

Acknowledgments

The University of Tulsa acknowledges Marathon Oil Company and DB Robinson for their efforts on characterizing and determining fluid properties on fluids from three wells: Mobil Oil Company's South Pelto Well No. 9-2, Shell Oil Company's Garden Banks 426 Well No. A-14 and Chevron Oil Company's Main Pass 299 Well No. B-4. Our thanks also go out to Jeff Creek at Chevron for converting the data presented in the quarterly reports to independent fluid and property evaluation reports.

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I. Introduction

This report presents all of the data determined in response to the contract awarded to Marathon Oil Company by The University of Tulsa Paraffin Deposition Joint Industry Project (JIP). The purpose of this work was to provide fluid property data on hydrocarbon fluids to be used in the JIP single phase and multiphase flow deposition tests. Required are:

1. Sample Conditioning and Physical Recombination for Recombined Oil 1, Recombined Oil 2, Recombined Condensate, Flow Loop Oil, and Flow Loop Condensate:

For each recombined oil, restore separator gas and separator liquid by heating and pressurization back to 150°F. From specified gas-oil ratio, use the conditioned separator products to reconstitute the original reservoir fluid. Work includes separator fluid quality checks, compositional analysis including C₃₀₊ composition of recombined reservoir fluid, density measurements, and physical recombination.

For each separator oil, check the stock tank oil for water content. Heat stock tank oil container walls and agitate fluid. Synthesize solution gas from supplied composition or liquefy natural gas if sample is provided. From specified gas-oil ratio, use stock tank oil and natural gas to reconstitute the flow loop fluids. Work includes compositional analysis including C₃₀₊ composition of reconstituted flow loop fluid, density of reservoir fluid at P_{ob}, synthesis or liquefaction of natural gas, and physical recombination.

For Recombined Oil 1 and Recombined Condensate, reconstitute approximately 1 additional liter of reservoir fluid and ship to D.B. Robinson & Associates in Edmonton, Alberta Canada.

2. Constant Composition Expansion (CCE) Studies for Recombined Oil 1, Recombined Oil 2, Recombined Condensate, Flow Loop Oil, and Flow Loop Condensate:

For each recombined fluid, measure phase volumes, phase densities (Anton-Paar "oscillating tube" densitometer), and liquid phase viscosities (capillary coil viscometer) at three pressures (the saturation pressure, 500 psia, and one intermediate pressure) for three temperatures each (40°F, reservoir temperature, and an intermediate temperature).

For each flow loop fluid, measure phase volume fractions, phase densities, and liquid phase viscosities at five pressures (the saturation pressure, 500 psia, and three intermediate pressure) for three temperatures each (40°F, reservoir temperature, and an intermediate temperature).

3. Cloud Point Determinations for Recombined Oil 1, Recombined Oil 2, Flow Loop Oil, and Flow Loop Condensate:

For each recombined oil, measure cloud point (wax appearance temperature [WAT]) and wax dissolution temperature (WDT) at five different pressures. One of two different techniques will be selected for these measurements based on results obtained by both techniques for one pressure (above saturation pressure). Filter plugging (10,000 psig pressure limit) measures cloud point under dynamic conditions. Scattering of Infrared energy (FTIR, 7,000 psi limit) measures the cloud point under static conditions.

For each flow loop oil, measure WAT and WDT at 5 different pressures using high-pressure cloud point technique selected above.

For each stock tank oil, cloud point measurements will be made at ambient pressure using FTIR, the differential scanning calorimetry (DSC) method, and the cross polarization microscopy method (CPM). An additional high-pressure measurement will be made using FTIR.

4. Phase Compositions for Flow Loop Oil and Flow Loop Condensate at P and T.

For each flow loop oil, measure vapor and liquid phase compositions to C_{30+} at one selected pressure for each of the three temperatures used for the CCE experiments.

5. Solid composition (Nenniger Analysis) and amount for Recombined Oil 1, Recombined Oil 2, Recombined Condensate, Flow Loop Oil, and Flow Loop Condensate from precipitation test.

Obtain Nenniger n-paraffin analyses of flashed dead oil and flashed spent oil from a solids harvesting experiment for each recombined oil. The difference represents solid formed during the solids harvesting experiment. Solids harvesting will be performed using one of the three different techniques. Filter plugging can be conducted to solids depletion for a given temperature, or a flow loop experiment can be performed using limited reservoir volume to pipe wall surface ratio for a given temperature. Alternatively, ultra centrifugation (up to 100,000 gal) can be conducted to solids depletion for a given temperature.

For each flow loop oil, obtain Nenniger n-paraffin analyses of spent oil from solids harvesting experiment described above.

The compositional differences between the spent oil and stock tank oil (see item 6) represents solid formed during the solids harvesting experiment.

6. Stock Tank Oil Compositional Analyses for Oil 1, Oil 2, and Condensate:

For each stock tank oil, determine C_{30+} composition and Nenniger n-paraffin analyses.

7. Viscosity and Density Measurements of stock tank fluids for Oil 1, Oil 2, and Condensate.

Measure viscosity as a function of shear and temperature (Rheometrics Fluid Spectrometer) and density as a function of temperature.

8. Reproducibility Check on Items 3 and 5 for Flow Loop Oil (Optional):

Assuming that Flow Loop Oil 1 is available first, repeat sub-sampling of Flow Loop Oil 1 towards the end of the project. Repeat cloud point determinations (selected techniques and pressures), solid composition and amount determinations including Nenniger n-paraffin analyses of original and spent stock tank oil.

2. Experimental Data

Separator and stock tank samples were taken from three wells: South Pelto 10 Well 9-2, Main Pass 299 Well B-4, and Garden Banks 426 Well A-14. The following field samples were taken from each well:

South Pelto 10 Well 9-2

- (8) one liter cylinders of separator gas
- (4) one liter cylinders of separator liquid
- (2) five gallon DOT cans of stock tank oil

Main Pass 299 Well B-4

- (5) one liter cylinders of separator gas
- (2) one liter cylinders of separator liquid
- (2) five gallon DOT cans of stock tank oil

Garden Banks 426 Well A-14

- (16) 500 cc cylinders of separator gas
- (6) 500 cc cylinders of separator liquid
- (2) one gallon DOT cans of stock tank oil

A 43.8-liter cylinder containing a synthetic five-component gas blend representing The University of Tulsa's natural gas stream was prepared by Marathon Oil Company. This gas and liquid samples were recombined to make the reservoir and flow loop fluids studied in this work.

The experiments were performed by Marathon Petroleum Technology Company, Nenniger Engineering, and D.B. Robinson Associates. The data are organized by fluid in three sections included as appendices. Each appendix is a properties report for a particular fluid. Appendix 3.1 reports data measured on oil from Mobil's South Pelto 10 Field. Appendix 3.2 reports data measured on condensate from Shell's Garden Banks 426 Field. Appendix 3.3 reports data measured on oil from Chevron's Main Pass 299 Field. The order for which the data appear in each section is approximately the same order as prescribed in the proposal. Also attached, without the sections from the Quarterly reports, as Appendix 3.4 is the Final Report prepared by Marathon that was distributed and presented to participants at the April 1997 Advisory Board meeting.

3. Appendices

- 3.1. S. Pelto 10 Well 9-2 Fluid Characterization and Property Evaluation Study
- 3.2. Garden Banks 426 Well A-14 Reservoir Fluid Characterization and Property Evaluation Study
- 3.3. Main Pass 299 Well B-4 Fluid Characterization and Property Evaluation Study
- 3.4. Marathon's Fluid Characterization and Property Evaluation Final Report

Appendix 3.I: S. Pelto 10 Well 9-2 Fluid Characterization and Property Evaluation Study

3.1. Oil I- South Pelto

On January 12, 1996, Weatherly Laboratories collected separator samples from Mobil Oil Company's South Pelto Well No. 9-2 for The University of Tulsa's JIP Recombined Oil No. 1 studies. Duplicate samples were collected resulting in a total of eight separator gas samples and four separator liquid samples. These samples, plus a five gallon can of stock tank oil, arrived at Marathon Oil Company's Petroleum Technology Center on January 19, 1996.

3.1.1. Separator Samples

As a quality check, the opening pressure of the separator gases and the bubble point pressure of the separator liquids were determined at ambient temperature. These results are presented in Table 3.1.1. One of the samples, separator gas Cylinder No. WL-142 appeared to have been compromised. Prior to taking any sample outage, each separator liquid cylinder was conditioned by being heated to 150°F and pressurized to 1500 psig. Each separator gas cylinder was also conditioned by being heated to 150°F.

Compositions were determined for all separator gases and liquids. The stock tank oil gravities from all produced samples are given in Table 3.1.2. The compositional results show that there is very good comparison between the duplicate gas and liquid samples. These data are presented in Tables 3.1.3 and 3.1.4. The composition of the separator liquid was also analyzed by using gas chromatography. The separator liquid compositions are reported through C₃₀₊ in Table 3.1.4. The mass percent values are measured. The properties of the individual C₆₊ fractions were not measured but rather estimated. The molecular weights of the C₆-C₂₉ fractions are values reported by Katz and Firoozabadi¹ for general petroleum fractions. The specific gravity values for C₆-C₃₀₊ fractions are calculated using a constant Watson K factor of 11.87. The C₃₀₊ molecular weight and overall Watson K factor were calculated to match the measured molecular weight, measured by Freezing Point Depression, and the 60°F density value, measured by using a Paar-Mettler densitometer, for the stabilized liquid created from the separator liquid.

Figure 3.1.1 shows the equilibrium K values plotted for gas composition from Cylinder No. WL-256 and liquid composition from Cylinder No. WL-170. The K-value results indicate that the collected separator gases and liquids were in equilibrium at separator conditions.

3.1.2. Reservoir Fluid Properties

3.1.2.1. Recombination

Erratic production rates of gas and liquid as well as the production of free gas, solution gas, and gas lift gas were observed during previous South Pelto sampling operations. Upon conferring with The University of Tulsa personnel and Marathon management, it was decided that the separator products should be recombined to the static shut-in conditions of 3192 psig and 232°F obtained from a Well No. 9-2 pressure/temperature survey run on December 5, 1995.

¹ Katz, D. L. and Firoozabadi, A., "Predicting Phase Behavior of Condensate Crude-Oil Systems using Methane Interaction Coefficients", J. Pet. Tech., November 1978, pp. 1649 - 1655.

Recombination calculations were completed using a tuned equation-of-state model to predict the gas-oil ratio (GOR) to achieve a bubble point pressure of 3192 psig and 232°F. Using these numbers, a 'pilot' mix was made in a high-pressure visual PVT cell. A bubble point pressure of 3235 psia was observed from the reconstituted fluids. From these data, a large recombined mixture was made in a cylinder for all remaining PVT work. This cylinder was then conditioned by pressurizing it to 5000 psig and heated to 150°F.

3.1.2.2. Reservoir Fluid Analysis

A small amount of the recombined fluid was taken out of the cylinder for compositional analysis to C_{30+} . This measured well stream fluid composition is compared with the estimated composition based on the gas-oil ratio and separator gas and liquid compositions in Table 3.1.5. The GOR for the recombined fluid was found to be 454.7 scf/bbl of stock tank oil. The D.B. Robinson compositional analysis of the recombined oil is given in Table 3.1.6. There are considerable differences between the Marathon and D.B. Robinson fluid analyses presented in Tables 3.1.5 and 3.1.6.

3.1.2.3. Constant Composition Expansion Test @ 232°F

A portion of the reservoir fluid was charged to a high-pressure visual PVT cell, contained within an air bath, and thermally equilibrated at the reservoir temperature of 232°F. The fluid was then subjected to a constant composition expansion (CCE). During this expansion a bubble point pressure of 3221 psia (3209 psig) was observed.

As the CCE was proceeding, an amount of fluid was also charged from the recombination cylinder to the Paar-Mettler densitometer and the capillary coil viscometer, both at 232°F. Single-phase density and viscosity measurements were taken at various pressures.

Calibration of the Capillary Coil Tube Viscometer

The calibration coefficient for the capillary tube is obtained from the relationship between viscosity (μ) and pressure difference across the capillary coil tube (Δp) at various flow rates (Q). For a given capillary tube, viscosity is directly proportional to $\Delta p/Q$ for fluid under laminar flow conditions. This is shown as follows:

$$\mu = [\Delta p/Q] \cdot C \quad \text{Where } C \text{ is the coil coefficient for water.}$$

In this study, water was used as the calibration agent to obtain coil coefficients at the same conditions that reservoir fluid viscosities were measured.

Viscosity at Different Conditions for Recombined Oil 1

The pressure drop across the capillary coil versus flow rate for the reservoir fluid was measured at the conditions identical to those of calibration. The slope of Δp versus Q times coil coefficient at corresponding conditions gives viscosity of the fluid, i. e.,

Example. At 42°F and 512 psi:

$$\text{coil coefficient of Water} = 8.8508 \text{ cp(cc/hr)/psi}$$

$$(\Delta p/Q)_{\text{recombined oil 1}} = 0.9338 \text{ psi/(cc/hr)}$$

$$\mu = 8.8508 (0.9338) = 8.263 \text{ cp}$$

As stated in the proposal, the fluid in the PVT cell was expanded down to 506 psia where the equilibrate gas was pumped off to the densitometer. All remaining gas was then pumped out of the PVT cell until the 506 psia equilibrium oil was all that remained in the cell. The oil at this pressure was then pumped to the densitometer and the viscometer.

After the 506 psia measurements, another small portion of recombined reservoir fluid was charged to the PVT cell. This fluid was used to verify the bubble point pressure and obtain property data at the intermediate pressure of 1874 psia.

The CCE data along with the density and viscosity data are presented in Table 3.1.7. The density values denoted by an asterisk are measured. All other oil densities above bubble point are interpolated from relative volume data. All oil viscosities denoted by asterisk are measured. The oil viscosity at the bubble point pressure is linearly interpolated from the measured single-phase oil viscosity values.

3.1.2.4. Constant Composition Expansion Test @ 136°F

A portion of the reservoir fluid was charged to a high-pressure visual PVT cell and thermally equilibrated at 136°F. The fluid was then subjected to a constant composition expansion, CCE. During this expansion a bubble point pressure of 2895 psia was observed.

As stated in the above CCE at 232°F, an amount of fluid was also charged from the recombination cylinder to the densitometer and viscometer. Single-phase density and viscosity measurements were taken at various pressures at 136°F.

The fluid in the PVT cell was expanded down to 506 psia where the equilibrate gas was pumped off to the densitometer. All remaining gas was then pumped out of the PVT cell until the 506 psia equilibrate oil was all that remained in the cell. The oil at this pressure was then pumped to the densitometer and the viscometer.

After the 506 psia measurements, another small portion of recombined reservoir fluid was charged to the PVT cell. This fluid was used to verify the bubble point pressure and obtain property data at the intermediate pressure of 1722 psia.

The CCE data along with the density and viscosity data are presented in Table 3.1.8. The measured and interpolated values for density and viscosity were determined by the same techniques used at 232°F (Table 3.1.7).

3.1.2.5. Constant Composition Expansion Test @ 42°F

A portion of the reservoir fluid was charged to a high-pressure visual PVT cell at 136°F. The PVT cell and airbath were then cooled down to the requested temperature of 42°F while being agitated. The fluid was then subjected to a constant composition expansion, CCE. During this expansion a bubble point pressure of 2518 psia was observed.

The fluid in the PVT cell was expanded down to 506 psia. The equilibrate gas was pumped off to the densitometer. Prior to removing any oil, the PVT cell was never allowed to remain static. The 506 psia equilibrate oil was then pumped to the densitometer and the viscometer. The data obtained for density appears reliable with no apparent problems being observed. The pressure drop at various flow rates needed to calculate the viscosity at this pressure were erratic. Several runs were performed in order to get stabilized readings.

A small portion of recombined reservoir fluid was charged to the PVT cell. This fluid was used to verify the bubble point pressure and obtain property data at the intermediate pressure of

1520 psia. As with the 506 psia data, gas and liquid density data appears reliable with no apparent problems. The pressure drop at various flow rates needed to obtain viscosity data at this pressure were also erratic. Several runs were again made at this pressure until stabilized readings were obtained. The CCE data along with the density and viscosity data are presented in Table 3.1.9. Table 3.1.8. The measured and interpolated values for density and viscosity were determined by the same techniques used for the CCE at 236°F.

The oil viscosity data below the bubble point pressure at 42°F appears peculiar in that the 506 psia and 1520 psia data are virtually identical.

In addition to low temperature, below the bubble point pressure, high concentration of wax structure causes complex flow toward a Bingham Plastic Type behavior. This phenomenon can cause plug flow that results in excess yield. Because of these effects, apparent viscosities have been measured, not true viscosities.

The viscosity data was obtained in three stages: 506 psia first, followed by the three pressures above the bubble point, then lastly 1520 psia. Prior to acquiring data at each stage, the coil was cleaned with 1,1,1 trichloroethane and purged with air. Then a vacuum was pulled on the system.

3.1.2.6. Additional Recombinations

A recombination of the original fluid mixture was made again in another high-pressure cylinder and sent to D.B. Robinson Ltd. for their paraffin characterization work. A third recombination was made in a high-pressure cylinder but this mixture was made to a GOR of 182 scf/bbl of stock tank oil. It was made for the sole purpose of being used in the cloud point measurements. The fluid had a bubble point pressure of 1250 psia at 160°F. This mixture was conditioned by pressurizing it to 5000 psig and 160°F, then sampled for compositional analysis to C₃₀₊. This measured Intermediate Recombined Oil 1 composition is presented in Table 3.1.11.

3.1.3. Flow Loop Oil

3.1.3.1. Physical Recombination of Flow Loop Oil

Recombination calculations were completed to predict the GOR to achieve a bubble point pressure of 500 psi and 140°F. Using these numbers, conditioned stock tank oil was first transferred into a high pressure cylinder. Then incrementally, synthetic City of Tulsa natural gas was added until a final bubble point pressure of 500 psig at 140°F was achieved. The composition of the City of Tulsa Synthetic Gas is given in Table 3.1.10. This recombination was then conditioned at 1,500 psig and 140°F. Upon conferring with the University of Tulsa, it was decided to perform the PVT portion of the Flow Loop Oil Study at the temperatures of 140°F, 90°F, and 40°F. The composition of the recombined flow loop oil is given in Table 3.1.12.

3.1.3.2. Constant Composition Expansion Test @ 140°F

A portion of Flow Loop Oil, still conditioned at 1,500 psig and 140°F, was charged into a high-pressure visual PVT cell, contained within an air bath and thermally equilibrated at a temperature of 140°F. The fluid was then subjected to a CCE. During this expansion a bubble point pressure of 533 psia was observed.

As the CCE proceeded, fluid was also charged from the recombination cylinder to the Paar-Mettler densitometer and the capillary coil viscosimeter, both at 140°F. Single-phase density and viscosity measurements were taken at various pressures. The oil density and viscosity at the bubble point pressure was linearly interpolated from the measured single-phase

oil values. All oil densities and viscosities denoted by an asterisk were measured.

CCE, density, and viscosity data are presented in Table 3.1.13.

As stated in the scope of work, the fluid in the PVT cell was expanded down to 97 psia. At this pressure, some equilibrated gas was pumped off to the densitometer and then collected into a small high pressure cylinder for compositional analysis. This data may be found in Table 3.1.14. Then all remaining gas was pumped out of the PVT cell until the 97 psia equilibrated oil was all that remained in the PVT cell. A portion of the oil phase was then pumped to the densitometer and the viscosimeter, while maintaining constant temperature and pressure. All remaining oil at 97 psia was pumped out of the PVT cell and collected into a small high pressure cylinder for compositional analysis. This data may be also found in Table 3.1.14.

After the 97 psia measurements, subsequent samples of conditioned Flow Loop Oil were charged to the PVT cell. The bubble point of this fluid was verified each time, then property data at the intermediate pressures of 386 psia, 289 psia, and 184 psia were obtained. This data may also be found in Table 3.1.13.

3.1.3.3. Constant Composition Expansion @90°F

A portion of Flow Loop Oil, still conditioned at 1,500 psig and 140°F, was charged into a high-pressure visual PVT cell, contained within an air bath and thermally equilibrated at a temperature of 90°F. The fluid was then subjected to a CCE. During this expansion a bubble point pressure of 423 psia was observed.

As the CCE proceeded, fluid was also charged from the recombination cylinder to the Paar-Mettler densitometer and the capillary coil viscosimeter, both at 90°F. Single-phase density and viscosity measurements were taken at various pressures. The oil density and viscosity at the bubble point pressure was linearly interpolated from the measured single-phase oil values. All oil densities and viscosities denoted by an asterisk were measured.

CCE, density, and viscosity data are presented in Table 3.1.15.

The fluid in the PVT cell was then expanded down to 97 psia. At this pressure, some equilibrated gas was pumped off to the densitometer and then collected into a small high pressure cylinder for compositional analysis. This data may be found in Table 3.1.16. Then all remaining gas was pumped out of the PVT cell until the 97 psia equilibrated oil was all that remained in the PVT cell. A portion of the oil phase was then pumped to the densitometer and the viscosimeter, while maintaining constant temperature and pressure. All remaining oil at 97 psia was pumped out of the PVT cell and collected into a small high pressure cylinder for compositional analysis. This data may be found in Table 3.1.16.

After the 97 psia measurements, another sample of conditioned Flow Loop Oil was charged to the PVT cell. The bubble point of this fluid was verified, then property data at the intermediate pressure of 234 psia was obtained. This data may also be found in Table 3.1.16.

3.1.3.4. Constant Composition Expansion Test @40°F

A portion of Flow Loop Oil, still conditioned at 1,500 psig and 140°F, was charged into a high-pressure visual PVT cell, contained within an air bath and thermally equilibrated at a temperature of 40°F. The fluid was then subjected to a CCE. During this expansion a bubble point pressure of 309 psia was observed. The fluid in the PVT cell was expanded down to a final pressure of 97 psia.

Fluid was also charged from the recombination cylinder to the Paar-Mettler densitometer at 40°F. Single-phase density measurements were taken at various pressures. The oil density at the bubble point pressure was linearly interpolated from the measured single-phase oil values. All oil densities denoted by an asterisk were measured. No viscosity data was obtained due to wax plugging in the capillary coil viscosimeter. Despite several attempts, this problem could not be corrected. Even though the PVT cell never stopped rocking, wax was plating out and depositing thus coating the inside of the PVT cell below the bubble point pressure at 40°F. Because of this occurrence, gas and oil phase densities and compositions could not be obtained so the remainder of this test was terminated. CCE and single phase density data are presented in Table 3.1.17.

3.1.4. Stock Tank Oil Viscosity and Density Measurements

Viscosity measurements were made using the Rheometrics Fluid Spectrometer at temperatures of 40, 50, 60, 70, and 80°F at four to six different shear rates. The South Pelto 10 Well 9-2 fluid is both time and shear dependent at 70°F and below. These values given in Table 3.1.20 are at stabilized conditions, i.e., after the viscosity had reached a constant value after shearing. The crude seems to fit a Bingham Plastic Model, and the parameters given those can be used to calculate apparent viscosity (μ_a) from this model. The density of the stock tank oil as a function of temperature determined with the Parr-Mettler Densimeter are given in Table 3.1.21.

3.1.5. Cloud Point Determinations

Cloud points or wax appearance temperatures (WAT) were determined for Recombined Oil 1 using the Filter Plugging (FP) and Fourier Transform Infrared Spectroscopy (FTIR) techniques. These data are given in Table 3.1.18 and plotted in Figure 3.1.2. Data were collected from dead stock tank oil (STO), flashed separator oil (FSO), the recombined intermediate fluid (RIF) and the recombined reservoir fluid (RRF) at several different compositions and pressures so they can be used for the modeling work. Two different cloud point techniques were used so the best method could be selected for future work. For these samples, the filter plugging technique gives data that is easier to interpret.

Both dead stock tank oil and flashed separator oil were tested because of concern that the stock tank oil might have lost some heavy n-paraffins during handling. The cloud point data does not indicate any significant differences between the two samples. The increase in cloud point with pressure shown in Figure 3.1.2 for the dead oil samples is difficult to quantify because of experimental error. A regression analysis line is shown.

Data from both cloud point techniques suggest a slightly greater increase in cloud point with pressure for the RRF and RIF samples than for the dead oils. However, based on the limited amount of data obtained, and the experimental error in the measurements, this difference may not be real. The FTIR values for the RIF sample were about 5°F lower than the filter plugging values. This difference was not observed for the RRF or the dead oils so it may be related to compositional effects related to sample conditioning rather than temperature calibration issues.

The RRF filter plugging cloud point data showed more scatter than expected. The second 4,000 psig cloud point of 102°F was measured after the sample had been held at 3,000, and 3,500 psig. Perhaps, lack of adequate sample conditioning caused the low value.

The WAT for the flow loop oil by FTIR and filter plugging are given in Table 3.1.19 as a function of pressure. These data are plotted in Figure 3.1.4.

Figures 3.1.6 and 3.1.8 are experimental data from the D.B. Robinson Associates "Onset Cell." These graphs give an indication as to the precision of the WAT data determined for the fluids in this section. The WAT is the departure of the signal from the initial slope with decreasing

temperature. The accuracy is clearly related to the to the rate of cooling and the homogeneity of the temperature in the experimental apparatus. The magnitude of the signal also depends on cooling rate in the DSC experiments for example. Clearly the best data are for the lowest reasonable cooling rates. The refer to Jim Tackett's (Marathon) work for Deepstar CTR 207 Final Report and Kathy Greenhill's Deepstar CTR 204 final report for more extensive explanation of the limitations and accuracy of the different techniques use to measure the WAT.

3.1.6. Wax Dissolution Determinations

Wax dissolution temperatures (WDT), the temperature when all of the wax dissolves when the sample is heated, were measured using the FTIR technique. The infrared scatter data obtained when the RRF sample was heated from 160°F to 44°F to 160°F at 0.3°F per minute is shown in Figure 3.1.3. The WAT and WDT points are labeled. (This curve was greatly amplified to obtain these values.) This curve represents "best" case data. The infrared scatter curves were not as well defined for some of the run conditions and differential techniques were used to locate the WAT and WDT points.

The WDT values are listed in Table 3.1.18. The average difference between WDT and WAT for all the run conditions was 14°F. All of the individual differences were between 10 and 17°F with the exception of a low value of 4°F and a high value of 28°F. These two values which are marked by a (*) in Table 3.1.18 appear to be outliers. Repeat runs were not made.

3.1.7. Solid Wax Determinations

Table 3.1.22 compares the data determined by Marathon and D.B. Robinson on solids collect from the flow loop oils at temperatures near 50°F.

3.1.7.1. Marathon Precipitation Experiments

The Marathon Oil Company made a set of equilibrium measurements to determine the composition and amount of solid wax from Recombined Oil 1 and flashed separator oil (FSO) by centrifugation and high-temperature gas chromatography. The dead oils were sub-sampled at 140°F and then centrifuged at 29,000 rpm while the temperature was slowly stepped down from 140°F to 50°F below cloud point for the South Pelto 10 Well 9-2 FSO.

After centrifugation, supernatant and solid samples were taken and sent to Nenniger Engineering for n-paraffin analyses. The Nenniger Engineering results are given in Table 3.1.23. The solid n-paraffin content was obtained from Nenniger data using two different methods. One method was based on a direct analysis of the solids. The other method was to subtract the composition of the supernatant that remained after centrifugation from the composition of the original stock tank oil. Figure 3.1.5 compares the solid n-paraffin distributions obtained by the two methods.

3.1.7.2. D.B. Robinson Associates Precipitation Experiments

D. B. Robinson was subcontracted to make determinations of solid wax contents of the Recombined Oil 1 system. These measurements were completed in the bulk deposition apparatus. This apparatus operates over a similar range of temperatures and pressures as the DBR onset apparatus and facilitates the isolation of a wax sample for qualitative and quantitative analysis. Typically, a live fluid (or dead if necessary) is charged to a blind, high pressure cylinder where it is initially equilibrated at conditions outside the wax formation envelope (i.e. at a temperature greater than the previously measured cloud point). The cylinder is mounted on a rocking mechanism and a Millipore filter is placed in-line so that the discharged solids may be collected. The system temperature is then lowered to the specified measurement value, and after

a period of equilibration, the precipitated solid and now de-waxed fluid (or fluids) are ejected from the cylinder. The wax fraction collected in the Millipore filter is weighed and analyzed for its composition to C90+ including a speciation of the n-paraffin content. The produced liquid and vapor (if the operating pressure is below saturation) phases are transferred into the standard phase behavior cell where their relative volumes are measured and in addition, a sample of each is taken for compositional analysis to C30+.

Based on the scope of work, bulk deposition trials were to be executed at temperatures approximately 50°F below the cloud points measured in the onset tests with the SDS. Therefore, the oil bulk depositions were completed at 58°F, 4000 psia and 50°F, 800 psia, while the condensate test conditions were 25°F, 8000 psia and 24°F, 4000 psia.

Recombined Oil Bulk Deposition Measurement @ 4000 psia, 58°F

The first trial was initiated by charging approximately 150 cm³ of the recombined oil to the bulk deposition apparatus at 160°F. After setting the system pressure to 4000 psia, the oven was cooled to the filtration temperature of 58°F. After equilibrating, the de-waxed oil and the solid sample were ejected from the cylinder through a high pressure filter with a 1.2 μm pore size filter paper. The amount of solid on the filter was then weighed and analyzed for its C90+ composition. Additionally, the filtered oil was sampled for its GOR and compositional analysis to C30+.

Table 3.1.24 contains summary data for the first bulk deposition trial at 4000 psia and 58°F. Included in this table are the physical properties of the de-waxed oil and the produced solid phase including its density and thermal conductivity. The mass of solid collected was 3.48 g which translates into 3.1 wt%; the density of this precipitated solid was measured with an immersion technique while its thermal conductivity was estimated by differential scanning calorimetry (see the bottom of Table 3.1.24 for those values). The compositional analyses of the produced liquid (to C30+) and solid (to C90+ including n-paraffins) are provided in Tables 3.1.25 and 3.1.26 respectively. Figure 3.1.7 compares the computed solids analysis derived from the oil composition before and after precipitation to the analyzed composition of the oil. This Figure illustrates the difficulty of using oil analyses to infer depletion during deposition testing. Though the curve shapes are approximately the same, there are large differences in the compositions at a given carbon number. An attempt to compute the change in deposition rate based on the compositional changes in the bulk oil would be futile since the fraction of material deposited from any one unit volume of oil is considerably smaller than the fraction of wax precipitated in this equilibrium experiment.

Recombined Oil Bulk Deposition Measurement @ 800 psia, 50°F

For the second bulk deposition trial (completed at 800 psia and 50°F) the experimental data is provided in Table 3.1.27. The collected solid weighed 4.38 g which represented a total precipitated quantity of 5.1 wt%. As before, the solid density was estimated by an immersion technique while the thermal conductivity was measured using a DSC. These values are also given in Table 3.1.27.

This second trial is represents a three phase (VLS) equilibrium. Therefore, both liquid and vapor densities and volumes were measured for this test (see Table 3.1.27). The compositional analyses for these fluids are supplied in Table 3.1.28 (produced liquid). As for the first trial, the collected solid phase was analyzed for its composition to C90+ (see Table 3.1.29).

In comparing the composition of the produced solids from the two bulk deposition procedures, there appears to be little difference between the precipitates. This is in keeping with the findings of the onset experiments which indicated that the presence of the light ends in the

liquid phase had little effect on stabilizing or altering the characteristics of the precipitating wax fraction.

Appendix I: South Pelto 10 Well 9-2

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Table 3.1.1**South Pelto 10 Well 9-2 Sample Summary**

<u>Cylinder Number</u>	<u>Separator Conditions</u>		<u>Laboratory Opening Pressure</u>	
	<u>Pressure (psig)</u>	<u>Temperature (°F)</u>	<u>Pressure (psig)</u>	<u>Temperature (°F)</u>
WL-142	178	66	98	69
WL-167	178	66	175	69
WL-212	178	66	175	69
WL-256	178	66	170	69
WL-284	178	66	169	69
WL-292	178	66	160	69
WL-312 *	178	66	178	69
WL-315	178	66	177	69

<u>Cylinder Number</u>	<u>Separator Conditions</u>		<u>Laboratory Bubble Point Conditions</u>	
	<u>Pressure (psig)</u>	<u>Temperature (°F)</u>	<u>Pressure (psig)</u>	<u>Temperature (°F)</u>
WL-170	178	66	164	68
WL-183	178	66	175	69
WL-286 *	178	66	181	69
WL-308	178	66	167	67

* Samples selected for recombination.

Table 3.1.2

**Stock Tank Oil API Gravities
for all measured Oil Compositions**

No.	Description	°API
1	South Pelto 10 Well 9-2 Separator Oil - Cylinder No. WL-170	35.2
2	South Pelto 10 Well 9-2 Separator Oil - Cylinder No. WL-183	34.9
3	South Pelto 10 Well 9-2 Separator Oil - Cylinder No. WL-286	34.9
4	South Pelto 10 Well 9-2 Separator Oil - Cylinder No. WL-308	34.9
5	South Pelto 10 Well 9-2 Recombined Oil 1	34.3
6	South Pelto 10 Well 9-2 Recombined Oil 1 - 182 GOR Mix	34.6
10	South Pelto 10 Well 9-2 Recombined Flow Loop Oil	33.9
11	Flow Loop Oil - Equilibrium Oil at 97 psia and 140°F	34.0
12	Flow Loop Oil - Equilibrium Oil at 97 psia and 90°F	34.0
13	Flow Loop Oil - Equilibrium Oil at 97 psia and 40°F	n/a
7	Main Pass 299 Well B-4 Separator Oil - Cylinder No. WL-204	40.0
8	Main Pass 299 Well B-4 Separator Oil - Cylinder No. WL-207	40.1
9	Main Pass 299 Well B-4 Recombined Oil 2	39.5
14	Garden Banks 426 Well A-14 Separator Oil - Cylinder No. WL-379	41.6
15	Garden Banks 426 Well A-14 Recombined Condensate	39.1
16	Garden Banks 426 Well A-14 Flow Loop Condensate	41.2
17	Flow Loop Condensate - Equilibrium Oil at 200 psig and 140°F	41.6
18	Flow Loop Condensate - Equilibrium Oil at 200 psig and 90°F	41.4
19	Flow Loop Condensate - Equilibrium Oil at 200 psig and 40°F	41.5

Table 3.1.3

**South Pelto 10 Well 9-2
Separator Gas Compositions**

Component	WL142 Mol %	WL256 Mol %	WL292 Mol %	WL312 Mol %	WL315 Mol %	WL212 Mol %	WL284 Mol %	WL167 Mol %
H2S	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
N2	0.281	0.264	0.270	0.321	0.271	0.229	0.267	0.243
CO2	1.069	1.073	1.082	1.074	1.076	1.084	1.074	1.077
C1	92.410	92.364	92.459	92.486	92.430	92.725	92.372	92.350
C2	3.976	4.005	3.953	3.923	3.981	3.786	4.043	4.024
C3	1.351	1.356	1.333	1.323	1.351	1.283	1.349	1.351
iC4	0.296	0.298	0.295	0.287	0.294	0.288	0.296	0.295
nC4	0.306	0.304	0.305	0.295	0.302	0.297	0.305	0.305
iC5	0.111	0.107	0.107	0.106	0.107	0.105	0.108	0.109
nC5	0.065	0.064	0.063	0.062	0.063	0.049	0.061	0.064
C6	0.070	0.082	0.069	0.067	0.068	0.064	0.067	0.073
C7	0.043	0.042	0.041	0.039	0.040	0.044	0.039	0.055
C8	0.021	0.028	0.020	0.018	0.017	0.027	0.017	0.034
C9	0.000	0.014	0.003	0.000	0.000	0.013	0.002	0.014
C10	0.000	0.000	0.000	0.000	0.000	0.004	0.000	0.005
C11	0.000	0.000	0.000	0.000	0.000	0.002	0.000	0.001
C12+	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	100.000	100.000	100.000	100.000	100.000	100.000	100.000	100.000

Hydrocarbon Properties

Mol Weight	17.73	17.76	17.72	17.70	17.72	17.69	17.72	17.78
Gas Gravity	0.612	0.613	0.612	0.611	0.612	0.611	0.612	0.614
GPM Value	1.748	1.770	1.734	1.714	1.743	1.686	1.743	1.782
Z Factor at separator conditions	0.969	0.969	0.966	0.969	0.969	0.969	0.969	0.969
BTU Content per dry gas at 14.73 psia and 60°F	1073.3	1075.0	1072.8	1071.3	1073.1	1071.7	1073.1	1076.6

Table 3.1.4

**South Pelto 10 Well 9-2
Separator Liquid Compositions**

Component	Cyl # WL170		Cyl # WL183		Cyl # WL286		Cyl # WL308	
	Mole Percent	Mass Percent						
N2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CO2	0.14	0.03	0.17	0.04	0.18	0.04	0.17	0.04
C1	5.99	0.49	6.43	0.51	6.64	0.53	6.44	0.51
C2	1.43	0.22	1.61	0.24	1.50	0.23	1.76	0.26
C3	1.50	0.34	1.51	0.33	1.64	0.36	1.74	0.38
iC4	0.73	0.22	0.66	0.19	0.77	0.23	0.84	0.24
nC4	1.15	0.34	0.98	0.28	1.20	0.35	1.30	0.38
iC5	1.02	0.38	0.80	0.29	1.03	0.37	1.12	0.40
nC5	1.41	0.52	1.19	0.42	1.25	0.45	1.21	0.43
C6	1.48	0.64	1.24	0.51	1.33	0.56	1.28	0.53
C7	6.87	3.37	5.56	2.65	6.07	2.92	5.78	2.77
C8	7.76	4.24	7.28	3.86	7.17	3.84	6.97	3.72
C9	6.78	4.20	6.52	3.92	6.66	4.04	6.29	3.80
C10	5.97	4.09	5.78	3.84	5.96	4.01	5.82	3.89
C11	4.82	3.62	5.11	3.72	4.73	3.49	4.71	3.45
C12	4.62	3.80	4.84	3.87	4.68	3.78	4.78	3.84
C13	4.71	4.21	5.02	4.36	4.74	4.16	4.77	4.17
C14	4.43	4.30	4.65	4.38	4.40	4.19	4.46	4.22
C15	4.02	4.23	4.11	4.20	4.16	4.30	4.12	4.23
C16	3.62	4.10	3.74	4.12	3.61	4.02	3.77	4.17
C17	3.29	3.98	3.38	3.98	3.20	3.80	3.26	3.85
C18	3.04	3.91	3.08	3.83	3.09	3.89	3.05	3.81
C19	2.82	3.80	2.78	3.63	2.77	3.65	2.82	3.70
C20	2.55	3.59	2.59	3.53	2.50	3.45	2.50	3.42
C21	2.27	3.38	2.23	3.22	2.27	3.31	2.28	3.31
C22	1.89	2.95	1.91	2.88	1.87	2.86	1.89	2.88
C23	1.80	2.92	1.84	2.90	1.75	2.80	1.82	2.88
C24	1.55	2.63	1.62	2.66	1.53	2.54	1.51	2.49
C25	1.44	2.55	1.45	2.49	1.47	2.55	1.53	2.64
C26	1.26	2.32	1.28	2.28	1.23	2.22	1.23	2.20
C27	1.14	2.18	1.21	2.24	1.21	2.26	1.21	2.25
C28	0.95	1.89	1.01	1.94	0.99	1.92	1.04	2.00
C29	0.94	1.93	1.00	1.98	0.97	1.96	0.99	1.99
C30+	6.60	18.62	7.45	20.70	7.42	20.91	7.53	21.13
	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Properties of Hydrocarbon Fractions

C7+ Fraction	85.14	96.83	85.44	97.19	84.45	96.88	84.14	96.81
C11+ Fraction	57.77	80.92	60.30	82.92	58.59	82.06	59.27	82.64
C15+ Fraction	39.19	64.98	40.68	66.59	40.04	66.44	40.54	66.96
C20+ Fraction	22.41	44.96	23.59	46.84	23.21	46.78	23.52	47.19
C30+ Fraction	6.60	18.62	7.45	20.70	7.42	20.91	7.53	21.13
Overall Mol Wt	195.5		201.6		199.4		200.6	
Overall Density	0.8158		0.8143		0.8137		0.8133	

Table 3.1.5

South Pelto 10 Well 9-2
Measured Hydrocarbon Analysis of Recombined Oil 1

Component	Mole Percent	Calculated	Weight Percent	Calculated	Molecular Weight	Specific Gravity
		Mole Percent		Weight Percent		
N2	0.00	0.15	0.00	0.04	28	0.8094
CO2	0.59	0.59	0.22	0.22	44	0.8180
C1	46.58	46.14	6.36	6.25	16	0.3000
C2	2.83	2.62	0.73	0.67	30.1	0.3562
C3	1.62	1.49	0.61	0.56	44.1	0.5070
iC4	0.62	0.55	0.31	0.27	58.1	0.5629
nC4	0.89	0.78	0.44	0.39	58.1	0.5840
iC5	0.66	0.61	0.41	0.37	72.2	0.6247
nC5	0.64	0.70	0.40	0.43	72.2	0.6311
C6	1.09	0.75	0.78	0.53	84	0.7094
C7	2.65	3.30	2.17	2.68	96	0.7286
C8	3.86	3.88	3.53	3.51	107	0.7447
C9	3.39	3.59	3.50	3.68	121	0.7606
C10	3.09	3.22	3.53	3.65	134	0.7748
C11	2.56	2.55	3.21	3.18	147	0.7872
C12	2.23	2.53	3.06	3.45	161	0.7990
C13	2.40	2.56	3.58	3.80	175	0.8093
C14	2.40	2.37	3.89	3.82	190	0.8195
C15	2.14	2.25	3.76	3.92	206	0.8298
C16	2.09	1.95	3.95	3.67	222	0.8385
C17	1.69	1.73	3.41	3.47	237	0.8468
C18	1.76	1.67	3.78	3.54	251	0.8531
C19	1.56	1.49	3.49	3.33	263	0.8590
C20	1.42	1.35	3.32	3.14	275	0.8652
C21	1.24	1.23	3.07	3.02	291	0.8713
C22	1.03	1.01	2.69	2.61	305	0.8769
C23	0.99	0.95	2.69	2.55	318	0.8823
C24	0.90	0.83	2.54	2.31	331	0.8873
C25	0.81	0.80	2.40	2.33	345	0.8922
C26	0.70	0.67	2.16	2.03	359	0.8969
C27	0.64	0.65	2.04	2.07	374	0.9013
C28	0.54	0.53	1.80	1.75	388	0.9056
C29	0.55	0.53	1.89	1.79	402	0.9092
C30+	3.85	4.00	20.30	20.96	618	0.9484
	100.00	100.00	100.00	100.00		

Properties of Hydrocarbon Fractions

	Mole Percent	Calculated Mole Percent	Weight Percent	Calculated Weight Percent	mol wt	density	Calculated Recom		
							density	mol wt	
C7+ Fraction	44.48	45.62	89.75	90.28	236.5	0.8558	0.858	233.6	
C11+ Fraction	31.49	31.64	77.02	76.74	286.6	0.8752	0.878	286.3	
C15+ Fraction	21.90	21.62	63.28	62.50	338.6	0.8922	0.896	341.2	
C20+ Fraction	12.68	12.53	44.89	44.56	415.0	0.9131	0.916	419.7	
C30+ Fraction	3.85	4.00	20.30	20.96	618.1	0.9484	0.948	618.0	
Overall Reservoir Fluid					117.2	0.7504	0.7543	118.0	
Gas Oil Ratio	454.7	scf/bbl of stock tank							

Table 3.1.6

DB Robinson Sample of Recombined Reservoir Oil
 RECOMBINED OIL COMPOSITION

<u>COMPONENT</u>	<u>MW</u>	<u>GAS</u>	<u>LIQUID</u>	<u>OVERALL</u>	<u>MOLE %</u>	<u>GROUP</u>
		<u>MOLE %</u>	<u>WT %</u>	<u>WT %</u>		<u>MOLE %</u>
CO2	44.01	1.111	0.000	0.190	0.550	0.550
H2S	34.08	0.000	0.000	0.000	0.000	0.000
N2	28.013	0.381	0.000	0.041	0.189	0.189
C1	16.043	83.738	0.000	5.209	41.472	41.472
C2	30.07	5.346	0.000	0.623	2.647	2.647
C3	44.097	3.068	0.081	0.599	1.734	1.734
I-C4	58.124	1.082	0.059	0.298	0.655	0.655
N-C4	58.124	1.423	0.126	0.436	0.958	0.958
I-C5	72.151	0.764	0.225	0.420	0.744	0.744
N-C5	72.151	0.543	0.217	0.350	0.620	0.620
C6	85	0.811	0.932	1.124	1.666	
MCYC-C5	84.16	0.080	0.199	0.209	0.317	
BENZENE	78.11	0.371	0.000	0.112	0.184	
CYCL-C6	82.15	0.154	0.237	0.266	0.413	2.580
C7	99	0.105	1.372	1.296	1.653	
MCYCL-C6	98.19	0.236	0.669	0.702	0.913	
TOLUENE	92.14	0.013	0.687	0.633	0.877	
C8	113	0.070	1.917	1.786	1.997	
C2-BENZEN	106.17	0.024	0.099	0.101	0.121	
M&P-XYLEN	106.17	0.161	0.864	0.857	1.031	
O-XYLENE	106.17	0.182	0.476	0.511	0.615	
C9	128.3	0.105	2.113	1.986	1.977	9.185
C10	134	0.066	3.886	3.591	3.422	
C11	147	0.098	3.660	3.405	2.959	
C12	161	0.036	3.675	3.386	2.686	
C13	175	0.030	4.563	4.196	3.063	
C14	190	0.002	4.294	3.931	2.643	14.772
C15	206	0.000	4.484	4.104	2.545	
C16	222	0.000	3.968	3.632	2.089	
C17	237	0.000	3.937	3.603	1.942	
C18	251	0.000	3.931	3.598	1.831	
C19	263	0.000	3.706	3.392	1.647	10.054
C20	275	0.000	3.346	3.062	1.422	
C21	291	0.000	3.076	2.815	1.236	
C22	305	0.000	2.796	2.559	1.072	
C23	318	0.000	2.645	2.421	0.972	
C24	331	0.000	2.463	2.254	0.870	
C25	345	0.000	2.241	2.051	0.759	
C26	359	0.000	2.112	1.933	0.688	
C27	374	0.000	2.189	2.004	0.684	
C28	388	0.000	1.926	1.763	0.580	
C29	402	0.000	1.681	1.538	0.489	8.772
C30+	580	0.000	25.146	23.013	5.068	5.068
MW=		21.9	231.6		127.7	
DENSITY=	0.767	g/cm3 at	160	°F &	4000	psia
WT. GAS/ WT. SAMPLE=			0.0848			
GOR @ STD		88.9	(M3/M3)	499.1	(SCF/BBL)	

Table 3.1.7

South Pelto 10 Well 9-2

**Constant Composition Expansion and Property Measurements
of Recombined Oil 1 @ 232°F**

Pressure (psia)	Relative Volume (2)	Liquid Volume Percent	Compressibility vol/vol x10-E06)	Oil Density (gm/cc)	Gas Density (gm/cc)	Oil Viscosity (cp)
6012						0.470 *
5066	0.9765			0.7355 *		0.390 *
4559	0.9822		11.392	0.7313		
4053	0.9882		12.087	0.7268 *		0.367 *
3546	0.9948		13.023	0.7220		
3445	0.9966		14.027	0.7207		
3343	0.9979			0.7198		
3242	0.9992			0.7188		
3221 (1)	1.0000	100.00		0.7182		0.312
3141	1.0033					
3090	1.0071					
3039	1.0107					
2533	1.0779					
2026	1.1868	82.24				
1874	1.2386	77.79		0.7361 *	0.1197 *	0.666 *
1520	1.3912	68.42				
1013	1.8287	50.44				
506	3.2428	27.60		0.7697 *	0.0219 *	0.953 *

(1) Bubble Point Pressure

(2) Relative Volume: V/V_{sat} is the total volume of fluid at the indicated pressure per volume of saturated fluid at the bubble point pressure.

* Measured Property Data

Table 3.1.8

South Pelto10 Well 9-2

**Constant Composition Expansion and Property Measurements
of Recombined Oil 1 @ 136°F**

Pressure (psia)	Relative Volume (2)	Liquid Volume Percent	Compressibility (vol/vol x10-E06)	Oil Density (gm/cc)	Gas Density (gm/cc)	Oil Viscosity (cp)
5066	0.9796			0.7559	*	1.245 *
4582	0.9838		8.814	0.7527		
4053	0.9886		9.169	0.7479	*	1.147 *
3546	0.9933		9.466	0.7444		
3242	0.9964		9.945	0.7419		
3141	0.9976			0.7412		
3039	0.9985			0.7405	*	1.048 *
2938	0.9992			0.7401		
2895	(1) 1.0000	100.00		0.7398		1.036
2735	1.0151					
2634	1.0252					
2533	1.0345					
2026	1.1122	88.86				
1722	1.1893	80.96		0.7719	*	0.0850 * 1.365 *
1520	1.2662	75.60				
1013	1.6147	57.92				
506	2.7958	32.39		0.8020	*	0.0230 * 2.154 *

(1) Bubble Point Pressure

(2) Relative Volume: V/V_{sat} is the total volume of fluid at the indicated pressure per volume of saturated fluid at the bubble point pressure.

* Measured Property Data

Table 3.1.9

South Pelto10 Well 9-2

**Constant Composition Expansion and Property Measurements
of Recombined Oil 1 @ 42°F**

Pressure (psia)	Relative Volume (2)	Liquid Volume Percent	Compressibility (vol/vol x10-E06)	Oil Density (gm/cc)	Gas Density (gm/cc)	Oil Viscosity (cp)
5066	0.9851			0.7958 *		9.007 *
4559	0.9880		5.709	0.7935		
4053	0.9909		5.861	0.7911 *		7.252 *
3546	0.9940		6.055	0.7887		
3039	0.9971		6.237	0.7862 *		6.204 *
2735	0.9987			0.7850		
2634	0.9994			0.7844		
2518 (1)	1.0000	100.00		0.7839		5.390
2432	1.0066					
2330	1.0145					
2229	1.0219					
2026	1.0437					
1520	1.1485	84.43		0.8057 *	0.0992 *	8.2550 *
1013	1.4250	65.03				
506	2.4196	37.61		0.8351 *	0.0288 *	8.2630 *

(1) Bubble Point Pressure

(2) Relative Volume: V/Vsat is the total volume of fluid at the indicated pressure per volume of saturated fluid at the bubble point pressure.

* Measured Property Data

Table 3.1.10

Hydrocarbon Composition for Synthetic Natural Gas used for Flow Loop Oil

<u>Component</u>	<u>Mol %</u>	<u>Weight %</u>	<u>Volume %</u>
H2S	0.00	0.00	0.00
C02	0.04	0.09	0.22
N2	0.09	0.14	0.31
C1	93.87	79.22	67.59
C2	3.45	5.57	5.64
C3	2.04	4.83	6.96
iC4	0.39	1.22	1.95
nC4	0.67	2.09	3.47
iC5	0.27	1.05	1.86
nC5	0.24	0.93	1.67
C6	0.23	1.04	2.02
C7+	0.19	0.98	2.01
	101.48	97.15	93.71

Gas molecular weight	17.0	g/mol
Gas Gravity	0.588	
BTU Content	1021.2	per dry gas at 14.73 psia and 60°F.
GPM Value	1.012	
Z Factor	0.974	

Table 3.1.11

**South Pelto 10 Well 9-2
Measured Hydrocarbon Analysis of Recombined Oil 1
Intermediate Mix of 182 Gas/Oil Ratio**

<u>Component</u>	<u>Mole Percent</u>	<u>Weight Percent</u>	<u>Molecular Weight</u>	<u>Specific Gravity</u>
N2	0.00	0.00	28	0.8094
CO2	0.40	0.11	44	0.8180
C1	28.95	2.94	16	0.3000
C2	2.25	0.43	30.1	0.3562
C3	1.69	0.47	44.1	0.5070
iC4	0.69	0.26	58.1	0.5629
nC4	1.01	0.37	58.1	0.5840
iC5	0.73	0.34	72.2	0.6247
nC5	0.85	0.39	72.2	0.6311
C6	1.00	0.53	84	0.7023
C7	3.99	2.43	96	0.7212
C8	5.23	3.55	107	0.7372
C9	4.90	3.76	121	0.7529
C10	4.48	3.81	134	0.7669
C11	3.48	3.25	147	0.7792
C12	3.38	3.45	161	0.7909
C13	3.26	3.62	175	0.8011
C14	3.25	3.92	190	0.8113
C15	3.17	4.14	206	0.8214
C16	2.81	3.96	222	0.8300
C17	2.36	3.54	237	0.8382
C18	2.34	3.73	251	0.8444
C19	2.11	3.52	263	0.8503
C20	1.87	3.27	275	0.8564
C21	1.71	3.15	291	0.8625
C22	1.44	2.79	305	0.8681
C23	1.30	2.63	318	0.8733
C24	1.21	2.55	331	0.8783
C25	1.09	2.39	345	0.8832
C26	0.96	2.18	359	0.8878
C27	0.90	2.14	374	0.8921
C28	0.74	1.82	388	0.8964
C29	0.73	1.87	402	0.9000
C30+	5.71	22.70	626	0.9759
	100.00	100.00		

Properties of Hydrocarbon Fractions

C7+ Fraction	62.42	94.16	237.7	0.8549
C11+ Fraction	43.83	80.61	289.9	0.8763
C15+ Fraction	30.46	66.38	343.4	0.8956
C20+ Fraction	17.68	47.49	423.4	0.9216
C30+ Fraction	5.71	22.70	626.1	0.9759
Overall Reservoir Fluid			157.6	0.7986
Gas Oil Ratio	182	scf/bbl of stock tank		

**Third Recombination used for cloud point measurements only.
wax and cloud point information only.
Pob = 1260@160°F**

Table 3.1.12

**South Pelto 9-2 Stock Tank Oil & City of Tulsa Synthesized Gas
Measured Hydrocarbon Analysis of Flow Loop Oil**

<u>Component</u>	<u>Mole Percent</u>	<u>Weight Percent</u>	<u>Molecular Weight</u>	<u>Specific Gravity</u>
N2	0.36	0.05	28.0	0.8094
CO2	0.10	0.02	44.0	0.8180
C1	13.34	1.06	16.0	0.3000
C2	0.66	0.10	30.1	0.3562
C3	0.27	0.06	44.1	0.5070
iC4	0.16	0.05	58.1	0.5629
nC4	0.35	0.10	58.1	0.5840
iC5	0.54	0.19	72.2	0.6247
nC5	0.44	0.16	72.2	0.6311
C6	0.95	0.40	84	0.7112
C7	3.36	1.61	96	0.7304
C8	5.77	3.08	107	0.7465
C9	5.93	3.58	121	0.7625
C10	5.65	3.77	134	0.7767
C11	4.92	3.60	147	0.7891
C12	4.88	3.91	161	0.8010
C13	5.05	4.41	175	0.8113
C14	4.73	4.48	190	0.8215
C15	4.60	4.72	206	0.8318
C16	4.29	4.74	222	0.8406
C17	3.30	3.90	237	0.8489
C18	3.35	4.19	251	0.8551
C19	2.93	3.83	263	0.8610
C20	2.71	3.71	275	0.8673
C21	2.35	3.40	291	0.8734
C22	2.02	3.06	305	0.8791
C23	1.84	2.91	318	0.8844
C24	1.52	2.51	331	0.8894
C25	1.55	2.66	345	0.8944
C26	1.24	2.21	359	0.8991
C27	1.22	2.28	374	0.9034
C28	1.01	1.95	388	0.9078
C29	1.03	2.06	402	0.9114
C30+	<u>7.59</u>	<u>21.23</u>		
	100.00	100.00		

Properties of Hydrocarbon Fractions

C7+ Fraction	82.83	97.82	237	0.8581
C11+ Fraction	62.12	85.79	277	0.8742
C15+ Fraction	42.54	69.39	327	0.8919
C20+ Fraction	24.07	47.99	400	0.9137
C30+ Fraction	7.59	21.23	561	0.9486
Overall Reservoir Fluid			200.7	0.8139
Gas Oil Ratio	84.9	scf/bbl of stock tank		

Table 3.1.13

South Pelto 9-2 Stock Tank Oil & City of Tulsa Synthesized Gas

**Constant Composition Expansion and Property Measurements
of Flow Loop Oil @ 140°F**

Pressure (psia)	Relative Volume (2)	Liquid Volume Percent	Compressibility (vol/vol x10-E06)	Oil Density (gm/cc)	Gas Density (gm/cc)	Oil Viscosity (cp)
2008	0.9905		5.236	0.8175	*	2.689 *
1501	0.9931		6.215	0.8146	*	2.593 *
994	0.9962		8.631	0.8119	*	2.463 *
792	0.9974					2.422 *
589	0.9991			0.8100	*	2.353 *
533	(1) 1.0000	100.00		0.8095		2.337
516	1.0057					
500	1.0190	96.43				
492	1.0243					
478	1.0406					
386	1.1287	89.05		0.8121	* 0.0162 *	2.460 *
289	1.3161	76.17		0.8141	* 0.0109 *	2.591 *
184	1.7662	57.63		0.8163	* 0.00759 *	2.677 *
97	2.5708	38.24		0.8194	* 0.0024 *	2.816 *

(1) Bubble Point Pressure

(2) Relative Volume: V/V_{sat} is the total volume of fluid at the indicated pressure per volume of saturated fluid at the bubble point pressure.

* Measured Property Data

Table 3.1.14

South Pelto 9-2 Stock Tank Oil & City of Tulsa Synthesized Gas
 Compositional Analysis of Flow Loop Oil
 Equilibrium at 97 psia and 140°F

Component	Oil			Gas		
	Mole Percent	Weight Percent	Molecular Weight	Specific Gravity	Mole Percent	Weight Percent
N2	0.04	0.01	28.0	0.8094	2.12	3.26
CO2	0.08	0.02	44.0	0.8180	0.61	1.47
C1	6.53	0.48	16.0	0.3000	92.44	81.47
C2	0.59	0.08	30.1	0.3562	2.31	3.82
C3	0.30	0.06	44.1	0.5070	0.59	1.43
iC4	0.21	0.06	58.1	0.5629	0.21	0.67
nC4	0.29	0.08	58.1	0.5840	0.32	1.02
iC5	0.28	0.09	72.2	0.6247	0.23	0.91
nC5	0.44	0.15	72.2	0.6311	0.18	0.71
C6	1.29	0.50	84	0.7090	0.34	1.57
C7	3.23	1.42	96	0.7282	0.33	1.74
C8	5.94	2.91	107	0.7443	0.27	1.59
C9	6.10	3.38	121	0.7602	0.04	0.27
C10	6.01	3.69	134	0.7743	0.01	0.07
C11	5.56	3.75	147	0.7867	0.00	0.00
C12	5.43	4.00	161	0.7986	0.00	0.00
C13	5.53	4.43	175	0.8089	100.00	100.00
C14	5.45	4.75	190	0.8191		
C15	5.19	4.90	206	0.8293		
C16	4.34	4.42	222	0.8380		
C17	3.76	4.08	237	0.8463		
C18	3.74	4.30	251	0.8526		
C19	3.24	3.91	263	0.8585		
C20	2.84	3.58	275	0.8647		
C21	2.65	3.54	291	0.8708		
C22	2.15	3.00	305	0.8764		
C23	2.04	2.97	318	0.8817		
C24	1.77	2.68	331	0.8867		
C25	1.62	2.55	345	0.8917		
C26	1.36	2.24	359	0.8964		
C27	1.37	2.36	374	0.9007		
C28	1.09	1.94	388	0.9051		
C29	1.11	2.04	402	0.9086		
C30+	8.43	21.66	561	0.9459		
	100.00	100.00				

Sample collected at 97 psia and 140°F
 Gas molecular weight 18.2 g/mol
 Gas Gravity 0.629
 BTU Content 1099 per dry gas at 14.73 psia and 60°F
 GPM Value 1.549
 Z Factor 0.988 at 97 psia and 140°F
 Gas Density, gm/cc 0.0024 at 97 psia and 140°F

Properties of Hydrocarbon Fractions

C7+ Fraction	89.94	98.49	239	0.8564
C11+ Fraction	68.67	87.09	277	0.8715
C15+ Fraction	46.70	70.16	328	0.8895
C20+ Fraction	26.43	48.55	401	0.9113
C30+ Fraction	8.43	10.43	561	0.9459
Overall Reservoir Fluid			218.2	0.8230
Gas Oil Ratio	44.2	scf/bbl of stock tank		

Table 3.1.15

South Pelto 9-2 Stock Tank Oil & City of Tulsa Synthesized Gas

**Constant Composition Expansion and Property Measurements
of Flow Loop Oil @ 90°F**

Pressure (psia)	Relative Volume (2)	Liquid Volume <u>Percent</u>	Compressibility <u>(vol/vol x10-E06)</u>	Oil Density (gm/cc)	Gas Density (gm/cc)	Oil Viscosity (cp)
1501	0.9945		4.565	0.8337	*	5.310 *
994	0.9968		5.545	0.8310	*	5.051 *
793	0.9979			0.8303	*	4.935 *
488	0.9996			0.8293	*	4.790 *
423	(1) 1.0000	100.00	6.181	0.8291		4.721
361	1.0415	97.27				
333	1.0776	95.02				
309	1.1105	93.53				
285	1.1545	89.42				
234	1.2912	80.03		0.8345	* 0.0111 *	5.244 *
97	2.6074	42.03		0.8387	* 0.0045 *	5.470 *

(1) Bubble Point Pressure

(2) Relative Volume: V/V_{sat} is the total volume of fluid at the indicated pressure per volume of saturated fluid at the bubble point pressure.

* Measured Property Data

TABLE 3.1.16

South Pelto 9-2 Stock Tank Oil & City of Tulsa Synthesized Gas
 Compositional Analysis of Flow Loop Oil & Gas
 Equilibrium at 97 psia and 90°F

Component	Oil		Molecular Weight	Specific Gravity	Gas	
	Mole Percent	Weight Percent			Mole Percent	Weight Percent
N2	0.00	0.00	28	0.8094	2.18	3.49
CO2	0.12	0.03	44	0.8180	0.71	1.78
C1	10.34	0.81	16	0.3000	93.42	85.59
C2	1.25	0.18	30.1	0.3562	2.33	4.00
C3	0.59	0.13	44.1	0.5070	0.45	1.13
iC4	0.38	0.11	58.1	0.5629	0.13	0.43
nC4	0.49	0.14	58.1	0.5840	0.19	0.63
iC5	0.41	0.15	72.2	0.6247	0.12	0.49
nC5	0.52	0.18	72.2	0.6311	0.09	0.37
C6	1.44	0.59	84	0.7101	0.14	0.67
C7	3.45	1.62	96	0.7293	0.13	0.71
C8	6.02	3.16	107	0.7454	0.09	0.55
C9	5.75	3.41	121	0.7613	0.02	0.14
C10	5.75	3.78	134	0.7755	0.00	0.00
C11	5.07	3.65	147	0.7879	0.00	0.00
C12	5.00	3.94	161	0.7998	0.00	0.00
C13	4.96	4.26	175	0.8101	100.00	100.00
C14	4.82	4.49	190	0.8203		
C15	4.85	4.89	206	0.8306		
C16	4.33	4.71	222	0.8393		
C17	3.41	3.96	237	0.8476		
C18	3.49	4.29	251	0.8539		
C19	3.04	3.92	263	0.8597		
C20	2.71	3.65	275	0.8660		
C21	2.48	3.53	291	0.8721		
C22	2.03	3.04	305	0.8777		
C23	1.88	2.93	318	0.8831		
C24	1.66	2.69	331	0.8881		
C25	1.54	2.60	345	0.8930		
C26	1.32	2.32	359	0.8977		
C27	1.20	2.21	374	0.9021		
C28	1.01	1.92	388	0.9064		
C29	1.02	2.01	402	0.9100		
C30+	7.67	20.69	550	0.9453		
	100.00	100.00				

Sample collected at 97 psia and 90°F
 Gas molecular weight 17.5 g/mol
 Gas Gravity 0.605
 BTU Content 1058 per dry gas at 14.73 psia and 60°F.
 GPM Value 1.108
 Z Factor 0.985 at 97 psia and 90°F
 Gas Density, gm/cc 0.0045 at 97 psia and 90°F

Properties of Hydrocarbon Fractions

C7+ Fraction	84.45	97.68	236	0.8560
C11+ Fraction	63.48	85.71	275	0.8720
C15+ Fraction	43.63	69.36	324	0.8894
C20+ Fraction	24.52	47.59	396	0.9111
C30+ Fraction	7.67	20.69	550	0.9453
Overall Reservoir Fluid			204.0	0.8152
Gas Oil Ratio	80.2	scf/bbl of stock tank		

Table 3.1.17

South Pelto 9-2 Stock Tank Oil & City of Tulsa Synthesized Gas

**Constant Composition Expansion and Property Measurements
of Flow Loop Oil @ 40°F**

Pressure (psia)	Relative Volume (2)	Liquid Volume <u>Percent</u>	Compressibility (vol/vol x10-E06)	Oil Density (gm/cc)	Gas Density (gm/cc)	Oil Viscosity (cp)
1501	0.9947			0.8531	*	
994	0.9964		3.312	0.8491	*	
792	0.9972		4.011	0.8477	*	
488	0.9986		4.777	0.8454	*	
386	0.9993					
309	(1) 1.0000	100.00		0.8440		
275	1.1216					
184	1.4479	70.89				
97	2.4422	44.89				

(1) Bubble Point Pressure

(2) Relative Volume: V/V_{sat} is the total volume of fluid at the indicated pressure per volume of saturated fluid at the bubble point pressure.

* Measured Property Data

NOTE: Gas and oil densities below bubble point pressure as well as viscosity data could not be obtained due to excessive wax buildup.

Table 3.1.18

South Pelito 10 Well 9-2
Summary of Wax Data for Recombined Oil 1 (°F)

Method Sample	FTIR FSO		FTIR STO		FTIR RIF		FTIR RIF		FTIR RRF		FTIR RRF	
	WAT	WDT	WAT	WDT	WAT	WDT	WAT	WDT	WAT	WDT	WAT	WDT
Pressure, psig												
1,000	121	134	122	132	120	120	106	118	106	123	102	102
2,000					123	123					100	
3,000	120	130	121	136	122	122	109	120	107	135*	109	102
3,500									112	128		
4,000												
4,000	126	130*							106	123		
5,000	128	140							107	135*		
6,000	130	145	127	138					112	128		

FTIR = FOURIER TRANSFORM INFRARED SPECTROSCOPY (ENERGY SCATTERING)

FP= FILTER PLUGGING

FSO = AMBIENT FLASHED SEPARATOR OIL

STO = STOCK TANK OIL

RIF = RECOMBINED INTERMEDIATE FLUID (GOR = 182, Rs=1,250 @ 160F)

RRF = RECOMBINED RESERVOIR FLUID (GOR = 455, Rs=3,209 @ 232F)

WAT = WAX APPEARANCE TEMPERATURE

WDT = WAX DISSOLUTION TEMPERATURE

* = DENOTES DESCREPNY OF TEMPERATURE DIFFERENCE BETWEEN WDT & WAT

Table 3.1.19

**South Pelto 9-2 Stock Tank Oil & City of Tulsa Synthesized Gas
Summary of Wax Data (°F)
for Flow Loop Oil**

Pressure <u>psig</u>	FTIR		FP	
	<u>WAT</u>	<u>WDT</u>	<u>WAT</u>	<u>WDT</u>
1,000	107	134	110	137
1,500	103	132		
3,000	113	145	115	140
5,000	124	138		

FTIR = FOURIER TRANSFORM INFRARED SPECTROSCOPY

FP= FILTER PLUGGING

WAT = WAX APPEARANCE TEMPERATURE

WDT = WAX DISSOLUTION TEMPERATURE

Table 3.1.20

**South Pelto 10 Well 9-2
Apparent Viscosity Equations on Stock Tank Oil**

Temperature °F	Bingham Plastic Equation, cp
40	$\mu_a = 76.01 + 3036 / \text{shear rate}$
50	$\mu_a = 45.08 + 2411 / \text{shear rate}$
60	$\mu_a = 27.70 + 910 / \text{shear rate}$
70	$\mu_a = 19.06 + 271 / \text{shear rate}$
80	$\mu_a = 10.5$

Table 3.1.21

**Stock Tank Oil Density From
Recombined Oil 1 and Recombined Oil 2**

	South Pelto 10 Well 9-2	Main Pass 299 Well B-4
Temperature °F	Density <u>gm/cc</u>	Density <u>gm/cc</u>
60	0.8496	0.8263
100	0.8346	0.8103
122	0.8269	0.8020
140	0.8205	0.7944

Table 3.1.22

Solid n-Paraffin Formation Results

Recombined Oil 1 - South Pelto 10 Well 9-2

DBR Filtration at 4,000 psia and 58°F

Cloud Point = 107°F (Cloud - Test Temp. = 49°F)

Percent Solids = 3.1

Percent n-C25+ in Solids = 21.2

Percent of RRF that is solid n-C25+ at 58°F = .67

Percent of Dead Oil that is solid n-C25+ at 58°F = .73

DBR Filtration at 800 psia and 50°F

Cloud Point = 101°F (Cloud - Test Temp. = 51°F)

Percent Solids = 5.1

Percent n-C25+ in Solids = 17.4

Percent of RRF that is solid n-C25+ at 50°F = .89

Percent of Dead Oil that is solid n-C25+ at 50°F = .96

Flashed Separator Oil - South Pelto 10 Well 9-2

Marathon Centrifugation at 15 psia and 70°F

Cloud Point = 120°F (Cloud - Test Temp. = 50°F)

Percent Solids = 7.5 (Water Corrected = 7.0)

Percent n-C25+ in Solids = 13.3

Percent of Dead Oil that is solid n-C25+ at 70°F = .93 by solids analysis

Percent of Dead Oil that is solid n-C25+ at 70°F = .86 by oil difference

Flashed Separator Oil - Main Pass 299 Well B-4

Marathon Centrifugation at 15 psia and 40°F

Cloud Point = 75°F (Cloud - Test Temp. = 35°F)

Percent Solids = 12.0

Percent n-C21+ in Solids = 8.0

Percent of Dead Oil that is solid n-C21+ at 40°F = .96 by solids analysis

Percent of Dead Oil that is solid n-C21+ at 40°F = .84 by oil difference

TABLE 3.1.23

Flashed Separator Oil Used For the Solids Analysis by Nenniger

n-Paraffin Analyses Before Cooling				n-Paraffin Analyses After Cooling			n-Paraffin Analyses Solids			Recombined Wax Frxn 0.06
CARBON NUMBER	WEIGHT PERCENT	NORMALIZE WEIGHT %	CUMULATIVE WEIGHT %	WEIGHT PERCENT	NORMALIZE WEIGHT %	CUMULATIVE WEIGHT %	WEIGHT PERCENT	NORMALIZE WEIGHT %	CUMULATIVE WEIGHT %	
17	1.0249	15.5573	6.5876	1.143	18.840	6.069				1.0747584
18	0.8352	12.6781	5.5627	0.880	14.494	4.926				0.826824
19	0.6156	9.3453	4.7276	0.632	10.406	4.046				0.5936194
20	0.5764	8.7504	4.1119	0.576	9.494	3.414				0.541628
21	0.3691	5.6034	3.5355	0.389	6.402	2.838				0.3652086
22	0.3720	5.6471	3.1664	0.390	6.422	2.450				0.3663368
23	0.3576	5.4285	2.7944	0.383	6.311	2.060				0.3600106
24	0.3321	5.0413	2.4367	0.341	5.624	1.677				0.3208596
25	0.2923	4.4367	2.1046	0.261	4.293	1.336	0.2413	1.81457	13.2979	0.2593762
26	0.2390	3.6286	1.8124	0.241	3.964	1.075	0.26511	1.99362	13.0566	0.2420518
27	0.1869	2.8370	1.5733	0.181	2.979	0.835	0.2713	2.04017	12.79149	0.1862206
28	0.1736	2.6356	1.3864	0.169	2.776	0.654	0.32959	2.47851	12.52019	0.1781654
29	0.1713	2.6005	1.2128	0.156	2.565	0.485	0.42772	3.21645	12.1906	0.1720024
30	0.1200	1.8210	1.0415	0.096	1.580	0.330	0.46483	3.49551	11.76288	0.1179982
31	0.0971	1.4744	0.9216	0.070	1.152	0.234	0.54541	4.10147	11.29805	0.0984588
32	0.0944	1.4327	0.8244	0.060	0.996	0.164	0.57216	4.30263	10.75264	0.0911714
33	0.0733	1.1132	0.7300	0.042	0.699	0.103	0.57049	4.29008	10.18048	0.0741042
34	0.0573	0.8694	0.6567	0.026	0.428	0.061	0.54695	4.11305	9.60999	0.0572476
35	0.0477	0.7247	0.5994	0.016	0.268	0.035	0.53068	3.9907	9.06304	0.047144
36	0.0399	0.6058	0.5517	0.008	0.137	0.019	0.49721	3.73901	8.53236	0.037644
37	0.0311	0.4720	0.5118	0.004	0.068	0.010	0.52145	3.9213	8.03515	0.0351786
38	0.0345	0.5243	0.4807	0.004	0.064	0.006	0.51726	3.88979	7.5137	0.034664
39	0.0432	0.6552	0.4482	0.002	0.038	0.002	0.4806	3.6141	6.99644	0.0310262
40	0.0382	0.5799	0.4030				0.4851	3.64794	6.51584	0.029106
41	0.0350	0.5310	0.3648				0.42719	3.21246	6.03074	0.0256314
42	0.0424	0.6438	0.3298				0.52647	3.95905	5.60365	0.0315882
43	0.0302	0.4584	0.2874				0.39922	3.00213	5.07708	0.0239532
44	0.0287	0.4349	0.2572				0.43042	3.23675	4.67786	0.0256252
45	0.0221	0.3347	0.2286				0.37885	2.84895	4.24744	0.022731
46	0.0223	0.3385	0.2065				0.43573	3.27668	3.86859	0.0261438
47	0.0203	0.3088	0.1842				0.35654	2.68117	3.43286	0.0213924
48	0.0189	0.2869	0.1639				0.36315	2.73098	3.07632	0.021789
49	0.0190	0.2884	0.1450				0.31088	2.33781	2.71317	0.0186528
50	0.0238	0.3608	0.1260				0.37686	2.83398	2.40229	0.0226116
51	0.0156	0.2371	0.1022				0.27328	2.05506	2.02543	0.0163968
52	0.0124	0.1881	0.0866				0.22357	1.68124	1.75215	0.0134142
53	0.0096	0.1450	0.0742				0.19538	1.46925	1.52858	0.0117228
54	0.0082	0.1251	0.0646				0.16234	1.22079	1.3332	0.0097404
55	0.0071	0.1082	0.0564				0.13737	1.03302	1.17086	0.0082422
56	0.0058	0.0882	0.0493				0.10887	0.8187	1.03349	0.0065322
57	0.0051	0.0776	0.0435				0.09652	0.72583	0.92462	0.0057912
58	0.0046	0.0694	0.0383				0.0836	0.62867	0.8281	0.005016
59	0.0042	0.0643	0.0338				0.07999	0.60152	0.7445	0.0047994
60	0.0035	0.0532	0.0295				0.06639	0.49925	0.66451	0.0039834
61	0.0036	0.0550	0.0260				0.06555	0.49293	0.59812	0.003933
62	0.0030	0.0454	0.0224				0.05432	0.40849	0.53257	0.0032592
63	0.0029	0.0440	0.0194				0.05178	0.38938	0.47825	0.0031068
64	0.0023	0.0342	0.0165				0.04122	0.30997	0.42647	0.0024732
65	0.0022	0.0336	0.0143				0.04343	0.32659	0.38525	0.0026058
66	0.0018	0.0273	0.0121				0.03622	0.27237	0.34182	0.0021732
67	0.0019	0.0280	0.0103				0.04116	0.30952	0.3056	0.0024696
68	0.0014	0.0209	0.0084				0.03236	0.24335	0.26444	0.0019416
69	0.0014	0.0206	0.0070				0.03198	0.24049	0.23208	0.0019188
70	0.0010	0.0152	0.0057				0.02706	0.20349	0.2001	0.0016236
71	0.0011	0.0161	0.0047				0.02799	0.21048	0.17304	0.0016794
72	0.0007	0.0105	0.0036				0.0203	0.15266	0.14505	0.001218
73	0.0008	0.0113	0.0029				0.02248	0.16905	0.12475	0.0013488
74	0.0005	0.0068	0.0022				0.01509	0.11348	0.10227	0.0009054
75	0.0005	0.0074	0.0017				0.01802	0.13551	0.08718	0.0010812
76	0.0003	0.0043	0.0013				0.01122	0.08437	0.06916	0.0006732
77	0.0003	0.0044	0.0010				0.01331	0.10009	0.05794	0.0007986
78	0.0002	0.0027	0.0007				0.00932	0.07009	0.04463	0.0005592
79	0.0002	0.0025	0.0005				0.00914	0.06873	0.03531	0.0005484
80	0.0001	0.0015	0.0003				0.00676	0.05084	0.02617	0.0004056
81							0.00663	0.04986	0.01941	0.0003978
82							0.00357	0.02685	0.01278	0.0002142
83							0.00277	0.02083	0.00921	0.0001662
84							0.00213	0.01602	0.00644	0.0001278
85							0.00235	0.01767	0.00431	0.000141
86							0.00121	0.0091	0.00196	0.0000726
87							0.00075	0.00564	0.00075	0.000045

TABLE 3.1.24

RECOMBINED OIL
BULK DEPOSITION SUMMARY DATA
(@ 4000 psia, 58°F)

Initial Charge of Recombined Oil
(@ 4000 psia, 160°F)

Mass:	115.4 g
Density:	0.767 g/cm ³
Volume:	150.46 cm ³

Reduce Temperature to 58°F and Equilibrate at 4000 psia

Liquid Phase:

Mass:	111.84 g
Density:	0.781 g/cm ³
Volume:	143.2 cm ³

Solid Phase:

Mass:	3.56 g
Density:	0.856 g/cm ³
Volume:	4.16 cm ³
Thermal Conductivity:	0.231.5 W/m.KBtu/[(h.ft ²)(°F/in)]

Weight Fraction of Solids Precipitated @ 4000 psia, 58°F: 3.1%

Table 3.1.25
RECOMBINED OIL - BULK DEPOSITION:
LIQUID COMPOSITION @ 4000 psia, 58°F

COMPONENT	MW	GAS		LIQUID		OVERALL		GROUP
		MOLE %	WT %	MOLE %	WT %	MOLE %	MOLE %	
CO2	44.01	1.158	0.000	0.000	0.263	0.657	0.657	
H2S	34.08	0.000	0.000	0.000	0.000	0.000	0.000	
N2	28.01	0.258	0.000	0.000	0.037	0.146	0.146	
C1	16.04	85.958	0.000	0.000	7.126	48.752	48.752	
C2	30.07	5.279	0.000	0.000	0.820	2.994	2.994	
C3	44.1	2.959	0.057	0.057	0.725	1.804	1.804	
I-C4	58.12	1.014	0.072	0.072	0.369	0.697	0.697	
N-C4	58.12	1.303	0.157	0.157	0.532	1.005	1.005	
I-C5	72.15	0.622	0.282	0.282	0.484	0.736	0.736	
N-C5	72.15	0.422	0.266	0.266	0.396	0.602	0.602	
C6	85	0.513	0.936	0.936	1.066	1.357		
MCYC-C5	84.16	0.044	0.223	0.223	0.219	0.286		
BENZENE	78.11	0.177	0.000	0.000	0.071	0.100		
CYCL-C6	82.15	0.065	0.256	0.256	0.257	0.343	2.087	
C7	99	0.040	1.518	1.518	1.379	1.511		
MCYCL-C6	98.19	0.068	0.715	0.715	0.675	0.754		
TOLUENE	92.14	0.005	0.732	0.732	0.657	0.783		
C8	113	0.015	2.024	2.024	1.821	1.749		
C2-BENZENE	106.17	0.006	0.104	0.104	0.096	0.099		
M&P-XYLENE	106.17	0.041	0.889	0.889	0.818	0.846		
O-XYLENE	106.17	0.037	0.486	0.486	0.456	0.471		
C9	128.3	0.013	2.169	2.169	1.950	1.668	7.882	
C10	134	0.002	3.907	3.907	3.499	2.866		
C11	147	0.002	3.675	3.675	3.291	2.457		
C12	161	0.001	3.689	3.689	3.303	2.252		
C13	175	0.000	4.572	4.572	4.093	2.567		
C14	190	0.001	4.337	4.337	3.884	2.244	12.386	
C15	206	0.000	4.542	4.542	4.066	2.166		
C16	222	0.000	4.043	4.043	3.620	1.790		
C17	237	0.000	4.022	4.022	3.601	1.668		
C18	251	0.000	4.015	4.015	3.594	1.572		
C19	263	0.000	3.808	3.808	3.409	1.423	8.618	
C20	275	0.000	3.446	3.446	3.085	1.231		
C21	291	0.000	3.170	3.170	2.838	1.070		
C22	305	0.000	2.913	2.913	2.608	0.938		
C23	318	0.000	2.759	2.759	2.470	0.852		
C24	331	0.000	2.572	2.572	2.302	0.763		
C25	345	0.000	2.520	2.520	2.256	0.718		
C26	359	0.000	2.080	2.080	1.862	0.569		
C27	374	0.000	2.170	2.170	1.943	0.570		
C28	388	0.000	2.264	2.264	2.027	0.573		
C29	402	0.000	2.373	2.373	2.125	0.580	7.867	
C30+	580	0.000	22.235	22.235	19.905	3.767	3.767	
MW=		20.3	227			109.76		
DENSITY=	0.781	g/cm3 at	58	°F &		4000	psia	
WT. GAS/ WT. SAMPLE=			0.092					
GOR @ STD		100.4	(M3/M3)	563.4	(SCF/BBL)			

Table 3.1.26

RECOMBINED OIL - BULK DEPOSITION:
 FILTERED SOLID COMPOSITION @ 4000 psia, 58°F

CarbonNumber	Mol. Weight	n-Paraffin(wt%)	non n- Paraffin (wt%)	CarbonNumber	Mol. Weight	n-Paraffin(wt%)	non n- Paraffin (wt%)
C10	134	1.052	1.101	C44	545	0.579	0
C11	147	0.932	3.032	C45	551	0.281	0
C12	161	1.185	2.722	C46	556	0.421	0
C13	175	1.42	3.877	C47	561	0.552	0.175
C14	190	2.351	2.962	C48	566	0.395	0
C15	206	2.468	2.999	C49	571	0.41	0
C16	222	2.289	2.865	C50	575	0.345	0
C17	237	2.843	2.735	C51	580	0.342	0
C18	251	2.452	2.404	C52	584	0.292	0
C19	263	2.21	2.276	C53	588	0.16	0
C20	275	2.252	2.027	C54	592	0.196	0
C21	291	1.643	1.946	C55	596	0.098	0
C22	305	1.563	1.357	C56	600	0.075	0.029
C23	318	1.56	1.819	C57	604	0.055	0.021
C24	331	1.437	1.569	C58	608	0.017	0
C25	345	1.335	1.467	C59	612	0.043	0
C26	359	1.223	1.428	C60	615	0.01	0
C27	374	1.008	1.469	C61	619	0.035	0
C28	388	1.005	1.382	C62	622	0.031	0
C29	402	0.571	2.185	C63	626	0.023	0
C30	422	0.907	0.563	C64	629	0.016	0
C31	435	0.959	0.982	C65	632	0.013	0
C32	448	0.907	0.906	C66	635	0.012	0
C33	462	0.995	0.783	C67	638	0.01	0
C34	473	0.955	0.726	C68	641	0.008	0
C35	485	1.132	0.649	C69	644	0.007	0
C36	493	1.091	0.513	C70	647	0.007	0
C37	501	0.818	0.316	C71	650	0.006	0
C38	509	0.803	0.496	C72	653	0.004	0
C39	516	0.715	0.414	C73	656	0.002	0
C40	522	0.689	0.379	C74	658	0.003	0
C41	528	0.582	0.123	C75	661	0.002	0
C42	534	0.895	0				
C43	540	0.605	0				
				Totals:		49.303	50.697

Table 3.1.27

**RECOMBINED OIL
BULK DEPOSITION SUMMARY DATA
(@ 800 psia, 50°F)**

**Initial Charge of Recombined Oil
(@ 4000 psia, 160°F)**

Mass:	85.07 g
Density:	0.767 g/cm ³
Volume:	110.91 cm ³

Reduce Temperature to 24°F and Equilibrate at 4000 psia

Liquid Phase:

Mass:	76.11 g
Density:	0.843 g/cm ³
Volume:	90.28 cm ³

Vapor Phase:

Mass:	4.58 g
Density:	0.0538 g/cm ³
Volume:	85.21 cm ³

Solid Phase:

Mass:	4.38 g
Density:	0.85 g/cm ³
Volume:	5.15 cm ³
Thermal Conductivity	0.23 W/m.K 1.6 Btu/[(h.ft ²)(°F/in)]

Weight Fraction Solids Precipitated @ 800 psia, 50°F: 5.1%

Table 3.1.28

RECOMBINED OIL - BULK DEPOSITION:		LIQUID COMPOSITION @ 800 psia, 50°F				VAPOR COMPOSITION @ 800 psia, 50°F			K
COMPONENT	MW	GAS MOLE %	LIQUID WT %	OVERALL WT %	OVERALL MOLE %	WT %	MOLE %	GROUP MOLE%	
CO2	44.01	1.56	0	0.114	0.434	2.157	0.85	0.85	1.96E+00
N2	28.01	0.158	0	0.007	0.044	0.485	0.301	0.301	6.84E+00
C1	16.04	73.528	0	1.951	20.472	87.956	95.067	95.067	4.64E+00
C2	30.07	9.82	0	0.488	2.734	4.269	2.462	2.462	9.01E-01
C3	44.1	6.218	0.157	0.604	2.305	1.493	0.587	0.587	2.55E-01
I-C4	58.12	2.009	0.126	0.314	0.908	0.421	0.126	0.126	1.39E-01
N-C4	58.12	2.449	0.243	0.469	1.358	0.435	0.13	0.13	9.57E-02
I-C5	72.15	1.089	0.348	0.464	1.082	0.22	0.053	0.053	4.90E-02
N-C5	72.15	0.731	0.312	0.386	0.901	0.151	0.036	0.036	4.00E-02
C6	85	0.903	1.079	1.164	2.274	0.315	0.063		2.77E-02
MCYC-C5	84.16	0.08	0.229	0.231	0.462	0.039	0.008		1.73E-02
BENZENE	78.11	0.353	0	0.046	0.098	0.197	0.044		4.49E-01
CYCL-C6	82.15	0.135	0.263	0.271	0.555	0.095	0.02	0.135	3.60E-02
C7	99	0.084	1.507	1.46	2.453	0.08	0.014		5.71E-03
MCYCL-C6	98.19	0.184	0.725	0.725	1.243	0.35	0.062		4.99E-02
TOLUENE	92.14	0.007	0.731	0.702	1.283	0.008	0.002		1.56E-03
C8	113	0.05	2.011	1.939	2.857	0.081	0.012		4.20E-03
C2-BENZEN	106.17	0.013	0.098	0.096	0.152	0.024	0.004		2.63E-02
M&P-XYLEN	106.17	0.098	0.884	0.865	1.372	0.193	0.031		2.26E-02
O-XYLENE	106.17	0.135	0.483	0.487	0.773	0.14	0.023		2.98E-02
C9	128.3	0.126	2.157	2.096	2.751	0.179	0.024	0.172	8.72E-03
C10	134	0.078	3.859	3.72	4.673	0.171	0.022		4.71E-03
C11	147	0.123	3.63	3.513	4.023	0.284	0.034		8.45E-03
C12	161	0.034	3.652	3.513	3.673	0.096	0.01		2.72E-03
C13	175	0.024	4.564	4.386	4.219	0.097	0.01		2.37E-03
C14	190	0.012	4.323	4.151	3.678	0.064	0.006	0.082	1.63E-03
C15	206	0	4.548	4.364	3.566	0	0	0	
C16	222	0	4.047	3.883	2.944	0	0		
C17	237	0	4.025	3.862	2.743	0	0		
C18	251	0	4.169	4	2.683	0	0		
C19	263	0	3.731	3.579	2.291	0	0		
C20	275	0	3.467	3.327	2.037	0	0		
C21	291	0	3.133	3.006	1.739	0	0		
C22	305	0	3.026	2.903	1.602	0	0		
C23	318	0	2.819	2.705	1.432	0	0		
C24	331	0	2.579	2.474	1.258	0	0		
C25	345	0	2.419	2.321	1.132	0	0		
C26	359	0	2.235	2.144	1.006	0	0		
C27	374	0	2.182	2.093	0.942	0	0		
C28	388	0	2.218	2.129	0.923	0	0		
C29	402	0	1.893	1.816	0.76	0	0		
C30+	580	0	22.127	21.23	6.162	0	0		

MW=	24.5	223.8	168.3	17.34
DENSITY=	0.843 g/cm3 at 50°F & 800 psia			0.0538 @ 800 psia & 50°F
WT. GAS/ WT. SAMPLE=	0.0405			
GOR @ STD	33.7	(M3/M3)	189.3	(SCF/BBL)

Table 3.1.29

RECOMBINED OIL - BULK DEPOSITION:
 FILTERED SOLID COMPOSITION @ 800 psia, 50°F

CarbonNumber	Mol. Weight	n-Paraffin(wt%)	non n- Paraffin (wt%)	CarbonNumber	Mol. Weight	n-Paraffin(wt%)	n- Paraffin (wt%)
C10	134	0.665	0.968	C44	545	0.567	0
C11	147	1.083	3.104	C45	551	0.459	0
C12	161	1.104	2.891	C46	556	0.391	0
C13	175	1.566	4.093	C47	561	0.355	0
C14	190	2.551	3.818	C48	566	0.324	0
C15	206	2.671	3.083	C49	571	0.271	0
C16	222	2.443	2.936	C50	575	0.237	0
C17	237	3.042	2.811	C51	580	0.208	0
C18	251	2.556	2.513	C52	584	0.162	0
C19	263	2.336	2.41	C53	588	0.139	0
C20	275	2.383	2.155	C54	592	0.102	0
C21	291	1.694	2.13	C55	596	0.088	0
C22	305	1.676	1.336	C56	600	0.04	0
C23	318	1.67	1.961	C57	604	0.045	0.015
C24	331	1.63	1.615	C58	608	0.035	0
C25	345	1.438	1.508	C59	612	0.02	0
C26	359	1.292	1.526	C60	615	0.019	0
C27	374	1.091	1.602	C61	619	0.009	0
C28	388	1.091	1.486	C62	622	0.003	0
C29	402	1.055	1.293	C63	626	0.003	0
C30	422	0.895	1.251	C64	629	0.002	0
C31	435	0.783	1.112	C65	632	0.001	0
C32	448	0.667	1.071	C66	635	0.001	0
C33	462	0.698	0.912	C67	638	0.002	0
C34	473	0.7	0.804				
C35	485	0.715	0.696				
C36	493	0.528	0.711	Totals:		42.986	53.516
C37	501	0.467	0.665				
C38	509	0.446	0.318				
C39	516	0.361	0.303				
C40	522	0.401	0.247				
C41	528	0.369	0.187				
C42	534	0.301	0				
C43	540	0.618	0				

Figure 3.1.1
"K" Values From 800 psia & 50°F

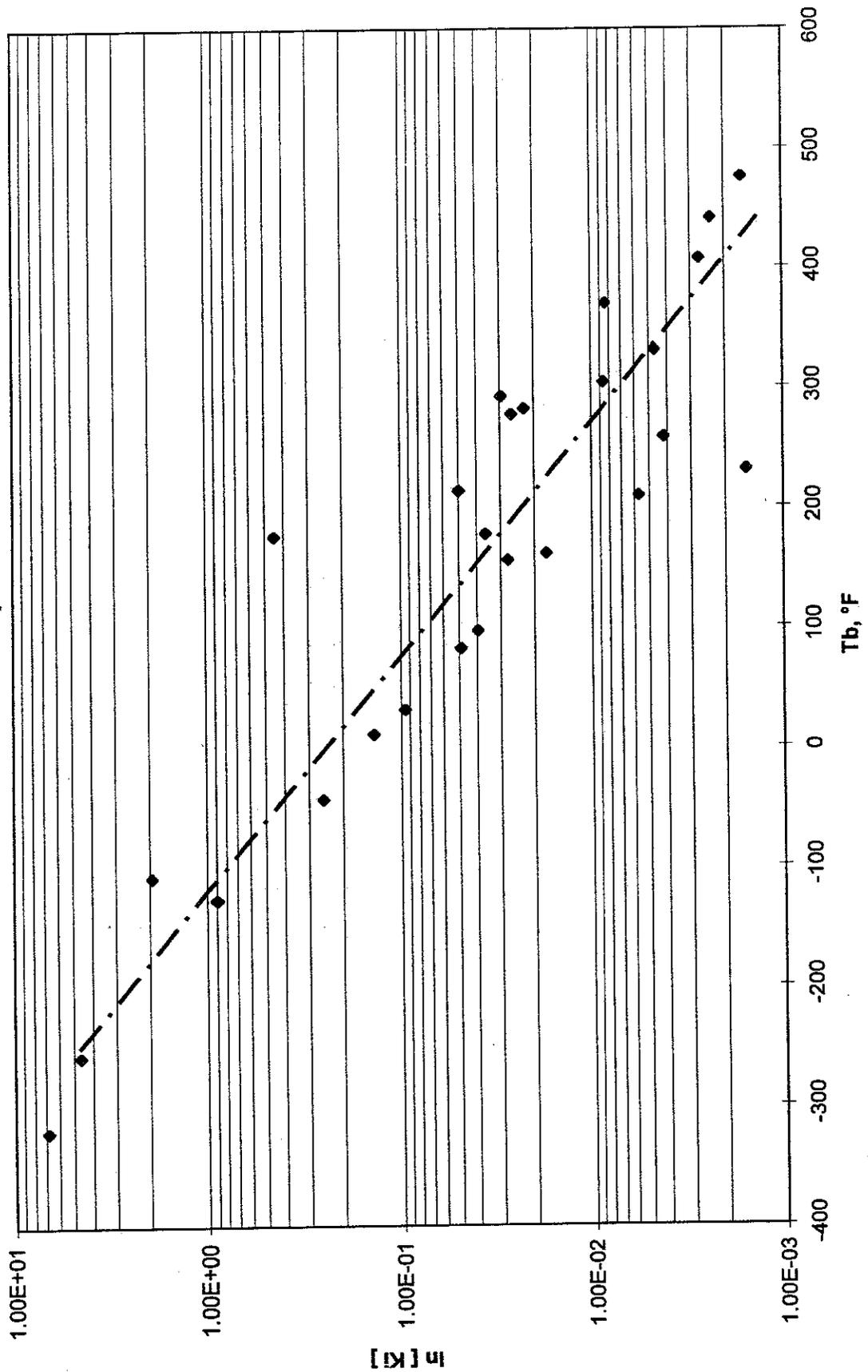


Figure 3.1.2

South Pelto 10 Well 9-2
Cloud Point Data for Recombined Oil 1

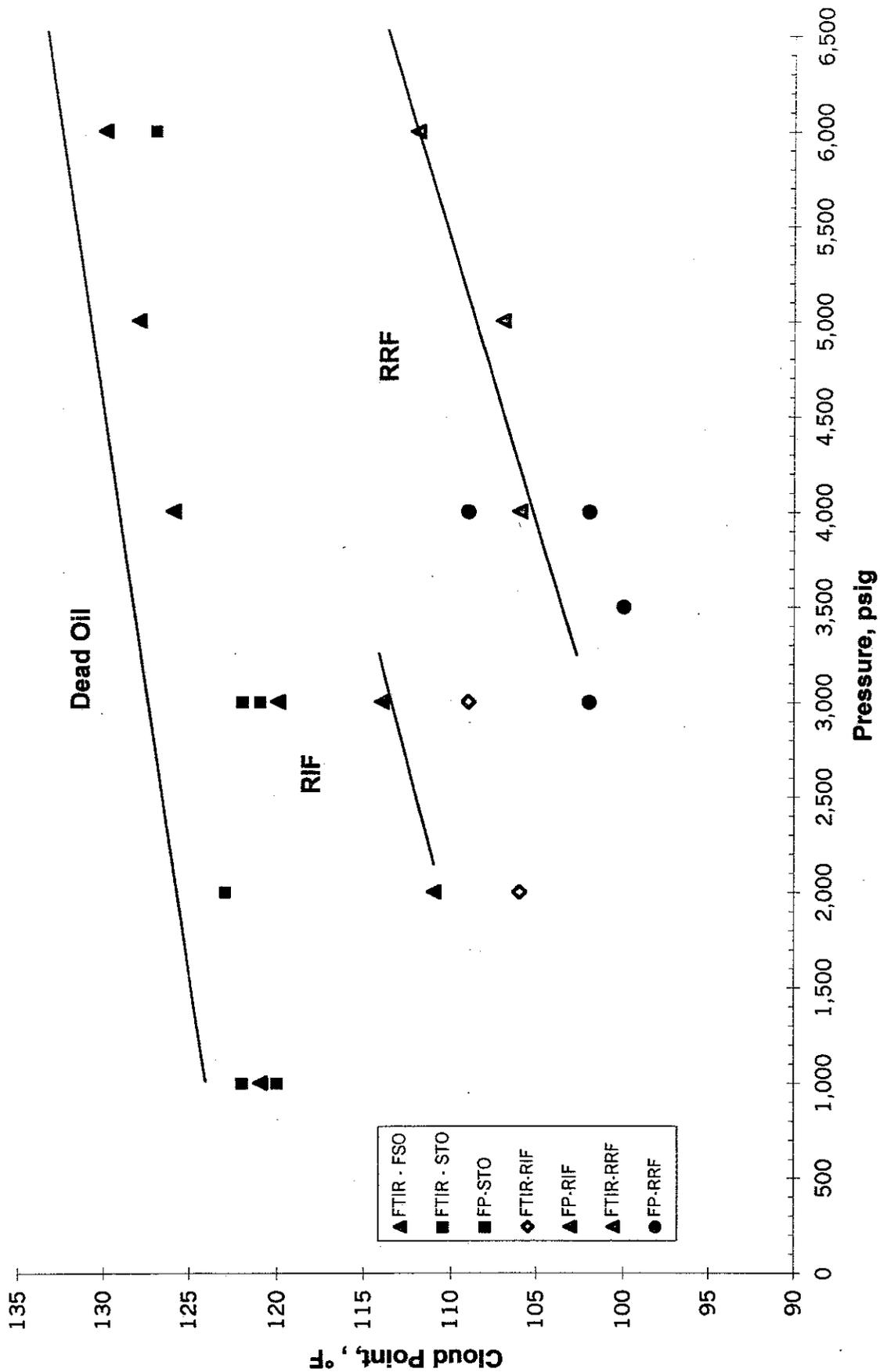


Figure 3.1.3

South Pelto 10 Well 9-2
Recombined Oil 1 : RRF FTIR Data @ 6,000psig

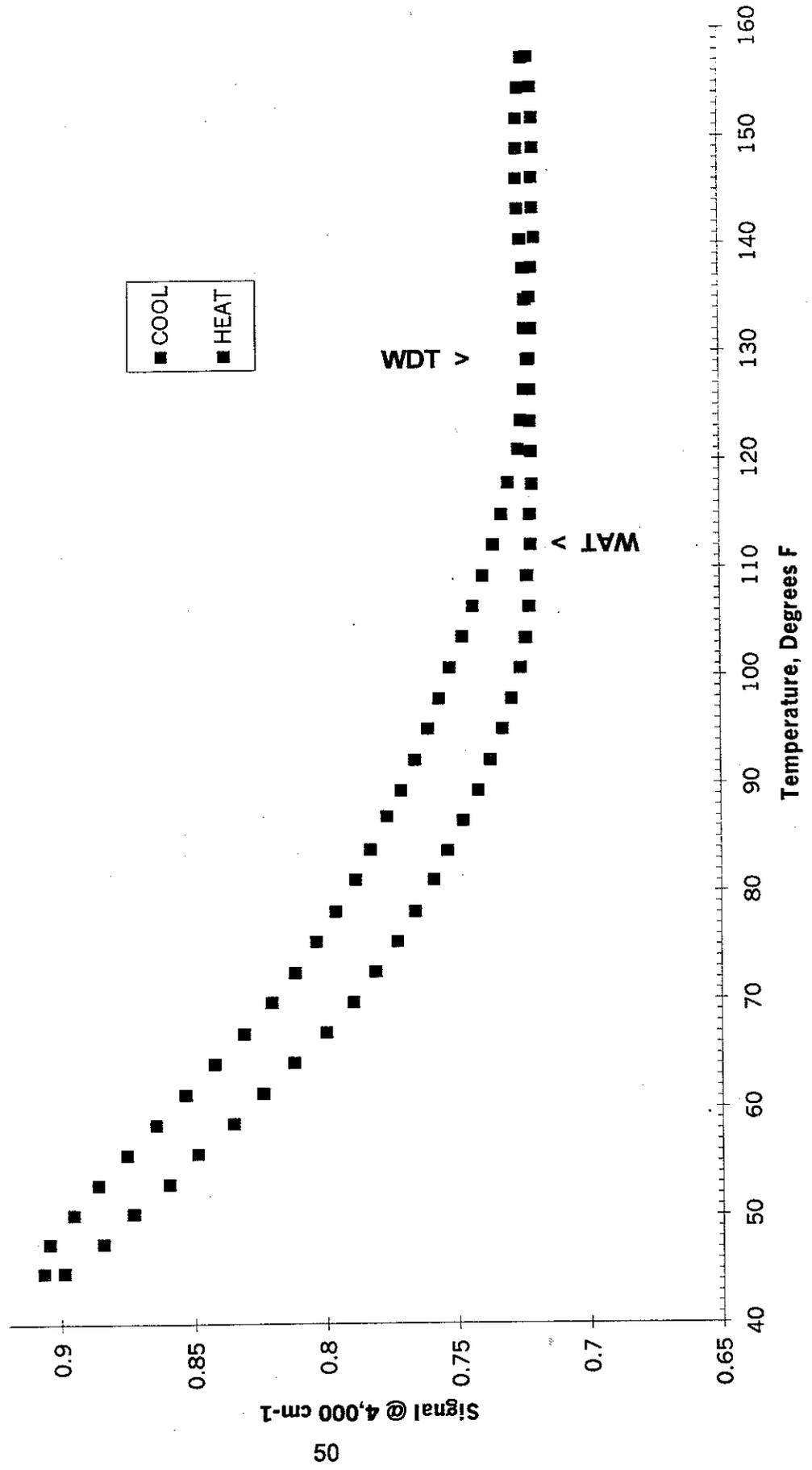


Figure 3.1.4

Cloud Point Data for Flow Loop Oil

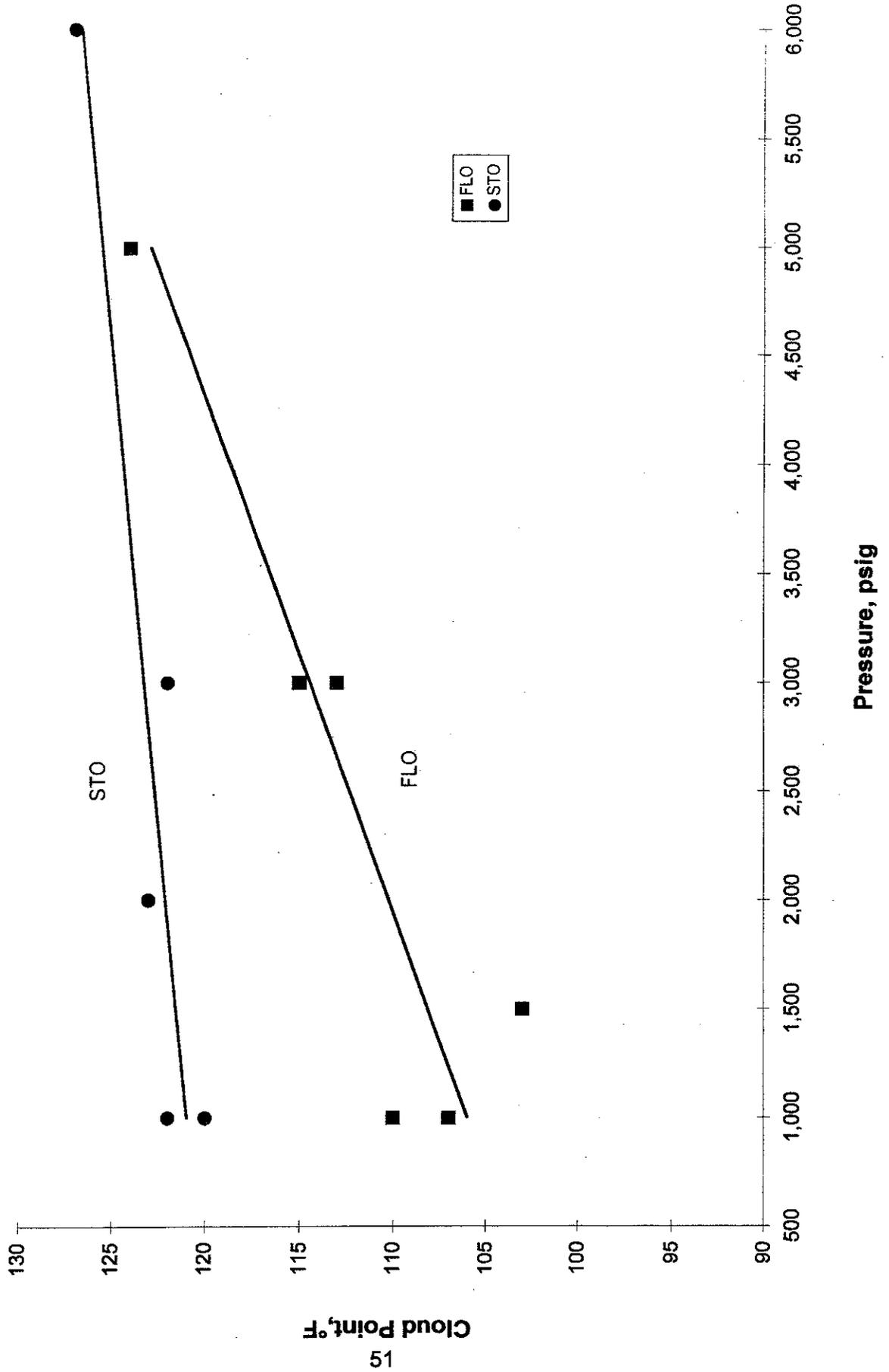


Figure 3.1.5
Nenniger Analyses of South Pelto Oil

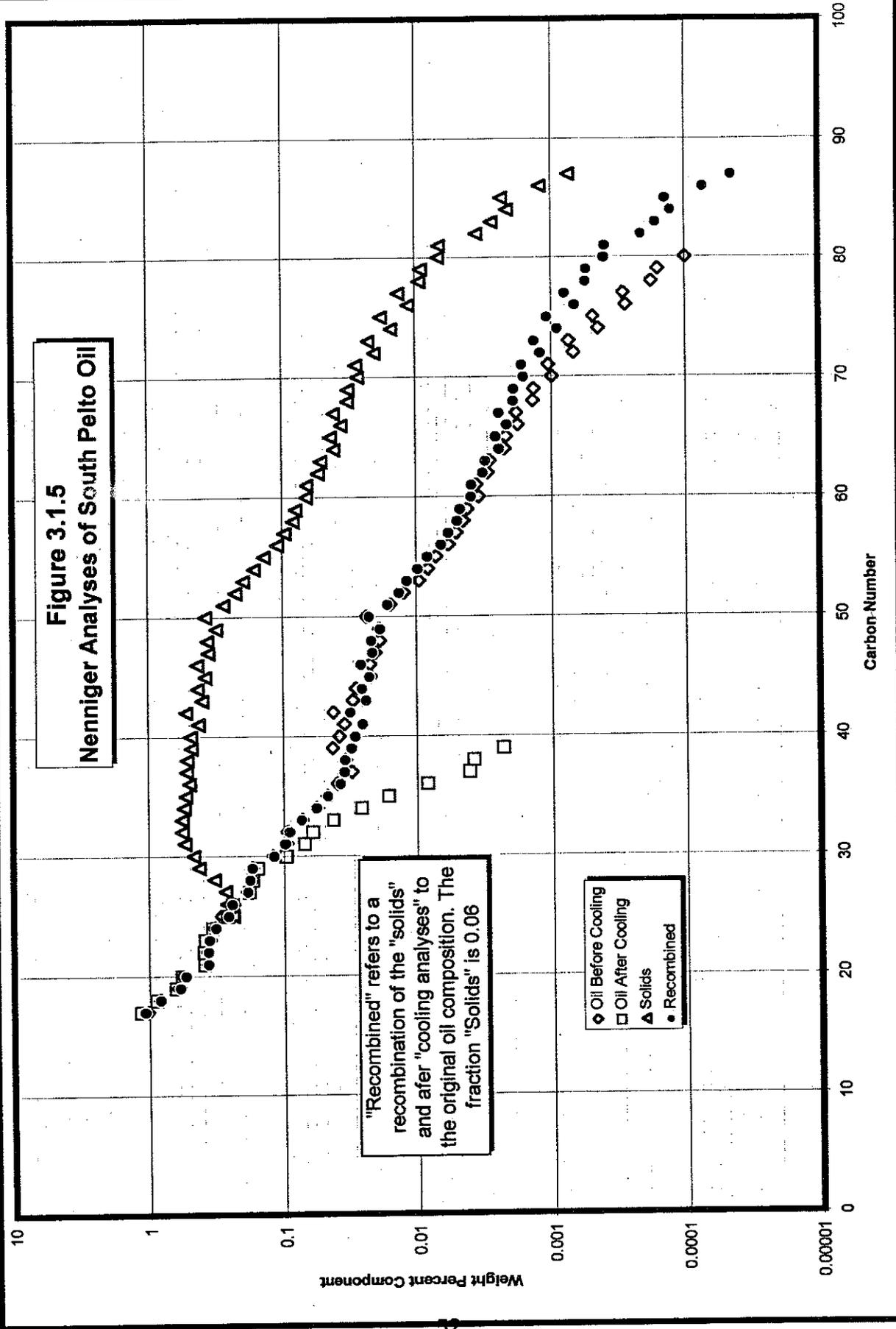


Figure 3.1.6

Recombined Oil: Reproducibility Test:
Cloud Point Determinations at 4000 psia

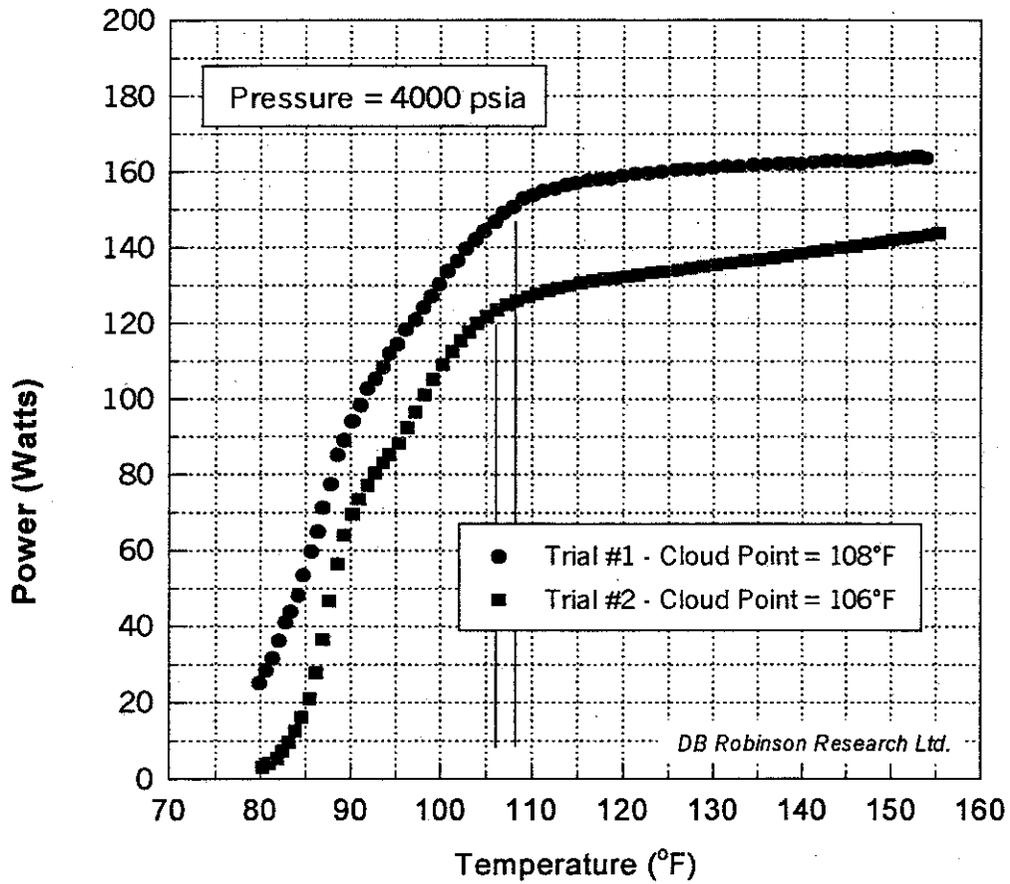


Figure 3.1.7

South Pelto 10 Well 9-2
Comparison of Solids Data by Centrifugation
Flashed Separator Oil

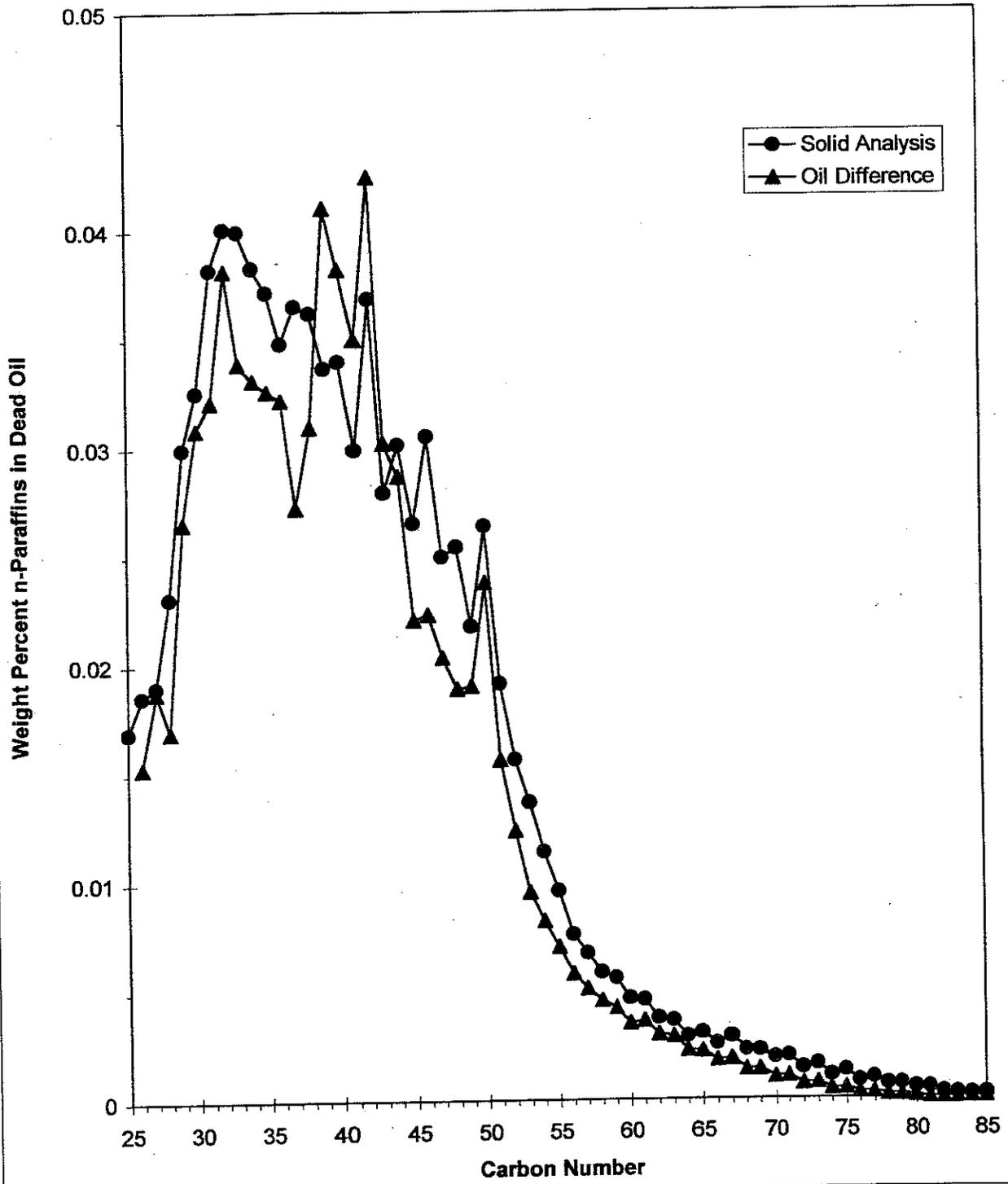
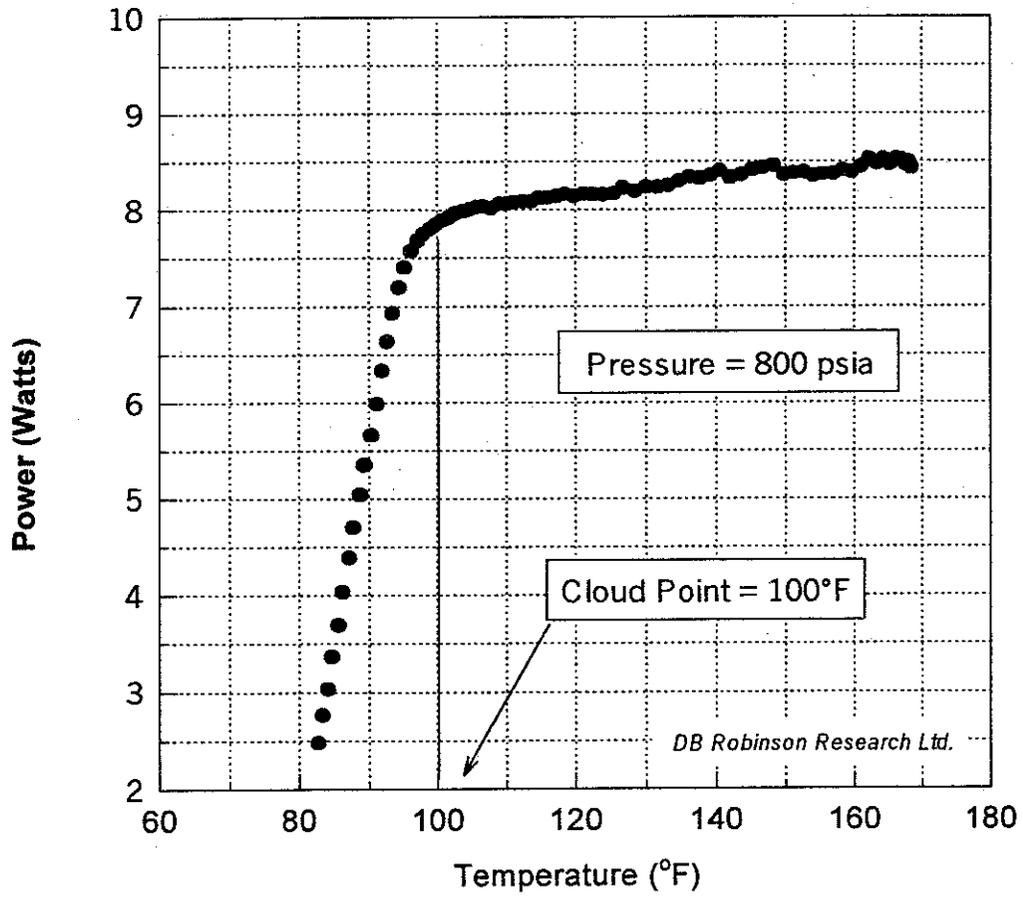


Figure 3.1.8

**Recombined Oil: Two Phase
Cloud Point Determination at 800 psia
(vapor phase expelled)**



Appendix 3.2: Garden Banks 426 Well A-14 Reservoir Fluid Characterization and Property Evaluation Study

3.2. Condensate – Garden Banks 426, Well A-14

Weatherly Laboratories collected separator samples on August 8, 1996 from Shell Oil Company's Garden Banks 426 Well A-14. Duplicate samples were collected, resulting in a total of sixteen separator gas samples and six separator liquid samples. These samples, plus (2) one gallon cans of stock-tank oil, arrived at Marathon Oil Company's Petroleum Technology Center (PTC) in Littleton Colorado on August 16, 1996. A summary of the samples collected is given in Table 3.2.1 and a summary of the API Gravity of the all stock tank oils produced in these tests in Table 3.2.2.

3.2.1. Separator Samples

As a quality check, the opening pressure of the separator gases and the bubble point pressure of the separator liquids were determined at ambient temperature. These results are presented in Table 3.2.1. Prior to taking any sample outage, each separator liquid cylinder was conditioned by being heated to 120°F and pressurized to 3,000 psig. Each separator gas cylinder was also conditioned by being heated to 120°F.

Compositions were determined for selected separator gas and liquid samples. The compositional results are shown in Tables 3.2.3 and 3.2.4. The separator liquid compositions are reported through C₃₀₊. The mass percent values were measured. The properties of the individual C₆₊ fractions were not measured but rather estimated. The molecular weights of the C₆-C₂₉ fractions were values reported by Katz and Firoozabadi¹ for general petroleum fractions. The specific gravity values for C₆-C₃₀₊ fractions were calculated using a constant Watson K factor of 12.01. The C₃₀₊ molecular weight and overall Watson K factor were calculated to match the molecular weight measured by Freezing Point Depression, and the 60°F density value measured by using a Paar-Mettler densitometer, for the stabilized liquid created from the separator liquid. Table 3.2.2 compares the API gravities of the different samples tested in this work.

All separator gas and liquid samples from Garden Banks 426 Well A-14 have been transferred to Marathon Oil Company storage containers for use in the JIP Project. All 22 empty cylinders belonging to Weatherly Laboratories were sent back to their facility on September 10, 1996.

3.2.2. Recombination to Reservoir Fluid

Conditions for mixing Recombined Condensate were made to that of current wellhead conditions of 6400 psig and 100°F. Through various discussions with representatives of Marathon Oil Company's Petroleum Technology Center, Shell Oil Company, and The University of Tulsa, a decision was made as to the conditions to use in the PVT portion of the Recombined Condensate Study. In conforming to the original contract, temperatures used will be reservoir temperature of 176°F, then 138°F, and 100°F. Pressures to be used will be the saturation pressure, 4000 psig, and 2000 psig.

¹ Katz, D. L. and Firoozabadi, A., "Predicting Phase Behavior of Condensate Crude Oil Systems using methane Interaction Coefficients", J. Pet. Tech., November 1978, pp. 1649 – 1655.

3.2.2.1. Physical Recombination and Conditioning

A pilot mix was made for the Recombined Condensate using the above stated conditions of 6400 psig and 100°F. Conditioned separator oil at 3000 psig and 140°F was charged into a high-pressure visual PVT cell, contained within an air-bath and thermally equilibrated at a temperature of 100°F. Then incrementally, conditioned separator gas was added until a final bubble point pressure of 6400 psig at 100°F was achieved. Based upon the initial recombined results, two large mixtures were made in high-pressure cylinders: one for Marathon Oil Company's Petroleum Technology Center and one for D.B. Robinson Research Ltd.

An interesting visual observation was noted during this endeavor. After the separator oil was initially charged to the PVT cell, the oil appeared to contain small dark specs of suspended material. With each addition of gas, these small specks seemed to grow larger in size. By the time all the gas that was needed was charged to the PVT cell to obtain the 6400 psig bubble point pressure, these specks were actually white flakes suspended in the single phase mixture. Upon depressurizing below the bubble point, density differences were such that the white flakes settled to the bottom of the PVT cell. A fluid sample was obtained and used to confirm that these white flakes were in fact wax crystals. The PVT cell was then heated to 200°F and the wax crystals disappeared. Knowing this, the large recombined mixture made in the cylinder was then conditioned and maintained at 8000 psig and 176°F.

3.2.2.2. Recombined Condensate Composition

The composition was determined for the Recombined Condensate. The measured compositional results are shown in Table 3.2.5 and 3.2.6. The overall composition is reported through C₃₀₊ for both the Marathon analysis in Table 3.2.5 and the D.B. Robinson analysis in Table 3.2.6. There is some disagreement between the two analyses but the differences are relatively minor. The differences between the two analyses are caused by differences in the fluid handling of two fluid mixes and because of the analytical techniques used by each laboratory. The mass percent values were measured. The properties of the individual C₆₊ fractions were not measured but rather estimated. The molecular weights of the C₆-C₂₉ fractions were values reported by Katz and Firoozabadi² for general petroleum fractions. The specific gravity values for C₆-C₃₀₊ fractions were calculated using a constant Watson K factor of 12.17. The C₃₀₊ molecular weight and overall Watson K factor were calculated to match the molecular weight measured by Freezing Point Depression, and the 60°F density value measured using a Paar-Mettler densitometer, for the stabilized liquid created from the separator liquid. This fluid exhibited a gas oil ratio of 4006 scf/stb.

Constant Composition Expansion @ 176°F

A portion of Recombined Condensate (Garden Banks 426 Well A14) conditioned at 8000 psig and 176°F, was charged into a high-pressure visual PVT cell, contained within an air-bath and thermally equilibrated at a temperature of 176°F. The fluid was then subjected to a Constant Composition Expansion (CCE). During this expansion a bubble point pressure of 6,457 psig was observed. After continuing the CCE below the bubble point pressure, it was observed that the fluid represents behavior of a near critical volatile oil system.

As the CCE proceeded, fluid was also charged from the recombination cylinder to the Paar-Mettler densitometer and the capillary coil viscometer, both at 176°F. Single-phase density and viscosity measurements were taken at various pressures. The oil density and viscosity at the

² Katz, D. L. and Firoozabadi, A., "Predicting Phase Behavior of Condensate Crude Oil Systems using methane Interaction Coefficients", J. Pet. Tech., November 1978, pp. 1649 - 1655.

bubble point pressure were linearly interpolated from the measured single-phase oil values. All oil densities and viscosities denoted by an asterisk were measured. The viscosity, density, and CCE data are presented in Table 3.2.7. A graph of the liquid volume percent is presented in Figure 3.2.3.

As stated in the scope of work, the fluid in the PVT cell was expanded down to 2000 psig. At this pressure, some equilibrated gas was pumped off to the densitometer. Then all remaining gas was pumped out of the PVT cell until the 2000 psig equilibrated oil was all that remained in the PVT cell. A portion of the oil phase was then pumped to the densitometer and the viscometer, while maintaining constant temperature and pressure.

After the 2000 psig measurements, a subsequent sample of conditioned Recombined Condensate was charged to the PVT cell. The bubble point of this fluid was verified. Property data at the intermediate pressure of 4000 psig was then obtained. This data may also be found in Table 3.2.7.

Constant Composition Expansion @ 138°F

A portion of Recombined Condensate (Garden Banks 426 Well A14) conditioned at 8000 psig and 176°F, was charged into a high-pressure visual PVT cell, contained within an airbath and thermally equilibrated at a temperature of 138°F. The fluid was then subjected to a Constant Composition Expansion (CCE). During this expansion a bubble point pressure of 6521 psig was observed. After continuing the CCE below the bubble point pressure, it was observed that the fluid represents behavior of a near critical volatile oil system.

As the CCE proceeded, fluid was also charged from the recombination cylinder to the Paar-Mettler densitometer and the capillary coil viscometer, both at 138°F. Single-phase density and viscosity measurements were taken at various pressures. The oil density and viscosity at the bubble point pressure were linearly interpolated from the measured single-phase oil values. All oil densities and viscosities denoted by an asterisk were measured. CCE, density, and viscosity data are presented in Table 3.2.8.

As stated in the scope of work, the fluid in the PVT cell was expanded down to 2000 psig. At this pressure, some equilibrated gas was pumped off to the densitometer. Then all remaining gas was pumped out of the PVT cell until the 2000 psig equilibrated oil was all that remained in the PVT cell. A portion of the oil phase was then pumped to the densitometer and the viscometer, while maintaining constant temperature and pressure.

After the 2000 psig measurements, a subsequent sample of conditioned Recombined Condensate was charged to the PVT cell. The bubble point of this fluid was verified, then property data at the intermediate pressure of 4000 psig was obtained. This data may also be found in Table 3.2.8.

Constant Composition Expansion @ 100°F

A portion of Recombined Condensate (Garden Banks 426 Well A14) conditioned at 8000 psig and 100°F, was charged into a high-pressure visual PVT cell, contained within an airbath and thermally equilibrated at a temperature of 100°F. The fluid was then subjected to a Constant Composition Expansion (CCE). During this expansion a bubble point pressure of 6575 psig was observed. After continuing the CCE below the bubble point pressure, it was observed that the fluid still represented behavior of a near critical volatile oil system.

As the CCE proceeded, fluid was also charged from the recombination cylinder to the Paar-Mettler densitometer and the capillary coil viscometer, both at 100°F. Single-phase density and viscosity measurements were taken at various pressures. The oil density and viscosity at the

bubble point pressure were linearly interpolated from the measured single-phase oil values. All oil densities and viscosities denoted by an asterisk were measured. CCE, density, and viscosity data are presented in Table 3.2.9.

The fluid in the PVT cell was then expanded down to 2000 psig. At this pressure, some equilibrated gas was pumped off to the densitometer. Then all remaining gas was pumped out of the PVT cell until the 2000 psig equilibrated oil was all that remained in the PVT cell. A portion of the oil phase was then pumped to the densitometer and the viscometer, while maintaining constant temperature and pressure.

After the 2000 psig measurements, a subsequent sample of conditioned Recombined Condensate was charged to the PVT cell. The bubble point of this fluid was verified, then property data at the intermediate pressure of 4000 psig was obtained. This data may also be found in Table 3.2.9.

Comparisons of viscosity, density, liquid volume percent, and relative volume data for Recombined Condensate from all three CCE temperature tests are shown graphically in Figures 3.2.1 through 3.2.4 respectively. These Figures also reveal the degree of uncertainty that exists in the experimental data. Figure 3.2.1 indicates that the viscosity for the 100°F experiment is less than that for the 138°F and 176°F experiments. This is contrary to normal experience. Similar unusual phenomena are shown in Figure 3.2.2 where the low temperature density is both greater and less than the high temperature density. Similar unusual behavior was observed in the volumetric data in Figures 3.2.3 and 3.2.4. These anomalies were not observed in the data for the flow loop condensate described later in this report.

Notes on the Reservoir Fluid CCE Experiments

Two interesting observations were noted during the CCE test at 100°F. First faint dark streaks appeared on the PVT cell window a day after the Recombined Condensate was charged to the PVT cell at 100°F. Secondly small specs of material were noticed floating in the oil phase portion of sample in the PVT cell at the 2,000 psig. A sample of this material was not obtained. If this material is wax, it may be same as the material previously analyzed.

3.2.3. Flow Loop Condensate

3.2.3.1. Physical Recombination

Recombination calculations were completed to predict the GOR to achieve a bubble point pressure of 500 psi at 140°F. Using these data conditioned Garden Banks 426 stock tank oil was first transferred into a high-pressure cylinder. Then synthetic City of Tulsa natural gas incrementally was added until a bubble point pressure of 500 psig at 140°F was achieved. This formed the basis for the recombination of the Flow Loop Condensate. A compositional analysis of this fluid is given in Table 3.2.10. Table 3.2.12 shows the composition of the synthetic gas used in this recombination.

Constant Composition Expansion @ 140°F

A portion of Flow Loop was conditioned at 1,500 psig and 140°F. The fluid was then subjected to a Constant Composition Expansion (CCE). During this expansion a bubble point pressure of 576 psig was observed.

The procedure identical to that for the reservoir condensate was used to determine the volumetric, density and viscosity data at 140°F. The results are given in Table 3.2.11.

The fluid in the PVT cell was expanded down to 200 psig. Some equilibrated gas was pumped off to the densitometer and then collected into a small high-pressure cylinder for compositional analysis at this pressure. This data may be found in Table 3.2.12. All remaining gas was pumped out of the PVT cell until the oil equilibrated at 200 psig was all that remained in the PVT cell. A portion of the oil phase was then pumped to the densitometer and the viscometer, while maintaining constant temperature and pressure. All remaining oil at 200 psig was pumped out of the PVT cell and collected into a small cylinder for compositional analysis. This data may be found in Table 3.2.13.

After the 200 psig measurements, subsequent samples of conditioned Flow Loop Condensate were charged to the PVT cell. The bubble point of this fluid was verified each time, then property data at the intermediate pressures of 400 psig, 300 psig, and 100 psig were obtained. This data may also be found in Table 3.2.11.

Constant Composition Expansion @ 90°F

A portion of Flow Loop Condensate, still conditioned at 1,500 psig and 140°F was charged into a high-pressure visual PVT cell at a temperature of 90°F. This fluid was then subjected to a CCE. During this expansion a bubble point pressure of 432 psig was observed.

The same procedure used in the other CCE experiments was used to measure the data given in Table 3.2.14 for the Flow Loop Condensate at 90°F.

The fluid in the PVT cell was then expanded down to 204 psig. The same procedure as was used at 140° was used to obtain samples for the analysis given in Tables 3.2.15 and 3.2.16.

After the 204 psig measurements, another sample of conditioned Flow Loop Condensate was charged to the PVT cell. The bubble point of this fluid was verified, then property data at the intermediate pressures of 303 and 105 psig were obtained. This data may also be found in Table 3.2.14.

Constant Composition Expansion @ 40°F

A portion of Flow Loop Condensate, still conditioned at 1,500 psig and 140°F, was charged into a high-pressure visual PVT cell at 40°F. The fluid was then subjected to a CCE. During this expansion a bubble point pressure of 364 psig was observed. The fluid in the PVT cell was expanded down to a final pressure of 100 psig. The CCE and density data are presented in Table 3.2.17. The gas density data were not reported because of problems in the density determination at these low temperatures.

After the initial CCE measurements, another sample of conditioned Flow Loop Condensate was charged to the PVT cell. The bubble point of this fluid was verified, then the fluid in the PVT cell was then expanded down to 200 psig. The gas and oil compositions were determined as before and are given in Tables 3.2.18 and 3.2.19.

No viscosity data was obtained due to wax plugging in the capillary coil viscometer. Despite several attempts, this problem could not be corrected. Wax was apparently plating out inside the viscometer below the bubble point pressure at 40°F. This made viscosity determination impossible and the experiments were terminated at that point.

Comparisons of viscosity, density, liquid volume percent, and relative volume data for Flow Loop Condensate are shown graphically in Figures 3.2.5, 3.2.6, 3.2.7, and 3.2.8, respectively.

3.2.4. Cloud Point Determinations

Cloud points or wax appearance temperatures (WAT) were determined for Garden Banks 426 Well A-14 fluids using the Fourier Transform Infrared Spectroscopy (FTIR) and Filter Plugging (FP) techniques. A complete set of Cloud Point data is given in Table 3.2.21. The estimated best values are plotted in Figure 3.2.9. FTIR and FP cloud points were measured on live separator oil (LSO), dead stock tank oil (STO), and live flow loop condensate (FLC) at several different pressures. Flashed separator oil (FSO) cloud points were only measured using differential scanning calorimetry (DSC) and cross polarization microscopy (CPM).

Both STO and FSO samples were tested because of concern that the STO might have lost some heavy wax during handling. The FSO cloud point values are slightly higher than the STO values.

The FTIR and FP cloud point values for the live separator oil are in good agreement. However, the FP values are about 10°F higher than the FTIR values for the STO and about 8°F lower than the FTIR values for the FLC. Also, the FP values for the STO are about 7°F lower than the values for the FLC, which is very unusual. STO values are typically higher than live oil values. These differences are greater than would be expected based on normal experimental error. For this reason the FP cloud point values for STO and FLC were not used in Figure 3.2.9.

The cloud point values shown in Figure 3.2.9 are consistent with expected behavior, based on previous results. The LSO cloud points are lower than the FLC cloud points and consequently lower than the STO values. The slopes of the trend-lines are somewhat different. This is due to the influence of experimental error on each value.

Based on the above information, Marathon repeated the filter plugging cloud point measurements on the FLC sample. This time the 3,000 psig value of 89°F agreed with the value obtained by FTIR.

FTIR was also used to obtain a 7,000 psig cloud point on the recombined condensate. This value of 70°F agrees with the 75°F obtained by DBR at 8,000 psig.

WAT data for the separator condensate are given in Table 3.2.20. A summary of wax point data for all the Garden Banks condensate oils are given in Table 3.2.21 with the same data plotted in Figure 3.2.9. The initial filter plugging cloud points for the FLC and STO samples are not plotted because they are suspect.

3.2.5. Solid Wax Determinations

3.2.5.1. Marathon Centrifugation Experiment

Solid wax determinations were made on the Garden Banks 426 stock tank oil using the same techniques as was used for the flashed separator oil samples from Main Pass 299 and South Pelto 10 fluids. The Garden Banks STO was sampled at 140°F and then spun at 29,000 rpm for 5 hours at 140°F and then slowly cooled to 45°F while spinning. Table 3.2.22 contains a summary of the centrifugation test results.

The bottoms were isolated, weighed and sent to Nenniger Engineering for high temperature gas chromatographic analysis. The original oil and the oil top layer from the centrifugation were also sent for gas chromatographic analyses. Gas chromatographic data from Nenniger Engineering is reported in Table 3.2.23.

After carefully decanting and blotting the excess oil from the centrifuge tube, 5.5 weight % of bottoms remained. A small portion looked like clay, but no attempt was made to identify or

quantify this material. Nenniger found that the bottoms contained 16.4 weight % C_{22+} n-paraffins. This calculated to a solid n-paraffin in the condensate of 0.89%. When the weight % solid n-paraffin in the condensate was calculated from the difference of C_{22+} n-paraffins in the original condensate and the top layer from the centrifuge test, the value was 0.46%. The difference between 0.89% and 0.46% was larger than what Marathon found for the Main Pass or South Pelto oils. We do not know the cause of this difference, nor which value is correct. The "oil difference" value of 0.46% should be less affected by the presence of clay or water in the sample. The condensate only contained 0.5% water, so this should not have caused the problem. A plot of the n-paraffin distribution data from the two different techniques is shown in Figure 3.2.10. It is interesting to note that the two curves are superimposable when the "oil difference" values are multiplied by two and compared to the "solid analysis" values. This Figure again illustrates the futility of trying to gauge the precipitate composition from the difference in two oil compositions.

3.2.5.2. Recombined Condensate Bulk Deposition Measurement @ 8000 psia, 25°F

Table 3.2.24 contains the summary data from the bulk deposition trial completed at 8000 psia and 25°F for the recombined condensate. One can determine that the precipitated wax content at 25°F was 0.83 wt% and that the density of the produced solid was 0.842 g/cm³ from the data in the table. Note that both the density and the measured thermal conductivity (0.22 W/m.K), are quite close to those measured for the solids precipitated from the recombined oil. As a result, it may be hypothesized (at least with the small sample set available at this stage) that solid wax properties do not appear to be heavily dependent on composition. Of course, this assumes that the solids precipitated in this project are different in composition and that may not be the case.

Table 3.2.25 and 3.2.26 contain the analysis of the produced liquid and filtered solid from this test. As expected, the liquid composition is quite close to that of the original single phase condensate (especially in the light components) but slightly lower in the heavier, wax forming molecules (e.g., C_{30+} for the single phase fluid is 0.496 mole % while for the liquid it is 0.451 mole %). A second observation is the fluid density that has increased from 0.515 g/cm³ to 0.570 g/cm³ despite the loss of some heavy components. The reason for this difference is found in the measurement temperatures for the fluids (140°F for the single-phase condensate and 25°F for the liquid from the test).

To conclude this trial, the composition of the produced solid phase is provided to C_{90+} including a resolution into n-paraffin and non n-paraffin fractions at each carbon number (see Table 3.2.26). The molecular weight distributions of this solid are somewhat similar to those obtained from the recombined oil although the concentration of lighter components is slightly higher. This observation is most likely a function of the lower operating temperature for this trial (25°F) which causes an increased portion of the lighter molecules to solidify. In any event, it is difficult to prove or disprove the earlier hypothesis with this data, as the solid compositions do not appear markedly different.

3.2.5.3. Recombined Condensate Bulk Deposition Measurement @ 4000 psia, 25°F

The second recombined condensate bulk deposition test was completed at 4000 psia and 24°F and the overall volumetric data have been summarized in Table 3.2.27 (note, this trial represented a Vapor-Liquid-Solid equilibrium). In this experiment, the precipitated wax content was found to be 1.6 wt% and in addition, the properties of the solid (i.e., density and thermal conductivity) were quite close to those measured for the three other waxes.

Table 3.2.28 and 3.2.29 contain the compositional analyses of the phases produced in this trial. From Table 3.2.28, the liquid composition has changed significantly from the liquid in the 8000 psia trial but that is mainly a function of the vapor phase. For example, the 4000 psia liquid now has a methane content of 53.571 mole % (down from 71.394 mole %) and a density of

0.710 g/cm³ (up from 0.570 g/cm³ due to the removal of the vapor). Note this vapor is mainly composed of methane, ethane and propane with very small concentrations of other molecules (see Table 3.2.28).

Finally, Table 3.2.29 contains the compositional analysis of the precipitated solids from the 4000 psia trial. By comparing this composition to that measured for the first condensate wax sample, there again appears to be little difference in the precipitates.

Appendix II: Garden Banks

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- 3.2.1 Garden Banks 426 Well A-14 Viscosity Data for Recombined Condensate
- 3.2.2 Garden Banks 426 Well A-14 Density Data for Recombined Condensate
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Table 3.2.1

**Garden Banks 426 Well A-14
Sample Summary**

<u>Cylinder Number</u>	<u>Separator Gas</u>		<u>Laboratory Opening Pressure</u>	
	<u>Separator Conditions</u>			
	<u>Pressure (psig)</u>	<u>Temperature (°F)</u>	<u>Pressure (psig)</u>	<u>Temperature (°F)</u>
WLE-371	1902	109	1695	71
WLE-375	1902	109	1695	71
WLE-289	1902	109	1680	70
WLE-296	1902	109	1690	72
WLE-386	1902	109	1660	71
WLE-303	1902	109	940	71
WLE-380	1902	109	1640	72
WLE-377	1902	109	1680	72
WLE-212 *	1902	109	1720	71
WLE-370	1902	109	1650	70
WLE-239	1902	109	1720	72
WLE-208	1902	109	1710	72
WLE-288	1902	109	1690	72
WLE-382	1902	109	1650	72
WLE-387	1902	109	1680	71
WLE-368	1902	109	1580	72

<u>Cylinder Number</u>	<u>Separator Liquid</u>		<u>Laboratory Bubble Point Conditions</u>	
	<u>Separator Conditions</u>			
	<u>Pressure (psig)</u>	<u>Temperature (°F)</u>	<u>Pressure (psig)</u>	<u>Temperature (°F)</u>
WLE-379 *	1902	109	1721	74
WLE-376	1902	109	1702	74
WLE-292	1902	109	1711	74
WLE-290	1902	109	1680	74
WLE-068	1902	109	1696	74
WLE-301	1902	109	1716	74

* Samples selected for compositional analyses.

Table 3.2.2

**Stock Tank Oil API Gravities
for all measured Oil Compositions**

No.	Description	°API
1	South Pelto 10 Well 9-2 Separator Oil - Cylinder No. WL-170	35.2
2	South Pelto 10 Well 9-2 Separator Oil - Cylinder No. WL-183	34.9
3	South Pelto 10 Well 9-2 Separator Oil - Cylinder No. WL-286	34.9
4	South Pelto 10 Well 9-2 Separator Oil - Cylinder No. WL-308	34.9
5	South Pelto 10 Well 9-2 Recombined Oil 1	34.3
6	South Pelto 10 Well 9-2 Recombined Oil 1 - 182 GOR Mix	34.6
7	Main Pass 299 Well B-4 Separator Oil - Cylinder No. WL-204	40.0
8	Main Pass 299 Well B-4 Separator Oil - Cylinder No. WL-207	40.1
9	Main Pass 299 Well B-4 Recombined Oil 2	39.5
10	South Pelto 10 Well 9-2 Recombined Flow Loop Oil	33.9
11	Flow Loop Oil - Equilibrium Oil at 97 psia and 140°F	34.0
12	Flow Loop Oil - Equilibrium Oil at 97 psia and 90°F	34.0
13	Flow Loop Oil - Equilibrium Oil at 97 psia and 40°F	n/a
14	Garden Banks 426 Well A-14 Separator Oil - Cylinder No. WI	41.6
15	Garden Banks 426 Well A-14 Recombined Condensate	39.1
16	Garden Banks 426 Well A-14 Flow Loop Condensate	41.2
17	Flow Loop Condensate - Equilibrium Oil at 200 psig and 140°	41.6
18	Flow Loop Condensate - Equilibrium Oil at 200 psig and 90°F	41.4
19	Flow Loop Condensate - Equilibrium Oil at 200 psig and 40°F	41.5

Table 3.2.3

**Garden Banks 426 Well A-14
Separator Gas Compositional Analysis**

Cylinder No. WLE 212

<u>Component</u>	<u>Mol %</u>	<u>Weight %</u>
H2S	0.00	0.00
C02	0.23	0.54
N2	0.10	0.15
C1	89.26	75.63
C2	5.50	8.74
C3	2.46	5.72
iC4	0.47	1.45
nC4	0.74	2.28
iC5	0.26	1.00
nC5	0.27	1.04
C6	0.33	1.46
C7	0.20	1.00
C8	0.12	0.70
C9	0.04	0.29
C10	0.00	0.00
C11	0.00	0.00
C12	<u>0.00</u>	<u>0.00</u>
	100.00	100.00

Sample collected at	1919 psia and 109°F
Gas molecular weight	18.9 g/mol
Gas Gravity	0.654
BTU Content	1183 per dry gas at 14.73 psia and 60°F.
GPM Value	3.082
Z Factor	0.790 at 1919 psia and 109°F
Gas Density, gm/cc	0.1207 at 1919 psia and 109°F

Table 3.2.4

Garden Banks 426 Well A14
 Separator Liquid Compositional Analysis

Cylinder No. WLE 379

<u>Component</u>	<u>Mole Percent</u>	<u>Weight Percent</u>	<u>Molecular Weight</u>	<u>Specific Gravity</u>
N2	0.12	0.04	28	0.8094
CO2	0.06	0.03	44	0.8180
C1	35.70	6.04	16	0.3000
C2	6.82	2.17	30.1	0.3562
C3	5.13	2.39	44.1	0.5070
iC4	1.60	0.98	58.1	0.5629
nC4	2.78	1.70	58.1	0.5840
iC5	1.63	1.25	72.2	0.6247
nC5	1.94	1.48	72.2	0.6311
C6	4.01	3.56	84	0.7050
C7	5.09	5.17	96	0.7241
C8	5.73	6.48	107	0.7401
C9	4.34	5.55	121	0.7559
C10	3.68	5.20	134	0.7699
C11	2.77	4.30	147	0.7823
C12	2.22	3.78	161	0.7940
C13	1.97	3.65	175	0.8043
C14	1.82	3.66	190	0.8144
C15	1.59	3.47	206	0.8246
C16	1.33	3.13	222	0.8333
C17	1.03	2.59	237	0.8415
C18	1.00	2.64	251	0.8477
C19	0.88	2.45	263	0.8536
C20	0.79	2.29	275	0.8598
C21	0.69	2.12	291	0.8658
C22	0.55	1.78	305	0.8715
C23	0.52	1.74	318	0.8767
C24	0.45	1.58	331	0.8817
C25	0.43	1.57	345	0.8867
C26	0.35	1.31	359	0.8913
C27	0.32	1.26	374	0.8956
C28	0.28	1.14	388	0.8999
C29	0.28	1.17	402	0.9035
C30+	2.10	12.34	557	0.9369
	<u>100.00</u>	<u>100.00</u>		

Properties of Hydrocarbon Fractions

C7+ Fraction	40.21	80.37	189	0.8233
C11+ Fraction	21.37	57.96	257	0.8572
C15+ Fraction	12.58	42.58	320	0.8809
C20+ Fraction	6.74	28.30	397	0.9038
C30+ Fraction	2.10	12.34	557	0.9369
Reservoir Fluid			95	0.6788
Gas Oil Ratio	769.6	scf/bbl of stock tank		

769.6

Table 3.2.5

Garden Banks 426 Well A14
Hydrocarbon Analysis of Recombined Condensate

Component	Calculated		Determined		Molecular Weight	Specific Gravity
	Mole Percent	Weight Percent	Mole Percent	Weight Percent		
N2	0.11	0.07	0.03	0.02	28	0.8094
CO2	0.17	0.17	0.10	0.10	44	0.8180
C1	71.39	25.90	71.51	26.30	16	0.3000
C2	5.94	4.04	6.20	4.29	30.1	0.3562
C3	3.35	3.34	3.44	3.49	44.1	0.5070
iC4	0.85	1.11	0.85	1.14	58.1	0.5629
nC4	1.42	1.87	1.58	2.11	58.1	0.5840
iC5	0.72	1.17	0.76	1.26	72.2	0.6247
nC5	0.83	1.35	0.90	1.50	72.2	0.6311
C6	1.56	2.96	1.40	2.71	84	0.7063
C7	1.83	3.98	2.02	4.46	96	0.7254
C8	1.99	4.82	1.96	4.82	107	0.7414
C9	1.48	4.04	1.27	3.53	121	0.7573
C10	1.23	3.72	1.14	3.50	134	0.7714
C11	0.93	3.08	0.84	2.85	147	0.7837
C12	0.75	2.72	0.72	2.65	161	0.7955
C13	0.66	2.60	0.64	2.59	175	0.8058
C14	0.61	2.61	0.56	2.44	190	0.8159
C15	0.53	2.47	0.48	2.28	206	0.8261
C16	0.44	2.23	0.43	2.22	222	0.8348
C17	0.34	1.84	0.36	1.94	237	0.8431
C18	0.33	1.89	0.31	1.78	251	0.8493
C19	0.29	1.75	0.28	1.72	263	0.8552
C20	0.26	1.64	0.25	1.56	275	0.8613
C21	0.23	1.52	0.22	1.47	291	0.8674
C22	0.18	1.27	0.18	1.28	305	0.8731
C23	0.17	1.25	0.17	1.26	318	0.8784
C24	0.15	1.12	0.15	1.11	331	0.8833
C25	0.14	1.12	0.13	1.07	345	0.8883
C26	0.12	0.95	0.11	0.91	359	0.8929
C27	0.11	0.90	0.11	0.93	374	0.8973
C28	0.09	0.82	0.09	0.84	388	0.9016
C29	0.09	0.85	0.09	0.82	402	0.9051
C30+	0.70	8.83	0.70	9.08	563	0.9414
	<u>100.00</u>	<u>100.00</u>	<u>100.00</u>	<u>100.00</u>		

Properties of Hydrocarbon Fractions

C7+ Fraction	13.67	58.02	13.22	57.09	188	0.8246
C11+ Fraction	7.14	41.46	6.83	40.78	260	0.8606
C15+ Fraction	4.20	30.45	4.07	30.25	324	0.8842
C20+ Fraction	2.26	20.26	2.20	20.31	401	0.9074
C30+ Fraction	0.70	8.83	0.70	9.08	563	0.9414
Reservoir Fluid					43.5	0.5064
Gas Oil Ratio			4006			

Table 3.2.6
Recombined Condensate Composition
D.B. Robinson Analysis

COMPONENT	MW	GAS		LIQUID		OVERALL		GROUP
		MOLE%	WT%	WT%	MOLE%	MOLE%		
CO2	44.01	0.125	0.000	0.111	0.108	0.108		
H2S	34.08	0.000	0.000	0.000	0.000	0.000		
N2	28.013	0.235	0.000	0.134	0.204	0.204		
C1	16.043	82.809	0.000	26.937	71.874	71.874		
C2	30.07	6.711	0.000	4.092	5.825	5.825		
C3	44.097	3.893	0.074	3.522	3.419	3.419		
I-C4	58.124	0.995	0.066	1.210	0.891	0.891		
N-C4	58.124	1.799	0.226	2.247	1.655	1.655		
I-C5	72.151	0.805	0.303	1.349	0.800	0.800		
N-C5	72.151	0.900	0.498	1.596	0.947	0.947		
C6	85	0.892	2.392	2.901	1.441			
MCYC-C5	84.16	0.081	0.312	0.313	0.159			
BENZENE	78.11	0.007	0.067	0.048	0.026			
CYCL-C6	82.15	0.074	0.491	0.399	0.208	1.834		
C7	99	0.328	3.870	2.840	1.213			
MCYCL-C6	98.19	0.005	1.148	0.655	0.286			
TOLUENE	92.14	0.036	0.108	0.128	0.060			
C8	113	0.181	6.077	3.830	1.435			
C2-BENZEN	106.17	0.020	0.100	0.100	0.040			
M&P-XYLEN	106.17	0.005	0.639	0.370	0.149			
O-XYLENE	106.17	0.013	0.055	0.058	0.023			
C9	128.3	0.037	6.259	3.610	1.205	4.411		
C10	134	0.035	6.641	3.824	1.222			
C11	147	0.010	5.572	3.157	0.919			
C12	161	0.002	4.962	2.792	0.742			
C13	175	0.000	4.885	2.743	0.671			
C14	190	0.001	4.473	2.514	0.566	4.121		
C15	206	0.001	4.337	2.439	0.507	3.909		
C16	222	0.000	3.867	2.171	0.419			
C17	237	0.000	3.521	1.977	0.357			
C18	251	0.000	3.404	1.911	0.326			
C19	263	0.000	3.206	1.800	0.293	1.902		
C20	275	0.000	2.874	1.614	0.251			
C21	291	0.000	2.554	1.434	0.211			
C22	305	0.000	2.428	1.363	0.191			
C23	318	0.000	2.213	1.243	0.167			
C24	331	0.000	2.025	1.137	0.147			
C25	345	0.000	1.892	1.062	0.132			
C26	359	0.000	1.724	0.968	0.115			
C27	374	0.000	1.682	0.944	0.108			
C28	388	0.000	1.697	0.953	0.105			
C29	402	0.000	1.393	0.782	0.083	1.512		
C30+	580	0.000	11.964	6.718	0.496	0.496		

MW=	21.6	182	42.8
DENSITY=	0.515 g/cm3 at F & 8500 psia		
WT. GAS/ WT. SAMPLE=	0.439		
GOR @ STD	717.7	(M3/M3)	4029.7 (SCF/BBL)

Table 3.2.7

Garden Banks 426 Well A14

**Constant Composition Expansion and Property Measurements
of Recombined Condensate @ 176°F**

<u>Pressure (psig)</u>	<u>Relative Volume (2)</u>	<u>Liquid Volume Percent</u>	<u>Compressibility (vol/vol x10-E06)</u>	<u>Oil Density (gm/cc)</u>	<u>Gas Density (gm/cc)</u>	<u>Oil Viscosity (cp)</u>
8001	0.9496		31.446	0.5168 *		0.207 *
7500	0.9648		32.962	0.5111 *		0.198 *
6999	0.9810			0.5042 *		0.188 *
6700	0.9917			0.4995 *		0.183 *
6600	0.9950		35.055			
6501	0.9980					
6457 (1)	1.0000	100.00		0.4965		0.178
6446	1.0010	53.35				
6420	1.0035	53.07				
6401	1.0053	52.85				
6351	1.0088	52.82				
6000	1.0332	52.67				
5001	1.0868	50.86		0.5790 *		
4002	1.2060	45.72		0.6190 *	0.2516 *	0.343 *
3002	1.4329	37.36				
2001	1.9929	25.61		0.6808 *	0.1103 *	0.470 *

(1) Bubble Point Pressure

(2) Relative Volume: V/V_{sat} is the total volume of fluid at the indicated pressure per volume of saturated fluid at the bubble point pressure.

* Measured Property Data

Table 3.2.8

Garden Banks 426 Well A14

**Constant Composition Expansion and Property Measurements
of Recombined Condensate @ 138°F**

<u>Pressure (psig)</u>	<u>Relative Volume (2)</u>	<u>Liquid Volume Percent</u>	<u>Compressibility (vol/vol x10-E06)</u>	<u>Oil Density (gm/cc)</u>	<u>Gas Density (gm/cc)</u>	<u>Oil Viscosity (cp)</u>
8000	0.9599			0.5679	*	0.186 *
7500	0.9728		2.647	0.5622	*	0.179 *
7000	0.9864		2.749	0.5556	*	0.175 *
6600	0.9975		2.845	0.5506	*	0.169 *
6521	(1) 1.0000	100.00		0.5497		0.166
6510	1.0001	60.57				
6500	1.0003	59.12				
6490	1.0007	58.29				
6450	1.0018	56.83				
6400	1.0040	56.24				
6000	1.0184	55.31				
4000	1.1629	48.15		0.6285	* 0.2445 *	0.313 *
2000	1.8937	26.25		0.6755	* 0.0993 *	0.427 *

(1) Bubble Point Pressure

(2) Relative Volume: V/V_{sat} is the total volume of fluid at the indicated pressure per volume of saturated fluid at the bubble point pressure.

* Measured Property Data

Table 3.2.9

Garden Banks 426 Well A14

**Constant Composition Expansion and Property Measurements
of Recombined Condensate @ 100°F**

<u>Pressure (psig)</u>	<u>Relative Volume (2)</u>	<u>Liquid Volume Percent</u>	<u>Compressibility (vol/vol x10-E05)</u>	<u>Oil Density (gm/cc)</u>	<u>Gas Density (gm/cc)</u>	<u>Oil Viscosity (cp)</u>
8000	0.9689		1.638	0.5515 *		0.147 *
7500	0.9769		2.215	0.5466 *		0.145 *
7000	0.9878		2.765	0.5419 *		0.144 *
6700	0.9961		3.120	0.5391 *		0.143 *
6600	0.9395					
6575 (1)	1.0000	100.00		0.5379		0.142
6560	1.0005					
6550	1.0016	68.75				
6538	1.0019	66.09				
6530	1.0022	64.99				
6500	1.0027	62.51				
6400	1.0065	60.04				
6000	1.0189	58.54				
4000	1.2303	48.35		0.6188 *	0.2984 *	0.369 *
2000	1.7505	32.10		0.6782 *	0.1316 *	0.512 *

(1) Bubble Point Pressure

(2) Relative Volume: V/V_{sat} is the total volume of fluid at the indicated pressure per volume of saturated fluid at the bubble point pressure.

* Measured Property Data

Table 3.2.10

Garden Banks 426 Stock Tank Oil & City of Tulsa Synthesized Gas
 Measured Hydrocarbon Analysis of Flow Loop Condensate

<u>Component</u>	<u>Mole Percent</u>	<u>Weight Percent</u>	<u>Molecular Weight</u>	<u>Specific Gravity</u>
N2	0.00	0.00	28.0	0.8094
CO2	0.08	0.02	44.0	0.8180
C1	12.96	1.29	16.0	0.3000
C2	0.85	0.16	30.1	0.3562
C3	0.98	0.27	44.1	0.5070
iC4	0.54	0.19	58.1	0.5629
nC4	1.39	0.50	58.1	0.5840
iC5	1.24	0.56	72.2	0.6247
nC5	2.34	1.05	72.2	0.6311
C6	3.65	1.90	84	0.6995
C7	7.87	4.69	96	0.7184
C8	9.75	6.47	107	0.7343
C9	7.94	5.95	121	0.7500
C10	6.96	5.78	134	0.7640
C11	5.41	4.94	147	0.7762
C12	4.64	4.63	131	0.7879
C13	4.07	4.42	175	0.7980
C14	3.61	4.25	190	0.8081
C15	3.08	3.93	206	0.8182
C16	2.55	3.51	222	0.8268
C17	2.23	3.27	237	0.8350
C18	1.94	3.02	251	0.8412
C19	1.75	2.85	263	0.8470
C20	1.48	2.52	275	0.8531
C21	1.36	2.46	291	0.8591
C22	1.10	2.08	305	0.8647
C23	1.01	2.00	318	0.8699
C24	0.90	1.85	331	0.8749
C25	0.85	1.82	345	0.8798
C26	0.69	1.54	359	0.8844
C27	0.66	1.53	374	0.8887
C28	0.54	1.31	388	0.8929
C29	0.57	1.41	402	0.8965
C30+	<u>5.01</u>	<u>17.85</u>	575	0.9391
	100.00	100.00		
Properties of Hydrocarbon Fractions				
C7+ Fraction	75.97	94.07	200	0.8252
C11+ Fraction	43.45	71.18	264	0.8559
C15+ Fraction	25.71	52.94	332	0.8805
C20+ Fraction	14.18	36.37	414	0.9044
C30+ Fraction	5.01	17.85	575	0.9391
Overall Reservoir Fluid			161.3	0.7712
Gas Oil Ratio	105	scf/bbl of stock tank		

Table 3.2.11

Garden Banks 426 Stock Tank Oil & City of Tulsa Synthesized Gas

**Constant Composition Expansion and Property Measurements
of Flow Loop Condensate @ 140°F**

<u>Pressure (psig)</u>	<u>Relative Volume (2)</u>	<u>Liquid Volume Percent</u>	<u>Compressibility (vol/vol x10-E06)</u>	<u>Oil Density (gm/cc)</u>	<u>Gas Density (gm/cc)</u>	<u>Oil Viscosity (cp)</u>
2000	0.9885		7.576	0.7750	*	1.218 *
1500	0.9923		7.728	0.7720	*	1.147 *
1000	0.9962		8.407	0.7693	*	1.086 *
800	0.9979		9.253	0.7680		1.060 *
600	0.9996			0.7665	*	*
576 (1)	1.0000	100.00		0.7663		1.027
550	1.0148					
525	1.0386					
500	1.0632	92.53				
400	1.2004	81.48		0.7698	* 0.0187 *	1.090 *
300	1.4562	66.58		0.7728	* 0.0140 *	1.154 *
200	1.9893	46.66		0.7758	* 0.0105 *	1.241 *
100	2.9394	17.81		0.7800	* 0.0063 *	1.352 *

(1) Bubble Point Pressure

(2) Relative Volume: V/Vsat is the total volume of fluid at the indicated pressure per volume of saturated fluid at the bubble point pressure.

* Measured Property Data

Table 3.2.12

**Garden Banks 426 Stock Tank Oil & City of Tulsa Synthesized Gas
Compositional Analysis of Flow Loop Condensate**

Equilibrium Gas at 200 psig and 140°F

<u>Component</u>	<u>Mol %</u>	<u>Weight %</u>
H2S	0.00	0.00
C02	0.48	1.09
N2	3.14	4.52
C1	88.58	73.02
C2	2.44	3.77
C3	1.59	3.61
iC4	0.53	1.60
nC4	1.04	3.12
iC5	0.49	1.81
nC5	0.54	1.99
C6	0.62	2.68
C7	0.34	1.68
C8	0.16	0.89
C9	0.03	0.20
C10	0.01	0.04
C11	0.00	0.00
C12	0.00	<u>0.00</u>
	100.00	100.00

Sample collected at	200 psig and 140°F
Gas molecular weight	19.5 g/mol
Gas Gravity	0.672
BTU Content	1154 per dry gas at 14.73 psia and 60°F.
GPM Value	2.494
Z Factor	0.976 at 200 psig and 140°F
Gas Density, gm/cc	0.0105 at 200 psig and 140°F

Table 3.2.13

**Garden Banks 426 Stock Tank Oil & City of Tulsa Synthesized Gas
Compositional Analysis of Flow Loop Condensate
Equilibrium Oil at 200 psig and 140°F**

<u>Component</u>	<u>Mole Percent</u>	<u>Weight Percent</u>	<u>Molecular Weight</u>	<u>Specific Gravity</u>
N2	0.00	0.00	28.0	0.8094
CO2	0.03	0.01	44.0	0.8180
C1	2.55	0.22	16.0	0.3000
C2	0.64	0.11	30.1	0.3562
C3	0.91	0.22	44.1	0.5070
iC4	0.54	0.17	58.1	0.5629
nC4	1.45	0.46	58.1	0.5840
iC5	1.36	0.54	72.2	0.6247
nC5	2.61	1.03	72.2	0.6311
C6	4.10	1.89	84	0.6957
C7	8.99	4.73	96	0.7145
C8	11.18	6.55	107	0.7303
C9	9.11	6.04	121	0.7459
C10	7.99	5.86	134	0.7598
C11	6.22	5.00	147	0.7720
C12	5.33	4.70	161	0.7836
C13	4.68	4.48	175	0.7937
C14	4.14	4.31	190	0.8037
C15	3.53	3.99	206	0.8138
C16	2.92	3.56	222	0.8223
C17	2.55	3.32	237	0.8305
C18	2.23	3.06	251	0.8366
C19	2.00	2.89	263	0.8424
C20	1.69	2.55	275	0.8485
C21	1.56	2.49	291	0.8545
C22	1.27	2.11	305	0.8600
C23	1.16	2.03	318	0.8652
C24	1.03	1.87	331	0.8701
C25	0.97	1.84	345	0.8750
C26	0.79	1.56	359	0.8796
C27	0.76	1.56	374	0.8838
C28	0.62	1.33	388	0.8881
C29	0.65	1.43	402	0.8916
C30+	<u>4.41</u>	<u>18.10</u>	750	0.9579
	100.00	100.00		

Properties of Hydrocarbon Fractions

C7+ Fraction	85.81	95.36	203	0.8242
C11+ Fraction	48.54	72.18	272	0.8562
C15+ Fraction	28.18	53.69	348	0.8827
C20+ Fraction	14.93	36.88	451	0.9102
C30+ Fraction	4.41	18.10	750	0.9579
Overall Reservoir Fluid			182.6	0.8098

Table 3.2.14

Garden Banks 426 Stock Tank Oil & City of Tulsa Synthesized Gas

**Constant Composition Expansion and Property Measurements
of Flow Loop Condensate @ 90°F**

<u>Pressure (psig)</u>	<u>Relative Volume (2)</u>	<u>Liquid Volume Percent</u>	<u>Compressibility (vol/vol x10-E06)</u>	<u>Oil Density (gm/cc)</u>	<u>Gas Density (gm/cc)</u>	<u>Oil Viscosity (cp)</u>
2000	0.9899		6.244	0.7963 *		2.087 *
1500	0.9930		6.465	0.7929 *		2.001 *
1000	0.9962		6.667	0.7901 *		1.925 *
800	0.9975		6.793	0.7888 *		1.889 *
601	0.9989			0.7879 *		1.855
501	0.9996					
455	0.9999					
432	(1) 1.0000	100.00		0.7866		1.826
400	1.0427					
352	1.1053					
303	1.1852	84.59		0.7880 *	0.0126 *	1.836 *
204	1.4727	67.74		0.7918 *	0.0101 *	1.861 *
105	2.0875	47.17		0.7966 *	0.0058 *	1.978 *

(1) Bubble Point Pressure

(2) Relative Volume: V/V_{sat} is the total volume of fluid at the indicated pressure per volume of saturated fluid at the bubble point pressure.

* Measured Property Data

Table 3.2.15

**Garden Banks 426 Stock Tank Oil & City of Tulsa Synthesized Gas
Compositional Analysis of Flow Loop Condensate**

Equilibrium Gas at 200 psig and 90°F

<u>Component</u>	<u>Mol %</u>	<u>Weight %</u>
H2S	0.00	0.00
C02	0.40	0.99
N2	2.89	4.56
C1	92.75	83.85
C2	1.67	2.84
C3	0.82	2.05
iC4	0.24	0.80
nC4	0.45	1.48
iC5	0.20	0.81
nC5	0.21	0.86
C6	0.22	1.05
C7	0.09	0.49
C8	0.02	0.12
C9	0.01	0.06
C10	0.00	0.02
C11	0.00	0.01
C12	<u>0.00</u>	<u>0.01</u>
	100.00	100.00

Sample collected at	200 psig and 90°F
Gas molecular weight	17.7 g/mol
Gas Gravity	0.613
BTU Content	1067 per dry gas at 15.025 psia and 60°F.
GPM Value	1.211
Z Factor	0.979 at 200 psig and 90°F
Gas Density, gm/cc	0.0101 at 200 psig and 90°F

Table 3.2.16

Garden Banks 426 Stock Tank Oil & City of Tulsa Synthesized Gas
 Compositional Analysis of Flow Loop Condensate
 Equilibrium Oil at 200 psig and 90°F

<u>Component</u>	<u>Mole Percent</u>	<u>Weight Percent</u>	<u>Molecular Weight</u>	<u>Specific Gravity</u>
N2	0.00	0.00	28	0.8094
CO2	0.04	0.01	44	0.8180
C1	2.43	0.21	16	0.3000
C2	0.76	0.13	30.1	0.3562
C3	1.02	0.25	44.1	0.5070
iC4	0.58	0.19	58.1	0.5629
nC4	1.53	0.49	58.1	0.5840
iC5	1.39	0.55	72.2	0.6247
nC5	2.65	1.05	72.2	0.6311
C6	4.14	1.91	84	0.7028
C7	8.99	4.74	96	0.7218
C8	11.15	6.55	107	0.7377
C9	9.07	6.03	121	0.7535
C10	7.96	5.85	134	0.7675
C11	6.19	5.00	147	0.7798
C12	5.31	4.69	161	0.7915
C13	4.66	4.48	175	0.8017
C14	4.12	4.30	190	0.8119
C15	3.52	3.98	206	0.8220
C16	2.91	3.55	222	0.8307
C17	2.54	3.31	237	0.8389
C18	2.22	3.06	251	0.8451
C19	2.00	2.88	263	0.8509
C20	1.69	2.55	275	0.8570
C21	1.56	2.49	291	0.8631
C22	1.26	2.11	305	0.8687
C23	1.16	2.02	318	0.8740
C24	1.03	1.87	331	0.8789
C25	0.97	1.84	345	0.8839
C26	0.79	1.56	359	0.8885
C27	0.76	1.55	374	0.8928
C28	0.62	1.33	388	0.8971
C29	0.65	1.43	402	0.9006
C30+	<u>4.32</u>	<u>18.07</u>	762	0.9665
	100.00	100.00		

Properties of Hydrocarbon Fractions

C7+ Fraction	85.45	95.22	203	0.8323
C11+ Fraction	48.27	72.05	272	0.8646
C15+ Fraction	27.99	53.59	349	0.8913
C20+ Fraction	14.80	36.81	453	0.9189
C30+ Fraction	4.32	18.07	762	0.9665
Overall Reservoir Fluid			182.2	0.8170

Table 3.2.17

Garden Banks 426 Stock Tank Oil & City of Tulsa Synthesized Gas

**Constant Composition Expansion and Property Measurements
of Flow Loop Condensate @ 40°F**

<u>Pressure (psia)</u>	<u>Relative Volume (2)</u>	<u>Liquid Volume Percent</u>	<u>Compressibility (vol/vol x10-E06)</u>	<u>Oil Density (gm/cc)</u>	<u>Gas Density (gm/cc)</u>	<u>Oil Viscosity (cp)</u>
2004	0.9919			0.8118	*	
1501	0.9942		4.592	0.8085	*	
1007	0.9966		4.886	0.8050	*	
810	0.9975		5.150	0.8035	*	
599	0.9987		5.532	0.8022	*	
404	0.9996					
364 (1)	1.0000	100.00		0.8003		
357	1.0100					
300	1.0816	90.81				
200	1.3444	74.22		0.8048	*	
100	2.0471	48.57		0.8073	*	

(1) Bubble Point Pressure

(2) Relative Volume: V/V_{sat} is the total volume of fluid at the indicated pressure per volume of saturated fluid at the bubble point pressure.

* Measured Property Data

NOTE: Gas densities could not be measured. Viscosity data could not be obtained due to excessive wax buildup.

Table 3.2.18

**Garden Banks 426 Stock Tank Oil & City of Tulsa Synthesized Gas
Compositional Analysis of Flow Loop Condensate**

Equilibrium Gas at 200 psig and 40°F

<u>Component</u>	<u>Mol %</u>	<u>Weight %</u>
H2S	0.00	0.00
C02	0.33	0.86
N2	3.38	5.58
C1	94.40	89.20
C2	1.11	1.96
C3	0.43	1.12
iC4	0.10	0.34
nC4	0.16	0.53
iC5	0.05	0.20
nC5	0.04	0.16
C6	0.01	0.04
C7	0.00	0.00
C8	0.00	0.00
C9	0.00	0.00
C10	0.00	0.00
C11	0.00	0.00
C12	<u>0.00</u>	<u>0.00</u>
	100.00	100.00

Sample collected at	200 psig and 40°F
Gas molecular weight	17.0 g/mol
Gas Gravity	0.586
BTU Content	1018 per dry gas at 15.025 psia and 60°F.
GPM Value	0.541
Z Factor	0.974 at 200 psig and 40°F
Gas Density, gm/cc	0.0100 at 200 psig and 40°F

Table 3.2.19

Garden Banks 426 Stock Tank Oil & City of Tulsa Synthesized Gas
 Compositional Analysis of Flow Loop Condensate
 Equilibrium Oil at 200 psig and 40°F

<u>Component</u>	<u>Mole Percent</u>	<u>Weight Percent</u>	<u>Molecular Weight</u>	<u>Specific Gravity</u>
N2	0.00	0.00	28	0.8094
CO2	0.05	0.01	44	0.8180
C1	1.56	0.14	16	0.3000
C2	0.83	0.14	30.1	0.3562
C3	1.07	0.26	44.1	0.5070
iC4	0.61	0.19	58.1	0.5629
nC4	1.58	0.50	58.1	0.5840
iC5	1.42	0.56	72.2	0.6247
nC5	2.69	1.06	72.2	0.6311
C6	4.19	1.92	84	0.7036
C7	9.06	4.74	96	0.7226
C8	11.23	6.55	107	0.7386
C9	9.14	6.03	121	0.7544
C10	8.01	5.85	134	0.7684
C11	6.23	5.00	147	0.7807
C12	5.34	4.69	161	0.7924
C13	4.69	4.48	175	0.8027
C14	4.15	4.30	190	0.8128
C15	3.54	3.98	206	0.8230
C16	2.93	3.55	222	0.8316
C17	2.56	3.31	237	0.8399
C18	2.23	3.06	251	0.8460
C19	2.01	2.88	263	0.8519
C20	1.70	2.55	275	0.8580
C21	1.57	2.49	291	0.8641
C22	1.27	2.11	305	0.8697
C23	1.17	2.02	318	0.8750
C24	1.04	1.87	331	0.8800
C25	0.98	1.84	345	0.8849
C26	0.80	1.56	359	0.8895
C27	0.76	1.55	374	0.8938
C28	0.63	1.33	388	0.8981
C29	0.65	1.43	402	0.9017
C30+	4.33	<u>18.07</u>	765	0.9677
	100.00	100.00		

Properties of Hydrocarbon Fractions

C7+ Fraction	86.01	95.23	203	0.8333
C11+ Fraction	48.58	72.05	272	0.8656
C15+ Fraction	28.16	53.59	349	0.8924
C20+ Fraction	14.88	36.81	454	0.9201
C30+ Fraction	4.33	18.07	765	0.9677
Overall Reservoir Fluid			183.4	0.8188

Table 3.2.20

**Garden Banks 426 Well A-14
Summary of Wax Data (°F)
for Live Separator Condensate**

Pressure <u>psig</u>	FTIR		FP	
	<u>WAT</u>	<u>WDT</u>	<u>WAT</u>	<u>WDT</u>
2,500			76	113
3,000	84	104		
3,500			88	111
4,000	83	103		
5,000	86	106		

FTIR = FOURIER TRANSFORM INFRARED SPECTROSCOPY
FP= FILTER PLUGGING
WAT = WAX APPEARANCE TEMPERATURE
WDT = WAX DISSOLUTION TEMPERATURE

Table 3.2.22

Solid n-Paraffin Formation Results

Garden Banks 426 Well A-14 - Stock Tank Oil

Marathon Centrifugation at 15 psia and 45°F

Cloud Point = 94°F (Cloud - Test Temp. = 49°F)

Percent Solids = 5.5

Percent n-C21+ in Solids = 16.4

Percent of Dead Oil that is solid n-C22+ at 45°F = .89 by solids analysis

Percent of Dead Oil that is solid n-C22+ at 45°F = .46 by oil difference

Table 3.2.24

**Recombined Condensate
Bulk Deposition Summary Data
(@ 8000 psia, 25°F)**

**Initial Charge of Recombined Condensate
(@ 8500 psia, 140°F)**

Mass:	46.35 g
Density:	0.515 g/cm ³
Volume:	90 cm ³

Reduce Temperature to 25°F and Equilibrate at 8000 psia

Liquid Phase:

Mass:	45.96 g
Density:	0.57 g/cm ³
Volume:	80.63 cm ³

Solid Phase:

Mass:	0.39 g
Density:	0.842 g/cm ³
Volume:	0.46 cm ³
Thermal Conductivity:	0.22 W/m.K 1.5 Btu/[(h.ft ²)(°F/in)]

??? Solid Precipitated @ 8000 psia, 25°F: 0.8%

Table 3.2.25
Recombined Condensate - Bulk Deposition:
Liquid Composition @ 8000 psia, 25°F

COMPONENT	MW	GAS		LIQUID OVERALL		GROUP	
		MOLE %	WT %	WT %	MOLE %	MOLE %	
CO2	44.01	0.127	0	0.112	0.11	0.11	
H2S	34.08	0	0	0	0	0	
N2	28.01	0.234	0	0.132	0.202	0.202	
C1	16.04	82.706	0	26.61	71.394	71.394	
C2	30.07	6.746	0	4.068	5.824	5.824	
C3	44.1	3.927	0.092	3.525	3.441	3.441	
I-C4	58.12	1.007	0.082	1.22	0.903	0.903	
N-C4	58.12	1.82	0.276	2.277	1.686	1.686	
I-C5	72.15	0.801	0.382	1.375	0.82	0.82	
N-C5	72.15	0.88	0.632	1.63	0.973	0.973	
C6	85	0.874	2.796	3.09	1.543		
MCYC-C5	84.16	0.081	0.352	0.336	0.172		
BENZENE	78.11	0.006	0.087	0.058	0.032		
CYCL-C6	82.15	0.065	0.51	0.395	0.207	1.954	
C7	99	0.349	4.15	3.045	1.308		
MCYCL-C6	98.19	0.005	1.202	0.688	0.302		
TOLUENE	92.14	0.034	0.1	0.119	0.056		
C8	113	0.167	6.252	3.914	1.475		
C2-BENZENE	106.17	0.006	0.071	0.054	0.022		
M&P-XYLENE	106.17	0.006	0.479	0.282	0.114		
O-XYLENE	106.17	0.013	0.056	0.06	0.024		
C9	128.3	0.047	6.497	3.79	1.272	4.572	
C10	134	0.034	6.676	3.861	1.24		
C11	147	0.018	5.638	3.237	0.948		
C12	161	0.02	4.998	2.886	0.772		
C13	175	0.017	4.907	2.832	0.697		
C14	190	0.006	4.494	2.561	0.58	4.236	
C15	206	0.004	4.307	2.448	0.511	3.884	
C16	222	0	3.868	2.185	0.424		
C17	237	0	3.543	2.001	0.363		
C18	251	0	3.407	1.924	0.33		
C19	263	0	3.202	1.809	0.296	1.924	
C20	275	0	2.872	1.622	0.254		
C21	291	0	2.538	1.433	0.212		
C22	305	0	2.43	1.372	0.194		
C23	318	0	2.196	1.24	0.168		
C24	331	0	1.993	1.126	0.146		
C25	345	0	1.885	1.064	0.133		
C26	359	0	1.653	0.933	0.112		
C27	374	0	1.618	0.914	0.105		
C28	388	0	1.582	0.894	0.099		
C29	402	0	1.408	0.795	0.085	1.508	
C30+	580	0	10.77	6.083	0.451	0.451	

MW= 21.7 177.7 43
DENSITY= 0.57 g/cm3 at 25°F & 8000 psia
VT. GAS/ WT. SAMPLE= 0.435
GOR @ STD 704.8 (M3/M3) 3957.3 (SCF/BBL)

Table 3.2.26
Recombined Condensate - Bulk Deposition:
Filtered Solid Composition @ 8000 psia, 25°F

CarbonNumber	Mol. Weight	n-Paraffin(wt%)	non n- Paraffin (wt%)	CarbonNumber	Mol. Weight	n-Paraffin(wt%)	non n- Paraffin (wt%)
C10	134	0.339	0.452	C44	545	0.14	0.208
C11	147	1.648	2.468	C45	551	0.112	0.183
C12	161	1.993	4.283	C46	556	0.118	0.143
C13	175	2.104	5.295	C47	561	0.093	0.12
C14	190	1.942	5.22	C48	566	0.081	0.095
C15	206	1.866	4.479	C49	571	0.061	0.09
C16	222	2.046	3.346	C50	575	0.056	0.072
C17	237	1.57	3.288	C51	580	0.053	0.108
C18	251	1.378	3.22	C52	584	0.041	0
C19	263	1.477	2.732	C53	588	0.036	0.065
C20	275	1.133	2.491	C54	592	0.058	0
C21	291	1.08	2.071	C55	596	0.035	0
C22	305	1.232	1.65	C56	600	0.034	0
C23	318	1.108	1.239	C57	604	0.013	0
C24	331	1.331	1.409	C58	608	0.021	0.005
C25	345	1.694	1.726	C59	612	0.008	0
C26	359	2.174	1.002	C60	615	0.015	0
C27	374	2.31	0.961	C61	619	0.003	0
C28	388	2.262	0.889	C62	622	0.011	0
C29	402	2.094	0.843	C63	626	0.002	0
C30	422	1.643	0.801	C64	629	0.006	0
C31	435	1.448	0.78	C65	632	0.004	0
C32	448	0.981	0.654				
C33	462	0.778	0.769				
C34	473	0.641	0.714				
C35	485	0.572	0.636				
C36	493	0.497	0.598				
C37	501	0.43	0.529				
C38	509	0.366	0.473				
C39	516	0.306	0.427				
C40	522	0.261	0.357				
C41	528	0.221	0.314				
C42	534	0.196	0.272				
C43	540	0.157	0.249				
				Totals:		42.275	57.725

Table 3.2.27

**Recombined Condensate
Bulk Deposition Summary Data
(@ 4000 psia, 24°F)**

**Initial Charge of Recombined Condensate
(@ 8500 psia, 140°F)**

Mass: 46.34 g
Density: 0.515 g/cm³
Volume: 89.98 cm³

Reduce Temperature to 24°F and Equilibrate at 4000 psia

Liquid Phase:

Mass: 33.88 g
Density: 0.71 g/cm³
Volume: 47.72 cm³

Vapor Phase:

Mass: 11.74 g
Density: 0.328 g/cm³
Volume: 35.8 cm³

Solid Phase: Solid Precipitated @ 4000 psia, 24°F: 1.6%

Mass: 0.72 g
Density: 0.838 g/cm³
Volume: 0.86 cm³
Thermal Conductivity: 0.23 W/m.K
1.5 Btu/[(h.ft²)(°F/in)]

Table 3.2.28
 Recombined Condensate Bulk Deposition:
 @ 4000 psia, 24°F
 Equilibrium Gas and Liquid Compositions

COMPONENT	MW	LIQUID COMPOSITION					VAPOR COMPOSITION			
		GAS MOLE %	LIQUID WT %	OVERALL WT %	GROUP MOLE %	GROUP MOLE %	WT %	MOLE %	GROUP MOLE %	
CO2	44.01	0.140	0.000	0.060	0.098	0.098	0.256	0.115	0.115	
H2S	34.08	0.000	0.000	0.000	0.000	0.000	0	0	0	
N2	28.01	0.134	0.000	0.036	0.093	0.093	0.337	0.238	0.238	
C1	16.04	76.863	0.000	11.918	53.571	53.571	70.706	87.478	87.478	
C2	30.07	8.783	0.000	2.553	6.122	6.122	8.723	5.758	5.758	
C3	44.1	5.799	0.130	2.572	4.207	4.207	6.218	2.799	2.799	
I-C4	58.12	1.517	0.117	0.943	1.170	1.170	1.85	0.632	0.632	
N-C4	58.12	2.804	0.402	1.887	2.341	2.341	2.997	1.024	1.024	
I-C5	72.15	1.094	0.559	1.195	1.194	1.194	1.408	0.387	0.387	
N-C5	72.15	1.147	0.853	1.460	1.459	1.459	1.507	0.414	0.414	
C6	85	0.913	2.761	2.898	2.425		1.844	0.425		
MCYC-C5	84.16	0.082	0.340	0.330	0.282		0.165	0.039		
BENZENE	78.11	0.006	0.103	0.084	0.078		0.016	0.004		
CYCL-C6	82.15	0.068	0.484	0.429	0.376	3.161	0.199	0.047	0.51	
C7	99	0.313	3.512	3.022	2.175		1.041	0.206		
MCYCL-C6	98.19	0.073	1.069	0.896	0.658		0.23	0.046		
TOLUENE	92.14	0.032	0.074	0.086	0.067		0.098	0.021		
C8	113	0.122	5.269	4.213	2.660		0.785	0.136		
C2-BENZENE	106.17	0.003	0.017	0.017	0.011		0.02	0.004		
M&P-XYLENE	106.17	0.019	0.648	0.521	0.354		0.074	0.014		
O-XYLENE	106.17	0.004	0.608	0.475	0.323		0.026	0.005		
C9	128.3	0.043	4.827	3.790	2.130	8.379	0.589	0.091	0.52	
C10	134	0.023	5.930	4.620	2.486		0.366	0.054		
C11	147	0.011	5.056	3.929	1.927		0.162	0.022		
C12	161	0.004	4.622	3.584	1.605		0.05	0.006		
C13	175	0.003	4.657	3.611	1.488		0.085	0.01		
C14	190	0.001	4.387	3.398	1.290	8.797	0.133	0.014	0.11	
C15	206	0.000	4.335	3.356	1.175	9.409	0.077	0.007	0.01	
C16	222	0.000	3.710	2.872	0.933		0.041	0.004		
C17	237	0.000	3.632	2.812	0.856		0	0		
C18	251	0.000	3.479	2.694	0.774		0	0		
C19	263	0.000	3.373	2.611	0.716	4.453	0	0		
C20	275	0.000	2.864	2.217	0.581		0	0		
C21	291	0.000	2.649	2.051	0.508		0	0		
C22	305	0.000	2.529	1.958	0.463		0	0		
C23	318	0.000	2.303	1.783	0.404		0	0		
C24	331	0.000	2.099	1.625	0.354		0	0		
C25	345	0.000	1.976	1.530	0.320		0	0		
C26	359	0.000	1.766	1.367	0.275		0	0		
C27	374	0.000	1.719	1.330	0.257		0	0		
C28	388	0.000	1.720	1.332	0.248		0	0		
C29	402	0.000	1.464	1.134	0.203	3.613	0	0		
C30+	580	0.000	13.955	10.803	1.343	1.343	0	0		
MW =		23.4	184.2		72.1		19.85			
DENSITY, g/cm3 =		0.71					0.328			
WT. GAS/ WT. SAMPLE =			0.226							
GOR @ STP			250 (M3/M3)	1403.4 (SCF/BBL)						

DENSITY TAKEN AT 24°F and 4,000 psia

**Table 3.2.29
Recombined Condensate - Bulk Deposition: Filtered Solid Composition @ 4000 psia, 24°F**

CarbonNumber	Mol. Weight	n-Paraffin(wt%)	non n- Paraffin(wt%)	CarbonNumber	Mol. Weight	n-Paraffin(wt%)	non n- Paraffin(wt%)
C10	134	1.542	5.169	C44	545	0.301	0.253
C11	147	2.157	4.49	C45	551	0.246	0.227
C12	161	1.909	4.488	C46	556	0.234	0.198
C13	175	1.784	4.616	C47	561	0.181	0.168
C14	190	1.594	4.289	C48	566	0.161	0.134
C15	206	1.476	3.639	C49	571	0.128	0.112
C16	222	1.624	2.696	C50	575	0.199	0.097
C17	237	1.198	2.599	C51	580	0.158	0
C18	251	1.077	2.559	C52	584	0.126	0
C19	263	1.458	2.101	C53	588	0.097	0
C20	275	0.864	1.633	C54	592	0.086	0
C21	291	0.838	1.575	C55	596	0.06	0
C22	305	0.905	1.232	C56	600	0.066	0
C23	318	0.696	0.929	C57	604	0.033	0
C24	331	0.762	1.019	C58	608	0.053	0
C25	345	1.021	0.886	C59	612	0.021	0
C26	359	1.403	0.698	C60	615	0.048	0
C27	374	1.733	0.692	C61	619	0.014	0
C28	388	2.057	0.644	C62	622	0.036	0
C29	402	2.282	0.598	C63	626	0.012	0
C30	422	2.158	0.562	C64	629	0.028	0
C31	435	2.191	0.548	C65	632	0.004	0
C32	448	1.775	0.463	C66	636	0.017	0.006
C33	462	1.49	0.59	C67	639	0.004	0
C34	473	1.259	0.595	C68	642	0.013	0
C35	485	1.101	0.566	C69	646	0.007	0
C36	493	0.956	0.56				
C37	501	0.841	0.509				
C38	509	0.736	0.48				
C39	516	0.602	0.453				
C40	522	0.542	0.394				
C41	528	0.449	0.358				
C42	534	0.419	0.316				
C43	540	0.338	0.288				
				Totals:		45.568	54.432

Figure 3.2.1

Garden Banks 426 Well A-14
Viscosity Data for Recombined Condensate

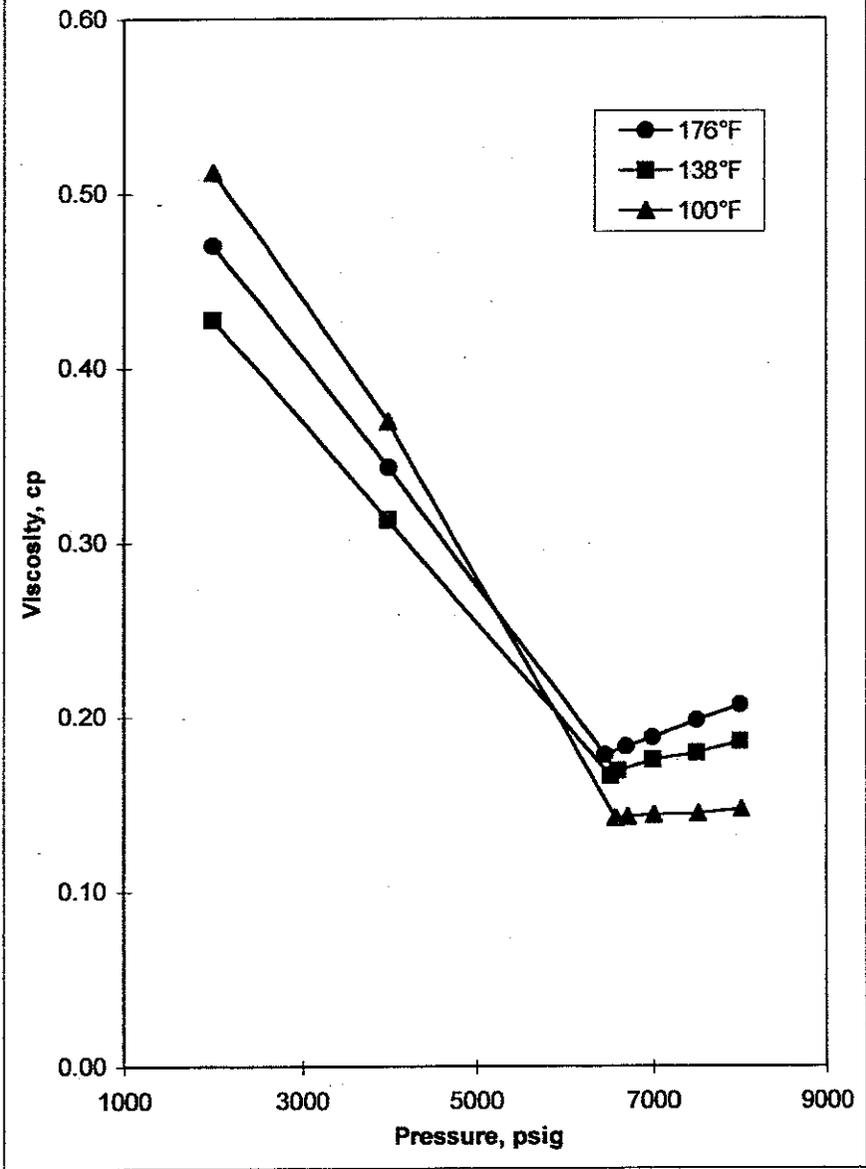


Figure 3.2.2
Garden Banks 426 Well A-14
Density Data for Recombined Condensate

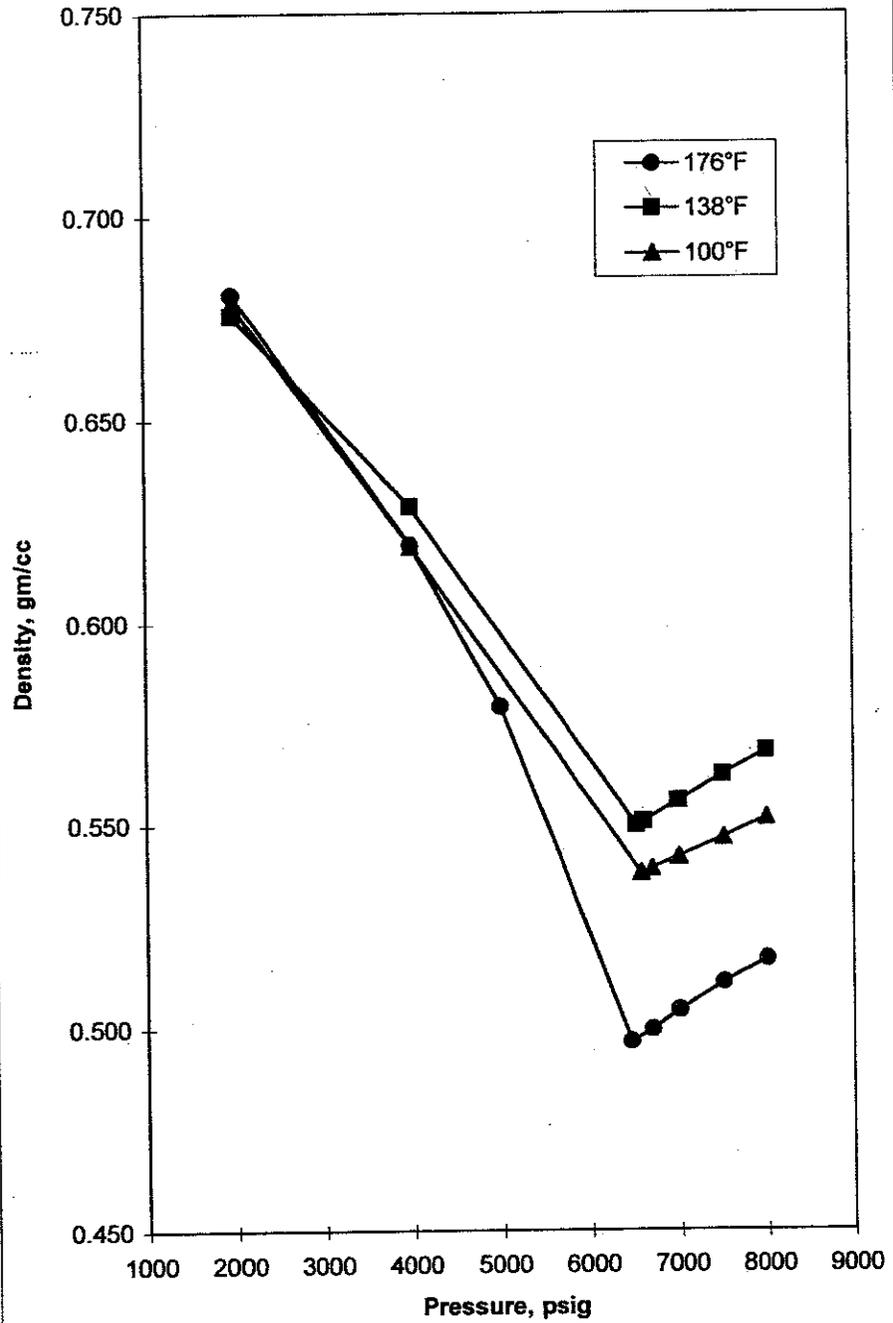


Figure 3.2.3
Garden Banks 426 Well A-14
Liquid Volume Percent for Recombined
Condensate

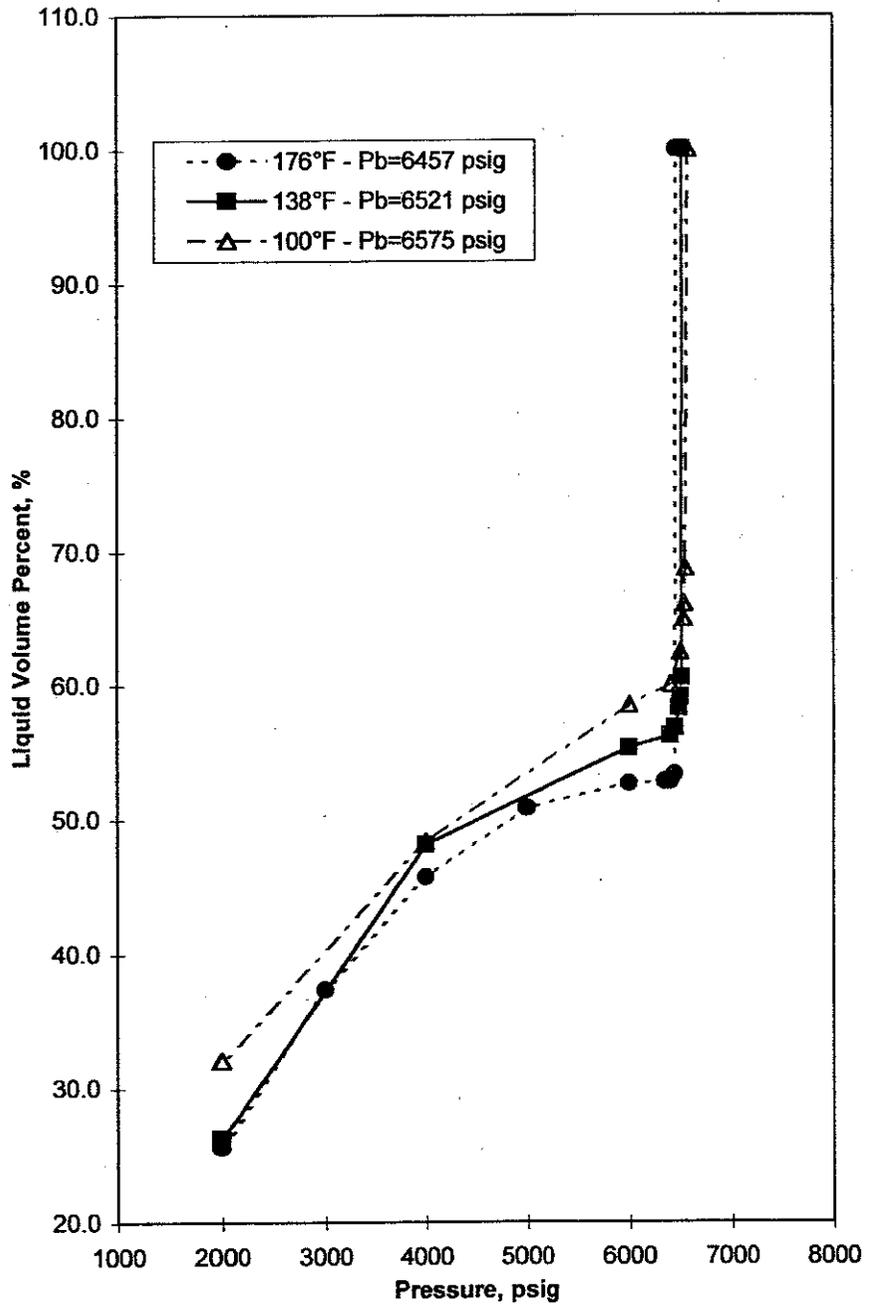


Figure 3.2.4
Garden Banks 426 Well A-14
Relative Volume Data for Recombined Condensate

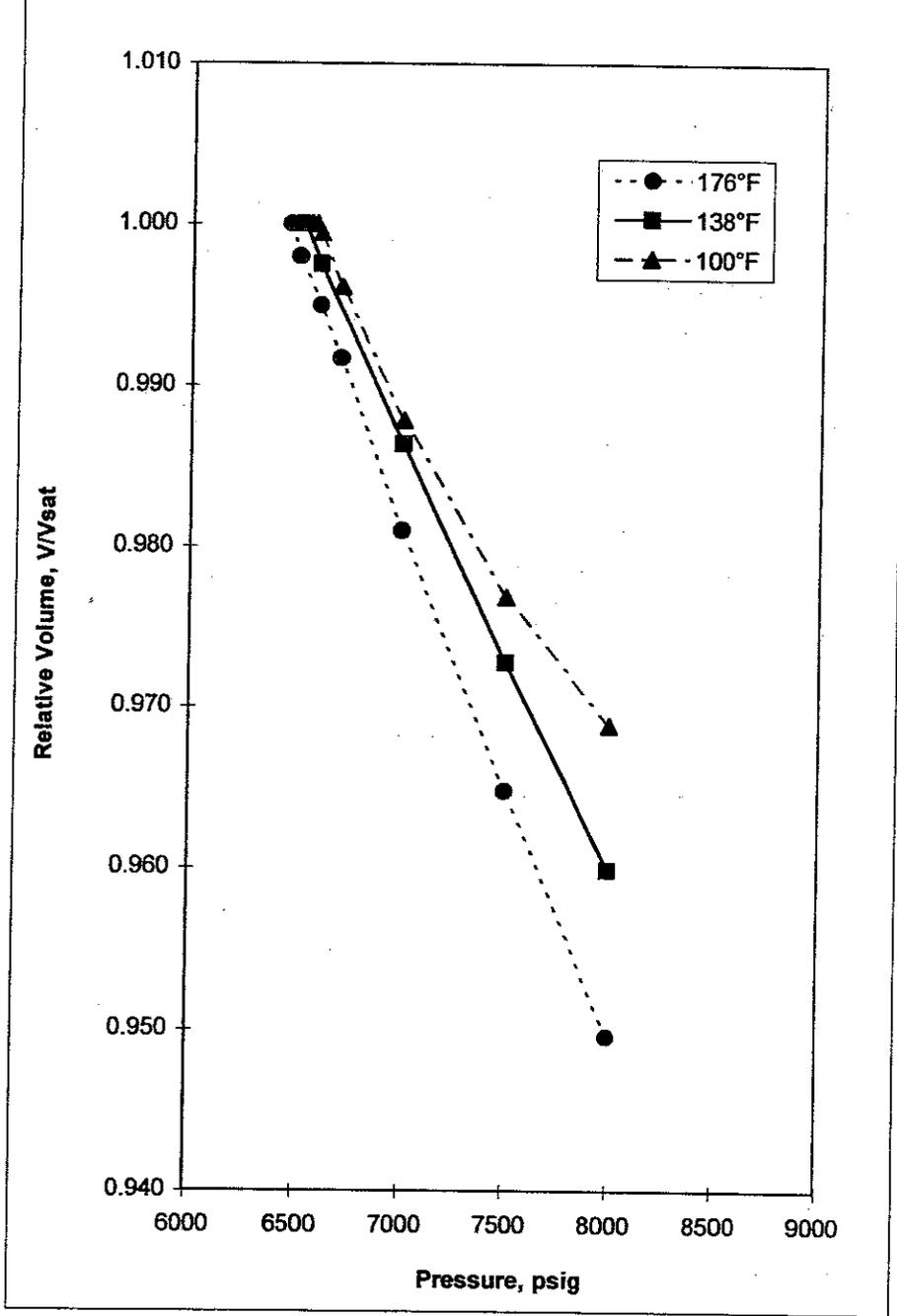


Figure 3.2.7
Garden Banks 426 Stock Tank Oil and City of Tulsa Gas
Liquid Volume Percent for Flow Loop Condensate

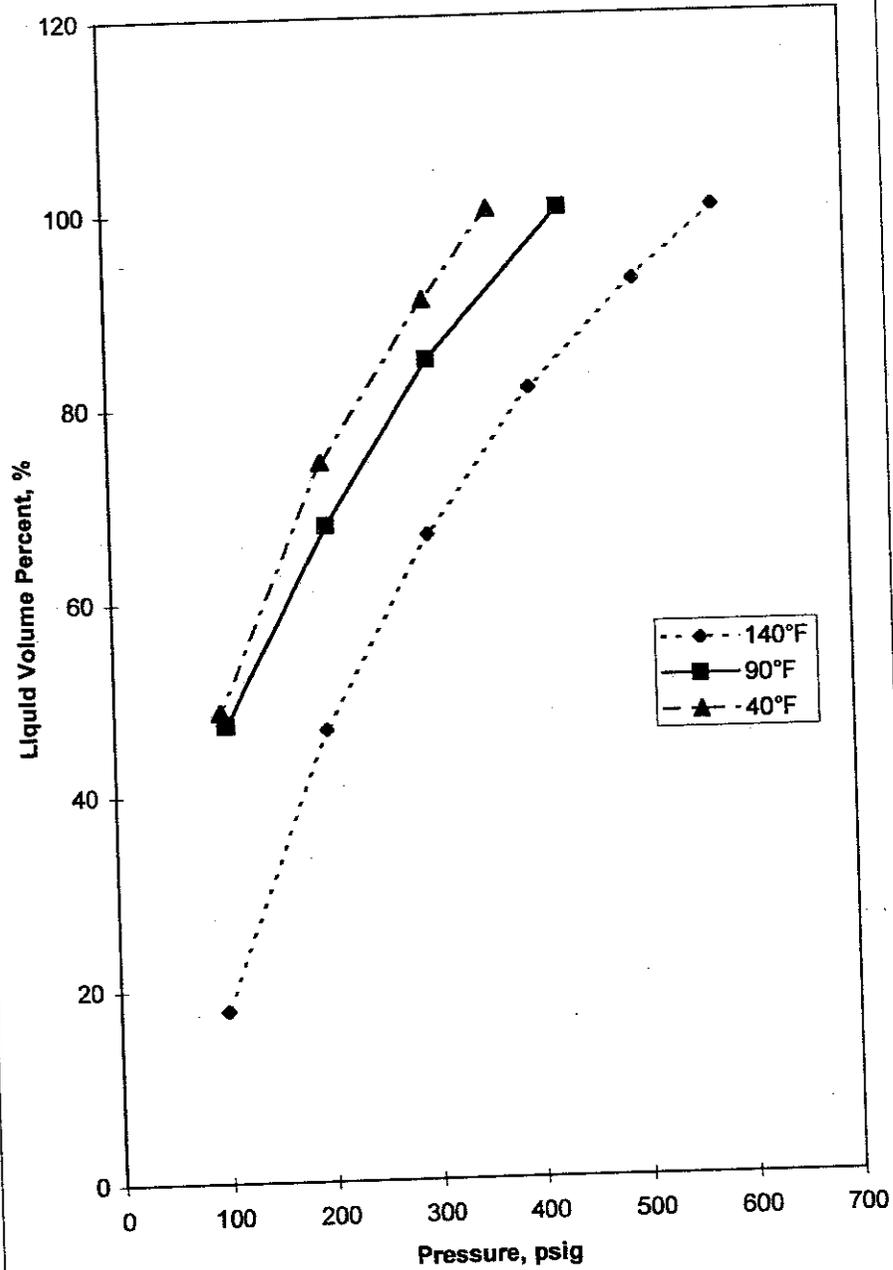


Figure 3.2.8
Garden Banks 426 Stock Tank Oil and City of Tulsa Gas
Relative Volume Data for Flow Loop Condensate

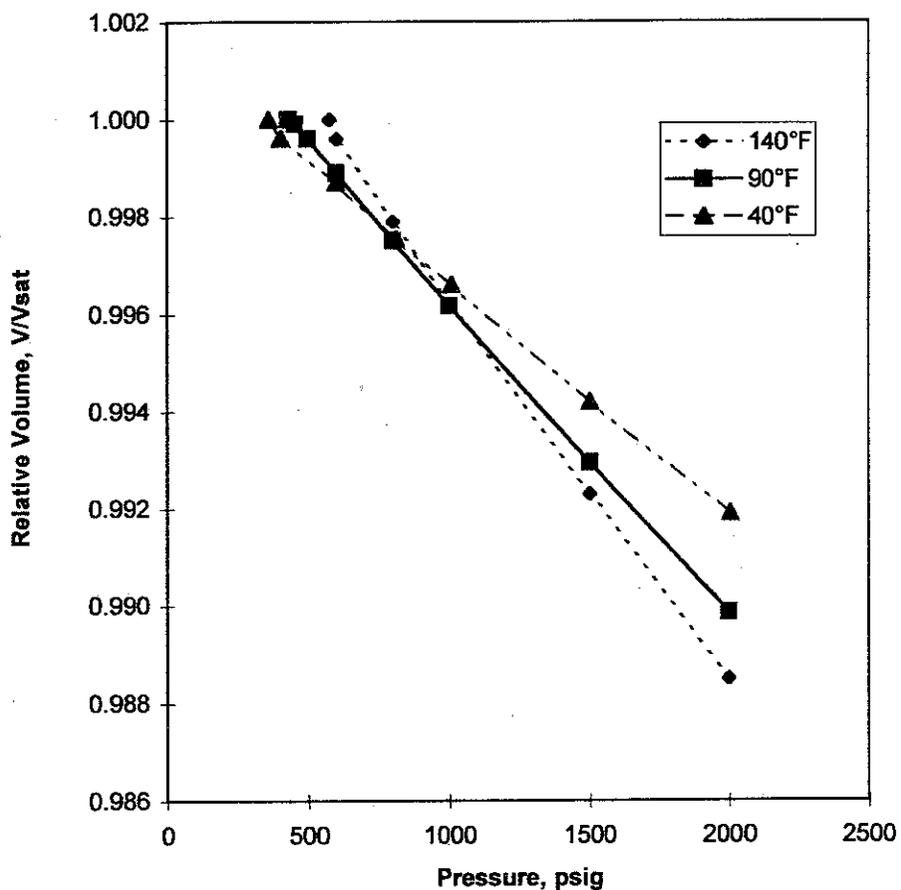


Figure 3.2.9
 Garden Banks 426 Well A14
 Cloud Point Data

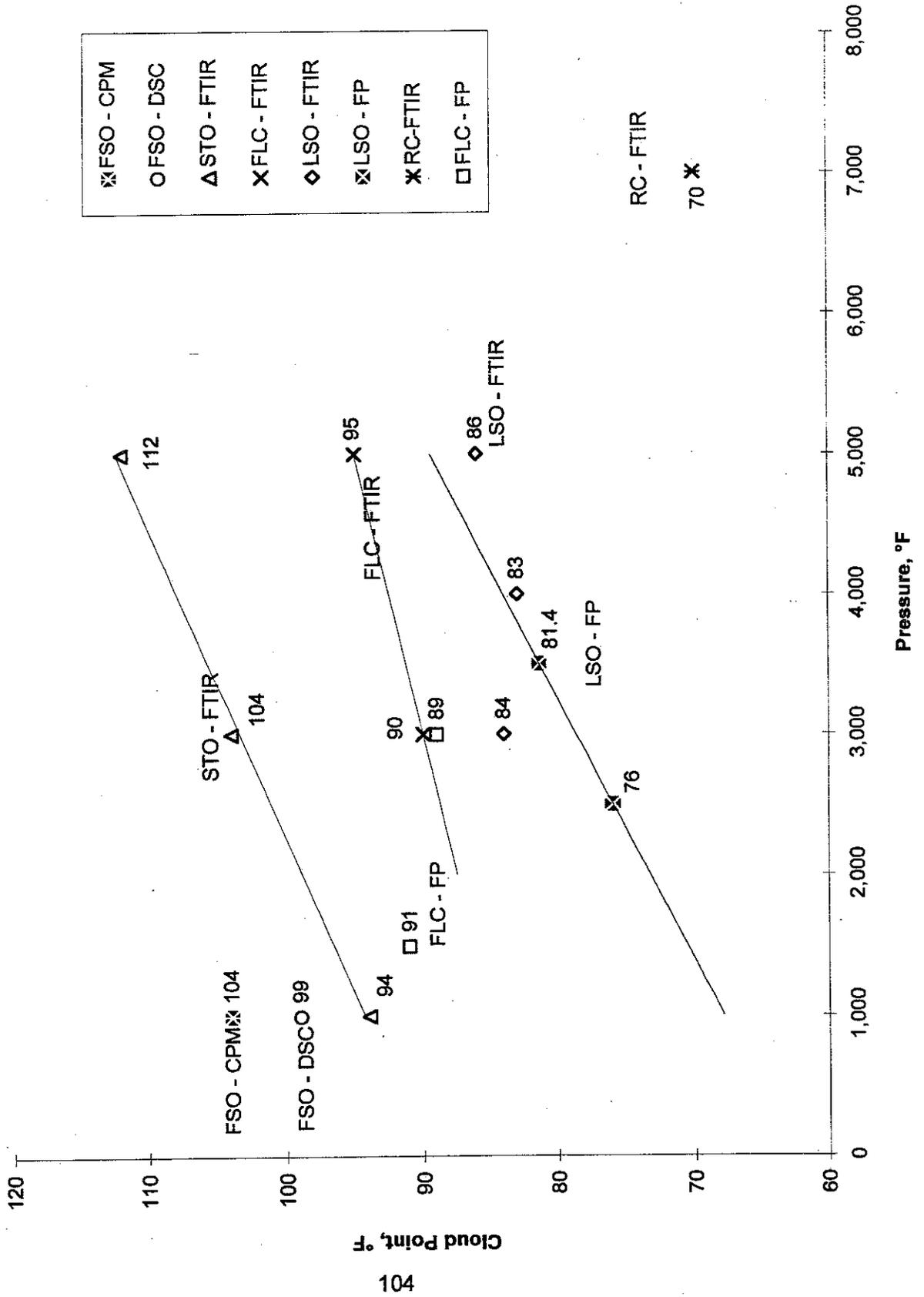
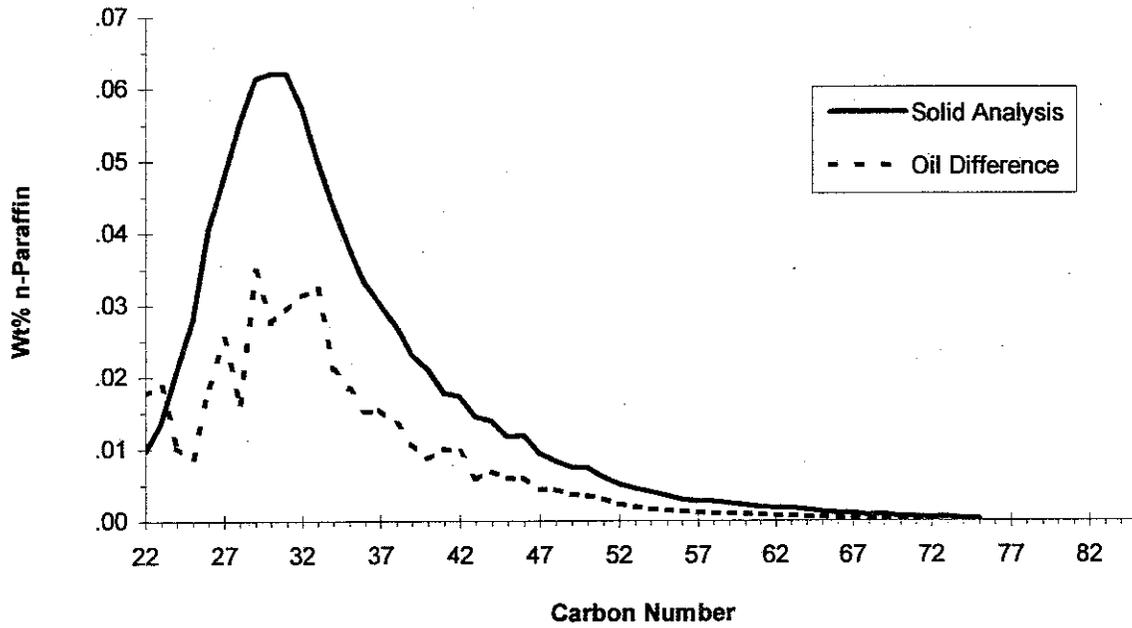


Figure 3.2.10

**Solid Composition Data
Centrifugation Test - Garden Banks 426 Well A-14**



Appendix 3.3: Main Pass 299 Well B-4 Fluid Characterization and Property Evaluation Study

3.3. Oil 2 – Main Pass 299

On March 11, 1996, Weatherly Laboratories sampled Chevron's Main Pass 299 Well No. B-4 to be used for The University of Tulsa's JIP Recombined Oil No. 2. Duplicate samples were collected resulting in a total of five separator gas samples and two separator oil samples. These samples, plus a five gallon can of stock tank oil, arrived at Marathon Oil Company's Petroleum Technology Center (PTC) on March 20, 1996.

3.3.1. Separator Samples

Table 3.3.1 reports the separator samples collected from well B-4 at Chevron's Main Pass 299 field. The separator conditions and a log of samples collected are given in Table 3.3.1.

Table 3.3.2 reports the stock tank gravity of all samples studied including those from Main Pass.

The separator gas and liquid samples were analyzed in the same fashion as the other fluids studied as part of this project. The compositional analyses of the separator gases and liquids are given in Tables 3.3.3 and 3.3.4. The usual quality checks were applied and the analyses found satisfactory.

3.3.2. Recombination

The samples were recombined per a gas-oil ratio provided by Chevron. The compositional analysis of the recombined reservoir fluid compared with the computed compositional analysis is given in Table 3.3.5. The fluid was reported to have a bubble point pressure of 998 psia at 165°F.

3.3.3. Constant Composition Expansion (CCE) Studies

The CCE studies for all fluids began with the fluids conditioned at reservoir temperature.

Tables 3.3.6 and 3.3.7 contain the CCE data at 165°F and 125°F respectively. As the CCE proceeded, fluid was also charged from the recombination cylinder to the Paar-Mettler densitometer and the capillary coil viscometer, both at temperature of the test. Single-phase density and viscosity measurements were taken at various pressures.

A portion of Recombined Oil 2 (Main Pass 299 well B-4) was conditioned at 1,500 psig and 165°F. The aliquot was charged into a high-pressure visual PVT cell at 40°F. The fluid was then subjected to a Constant Composition Expansion (CCE). During this expansion a bubble point pressure of 716 psia was observed.

As the CCE proceeded, fluid was also charged from the recombination cylinder to the Paar-Mettler densitometer and the capillary coil viscometer, both at 40°F. Single-phase density and viscosity measurements were taken at various pressures.

The fluid in the PVT cell was expanded down to approximately 500 psia. At 491 psia, some equilibrated gas was pumped off to the densitometer, then all remaining gas was pumped out of the PVT cell until the 491 psia equilibrated oil was all that remained in the cell. The oil phase was then pumped to the densitometer and the viscometer, while maintaining constant

temperature and pressure.

Another sample of conditioned Recombined Oil 2 was charged to the PVT cell. The bubble point of this fluid was verified, then property data at the intermediate pressure of 604 psia was obtained.

CCE, density, and viscosity data are presented in Table 3.3.8. All oil densities and viscosities denoted by an asterisk were measured. The oil density and viscosity at the bubble point pressure was linearly interpolated from the measured single-phase oil values.

Viscosity and density data for the stock tank oil are given in Table 3.3.9.

3.3.4. Cloud Point Determinations

Cloud points or wax appearance temperatures (WAT) were determined for Main Pass using the Fourier Transform Infrared Spectroscopy (FTIR) and Filter Plugging (FP) techniques. These data are given in Table 3.3.10 and plotted in Figure 3.3.1. Data were collected from dead stock tank oil (STO), ambient flashed separator oil (FSO), and recombined reservoir fluid (RRF) at several different pressures.

Both STO and FSO samples were tested because of concern that the stock tank oil might have lost some heavy n-paraffins during handling. Trend lines are shown for each sample type. At 1,000 psig, the FSO and STO samples have very similar cloud points. However, at 3,000 and 6,000 psig, the STO cloud points appears to be significantly lower than the FSO cloud points.

As expected the RRF sample has lower cloud points than the dead oil samples. The change in cloud point with pressure is less for Main Pass than it was for South Pelto, which is consistent with the lower gas-oil ratio (GOR) of the Main Pass Fluid.

3.3.5. Wax Dissolution Determinations

Wax dissolution temperatures (WDT), the temperature when all of the wax dissolves as the sample is heated, were measured using the FTIR technique. Some WDT values were also measured by the filter plugging technique. For the dead oil samples, WDT values by FTIR and filter plugging agreed. However, for the RRF sample, the filter plugging WDT was much higher than the FTIR value (Table 3.3.10).

3.3.6. Density and Viscosity Determinations

The densities of the stock tank oil for Recombined Oil 1 and Recombined Oil 2 were measured as a function of temperature. This data is provided in Table 3.3.9.

Viscosity measurements were made using the Rheometrics Fluid Spectrometer at temperatures of 40, 50, 60, 70, and 80°F at four to six different shear rates. Table 3.3.9 indicates that Main Pass 299 Well B-4 is Newtonian at all temperatures but there is an indication of wax precipitation at lower temperatures.

3.3.7. Solid Wax Determinations

Solid wax determinations were made on the stock tank oil using the flashed separator oil samples from Main Pass 299. The STO was sampled at 140°F and then spun at 29,000 rpm for 5 hours at 140°F and then slowly cooled to 45°F while spinning.

The bottoms were isolated, weighed and sent to Nenniger Engineering for high

temperature gas chromatographic analysis. The original oil and the oil top layer from the centrifugation were also sent for gas chromatographic analyses. A summary of the experimental data is given in Table 3.3.11.

After carefully decanting and blotting the excess oil from the centrifuge tube, 5.5 weight % of bottoms remained. A small portion looked like clay, but no attempt was made to identify or quantify this material. Nenniger found that the bottoms contained 16.4 weight % C_{22+} n-paraffins. This calculated to a solid n-paraffin in the condensate of 0.89%. When the weight % solid n-paraffin in the condensate was calculated from the difference of C_{22+} n-paraffins in the original condensate and the top layer from the centrifuge test, the value was 0.46%. The difference between 0.89% and 0.46% was larger than we found for the Main Pass or South Pelto oils. We do not know the cause of this difference, nor which value is correct. The "oil difference" value of 0.46% should be less affected by the presence of clay or water in the sample. The condensate only contained 0.5% water, so this should not have caused the problem. A plot of the n-paraffin distribution data from the two different techniques is shown in Figure 3.32. It is interesting to note that the two curves are superimposable when the "oil difference" values are multiplied by two and compared to the "solid analysis" values.

There was 5.05 weight percent of C_{17+} n-paraffins in the FSO before cooling and 4.6 weight percent after cooling. The analyses are reported in Tables 3.3.11 and 3.3.12. Paraffins were observed up to C_{86} , in the "before cooling" sample and only C_{38} in the after cooling sample. Nenniger was unable to track the n-paraffins down to the 1 ppm sensitivity threshold in the "after cooling" sample due to interference from other species present in the oil.

The n-paraffin content of the FSO #2 solids after cooling was 8.0 weight percent. The analysis is reported in Table 3.3.13. The solids showed enrichment of C_{21} through C_{77} . Paraffins below C_{21} were not reported because they are due to entrained oil in the sample. The solids show a maximum at C_{29} . If no oil/solvent was present, the deposit has a predicted melting point of 72°C.

Figure 3.3.2 compares the material balance of the original oil with the deposit and depleted oil. Figure 3.3.3 shows the difference in compositional profiles between the solid analysis and the original oil.

Appendix III: Main Pass

Index of Tables and Figures

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- 3.3.5 Main Pass 299 Well B-4 Hydrocarbon Analysis of Recombined Oil 2
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Figures

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- 3.3.3 Nenniger Solid and Oil Analysis

Table 3.3.1

**Main Pass 299 Well B-4
Sample Summary**

<u>Cylinder Number</u>	<u>Separator Gas</u>		<u>Laboratory Opening Pressure</u>	
	<u>Separator Conditions</u>		<u>Laboratory Opening Pressure</u>	
	<u>Pressure (psig)</u>	<u>Temperature (°F)</u>	<u>Pressure (psig)</u>	<u>Temperature (°F)</u>
WL-205	64	61	65	69
WL-251 *	64	61	62	69
WL-253	64	61	69	70
WL-275	64	61	71	69
WL-291	64	61	62	70

<u>Cylinder Number</u>	<u>Separator Liquid</u>		<u>Laboratory Bubble Point Conditions</u>	
	<u>Separator Conditions</u>		<u>Laboratory Bubble Point Conditions</u>	
	<u>Pressure (psig)</u>	<u>Temperature (°F)</u>	<u>Pressure (psig)</u>	<u>Temperature (°F)</u>
WL-204	64	61	65	72
WL-207 *	64	61	77	72

* Samples selected for recombination.

Table 3.3.2

Stock Tank Oil API Gravities
for all measured Oil Compositions

No.	Description	°API
1	South Pelto 10 Well 9-2 Separator Oil - Cylinder No. WL-170	35.2
2	South Pelto 10 Well 9-2 Separator Oil - Cylinder No. WL-183	34.9
3	South Pelto 10 Well 9-2 Separator Oil - Cylinder No. WL-286	34.9
4	South Pelto 10 Well 9-2 Separator Oil - Cylinder No. WL-308	34.9
5	South Pelto 10 Well 9-2 Recombined Oil 1	34.3
6	South Pelto 10 Well 9-2 Recombined Oil 1 - 182 GOR Mix	34.6
7	Main Pass 299 Well B-4 Separator Oil - Cylinder No. WL-204	40.0
8	Main Pass 299 Well B-4 Separator Oil - Cylinder No. WL-207	40.1
9	Main Pass 299 Well B-4 Recombined Oil 2	39.5
10	South Pelto 10 Well 9-2 Recombined Flow Loop Oil	33.9
11	Flow Loop Oil - Equilibrium Oil at 97 psia and 140°F	34.0
12	Flow Loop Oil - Equilibrium Oil at 97 psia and 90°F	34.0
13	Flow Loop Oil - Equilibrium Oil at 97 psia and 40°F	n/a
14	Garden Banks 426 Well A-14 Separator Oil - Cylinder No. WL-379	41.6
15	Garden Banks 426 Well A-14 Recombined Condensate	39.1
16	Garden Banks 426 Well A-14 Flow Loop Condensate	41.2
17	Flow Loop Condensate - Equilibrium Oil at 200 psig and 140°F	41.6
18	Flow Loop Condensate - Equilibrium Oil at 200 psig and 90°F	41.4
19	Flow Loop Condensate - Equilibrium Oil at 200 psig and 40°F	41.5

Table 3.3.3

**Main Pass 299 Well B-4
Separator Gas Compositions**

<u>Component</u>	<u>WL-205 Mol %</u>	<u>WL-251 Mol %</u>	<u>WL-253 Mol %</u>	<u>WL-275 Mol %</u>	<u>WL-291 Mol %</u>
H2S	0.00	0.00	0.00	0.00	0.00
N2	0.75	0.76	0.76	0.76	0.76
CO2	0.11	0.12	0.13	0.12	0.12
C1	91.12	91.12	90.91	91.02	91.15
C2	4.03	4.01	4.05	4.01	4.01
C3	1.93	1.94	1.98	1.90	1.94
iC4	0.49	0.49	0.51	0.48	0.49
nC4	0.67	0.67	0.70	0.65	0.67
iC5	0.27	0.26	0.28	0.26	0.26
nC5	0.19	0.19	0.21	0.18	0.19
C6	0.19	0.19	0.21	0.21	0.19
C7	0.15	0.15	0.17	0.14	0.14
C8	0.07	0.07	0.08	0.09	0.07
C9	0.02	0.01	0.02	0.05	0.02
C10	0.01	0.01	0.01	0.03	0.01
C11	0.00	0.00	0.00	0.01	0.00
C12+	<u>0.00</u>	<u>0.01</u>	<u>0.00</u>	<u>0.08</u>	<u>0.01</u>
	100.00	100.00	100.00	100.00	100.00

Hydrocarbon Properties

Mol Weight	18.46	18.47	18.56	18.64	18.45
Gas Gravity	0.637	0.638	0.641	0.644	0.637
GPM Value	2.331	2.330	2.397	2.398	2.32
Z Factor at separator conditions	0.986	0.986	0.986	0.986	0.986
BTU Content per dry gas at 14.73 psia and 60°F	1121.4	1121.6	1126.3	1130.6	1120.7

Table 3.3.4

**Main Pass 299 Well B-4
Separator Liquid Compositions**

<u>Component</u>	<u>Cyl # WL204</u>		<u>Cyl # WL207</u>	
	<u>Mole Percent</u>	<u>Mass Percent</u>	<u>Mole Percent</u>	<u>Mass Percent</u>
N2	0.00	0.00	0.00	0.00
CO2	0.04	0.01	0.03	0.01
C1	2.63	0.24	3.03	0.28
C2	0.65	0.11	1.03	0.18
C3	0.78	0.20	0.82	0.20
iC4	0.43	0.14	0.42	0.14
nC4	0.87	0.29	0.84	0.28
iC5	0.86	0.35	0.80	0.33
nC5	1.78	0.73	1.79	0.73
C6	2.06	0.98	1.92	0.91
C7	10.97	5.98	10.16	5.53
C8	12.18	7.39	11.80	7.16
C9	9.73	6.68	9.50	6.52
C10	7.27	5.53	8.30	6.31
C11	7.06	5.89	6.41	5.34
C12	5.68	5.19	5.67	5.18
C13	5.22	5.19	5.13	5.09
C14	3.66	3.94	4.22	4.55
C15	3.96	4.63	4.02	4.70
C16	3.43	4.32	3.27	4.12
C17	2.69	3.62	2.71	3.65
C18	2.44	3.48	2.42	3.44
C19	2.22	3.31	2.19	3.27
C20	1.85	2.88	1.83	2.86
C21	1.47	2.43	1.52	2.50
C22	1.32	2.29	1.27	2.19
C23	1.15	2.07	1.19	2.14
C24	0.95	1.79	0.96	1.81
C25	0.88	1.73	0.92	1.79
C26	0.77	1.57	0.78	1.59
C27	0.67	1.41	0.67	1.43
C28	0.58	1.27	0.60	1.32
C29	0.58	1.31	0.57	1.29
C30+	3.20	13.07	3.22	13.17
	<u>100.00</u>	<u>100.00</u>	<u>100.00</u>	<u>100.00</u>

Properties of Hydrocarbon Fractions

C7+ Fraction	89.92	96.96	89.32	96.95
C11+ Fraction	49.76	71.38	49.56	71.42
C15+ Fraction	28.15	51.18	28.14	51.26
C20+ Fraction	13.41	31.82	13.52	32.09
C30+ Fraction	3.20	13.07	3.22	13.17
Overall Mol Wt		176.2		176.3
Overall Density		0.8192		0.8188

Table 3.3.5

Main Pass 299 Well B-4
Hydrocarbon Analysis of Recombined Oil 2
Measured Composition

<u>Component</u>	<u>Mole Percent</u>	<u>Weight Percent</u>	<u>Molecular Weight</u>	<u>Specific Gravity</u>
N2	0.00	0.00	28	0.8094
CO2	0.19	0.06	44	0.8180
C1	20.43	2.35	16	0.3000
C2	1.22	0.27	30.1	0.3562
C3	1.38	0.44	44.1	0.5070
iC4	0.65	0.27	58.1	0.5629
nC4	1.05	0.44	58.1	0.5840
iC5	1.04	0.54	72.2	0.6247
nC5	2.57	1.34	72.2	0.6311
C6	2.61	1.58	84	0.7138
C7	7.49	5.18	96	0.7330
C8	9.51	7.33	107	0.7492
C9	7.78	6.78	121	0.7653
C10	6.52	6.29	134	0.7795
C11	5.03	5.32	147	0.7919
C12	4.40	5.10	161	0.8039
C13	3.82	4.81	175	0.8143
C14	3.60	4.92	190	0.8245
C15	2.89	4.29	206	0.8348
C16	2.32	3.71	222	0.8436
C17	2.09	3.58	237	0.8520
C18	1.83	3.30	251	0.8582
C19	1.48	2.81	263	0.8642
C20	1.33	2.64	275	0.8704
C21	1.10	2.30	291	0.8766
C22	0.90	1.98	305	0.8823
C23	0.84	1.93	318	0.8876
C24	0.71	1.70	331	0.8927
C25	0.68	1.69	345	0.8976
C26	0.55	1.43	359	0.9023
C27	0.51	1.36	374	0.9067
C28	0.41	1.16	388	0.9111
C29	0.42	1.22	402	0.9147
C30+	2.66	11.89	620	0.9821
	100.00	100.00		
Properties of Hydrocarbon Fractions				
C7+ Fraction	68.86	92.72	186.9	0.8337
C11+ Fraction	37.57	67.14	248.1	0.8671
C15+ Fraction	20.74	46.99	314.5	0.8951
C20+ Fraction	10.12	29.30	401.8	0.9254
C30+ Fraction	2.66	11.89	620.2	0.9821
Overall Reservoir Fluid			138.8	0.7864
Gas Oil Ratio	157.1	scf/bbl of stock tank		

Table 3.3.6

Main Pass 299 Well B-4

**Constant Composition Expansion and Property Measurements
of Recombined Oil 2 @ 165°F**

<u>Pressure (psia)</u>	<u>Relative Volume (2)</u>	<u>Liquid Volume Percent</u>	<u>Compressibility (vol/vol x10-E06)</u>	<u>Oil Density (gm/cc)</u>	<u>Gas Density (gm/cc)</u>	<u>Oil Viscosity (cp)</u>
5047	0.9646					
4034	0.9727		8.220	0.7770 *		0.927 *
2008	0.9898		8.526	0.7627 *		0.821 *
1501	0.9946		9.526	0.7592 *		0.782 *
1197	0.9981		10.659	0.7563 *		0.765 *
1096	0.9991					
998 (1)	1.0000	100.00		0.7554		0.758
944	1.0324					
893	1.0571					
842	1.0878	92.42				
741	1.1612	86.18		0.7643 *	0.1316 *	0.820 *
488	1.4998	65.85		0.7708 *	0.0284 *	0.907 *

(1) Bubble Point Pressure

(2) Relative Volume: V/V_{sat} is the total volume of fluid at the indicated pressure per volume of saturated fluid at the bubble point pressure.

* Measured Property Data

Table 3.3.7

Main Pass 299 Well B-4

**Constant Composition Expansion and Property Measurements
of Recombined Oil 2 @ 125°F**

<u>Pressure (psia)</u>	<u>Relative Volume (2)</u>	<u>Liquid Volume Percent</u>	<u>Compressibility (vol/vol x10-E06)</u>	<u>Oil Density (gm/cc)</u>	<u>Gas Density (gm/cc)</u>	<u>Oil Viscosity (cp)</u>
4034	0.9771			0.7875 *		1.164 *
3021	0.9832		6.121			1.064 *
2513	0.9864			0.7798 *		1.022 *
2008	0.9899		6.711	0.7762 *		0.906 *
1501	0.9940		8.150	0.7738 *		0.872 *
1197	0.9967		10.559	0.7722 *		0.852 *
1096	0.9978					
994	0.9991					
926	(1) 1.0000	100.00		0.7703		0.805
893	1.0125					
842	1.0376					
741	1.1011	90.84		0.7697 *	0.0343 *	0.854 *
488	1.4105	69.80		0.7779 *	0.0258 *	0.928 *

(1) Bubble Point Pressure

(2) Relative Volume: V/V_{sat} is the total volume of fluid at the indicated pressure per volume of saturated fluid at the bubble point pressure.

* Measured Property Data

Table 3.3.8

Main Pass 299 Well B-4

**Constant Composition Expansion and Property Measurements
of Recombined Oil 2 @ 40°F**

<u>Pressure (psia)</u>	<u>Relative Volume (2)</u>	<u>Liquid Volume Percent</u>	<u>Compressibility (vol/vol x10-E06)</u>	<u>Oil Density (gm/cc)</u>	<u>Gas Density (gm/cc)</u>	<u>Oil Viscosity (cp)</u>
4034	0.9855		3.842	0.8172	*	4.508 *
3021	0.9893		4.021	0.8129	*	4.158 *
2009	0.9933		4.646	0.8086	*	3.607 *
1197	0.9970		6.186	0.8042	*	3.220 *
994	0.9980					
893	0.9986					
792	0.9994					
716	(1) 1.0000	100.00		0.8027		3.050
604	1.0895	92.49		0.8053	* 0.07971 *	3.078 *
491	1.2209	82.27		0.8101	* 0.0278 *	3.489 *

(1) Bubble Point Pressure

(2) Relative Volume: V/V_{sat} is the total volume of fluid at the indicated pressure per volume of saturated fluid at the bubble point pressure.

* Measured Property Data

Table 3.3.9

**Recombined Oil 2
Main Pass 299 Well B-4**

Viscosity Data for Stock Tank Oil		Stock Tank Oil Density of	
Temperature °F	Viscosity cp	Temperature °F	Density gm/cc
40	14.8	60	0.8263
50	6.6	100	0.8103
60	4.2	122	0.8020
70	3.4	140	0.7944

Table 3.3.10

Main Pass 299 Well B-4

Summary of Wax Point Data (°F) for Recombined Oil 2

Pressure psig	RRF		FSO		STO		RRF		STO		FSO	
	WAT	WDT										
1,000	64	93	78	98	82	97						
2,000	64	90					65	111				80
3,000	64	94	84	101	75	93	66	111	75	89		91
5,000	67	95	87	101								
6,000					84	102						

FTIR = FOURIER TRANSFORM INFRARED SPECTROSCOPY (ENERGY SCATTERING)

FP= FILTER PLUGGING

RRF = RECOMBINED RESERVOIR FLUID

FSO = AMBIENT FLASHED SEPARATOR OIL

STO = DEAD STOCK TANK OIL

WAT = WAX APPEARANCE TEMPERATURE

WDT = WAX DISSOLUTION TEMPERATURE

Table 3.3.11
Main Pass 299 Recombined Reservoir Fluid
Weight Percent C17+ n-Paraffins Before Cooling

Marathon Centrifugation at 15 psia and 40°F
 Cloud Point = 75°F (Cloud - Test Temp. = 35°F)
 Percent Solids = 12.0
 Percent n-C21+ in Solids = 8.0
 Percent of Dead Oil that is solid n-C21+ at 40°F = .96 by solids analysis
 Percent of Dead Oil that is solid n-C21+ at 40°F = .84 by oil difference

CARBON NUMBER	WEIGHT PERCENT	NORMALIZE WEIGHT %	CUMULATIVE WEIGHT %	CARBON NUMBER	WEIGHT PERCENT	NORMALIZE WEIGHT %	CUMULATIVE WEIGHT %
17	0.99816	19.75206	5.05345	51	0.00235	0.04654	0.01716
18	0.74463	14.73509	4.05529	52	0.00187	0.03709	0.01481
19	0.47335	9.36687	3.31066	53	0.00162	0.03212	0.01293
20	0.40952	8.10378	2.83731	54	0.00133	0.02633	0.01131
21	0.34491	6.82524	2.42779	55	0.00114	0.02255	0.00998
22	0.30599	6.05508	2.08288	56	0.00097	0.01921	0.00884
23	0.28025	5.54572	1.77689	57	0.00081	0.01607	0.00787
24	0.25736	5.09276	1.49664	58	0.00073	0.01442	0.00706
25	0.19259	3.81106	1.23928	59	0.00068	0.01342	0.00633
26	0.17619	3.48653	1.04669	60	0.00058	0.01156	0.00565
27	0.14667	2.90238	0.8705	61	0.00056	0.01115	0.00507
28	0.13161	2.60436	0.72383	62	0.00052	0.0103	0.0045
29	0.12433	2.4603	0.59222	63	0.00051	0.01011	0.00398
30	0.08595	1.70082	0.46789	64	0.00043	0.0086	0.00347
31	0.07422	1.4687	0.38194	65	0.00043	0.00842	0.00304
32	0.06442	1.27477	0.30772	66	0.00035	0.00685	0.00261
33	0.04999	0.98923	0.2433	67	0.00042	0.00822	0.00227
34	0.03551	0.70269	0.19331	68	0.00028	0.0055	0.00185
35	0.02609	0.51628	0.1578	69	0.00023	0.00456	0.00157
36	0.01689	0.33423	0.13171	70	0.00017	0.00339	0.00134
37	0.01458	0.28852	0.11482	71	0.0002	0.00402	0.00117
38	0.01263	0.24993	0.10024	72	0.00011	0.00216	0.00097
39	0.00895	0.17711	0.08761	73	0.00012	0.00228	0.00086
40	0.00796	0.15752	0.07866				
41	0.00667	0.13199	0.0707				
42	0.00894	0.17691	0.06403				
43	0.00607	0.12012	0.05509				
44	0.00636	0.12585	0.04902				
45	0.00511	0.10116	0.04266				
46	0.00555	0.10984	0.03754				
47	0.0041	0.08122	0.03199				
48	0.00399	0.07887	0.02789				
49	0.00318	0.06299	0.0239				
50	0.00356	0.07043	0.02072				

Table 3.3.12
Main Pass 299 Recombined Reservoir Fluid
Weight Percent C17+ n-Paraffins After Cooling

CARBON NUMBER	WEIGHT PERCENT	NORMALIZE WEIGHT %	CUMULATIVE WEIGHT %
17	1.04111	22.7189	4.58257
18	0.77303	16.86891	3.54146
19	0.49179	10.73174	2.76843
20	0.46794	10.21129	2.27664
21	0.36931	8.05901	1.8087
22	0.31481	6.86972	1.43939
23	0.28037	6.11818	1.12458
24	0.24371	5.31819	0.84421
25	0.16144	3.52291	0.6005
26	0.13521	2.95053	0.43906
27	0.09121	1.99037	0.30385
28	0.07093	1.54782	0.21264
29	0.05535	1.2079	0.14171
30	0.03554	0.77546	0.08636
31	0.02257	0.49248	0.05083
32	0.01258	0.27454	0.02826
33	0.00711	0.15521	0.01568
34	0.00382	0.08333	0.00856
35	0.00201	0.04379	0.00474
36	0.00143	0.0313	0.00274
37	0.00083	0.01801	0.0013
38	0.00048	0.01044	0.00048

Table 3.3.13
Main Pass 299 Recombined Reservoir Fluid
Weight Percent C17+ n-Paraffins In Produced Solid

CARBON NUMBER	WEIGHT PERCENT	NORMALIZE WEIGHT %	CUMULATIVE WEIGHT %	CARBON NUMBER	WEIGHT PERCENT	NORMALIZE WEIGHT %	CUMULATIVE WEIGHT %
21	0.28868	3.60974	7.99726	51	0.00859	0.10736	0.05671
22	0.33928	4.24245	7.70858	52	0.00673	0.08420	0.04812
23	0.37212	4.65309	7.36930	53	0.00541	0.06768	0.04139
24	0.44320	5.54190	6.99718	54	0.00466	0.05821	0.03598
25	0.48679	6.08696	6.55398	55	0.00369	0.04611	0.03132
26	0.56877	7.11206	6.06719	56	0.00313	0.03918	0.02763
27	0.60815	7.60448	5.49842	57	0.00295	0.03684	0.02450
28	0.63707	7.96610	4.89027	58	0.00268	0.03347	0.02155
29	0.68850	8.60920	4.25320	59	0.00270	0.03377	0.01888
30	0.62961	7.87282	3.56470	60	0.00218	0.02722	0.01618
31	0.60617	7.57972	2.93509	61	0.00223	0.02782	0.01400
32	0.51420	6.42970	2.32892	62	0.00181	0.02262	0.01177
33	0.42178	5.27406	1.81472	63	0.00184	0.02301	0.00997
34	0.31104	3.88933	1.39294	64	0.00142	0.01771	0.00813
35	0.23489	2.93713	1.08190	65	0.00141	0.01767	0.00671
36	0.15823	1.97855	0.84701	66	0.00103	0.01288	0.00530
37	0.12937	1.61768	0.68878	67	0.00129	0.01614	0.00427
38	0.09791	1.22429	0.55941	68	0.00072	0.00896	0.00298
39	0.07407	0.92619	0.46150	69	0.00062	0.00772	0.00226
40	0.06184	0.77326	0.38743	70	0.00042	0.00523	0.00164
41	0.05200	0.65022	0.32559	71	0.00041	0.00512	0.00122
42	0.03883	0.48554	0.27359	72	0.00024	0.00295	0.00081
43	0.03658	0.45741	0.23476	73	0.00021	0.00258	0.00058
44	0.03237	0.40476	0.19818	74	0.00012	0.00149	0.00037
45	0.02517	0.31476	0.16581	75	0.00011	0.00135	0.00025
46	0.02409	0.30123	0.14064				
47	0.01889	0.23618	0.11655				
48	0.01590	0.19879	0.09766				
49	0.01222	0.15286	0.08176				
50	0.01283	0.16040	0.06954				

Figure 3.3.1

Main Pass 299 Well B-4
Cloud Point Data for Recombined Oil 2

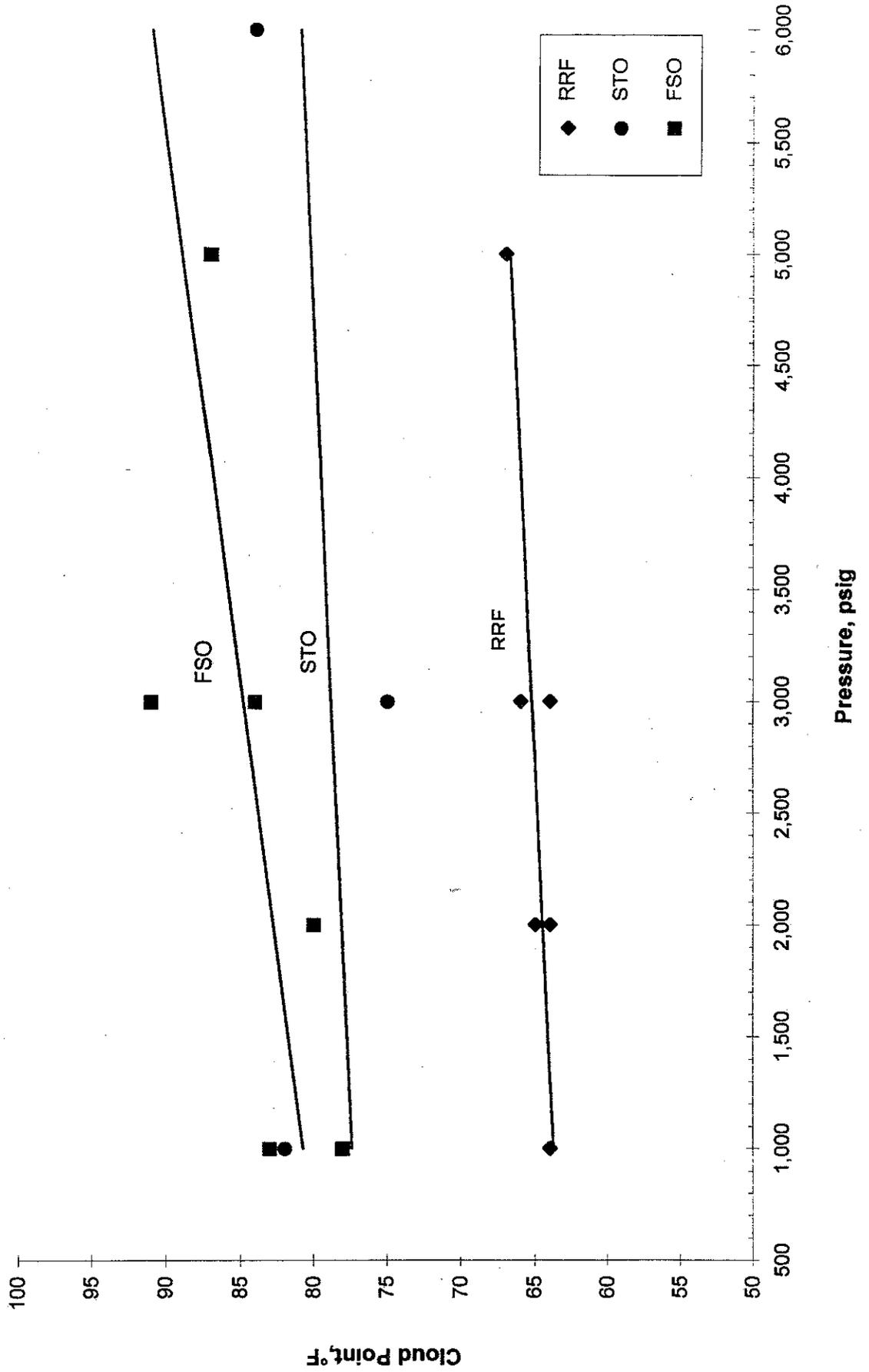


Figure 3.3.2

Main Pass 299 Well B-4
Comparison of Solids Data by Centrifugation
Flashed Separator Oil

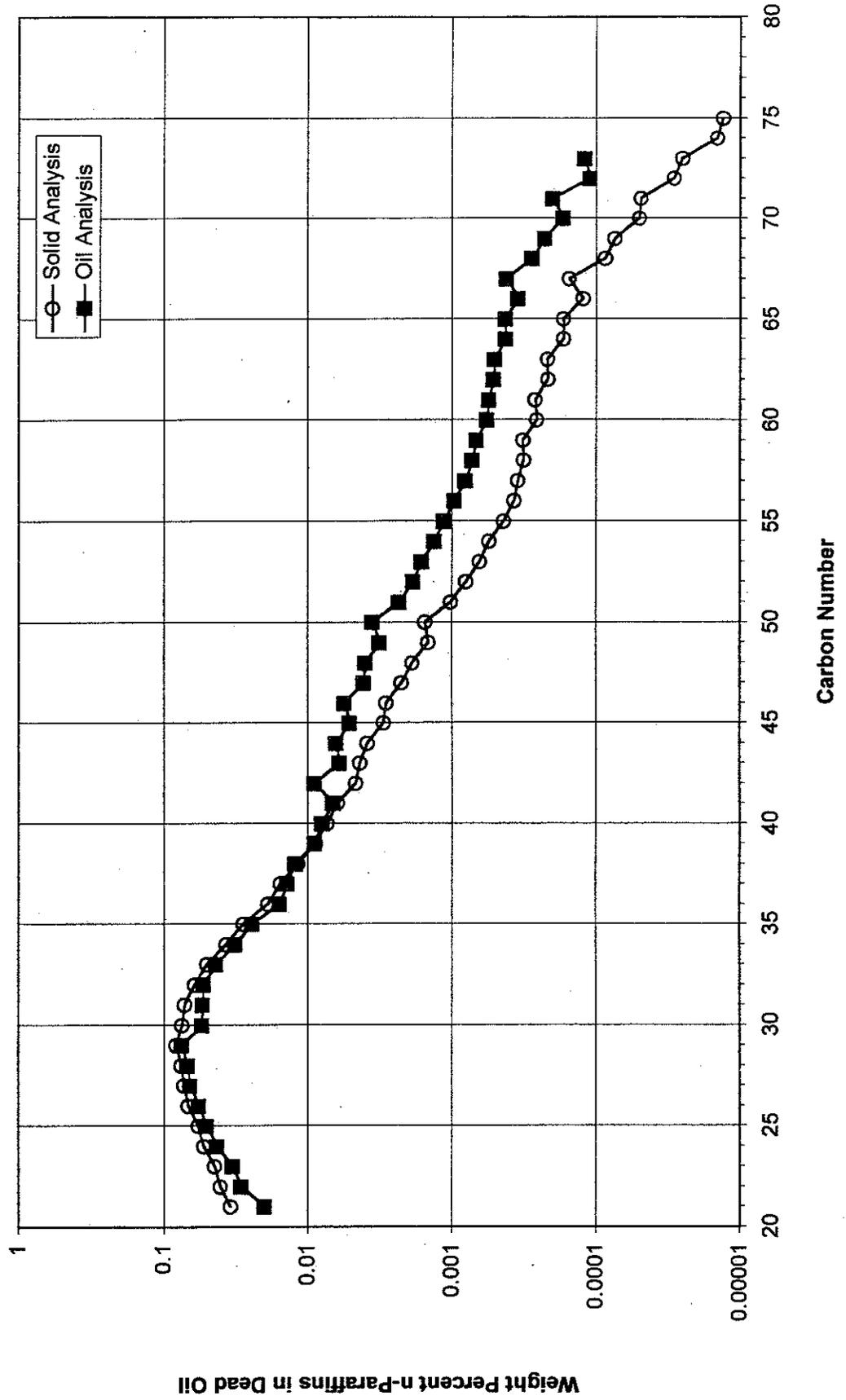
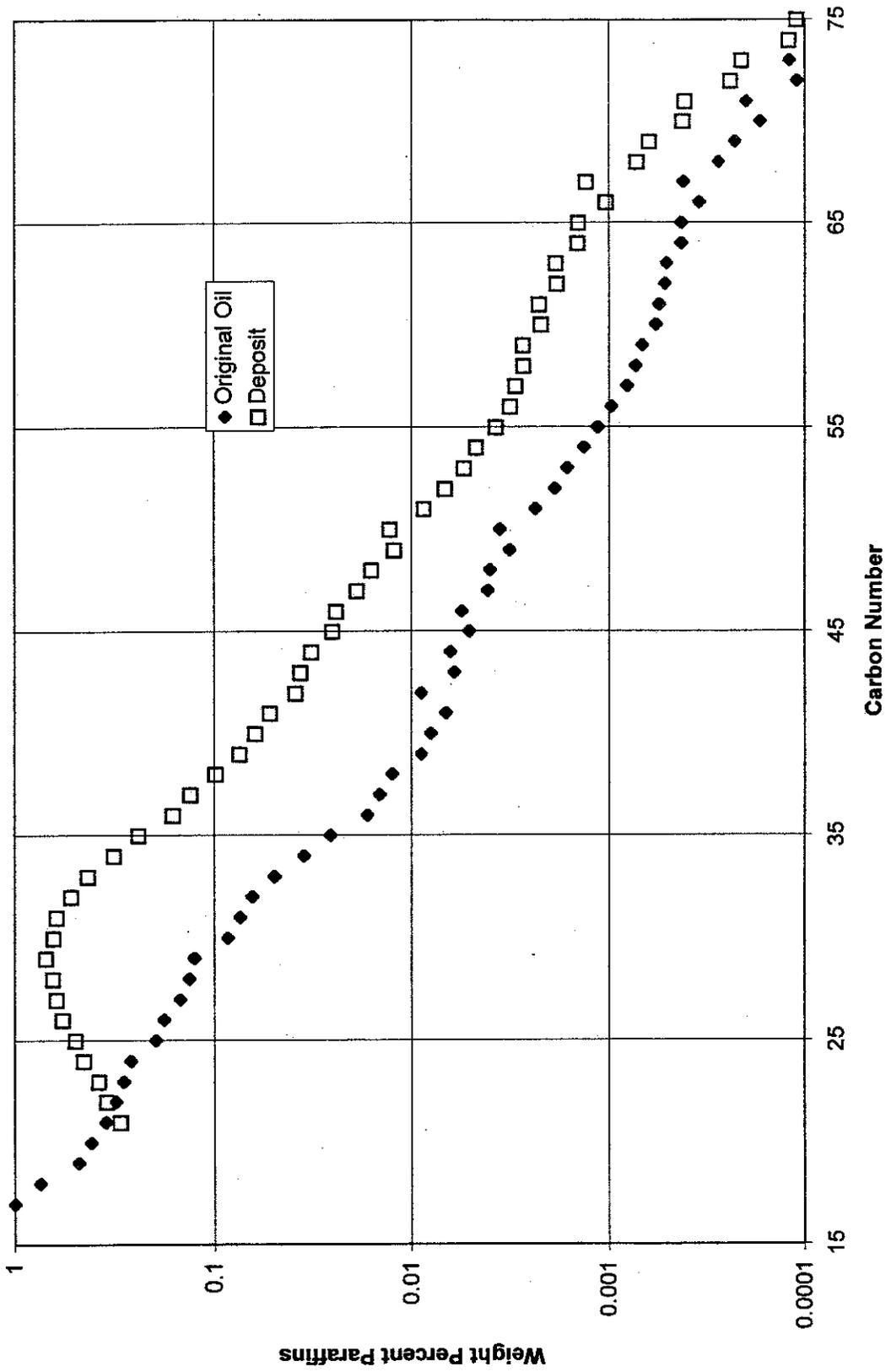


Figure 3.3.3
Nenniger Solid and Oil Analysis



**Appendix 3.4: Fluid Characterization and Property Evaluation –
Marathon Final Report – April 1997**

EXECUTIVE SUMMARY

This report and its attached Appendix present all of the data collected in response to the contract awarded to Marathon Oil Company by the University of Tulsa, Wax Joint Industry Project (JIP). These fluid characterization and property evaluation data were necessary to support the modeling and flowline studies being carried out by the JIP.

Much of this work was performed at Marathon Oil Company's Petroleum Technology Center. Data was also obtained by DB Robinson (DBR) Research Ltd. In addition, Nenniger Engineering Inc. supplied high temperature gas chromatography data.

Two black oils (South Pelto 10 Well 9-2 and Main Pass 299 Well B-4) were included in this study along with one "gas condensate" (Garden Banks 426 Well A-14). Recombinations, PVT measurements, cloud point determinations and solids studies were done by Marathon for each fluid system. DBR did some cloud point measurements and solids studies on recombined South Pelto oil and recombined Garden Banks "gas condensate." Although measurements were made under different conditions, data from Marathon and DBR were compatible. No laboratory bias was detected in the cloud point or solids formation data.

After reviewing the data and looking for trends or inconsistencies, we found the following:

Many of the PVT measurements were made above the wax cloud point, so the presence of wax crystals was not an issue. However, wax crystal effects did show up in 40°F viscosity measurements. For the Flow Loop Oil (FLO) and Flow Loop Condensate (FLC), both of which had low gas oil ratios (GOR), the capillary coil plugged so viscosity could not be measured. This was not a problem for the other fluid systems. The expected increase in viscosity due to wax crystals was observed for both black oils. Also, the change in viscosity with pressure was greater below the black oil cloud point than at higher temperatures.

Viscosity decreased with decreasing temperature for the "gas condensate." Also, the bubblepoint increased with decreasing temperature. Both effects were the opposite of observed black oil behavior.

The fluid systems characterized by this study obeyed the general correlation reported by DeepStar between stock tank oil (STO) cloud point values and the wt% C₅₀₊ n-paraffin. Using this correlation, the average STO cloud points were predicted to ±7°F.

Cloud points for the two black oils and the "gas condensate" showed about the same sensitivity to light ends addition. The change of cloud point with pressure was dependent

on the pressure range and the presence of light ends. Adding small amounts of gas to STO produced a larger decrease of cloud point than adding the same amount of gas to a fluid that already contained some light ends.

For a temperature range of 24 to 70°F, there was a minimum "total paraffin carbon number" (TPCN) above which all of the higher molecular weight n-paraffins partitioned to the solid phase. The relationship between TPCN and solids precipitation temperature was not dependent on crude oil type, composition, pressure, or solids isolation technique.

Above the TPCN the wt% n-paraffin distribution of the solid was equal to the n-paraffin distribution of the STO. Below the TPCN, a single set of wt% distribution coefficients could be used along with the STO n-paraffin analysis to estimate the n-paraffin distribution in the solid at a given temperature.

To maximize solids data reliability, it was valuable to have more than one technique for determining wt% solids.

Based on solids precipitation behavior and the TPCN prediction method for solids n-paraffin composition, condensate may be a poorer n-paraffin solvent than black oil.

INTRODUCTION

To complete this study, many different tests were performed using a variety of fluid types generated in the laboratory. These tests and fluids were given acronyms to aid in clarification throughout the project. A list of these acronyms is presented in Table 1.

Separator and stock tank samples from three wells (South Pelto 10 Well 9-2, Main Pass 299 Well B-4, and Garden Banks 426 Well A-14) were received by Marathon Oil Company. Also, a cylinder containing a synthetic five component gas blend was made representing The University of Tulsa's natural gas stream. These field samples and the synthetic gas were used in making the various fluid systems studied in this project. A listing of these may be found in Table 2.

All tests performed for each of the fluid systems are illustrated in Tables 3a through 3c. These tests are shown in a matrix format with corresponding samples generated in the laboratory. Blocks showing a date indicate which progress report contains the data for each individual test (row) and the sample (column) used to obtain the data.

PVT DATA

PVT properties were measured at Marathon's Petroleum Technology Center. Complete data are given in the Appendix. PVT measurements were made using standard procedures and data were reviewed for consistency. With the exception of viscosity, the presence of wax solids was not expected to affect the PVT properties.

Data Consistency Check

Figure 1 is a plot of liquid volume percent versus pressure for Recombined Oil 1, Recombined Oil 2, Recombined Condensate (RC), FLO, and FLC. It should be noted that all five fluid systems including the "gas condensate" exhibited bubble point behavior, although RC was a volatile oil. The trend of higher percent liquid at lower temperatures was true for all five fluid systems. Figure 1 shows typical PVT data consistency. Density behavior was also very consistent except for RC which showed similar anomalies to those discussed in the viscosity section below.

Viscosity

A plot of the natural logarithm of viscosity versus $1/T$ for three of the fluids is given in Figure 2. For Recombined Oil 1 and Recombined Oil 2, the viscosity increased with a temperature decrease, but the rate of increase was different for the two fluids. Above the cloud point, viscosity of Recombined Oil 2 was less sensitive to temperature changes than Recombined Oil 1. For both fluids, low temperature viscosity was higher than would have

been expected based on extrapolation of high temperature data. The increase in viscosity was due to the presence of wax crystals at substantially lower than cloud point temperatures.

For FLO (85 scf/bbl GOR) at 40°F, the capillary coil plugged and viscosity could not be measured. It was, however, possible to measure a 40°F viscosity for Recombined Oil 1 (455 scf/bbl GOR) where the increased solution gas lowered the concentration of wax present. FLC (105 scf/bbl GOR) also plugged the capillary coil at 40°F.

RC viscosity behavior is difficult to explain. At 8,000 psia it was single phase, but the viscosity decreased as the temperature decreased (Figure 2). RC had over 80 mole% methane. The effect of pressure on viscosity is shown in Figure 3. All fluids analyzed showed the typical V shape curve with the minimum at the bubble point. Below the cloud point, viscosities changed more with pressure than above the cloud point. Modeling would be required to quantitatively relate this directly to wax crystal effects. Near 140°F, at low pressure (below 500 psig) when both fluids are in the two-phase region, Recombined Oil 1 and FLO have similar viscosity behavior. This is a good check of data consistency.

The insert in Figure 3 shows the odd viscosity behavior of RC. Viscosity went down with decreasing temperature (Figure 2) rather than up. As is common for a volatile oil, bubble point increased with temperature rather than decreasing as it did for the black oils. While recombining this fluid, some wax precipitation was observed at 100°F, well above the measured 7,000 psig cloud point of 70°F. More phase information would be necessary to understand this behavior or to preclude an influence of sample handling on the accuracy of the low viscosities measured.

PVT Conclusions

For the South Pelto and Main Pass fluids, no inconsistencies in the PVT data were found. The viscosity increased with decreasing temperature and this increase was greater below the cloud point when wax crystals were present. The change in viscosity with temperature was crude oil dependent.

For the black oils, the change in viscosity with pressure below the cloud point was greater than at temperatures above the cloud point.

At 8,000 psia, the Garden Banks RC viscosity decreased with temperature. These fairly small viscosity changes could not be explained using existing data.

CLOUD POINT DATA

Three different methods were used to measure live oil cloud points. Marathon used infrared energy scattering, measured with a conventional laboratory Fourier Transform Infrared (FTIR) instrument, and filter plugging. DBR used their laser light scattering equipment. Marathon also measured cloud points for STO using the Differential Scanning Calorimetry (DSC) and Cross Polarization Microscopy (CPM) methods. Marathon measured cloud points on all of the fluid systems studied in this project as well as those previously studied for DeepStar.¹ DBR measured cloud points on recombined South Pelto 10 and Garden Banks 426 samples.

We reviewed the cloud point data to look for trends among cloud points, measurement conditions, sample types and compositions. We also looked for inconsistencies among the data. The data collected during the previous DeepStar study served as a general background for some aspects of this review.

Comments on Reported Cloud Point Data

During our review of the reported cloud point data, we found three tables that contained errors as corrected below. We also corrected these errors in the Quarterly reports copied in the Appendix.

Table 16 of the September 23, 1996 Quarterly Progress Report indicated that we obtained wax data at 2,500 and 3,500 psig using the FTIR method on the Garden Banks live separator oil (LSO) sample. The reported data were actually from the filter plugging method rather than the FTIR method.

Table 11 of the December 20, 1996 Quarterly Progress Report had errors which were repeated in Table 5 of the March 26, 1997 Quarterly Progress Report. All of these errors were on Garden Banks samples. Some of these errors were simply typographical. Others were identified when analyses were repeated. The 2,212 psig pressure should read 2,500 psig. The LSO cloud point determined by filter plugging at 3,500 psig should be 88°F. The STO cloud points determined by filter plugging were 96°F at 1,000 psig, 97°F at 1,500 psig, and 98°F at 3,000 psig. The FLC cloud points determined by filter plugging were 89°F at 2,000 psig and 91°F at 3,000 psig.

We further discovered that the DSC and CPM cloud points for the two black oil STO samples had not been reported. For South Pelto STO, the DSC cloud point was 126°F and the CPM cloud point was 120°F. The DSC cloud point for Main Pass STO was 76°F, and the CPM cloud point was 79°F.

Reliability of Cloud Point Data

Two concepts must be considered when reliability of cloud point data is discussed, namely accuracy and precision. Accuracy, which is how well the measured value agrees with the actual value, is difficult to determine because of a lack of standards with known cloud point values. Standards are used to determine the accuracy of instrument temperature measurements, but this is different from the accuracy of the cloud point value. The latter is dependent upon instrument wax detection sensitivity as well as temperature measurement accuracy. DeepStar tried to correlate measured cloud point values with field experience (highest temperature at which wax was cut in the wellbore), but this was more of a field validation test than an accuracy test.

It is possible, however, to compare cloud point values obtained by different instruments or techniques applied to the same crude oil. When the DeepStar Standard B was run by Marathon using FTIR (sample static during measurement) versus filter plugging (sample flowing during measurement) methods, the FTIR cloud point of 2 wt% n-C₂₈ in dodecane was 66°F and the filter plugging cloud point was 64°F. Similarly, we did not find significant differences in the measured cloud point values obtained for crude oils by the two methods.

For the 13 DeepStar crude oils, the FTIR method had a 3°F bias from the average cloud points determined by the four DeepStar methods (FTIR, filter plugging, DSC, and CPM), while the filter plugging method bias was -0.3°F. A rigorous quality assurance program has not been set up for these methods, so we do not know the precision of each method. However, DeepStar data suggested that when sampling errors were considered along with analytical errors, the FTIR cloud point values had a repeatability of about ±4°F and the filter plugging values, about ±2°F.

For the South Pelto recombined intermediate fluid (RIF), the difference in cloud point values obtained by the FTIR and filter plugging methods at 2,000 and 3,000 psig was a constant 5°F with the FTIR values being lower. This difference may have been due to sub-sampling inconsistencies. For the Garden Banks FLC at 3,000 psig, the filter plugging cloud point was 8°F higher than the FTIR cloud point. When another sample of the same oil was rerun by the filter plugging method at a later date, the cloud point was 1°F lower than the FTIR cloud point. This indicated that sub-sampling was a problem in that case.

For the Main Pass dead oil samples, at 1,000 psig both STO and flashed separator oil (FSO) had cloud points near 80°F by both Marathon methods. At 3,000 psig, STO had a cloud point of 75°F by both methods, but FSO had a FTIR cloud point of 84°F and a filter plugging cloud point of 91°F. This data set was confusing and more work would be necessary to sort out the cause of such a large discrepancy.

To simplify data interpretation, the discussion below assumes that there was no experimental error in the cloud point values. Single determinations were made, so it should

be assumed that an error of at least +/- 4°F was present.

Effect of Crude Oil n-Paraffin Composition on Dead Oil Cloud Points

Two major factors that affect crude oil cloud points are the composition of the n-paraffins in the oil and the composition of the other components in the oil which act as wax solvents. DeepStar data suggested that there might be a general correlation between the crude oil wt% C₅₀₊ n-paraffin content and cloud point. In Figure 4, wt% n-C₅₀₊ and cloud point data for South Pelto (SP), Main Pass (MP) and Garden Banks (GB) are plotted along with data for the DeepStar oils. The line in this Figure was from a least squares fit of the semi-log relationship (cloud point = 13.64ln(wt% C₅₀₊) + 145.9). An average cloud point deviation of ±7°F was obtained when the equation of this line was used to calculate the 16 crude oil cloud points. The Tulsa crudes fit the same line as the DeepStar crudes. No doubt some of the scatter in Figure 4 data is due to the presence of different wax solvency effects caused by variations in crude oil composition.

Effect of Pressure and Light Ends on Crude Oil Cloud Points

DeepStar data showed that both pressure and light ends affected crude oil cloud points. Cloud point data for each fluid system studied in this project are given in the Quarterly Reports provided in the Appendix. We have plotted that data in a slightly different manner to obtain a more detailed assessment of the relationships. We used our estimates of the best cloud point values in these plots to minimize the effect of experimental error on our interpretation of the data.

South Pelto Oil

Figure 5 is a plot of cloud point values versus the amount of light ends (wt% C₁, C₂, and C₃) in the South Pelto samples. Available cloud point data obtained by Marathon are plotted for three different pressures. Data from DBR are also included. STO was assumed to be free of light ends. Light ends in FLO were added as City of Tulsa synthesized gas. Separator gas was used to obtain RIF and recombined reservoir fluid (RRF). DBR ran the RRF fluid and then flashed it at 800 psig to obtain flashed recombined reservoir fluid (FRRF). This sample had a composition that was similar to FLO but the light end source was separator gas rather than Tulsa gas.

The two DBR cloud points fit quite well with the Marathon cloud point data. For the RRF sample, the 4,000 psig DBR value is near the average of the 3,000 and 5,000 psig values. The 800 psig DBR FRRF value of 100°F was about 5 °F lower than would be expected from the 1,000 psig FLO value, but this difference was not unreasonable because there were compositional differences and two different measurement techniques were used. It is interesting that the FRRF cloud point at 800 psig was lower than the RRF cloud point at

4,000 psig. If there were no pressure effect, the FRRF cloud point would be expected to be higher than the RRF cloud point because less light ends were present in FRRF.

The 3,000 psig data in Figure 5 suggested that adding the first 1 wt% C_1 to C_3 caused a larger cloud point depression (slope of -7.4 °F/wt% C_1 to C_3) than adding additional increments of C_1 to C_3 (slope of about -3 °F/wt% C_1 to C_3). At 1,000 psig, data were not available for RIF and RRF because their bubble points were too high, but the STO to FLO slope was -9.8 °F/wt% C_1 to C_3 . FLO was made with Tulsa gas while the other samples were made with separator gas which has a slightly different composition, so the larger cloud point depression might have been due to gas composition rather than the amount of gas added. The FRRF sample run at 800 psig was flashed from RRF made with separator gas. The FRRF cloud point was 8 °F lower than the cloud point of the 1,000 psig FLO sample. This suggested that the gas compositional difference between Tulsa gas and separator gas had a minor effect. We conclude that the first 1 wt% incremental gas addition to STO depressed the cloud point more than subsequent additions.

Main Pass Oil

The same type of cloud point, "light ends" and pressure plot is shown for the Main Pass samples in Figure 6. Only two samples, STO and RRF, were studied for this system. The RRF sample was similar in light ends content to the South Pelto RIF sample. Slopes of the STO to RRF lines for the Main Pass oils were -5.7 -6.4 and -7.0 °F/wt% C_1 to C_3 for 1,000, 3,000 and 5,000 psig, respectively. These slopes were similar to the slopes found for South Pelto (STO to FLO) but greater than the slopes for South Pelto (FLO to RRF).

Garden Banks Condensate

Figure 7 shows the cloud point, "light ends," pressure relationship for the Garden Banks samples. Data are shown for STO, FLC (made with Tulsa gas), LSO, RC, and flashed recombined condensate (FRC) which was prepared by DBR at 4,000 psig. These data were consistent with black oil data in that the addition of small amounts of methane to STO produced a larger depression of cloud point than the addition of small amounts of methane to oils that already contained significant amounts of methane. The STO to FLC linear slopes for the Garden Banks system (-8.2 and -9.9 °F/wt% C_1 to C_3 at 3,000 and 5,000 psig, respectively) were similar to those obtained for the corresponding South Pelto and Main Pass oils. It was difficult to evaluate slopes for condensates with higher concentrations of light ends because fewer samples were run under the same conditions, but data in Figure 7 suggested the slopes may be near -1 °F/wt% C_1 to C_3 when the wt% C_1 to C_3 was greater than about 3.

Cloud Point Conclusions

Based on results obtained for this project and DeepStar dead oil cloud point data, there appears to be a general relationship between the natural log of the wt% C_{50+} n-paraffins in STO and STO cloud point. This correlation can be used to calculate a dead crude oil cloud point with an average deviation from a measured cloud point of $\pm 7^{\circ}\text{F}$, but the actual deviation for a single crude oil may be as high as 16°F .

Cloud points measured by DBR using their laser energy scattering cell were consistent with cloud points measured by Marathon using either FTIR or filter plugging.

The change of cloud point with pressure was dependent on both crude oil "light ends" content and pressure range.

The decrease in crude oil cloud point obtained by adding a small increment of separator gas or Tulsa synthesized gas was not affected appreciably by the small differences in gas composition, but was affected by the amount of "light ends" already present in the crude oil.

The two black oils and the condensate sample show about the same sensitivity to changes in cloud point with light ends addition. In all cases, a relatively large decrease (-6 to $-10^{\circ}\text{F}/\text{wt}\% C_1$ to C_3) occurs at C_1 to C_3 concentrations less than about 3 wt%. At higher C_1 to C_3 concentrations the decrease was smaller (-3 to $-0.5^{\circ}\text{F}/\text{wt}\% C_1$ to C_3).

SOLID n-PARAFFIN DATA

Two types of experiments were used to obtain solid n-paraffin data. Marathon slowly cooled dead oil from about 140°F to about 50°F below the cloud point in a sealed spinning centrifuge cell and then isolated the solids from the solids-free oil. High temperature gas chromatography was used by Nenniger Engineering to obtain a quantitative wt% n-paraffin carbon number distribution for the original oil, and the solids and solids-free oil obtained by centrifugation. Marathon determined solid precipitate amount by directly weighing the residue and from an "oil difference" method based on the difference in n-paraffin concentration of the original oil and the solids-free oil (after correcting for concentration effects due to solids loss). As shown in the Appendix, for most cases, the carbon number distribution data for the solid obtained by the "oil difference" method was very similar to that obtained by analyzing the solid directly, and the latter analysis is significantly cheaper. Values from direct analysis of the solids are used in the discussion below.

DBR cooled live oil from about 160°F to about 50°F below the cloud point in a rocking cell and used filtration to isolate the solids. The solids were then weighed and analyzed by high temperature gas chromatography to obtain a quantitative wt% n-paraffin distribution.

They also obtained carbon number distribution data for "other" hydrocarbons in the solids. DBR supplied "weight gas to weight sample" ratios that we used to convert DBR solid precipitate values from a live oil to a dead oil basis. The DBR and two Marathon methods gave comparable n-paraffin carbon number distribution data for the precipitated solids.

All of the solids precipitation data are given in the Appendix. We analyzed these data to look for trends and possible inconsistencies.

Prediction of Solid n-Paraffin Data

Data in Figure 8 will be used to explain the technique we developed to predict the solids composition from STO n-paraffin analysis. Figure 8 shows carbon number distribution data from the South Pelto centrifugation test at 70°F. Wt% n-paraffin results are plotted for the original dead oil, solids recovered from the oil (wt% solids recovered from the oil at 70°F multiplied by wt% of each n-paraffin in the solid), and a solids composition we predicted (discussed below).

A comparison of the n-paraffin compositions of dead oil and isolated solid (expressed as a dead oil equivalent wt% n-paraffin concentration) showed that within experimental accuracy, all of the n-paraffins present which were above a carbon number of C_{42} precipitated with the solid at 70°F. The concept that there is a minimum carbon number for crude oil above which all of the heavier n-paraffins in the oil precipitate with the solid is important. We define this minimum carbon number as the TPCN.

We used the same type of plot as Figure 8 with data from the other oils and other precipitation conditions (see below) to establish a relationship between precipitation temperature and the TPCN. This relationship is shown in Figure 9. Data from each solids determination are included in this plot. The correlation appears to be independent of oil type, light ends content or pressure.

Using the data in Figure 9 we can predict the TPCN for each precipitation temperature of interest. Above the TPCN, the distribution of n-paraffins in the solid is the same as the STO. Below the TPCN, the n-paraffins are distributed between the liquid and solid phases. Weight percent distribution coefficients for each n-paraffin can be calculated by dividing the wt% n-paraffin in the STO by the wt% n-paraffin in the solid. We attempted this for each solids determination. Nenniger was able to differentiate between crude oil entrapped in the solids and low carbon number n-paraffins in the solids. Presumably, this was done by extrapolating the original crude oil data. The lower carbon number limit to the solid n-paraffin analysis was established by Nenniger's ability to make the crude oil correction. It varied from crude to crude. DBR did not make this correction because they felt the entrapped crude oil should be included with the solid. The DBR data was therefore not useful for calculating n-paraffin distribution coefficients.

The black oil distribution coefficients used for our predictions were an average based on the South Pelto and Main Pass centrifugation data. South Pelto at 70°F had a TPCN of 42 and Main Pass at 40°F had a TPCN of 31, so it was necessary to place the distribution coefficient values on a comparable basis before averaging. To do this we arbitrarily set the distribution coefficient value equal to 1 for n-C₃₀ for each data set. Distribution values were then averaged for each n-paraffin from n-C₃₀ to n-C₁₅. The black oil distribution coefficients used for solids composition predictions are shown in Figure 10 and Table 4.

We also attempted to determine distribution coefficients for the condensate samples, but the two DBR determinations did not correct for entrapped condensate so they were significantly different from the Marathon determination and an average was not useful.

To predict the solid n-paraffin distribution at a given temperature it was first necessary to consult Figure 9 and determine the TPCN for that temperature. Once that was known, the black oil distribution coefficients were set equal to 1 at the TPCN and then the data in Table 4 were used to assign distribution coefficients to the carbon numbers below the TPCN. These distribution coefficient values were then divided into the corresponding STO individual n-paraffin concentrations to calculate the n-paraffin distribution in the solid below the TPCN.

South Pelto Solids Data

Solids data from the Marathon centrifugation test at 70°F were already discussed. The data are shown in Figure 8. The predicted solids n-paraffin distribution agrees with the measured solids distribution about as well as the STO n-paraffin distribution above the TPCN (42) agrees with the measured solids distribution. The peak in STO at n-C₅₆ was not observed in the solid sample, but this was probably due to the gas chromatographic uncertainty rather than compositional differences. The same may be said for the n-C₄₀ and n-C₄₈ peaks in the oil. The predicted distribution was about 0.01 wt% higher than measured in the n-C₃₅ to n-C₄₁ range. However, this data should be of sufficient quality to check any modeling results.

The DBR South Pelto RRF filtration data at 4,000 psig and 58°F are summarized in Figure 11. The dead oil n-paraffin distribution was obtained by Nenniger, while DBR used their own gas chromatographic method to analyze the solids. The TPCN for this sample was 36. When the black oil distribution coefficients were used to predict the solids n-paraffin distribution, the results agreed quite well with the measured solids value.

DBR flashed the RRF sample at 800 psig and ran the filtration test at 50°F. The data are shown in Figure 12. The dead oil (and n-paraffin distribution) was the same as for the 4,000 psig run. The TPCN was lowered to 35 due to the lower filtration temperature. The predicted solids n-paraffin distribution was in good agreement with the measured solids values except below n-C₃₁, where the contribution from entrapped crude oil was significant.

Main Pass Solids Data

DBR did not run Main Pass oil. Marathon centrifugation data at 40°F are summarized in Figure 13. The TPCN was 31. Prediction of the solids n-paraffin distribution agreed quite well with the measured values.

Garden Banks Solids Data

For the two black oils, the weight percent precipitated n-paraffins obtained by subtracting the n-paraffin distribution of the spent-oil from the n-paraffin distribution of the original oil ("oil difference" technique mentioned above) agreed with the result obtained by direct analysis of the solid. For the Garden banks condensate, the "oil difference" value was 0.46 wt% and the direct solids analysis gave 0.89 wt%. If 3 wt% solids rather than the recorded 5.5 wt% solids had actually been recovered from the centrifugation test, then the calculated 0.49 wt% solid n-paraffins would agree with the "oil difference" value. Figure 14 shows n-paraffin distribution data for the centrifugation solid (expressed in dead oil equivalents) based on the "oil difference" technique, using the 5.5 wt% solids that were reported and the 3 wt% solids that gives good agreement with the "oil difference" value. The solid sample contained some inorganics as well as wax. A review of the lab notebook indicated that a weighing error may have occurred that caused the problem.

Marathon centrifugation data for Garden Banks sample at 45°F are plotted in Figure 15. The amount of recovered solids was assumed to be 3 wt% for this plot. Above the TPCN of 34, the measured solid n-paraffin data tracked the STO data very well. The predicted solids n-paraffin data below C_{34} was within about 0.01 wt% of the measured solids values. However, between C_{28} and C_{31} it was 0.01 wt% too low, and between C_{22} and C_{24} , it was about 0.01 wt% too high.

DBR filtration data for the Garden Banks FRC filtered at 4,000 psig and 24°F are shown in Figure 16. The TPCN for this determination was 31. Above C_{31} , the measured solid n-paraffin distribution data agreed with the dead oil data. Below C_{31} the predicted solids data agreed with the measured solids data down to about C_{25} , but below that, the predicted values increased while the measured values decreased.

DBR reported 0.86 wt% solids when the Garden Banks RC was filtered at 8,000 psig and 25°F. They also commented that this value may be low due to hold-up in the cylinder. For all the other determinations, when the percent solids was multiplied by the percent of each n-paraffin in the solid sample, the result matched the n-paraffin distribution in the oil above the TPCN. This was not the case for the 8,000 psig filtration of the recombined condensate. Figure 17 shows n-paraffin distribution data for the oil and 0.86 wt% solid sample. If we assume that 2 wt% solids were present then the expected match of n-paraffins above the TPCN of 28 was observed. Figure 18 shows the oil and measured

solids n-paraffin distribution data (2 wt% solids assumed) along with the predicted solids n-paraffin distribution. In agreement with the other Garden Banks condensate solids determinations, the predicted values have too high a n-paraffin concentration for the lower molecular weight n-paraffins. This suggests the condensate distribution coefficients increase faster with decreasing carbon number than the black oil distribution coefficients indicating that condensate may be a poorer solvent for solid than black oil.

Summary of Solids Data

The n-paraffin content of precipitated solids was obtained by isolating the solids generated at a given temperature using filtration or centrifugation and then weighing and analyzing the solids for wt% n-paraffin distribution using high temperature gas chromatography. This worked quite well when the solids generation temperature was about 50°F below the cloud point and significant amounts of solids were produced. However, these tests are expensive and the amount of solids will be limited as the solids precipitation temperature approaches the cloud point.

Using the correlations developed from the data gathered in this study, it should be possible to predict the solids n-paraffin distribution directly from the wt% n-paraffin distribution of the dead crude oil.

Solids Conclusions

For a temperature range of 24 to 70°F, there was a minimum TPCN above which, all of the higher molecular weight n-paraffins, within experimental accuracy, partition to the solid phase.

The relationship between TPCN and precipitation temperature was not dependent on sample type or composition, pressure, or solids isolation technique.

Above the TPCN, the wt% n-paraffin distribution of the solid was equal to the STO wt% n-paraffin distribution.

Below the TPCN, a single set of wt% partition coefficients was used to estimate the n-paraffin distribution in the solid.

To maximize data reliability, it was desirable to have more than one technique for calculating wt% solids isolated.

DBR filtration solids data was comparable to Marathon centrifugation solids data.

Based on solids precipitation behavior and the TPCN prediction method for solids n-paraffin composition, condensate may be a poorer n-paraffin solvent than black oil.

REFERENCES

1. Tackett, J.E.: Final Report, "Comparison of Cloud Point Methods", DeepStar II-A CTR No. 907, September 1996.

Table 1

Nomenclature

The following acronyms were used in the quarterly reports and are used in the final report:

WAT	Wax Appearance Temperature
WDT	Wax Disappearance Temperature
FTIR	Fourier Transform Infrared Spectroscopy
FP	Filter Plugging
DSC	Differential Scanning Calorimetry
CPM	Cross Polarization Microscopy
CCE	Constant Composition Expansion
GOR	Gas Oil Ratio
STO	Stock Tank Oil
RIF	Recombined Intermediate Fluid (South Pelto 182 scf/bbl GOR Mixture)
FSO	Flashed Separator Oil
RRF	Recombined Reservoir Fluid
HTGC	High Temperature Gas Chromatography
FLO	Flow Loop Oil
LSO	Live Oil Separator Oil
FLC	Flow Loop Condensate
RC	Recombined Condensate
DBR	DB Robinson
FRRF	Flashed Recombined Reservoir Fluid (by DBR)
FRC	Flashed Recombined Condensate (by DBR)

Table 2

Samples Received from the Field

1. **South Pelto 10 Well 9-2**
 (8) one liter cylinders of separator gas
 (4) one liter cylinders of separator liquid
 (2) five gallon DOT cans of stock tank oil

2. **Main Pass 299 Well B-4**
 (5) one liter cylinders of separator gas
 (2) one liter cylinders of separator liquid
 (2) five gallon DOT cans of stock tank oil

3. **Garden Banks 426 Well A-14**
 (16) 500 cc cylinders of separator gas
 (6) 500 cc cylinders of separator liquid
 (2) one gallon DOT cans of stock tank oil

4. **City of Tulsa Synthesized Gas**
 (1) "A" type cylinder with a 43.8 liter volume at 70°F and 1 atm

Samples Generated in the Laboratory

South Pelto	Main Pass	Garden Banks
Recombined Oil 1 RRF RIF FSO spent FSO flashed fluid FRRF harvested solids	Recombined Oil 2 RRF FSO spent FSO flashed fluid harvested solids	Recombined Condensate RRF FSO spent FSO flashed fluid harvested solids FRC
Flow Loop Oil FLO flashed fluid equilibrium gas equilibrium oil		Flow Loop Condensate FLC flashed fluid equilibrium gas equilibrium oil

Table 3a

South Pelto 10 Well 9-2 (Recombined Oil 1)

Tests Performed	FLUID TYPES						
	Sep. Gas	Sep Oil	RRF	RIF	FSO	STO	Solids
Sample Quality Checks	4/1/96	4/1/96	4/1/96	4/1/96			
Heat/Condition Samples	4/1/96	4/1/96	4/1/96	4/1/96	7/1/96	7/1/96	
Sample Compositions	4/1/96	4/1/96	4/1/96	7/1/96			
Physical Recombination			4/1/96				
Calculated WellStream			4/1/96				
CCE @ 232°F			4/1/96				
CCE @ 136°F			4/1/96				
CCE @ 42°F			4/1/96				
WAT - FTIR & Filter Plugging			7/1/96	7/1/96	7/1/96	7/1/96	
WDT - FTIR & Filter Plugging			7/1/96	7/1/96	7/1/96	7/1/96	
Cloud point - DSC						Final	
Cloud point - CPM						Final	
Solids Harvest - Centrifugation					9/23/96		
Nenninger Analyses					9/23/96		9/23/96
Viscosity at shear conditions						7/1/96	
Density - function of temp						9/23/96	
DBR Recombination			4/1/96				
DBR Data Results			Final				

Main Pass 299 Well B-4 (Recombined Oil 2)

Tests Performed	FLUID TYPES					
	Sep. Gas	Sep Oil	RRF	FSO	STO	Solids
Sample Quality Checks	7/1/96	7/1/96	7/1/96			
Heat/Condition Samples	7/1/96	7/1/96	7/1/96			
Sample Compositions	7/1/96	7/1/96	7/1/96			
Physical Recombination			7/1/96			
Calculated WellStream			7/1/96			
CCE @ 165°F			7/1/96			
CCE @ 125°F			7/1/96			
CCE @ 42°F			9/23/96			
WAT - FTIR & Filter Plugging			9/23/96	9/23/96	9/23/96	
WDT - FTIR & Filter Plugging			9/23/96	9/23/96	9/23/96	
Cloud point - DSC					Final	
Cloud point - CPM					Final	
Solids Harvest - Centrifugation				9/23/96		
Nenninger Analyses				9/23/96		9/23/96
Visc. at shear cond. (RFS)					7/1/96	
Density - function of temp					9/23/96	

Note: The date in each block denotes in which quarterly report this test data may be found.

Table 3b

**Garden Banks STO & City of Tulsa Gas
(Flow Loop Condensate)**

Tests Performed	FLUID TYPES	
	Synthetic Gas	FLC
Sample Quality Checks	4/1/96	12/20/96
Heat/Condition Samples	4/1/96	12/20/96
Sample Compositions	4/1/96	12/20/96
Physical Recombination		12/20/96
Calculated WellStream		12/20/96
CCE @ 140°F		12/20/96
Vapor Phase Composition		12/20/96
Oil Phase Composition		12/20/96
CCE @ 90°F		12/20/96
Vapor Phase Composition		12/20/96
Oil Phase Composition		12/20/96
CCE @ 40°F		12/20/96
Vapor Phase Composition		12/20/96
Oil Phase Composition		12/20/96
WAT - FTIR & Filter Plugging		3/26/97

**South Peito STO & City of Tulsa Gas
(Flow Loop Oil)**

Tests Performed	FLUID TYPES	
	Synthetic Gas	FLO
Sample Quality Checks	4/1/96	9/23/96
Heat/Condition Samples	4/1/96	9/23/96
Sample Composition	4/1/96	3/26/97
Physical Recombination		9/23/96
Calculated WellStream		9/23/96
CCE @ 140°F		9/23/96
Vapor Phase Composition		9/23/96
Oil Phase Composition		9/23/96
CCE @ 90°F		9/23/96
Vapor Phase Composition		9/23/96
Oil Phase Composition		9/23/96
CCE @ 40°F		9/23/96
Vapor Phase Composition		NA
Oil Phase Composition		NA
WAT - FTIR & Filter Plugging		9/23/96
WDT - FTIR & Filter Plugging		9/23/96

Note: The date in each block denotes in which quarterly report this test data may be found.

Table 3c

Garden Banks 429 Well A-14 (Recombined Condensate)

Tests Performed	FLUID TYPES					
	Sep Gas	Sep Oil	RC	FSO	STO	Solids
Sample Quality Checks	9/23/96	9/23/96	12/20/96			
Heat/Condition Samples		9/23/96			12/20/96	
Sample Compositions	9/23/96	9/23/96	12/20/96			
Physical Recombination			12/20/96			
Calculated WellStream			12/20/96			
CCE @ 176°F			12/20/96			
CCE @ 138°F			3/26/97			
CCE @ 100°F			3/26/97			
WAT - FTIR & Filter Plugging		3/26/97				
WDT - FTIR & Filter Plugging		3/26/97				
Cloud point - DSC				12/20/96		
Cloud point - CPM				12/20/96		
Solids Harvest - Centrifugation					3/26/97	
Nenninger Analyses					3/26/97	3/26/97
DBR Recombination			9/23/96			
DBR Data Results			Final			

Note: The date in each block denotes in which quarterly report this test data may be found.

Table 4

**Weight Percent Distribution Coefficients
for Black Oils**

Relative Carbon Number*	<u>Distribution Coefficients</u>
15	28.99
16	18.14
17	15.05
18	11.15
19	9.74
20	7.33
21	5.92
22	4.60
23	3.76
24	3.44
25	2.61
26	2.10
27	1.97
28	1.59
29	1.30
30	1.00

* Based upon distribution coefficient at C-30 = 1

Figure 1. Change In Liquid Volume Percent During CCE

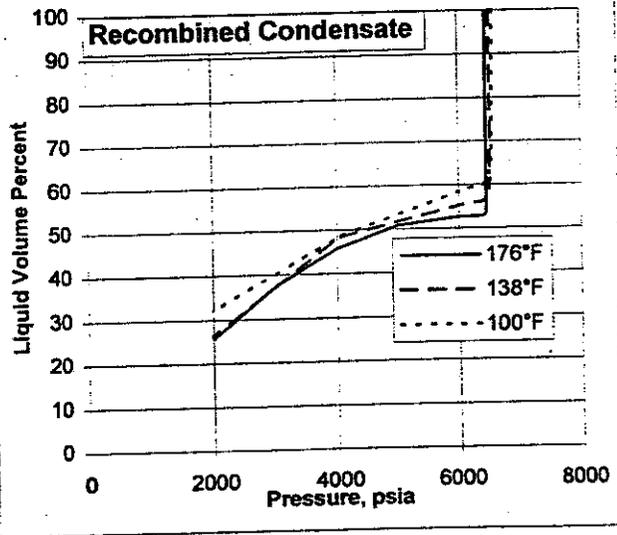
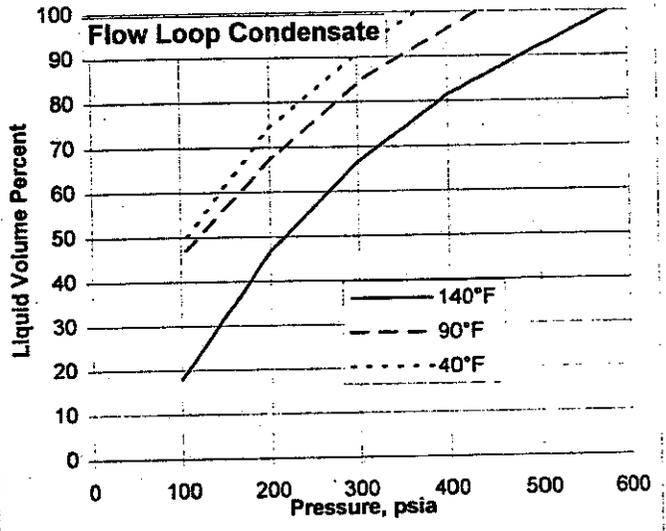
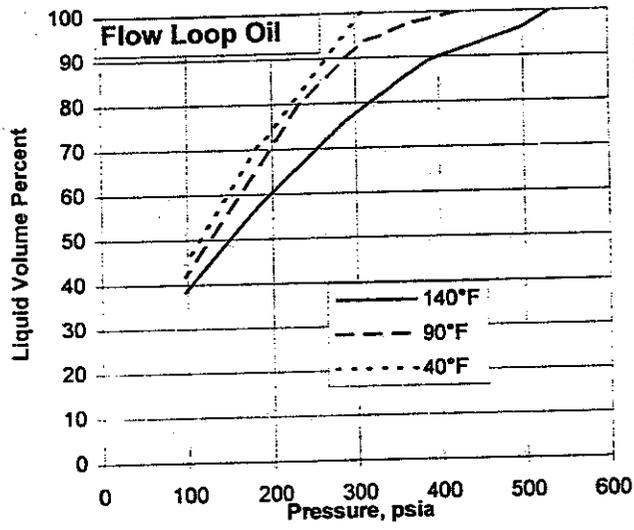
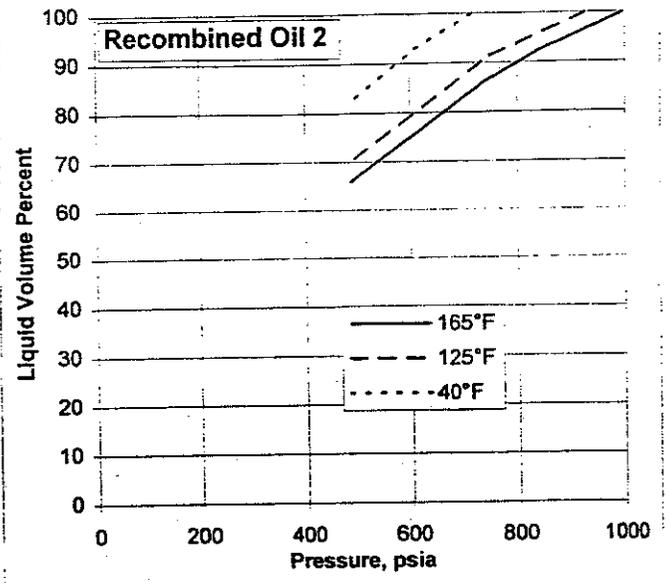
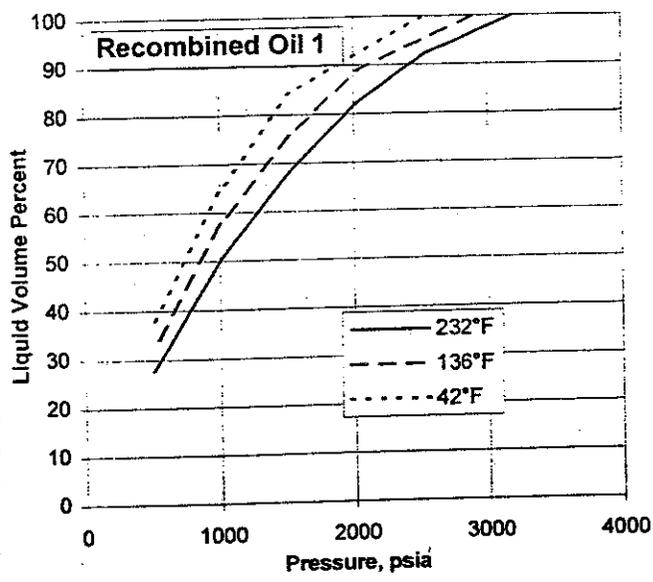


Figure 2.
Change in Viscosity with Reciprocal Temperature

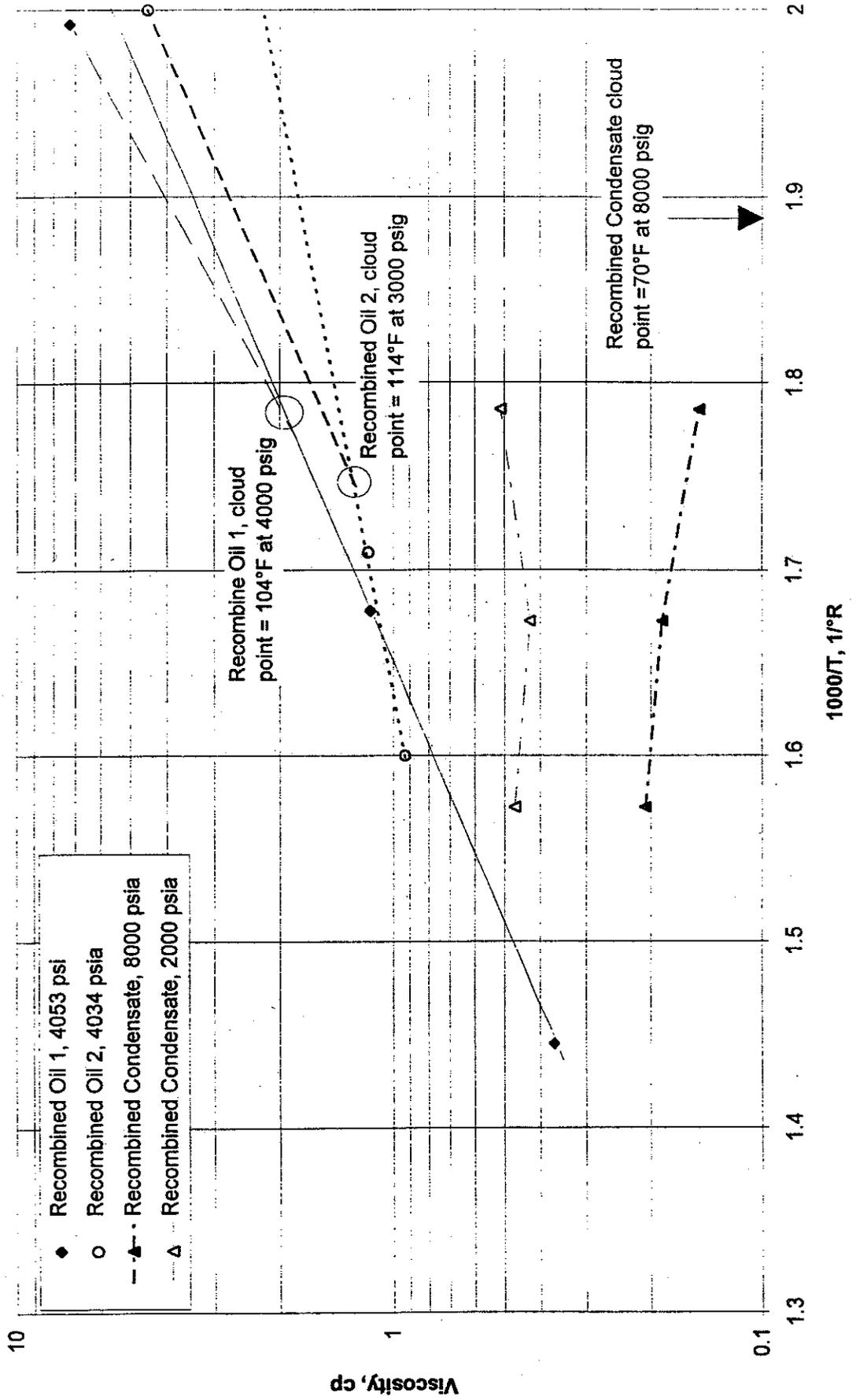


Figure 3.
Change in Viscosity With Pressure

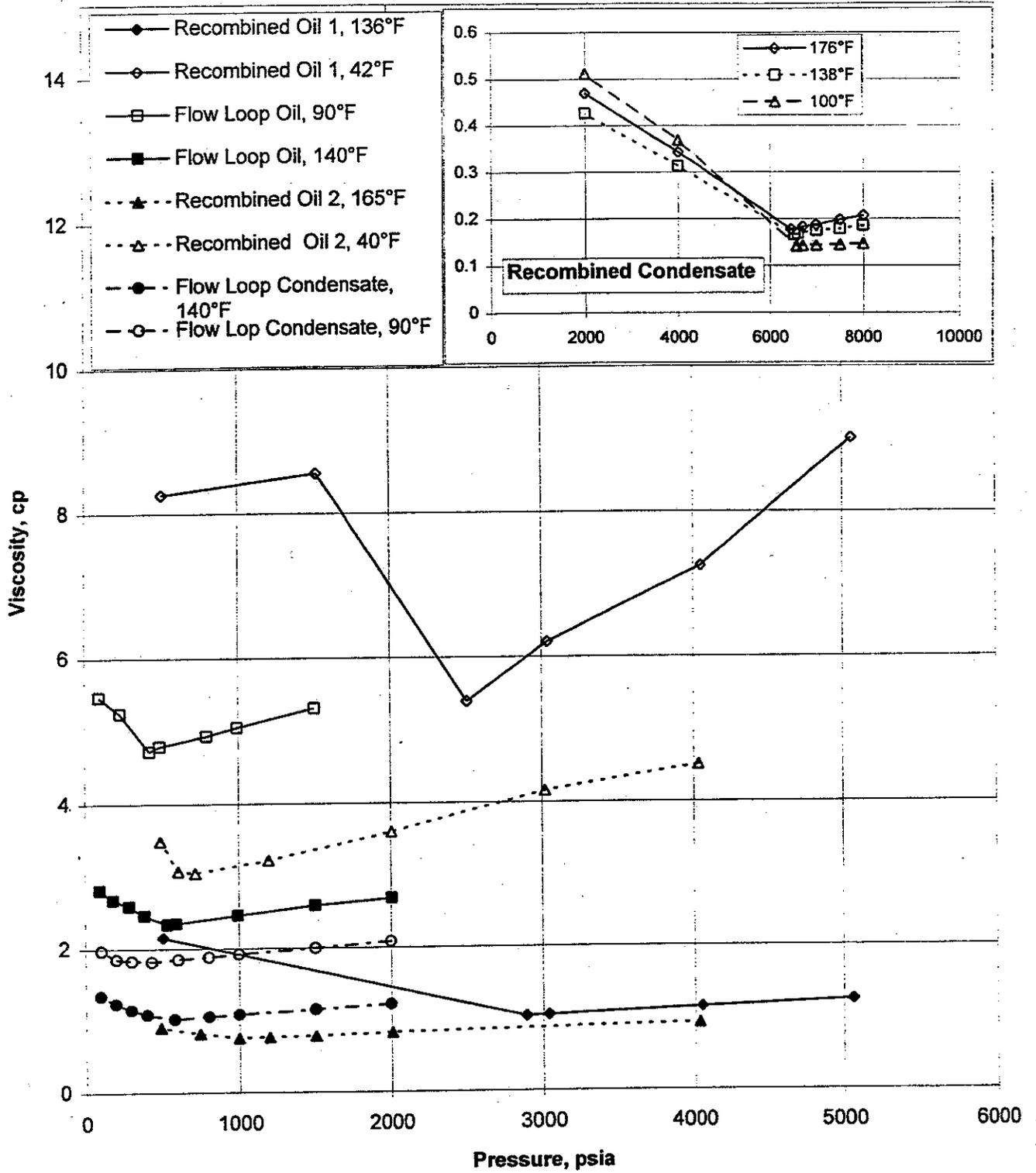


FIGURE 4. CORRELATION BETWEEN n-C₅₀₊ AND CLOUD POINT

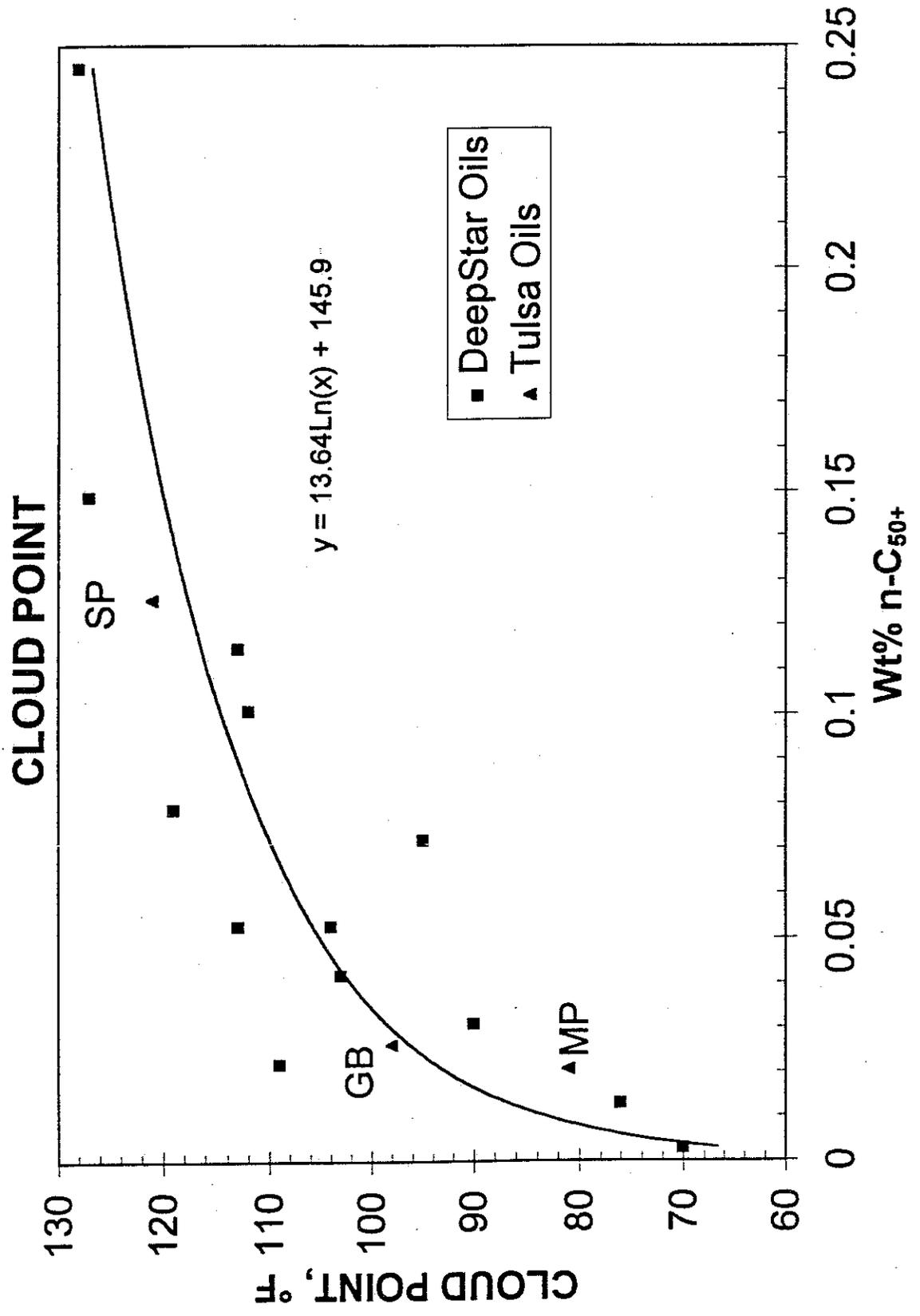


FIGURE 5. SOUTH PELTO
Cloud Point vs Wt% C1 to C3

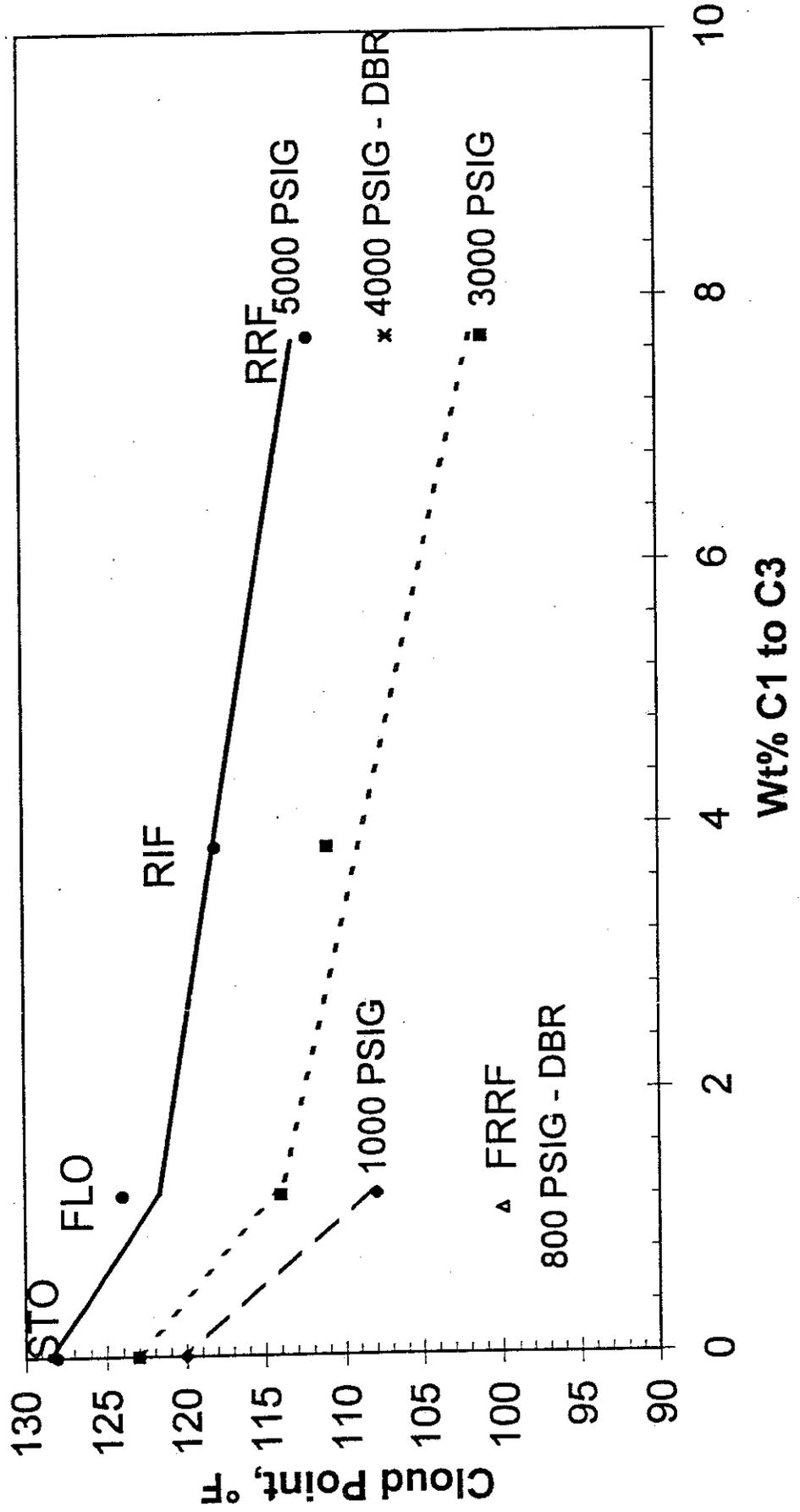


FIGURE 6. MAIN PASS
Cloud Point vs Wt% C1 to C3

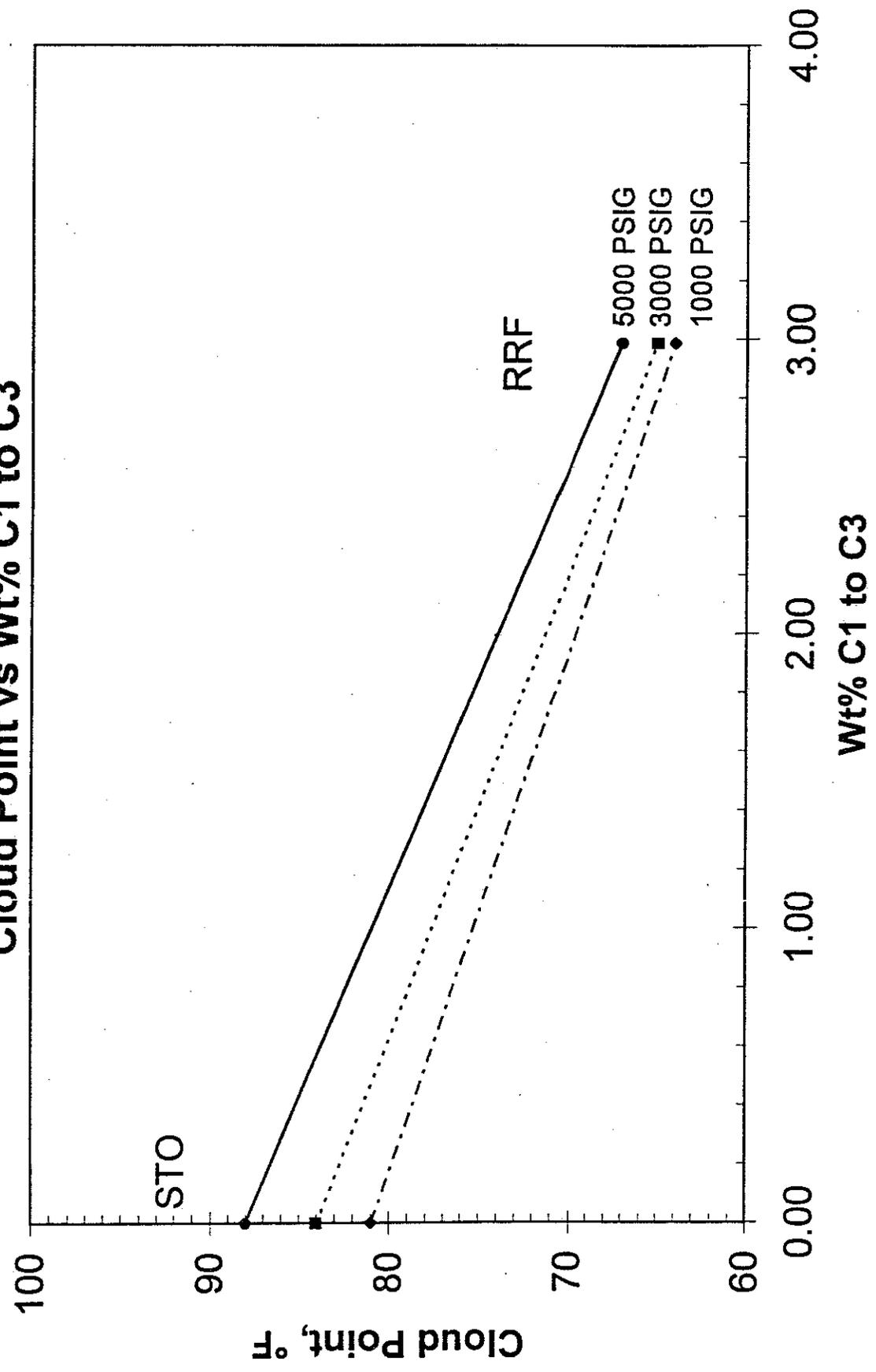
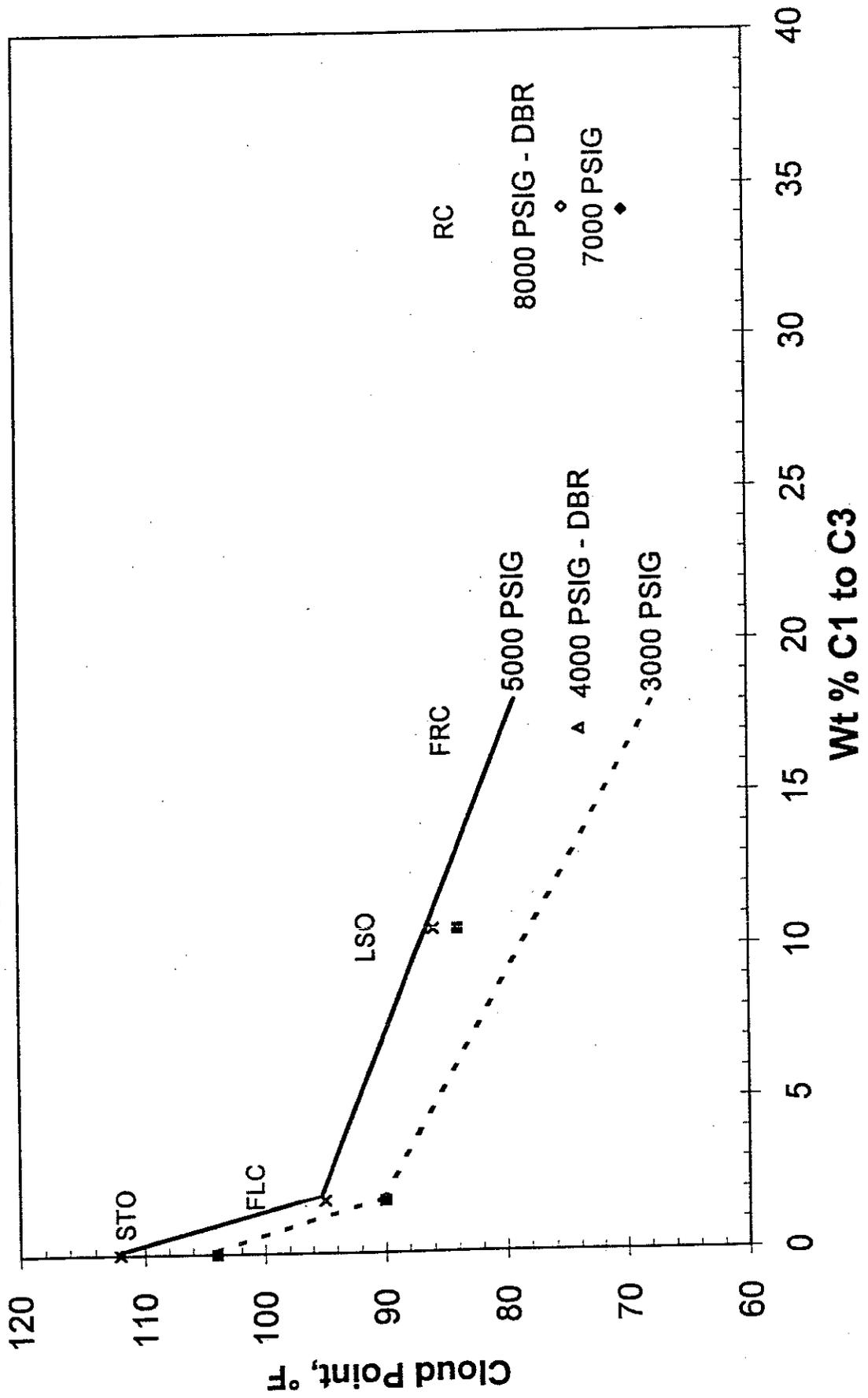


FIGURE 7. GARDEN BANKS
Cloud Point vs Wt% C1 to C3



**FIGURE 8. SOUTH PELTO
CENTRIFUGATION AT 70 °F**

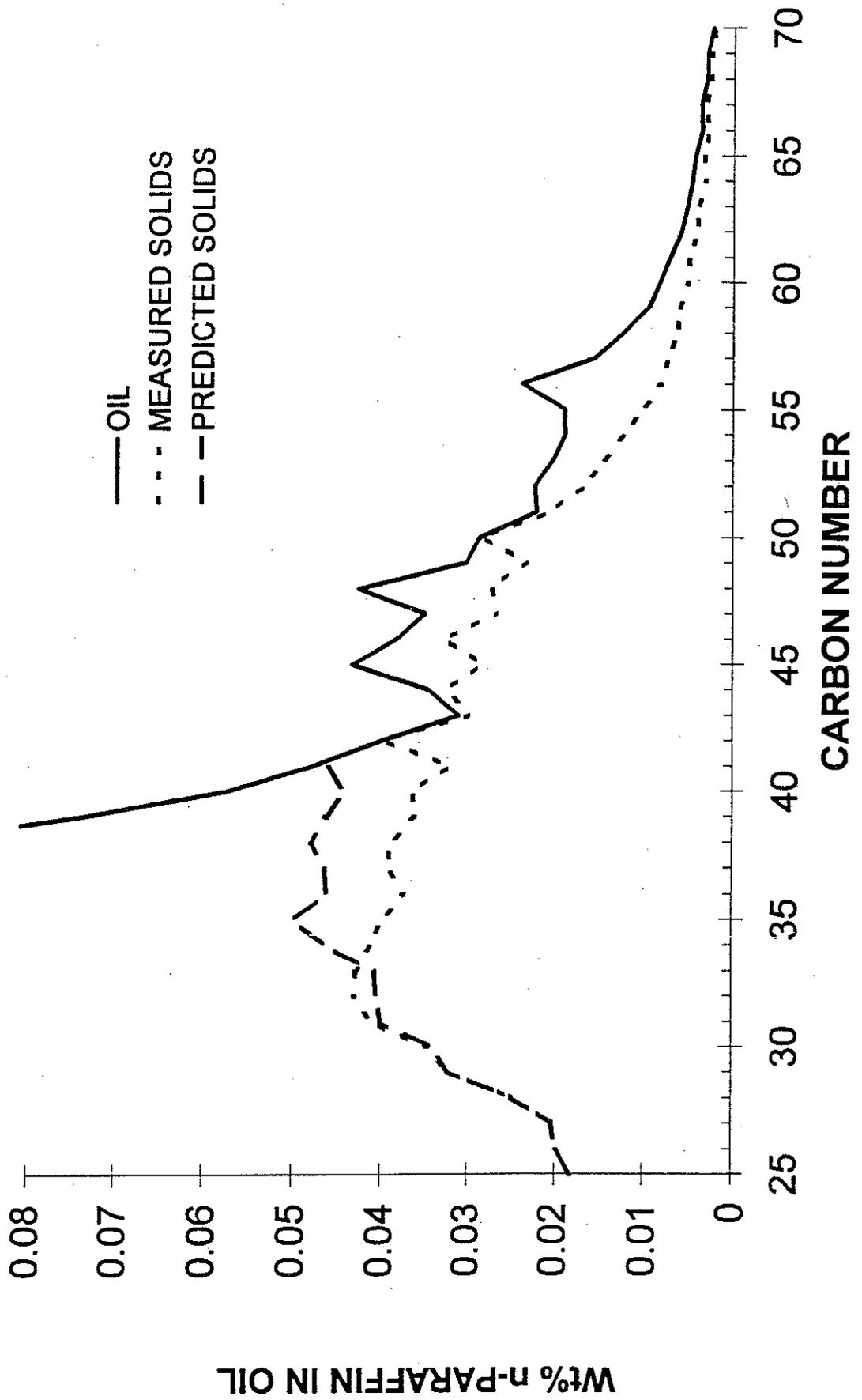


FIGURE 9. TPCN VS PRECIPITATION TEMPERATURE

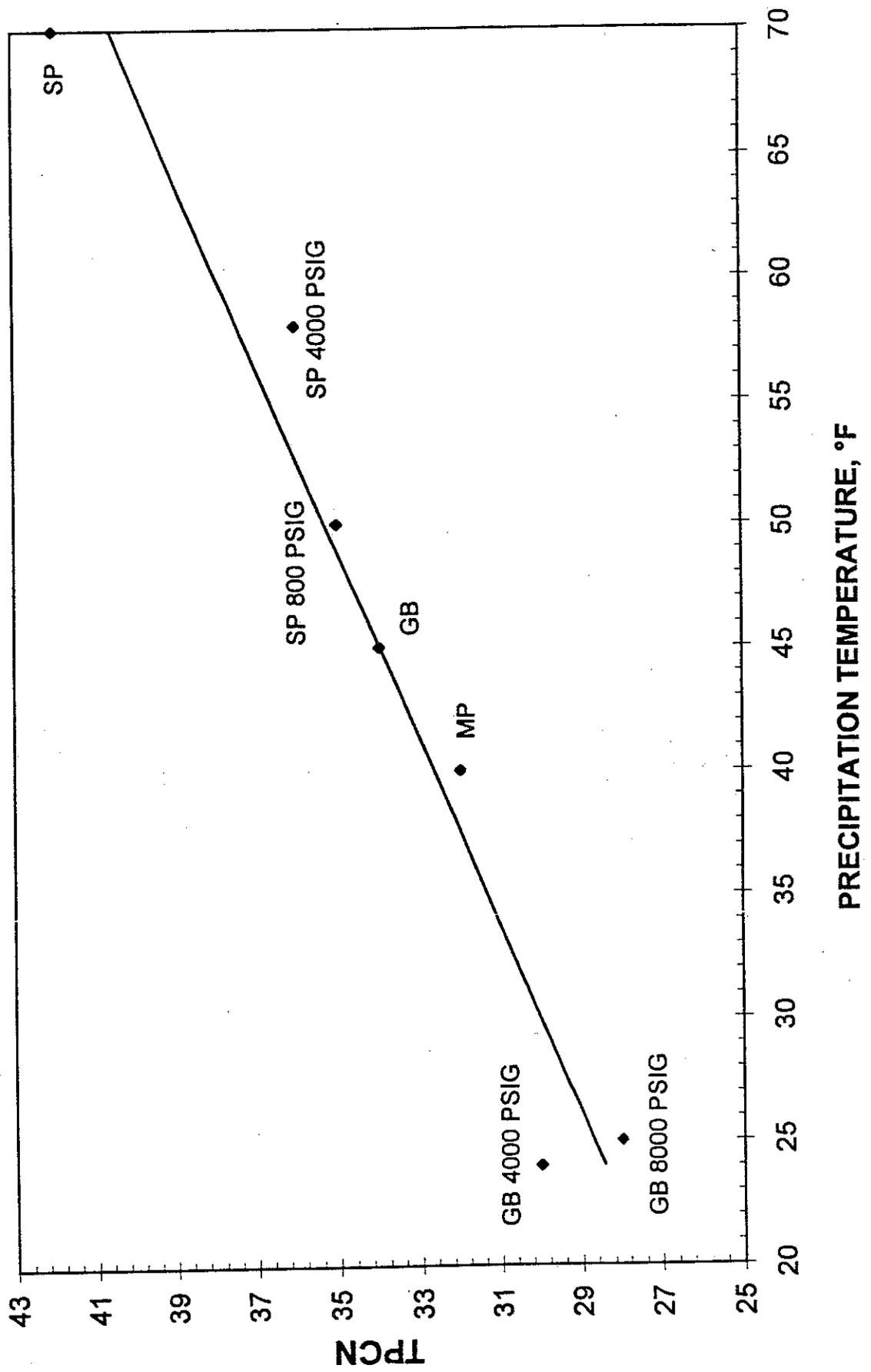
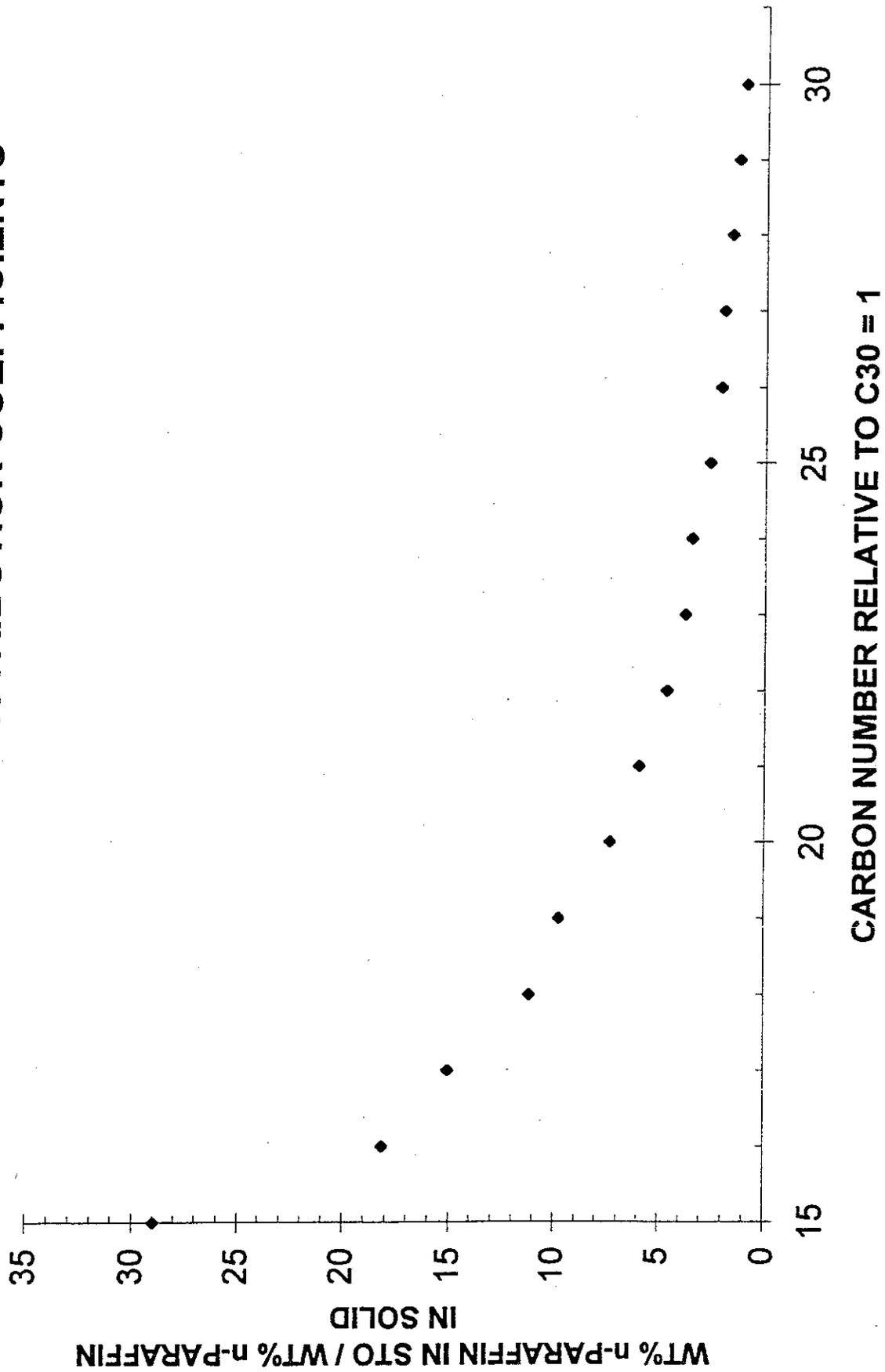


FIGURE 10. BLACK OIL DISTRIBUTION COEFFICIENTS



**FIGURE 11. SOUTH PELTO AT 4,000 PSIG - FILTRATION
AT 58°F**

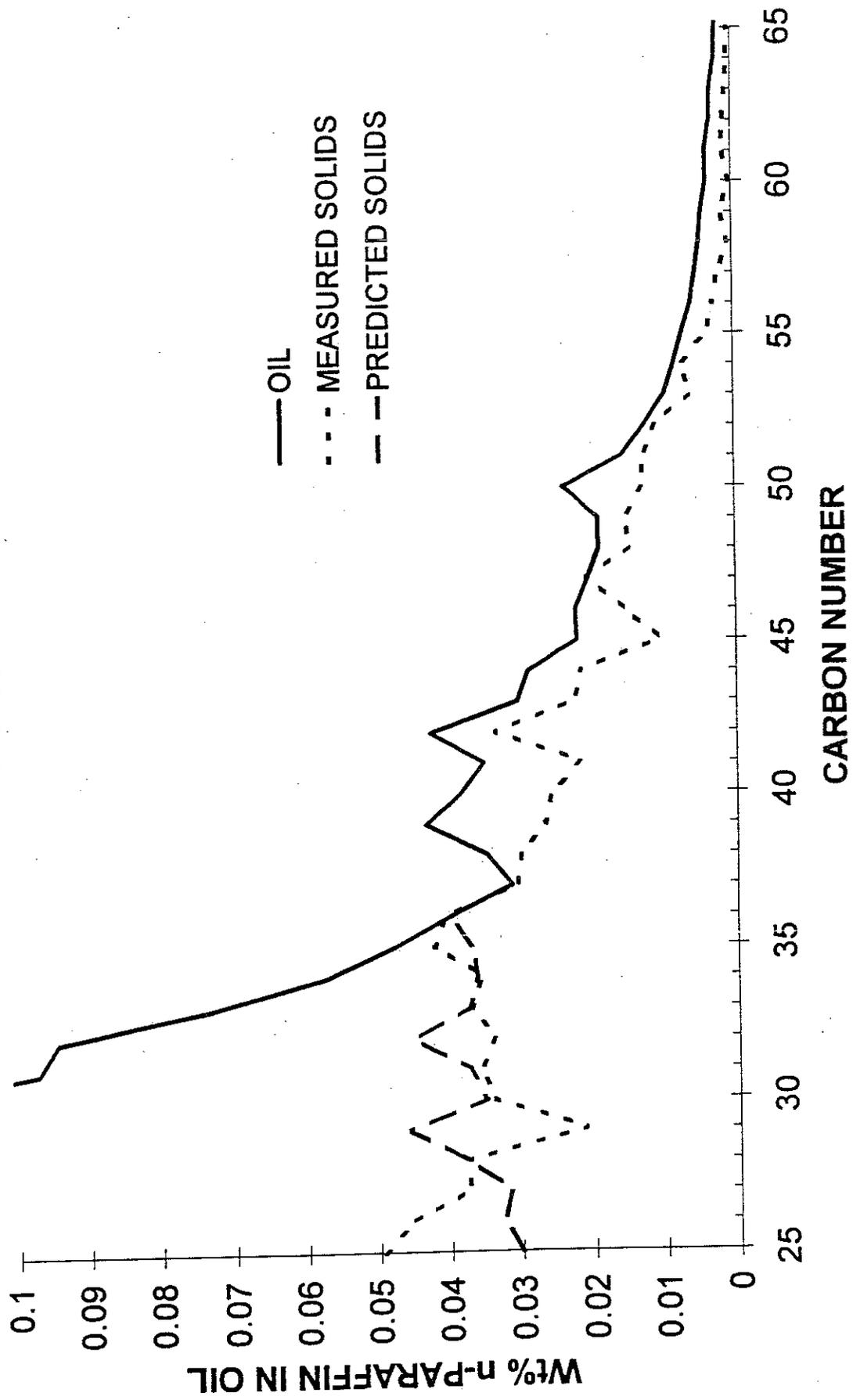
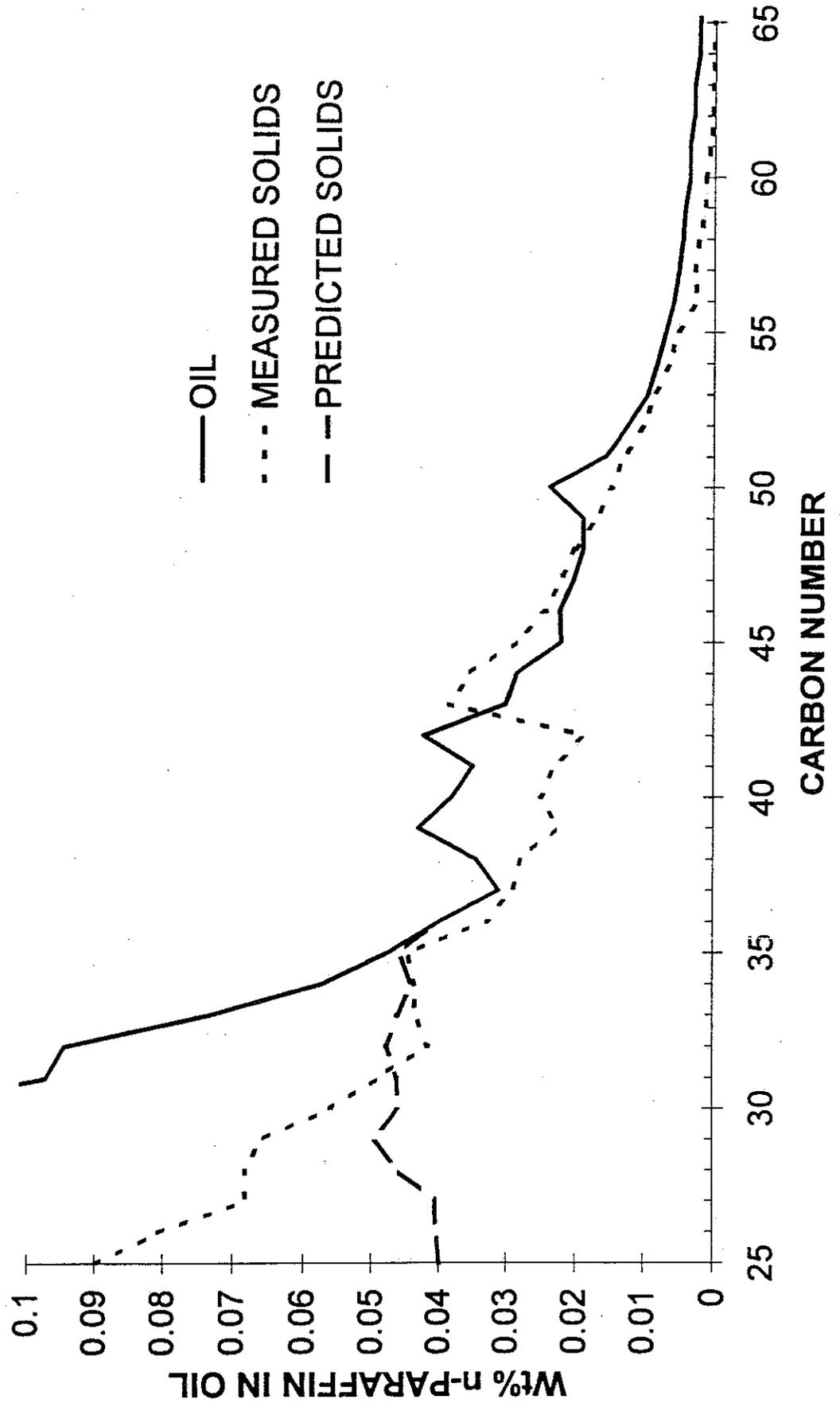
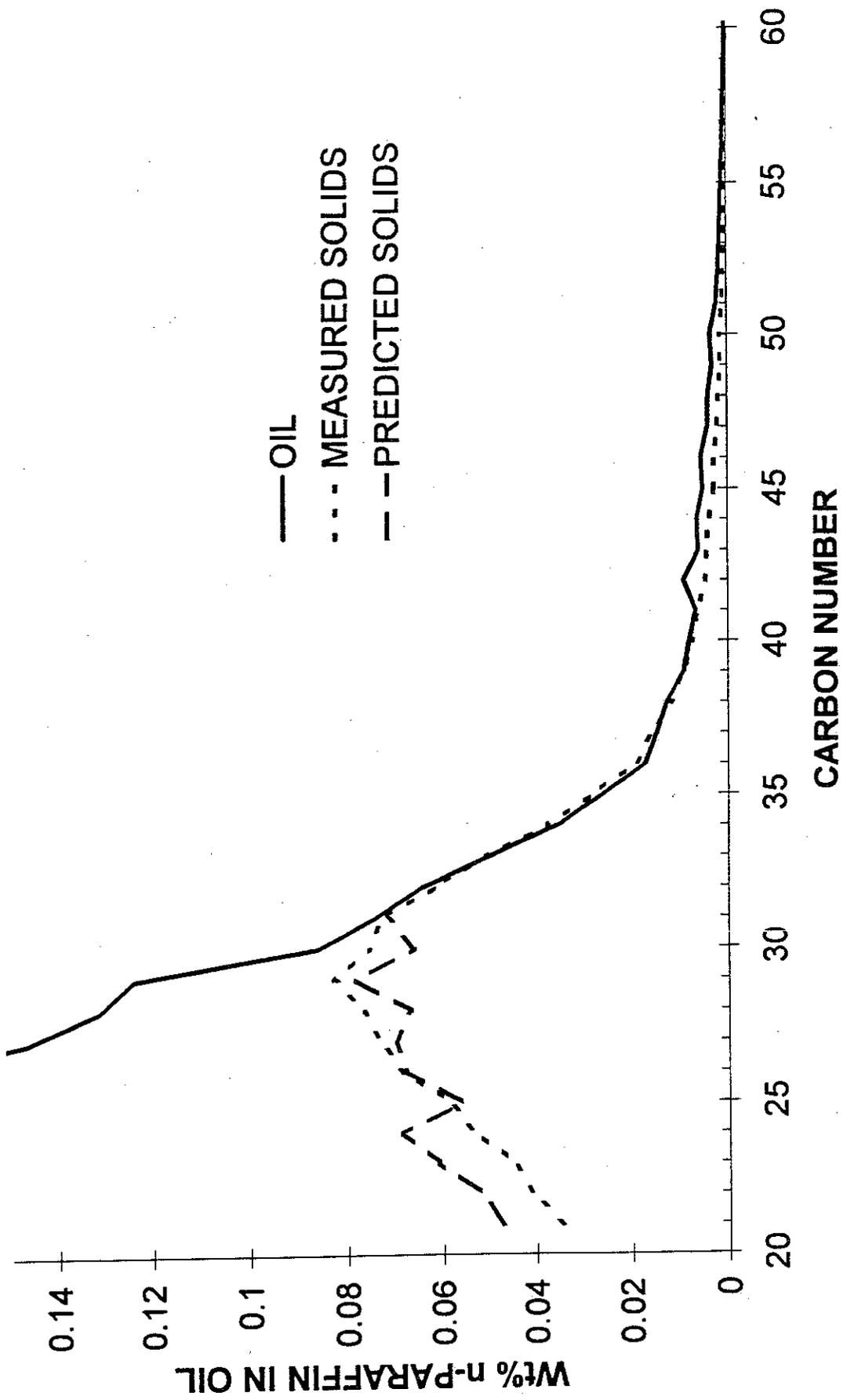


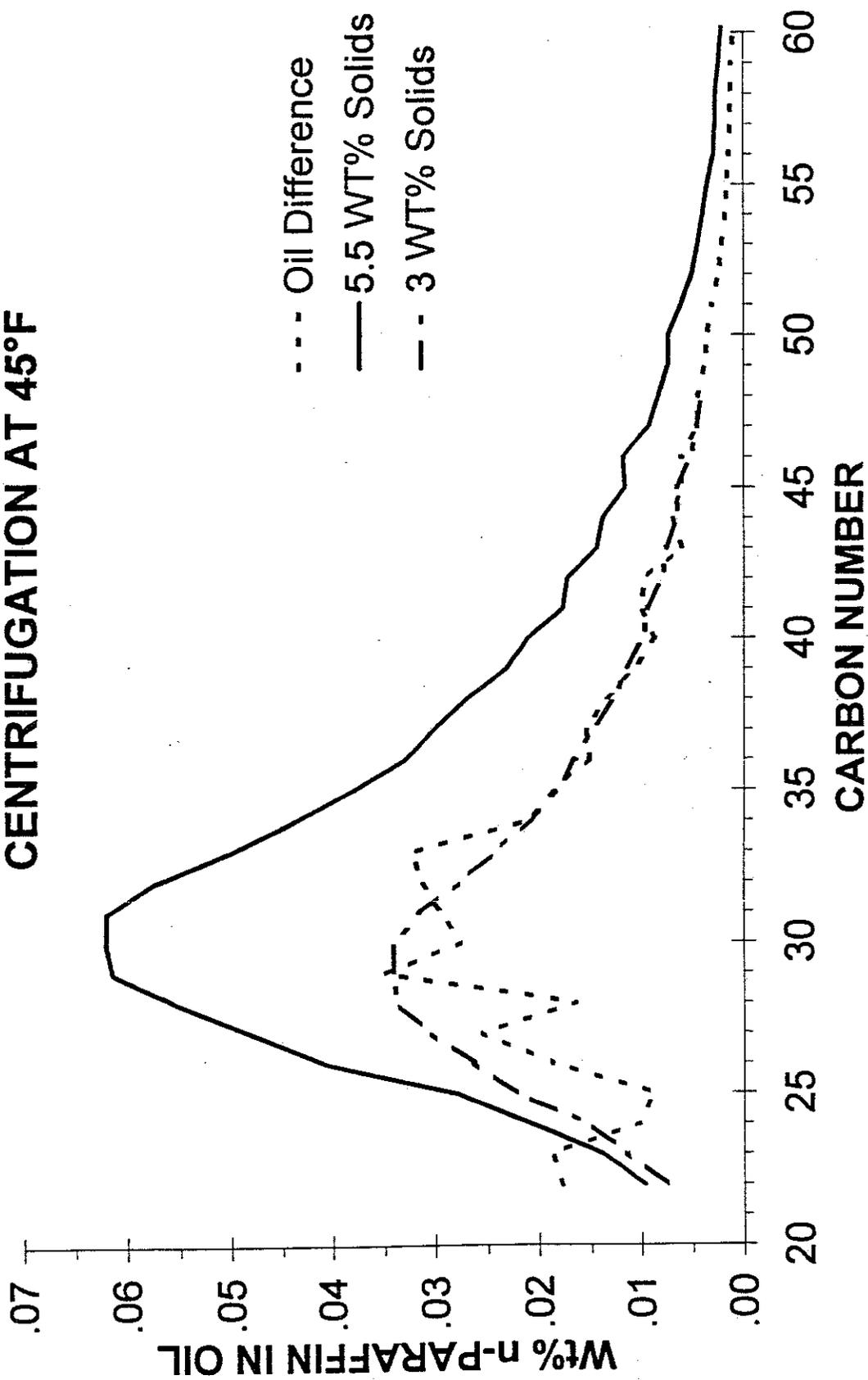
FIGURE 12. SOUTH PELTO AT 800 PSIG - FILTRATION
AT 50°F



**FIGURE 13. MAIN PASS
CENTRIFUGATION AT 40°F**



**FIGURE 14. COMPARISON OF SOLIDS DATA
GARDEN BANKS
CENTRIFUGATION AT 45°F**



**FIGURE 15. GARDEN BANKS
CENTRIFUGATION AT 45°F**

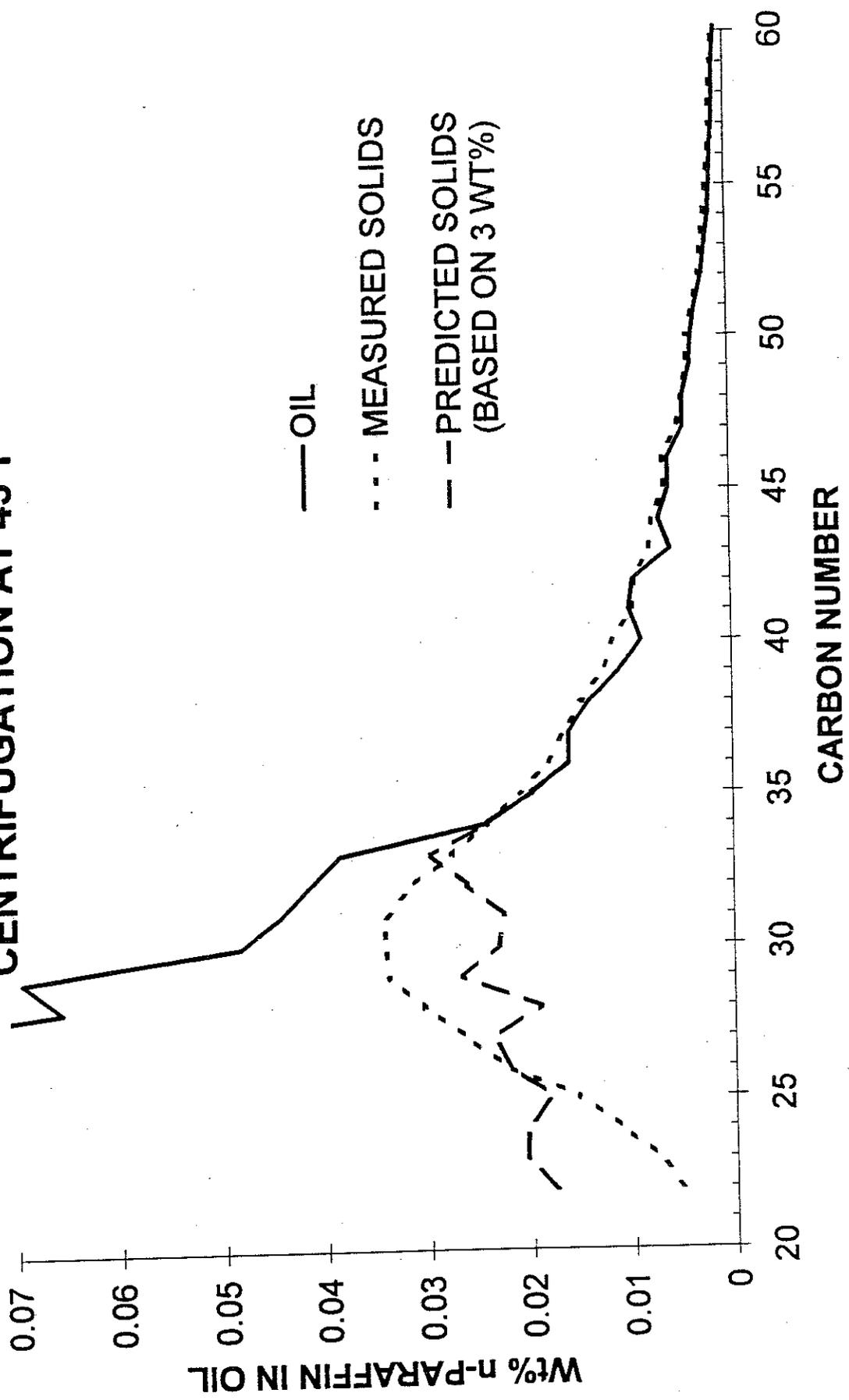


FIGURE 16. GARDEN BANKS AT 4000 PSIG
FILTRATION AT 24°F

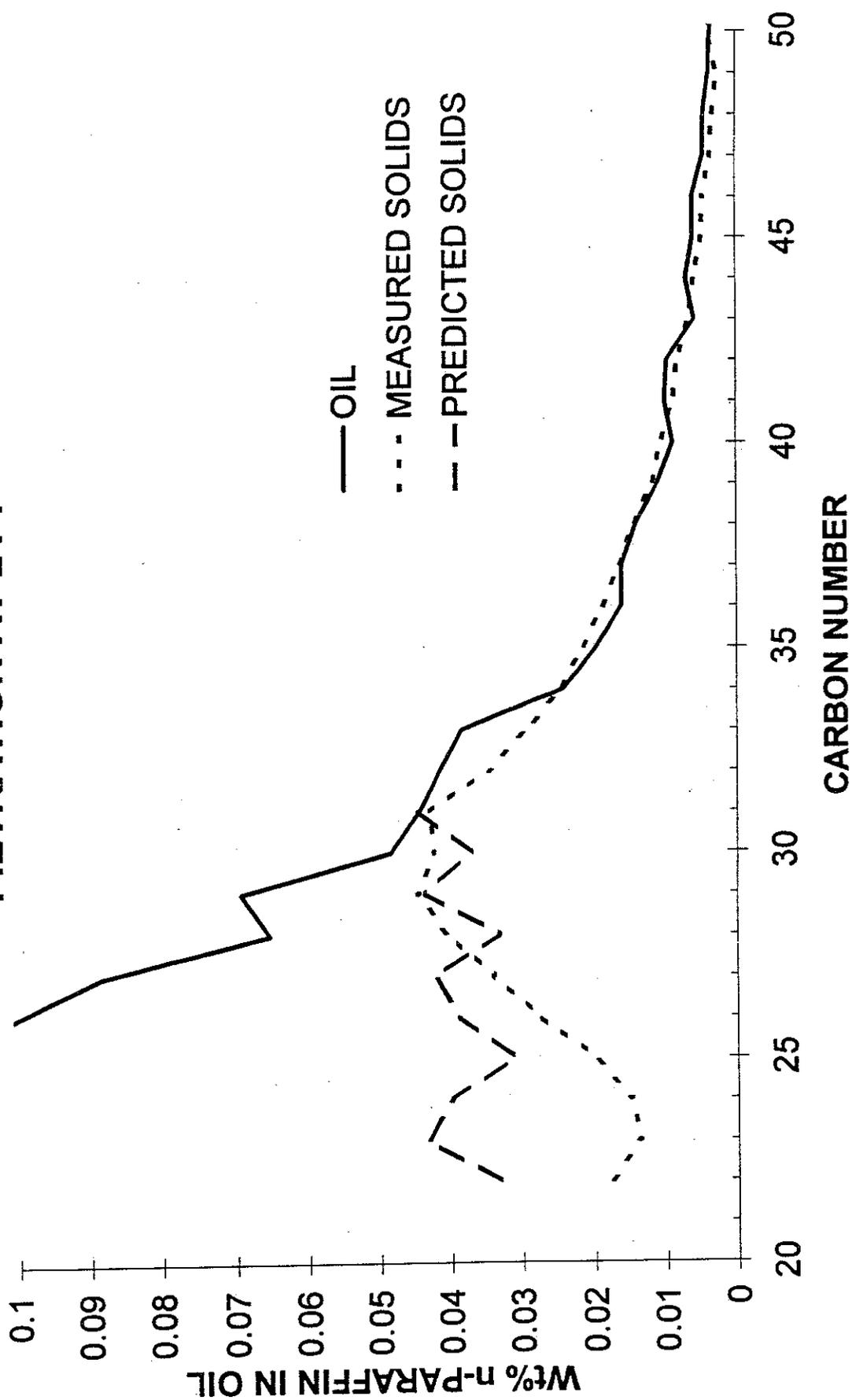


FIGURE 17. COMPARISON OF SOLIDS DATA GARDEN BANKS AT 8000 PSIG FILTRATION AT 25°F

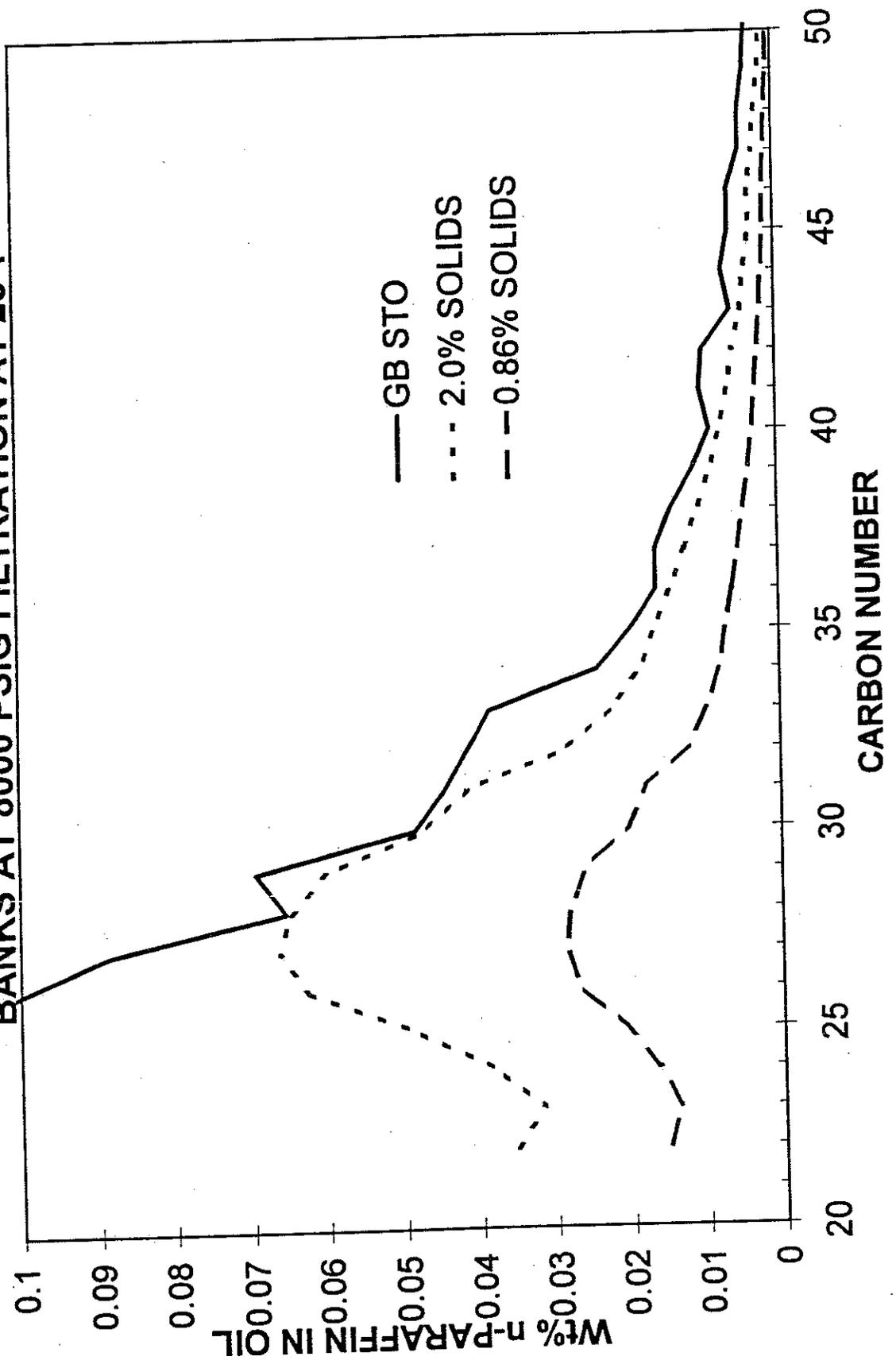


FIGURE 18. GARDEN BANKS AT 8000 PSIG
FILTRATION AT 25°F

