWING FIBERGLASS LINER INSTALLATION

FIGURE 18
Fiberglass Liner :
Picking Up Landing Assembly

FIGURE 19
Fiberglass Liner :
Making Up A Connection With Epoxy

FIGURE 20
Fiberglass Liner:
Completed Connection
Ready To Run In Hole

FIGURE 21

CARBON-OXYGEN LOG

GARY ENERGY CORPORATION
SOR #1
 SE SE Sec. 1, T8S-R54E
 BELL CREEK FIELD
 POWDER RIVER COUNTY, MONTANA

Date: 12-20-78
 Depth-Driller: 4700
 Depth-Logger: 4688
 Bottom Logged Interval: 4682
 Top Logged Interval: 4600

Type Fluid in Hole: FRESH GEL MUD
 Salinity ppm. Cl.: 3000
 Density & Viscosity: 9.6 80
 Level: FULL
 Max. Rec. Temp. Deg. F.: 100°F

FIGURE 22

CARBON-OXYGEN LOG

GARY ENERGY CORPORATION
SOR #1
 SE SE Sec. 1, T8S-R54E
 BELL CREEK FIELD
 POWDER RIVER COUNTY, MONTANA

Date: 4-26-79

Depth - Driller: 4691

Depth - Logger: 4680

Bottom Logged Interval: 4672

Top Logged Interval: 4610

Type Fluid in Hole: FORMATION WATER

Salinity ppm. Cl.: NA

Density & Viscosity: NA NA

Level: @ 2530

Max. Rec. Temp. Deg. F.: 107°F

FIGURE 23 SPECTRALOG

GARY ENERGY CORPORATION
SOR #1
SE SE Sec. 1, T8S-R54 E
BELL CREEK FIELD
POWDER RIVER COUNTY, MONTANA

Date: 4-26-79
Depth-Driller: 4691
Depth-Logger: 4680
Bottom Logged Interval: 4676
Top Logged Interval: 4580

Type Fluid in Hole: FORMATION WATER
Salinity ppm. Cl.: NA
Density & Viscosity: NA NA
Level: @ 2530
Max. Rec. Temp. Deg. F.: 107°F

FIGURE 24 SPECTRALOG ANALYSIS

Figure 25

Correllation Between Compensated Formation Density Log And Injection Profile

COMPENSATED FORMATION
DENSITY LOG
12-19-78
(Original Completion)

INJECTIVITY SURVEY
VELOCITY SURVEY
5-2-79
(Before Log-Inject-Log)

GAMMA RAY BULK DENSITY

0 200 2.0 2.5 3.0

TEMPERATURE SURVEY °F

94 96 98 100 102 104

FIGURE 27

DUAL SPACING THERMAL NEUTRON DECAY TIME "K" LOG

GARY ENERGY CORPORATION
 SOR #1
 SE SE Sec. 1, T8 S-R54 E
 BELL CREEK FIELD
 POWDER RIVER COUNTY, MONTANA

Date: 5-20-79
 Depth-Driller: 4686
 Depth-Logger: 4686
 Bottom Logged Interval: 4679
 Top Logged Interval: 4600

Type Fluid in Hole: SALT WATER
 Salinity ppm. Cl.: 130,000 PPM
 Density Lb./Gal.: NA
 Level: FULL
 Max. Rec. Temp. Deg. F.: NA

FIGURE 28
PARTITIONING COEFFICIENT

FIGURE 29 BELL CREEK REACTION RATE EXPERIMENTS

FIGURE 30

WELLBORE CONFIGURATION DURING DRIFT RATE MEASUREMENTS

NOTE : ALL DEPTHS REFERENCED TO KELLY BUSHING ELEVATION

FIGURE 31

DRIFT TEST NO. 1 RETURNING METHANOL CONCENTRATION

Figure 32

Correlation Between Formation Compensated Density Log And Radioactive Injection And Production Profiles During Drift Test NO. 1

COMPENSATED FORMATION
DENSITY LOG
12-19-78
(Original Completion)

INJECTIVITY SURVEY
VELOCITY SURVEY
6-24-79
(Before Perforating Fiberglass Liner)

FLUID ENTRY SURVEY
6-26-79
(Before Perforating Fiberglass Liner)

GAMMA RAY BULK DENSITY

0 200 2.0 2.5 3.0

TEMPERATURE SURVEY

80 82 84 86 88 90

TEMPERATURE SURVEY

88 86 84 82 80 78

FIGURE 33
DRIFT TEST NO. 3
RETURNING CHEMICAL CONCENTRATIONS

Figure 34

Correlation Between Formation Compensated Density Log And Radioactive Injection Profile Before Partitioning Tracer Test

COMPENSATED FORMATION
DENSITY LOG
12-19-78

INJECTION SURVEY
VELOCITY SURVEY
8-14-79

106

FIGURE 35

WELLBORE CONFIGURATION DURING PARTITIONING TRACER TEST

NOTE: ALL DEPTHS REFERENCED TO KELLY BUSHING ELEVATION

FIGURE 36

MATCH OF FIELD DATA WITH RESIDUAL OIL SATURATION

FIGURE 37

SCHEMATIC OF RESERVOIR CROSS SECTION SHOWING CHEMICAL INVASION

FIGURE 38

MATCH OF PROPANOL CONCENTRATION WITH RESIDUAL OIL SATURATION

INJECTION DATA

APPENDIX A

PAGE 1

MAIN PARTITIONING TRACER TEST

TIME	ELAPSED TIME	SAMPLE NUMBER	METER # 1		RATE B/D
	HOURS		BBLS.	CUM.	
1700	0	1	5975.6	0	398
1730	0.50	2	5983.9	8	398
1800	1.00	3	5992.3	17	403
1830	1.50	4	6000.7	25	403
1900	2.00	5	6009.1	34	403
1930	2.50	6	6017.6	42	408
2000	3.00	7	6025.1	50	360
2030	3.50	8	6034.6	59	456
2100	4.00	9	6043.1	68	408
2130	4.50	10	6051.7	76	413
2200	5.00	11	6060.2	85	408
2230	5.50	12	6068.8	93	413
2300	6.00	13	6077.4	102	413
2330	6.50	14	6085.9	110	408
2400	7.00	15	6094.5	119	413
30	7.50	16	6103.1	128	413
100	8.00	17	6111.7	136	413
130	8.50	18	6120.3	145	413
200	9.00	19	6128.9	153	413
230	9.50	20	6137.5	162	413
300	10.00	21	6146.1	171	413
330	10.50	22	6154.8	179	418
400	11.00	23	6163.4	188	413
430	11.50	24	6172.0	196	413
500	12.00	25	6180.7	205	418
530	12.50	26	6189.4	214	418
600	13.00	27	6198.0	222	413
630	13.50	28	6206.7	231	418
700	14.00	29	6215.4	240	418
730	14.50	30	6224.0	248	413
800	15.00	31	6232.6	257	413
830	15.50	32	6241.4	266	422
900	16.00	33	6249.6	274	394
930	16.50	34	6258.1	283	408
1000	17.00	35	6266.4	291	398
1030	17.50	36	6274.9	299	408
1100	18.00	37	6283.3	308	403
1130	18.50	38	6291.8	316	408
1200	19.00	39	6300.2	325	403
1230	19.50	40	6308.6	333	403
1300	20.00	41	6316.9	341	398
1330	20.50	42	6325.3	350	403
1400	21.00	43	6333.6	358	398
1430	21.50	44	6342.0	366	403
1500	22.00	45	6350.5	375	408
1530	22.50	46	6358.8	383	398
1600	23.00	47	6367.0	391	394
1630	23.50	48	6375.5	400	408
1700	24.00	49	6383.9	408	403
1700	24.00	49	6383.9	408	0
1700	24.00	49	6383.9	408	0

TIME	ELAPSED TIME HOURS	SAMPLE NUMBER	METER # 1		RATE B/D
			BBLs.	CUM.	
1730	24.50	50	6392.1	417	394
1800	25.00	51	6400.5	425	403
1830	25.50	52	6408.9	433	403
1900	26.00	53	6417.3	442	403
1930	26.50	54	6425.8	450	408
2000	27.00	55	6434.1	459	398
2030	27.50	56	6442.5	467	403
2100	28.00	57	6450.9	475	403
2130	28.50	58	6459.4	484	408
2200	29.00	59	6467.9	492	408
2230	29.50	60	6476.4	501	408
2300	30.00	61	6484.9	509	408
2330	30.50	62	6493.4	518	408
2400	31.00	63	6501.9	526	408
30	31.50	64	6510.3	535	403
100	32.00	65	6518.8	543	408
130	32.50	66	6527.4	552	413
200	33.00	67	6536.0	560	413
230	33.50	68	6544.6	569	413
300	34.00	69	6553.2	578	413
330	34.50	70	6561.7	586	408
400	35.00	71	6570.3	595	413
430	35.50	72	6578.9	603	413
500	36.00	73	6587.5	612	413
530	36.50	74	6596.1	621	413
600	37.00	75	6604.7	629	413
630	37.50	76	6613.3	638	413
700	38.00	77	6621.8	646	408
730	38.50	78	6630.5	655	418
800	39.00	79	6639.0	663	408
830	39.50	80	6647.6	672	413
900	40.00	81	6656.2	681	413
930	40.50	82	6664.9	689	418
1000	41.00	83	6673.3	698	403
1030	41.50	84	6681.9	706	413
1100	42.00	85	6690.5	715	413
1130	42.50	86	6699.1	724	413
1200	43.00	87	6707.6	732	408
1230	43.50	88	6716.3	741	418
1300	44.00	89	6724.8	749	408
1330	44.50	90	6733.3	758	418
1400	45.00	91	6742.0	766	418
1430	45.50	92	6750.5	775	408
1500	46.00	93	6759.0	783	408
1530	46.50	94	6767.5	792	408
1600	47.00	95	6776.0	800	408
1630	47.50	96	6784.4	809	403
1700	48.00	97	6792.9	817	408
1730	48.50	98	6801.3	826	403

TIME	ELAPSED TIME HOURS	SAMPLE NUMBER	METER # 1		RATE B/D
			BBLs.	CUM.	
1800	49.00	99	6809.8	834	408
1830	49.50	100	6818.3	843	408
1900	50.00	101	6826.8	851	408
1930	50.50	102	6835.3	860	408
2000	51.00	103	6843.9	868	413
2030	51.50	104	6852.4	877	408
2100	52.00	105	6861.0	885	413
2130	52.50	106	6869.6	894	413
2200	53.00	107	6878.2	903	413
2230	53.50	108	6886.8	911	413
2300	54.00	109	6895.4	920	413
2330	54.50	110	6903.0	927	365
2400	55.00	111	6912.6	937	461
30	55.50	112	6921.1	946	408
100	56.00	113	6929.7	954	413
130	56.50	114	6938.4	963	418
200	57.00	115	6947.3	972	427
230	57.50	116	6955.0	979	370
300	58.00	117	6964.7	989	466
330	58.50	118	6972.4	997	370
400	59.00	119	6981.1	1006	418
430	59.50	120	6990.8	1015	466
500	60.00	121	6999.5	1024	418
530	60.50	122	7007.2	1032	370
600	61.00	123	7016.0	1040	422
630	61.50	124	7025.7	1050	466
700	62.00	125	7034.3	1059	413
730	62.50	126	7043.0	1067	418
800	63.00	127	7051.7	1076	418
830	63.50	128	7060.4	1085	418
900	64.00	129	7068.9	1093	408
930	64.50	130	7077.8	1102	427
1000	65.00	131	7086.4	1111	413
1030	65.50	132	7095.1	1120	418
1100	66.00	133	7103.8	1128	418
1130	66.50	134	7112.3	1137	408
1200	67.00	135	7120.9	1145	413
1230	67.50	136	7129.6	1154	418
1300	68.00	137	7138.0	1162	403
1330	68.50	138	7146.6	1171	413
1330	68.50	138	7146.6	1171	0
1330	68.50	138	7146.6	1171	0
1400	69.00	139	7155.3	1180	418
1430	69.50	140	7163.9	1188	403
1500	70.00	141	7172.3	1197	403
1530	70.50	142	7181.0	1205	418
1600	71.00	143	7189.6	1214	413
1630	71.50	144	7198.2	1223	413
1700	72.00	145	7206.8	1231	413

SAMPLE NUMBER	GALLON	MEOH		GALLON	ETOH		GALLON	PF	
		METER CUM	RATE		METER CUM	RATE		METER CUM	RATE
1	121.46	0	0	0	0	0	165.33	0	0
2	0	0	0	0	0	0	0	0	0
3	124.28	2.8	0	0	0	0	168.63	3.3	0
4	125.47	4.0	57.1	0	0	0	170.35	5.0	82.6
5	127.04	5.6	75.4	0	0	0	172.10	6.8	84.0
6	128.70	7.2	79.7	0	0	0	173.85	8.5	84.0
7	130.58	9.1	90.2	0	0	0	175.74	10.4	90.7
8	131.92	10.5	64.3	0	0	0	177.84	12.5	100.8
9	133.84	12.4	92.2	0	0	0	179.93	14.6	100.3
10	135.70	14.2	89.3	0	0	0	182.03	16.7	100.8
11	137.47	16.0	85.0	0	0	0	184.11	18.8	99.8
12	139.09	17.6	77.8	0	0	0	186.21	20.9	100.8
13	140.70	19.2	77.3	0	0	0	183.32	23.0	101.3
14	142.12	20.7	68.2	0	0	0	190.40	25.1	99.8
15	143.21	21.8	52.3	0	0	0	192.52	27.2	101.8
16	144.74	23.3	73.4	0	0	0	194.58	29.3	98.9
17	145.82	24.4	51.8	0	0	0	196.65	31.3	99.4
18	147.48	26.0	79.7	0	0	0	198.48	33.1	87.8
19	149.25	27.8	85.0	0	0	0	200.32	35.0	88.3
20	150.96	29.5	82.1	0	0	0	202.04	36.7	82.6
21	152.66	31.2	81.6	0	0	0	203.77	38.4	83.0
22	154.59	33.0	87.8	0	0	0	205.51	40.2	83.5
23	156.29	34.8	86.4	0	0	0	207.21	41.9	81.6
24	158.11	36.6	87.4	0	0	0	208.92	43.6	82.1
25	159.91	38.4	86.4	0	0	0	210.65	45.3	83.0
26	161.75	40.3	88.3	0	0	0	212.36	47.0	82.1
27	163.51	42.0	84.5	0	0	0	214.07	48.7	82.1
28	165.35	43.9	88.3	0	0	0	215.79	50.5	82.6
29	167.21	45.8	89.3	0	0	0	217.74	52.4	93.6
30	169.14	47.7	93.1	0	0	0	219.57	54.2	87.8
31	171.07	49.6	92.2	0	0	0	221.42	56.1	88.8
32	172.90	51.4	87.8	0	0	0	233.30	58.0	90.2
33	174.69	53.2	85.9	0	0	0	225.11	59.8	86.9
34	176.49	55.0	86.4	0	0	0	226.92	61.6	86.9
35	178.27	56.8	85.4	0	0	0	228.74	63.4	87.4
36	180.08	58.6	86.9	0	0	0	230.56	65.2	87.4
38	183.67	62.2	86.4	0	0	0	234.19	68.9	63.4
39	185.49	64.0	87.4	0	0	0	236.00	70.7	86.9
40	187.29	65.8	86.4	0	0	0	237.83	72.5	87.8
41	189.09	67.6	86.4	0	0	0	239.70	74.4	89.8
42	190.90	69.4	86.9	0	0	0	241.52	76.2	87.4
43	192.69	71.2	85.9	0	0	0	243.35	78.0	87.8
44	194.50	73.0	86.9	0	0	0	245.24	79.9	90.7
45	196.31	74.8	86.9	0	0	0	247.08	81.8	88.3
46	198.07	76.6	84.5	0	0	0	248.91	83.6	87.8
47	199.86	78.4	85.9	0	0	0	250.75	85.4	88.3
48	201.65	80.2	85.9	0	0	0	252.59	87.3	88.3
49	203.45	82.0	86.4	0	0	0	254.41	89.1	87.4
49	203.45	82.0	0	0	0	0	254.41	89.1	0
50	205.29	83.8	88.3	0	0	0	0	89.1	0
51	207.11	85.6	87.4	0	0	0	0	89.1	0

SAMPLE NUMBER	GALLON	MEOH METER CUM	RATE	GALLON	ETOH METER CUM	RATE	GALLON	PF METER CUM	RATE
52	208.94	87.5	87.8	0	0	0	0	89.1	0
53	210.79	89.3	88.8	0	0	0	0	89.1	0
54	212.45	91.0	79.7	0	0	0	0	89.1	0
55	214.47	93.0	97.0	0	0	0	0	89.1	0
56	216.31	94.8	88.3	0	0	0	0	89.1	0
57	218.12	96.7	86.9	0	0	0	0	89.1	0
58	220.05	98.6	92.6	0	0	0	0	89.1	0
59	221.82	100.4	85.0	0	0	0	0	89.1	0
60	223.76	102.3	93.1	0	0	0	0	89.1	0
61	225.13	103.7	65.8	0	0	0	0	89.1	0
62	226.00	104.5	41.8	0	0	0	0	89.1	0
63	227.59	106.1	76.3	0	0	0	0	89.1	0
64	227.60	106.1	0.5	0	0	0	0	89.1	0
65	229.35	107.9	84.0	0	0	0	0	89.1	0
66	231.19	109.7	88.3	0	0	0	0	89.1	0
67	233.04	111.6	88.8	0	0	0	0	89.1	0
68	234.91	113.4	89.8	0	0	0	0	89.1	0
69	236.77	115.3	89.3	0	0	0	0	89.1	0
70	238.63	117.2	89.3	0	0	0	0	89.1	0
71	240.48	119.0	88.8	0	0	0	0	89.1	0
72	242.33	120.9	88.8	0	0	0	0	89.1	0
73	244.05	122.6	82.6	0	0	0	0	89.1	0
74	245.06	123.6	48.5	0	0	0	0	89.1	0
75	246.91	125.4	88.8	0	0	0	0	89.1	0
76	248.69	127.2	85.4	0	0	0	0	89.1	0
77	250.50	129.0	86.9	0	0	0	0	89.1	0
78	252.26	130.8	84.5	0	0	0	0	89.1	0
79	254.01	132.5	84.0	0	0	0	0	89.1	0
80	255.77	134.3	84.5	0	0	0	0	89.1	0
81	257.51	136.1	83.5	0	0	0	0	89.1	0
82	259.30	137.8	85.9	0	0	0	0	89.1	0
83	261.16	139.7	89.3	0	0	0	0	89.1	0
84	263.01	141.6	88.8	0	0	0	0	89.1	0
85	264.84	143.4	87.8	0	0	0	0	89.1	0
86	266.72	145.3	90.2	0	0	0	0	89.1	0
87	268.55	147.1	87.8	0	0	0	0	89.1	0
88	270.43	149.0	90.2	0	0	0	0	89.1	0
89	272.25	150.8	87.4	0	0	0	0	89.1	0
90	274.09	152.6	88.3	0	0	0	0	89.1	0
91	275.94	154.5	88.8	0	0	0	0	89.1	0
92	277.75	156.3	86.9	0	0	0	0	89.1	0
93	279.62	158.2	89.8	0	0	0	0	89.1	0
94	281.48	160.0	89.3	0	0	0	0	89.1	0
95	283.34	161.9	89.3	0	0	0	0	89.1	0
96	285.18	163.7	88.3	0	0	0	0	89.1	0
97	287.02	165.6	88.3	261.73	0	0	0	89.1	0
98	0	165.6	0	263.27	1.5	73.9	0	89.1	0
99	0	165.6	0	264.98	3.3	82.1	0	89.1	0
100	0	165.6	0	266.67	4.9	81.1	0	89.1	0

SAMPLE NUMBER	GALLON	MEOH METER CUM	RATE	GALLON	ETOH METER CUM	RATE	GALLON	PF METER CUM	RATE
101	0	165.6	0	268.37	6.6	81.1	0	89.1	0
102	0	165.6	0	270.18	8.4	87.4	0	89.1	0
103	0	165.6	0	272.12	10.4	93.1	0	89.1	0
104	0	165.6	0	274.05	12.3	92.6	0	89.1	0
105	0	165.6	0	276.12	14.4	99.4	0	89.1	0
106	0	165.6	0	278.18	16.4	98.9	0	89.1	0
107	0	165.6	0	280.23	18.5	98.4	0	89.1	0
108	0	165.6	0	282.29	20.6	98.9	0	89.1	0
109	0	165.6	0	284.34	22.6	98.4	0	89.1	0
110	0	165.6	0	286.44	24.7	100.8	0	89.1	0
111	0	165.6	0	288.52	26.8	99.8	0	89.1	0
112	0	165.6	0	290.48	28.8	94.1	0	89.1	0
113	0	165.6	0	292.50	30.8	97.0	0	89.1	0
114	0	165.6	0	294.58	32.9	99.8	0	89.1	0
115	0	165.6	0	296.64	34.9	98.9	0	89.1	0
116	0	165.6	0	298.68	36.9	97.9	0	89.1	0
117	0	165.6	0	300.73	39.0	98.4	0	89.1	0
118	0	165.6	0	302.79	41.1	98.9	0	89.1	0
119	0	165.6	0	304.87	43.1	99.8	0	89.1	0
120	0	165.6	0	306.88	45.1	96.5	0	89.1	0
121	0	165.6	0	308.94	47.2	98.9	0	89.1	0
122	0	165.6	0	311.01	49.3	99.4	0	89.1	0
123	0	165.6	0	313.05	51.3	97.9	0	89.1	0
124	0	165.6	0	315.11	53.4	98.9	0	89.1	0
125	0	165.6	0	317.20	55.5	100.3	0	89.1	0
126	0	165.6	0	319.21	57.5	96.5	0	89.1	0
127	0	165.6	0	321.24	59.5	97.4	0	89.1	0
128	0	165.6	0	323.30	61.6	98.9	0	89.1	0
129	0	165.6	0	325.32	63.6	97.0	0	89.1	0
130	0	165.6	0	327.43	65.7	101.3	0	89.1	0
131	0	165.6	0	329.46	67.7	97.4	0	89.1	0
132	0	165.6	0	331.54	69.8	99.8	0	89.1	0
133	0	165.6	0	333.60	71.9	98.9	0	89.1	0
134	0	165.6	0	335.65	73.9	98.4	0	89.1	0
135	0	165.6	0	337.66	75.9	96.5	0	89.1	0
136	0	165.6	0	339.78	78.1	101.8	0	89.1	0
137	0	165.6	0	340.93	79.2	55.2	0	89.1	0
138	0	165.6	0	0	79.2	0	0	89.1	0
139	0	165.6	0	0	79.2	0	0	89.1	0
140	0	165.6	0	0	79.2	0	0	89.1	0
141	0	165.6	0	0	79.2	0	0	89.1	0
142	0	165.6	0	0	79.2	0	0	89.1	0
143	0	165.6	0	0	79.2	0	0	89.1	0
144	0	165.6	0	0	79.2	0	0	89.1	0
145	0	165.6	0	0	79.2	0	0	89.1	0

<u>SAMPLE NUMBER</u>	<u>MEOH GC PPM</u>	<u>MEOH METER PPM</u>	<u>ETOH GC PPM</u>	<u>ETOH METER PPM</u>	<u>NPA GC PPM</u>	<u>NPA METER PPM</u>	<u>PF GC PPM</u>	<u>PF METER PPM</u>
1	0.1241	0	0	0	0.0181	0	0.2968	0
2	0.4534	0	0	0	0.0313	0	0.4785	0
3	0.3425	0	0	0	0.0275	0	0.4273	0
4	0.4117	0.3374	0	0	0.0297	0	0.4505	0.4876
5	0.1555	0.4449	0	0	0.0359	0	0.4590	0.4959
6	0.4325	0.4650	0	0	0.0275	0	0.4555	0.4902
7	0.5904	0.5235	0	0	0.0335	0	0.5077	0.5263
8	0.5726	0.3732	0	0	0.0355	0	0.5045	0.5848
9	0.5980	0.5376	0	0	0.0311	0	0.5084	0.5854
10	0.5139	0.5151	0	0	0.0315	0	0.4879	0.5816
11	0.5137	0.4958	0	0	0.0377	0	0.5643	0.5826
12	0.4617	0.4484	0	0	0.0358	0	0.5483	0.5813
13	0.5621	0.4459	0	0	0.0368	0	0.5685	0.5843
14	0.4369	0.3976	0	0	0.0360	0	0.5541	0.5826
15	0.3618	0.3017	0	0	0.0387	0	0.6005	0.5868
16	0.2497	0.4235	0	0	0.0384	0	0.6177	0.5702
17	0.4681	0.2991	0	0	0.0368	0	0.5887	0.5732
18	0.6239	0.4595	0	0	0.0332	0	0.5379	0.5066
19	0.5190	0.4902	0	0	0.0318	0	0.5224	0.5096
20	0.5019	0.4733	0	0	0.0318	0	0.5058	0.4761
21	0.4853	0.4706	0	0	0.0285	0	0.4493	0.4789
22	0.5282	0.5009	0	0	0.0319	0	0.4603	0.4762
23	0.5404	0.4985	0	0	0.0311	0	0.4390	0.4708
24	0.5444	0.5038	0	0	0.0311	0	0.4788	0.4733
25	0.5206	0.4927	0	0	0.0316	0	0.4635	0.4735
26	0.5347	0.5036	0	0	0.0301	0	0.4646	0.4680
27	0.5399	0.4872	0	0	0.0297	0	0.4581	0.4733
28	0.5239	0.5036	0	0	0.0293	0	0.4567	0.4708
29	0.5156	0.5091	0	0	0.0320	0	0.4546	0.5337
30	0.5343	0.5370	0	0	0.0322	0	0.4587	0.5066
31	0.5348	0.5315	0	0	0.0331	0	0.5029	0.5121
32	0.5451	0.5096	0	0	0.0320	0	0.4906	0.5235
33	0.5542	0.4985	0	0	0.0433	0	0.4915	0.5040
34	0.5173	0.5042	0	0	0.0337	0	0.4723	0.5070
35	0.5332	0.4957	0	0	0.0334	0	0.4912	0.5068
36	0.5459	0.5070	0	0	0.0317	0	0.4676	0.5098
37	0.5632	0.5072	0	0	0.0328	0	0.4893	0.6546
38	0.5231	0.5042	0	0	0.0312	0	0.4575	0.3697
39	0.5171	0.5160	0	0	0.0311	0	0.4691	0.5131
40	0.5118	0.5101	0	0	0.0311	0	0.4479	0.5186
41	0.5255	0.501d	0	0	0.0321	0	0.4671	0.5207
42	0.5572	0.5129	0	0	0.0343	0	0.5000	0.5157
43	0.5426	0.4985	0	0	0.0348	0	0.4862	0.5096
44	0.5142	0.5131	0	0	0.0342	0	0.4979	0.5358
45	0.5353	0.5070	0	0	0.0320	0	0.4968	0.5154

SAMPLE NUMBER	MEOH GC PPM	MEOH METER PPM	ETOH GC PPM	ETOH METER PPM	NPA GC PPM	NPA METER PPM	PF GC PPM	PF METER PPM
46	0.5023	0.4901	0	0	0.0331	0	0.4931	0.5096
47	0.5220	0.4985	0	0	0.0330	0	0.4830	0.5124
48	0.4993	0.5014	0	0	0.0312	0	0.4593	0.5154
49	0.4939	0.5103	0	0	0.0317	0	0.4708	0.5160
49	0.5276	0	0	0	0.0322	0	0.4889	0
50	0.5408	0.5124	0	0	0	0	0.0077	0
51	0.5180	0.5160	0	0	0	0	0	0
52	0.5187	0.5188	0	0	0	0	0	0
53	0.5285	0.5242	0	0	0	0	0	0
54	0.5147	0.4650	0	0	0	0	0	0
55	0.4967	0.5625	0	0	0	0	0	0
56	0.5225	0.5216	0	0	0	0	0	0
57	0.5091	0.5131	0	0	0	0	0	0
58	0.5179	0.5406	0	0	0	0	0	0
59	0.4912	0.4958	0	0	0	0	0	0
60	0.5147	0.5434	0	0	0	0	0	0
61	0.0181	0.3838	0	0	0	0	0	0
62	0.4887	0.2437	0	0	0	0	0	0
63	0.4287	0.4454	0	0	0	0	0	0
64	0.0001	0.0028	0	0	0	0	0	0
65	0.5295	0.4902	0	0	0	0	0	0
66	0.5106	0.5196	0	0	0	0	0	0
67	0.5006	0.5121	0	0	0	0	0	0
68	0.5083	0.5176	0	0	0	0	0	0
69	0.5243	0.5151	0	0	0	0	0	0
70	0.4969	0.5210	0	0	0	0	0	0
71	0.5152	0.5121	0	0	0	0	0	0
72	0.5007	0.5123	0	0	0	0	0	0
73	0.4314	0.4761	0	0	0	0	0	0
74	0.4742	0.2796	0	0	0	0	0	0
75	0.5300	0.5123	0	0	0	0	0	0
76	0.4764	0.4927	0	0	0	0	0	0
77	0.4808	0.5070	0	0	0	0	0	0
78	0.4698	0.4817	0	0	0	0	0	0
79	0.4809	0.4902	0	0	0	0	0	0
80	0.4897	0.4872	0	0	0	0	0	0
81	0.4883	0.4819	0	0	0	0	0	0
82	0.5007	0.4899	0	0	0	0	0	0
83	0.5247	0.5270	0	0	0	0	0	0
84	0.5093	0.5123	0	0	0	0	0	0
85	0.5168	0.5066	0	0	0	0	0	0
86	0.5079	0.5204	0	0	0	0	0	0
87	0.5168	0.5126	0	0	0	0	0	0
88	0.4957	0.5145	0	0	0	0	0	0
89	0.5077	0.5098	0	0	0	0	0	0
90	0.5168	0.5154	0	0	0	0	0	0
91	0.5279	0.5063	0	0	0	0	0	0
92	0.5171	0.5070	0	0	0	0	0	0

<u>SAMPLE NUMBER</u>	<u>MEOH GC PPM</u>	<u>MEOH METER PPM</u>	<u>ETOH GC PPM</u>	<u>ETOH METER PPM</u>	<u>NPA GC PPM</u>	<u>NPA METER PPM</u>	<u>PF GC PPM</u>	<u>PF METER PPM</u>
93	0.5329	0.5238	0	0	0	0	0	0
94	0.5298	0.5210	0	0	0	0	0	0
95	0.5170	0.5210	0	0	0	0	0	0
96	0.5017	0.5216	0	0	0	0	0	0
97	0.5044	0.5154	0	0	0	0	0	0
98	0.0222	0	0.4172	0.4364	0	0	0	0
99	0.0227	0	0.4380	0.4790	0	0	0	0
100	0.0225	0	0.3978	0.4734	0	0	0	0
101	0.0201	0	0.3976	0.4734	0	0	0	0
102	0.0214	0	0.4534	0.5098	0	0	0	0
103	0.0225	0	0.4903	0.5373	0	0	0	0
104	0.0231	0	0.4989	0.5406	0	0	0	0
105	0.0224	0	0.4748	0.5730	0	0	0	0
106	0.0239	0	0.5036	0.5702	0	0	0	0
107	0.0223	0	0.4777	0.5677	0	0	0	0
108	0.0237	0	0.5022	0.5702	0	0	0	0
109	0.0229	0	0.4902	0.5677	0	0	0	0
110	0.0219	0	0.4841	0.5848	0	0	0	0
111	0.0237	0	0.4930	0.5792	0	0	0	0
112	0.0228	0	0.4916	0.5490	0	0	0	0
113	0.0216	0	0.4643	0.5594	0	0	0	0
114	0.0224	0	0.4914	0.5693	0	0	0	0
115	0.0224	0	0.4846	0.5746	0	0	0	0
116	0.0239	0	0.4968	0.5681	0	0	0	0
117	0.0227	0	0.4901	0.5709	0	0	0	0
118	0.0229	0	0.4975	0.5737	0	0	0	0
119	0.0232	0	0.5038	0.5691	0	0	0	0
120	0.0217	0	0.4693	0.5597	0	0	0	0
121	0.0222	0	0.4822	0.5638	0	0	0	0
122	0.0223	0	0.4823	0.5765	0	0	0	0
123	0.0252	0	0.5184	0.5681	0	0	0	0
124	0.0224	0	0.4857	0.5737	0	0	0	0
125	0.0222	0	0.4858	0.5785	0	0	0	0
126	0.0235	0	0.5092	0.5501	0	0	0	0
127	0.0235	0	0.5088	0.5556	0	0	0	0
128	0.0245	0	0.5068	0.5638	0	0	0	0
129	0.0250	0	0.5210	0.5638	0	0	0	0
130	0.0251	0	0.5192	0.5875	0	0	0	0
131	0.0257	0	0.5137	0.5622	0	0	0	0
132	0.0243	0	0.5182	0.5691	0	0	0	0
133	0.0279	0	0.5027	0.5638	0	0	0	0
134	0.0247	0	0.5121	0.5742	0	0	0	0
135	0.0242	0	0.5194	0.5566	0	0	0	0

<u>SAMPLE NUMBER</u>	<u>MEOH GC PPM</u>	<u>MEOH METER PPM</u>	<u>ETOH GC PPM</u>	<u>ETOH METER PPM</u>	<u>NPA GC PPM</u>	<u>NPA METER PPM</u>	<u>PF GC PPM</u>	<u>PF METER PPM</u>
136	0.0254	0	0.5229	0.5800	0	0	0	0
137	0.0001	0	0.0201	0.3260	0	0	0	0
138	0.0001	0	0.0042	0	0	0	0	0
138	0.0275	0	0.5404	0	0	0	0.0057	0
139	0.0268	0	0.5401	0	0	0	0.0055	0
140	0.0280	0	0.5479	0	0	0	0.0053	0
141	0.0281	0	0.5608	0	0	0	0.0060	0
142	0.0291	0	0.5571	0	0	0	0.0060	0
143	0.0329	0	0.6754	0	0	0	0.0071	0
144	0.0297	0	0.6358	0	0	0	0.0076	0
145	0.0275	0	0.6216	0	0	0	0.0067	0

Methanol meter bulk ppm average	=	0.48231 ppm*100
Ethanol meter bulk ppm average	=	0.54624 ppm*100
Propyl formate meter bulk ppm average	=	0.51946 ppm*100
Propanol meter bulk ppm average	=	0 ppm*100

TIME	SAMPLE NUMBER	METER #1		METER #2		PPM MEOH	PPM ETOH	PPM NPA	PPM PF
		BBLs.	CUM.	BBLs.	CUM.				
1845	1	7236.6	0	3220.5	0	0	0	0	0
2000	2	7236.6	0	3227.1	7	0	0	0	0
2030	3	7236.6	0	3233.6	13	0	0	0	0
2100	4	7236.6	0	3239.8	19	0.0247	0.3470	0.0054	0
2130	5	7236.6	0	3245.4	25	0.0508	0.3563	0.0109	0.0058
2200	6	7236.6	0	3250.9	30	0.0521	0.3154	0.0109	0.0059
2200	6	7236.6	0	3250.9	30	0.0604	0.3484	0.0120	0.0069
2230	7	7241.8	5	3256.3	36	0.0580	0.3251	0.0125	0.0074
2230	7	7241.8	5	3256.3	36	0.0634	0.3550	0.0135	0.0085
2300	8	7246.0	9	3261.4	41	0.0697	0.3548	0.0151	0.0099
2330	9	7251.1	15	3266.3	46	0.0736	0.3534	0.0163	0.0117
2400	10	7257.0	20	3271.2	51	0.0751	0.3467	0.0167	0.0119
30	11	7261.9	25	3275.9	55	0.0770	0.3497	0.0174	0.0110
100	12	7266.6	30	3280.6	60	0.0740	0.3277	0.0167	0.0115
100	12	7266.6	30	3280.6	60	0.0769	0.3488	0.0178	0.0105
130	13	7271.4	35	3285.2	65	0.0818	0.3527	0.0183	0.0111
200	14	7275.0	38	3289.8	69	0.0812	0.3604	0.0187	0.0107
230	15	7280.5	44	3294.3	74	0.0825	0.3552	0.0189	0.0126
300	16	7284.0	47	3298.7	78	0.0827	0.3547	0.0190	0.0114
330	17	7289.4	53	3303.1	83	0.0858	0.3612	0.0198	0.0119
330	17	7289.4	53	3303.1	83	0.0863	0.3586	0.0196	0.0117
400	18	7293.9	57	3307.5	87	0.0863	0.3647	0.0200	0.0114
400	18	7293.9	57	3307.5	87	0.1005	0.4199	0.0231	0.0136
430	19	7298.2	62	3311.8	91	0.0873	0.3523	0.0198	0.0114
500	20	7302.4	66	3316.1	96	0.0932	0.3589	0.0206	0.0119
530	21	7306.6	70	3320.2	100	0.0917	0.3612	0.0206	0.0133
530	21	7306.6	70	3320.2	100	0.0926	0.3627	0.0210	0.0122
600	22	7310.6	74	3324.3	104	0.0913	0.3538	0.0209	0.0121
630	23	7314.0	77	3328.2	108	0.0925	0.3537	0.0213	0.0125
700	24	7318.3	82	3332.1	112	0.0943	0.3540	0.0215	0.0126
730	25	7322.3	86	3335.9	115	0.0958	0.3620	0.0223	0.0130
800	26	7326.2	90	3339.7	119	0.0690	0.2627	0.0163	0.0118
830	27	7330.1	94	3343.6	123	0	0	0	0
900	28	7333.8	97	3347.3	127	0.0954	0.3583	0.0229	0.0159
930	29	7337.5	101	3351.0	131	0.0964	0.3487	0.0225	0.0156
1000	30	7341.1	105	3354.4	134	0.0997	0.3471	0.0228	0.0163
1030	31	7343.7	107	3357.2	137	0.0960	0.3397	0.0227	0.0158
1030	31	7343.7	107	3357.2	137	0.0962	0.3474	0.0228	0.0146
1100	32	7347.0	110	3360.6	140	0.1020	0.3485	0.0237	0.0160
1130	33	7350.3	114	3364.1	144	0.0923	0.3226	0.0223	0.0136
1130	33	7350.3	114	3364.1	144	0.0964	0.3257	0.0244	0.0144
1200	34	7353.5	117	3367.4	147	0.1025	0.3413	0.0244	0.0160
1230	35	7356.6	120	3370.6	150	0.1011	0.3363	0.0244	0.0171
1300	36	7359.5	123	3370.6	150	0.1045	0.3415	0.0253	0.0154
1300	36	7359.5	123	3373.7	153	0.1045	0.3415	0.0253	0.0154
1330	37	7362.4	126	3376.6	156	0.1073	0.3404	0.0256	0.0157
1345	38	7363.7	127	3378.1	158	0.1048	0.3363	0.0256	0.0200
1700	39	7366.8	130	3381.5	161	0.1046	0.3177	0.0257	0.0126

TIME	SAMPLE NUMBER	METER #1		METER #2		PPM MEOH	PPM ETOH	PPM NPA	PPM PF
		BBLs.	CUM.	BBLs.	CUM.				
1730	40	7374.8	138	3389.6	169	0.1083	0.2965	0.0274	0.0189
1730	40	7374.8	138	3389.6	169	0.1184	0.3054	0.0284	0.0162
1800	41	7383.4	147	3405.7	185	0.1117	0.2998	0.0280	0.0135
1830	42	7391.8	155	3405.7	185	0.1211	0.3117	0.0293	0.0171
1900	43	7398.9	162	3413.5	193	0.1066	0.2785	0.0248	0.0176
1930	44	7406.7	170	3421.5	201	0.1276	0.3024	0.0294	0.0208
2000	45	7414.6	178	3429.4	209	0.0876	0.1900	0.0193	0.0125
2000	45	7414.5	178	3429.4	209	0.1284	0.2892	0.0300	0.0163
2030	46	7422.6	186	3437.2	217	0.1321	0.2896	0.0311	0.0156
2100	47	7430.5	194	3445.0	225	0.1336	0.2659	0.0306	0.0153
2130	48	7438.4	202	3452.9	232	0.1384	0.2579	0.0313	0.0159
2200	49	7446.3	210	3460.8	240	0.1441	0.2567	0.0324	0.0169
2230	50	7454.2	218	3468.8	248	0.1493	0.2511	0.0328	0.0169
2300	51	7461.3	225	3476.9	256	0.1521	0.2421	0.0328	0.0172
2330	52	7470.3	234	3484.9	264	0.1581	0.2388	0.0336	0.0171
2400	53	7478.4	242	3492.9	272	0.1677	0.2394	0.0350	0.0182
30	54	7486.5	250	3500.9	280	0.1688	0.2294	0.0347	0.0181
100	55	7494.5	258	3508.8	288	0.1749	0.2254	0.0352	0.0182
130	56	7502.7	266	3516.8	296	0.1750	0.2171	0.0350	0.0181
200	57	7510.9	274	3524.9	304	0.1792	0.2118	0.0356	0.0201
230	58	7518.0	281	3532.9	312	0.1846	0.2082	0.0363	0.0202
300	59	527.5	291	3541.0	321	0.1862	0.2018	0.0367	0.0196
330	60	7535.7	299	3549.0	329	0.1827	0.1901	0.0359	0.0199
330	60	7535.7	299	3549.0	329	0.1930	0.1941	0.0380	0.0208
400	61	7543.9	307	3557.0	337	0.1873	0.1882	0.0368	0.0200
400	61	7543.9	307	3557.0	337	0.1966	0.1941	0.0381	0.0202
430	62	7551.3	315	3565.1	345	0.1991	0.1922	0.0391	0.0222
500	63	7560.6	324	3573.1	353	0.1968	0.1828	0.0386	0.0214
530	64	7568.9	332	3581.2	361	0.2008	0.1766	0.0389	0.0214
600	65	7576.2	340	3589.4	369	0.1990	0.1699	0.0389	0.0225
630	66	7585.8	349	3597.3	377	0.2108	0.1739	0.0413	0.0231
700	67	7593.9	357	3605.4	385	0.2107	0.1668	0.0413	0.0210
700	67	7593.9	357	3605.4	385	0.2108	0.1650	0.0409	0.0230
730	68	7602.4	366	3613.7	393	0.2020	0.1567	0.0402	0.0247
730	68	7602.4	366	3613.7	393	0.2051	0.1584	0.0401	0.0243
800	69	7610.7	374	3621.6	401	0.1882	0.1457	0.0378	0.0224
800	69	7610.7	374	3621.6	401	0.1907	0.1454	0.0378	0.0227
830	70	7619.0	382	3629.7	409	0	0	0	0
900	71	7627.4	391	3637.8	417	0.1695	0.1255	0.0345	0.0205
900	71	7627.4	391	3637.8	417	0.1743	0.1286	0.0353	0.0214
900	71	7627.4	391	3637.8	417	0.2068	0.1525	0.0419	0.0254
930	72	7635.8	399	3645.8	425	0.2005	0.1481	0.0426	0.0262
1000	73	7644.0	407	3653.9	433	0.2099	0.1459	0.0432	0.0269
1030	74	7652.5	416	3662.0	442	0.2202	0.1474	0.0454	0.0284
1030	74	7652.5	416	3662.0	442	0.2236	0.1494	0.0459	0.0284
1100	75	7660.0	424	3670.2	450	0.2212	0.1470	0.0462	0.0302
1100	75	7660.1	424	3670.2	450	0.2214	0.1457	0.0466	0.0299

TIME	SAMPLE NUMBER	METER #1		METER #2		PPM MEOH	PPM ETOH	PPM NPA	PPM PF
		BBLs.	CUM.	BBLs.	CUM.				
1130	76	7666.8	430	3678.4	458	0.2167	0.1416	0.0456	0.0293
1130	76	7666.8	430	3678.4	458	0.2167	0.1416	0.0456	0.0293
1200	77	7674.9	438	3686.8	466	0.2225	0.1370	0.0474	0.0315
1200	77	7674.9	438	3686.8	466	0.2225	0.1370	0.0474	0.0315
1230	78	7683.1	447	3695.1	475	0.1713	0.1021	0.0369	0.0240
1230	78	7683.1	447	3695.1	475	0.1812	0.1007	0.0371	0.0250
1300	79	7691.2	455	3703.4	483	0.1579	0.0911	0.0344	0.0231
1330	80	7699.6	463	3711.7	491	0.1588	0.0891	0.0338	0.0226
1400	81	7707.6	471	3719.9	499	0.2286	0.1262	0.0494	0.0337
1430	82	7716.0	479	3728.2	508	0.2442	0.1233	0.0502	0.0351
1500	83	7724.1	488	3736.4	516	0.2336	0.1233	0.0521	0.0385
1530	84	7732.2	496	3744.7	524	0.2382	0.1204	0.0544	0.0403
1600	85	7740.4	504	3752.9	532	0.2606	0.1776	0.0542	0.0394
1630	86	7748.5	512	3761.2	541	0.2295	0.1073	0.0514	0.0360
1700	87	7756.6	520	3769.5	549	0.2366	0.1072	0.0527	0.0372
1730	88	7764.7	528	3777.8	557	0.2405	0.1105	0.0561	0.0427
1800	89	7772.3	536	3785.9	565	0.2365	0.1081	0.0568	0.0429
1830	90	7780.4	544	3794.3	574	0.2693	0.1091	0.0580	0.0421
1900	91	7788.8	552	3802.8	582	0.2300	0.1022	0.0549	0.0401
1930	92	7797.0	560	3811.2	591	0.2320	0.1002	0.0575	0.0422
2000	93	7805.2	569	3819.6	599	0.2299	0.0960	0.0571	0.0425
2030	94	7813.3	577	3828.0	608	0.2234	0.0945	0.0560	0.0411
2100	95	7821.5	585	3836.3	616	0.2335	0.0965	0.0584	0.0437
2130	96	7829.6	593	3844.7	624	0.2323	0.0933	0.0582	0.0456
2200	97	7838.8	602	3853.0	633	0.2257	0.0880	0.0572	0.0433
2230	98	7845.9	609	3861.4	641	0.2309	0.0880	0.0578	0.0448
2300	99	7853.1	617	3869.9	649	0.2323	0.0871	0.0583	0.0450
2330	100	7861.2	625	3878.2	658	0.2219	0.0822	0.0563	0.0422
2330	100	7861.2	625	3878.2	658	0.2271	0.0854	0.0574	0.0458
2400	101	7870.4	634	3886.5	666	0.2266	0.0836	0.0570	0.0445
30	102	7878.4	642	3894.8	674	0.2336	0.0838	0.0590	0.0462
30	102	7878.4	642	3894.8	674	0.2407	0.0850	0.0583	0.0451
100	103	7886.5	650	3903.1	683	0.2326	0.0797	0.0578	0.0448
130	104	7894.6	658	3911.5	691	0.2256	0.0786	0.0656	0.0445
200	105	7902.7	666	3919.8	699	0.2260	0.0772	0.0565	0.0452
230	106	7910.8	674	3928.1	708	0.2245	0.0746	0.0559	0.0445
230	106	7910.8	674	3928.1	708	0.2249	0.0687	0.0549	0.0444
300	107	7918.1	682	3936.4	716	0.2244	0.0739	0.0558	0.0445
330	108	7926.2	690	3944.8	724	0.2272	0.0678	0.0555	0.0452
400	109	7934.2	698	3961.3	741	0.2213	0.0702	0.0544	0.0433
400	109	7934.2	698	3961.3	741	0.2246	0.0689	0.0550	0.0450
430	110	7943.3	707	3961.3	741	0.2239	0.0698	0.0551	0.0454
500	111	7951.3	715	3969.5	749	0.2249	0.0613	0.0540	0.0446
530	112	7959.3	723	3977.7	757	0.2261	0.0597	0.0539	0.0446
600	113	7967.4	731	3985.9	765	0.2261	0.0605	0.0541	0.0466
600	113	7967.4	731	3985.9	765	0.2272	0.0666	0.0536	0.0451
630	114	7975.4	739	3994.1	774	0.2180	0.0644	0.0528	0.0436
630	114	7975.4	739	3994.1	774	0.2181	0.0637	0.0521	0.0430
700	115	7983.5	747	4002.4	782	0.2171	0.0635	0.0530	0.0435

<u>TIME</u>	<u>SAMPLE NUMBER</u>	<u>METER #1</u>		<u>METER #2</u>		<u>PPM MEOH</u>	<u>PPM ETOH</u>	<u>PPM NPA</u>	<u>PPM PF</u>
		<u>BBLs.</u>	<u>CUM.</u>	<u>BBLs.</u>	<u>CUM.</u>				
730	116	7991.7	755	4010.6	790	0.2183	0.0553	0.0519	0.0431
800	117	7999.7	763	4018.8	798	0.2022	0.0574	0.0536	0.0466
800	117	7999.7	763	4018.8	798	0.2022	0.0574	0.0536	0.0466
830	118	8007.5	771	4026.9	806	0.2157	0.0599	0.0539	0.0507
900	119	8015.6	779	4035.2	815	0.2134	0.0581	0.0522	0.0481
930	120	8023.7	787	4043.5	823	0.2051	0.0562	0.0503	0.0488
1000	121	8031.6	795	4051.7	831	0.2169	0.0547	0.0489	0.0479
1030	122	8039.8	803	4060.0	840	0.2051	0.0493	0.0491	0.0467
1100	123	8047.9	811	4068.2	848	0.1881	0.0497	0.0455	0.0449
1130	124	8055.9	819	4076.3	858	0.1998	0.0500	0.0484	0.0475
1200	125	8063.7	827	4084.2	864	0.1922	0.0516	0.0471	0.0456
1230	126	8072.0	835	4092.6	872	0.2026	0.0526	0.0497	0.0480
1300	127	8080.3	844	4100.7	880	0.2031	0.0523	0.0501	0.0486
1330	128	8088.5	852	4109.0	889	0.1963	0.0431	0.0467	0.0478
1400	129	8096.6	860	4117.2	897	0.1934	0.0465	0.0471	0.0478
1430	130	8104.8	868	4125.5	905	0.2018	0.0502	0.0492	0.0477
1500	131	8113.0	876	4133.7	913	0.2031	0.0490	0.0488	0.0490
1530	132	8121.1	885	4141.9	921	0.2001	0.0479	0.0490	0.0511
1600	133	8129.2	893	4150.2	930	0.1936	0.0450	0.0475	0.0478
1630	134	8137.4	901	4158.4	938	0.1941	0.0444	0.0475	0.0460
1700	135	8145.5	909	4166.6	946	0.1962	0.0457	0.0481	0.0456
1730	136	8153.7	917	4174.8	954	0.1936	0.0437	0.0464	0.0449
1800	137	8161.8	925	4183.1	963	0.1917	0.0433	0.0459	0.0439
1830	138	8169.9	933	4191.2	971	0.1887	0.0423	0.0461	0.0444
1900	139	8178.4	942	4199.5	979	0.2019	0.0466	0.0475	0.0475
1930	140	8186.5	950	4207.7	987	0.2103	0.0421	0.0457	0.0456
2000	141	8194.7	958	4215.9	995	0.1865	0.0390	0.0432	0.0335
2030	142	8202.7	966	4224.0	1004	0.1872	0.0385	0.0433	0.0386
2030	142	8202.7	966	4224.0	1004	0.1885	0.0385	0.0433	0.0390
2100	143	8210.8	974	4232.2	1012	0.1803	0.0364	0.0422	0.0375
2100	143	8210.8	974	4232.2	1012	0.1862	0.0337	0.0433	0.0400
2130	144	8318.9	982	4240.5	1020	0.1771	0.0355	0.0413	0.0370
2130	144	8218.9	982	4240.5	1020	0.1788	0.0358	0.0420	0.0373
2200	145	8227.0	990	4248.7	1028	0.1714	0.0337	0.0403	0.0363
2230	146	8235.2	999	4256.9	1036	0.1817	0.0359	0.0420	0.0383
2300	147	8243.3	1007	4265.2	1045	0.1831	0.0351	0.0420	0.0372
2330	148	8251.4	1015	4273.3	1053	0.1706	0.0331	0.0403	0.0364
2400	149	8259.5	1023	4281.5	1061	0.1784	0.0345	0.0415	0.0369
2400	149	8259.5	1023	4281.5	1061	0.1784	0.0341	0.0423	0.0373
30	150	8267.6	1031	4289.8	1069	0.1648	0.0315	0.0399	0.0340
100	151	8275.7	1039	4298.0	1078	0.1696	0.0317	0.0411	0.0343
130	152	8283.8	1047	4306.2	1086	0.1664	0.0288	0.0402	0.0346
130	152	8283.8	1047	4306.2	1086	0.1668	0.0308	0.0384	0.0333
200	153	8291.9	1055	4314.1	1094	0.1597	0.0292	0.0371	0.0313
230	154	8299.1	1063	4322.7	1102	0.1680	0.0302	0.0407	0.0344
300	155	8307.2	1071	4330.0	1110	0.1614	0.0255	0.0385	0.0325
300	155	8307.2	1071	4330.0	1110	0.1653	0.0291	0.0401	0.0340
330	156	8316.4	1080	4339.2	1119	0.1627	0.0274	0.0392	0.0334
400	157	8324.8	1088	4347.5	1127	0.1544	0.0271	0.0376	0.0327
430	158	8332.9	1096	4355.7	1135	0.1561	0.0275	0.0383	0.0328

TIME	SAMPLE NUMBER	METER #1		METER #2		PPM MEOH	PPM ETOH	PPM NPA	PPM PF
		BBLs.	CUM.	BBLs.	CUM.				
500	159	8340.0	1103	4363.9	1143	0.1578	0.0272	0.0389	0.0328
530	160	8348.1	1112	4372.3	1152	0.1579	0.0279	0.0385	0.0322
600	161	8357.2	1121	4380.8	1160	0.1570	0.0247	0.0383	0.0315
630	162	8365.5	1129	4388.8	1168	0.1568	0.0269	0.0388	0.0321
700	163	8373.8	1137	4397.0	1177	0.1461	0.0260	0.0359	0.0307
700	163	8373.8	1137	4397.0	1177	0.1613	0.0220	0.0369	0.0347
730	164	8381.9	1145	4405.3	1185	0.1566	0.0267	0.0386	0.0322
730	164	8381.9	1145	4405.3	1185	0.1578	0.0232	0.0390	0.0322
800	165	8390.0	1153	4413.5	1193	0.1522	0.0252	0.0391	0.0383
830	166	8398.2	1162	4421.8	1201	0.1316	0.0209	0.0338	0.0255
830	166	8298.2	1162	4421.8	1201	0.1341	0.0220	0.0347	0.0251
900	167	8406.4	1170	4430.0	1210	0.1551	0.0237	0.0394	0.0299
930	168	8414.6	1178	4438.3	1218	0.1563	0.0239	0.0401	0.0301
1000	169	8422.7	1186	4446.6	1226	0.1522	0.0247	0.0381	0.0288
1030	170	8430.9	1194	4454.9	1234	0.1487	0.0245	0.0392	0.0278
1030	170	8430.9	1194	4454.9	1234	0.1554	0.0262	0.0400	0.0299
1100	171	8439.1	1203	4463.1	1243	0.1494	0.0247	0.0388	0.0261
1130	172	8447.3	1211	4471.4	1251	0.1510	0.0236	0.0400	0.0280
1130	172	8447.3	1211	4471.4	1251	0.1547	0.0230	0.0407	0.0290
1200	173	8455.5	1219	4479.7	1259	0.1519	0.0243	0.0398	0.0293
1200	173	8455.5	1219	4479.7	1259	0.1713	0.0254	0.0398	0.0288
1230	174	8463.7	1227	4488.0	1268	0.1556	0.0246	0.0397	0.0279
1300	175	8471.9	1235	4496.3	1276	0.1447	0.0229	0.0372	0.0279
1330	176	8480.3	1244	4504.6	1284	0.1465	0.0227	0.0385	0.0273
1400	177	8488.5	1252	4512.9	1292	0.1507	0.0234	0.0390	0.0277
1430	178	8496.8	1260	4521.2	1301	0.1384	0.0213	0.0369	0.0256
1500	179	8505.1	1269	4529.5	1309	0.1471	0.0224	0.0379	0.0274
1530	180	8513.4	1277	4537.8	1317	0.1433	0.0216	0.0371	0.0270
1600	181	8521.7	1285	4546.1	1326	0.1545	0.0229	0.0402	0.0289
1630	182	8530.0	1293	4554.5	1334	0.1351	0.0198	0.0351	0.0261
1700	183	8538.3	1302	4562.7	1342	0.1451	0.0204	0.0371	0.0293
1730	184	8546.6	1310	4571.0	1351	0.1671	0.0241	0.0431	0.0300
1800	185	8554.7	1318	4579.3	1359	0.1319	0.0190	0.0334	0.0258
1830	186	8563.0	1326	4587.6	1367	0.1367	0.0196	0.0358	0.0249
1900	187	8571.4	1335	4596.0	1376	0.1367	0.0186	0.0379	0.0249
1930	188	8579.7	1343	4604.3	1384	0.1358	0.0185	0.0356	0.0239
2000	189	8587.8	1351	4612.6	1392	0.1439	0.0199	0.0365	0.0249
2030	190	8596.0	1359	4620.9	1400	0.1490	0.0197	0.0363	0.0243
2100	191	8604.1	1368	4629.2	1409	0.1323	0.0188	0.0356	0.0231
2100	191	8604.1	1368	4629.2	1409	0.1382	0.0190	0.0370	0.0236
2130	192	8612.3	1376	4637.5	1417	0.1468	0.0188	0.0362	0.0236
2200	193	8620.4	1384	4645.8	1425	0.1347	0.0181	0.0360	0.0234
2230	194	8628.6	1392	4654.1	1434	0.1335	0.0172	0.0364	0.0227
2230	194	8628.6	1392	4654.1	1434	0.1367	0.0181	0.0365	0.0232
2300	195	8636.7	1400	4662.4	1442	0.1274	0.0174	0.0337	0.0220
2330	196	8644.8	1408	4670.7	1450	0.1305	0.0175	0.0352	0.0217
2400	197	8652.9	1416	4679.0	1459	0.1397	0.0171	0.0332	0.0222

TIME	SAMPLE NUMBER	METER #1		METER #2		PPM MEOH	PPM ETOH	PPM NPA	PPM PF
		BBLs.	CUM.	BBLs.	CUM.				
30	198	8660.0	1423	4687.3	1467	0.1276	0.0166	0.0334	0.0210
100	199	8668.1	1432	4695.6	1475	0.1347	0.0177	0.0350	0.0217
130	200	8676.2	1440	4703.8	1483	0.1226	0.0161	0.0328	0.0207
200	201	8685.3	1449	4712.1	1492	0.1261	0.0160	0.0334	0.0210
200	201	8685.3	1449	4712.1	1492	0.1276	0.0118	0.0326	0.0207
230	202	8693.3	1457	4720.4	1500	0.1213	0.0159	0.0325	0.0208
300	203	8701.4	1465	4728.6	1508	0.1265	0.0161	0.0327	0.0207
330	204	8709.5	1473	4737.1	1517	0.1215	0.0155	0.0309	0.0199
330	204	8709.5	1473	4737.1	1517	0.1217	0.0138	0.0326	0.0202
400	205	8717.6	1481	4745.2	1525	0.0909	0.0143	0.0304	0.0194
400	205	8717.6	1481	4745.2	1525	0.1210	0.0150	0.0323	0.0202
430	206	8725.7	1489	4753.6	1533	0.1227	0.0151	0.0329	0.0193
500	207	8733.8	1497	4761.8	1541	0.1186	0.0152	0.0312	0.0196
530	208	8741.9	1505	4770.2	1550	0.1151	0.0146	0.0298	0.0189
600	209	8749.0	1512	4778.4	1558	0.1165	0.0141	0.0305	0.0188
600	209	8749.0	1512	4778.4	1558	0.1180	0.0085	0.0298	0.0185
630	210	8758.1	1522	4786.7	1566	0.1142	0.0136	0.0303	0.0183
630	210	8758.1	1522	4786.7	1566	0.1197	0.0143	0.0293	0.0185
700	211	8766.1	1530	4794.8	1574	0.1151	0.0111	0.0300	0.0185
730	212	8774.4	1538	4803.1	1583	0.1146	0.0123	0.0301	0.0173
800	213	8782.4	1546	4811.3	1591	0.1101	0.0088	0.0281	0.0171
830	214	8790.6	1554	4819.5	1599	0.1009	0.0094	0.0261	0.0158
830	214	8790.6	1554	4819.5	1599	0.1091	0.0074	0.0275	0.0165
900	215	8798.7	1562	4827.7	1607	0.0957	0.0118	0.0279	0.0165
930	216	8806.9	1570	4836.0	1616	0.1029	0.0127	0.0276	0.0175
1000	217	8814.1	1578	4844.1	1624	0.1056	0.0130	0.0274	0.0179
1030	218	8823.2	1587	4852.7	1632	0.1028	0.0128	0.0273	0.0172
1100	219	8831.3	1595	4861.0	1641	0.1006	0.0118	0.0266	0.0168
1130	220	8839.5	1603	4869.1	1649	0.0987	0.0112	0.0256	0.0165
1200	221	8847.6	1611	4877.4	1657	0.1022	0.0125	0.0262	0.0169
1230	222	8855.8	1619	4885.7	1665	0.0848	0.0104	0.0219	0.0138
1230	222	8855.8	1619	4885.7	1665	0.0850	0.0092	0.0222	0.0134
1300	223	8863.9	1627	4893.8	1673	0.0997	0.0119	0.0260	0.0161
1330	224	8871.8	1635	4901.8	1681	0.0991	0.0109	0.0254	0.0159
1400	225	8880.3	1644	4910.4	1690	0.0966	0.0111	0.0252	0.0153
1400	225	8880.3	1644	4910.4	1690	0.0966	0.0111	0.0252	0.0153
1430	226	8888.5	1652	4918.6	1698	0.1020	0.0113	0.0237	0.0151
1500	227	8896.7	1660	4926.9	1706	0.0971	0.0081	0.0246	0.0137
1530	228	8904.8	1668	4935.1	1715	0.1198	0.0135	0.0277	0.0175
1600	229	8913.3	1677	4943.3	1723	0.1017	0.0113	0.0240	0.0148
1630	230	8921.4	1685	4951.6	1731	0.0958	0.0092	0.0240	0.0137
1700	231	8929.6	1693	4959.8	1739	0.1039	0.0110	0.0231	0.0147
1730	232	8937.8	1701	4968.1	1748	0.0890	0.0098	0.0226	0.0129
1800	233	8946.0	1709	4976.3	1756	0.0973	0.0106	0.0220	0.0138
1830	234	8954.2	1718	4984.6	1764	0.0945	0.0108	0.0228	0.0142
1900	235	8962.4	1726	4992.8	1772	0.0725	0.0081	0.0185	0.0110
1900	235	8962.4	1726	4992.8	1772	0.0892	0.0089	0.0201	0.0122

<u>TIME</u>	<u>SAMPLE NUMBER</u>	<u>METER #1</u>		<u>METER #2</u>		<u>PPM MEOH</u>	<u>PPM ETOH</u>	<u>PPM NPA</u>	<u>PPM PF</u>
		<u>BBLs.</u>	<u>CUM.</u>	<u>BBLs.</u>	<u>CUM.</u>				
1930	236	8970.6	1734	5001.1	1781	0.0874	0.0094	0.0217	0.0128
2000	237	8978.8	1742	5009.3	1789	0.0922	0.0101	0.0215	0.0138
2000	237	8978.8	1742	5009.3	1789	0.0934	0.0095	0.0225	0.0127
2030	238	8987.0	1750	5017.5	1797	0.0813	0.0085	0.0207	0.0117
2100	239	8995.1	1759	5025.8	1805	0.0816	0.0086	0.0204	0.0113
2130	240	9003.2	1767	5034.0	1814	0.0800	0.0087	0.0201	0.0115
2200	241	9011.3	1775	5042.2	1822	0.0726	0.0078	0.0178	0.0105
2200	241	9011.3	1775	5042.2	1822	0.0792	0.0083	0.0207	0.0114
2230	242	9019.5	1783	5050.5	1830	0.0693	0.0066	0.0181	0.0097
2230	242	9019.5	1783	5050.5	1830	0.0799	0.0076	0.0209	0.0111
2300	243	9027.6	1791	5058.8	1838	0.0798	0.0065	0.0200	0.0110
2330	244	9035.7	1799	5067.0	1847	0.0815	0.0088	0.0205	0.0145
2400	245	9043.7	1807	5075.2	1855	0.0854	0.0089	0.0210	0.0112
2400	245	9043.7	1807	5075.2	1855	0.0911	0.0096	0.0025	0.0126
30	246	9051.8	1815	5083.4	1863	0.0745	0.0078	0.0190	0.0106
100	247	9059.9	1823	5091.5	1871	0.0762	0.0076	0.0194	0.0106
100	247	9059.9	1823	5091.5	1871	0.0834	0.0082	0.0196	0.0111
130	248	9067.1	1831	5099.8	1879	0.0817	0.0081	0.0188	0.0109
200	249	9075.1	1839	5107.9	1887	0.0760	0.0075	0.0197	0.0105
200	249	9075.1	1839	5107.9	1887	0.0790	0	0.0187	0.0102
230	250	9084.2	1848	5116.1	1896	0.0710	0.0059	0.0174	0.0095
300	251	9092.4	1856	5120.2	1900	0.0851	0.0081	0.0210	0.0118
300	251	9092.4	1856	5120.2	1900	0.0880	0.0072	0.0212	0.0117
330	252	9100.4	1864	5132.4	1912	0.0710	0.0063	0.0173	0.0105
400	253	9108.5	1872	5140.6	1920	0.0715	0.0066	0.0176	0.0101
430	254	9116.7	1880	5148.8	1928	0.0700	0.0071	0.0161	0.0094
500	255	9124.8	1888	5157.0	1937	0.0715	0.0074	0.0176	0.0100
530	256	9132.9	1896	5165.1	1945	0.0671	0.0062	0.0160	0.0094
600	257	9140.9	1904	5173.4	1953	0.0649	0.0066	0.0159	0.0093
600	257	9140.9	1904	5173.4	1953	0.0667	0.0055	0.0160	0.0092
630	258	9149.2	1913	5181.5	1961	0.0627	0.0065	0.0153	0.0090
630	258	9149.2	1913	5181.5	1961	0.0635	0.0061	0.0158	0.0089
700	259	9157.2	1921	5189.4	1969	0.0639	0.0066	0.0155	0.0091
730	260	9165.7	1929	5197.7	1977	0.0726	0.0067	0.0149	0.0093
730	260	9165.7	1929	5197.7	1977	0.0726	0.0067	0.0149	0.0093
800	261	9173.8	1937	5205.8	1985	0.0654	0.0056	0.0157	0.0092
830	262	9182.1	1946	5214.0	1994	0.0582	0.0060	0.0138	0.0082
900	263	9190.3	1954	5222.1	2002	0.0610	0.0068	0.0150	0.0096
930	264	9198.6	1962	5230.4	2010	0.0533	0.0056	0.0135	0.0082
1000	265	9206.7	1970	5238.4	2018	0.0561	0.0063	0.0140	0.0088
1030	266	9215.2	1979	5246.7	2026	0.0524	0.0058	0.0131	0.0081
1030	266	9215.2	1979	5246.7	2026	0.0602	0.0061	0.0147	0.0094
1100	267	9223.4	1987	5254.8	2034	0.0524	0.0058	0.0131	0.0081
1130	268	9231.9	1995	5263.2	2043	0.0598	0.0067	0.0144	0.0093
1200	269	9240.2	2004	5271.3	2051	0.0605	0.0063	0.0137	0.0090
1230	270	9248.5	2012	5279.5	2059	0.0578	0.0062	0.0136	0.0097
1300	271	9256.7	2020	5287.7	2067	0.0570	0.0061	0.0139	0.0089
1330	272	9264.9	2028	5295.8	2075	0.0526	0.0056	0.0124	0.0081
1400	273	9273.3	2037	5304.1	2084	0.0570	0.0056	0.0123	0.0081
1430	274	9281.4	2045	5312.2	2092	0.0599	0.0054	0.0137	0.0073

TIME	SAMPLE NUMBER	METER #1		METER #2		PPM MEOH	PPM ETOH	PPM NPA	PPM PF
		BBLs.	CUM.	BBLs.	CUM.				
1500	275	9289.5	2053	5320.2	2100	0.0554	0.0054	0.0123	0.0055
1530	276	9297.6	2061	5328.4	2108	0.0575	0.0053	0.0128	0.0072
1530	276	9297.6	2061	5328.4	2108	0.0580	0.0053	0.0134	0.0071
1600	277	9305.7	2069	5336.6	2116	0.0567	0.0054	0.0134	0.0075
1600	277	9305.7	2069	5336.6	2116	0.0578	0.0050	0.0128	0.0219
1630	278	9313.8	2077	5344.8	2124	0.0590	0.0049	0.0134	0.0208
1630	278	9313.8	2077	5344.8	2124	0.0618	0.0054	0.0128	0.0234
1700	279	9231.9	2085	5353.0	2133	0.0563	0.0049	0.0119	0.0173
1730	280	9329.9	2093	5361.1	2141	0.0571	0.0051	0.0119	0.0206
1800	281	9338.3	2102	5369.3	2149	0.0560	0.0048	0.0119	0.0206
1830	282	9346.5	2110	5377.0	2157	0.0580	0.0050	0.0118	0.0219
1900	283	9354.6	2118	5385.7	2165	0.0534	0.0047	0.0139	0.0192
1000	284	9507.5	2271	0	-3221	0.0384	0	0.0073	0.0050
1000	284	9597.5	2361	0	-3221	0.0405	0	0.0072	0.0048
1030	285	9604.9	2368	5638.8	2418	0.0410	0.0028	0.0068	0.0046
1100	286	9613.0	2376	5647.0	2427	0.0372	0	0.0068	0.0041
1100	286	9613.0	2376	5647.0	2427	0.0400	0	0.0067	0.0042
1130	287	9621.1	2385	5655.2	2435	0.0355	0	0.0061	0.0037
1200	288	9629.3	2393	5663.4	2443	0.0382	0	0.0064	0.0041
1200	288	9629.3	2393	5663.4	2443	0.0382	0	0.0064	0.0041
1845	1	7236.6	0	3220.5	0	0	0	0	0
2000	2	7236.6	0	3227.1	7	0	0	0	0
2030	3	7236.6	0	3233.6	13	0	0	0	0
2100	4	7236.6	0	3239.8	19	0	0	0	0
2130	5	7236.6	0	3245.4	25	0	0	0	0
2200	6	7236.6	0	3250.9	30	0	0	0	0
2200	6	7236.6	0	3250.9	30	0	0	0	0
2230	7	7241.8	5	3256.3	36	0	0	0	0
2230	7	7241.8	5	3256.3	36	0	0	0	0
2300	8	7246.0	9	3261.4	41	0	0	0	0
2330	9	7251.1	15	3266.3	46	0	0	0	0
2400	10	7257.0	20	3271.2	51	0	0	0	0
30	11	7261.9	25	3275.9	55	0	0	0	0
100	12	7266.7	30	3280.6	60	0	0	0	0
100	12	7266.7	30	3280.6	60	0	0	0	0
130	13	7271.4	35	3285.2	65	0	0	0	0
200	14	7275.0	38	3289.8	69	0	0	0	0
230	15	7280.5	44	3294.3	74	0	0	0	0
300	16	7284.0	47	3298.7	78	0	0	0	0
330	17	7289.4	53	3303.1	83	0	0	0	0
330	17	7289.4	53	3303.1	83	0	0	0	0
400	18	7293.9	57	3307.5	87	0	0	0	0
400	18	7293.9	57	3307.5	87	0	0	0	0
430	19	7298.2	62	3311.8	91	0	0	0	0

<u>TIME</u>	<u>SAMPLE NUMBER</u>	<u>METER #1</u>		<u>METER #2</u>		<u>PPM MEOH</u>	<u>PPM ETOH</u>	<u>PPM NPA</u>	<u>PPM PF</u>
		<u>BBLs.</u>	<u>CUM.</u>	<u>BBLs.</u>	<u>CUM.</u>				
500	20	7302.4	66	3316.1	96	0	0	0	0
530	21	7306.6	70	3320.2	100	0	0	0	0
530	21	7306.6	70	3320.2	100	0	0	0	0
600	22	7310.6	74	3324.3	104	0	0	0	0
630	23	7314.0	77	3328.2	108	0	0	0	0
700	24	7318.3	82	3332.1	112	0	0	0	0
730	25	7322.3	86	3335.9	115	0	0	0	0
800	26	7326.2	90	3339.7	119	0	0	0	0
800	26	7326.2	90	3339.7	119	0	0	0	0
830	27	7330.1	94	3343.6	123	0	0	0	0
900	28	7333.8	97	3347.3	127	0	0	0	0
930	29	7337.5	101	3351.0	131	0	0	0	0
1000	30	7341.1	105	3354.4	134	0	0	0	0