Sudan University of science & Technology

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Characterization of a Black oil PVT data using PVTi software from X-Field

تشخيص بيانات الضغط والحجم والحرارة لل(Black Oil) بإستخدام برنامج PVTi للحقل س

A project Submitted in partial fulfillment of the requirements of the degree of B.Sc. (honor) in petroleum Engineering

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PREFACE

(لا يـزال المرء عالـــماً ما دام يطلب العلم فإن ظن أنه علم فقد جهُـــل)

حديث شريـف

DEDICATION

We dedicate this humble work for our families for their endless encouragement support and for being a constant source for inspiration, we also want to express our gratitude for everything that they have done to us, you are truly the Lights of our life.

We also want to thank our teachers and our colleagues for being more than just a merely friends to us and for being by our side during the entire journey, we really can't thank all of you enough.

ACKNOLEDGMENT

At first we want to express our sincerely and deeply gratitude to **Mr.Sati Mergani** who guide us in every step throughout this project.

We also want to thank our dear co-supervisor **Mr.Eng.Mustafa Talb** for his devotion, support and for being a great example of what engineer should be, so thank you for everything that you have taught us.

ABSTRACT

Using the computer software PVTi a fluid definition was established from the PVT data obtained from the laboratory experiments, the laboratory data prepared to be a suitable input data so it can be used in PVTi. Using the PVTi a simulation process for the laboratory experiment was created, the fluid model created from the software was adjusted to represent the fluid sample more accurately using the regression process which reduces the error in the program's calculated value by changing the equation of state variables.

The adjusted fluid model used to export the PVTi Keyword, the exported Keywords include the Black Oil equilibration Keywords and Black Oil PVT table were generated using the same software.

Keywords: Black oil,PVTi,PVT data,Regression.

التجريد

بإستخدام برنامج الحاسوب PVTi تم عمل وصف للمائع (Black Oil) من بيانات الضغط والحجم والحرارة (PVT data) المتحصل عليها من التجارب المعملية،البيانات المعملية تم تجهيزها لكي يمكن إستخدامها في برنامج PVTi ،بإستخدام نفس البرامج تم عمل تمثيل حاسوبي للتجارب التتي تم اجراؤها في المعمل، نموذج المائع الذي تم توليده من خلال البرنامج تم تصحيحه ليقوم بتمثيل عينة المائع بصورة أفضل بإستخدام عملية (regression) والتي تقوم بتعديل الإخطاء للقيم المحسوبة بواسطة البرنامج عن طريق تتعديل متغيرات معادلة الحالة من داخل البرنامج.

نموذج المائع المصحح أستخدم لتصدير مخرجات PVTi (PVTi Keyword)،هذه المخرجات تشمل كل من كلمات الإتزان الأساسية (Black Oil equilibration Keywords) وجداول PVT (Black Oil PVT table) بإستخدام نفس البرنامج الحاسوبي.

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1.1 Introduction

To understand and predict the volumetric behavior of oil and gas reservoirs as a function of pressure, knowledge of the physical properties of reservoir fluids must be gained. These fluid properties are usually determined by laboratory experiments performed on samples of actual reservoir fluids. In the absence of experimentally measured properties, it is necessary for the petroleum engineer to determine the properties from empirically derived correlations.

A Black Oil reservoir fluid study-also known as PVT study- consists of a series of laboratory Procedures designed to provide values of the physical properties for the fluid sample. These procedures are performed with samples of reservoir liquid, the laboratory experiment data are then collected into a report, the laboratory experiments can be simulated using PVTi which can be described as an equation-of-state based program used for characterizing a set of fluid samples for use in ECLIPSE simulators.

1.2 Problem statement

Create adjusted fluid model that can represent the fluid sample accurately by using PVTi, and generate PVTi keywords.

1.3 Methodology

1. Prepare the laboratory data to a suitable input data for PVTi software using Microsoft build-in Text editor.
2. Establish a fluid definition by regression process.
3. Generating PVTi Keywords.

1.4 Objectives

The main objectives of this study are to perform the following:

1-Prepare the laboratory PVT data to be a suitable input data for PVTi.

2-Perform a fluid definition for the PVT data.

3-Generating ECLIPSE Black Oil PVT tables.

4-Generating ECLIPSE Black Oil equilibration Keywords.

5-Perform a simulation for data using PVTi.

Chapter Two

Chapter two

Literature Review and Background

2.1 Reservoir fluid properties

To understand and predict the volumetric behavior of oil and gas reservoirs as a function of pressure, knowledge of the physical properties of reservoir fluids must be gained. These fluid properties are usually determined by laboratory experiments performed on samples of actual reservoir fluids. In the absence of experimentally measured properties, it is necessary for the petroleum engineer to determine the properties from empirically derived correlations. Those properties include: formation volume factor of oil, solution gas-oil ratio, and total formation volume factor, oil viscosity, and gas oil ratio,(McCain, 1990).

2.1.1 Specific gravity

The specific gravity is defined as the ratio of the gas density to that of the air. Both densities are measured or expressed at the same pressure and temperature,(Ahmed , 2001)

$$\gamma_g = \frac{\rho_g}{\rho_{air}} \qquad (2\text{-}1)$$

For oil the liquid specific gravity, γ_o , is defined as the ratio of the density of the liquid to the density of water, both taken at the same temperature and pressure, (McCain ,1990).

$$\gamma_o = \frac{\rho_o}{\rho w} \qquad (2\text{-}2)$$

The petroleum industry also uses another gravity term called API gravity which is defined as:

$$^\circ API = \frac{141.5}{\gamma_O} - 131.5 \qquad (2\text{-}3)$$

2.1.2 Formation Volume Factor of Oil

FVF is defined as the volume of a mixture at specified pressure and temperature divided by the volume of a product phase measured at standard conditions, (Whitson & Brulé, 2000).

$$B = \frac{V(P,T)}{V(P_{SC},T_{SC})} \qquad (2\text{-}4)$$

The volume of oil that enters the stock tank at the surface is less than the volume of oil which flows into the wellbore from the reservoir. This Change in oil volume which accompanies the change from reservoir conditions to surface conditions is due to three factors, the most important factor is the evolution of gas from the oil as pressure is decreased from reservoir pressure to surface pressure. This causes a rather large decrease in volume of the oil when there is a significant amount of dissolved gas, the reduction in pressure also causes the remaining oil to expand slightly, but this is somewhat offset by the contraction of the oil due to the reduction of temperature. The change in oil volume due to these three factors is expressed in terms of the formation volume factor of oil. Oil formation volume factor is defined as the volume of reservoir oil required to produce one barrel of oil in the stock tank.

$$\text{BO} = \frac{\text{volume of oil + dissolved gas leaving reservoir at reservoir conditions}}{\text{volume of oil entering stock tank at standard conditions}} \qquad (2\text{-}5)$$

The units are barrels of oil at reservoir conditions per barrel of stock-tank oil, res bbl/STB. The relationship of formation volume factor of oil to reservoir pressure for typical black oil is given in Figure 1- 1 this figure shows the initial reservoir pressure to be above the bubble- point pressure of the oil. As reservoir pressure is decreased from initial Pressure to bubble-point pressure, the formation volume factor increases slightly because of the expansion of the liquid in the reservoir. A reduction in reservoir pressure below bubble-point pressure results in the evolution of gas in the pore spaces of the reservoir. The liquid remaining in the reservoir has less gas in solution and, consequently, a smaller formation volume factor,(McCain,1990).

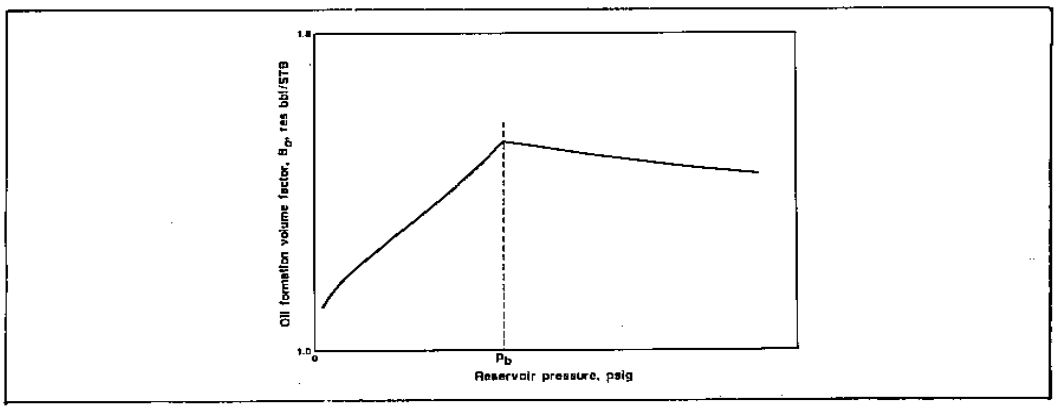

Figure 2.1: Typical shape of formation volume factor of black oil as a function of pressure at constant reservoir temperature (McCain, 1990).

2.1.3 Solution Gas-Oil Ratio

Solution gas-oil ratio is the amount of gas that evolves from the oil as the oil is transported from the reservoir to surface conditions, (McCain, 1990).

This ratio is defined in terms of the quantities of gas and oil which appear at the surface during production.

$$Rs = \frac{\text{volume of gas produced at surface at standard conditions}}{\text{volume of oil entering stock tank at standard condition}} \qquad (2\text{-}6)$$

The quantity of gas-forming molecules (light molecules) in the liquid phase at reservoir temperature is limited only by the pressure and the quantity of light molecules present. Black oil is said to be saturated when a slight decrease in pressure will allow release of some gas. The bubble-point pressure is a special case of saturation at which the first release of gas occurs On the other hand, when the black oil is above its bubble-point pressure, it is said to be undersaturated. An undersaturated oil could dissolve more gas (light molecules) if the gas were present. The quantity of gas dissolved in the oil at reservoir conditions is called Solution gas-oi1 ratio.

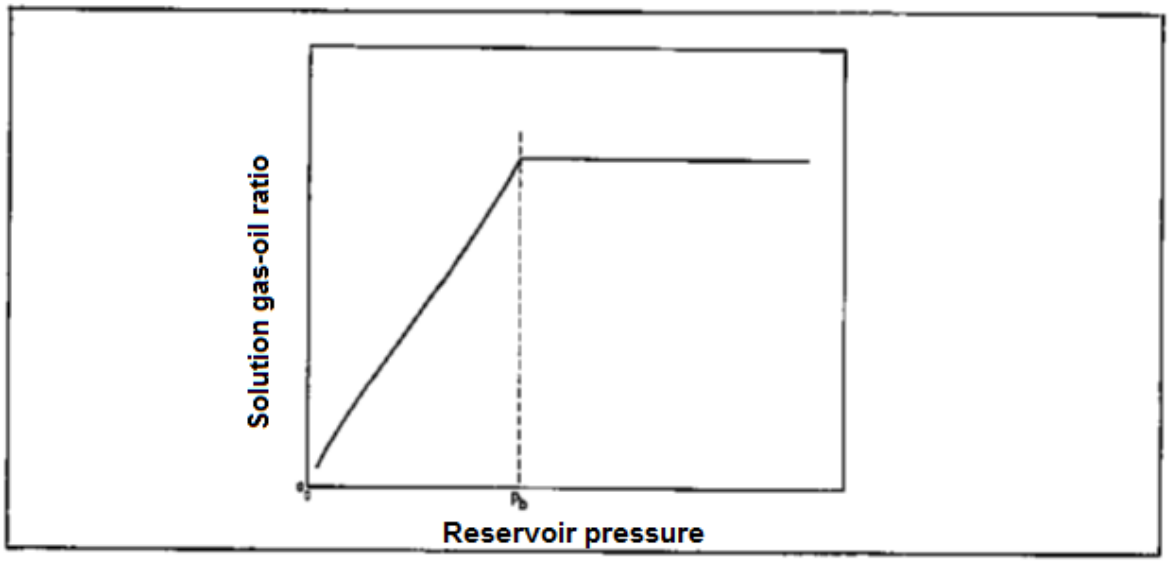

Figure 2.2: Typical shape of solution gas-oil ratio of black oil as a function of pressure at constant reservoir temperature (McCain, 1990).

In fig 1-2 the line is horizontal at pressures above the bubble-point pressure because at these pressures no gas is evolved in the pore space and the entire liquid mixture is produced into the wellbore. When reservoir pressure is reduced below bubble-point pressure, gas evolves in the reservoir, leaving less gas dissolved in the liquid.

2.1.4 Total Formation Volume Factor

Figure 2-3 show the volume occupied by one barrel of stock-tank oil plus its dissolved gas at bubble-point pressure. The figure also shows the volume occupied by the same mass of material after an increase in cell volume has caused a reduction in pressure. The volume of oil has decreased; however, the total volume has increased. The volume of oil at the lower pressure is Bo. The quantity of gas evolved is the quantity in solution at the bubble point, R_{sb} , minus the quantity remaining in solution at the lower pressure, R_s . The evolved gas is called free gas. It is converted to reservoir conditions by multiplying by the formation volume factor of gas, Bg. This total volume is the total formation volume factor,(McCain,1990).

$$B_t = B_O + B_g (R_{sb} - R_s) \qquad (2\text{-}7)$$

The gas formation volume factor must be expressed in units of res bbl/scf, and total formation volume factor has units of res bbl/STB. Figure 1-3 gives a comparison of total formation volume factor with the formation volume factor of oil. The two

formation volume factors are identical at pressures above the bubble-point pressure since no gas is released into the reservoir at these pressures. The difference between the two factors at pressures below the bubble-point pressure represents the volume of gas released in the reservoir.

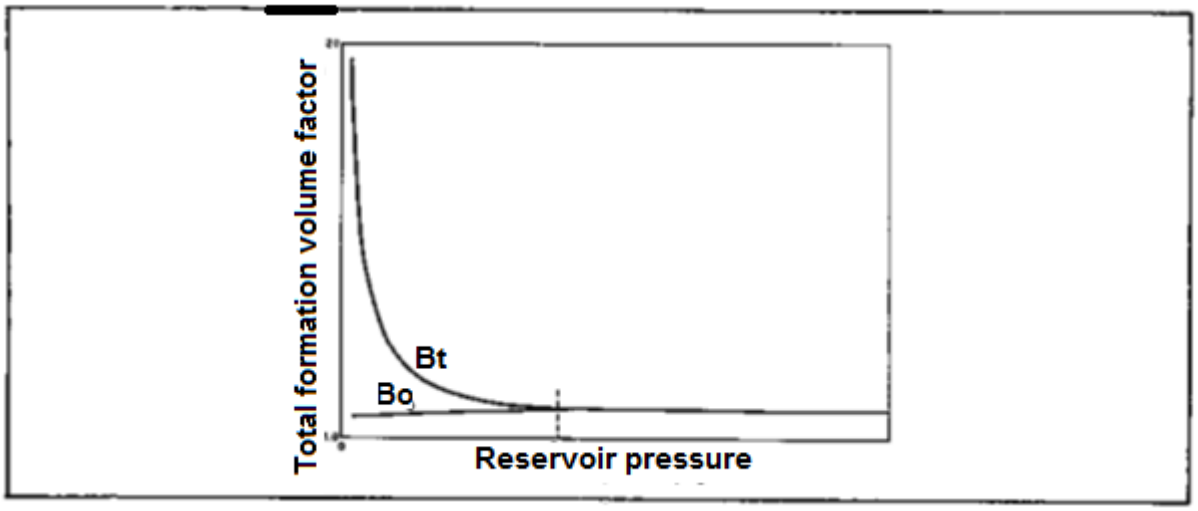

Figure 2.3: Typical shape of total formation volume factor of a black oil compared to shape of black oil formation volume factor at same conditions (McCain, 1990).

2.1.5 Viscosity

The coefficient of viscosity is a measure of the resistance to flow exerted by a fluid,(McCain,1990). .

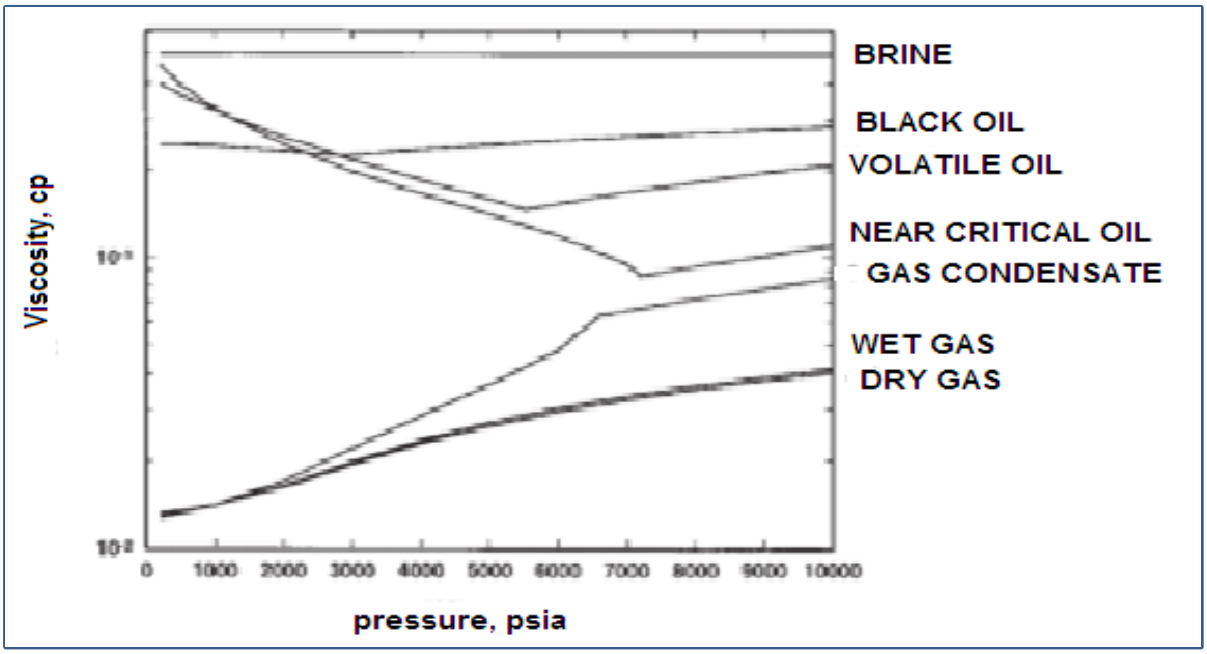

Figure 2.4: Solution gas/oil ratios as functions of pressure (Whitson & Brulé, 2000).

2.1.6 Gas oil ratio

When a reservoir mixture produces both surface gas and oil, the GOR, R_{go} defines the ratio of standard gas volume to a reference oil volume, (Whitson & Brulé, 2000).

$$\text{StockTank}: R_{go} = \frac{V_{g,sc}}{V_{o,sc}}\left[\frac{\text{scf}}{\text{STB}}\right] \quad (2\text{-}8)$$

$$\text{Seperator}: R_{sp} = \frac{V_{g,sc}}{V_{o,sp}}\left[\frac{\text{scf}}{\text{bbl}}\right] \quad (2\text{-}9)$$

2.2 Pressure-Temperature Diagram

The figure below shows a typical pressure-temperature diagram of a multi component system with a specific overall composition. Although a different hydrocarbon system would have a different phase diagram, the general configuration is similar.

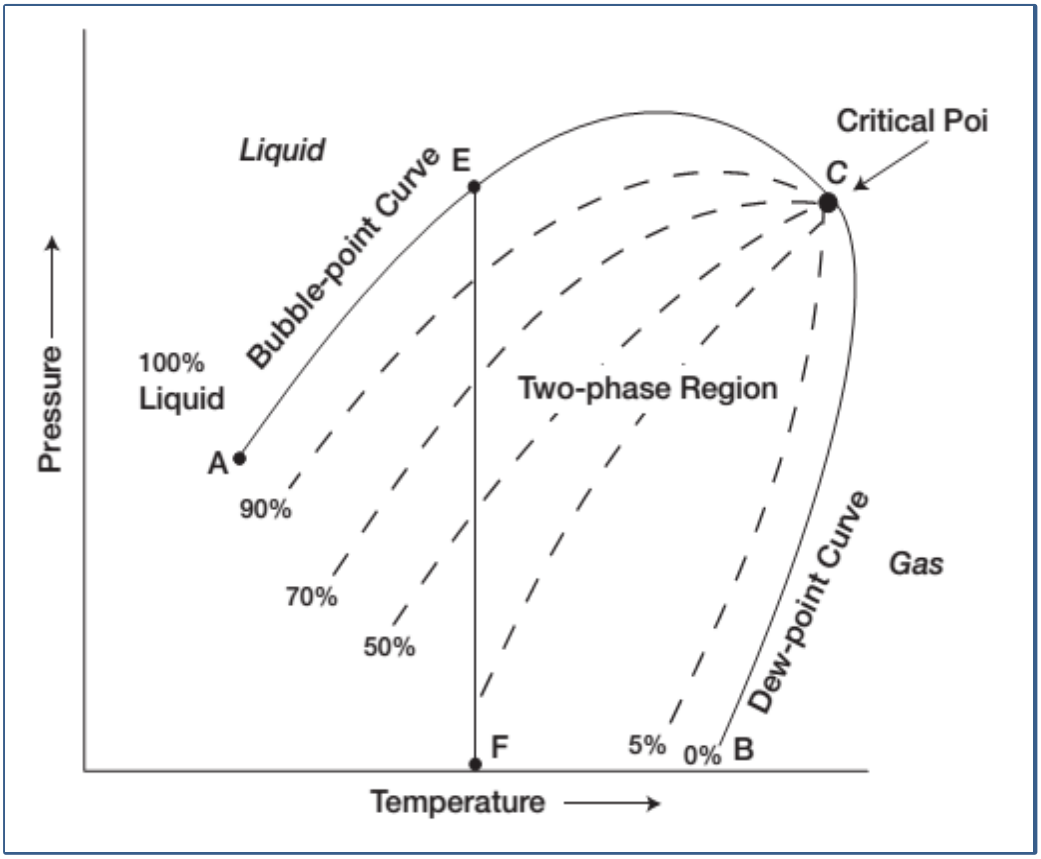

Figure 2.5: The typical pressure-temperature diagram for a multi component system (Ahmed, 2001).

These multi component pressure-temperature diagrams are essentially used to:

• Classify reservoirs.

• Classify the naturally occurring hydrocarbon systems

• Describe the phase behavior of the reservoir fluid

In The diagram critical point is referred to as the state of pressure and temperature at which all intensive Properties of the gas and liquid phases are equal (point C). At the Critical point, the corresponding pressure and temperature are called the Critical pressure pc and critical temperature Tc of the mixture. The region enclosed by the bubble-point curve and the dew-point curve (line BCA), where in gas and Liquid coexist in equilibrium, is identified as the phase envelope of the Hydrocarbon system.

The dashed lines within the phase diagram are called Quality lines. They describe the pressure and temperature conditions for Equal volumes of liquids, the bubble-point curve (line BC) is defined as the line separating the liquid-phase region from the two-phase region. The dew-point curve (line AC) is defined as the line separating the vapor-phase region from the two-phase region. In general, reservoirs are conveniently classified on the basis of the location of the point representing the initial reservoir pressure pi and temperature T with respect to the pressure-temperature diagram of the reservoir fluid.

2.2.1 Phase diagram for black oil

Black oils consist of a wide variety of chemical species including large, heavy nonvolatile molecules. The phase diagram predictably the covers a wide temperature range, the critical point is well up the slope of the phase envelope.

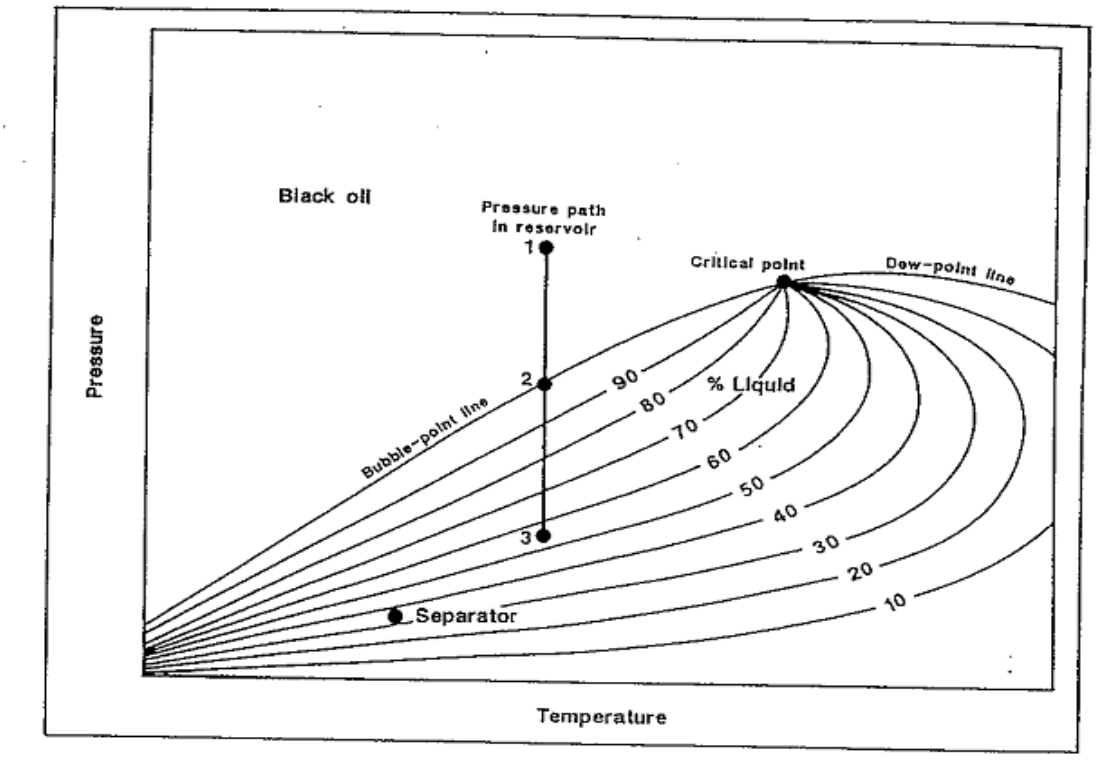

Figure 2.6: Phase diagram of a typical black oil (McCain ,1990).

The phase diagram of a typical oil is shown in figure 2-6 .the line within the phase envelope represent constant liquid volume measured as present of the total volume. Quality lines for the Black Oil case are spaced fairly evenly within the envelope

2.2 PVTi software

Schlumberger Company the owner of the PVTi program defines PVTi as: compositional PVT equation-of-state based program used for characterizing a set of fluid samples for use in our ECLIPSE simulators,(Schlumberger, 2008).

PVTi can be used to simulate experiments that have been performed in the lab on a set of fluid samples and then theoretical predictions can be made of any observations that were performed during a lab experiment, any differences between the measured and calculated data are minimized using a regression facility which adjusts various Equation of State parameters. This tuned model is then exported in a form suitable for one of ECLIPSE simulators

2.2.1 Black Oil model and Compositional model

black-oil model

The black-oil model is that a certain volume of gas (defined by the value of Rs) has dissolved in the oil. The dissolved gas is the same as the free gas in contact with the oil. If any gas is injected into the reservoir, it too will be the same gas as the dissolved gas and the gas cap gas. Any produced gas will also be the same. All these gases will have the same physical properties,(Schulmeberger, 2005).

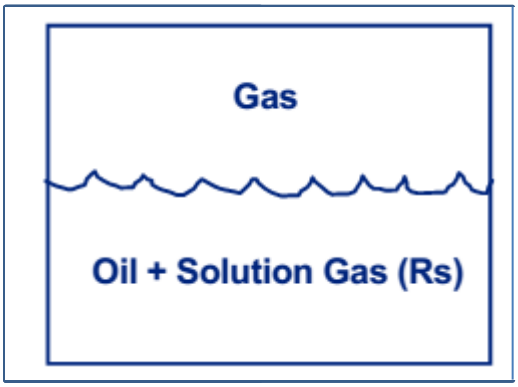

Figure 2.7 Black oil model,(schlumberger,2005).

The Compositional model

The compositional model is very different than the black oil model. Both the oil phase and the liquid phase are made up of the different amounts of the same components. Methane for instance will be present in both phases, but the gas phase may be 80% methane whereas the oil phase could be only 30% methane. The composition of injected gas could be completely different, for instance injected gas could be 100% methane. The composition of the produced gas is likely to vary with time. The physical properties of all these gases will be different,(Schulmeberger, 2005).

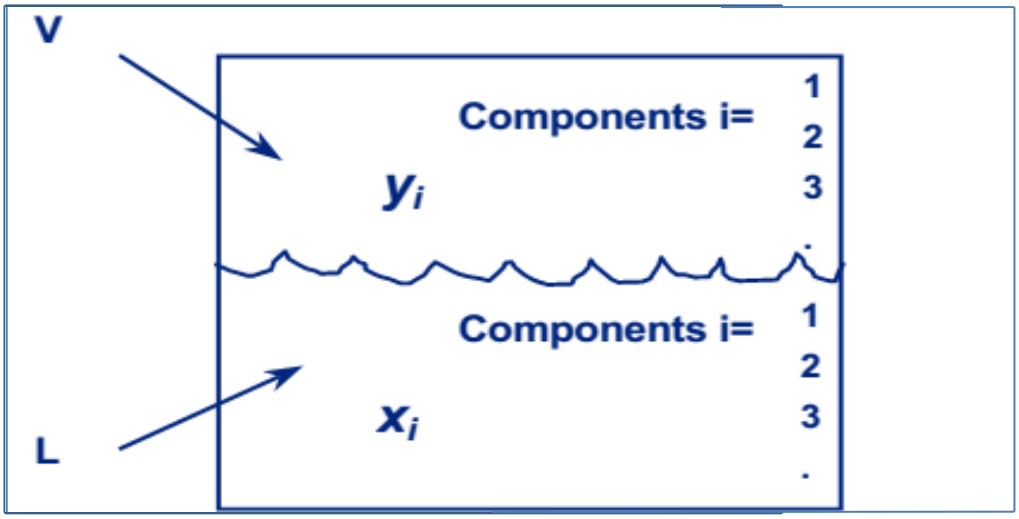

Figure 2.8: Compositional model,(Schlumbergre, 2005).

Both of the black oil model and compositional model consider that there are two phases but the compositional model is more accurate than the black oil model since it consider the composition of each phase.

2.3 Equations of state

An analytic expression relating pressure to temperature and volume is called an Equation of State (Schlumberger, 2005).

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2.3.1 Equation of State for Ideal Gas

Gas is defined as homogeneous fluid of low density and low viscosity, which has neither independent shape nor volume but expand to fill completely the vessel in which it is contained, (McCain, 1990).

An ideal gas has these properties:

1. The volume occupied by the molecules is insignificant with respect to the volume occupied by the gas.

2. There are no attractive or repulsive forces between the molecules or between the molecules and the walls of the container.

3. All collisions of molecules are perfectly elastic, that is, there is no loss of internal energy upon collision,(Schlumberger,2008).

Boyle's Equation

Boyle experimentally observed that the volume of an ideal gas is inversely proportional to pressure for a given mass of gas when temperature is maintained constant. This may be expressed as:

$V \propto \frac{1}{P}$ or PV =constant (2-10)

Charles' Equation

Charles discovered that the volume of an ideal gas is directly proportional to temperature for a given mass of gas when pressure is maintained constant. Symbolically:

$V \propto T$ or $\frac{V}{T}$ =constant (2-11)

Avogadro's Law

Avogadro's law states that, under the same conditions of temperature and pressure, equal volumes of all ideal gases contain the same number of molecules. This is equivalent to the statement that at a given temperature and pressure one molecular weight of any ideal gas occupies the same volume as one molecular weight of any other ideal gas. There are 2.73 X 10^{26} molecules per pound mole of ideal gas.

The Equation of State for an Ideal Gas, The equations of Boyle, Charles, and Avogadro can be combined to give an equation of state for an ideal gas:

$PV = \frac{m}{M}RT$ or as $PV = \frac{RT}{M}$ (2-12)

This expression is known by various names such as the ideal Gas Law, the General Gas Law, or the Perfect Gas Law, the numerical value of the constant R Depends on the units used to express the variable.

2.3.2 Equation of State for real gases

One of the limitations in the use of the compressibility equation of state to describe the behavior of gases is that the compressibility factor is not constant. Therefore, mathematical manipulations cannot be made directly but must be accomplished through graphical or numerical techniques.

2.3.2.1 Van der Waals' Equation of State

One of the earliest attempts to represent the behavior of real gases by an equation was that of van der Waals (1873),He proposed the Following equation:

$$\left(p + \frac{a}{v^2}\right)(v - b) = RT \Rightarrow \frac{pv}{RT} = Z = \frac{v}{v - b} - \frac{a}{vRT} \quad (2\text{-}13)$$

The numerical constants in the equations (a, b) are referred to as the Ω_a Ω_b, For Van der Waals EoS:

$\Omega_a = \frac{27}{64}$

$\Omega_b = \frac{1}{8}$

The critical Z-factor of the Van der Waals EoS is 0.375. This value is considerably larger than that of real hydrocarbon components, which typically have a Zc<0.29, this equation differs from the ideal gas equation by the addition of the term a/VM2 to pressure and the subtraction of the constant b from molar volume.

The term a/VM2 represents an attempt to correct pressure for the force of attraction between the molecules, The actual pressure exerted on the walls of the vessel by real gas is less, by the amount a/VM2, than the pressure exerted by an ideal gas The constant b is regarded as the correction to the molar volume due to the volume occupied by the molecules. Constants a and b are characteristic of the particular gas, whereas R is the universal gas constant, The limitation of this equation is that is not valid for high pressure,(Schlumberger,2008).

2.3.2.2 Redlich-Kwong Equation of State

Redlich and Kwong proposed an equation of state which takes into account the temperature dependencies of the molecular attraction term:

$$P = \frac{RT}{(V-b)} - \frac{a}{V(V+b)} \qquad (2\text{-}14)$$

Where the a parameter is now a function of temperature, for the RK Eos $a = a'T^{-1/2}$ where a' is a constant. The value of a' is set by conditions imposed at the critical point. More generally, the a parameter can be written as a=a'f(T) so that at the critical point a_c =a'f(Tc)

$a = a_c \frac{f(T)}{f(T_c)}$, Usually the ratio f(T)/f(Tc) is denoted by α, and α→1 as T→Tc. For the basic Redlich-Kwong EoS, $\alpha = T_r^{-1/2}$

Where Tr is the reduced temperature, Tr=T/Tc.

The constant for RK Eos are:

Zc =0.333

$\Omega_a = 0.42748$

$\Omega_b = .08664$

2.3.2.3 Soave Addition to RK EoS

Several authors improved on the Redlich-Kwong EoS by introducing additional functionality into the α parameter. In particular, Soave (1972) made αa function of Acentric factor-measure of the non-sphericity of a molecule and thus of non-ideal behavior-as well as reduced temperature, i.e.:

$$\alpha^{1/2} = 1 + (0.480 + 1.574\omega - 0.17v\omega^2)(1 - T_r^{1/2}) \qquad (2\text{-}15)$$

$$\omega = -(\log_{10} P_r^s + 1) \text{ at Tr=0.7} \qquad (2\text{-}16)$$

Where P_r^s represents the reduced vapor pressure at a reduced temperature of Tr=0.7, the values of $Z_c, \Omega_a,$ and Ω_b for the SRK equation are equal to those of the original RK EoS.

ω>0.49

2.3.2.4 Peng Robinson Equation of State

Peng and Robinson proposed a slightly different form of the molecular attraction, the equation is

$$P = \frac{RT}{v-b} - \frac{a(T)}{v(v+b)+b(v-b)} \qquad (2\text{-}17)$$

$$a = 0.45724\frac{R^2 T_c^{\,2}}{P_c}\alpha(T)$$

$$b = 0.07780\frac{RT_c}{P_c}$$

$$\alpha(T) = \left[1 + m\left(1 - Tr^{1/2}\right)\right]^2$$

$$m = 0.37464 + 1.54226\omega - 0.26992\omega^2$$

For components with large Acentric factors, i.e., plus fractions with ω>0.49 the ω term can be modified to:

$(0.379642 + 1.48503\,\omega - .164423\,\omega^2 + 0.016666\,\omega^3)$.

The value of Zc=0.307 is a significant improvement over that of the RK and SRK EoS, and consequently the PR EoS predicts liquid properties significantly better. However, this value is still larger than the Zcs of real hydrocarbons, which are always less than 0.29.

2.3.2.5 Zudkevitch-Joffe EoS

Another attempt to improve on the original RK EoS was made by Zudkevitch and Joffe who made the Ω_a, Ω_b constants into functions of temperature, i.e.:

$\Omega_a(T), \Omega_b(T)$.

2.3.2.6 The 3-Parameter EoS

The 3-parameter EoS introduces a third parameter, usually referred to as c, and treated as a volume shift:

$$V^{(3)} = V^{(2)} - \sum_{i=1}^{N} x_i c_i \qquad (2\text{-}18)$$

In this equation $V^{(2)}$ is the volume predicted by the 2-parameter EoS and $V^{(3)}$ is the corrected 3-parameter volume. This shift in volume leads to a reduced Z-factor.

Values of the coefficients c_i can be determined by comparing the liquid molar volume V of a component at standard conditions with that predicted by the two parameter at the same conditions. The difference defines the c_i for that component:

$$c_i = V_i^{Eos}(P_{st}, T_{st}) - V_i^{Obs}(P_{st}, T_{st}) \qquad (2\text{-}19)$$

$$s_i = \frac{c_i}{b_i} \qquad (2\text{-}20)$$

$$b_i = \Omega_{b,i} \frac{RT_{c,i}}{P_{c,i}} \qquad (2\text{-}21)$$

2.4 Viscosity correlation

The EoS will predict static equilibrium properties, but not flowing properties such as viscosity in PVTi the correlation that are available for estimating viscosity are Lohrenz, Bray and Clark (LBC) and Pedersen et al,(Shlumberger, 2008).

2.4.1 Lohrenz, Bray and Clark

The most widely used correlation for the prediction of liquid and vapor viscosities in reservoir simulators is that due to Lohrenz, Bray and Clark (LBC):

the viscosity being related to a fourth-degree polynomial in reduced density,

$$\rho_r = \frac{\rho}{\rho_c} \tag{2-22}$$

$$\left[\left(\mu - \mu^*\right)\xi + 10^{-4}\right]^{1/4} = a_1 + a_2\rho_r + a_3{\rho_r}^2 + a_4{\rho_r}^3 + a_5{\rho_r}^4 \tag{2-23}$$

Where

$a_1 = +0.1023000$
$a_2 = +0.0233640$
$a_3 = +0.0585330$
$a_4 = -0.0407580$
$a_5 = +0.0093324$

And μ^* is the low-pressure gas mixture viscosity and ξ the viscosity-reducing parameter, which for a fluid mixture, is given by:

$$\xi = \left[\sum_{i=1}^{N} z_i T_{ci}\right]^{1/6}\left[\sum_{i=1}^{N} z_i M_{\omega i}\right]^{-1/2}\left[\sum_{i=1}^{N} z_i P_{ci}\right]^{-2/3} \tag{2-24}$$

The critical density ρ_c is evaluated from:

$$\rho_c = V_c^{-1} = \left(\sum_{i=1, i\neq c_{7+}}^{N} (z_i V_{cc_{7+}}\right)^{-1} \tag{2-25}$$

Where the critical volume of the plus fraction is found from:

$$V_{cc_{7+}} = 21.573 + 0.015122 M_{\omega c_{7+}} - 27.656\gamma_{c_{7+}} + 0.070615 M_{\omega c_{7+}}\gamma_{c_{7+}} \tag{2-26}$$

The dilute gas mixture viscosity as given by Herning and Zippener:

$$\mu^* = \left[\sum_{i=1}^{N} z_i \eta_i^* M_{\omega i}^{1/2}\right]\left[\sum_{i=1}^{N} z_i M_{\omega i}^{1/2}\right]^{-1} \tag{2-27}$$

Where the dilute gas viscosities of the individual components, μ_i^* are derived from expressions due to Stiel and Thodos:

$$\mu_i^* = 34\times 10^{-5}\frac{1}{\xi_i} T_{ri}^{0.94} \quad T_{ri} < 1.5 \tag{2-28}$$

$$\mu_i^* = 17.78 \times 10^{-5} \frac{1}{\xi_i} (4.58 T_{ri} - 1.67)^{0.625} \quad T_{ri} > 1.5 \qquad (2\text{-}29)$$

Where:

$$\xi_i = T_{ci}^{1/6} M_{\omega i}^{-1/2} P_{ci}^{-2/3} \qquad (2\text{-}30)$$

2.4.2 Pedersen et al

Viscosities can be calculated from a modified form of the corresponding states method. A group of substances obey the corresponding states principle if the functional dependence of the reduced viscosity, μ_r on reduced density and temperature, ρ_r and T_r is the same for all components within the group, namely:

$$\mu_r(\rho, T) = f(\eta_r, T_r) \qquad (2\text{-}31)$$

Pedersen modified the CSM to use the acentric factor, which is related to the shape of the molecule.

2.5 Reservoir Fluid Studies

A black oil reservoir fluid study consists of a series of laboratory Procedures designed to provide values of the physical properties required in the calculation method known as material balance calculations. There are five main procedures in the black oil reservoir fluid study. These procedures are performed with samples of reservoir liquid, (McCain, 1990).

A sample which is representative of the liquid originally in the reservoir must be obtained for the laboratory work. Obtaining a representative sample of the reservoir liquid requires great care in both conditioning the well and in the sampling technique. Samples can be obtained in two ways.

1- A bottom-hole sample or a subsurface sample.

In this method the well is shut in, and the liquid at the bottom of the wellbore is sampled.

2- Separator samples or surface samples

In this method, production rate is carefully controlled, and separator gas and separator liquid are sampled.

The five major procedures in the reservoir fluid study or PVT tests are: composition measurement, flash vaporization, differential vaporization, and separator tests, and oil viscosity measurement. The results of these procedures are called a reservoir fluid study. Often the term PVT study is used.

2.5.1 Composition measurement

Determining the composition of every one of the hundreds of different chemical species present in black oil is impossible. Even determining the composition of a major fraction of the crude is difficult. In every case the compositions of the light components are determined, and all of the heavier components are grouped together in a plus component. The plus component consists of hundreds of different chemical species the remaining components are lumped together as heptanes plus (C7+). The apparent molecular weight and specific gravity of the heptanes plus fraction is measured in an attempt to characterize its properties.

2.5.2 Constant composition expansion

In the constant composition expansion test a sample of oil is placed in an equilibrium cell at a pressure equal or greater than the initial reservoir pressure. The pressure is reduced incrementally by expanding the fluid volume. The total volume V_t, is measured at each pressure stage.

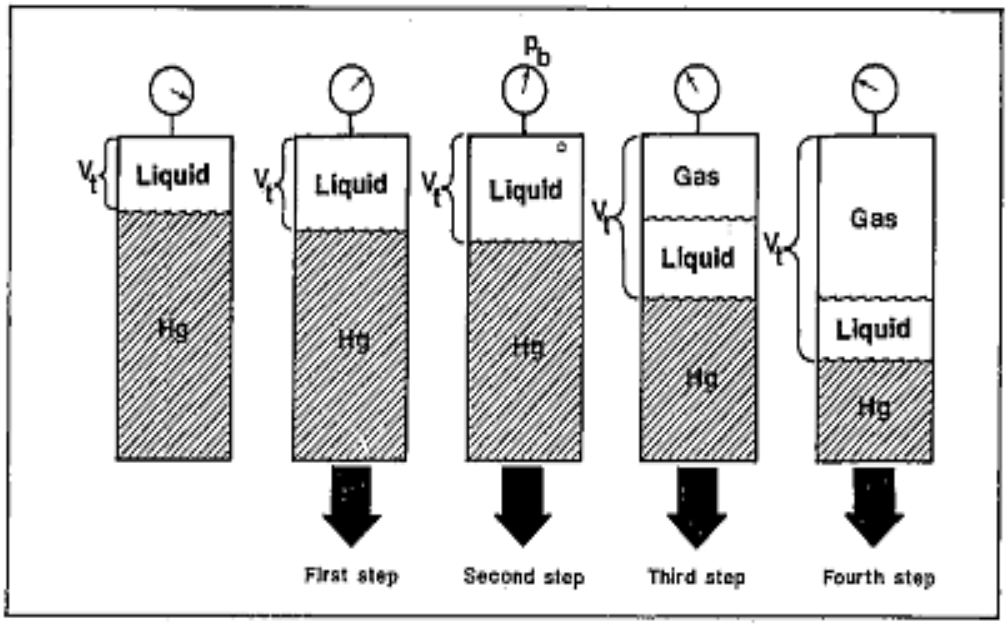

Figure 2.9**:** Laboratory flash vaporization procedure, (McCain, 1990).

The test is also known as flash liberation, flash expansion and pressure volume relation. For an oil sample, the CCE experiment is use to determine bubble point pressure, under saturated-oil density, isothermal oil compressibility, and two-phase volumetric behavior for pressure below the bubble point. Typical PVT test data as reported by a laboratory is given in Table 1.1. The laboratory data is often evaluated, smoothed, and extrapolated by a dimensionless function Y defined as:

$$Y = [(P_b - P)/P]/[(V_t - V_b)/V_b] \qquad (2\text{-}22)$$

where the subscript b, refers to the bubble point conditions.

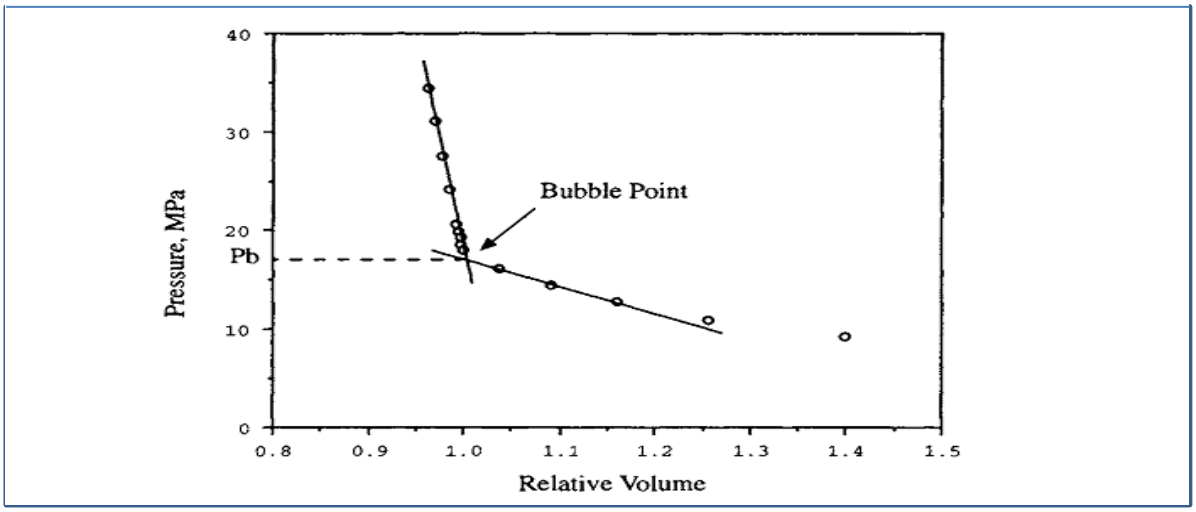

Figure 2.10: Pressure-volume plot to determine the bubble point pressure, (McCain, 1990).

2.5.3 Differential Liberation Expansion

In the differential vaporization or liberation test, the oil pressure is reduced below its bubble point at the reservoir temperature by expanding the system volume. All the evolved gas is then expelled at constant pressure by reducing the equilibrium cell volume the procedure is repeated in 10-15 pressure stages down to the atmospheric pressure at every stage the remaining oil volume, the expelled gas volume at the cell, the standard conditions and the gas specific gravity are measured.

.

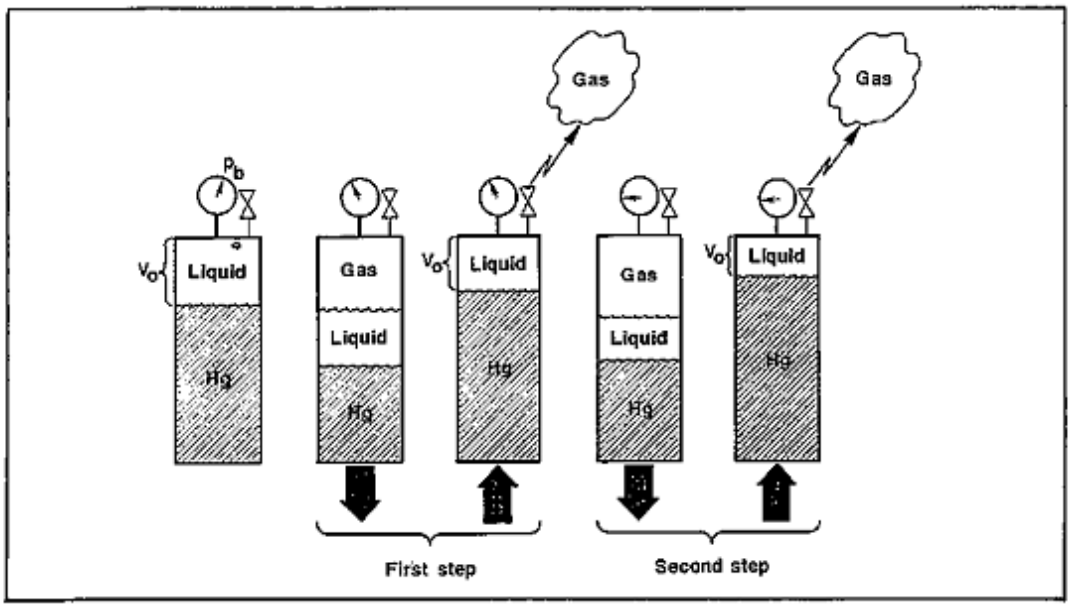

Figure 2.11: Typical differential Liberation Test, (McCain, 1990).

The remaining oil volume, at the atmospheric pressure, at the end of the test is referred to as the residual oil. The volume of oil at each stage is reported by the relative oil volume, Bod, defined as the ratio of oil volume/residual volume. The total volume of gas evolved at each pressure and all previous pressure stages, at the standard conditions (sc), is calculated and converted to the volume at the test pressure, using the prevailing Bg, and is added to the oil volume to obtain the total (two-phase) volume. The total volume is reported by the relative total volume, Btd, defined as the ratio of total volume/residual volume. The evolved gas is reported by the solution gas to oil ratio, Rsd, as the defined as difference between the total gas evolved at the atmospheric Pressure (the final stage), and each pressure stage divided by the residual oil volume, in barrels.

2.5.4 Separator Tests

A sample of reservoir liquid is placed in the laboratory cell and brought to reservoir temperature and bubble-point pressure. Then the liquid is expelled from the cell through two stages of separation. The vessel representing the stock tank is a stage of separation if it has lower pressure than the separator. Pressure in the cell is held constant at the bubble point by reducing cell volume as the liquid is expelled. The temperatures of the laboratory separator and stock tank usually are set to represent average conditions in the field.

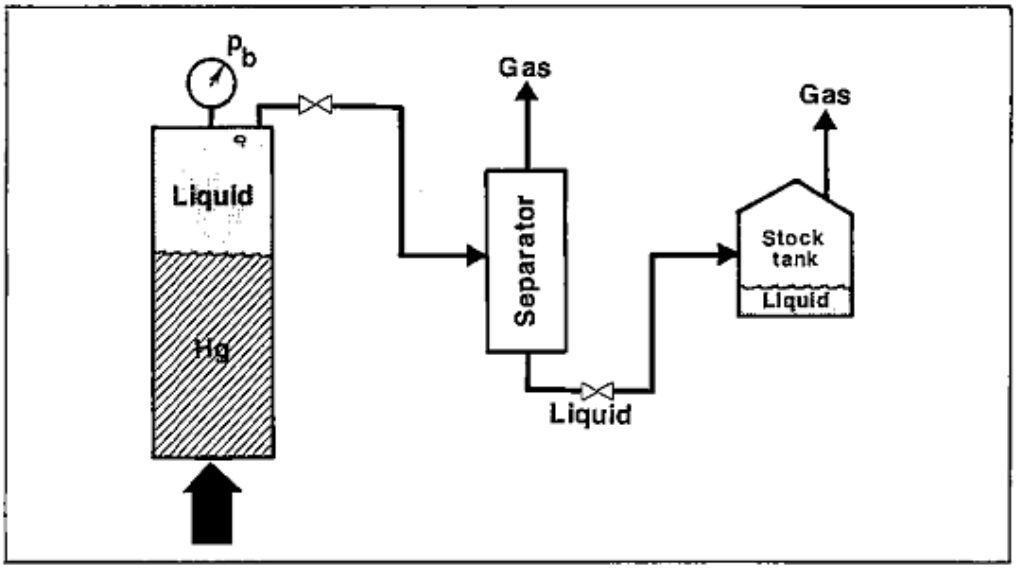

Figure 2.12: Separator test,(McCain, 1990)

The specific gravities of the separator gas and stock-tank gas are measured. Often the composition of the separator gas is determined. Finally, a separator volume factor is calculated. It is the volume of separator liquid measured at separator conditions divided by the volume of stock-tank oil at standard conditions. The separator test usually is repeated for various values of separator pressure.

2.5.5 Oil Viscosity

Oil viscosity is measured in a rolling-ball viscometer or a capillary viscometer, either designed to simulate differential liberation. Measurements are made at several values of pressure in a stepwise process .The liquid used in each measurement is the liquid remaining after gas has been removed at that pressure.

Chapter Three

Chapter three

Methodology

3.1 Introduction

PVTi is an Equation of State based package for generating PVT data from the laboratory analysis of oil and gas samples, this chapter discuss the PVT data usage using the PVTi software.

The main experiments performed by the PVT laboratory on the fluid sample are:

• Single-point experiments, such as Psat

• Pressure depletion experiments, such as Constant composition expansion.

The laboratory may also perform

• Swelling tests

• Vaporization tests

The two fundamental experiments performed on Back oil systems are the Differential liberation experiment, and the constant composition expansion experiment, often reduced and referred to by their initials, DL and CCE respectively. For the purpose of this study the Available laboratory data is represented below:

Table 3.1: Basic reservoir properties

Initial reservoir pressure psig	3580
Reservoir temperature F	220

Table 3.2: Compositional data

Components	Zi(percent)	Weight fraction	Mole fraction	Specific gravity
CO2	0.91	0.42719		
N2	0.16	0.047809		
C1	36.47	6.2409		
C2	9.67	3.1016		
C3	6.95	3.2691		
IC4	1.44	0.89278		
NC4	3.93	2.4366		
IC5	1.44	1.1082		
NC5	1.41	1.0852		
C6	4.33	3.9803		
C7+	33.29	77.41	218	0.8515

Table 3.3: Constant composition expansion data

Pressure (psig)	(Relative volume (V(p)/V(pb))
5000	0.9453
4500	0.9541
4000	0.9638
3500	0.9746
3000	0.9867
2900	0.9893
2800	0.992
2700	0.9948
2620	0.997
2605	0.9974
2591	0.9978
2516	1.0001
2401	1.0243
2253	1.0599
2090	1.1066
1897	1.175
1698	1.2655
1477	1.4006
1292	1.5557
1040	1.8696
830	2.2956
640	2.9457
472	3.9877

Table 3.4: Bubble point experiment data

Saturation pressure	Liquid density
2516.7	45.11

Table 3.5: Differential liberation data

Pressure (psig)	Vapor z-factor	Liquid density (lb/ft^3)	GOR (Mscf/STB)	Oil relative volume	Gas gravity	Gas FVF (rb/Mscf)
2516.7		45.11	1.1342	1.7493		0
2350	0.8686	45.669	1.0526	1.7095	0.7553	1.2574
2100	0.8692	46.502	0.9378	1.6535	0.7547	1.407
1850	0.8719	47.331	0.8309	1.6013	0.7565	1.6006
1600	0.8767	48.16	0.7307	1.5523	0.7614	1.8586
1350	0.8836	48.992	0.6361	1.5057	0.7704	2.2164
1100	0.8926	49.835	0.546	1.4609	0.7859	2.7411
850	0.9036	50.699	0.4591	1.4171	0.8121	3.5773
600	0.9167	51.608	0.3732	1.3726	0.8597	5.105
350	0.9324	52.632	0.2824	1.3234	1.3234	8.7518
159	0.9481	53.673	0.196	1.272	1.1726	18.685
0		56.323		1.1228	1.8901	1.8901

Table 3.6: composition with depth data

Temperature F	Pressure psig	Depth ft	Temperature gradient F/ft
220	**3580**	**9200**	**0**

3.2 Defining Components in PVTi

The first step in using PVTi is to define the components; components can be defined as one of three possible types:

1 -Library is the default. PVTi has a built-in tables of properties of the common hydrocarbons up to C45and of specific non-hydrocarbons H20, H2S, CO2, N2, H2and CO.

2 – Characterized is usually reserved for the plus component

3 -User-defined properties.

3.3 Setting equation of state and viscosity correlation type

PVTi software includes multiple equation of state to choose from include:

- **Peng-Robinson (PR)**
- **Redlich-Kwong (RK)**
- **Soave-Redlich-Kwong (SRK)**
- **Zudkevitch-Joffe EoS**

The available viscosity correlations are:

- **Lohrenz, Bray and Clark**
- **Pedersen et al**

For the purpose of this study Peng-Robeson (three parameters) equation of state and Lohrenz, Bray and Clark viscosity correlation have been chosen.

3.4 Regression of equation-of-state to measured data

The regression process is performed to fit the equation of state to the observation data to produce a better representation of the fluid. A sensitivity analysis is carried out to determine which attributes of the fluid components improve the solution by the smallest change. The most sensitive attributes are then adjusted slightly by regression to improve the equation of state model of the fluid.

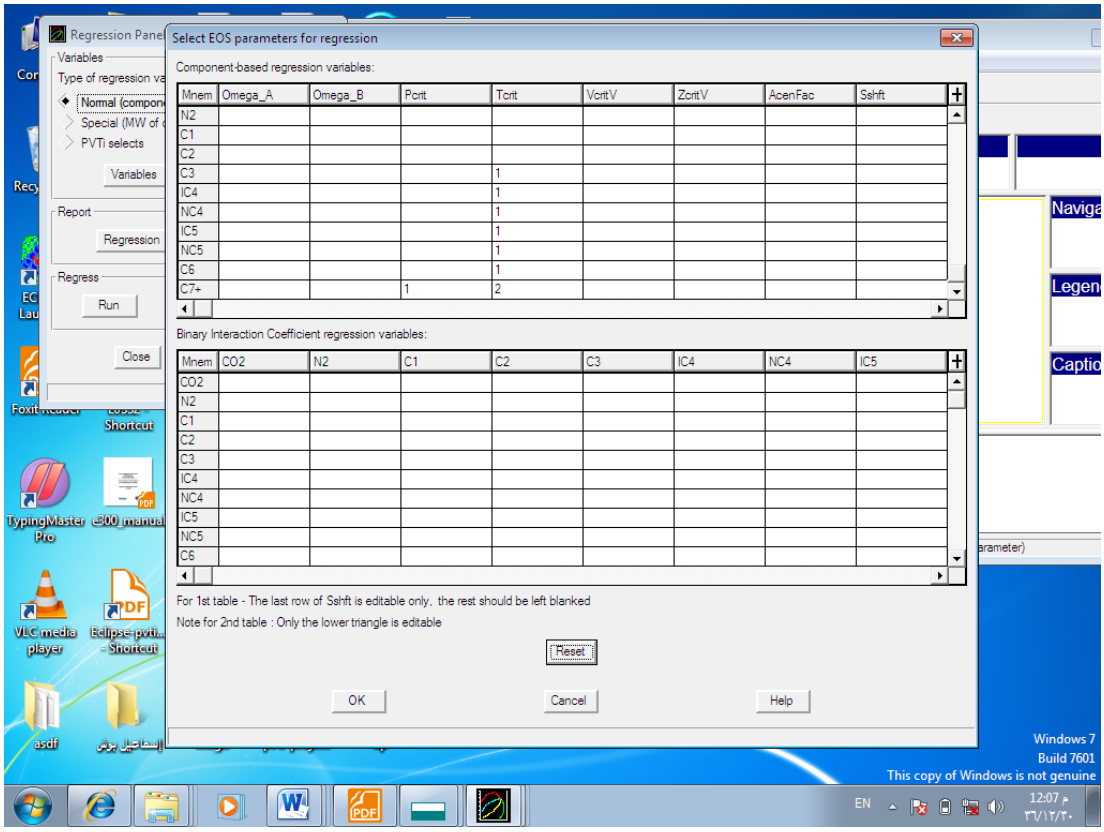

Figure 3.1: Regression panel.

Properties of hydrocarbon series

For the hydrocarbon series, most physical properties are found to either increase of decrease.

Properties increasing with increasing molecular weight:

1 - T_c Critical Temperature

2 - T_b Normal Boiling Point

3 - V_c Critical Volume

4 ω Acentric Factor

5- ρ Liquid Density

Properties decreasing with increasing molecular weight:

1 -Pc Critical Pressure

2 -Zc Critical Z-Factor

It is the monotonicity of these properties that is used as the basis for the characterization of “unknown” components such as the plus fraction. During

regression the monotonicity should be maintained, and if any of these properties are changed in such a way that they are no longer monotonic with molecular weight then PVTi will give a warning message.

The result of regression process is the fluid definition the extension of the output file is PVI.

3.5 Exporting ECLIPSE Black Oil PVT tables

3.5.1 Introduction

Once the fluid description has been fitted to the experimental observations, it may be used in a reservoir simulation. PVTi facilitates the transition between a fluid description and the PVT keyword description required by the ECLIPSE family of simulators PVT tables that are then used in an ECLIPSE Black Oil simulation.

3.5.2 Exporting water properties

The water properties exported from PVTi are generated by correlation. This is effectively separate from the fluid model, the data required are the initial reservoir pressure and reservoir temperature, the output of this process is file with pvo extension.

3.5.3 Generating ECLIPSE Black Oil PVT tables

In order to generate ECLIPSE Black Oil simulation PVT tables, PVTi requires either a Differential Liberation experiment or a Constant Volume Depletion experiment to be simulated from the fitted equation of state. The PVT tables are generated off either of these experiments, for the purpose of this study we use the Differential Liberation experiments data represented in table (3-4).

3.5.3 Generating ECLIPSE Black Oil equilibration Keywords

Generating Eclipse Black Oil equilibration Keywords is similar to the generation of PVT tables. To generate equilibration tables, a composition versus depth experiment is required, the required data is represented in table (3-5).

Chapter Four

Chapter four

Results and Discussions

4.1 Results

The result of the processing the laboratory data using the PVTi software are expressed in the following figures:

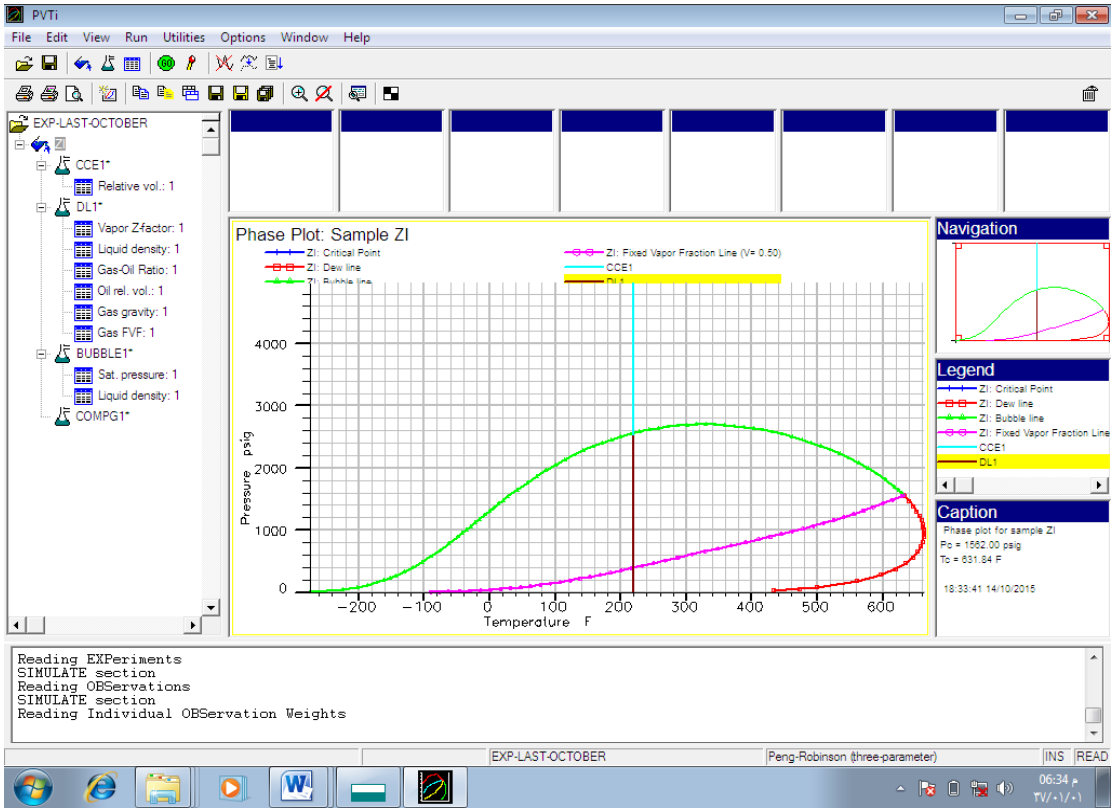

Figure 4.1:PVTi interface after simulating all the experiments

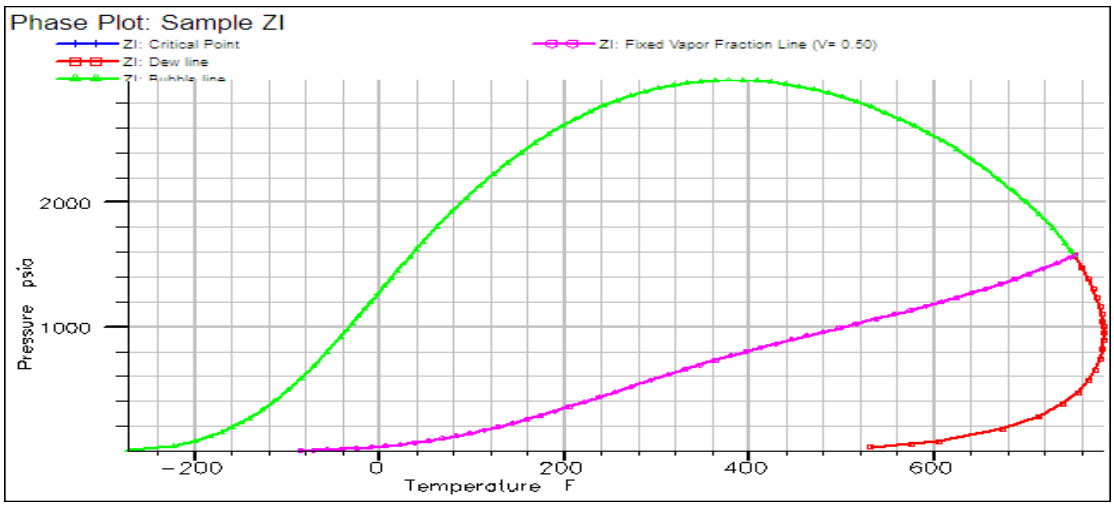

Figure 4.2: Phase diagram for the available PVT data

The phase envelope, together with the quality lines, can be measured from experiments for any mixture but the procedure is both time consuming and expensive.

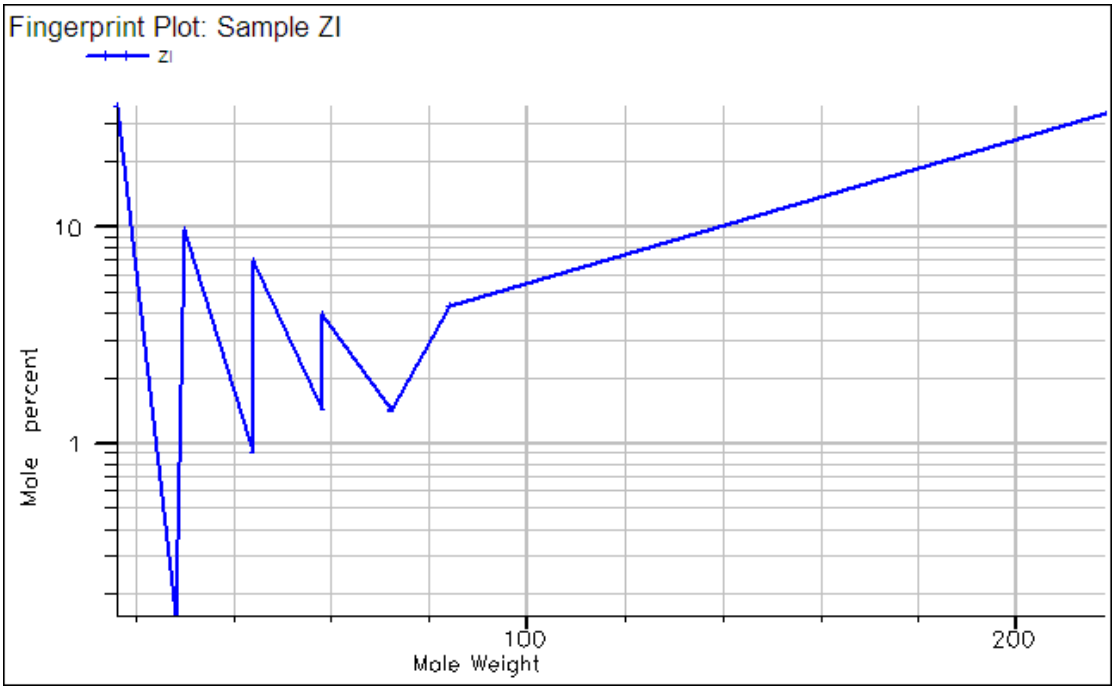

Figure 4.3: finger plot sample ZI Mole percent vs. Mole Weight

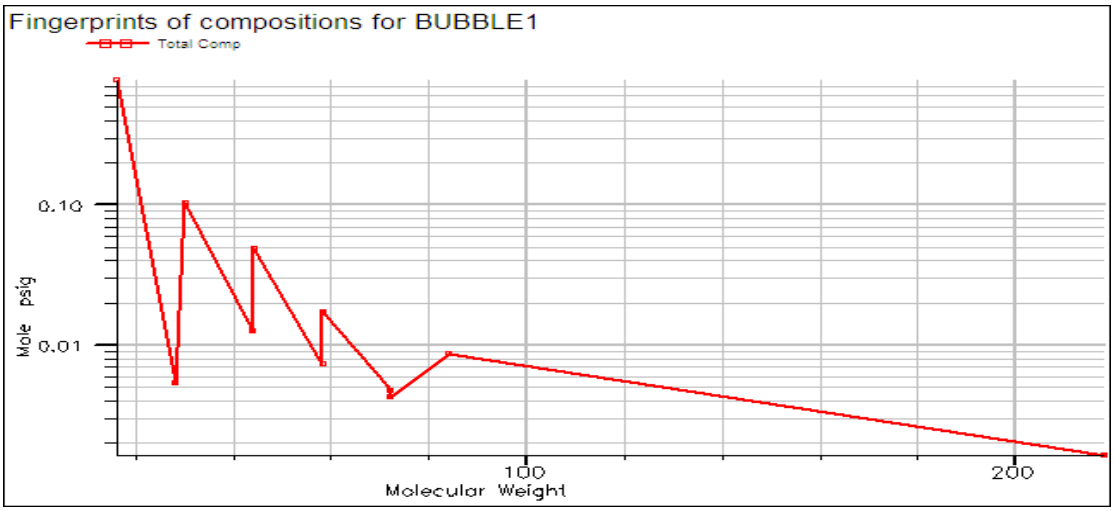

Figure 4.4: Fingerprint of compositional for bubble point experiment

Plots of mole fraction vs. Molecular weight are known as fingerprint plots, and can be displayed in PVTi either byright clicking on the sample name and choosing "fingerprint plot" or by View | Samples | Fingerprint Plot.

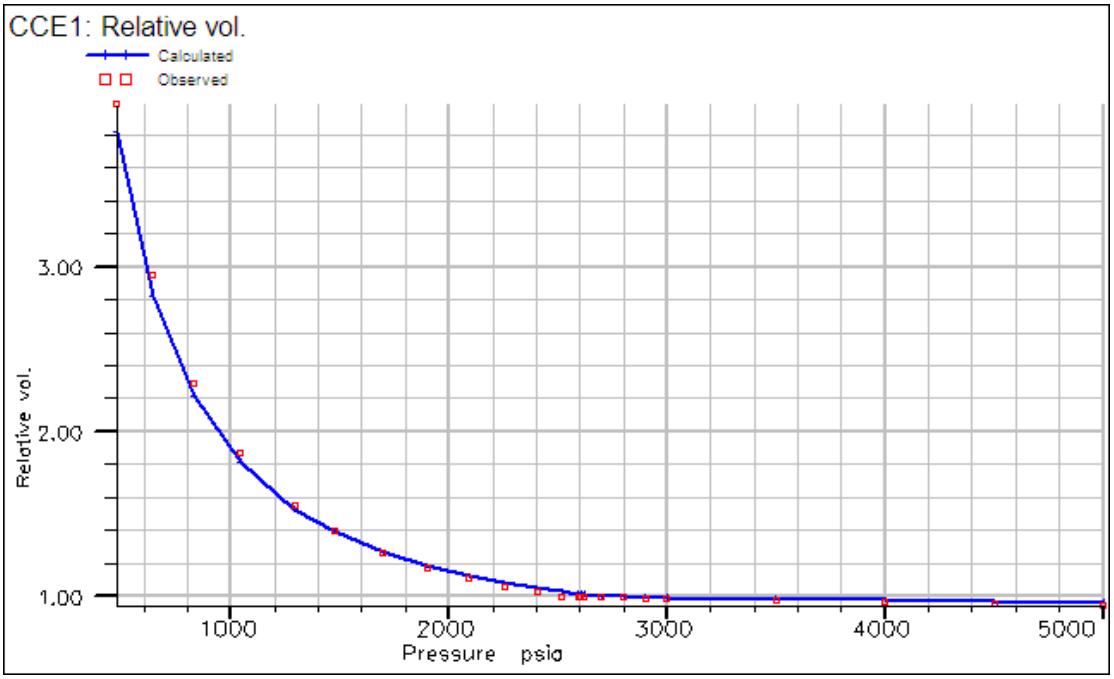

Figure 4.5.Relative volume vs. Pressure.

Figure 4-6: vapor z-factor vs. pressure

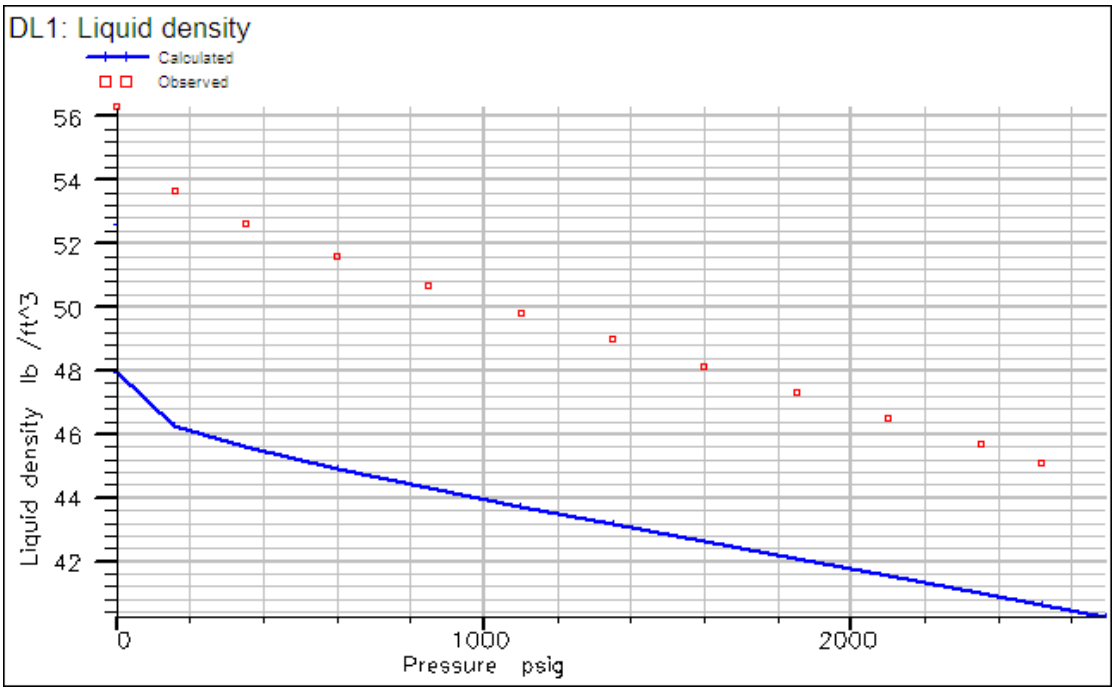

Figure 4.6: Liquid density vs. pressure(before regression)

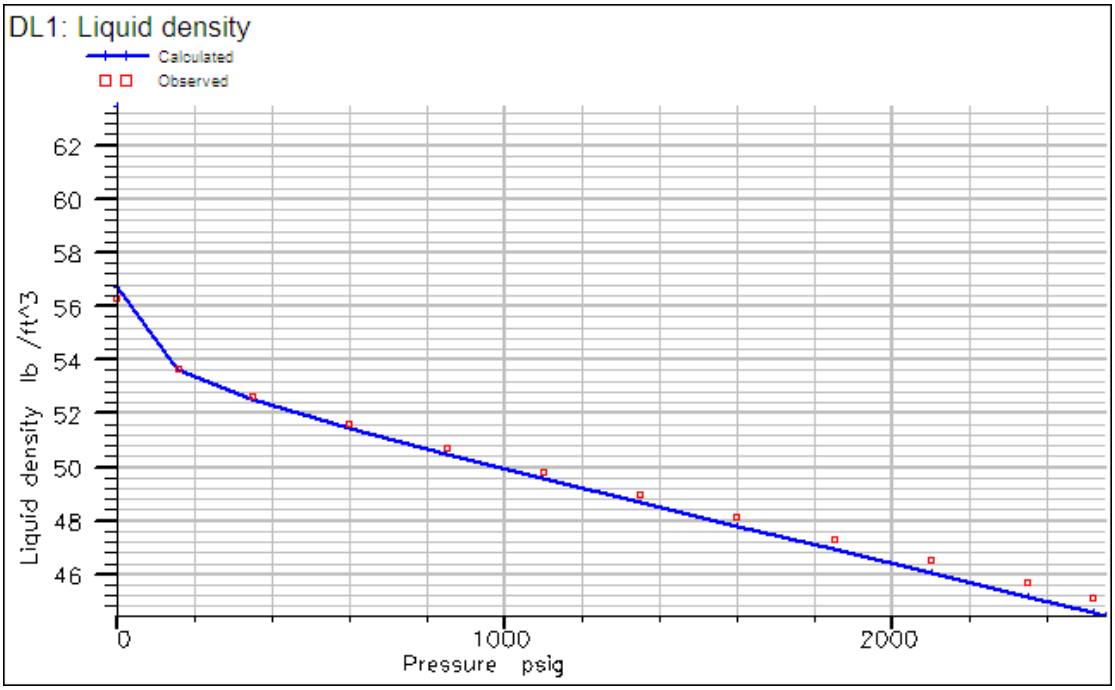

Figure 4.7: Liquid density vs. pressure (after regression)

After performing the regression process the line represent the calculated value change untile it fit with the observed value

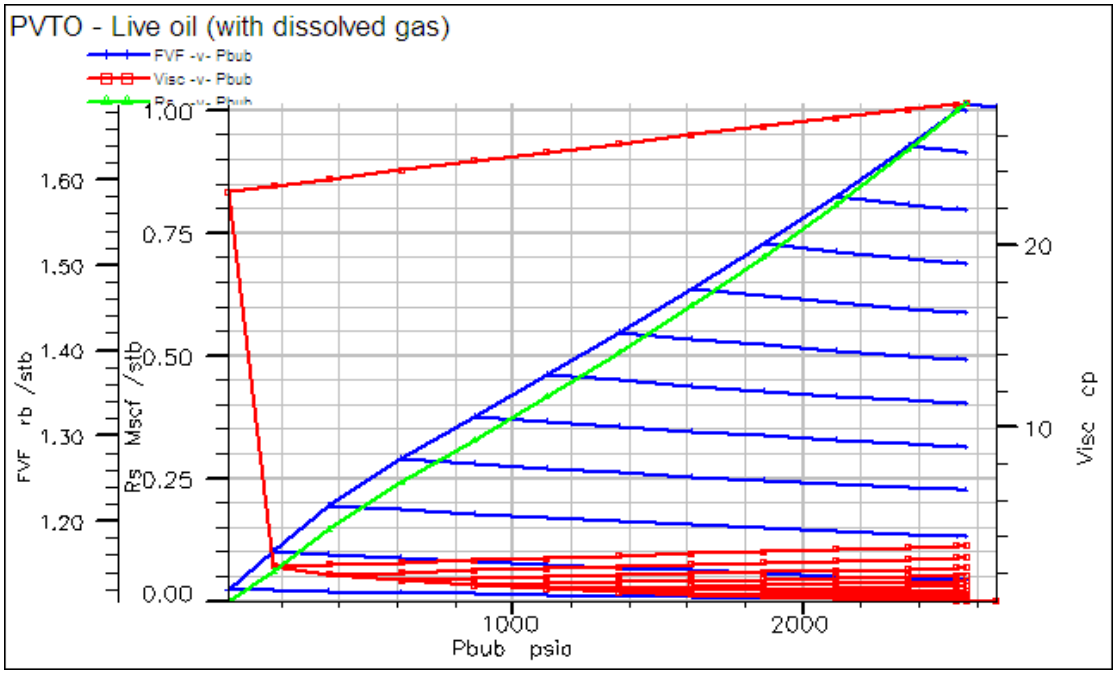

Figure 4.8: Oil FVF, Viscosity and Rs versus pressure for the output black oil property tables

4.2 Discussions

In this study laboratory data include the following experiments: Constant Composition Expansion, Bubble Point and Differential Liberation experiments were imported and simulated for the defined fluid after setting the software units and options. The match between the experimental observations and the simulated results was examined using the plotting facilities in PVT and the regression report, the matching performed using the regression panel. The fluid model can then be adjusted so that it provides the best fit to the experimental observations, matching was performed because the equation of state need to be tuned, after tuning the Equation of State parameters to experimental measurements the fitted fluid definition is finally used to generate PVT tables and Black Oil equilibration Keywords for ECLIPSE.

Chapter Five

Chapter five

Conclusions and recommendation

5.1 Conclusions

1- PVTi is suitable for generating the Black Oil table from the laboratory PVT data.

2- Regression process is almost always required to obtain a better fluid description.

3- Most of the errors encountered in this research were either due to mistakes in the raw data or wrong interaction with the software (providing the software with insufficient data or options).

5.2 Recommendations

1-We recommend to use the PVTi software for the Black Oil PVT data.

2-We recommend to use the appropriate experiments data that is sufficient to perform characterization.

References

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2- Ahmed, T., 2001. Reservoir Engineering Hand book. Second edition. Houston: Gulf Professional Publishing.

3-Schlumberger.,2008. PVTi Reference Manual. Schlumberger.

4-Curtisc H.Whitson and Michael R.Brulé., 2000. Phase Behavior. First edition. Texas: SPE.

5- Schlumberger., 2005. PVTi and ECLIPSE 300. Schlumberger.

Appendix A

Simulation output

Expt CCE1 : Constant Composition Expansion

Peng-Robinson (3-Parm) on ZI with PR corr.
Lohrenz-Bray-Clark Viscosity Correlation
Density units are LB/FT3
Specific volume units are CF/LB-ML
Viscosity units are CPOISE
Surface Tension units are DYNES/CM

Specified temperature Deg F 220.0000

Liq Sat calc. is Vol oil/Vol Fluid at Sat. Vol

Pressure PSIG	Inserted Point	Rel Volume Observed	Rel Volume Calculated	Vap Mole Frn Calculated	Liq Density Calculated
4985.304		0.9453	0.9513		46.7517
4485.304		0.9541	0.9593		46.3648
3985.304		0.9638	0.9681		45.9435
3485.304		0.9746	0.9779		45.4816
2985.304		0.9867	0.9890		44.9713
2885.304		0.9893	0.9914		44.8626
2785.304		0.9920	0.9939		44.7514
2685.304		0.9948	0.9964		44.6376
2605.304		0.9970	0.9985		44.5447
2590.304		0.9974	0.9989		44.5271
2576.304		0.9978	0.9992		44.5106
2547.590	- Psat		1.0000		44.4766
2501.304		1.0001	1.0085	0.0128	44.6412
2386.304		1.0243	1.0316	0.0438	45.0493
2238.304		1.0599	1.0658	0.0821	45.5730
2075.304		1.1066	1.1108	0.1224	46.1497
1882.304		1.1750	1.1771	0.1679	46.8352
1683.304		1.2655	1.2653	0.2129	47.5491
1462.304		1.4006	1.3978	0.2611	48.3575
1277.304		1.5557	1.5508	0.3005	49.0540
1025.304		1.8696	1.8632	0.3536	50.0495
815.304		2.2956	2.2914	0.3983	50.9444
625.304		2.9457	2.9527	0.4405	51.8387
457.304		3.9877	4.0299	0.4807	52.7413

Pressure PSIG	Inserted Point	Vap Density Calculated	Liq Z-Fac Calculated	Vap Z-Fac Calculated	Surf Tension Calculated
4985.304			1.3733		
4485.304			1.2463		
3985.304			1.1179		
3485.304			0.9881		
2985.304			0.8566		
2885.304			0.8300		
2785.304			0.8034		
2685.304			0.7767		
2605.304			0.7552		
2590.304			0.7512		
2576.304			0.7475		
2547.590	- Psat	9.0606	0.7397	0.8648	4.1533
2501.304		8.8903	0.7309	0.8642	4.3378
2386.304		8.4686	0.7083	0.8631	4.8231
2238.304		7.9283	0.6781	0.8624	5.5075
2075.304		7.3364	0.6435	0.8626	6.3450
1882.304		6.6399	0.6003	0.8642	7.4598
1683.304		5.9271	0.5533	0.8676	8.7621
1462.304		5.1427	0.4980	0.8734	10.4085
1277.304		4.4929	0.4489	0.8801	11.9660
1025.304		3.6185	0.3775	0.8921	14.3854
815.304		2.8996	0.3136	0.9047	16.7095
625.304		2.2553	0.2519	0.9186	19.1133
457.304		1.6878	0.1936	0.9332	21.5562

Pressure PSIG	Inserted Point	Vap Mole Wt Calculated	Liq Mol Vol Calculated	Vap Mol Vol Calculated
4985.304			2.0033	
4485.304			2.0200	
3985.304			2.0385	
3485.304			2.0592	
2985.304			2.0826	
2885.304			2.0876	
2785.304			2.0928	
2685.304			2.0981	
2605.304			2.1025	
2590.304			2.1033	
2576.304			2.1041	
2547.590	- Psat	22.3055	2.1057	2.4618
2501.304		22.2737	2.1187	2.5054
2386.304		22.2041	2.1516	2.6219
2238.304		22.1344	2.1954	2.7918
2075.304		22.0843	2.2456	3.0102
1882.304		22.0630	2.3082	3.3228
1683.304		22.0883	2.3769	3.7267
1462.304		22.1815	2.4591	4.3132
1277.304		22.3232	2.5340	4.9686
1025.304		22.6384	2.6474	6.2562
815.304		23.0527	2.7559	7.9503
625.304		23.6109	2.8705	10.4689
457.304		24.3408	2.9922	14.4213

Molar Distributions K-Values	Inserted Point	Com(1 ,CO2) Calculated	Com(2 ,N2) Calculated	Com(3 ,C1) Calculated	Com(4 ,C2) Calculated
4985.304		1.0000	1.0000	1.0000	1.0000
4485.304		1.0000	1.0000	1.0000	1.0000
3985.304		1.0000	1.0000	1.0000	1.0000
3485.304		1.0000	1.0000	1.0000	1.0000
2985.304		1.0000	1.0000	1.0000	1.0000
2885.304		1.0000	1.0000	1.0000	1.0000
2785.304		1.0000	1.0000	1.0000	1.0000
2685.304		1.0000	1.0000	1.0000	1.0000
2605.304		1.0000	1.0000	1.0000	1.0000
2590.304		1.0000	1.0000	1.0000	1.0000
2576.304		1.0000	1.0000	1.0000	1.0000
2547.590	- Psat	1.4006	3.3515	2.1427	1.0750
2501.304		1.4145	3.4205	2.1740	1.0810
2386.304		1.4515	3.6034	2.2567	1.0972
2238.304		1.5052	3.8664	2.3751	1.1215
2075.304		1.5738	4.1994	2.5247	1.1533
1882.304		1.6715	4.6685	2.7345	1.2000
1683.304		1.7969	5.2652	3.0006	1.2619
1462.304		1.9781	6.1186	3.3804	1.3539
1277.304		2.1798	7.0604	3.7988	1.4587
1025.304		2.5748	8.8905	4.6109	1.6686
815.304		3.0932	11.2784	5.6698	1.9492
625.304		3.8626	14.8128	7.2360	2.3707
457.304		5.0685	20.3520	9.6886	3.0361

Molar Distributions K-Values	Inserted Point	Com(5 ,C3) Calculated	Com(6 ,IC4) Calculated	Com(7 ,NC4) Calculated	Com(8 ,IC5) Calculated
4985.304		1.0000	1.0000	1.0000	1.0000
4485.304		1.0000	1.0000	1.0000	1.0000
3985.304		1.0000	1.0000	1.0000	1.0000
3485.304		1.0000	1.0000	1.0000	1.0000
2985.304		1.0000	1.0000	1.0000	1.0000
2885.304		1.0000	1.0000	1.0000	1.0000
2785.304		1.0000	1.0000	1.0000	1.0000
2685.304		1.0000	1.0000	1.0000	1.0000
2605.304		1.0000	1.0000	1.0000	1.0000
2590.304		1.0000	1.0000	1.0000	1.0000
2576.304		1.0000	1.0000	1.0000	1.0000
2547.590	- Psat	0.7123	0.5152	0.4472	0.3332
2501.304		0.7119	0.5124	0.4440	0.3293
2386.304		0.7115	0.5059	0.4365	0.3200
2238.304		0.7125	0.4984	0.4277	0.3086
2075.304		0.7159	0.4915	0.4193	0.2971
1882.304		0.7239	0.4857	0.4114	0.2851
1683.304		0.7383	0.4832	0.4062	0.2749
1462.304		0.7645	0.4861	0.4051	0.2666
1277.304		0.7987	0.4952	0.4097	0.2631
1025.304		0.8745	0.5229	0.4283	0.2656
815.304		0.9834	0.5696	0.4626	0.2783
625.304		1.1538	0.6484	0.5225	0.3053
457.304		1.4297	0.7813	0.6250	0.3556

Molar Distributions K-Values	Inserted Point	Com(9 ,NC5) Calculated	Com(10,C6) Calculated	Com(11,C7+) Calculated
4985.304		1.0000	1.0000	1.0000
4485.304		1.0000	1.0000	1.0000
3985.304		1.0000	1.0000	1.0000
3485.304		1.0000	1.0000	1.0000
2985.304		1.0000	1.0000	1.0000
2885.304		1.0000	1.0000	1.0000
2785.304		1.0000	1.0000	1.0000
2685.304		1.0000	1.0000	1.0000
2605.304		1.0000	1.0000	1.0000
2590.304		1.0000	1.0000	1.0000
2576.304		1.0000	1.0000	1.0000
2547.590	- Psat	0.3034	0.2026	0.0125
2501.304		0.2995	0.1989	0.0118
2386.304		0.2900	0.1901	0.0101
2238.304		0.2786	0.1793	0.0084
2075.304		0.2669	0.1684	0.0068
1882.304		0.2546	0.1567	0.0052
1683.304		0.2440	0.1461	0.0040
1462.304		0.2350	0.1364	0.0029
1277.304		0.2304	0.1301	0.0023
1025.304		0.2306	0.1252	0.0017
815.304		0.2398	0.1258	0.0013
625.304		0.2613	0.1327	0.0011
457.304		0.3023	0.1489	0.0010

Molar Distributions Liquid, X	Inserted Point	Com(1 ,CO2) Calculated	Com(2 ,N2) Calculated	Com(3 ,C1) Calculated	Com(4 ,C2) Calculated
4985.304		0.9100	0.1600	36.4700	9.6700
4485.304		0.9100	0.1600	36.4700	9.6700
3985.304		0.9100	0.1600	36.4700	9.6700
3485.304		0.9100	0.1600	36.4700	9.6700
2985.304		0.9100	0.1600	36.4700	9.6700
2885.304		0.9100	0.1600	36.4700	9.6700
2785.304		0.9100	0.1600	36.4700	9.6700
2685.304		0.9100	0.1600	36.4700	9.6700
2605.304		0.9100	0.1600	36.4700	9.6700
2590.304		0.9100	0.1600	36.4700	9.6700
2576.304		0.9100	0.1600	36.4700	9.6700
2547.590	- Psat	0.9100	0.1600	36.4700	9.6700
2501.304		0.9052	0.1552	35.9296	9.6600
2386.304		0.8924	0.1436	34.5674	9.6290
2238.304		0.8738	0.1295	32.7719	9.5746
2075.304		0.8503	0.1150	30.7363	9.4919
1882.304		0.8178	0.0990	28.2433	9.3557
1683.304		0.7780	0.0838	25.5745	9.1592
1462.304		0.7249	0.0685	22.4898	8.8520
1277.304		0.6718	0.0567	19.8091	8.4985
1025.304		0.5845	0.0422	16.0184	7.8210
815.304		0.4962	0.0314	12.7511	7.0168
625.304		0.4025	0.0226	9.7331	6.0295
457.304		0.3079	0.0155	7.0455	4.8870

Molar Distributions Liquid, X	Inserted Point	Com(5 ,C3) Calculated	Com(6 ,IC4) Calculated	Com(7 ,NC4) Calculated	Com(8 ,IC5) Calculated
4985.304		6.9500	1.4400	3.9300	1.4400
4485.304		6.9500	1.4400	3.9300	1.4400
3985.304		6.9500	1.4400	3.9300	1.4400
3485.304		6.9500	1.4400	3.9300	1.4400
2985.304		6.9500	1.4400	3.9300	1.4400
2885.304		6.9500	1.4400	3.9300	1.4400
2785.304		6.9500	1.4400	3.9300	1.4400
2685.304		6.9500	1.4400	3.9300	1.4400
2605.304		6.9500	1.4400	3.9300	1.4400
2590.304		6.9500	1.4400	3.9300	1.4400
2576.304		6.9500	1.4400	3.9300	1.4400
2547.590	- Psat	6.9500	1.4400	3.9300	1.4400
2501.304		6.9757	1.4491	3.9582	1.4525
2386.304		7.0389	1.4719	4.0294	1.4842
2238.304		7.1179	1.5018	4.1237	1.5266
2075.304		7.2003	1.5355	4.2306	1.5755
1882.304		7.2879	1.5761	4.3611	1.6365
1683.304		7.3602	1.6181	4.4989	1.7030
1462.304		7.4054	1.6632	4.6528	1.7811
1277.304		7.3975	1.6975	4.7775	1.8496
1025.304		7.2727	1.7322	4.9257	1.9450
815.304		6.9964	1.7380	5.0005	2.0210
625.304		6.5090	1.7039	4.9768	2.0749
457.304		5.7602	1.6092	4.7941	2.0862

Molar Distributions Liquid, X	Inserted Point	Com(9 ,NC5) Calculated	Com(10,C6) Calculated	Com(11,C7+) Calculated	Total Calculated
4985.304		1.4100	4.3300	33.2900	100.0000
4485.304		1.4100	4.3300	33.2900	100.0000
3985.304		1.4100	4.3300	33.2900	100.0000
3485.304		1.4100	4.3300	33.2900	100.0000
2985.304		1.4100	4.3300	33.2900	100.0000
2885.304		1.4100	4.3300	33.2900	100.0000
2785.304		1.4100	4.3300	33.2900	100.0000
2685.304		1.4100	4.3300	33.2900	100.0000
2605.304		1.4100	4.3300	33.2900	100.0000
2590.304		1.4100	4.3300	33.2900	100.0000
2576.304		1.4100	4.3300	33.2900	100.0000
2547.590	- Psat	1.4100	4.3300	33.2900	100.0000
2501.304		1.4228	4.3749	33.7169	100.0000
2386.304		1.4553	4.4893	34.7987	100.0000
2238.304		1.4987	4.6427	36.2388	100.0000
2075.304		1.5489	4.8205	37.8952	100.0000
1882.304		1.6117	5.0444	39.9665	100.0000
1683.304		1.6806	5.2923	42.2515	100.0000
1462.304		1.7620	5.5909	45.0094	100.0000
1277.304		1.8342	5.8625	47.5451	100.0000
1025.304		1.9369	6.2689	51.4524	100.0000
815.304		2.0224	6.6434	55.2827	100.0000
625.304		2.0902	7.0073	59.4503	100.0000
457.304		2.1214	7.3279	64.0451	100.0000

Molar Distributions Vapour, Y	Inserted Point	Com(1 ,CO2) Calculated	Com(2 ,N2) Calculated	Com(3 ,C1) Calculated	Com(4 ,C2) Calculated
4985.304					
4485.304					
3985.304					
3485.304					
2985.304					
2885.304					
2785.304					
2685.304					
2605.304					
2590.304					
2576.304					
2547.590	- Psat	1.2745	0.5362	78.1447	10.3949
2501.304		1.2804	0.5308	78.1097	10.4421
2386.304		1.2953	0.5175	78.0067	10.5653
2238.304		1.3152	0.5008	77.8380	10.7375
2075.304		1.3382	0.4829	77.5990	10.9472
1882.304		1.3669	0.4622	77.2324	11.2272
1683.304		1.3979	0.4415	76.7400	11.5579
1462.304		1.4338	0.4190	76.0238	11.9844
1277.304		1.4644	0.4004	75.2508	12.3969
1025.304		1.5050	0.3753	73.8602	13.0505
815.304		1.5350	0.3542	72.2960	13.6775
625.304		1.5546	0.3345	70.4288	14.2939
457.304		1.5605	0.3161	68.2608	14.8376

Molar Distributions Vapour, Y	Inserted Point	Com(5 ,C3) Calculated	Com(6 ,IC4) Calculated	Com(7 ,NC4) Calculated	Com(8 ,IC5) Calculated
4985.304					
4485.304					
3985.304					
3485.304					
2985.304					
2885.304					
2785.304					
2685.304					
2605.304					
2590.304					
2576.304					
2547.590	- Psat	4.9505	0.7419	1.7574	0.4798
2501.304		4.9660	0.7425	1.7575	0.4783
2386.304		5.0083	0.7446	1.7589	0.4749
2238.304		5.0715	0.7485	1.7637	0.4711
2075.304		5.1547	0.7547	1.7738	0.4681
1882.304		5.2760	0.7656	1.7940	0.4666
1683.304		5.4340	0.7819	1.8272	0.4681
1462.304		5.6616	0.8085	1.8850	0.4749
1277.304		5.9084	0.8406	1.9573	0.4866
1025.304		6.3600	0.9058	2.1097	0.5167
815.304		6.8799	0.9899	2.3131	0.5624
625.304		7.5101	1.1049	2.6004	0.6335
457.304		8.2355	1.2572	2.9964	0.7419

Molar Distributions Vapour, Y	Inserted Point	Com(9 ,NC5) Calculated	Com(10,C6) Calculated	Com(11,C7+) Calculated	Total Calculated
4985.304					
4485.304					
3985.304					
3485.304					
2985.304					
2885.304					
2785.304					
2685.304					
2605.304					
2590.304					
2576.304					
2547.590	- Psat	0.4278	0.8774	0.4148	100.0000
2501.304		0.4261	0.8703	0.3962	100.0000
2386.304		0.4220	0.8532	0.3532	100.0000
2238.304		0.4175	0.8325	0.3037	100.0000
2075.304		0.4134	0.8116	0.2561	100.0000
1882.304		0.4104	0.7903	0.2086	100.0000
1683.304		0.4100	0.7732	0.1682	100.0000
1462.304		0.4140	0.7625	0.1325	100.0000
1277.304		0.4227	0.7630	0.1090	100.0000
1025.304		0.4467	0.7852	0.0850	100.0000
815.304		0.4850	0.8358	0.0712	100.0000
625.304		0.5461	0.9295	0.0636	100.0000
457.304		0.6414	1.0910	0.0616	100.0000

Expt DL1 : Differential Liberation

Peng-Robinson (3-Parm) on ZI with PR corr.
Lohrenz-Bray-Clark Viscosity Correlation

Density units are	LB/FT3	
Specific volume units are	CF/LB-ML	
Viscosity units are	CPOISE	
Surface Tension units are	DYNES/CM	
Gas-Oil Ratio units are	MSCF/STB	
Relative Volume units are	RB/STB	
Gas FVF units are	RB/MSCF	
Extracted Gas Volume units are	FT3	
Oil Relative Volume units are	BBL/STB	
Specified temperature	Deg F	220.0000
Relative Oil Saturated Volume (Bo(Pbub))		1.7833

GOR calc. is Gas Vol at STC/Stock Tank Oil Vol
Oil Rel Vol calc. is Stage Vol oil/Stock Tank Oil Vol

Pressure PSIG	Inserted Point	GOR Observed	GOR Calculated	Total RelVol Calculated
2547.590	- Psat		1.1390	1.7833
2516.700		1.1342	1.1235	1.7934
2350.000		1.0526	1.0427	1.8536
2100.000		0.9378	0.9295	1.9673
1850.000		0.8309	0.8243	2.1197
1600.000		0.7307	0.7260	2.3300
1350.000		0.6361	0.6332	2.6316
1100.000		0.5460	0.5449	3.0886
850.000		0.4591	0.4596	3.8400
600.000		0.3732	0.3752	5.2566
350.000		0.2824	0.2856	8.7657
159.000		0.1960	0.1997	18.7791
0.000	@ Tres			263.0968
0.000	@ Tstd			203.8574

Pressure PSIG	Inserted Point	Oil RelVol		Liq Dens	
		Observed	Calculated	Observed	Calculated
2547.590	- Psat		1.7833		44.4766
2516.700		1.7493	1.7753	45.1100	44.5865
2350.000		1.7095	1.7334	45.6690	45.1773
2100.000		1.6535	1.6749	46.5020	46.0562
1850.000		1.6013	1.6205	47.3310	46.9291
1600.000		1.5523	1.5695	48.1600	47.8007
1350.000		1.5057	1.5213	48.9920	48.6763
1100.000		1.4609	1.4750	49.8350	49.5634
850.000		1.4171	1.4297	50.6990	50.4742
600.000		1.3726	1.3839	51.6080	51.4350
350.000		1.3234	1.3329	52.6320	52.5271
159.000		1.2720	1.2794	53.6730	53.6577
0.000	@ Tres	1.1228	1.1198	56.3230	56.7003
0.000	@ Tstd		1.0000		63.4917

Pressure PSIG	Inserted Point	Vap Dens	Gas Grav	
		Calculated	Observed	Calculated
2547.590	- Psat	9.0606		0.7700
2516.700		8.9469		0.7692
2350.000		8.3361	0.7553	0.7658
2100.000		7.4289	0.7547	0.7627
1850.000		6.5335	0.7565	0.7623
1600.000		5.6516	0.7614	0.7653
1350.000		4.7853	0.7704	0.7727
1100.000		3.9372	0.7859	0.7865
850.000		3.1088	0.8121	0.8112
600.000		2.2987	0.8597	0.8572
350.000		1.4945	0.9618	0.9573
159.000		0.8509	1.1726	1.1658
0.000	@ Tres	0.1124	1.8901	1.9008
0.000	@ Tstd			

Pressure PSIG	Inserted Point	Vap Z-Fac		Liq Z-Fac	Surf Tension
		Observed	Calculated	Calculated	Calculated
2547.590	- Psat		0.8648	0.7397	4.1533
2516.700			0.8644	0.7338	4.2757
2350.000		0.8686	0.8628	0.7010	4.9842
2100.000		0.8692	0.8623	0.6487	6.2066
1850.000		0.8719	0.8642	0.5925	7.6385
1600.000		0.8767	0.8685	0.5321	9.2998
1350.000		0.8836	0.8752	0.4670	11.2095
1100.000		0.8926	0.8844	0.3968	13.3870
850.000		0.9036	0.8962	0.3210	15.8572
600.000		0.9167	0.9104	0.2388	18.6669
350.000		0.9324	0.9279	0.1493	21.9593
159.000		0.9481	0.9453	0.0750	25.1716
0.000	@ Tres		0.9874	0.0072	31.3869
0.000	@ Tstd		1.0000	0.0084	

Pressure PSIG	Inserted Point	Gas FVF Observed	Gas FVF Calculated	Liq Visc Calculated	Vap Visc Calculated
2547.590	- Psat		1.1555	0.4979	0.0195
2516.700			1.1690	0.5067	0.0193
2350.000		1.2574	1.2491	0.5570	0.0186
2100.000		1.4070	1.3960	0.6428	0.0175
1850.000		1.6006	1.5865	0.7430	0.0166
1600.000		1.8586	1.8412	0.8605	0.0157
1350.000		2.2164	2.1954	0.9993	0.0150
1100.000		2.7411	2.7161	1.1646	0.0144
850.000		3.5773	3.5479	1.3645	0.0138
600.000		5.1050	5.0704	1.6142	0.0132
350.000		8.7518	8.7097	1.9555	0.0126
159.000		18.6850	18.6308	2.3875	0.0118
0.000	@ Tres		230.0142	4.1713	0.0100
0.000	@ Tstd		178.1076	22.9146	

Pressure PSIG	Inserted Point	Moles Extrac Calculated	GasVol Extrc Calculated	Liquid Sat Calculated	Vapour Sat Calculated
2547.590	- Psat			1.0000	
2516.700		0.0086	7.1725	0.9899	0.0101
2350.000		0.0533	44.6133	0.9450	0.0550
2100.000		0.1161	97.1296	0.9137	0.0863
1850.000		0.1744	145.8834	0.9067	0.0933
1600.000		0.2289	191.4931	0.8965	0.1035
1350.000		0.2803	234.5046	0.8819	0.1181
1100.000		0.3293	275.4547	0.8601	0.1399
850.000		0.3765	314.9840	0.8254	0.1746
600.000		0.4233	354.1402	0.7637	0.2363
350.000		0.4730	395.6841	0.6307	0.3693
159.000		0.5206	435.5072	0.4443	0.5557
0.000	@ Tres	0.6312	528.0870	0.0238	0.9762
0.000	@ Tstd	0.6312	528.0870	1.0000	

Pressure PSIG	Inserted Point	Liq Mol Wt Calculated	Vap Mol Wt Calculated	Liq Visc Calculated	Vap Visc Calculated
2547.590	- Psat	93.6557	22.3055	0.4979	0.0195
2516.700		94.2729	22.2840	0.5067	0.0193
2350.000		97.6807	22.1854	0.5570	0.0186
2100.000		103.0487	22.0958	0.6428	0.0175
1850.000		108.7634	22.0852	0.7430	0.0166
1600.000		114.8856	22.1707	0.8605	0.0157
1350.000		121.4935	22.3837	0.9993	0.0150
1100.000		128.6969	22.7848	1.1646	0.0144
850.000		136.6689	23.4998	1.3645	0.0138
600.000		145.7455	24.8325	1.6142	0.0132
350.000		156.8648	27.7325	1.9555	0.0126
159.000		169.0859	33.7744	2.3875	0.0118
0.000	@ Tres	203.3009	55.0668	4.1713	0.0100
0.000	@ Tstd	203.3009		22.9146	

Pressure PSIG	Inserted Point	Liq Mol Vol Calculated	Vap Mol Vol Calculated
2547.590	- Psat	2.1057	2.4618
2516.700		2.1144	2.4907
2350.000		2.1622	2.6614
2100.000		2.2375	2.9743
1850.000		2.3176	3.3803
1600.000		2.4034	3.9229
1350.000		2.4959	4.6776
1100.000		2.5966	5.7870
850.000		2.7077	7.5591
600.000		2.8336	10.8030
350.000		2.9864	18.5569
159.000		3.1512	39.6949
0.000	@ Tres	3.5855	490.0690
0.000	@ Tstd	3.2020	

Molar Distributions K-Values	Inserted Point	Com(1 ,CO2) Calculated	Com(2 ,N2) Calculated	Com(3 ,C1) Calculated	Com(4 ,C2) Calculated
2547.590	- Psat	1.4006	3.3515	2.1427	1.0750
2516.700		1.4098	3.3973	2.1634	1.0789
2350.000		1.4640	3.6647	2.2844	1.1028
2100.000		1.5626	4.1445	2.5002	1.1481
1850.000		1.6896	4.7522	2.7724	1.2091
1600.000		1.8582	5.5473	3.1275	1.2934
1350.000		2.0916	6.6327	3.6116	1.4140
1100.000		2.4338	8.2032	4.3119	1.5958
850.000		2.9793	10.6803	5.4170	1.8922
600.000		3.9766	15.1742	7.4228	2.4428
350.000		6.3556	25.8701	12.1944	3.7695
159.000		12.8199	55.0867	25.1933	7.3842
0.000	@ Tres	149.9881	691.9507	306.2747	83.6216
0.000	@ Tstd	1.0000	1.0000	1.0000	1.0000

Molar Distributions K-Values	Inserted Point	Com(5 ,C3) Calculated	Com(6 ,IC4) Calculated	Com(7 ,NC4) Calculated	Com(8 ,IC5) Calculated
2547.590	- Psat	0.7123	0.5152	0.4472	0.3332
2516.700		0.7120	0.5134	0.4451	0.3306
2350.000		0.7116	0.5040	0.4343	0.3171
2100.000		0.7153	0.4926	0.4206	0.2989
1850.000		0.7262	0.4855	0.4107	0.2837
1600.000		0.7475	0.4844	0.4060	0.2721
1350.000		0.7852	0.4925	0.4088	0.2655
1100.000		0.8500	0.5151	0.4236	0.2661
850.000		0.9651	0.5644	0.4596	0.2789
600.000		1.1913	0.6709	0.5410	0.3166
350.000		1.7533	0.9488	0.7575	0.4266
159.000		3.3009	1.7264	1.3668	0.7452
0.000	@ Tres	35.6645	17.8747	13.9936	7.3455
0.000	@ Tstd	1.0000	1.0000	1.0000	1.0000

Molar Distributions K-Values	Inserted Point	Com(9 ,NC5) Calculated	Com(10,C6) Calculated	Com(11,C7+) Calculated
2547.590	- Psat	0.3034	0.2026	0.0125
2516.700		0.3008	0.2002	0.0120
2350.000		0.2871	0.1874	0.0097
2100.000		0.2687	0.1701	0.0070
1850.000		0.2531	0.1551	0.0050
1600.000		0.2409	0.1428	0.0036
1350.000		0.2332	0.1334	0.0026
1100.000		0.2318	0.1278	0.0019
850.000		0.2409	0.1278	0.0014
600.000		0.2711	0.1381	0.0011
350.000		0.3619	0.1765	0.0011
159.000		0.6273	0.2947	0.0013
0.000	@ Tres	6.1247	2.7454	0.0091
0.000	@ Tstd	1.0000	1.0000	1.0000

Molar Distributions Fluid, Z	Inserted Point	Com(1 ,CO2) Calculated	Com(2 ,N2) Calculated	Com(3 ,C1) Calculated	Com(4 ,C2) Calculated
2547.590	- Psat	0.9100	0.1600	36.4700	9.6700
2516.700		0.9100	0.1600	36.4700	9.6700
2350.000		0.9068	0.1568	36.1098	9.6635
2100.000		0.8882	0.1399	34.1310	9.6188
1850.000		0.8563	0.1158	31.0430	9.5253
1600.000		0.8190	0.0928	27.7951	9.3957
1350.000		0.7751	0.0714	24.3713	9.2171
1100.000		0.7225	0.0519	20.7570	8.9696
850.000		0.6583	0.0348	16.9410	8.6202
600.000		0.5778	0.0207	12.9207	8.1105
350.000		0.4722	0.0100	8.7176	7.3179
159.000		0.3232	0.0032	4.4389	5.9088
0.000	@ Tres	0.1563	0.0005	1.3936	3.7478
0.000	@ Tstd	0.0044	3.3822E-06	0.0195	0.1867

Molar Distributions Fluid, Z	Inserted Point	Com(5 ,C3) Calculated	Com(6 ,IC4) Calculated	Com(7 ,NC4) Calculated	Com(8 ,IC5) Calculated
2547.590	- Psat	6.9500	1.4400	3.9300	1.4400
2516.700		6.9500	1.4400	3.9300	1.4400
2350.000		6.9672	1.4460	3.9488	1.4483
2100.000		7.0591	1.4792	4.0523	1.4944
1850.000		7.1949	1.5307	4.2142	1.5672
1600.000		7.3272	1.5844	4.3845	1.6449
1350.000		7.4514	1.6402	4.5635	1.7280
1100.000		7.5597	1.6977	4.7508	1.8170
850.000		7.6377	1.7556	4.9447	1.9124
600.000		7.6565	1.8112	5.1404	2.0148
350.000		7.5481	1.8570	5.3238	2.1237
159.000		7.0883	1.8653	5.4373	2.2340
0.000	@ Tres	5.8687	1.7504	5.2630	2.2866
0.000	@ Tstd	0.6520	0.3576	1.3160	0.9278

Molar Distributions Fluid, Z Inserted Point	Com(9 ,NC5) Calculated	Com(10,C6) Calculated	Com(11,C7+) Calculated	Total Calculated
2547.590 - Psat	1.4100	4.3300	33.2900	100.0000
2516.700	1.4100	4.3300	33.2900	100.0000
2350.000	1.4185	4.3599	33.5744	100.0000
2100.000	1.4657	4.5259	35.1455	100.0000
1850.000	1.5404	4.7895	37.6228	100.0000
1600.000	1.6201	5.0720	40.2641	100.0000
1350.000	1.7056	5.3764	43.0999	100.0000
1100.000	1.7975	5.7061	46.1702	100.0000
850.000	1.8966	6.0659	49.5328	100.0000
600.000	2.0038	6.4630	53.2807	100.0000
350.000	2.1198	6.9101	57.5997	100.0000
159.000	2.2430	7.4375	63.0205	100.0000
0.000 @ Tres	2.3212	7.9435	69.2683	100.0000
0.000 @ Tstd	1.0634	5.6623	89.8103	100.0000

Molar Distributions Liquid, X Inserted Point	Com(1 ,CO2) Calculated	Com(2 ,N2) Calculated	Com(3 ,C1) Calculated	Com(4 ,C2) Calculated
2547.590 - Psat	0.9100	0.1600	36.4700	9.6700
2516.700	0.9068	0.1568	36.1098	9.6635
2350.000	0.8882	0.1399	34.1310	9.6188
2100.000	0.8563	0.1158	31.0430	9.5253
1850.000	0.8190	0.0928	27.7951	9.3957
1600.000	0.7751	0.0714	24.3713	9.2171
1350.000	0.7225	0.0519	20.7570	8.9696
1100.000	0.6583	0.0348	16.9410	8.6202
850.000	0.5778	0.0207	12.9207	8.1105
600.000	0.4722	0.0100	8.7176	7.3179
350.000	0.3232	0.0032	4.4389	5.9088
159.000	0.1563	0.0005	1.3936	3.7478
0.000 @ Tres	0.0044	3.3822E-06	0.0195	0.1867
0.000 @ Tstd	0.0044	3.3822E-06	0.0195	0.1867

Molar Distributions Liquid, X Inserted Point	Com(5 ,C3) Calculated	Com(6 ,IC4) Calculated	Com(7 ,NC4) Calculated	Com(8 ,IC5) Calculated
2547.590 - Psat	6.9500	1.4400	3.9300	1.4400
2516.700	6.9672	1.4460	3.9488	1.4483
2350.000	7.0591	1.4792	4.0523	1.4944
2100.000	7.1949	1.5307	4.2142	1.5672
1850.000	7.3272	1.5844	4.3845	1.6449
1600.000	7.4514	1.6402	4.5635	1.7280
1350.000	7.5597	1.6977	4.7508	1.8170
1100.000	7.6377	1.7556	4.9447	1.9124
850.000	7.6565	1.8112	5.1404	2.0148
600.000	7.5481	1.8570	5.3238	2.1237
350.000	7.0883	1.8653	5.4373	2.2340
159.000	5.8687	1.7504	5.2630	2.2866
0.000 @ Tres	0.6520	0.3576	1.3160	0.9278
0.000 @ Tstd	0.6520	0.3576	1.3160	0.9278

Molar Distributions Liquid, X Inserted Point	Com(9 ,NC5) Calculated	Com(10,C6) Calculated	Com(11,C7+) Calculated	Total Calculated
2547.590 - Psat	1.4100	4.3300	33.2900	100.0000
2516.700	1.4185	4.3599	33.5744	100.0000
2350.000	1.4657	4.5259	35.1455	100.0000
2100.000	1.5404	4.7895	37.6228	100.0000
1850.000	1.6201	5.0720	40.2641	100.0000
1600.000	1.7056	5.3764	43.0999	100.0000
1350.000	1.7975	5.7061	46.1702	100.0000
1100.000	1.8966	6.0659	49.5328	100.0000
850.000	2.0038	6.4630	53.2807	100.0000
600.000	2.1198	6.9101	57.5997	100.0000
350.000	2.2430	7.4375	63.0205	100.0000
159.000	2.3212	7.9435	69.2683	100.0000
0.000 @ Tres	1.0634	5.6623	89.8103	100.0000
0.000 @ Tstd	1.0634	5.6623	89.8103	100.0000

Molar Distributions Vapour, Y Inserted Point	Com(1 ,CO2) Calculated	Com(2 ,N2) Calculated	Com(3 ,C1) Calculated	Com(4 ,C2) Calculated
2547.590 - Psat	1.2745	0.5362	78.1447	10.3949
2516.700	1.2784	0.5326	78.1217	10.4262
2350.000	1.3004	0.5129	77.9673	10.6078
2100.000	1.3380	0.4799	77.6126	10.9362
1850.000	1.3838	0.4412	77.0581	11.3606
1600.000	1.4403	0.3961	76.2215	11.9213
1350.000	1.5112	0.3443	74.9661	12.6830
1100.000	1.6022	0.2858	73.0487	13.7563
850.000	1.7213	0.2212	69.9916	15.3464
600.000	1.8779	0.1523	64.7094	17.8762
350.000	2.0541	0.0826	54.1294	22.2735
159.000	2.0040	0.0299	35.1102	27.6745
0.000 @ Tres	0.6625	0.0023	5.9728	15.6148
0.000 @ Tstd				

Molar Distributions Vapour, Y Inserted Point	Com(5 ,C3) Calculated	Com(6 ,IC4) Calculated	Com(7 ,NC4) Calculated	Com(8 ,IC5) Calculated
2547.590 - Psat	4.9505	0.7419	1.7574	0.4798
2516.700	4.9608	0.7423	1.7575	0.4788
2350.000	5.0233	0.7454	1.7598	0.4739
2100.000	5.1467	0.7540	1.7724	0.4685
1850.000	5.3208	0.7692	1.8007	0.4666
1600.000	5.5701	0.7946	1.8527	0.4702
1350.000	5.9356	0.8360	1.9421	0.4823
1100.000	6.4917	0.9044	2.0943	0.5089
850.000	7.3896	1.0221	2.3623	0.5619
600.000	8.9917	1.2459	2.8803	0.6724
350.000	12.4281	1.7698	4.1187	0.9530
159.000	19.3719	3.0220	7.1932	1.7040
0.000 @ Tres	23.2530	6.3919	18.4160	6.8150
0.000 @ Tstd				

Molar Distributions Vapour, Y	Inserted Point	Com(9 ,NC5) Calculated	Com(10,C6) Calculated	Com(11,C7+) Calculated	Total Calculated
2547.590	- Psat	0.4278	0.8774	0.4148	100.0000
2516.700		0.4267	0.8727	0.4023	100.0000
2350.000		0.4209	0.8480	0.3405	100.0000
2100.000		0.4139	0.8145	0.2632	100.0000
1850.000		0.4101	0.7868	0.2021	100.0000
1600.000		0.4109	0.7675	0.1548	100.0000
1350.000		0.4191	0.7611	0.1191	100.0000
1100.000		0.4396	0.7751	0.0931	100.0000
850.000		0.4826	0.8257	0.0752	100.0000
600.000		0.5746	0.9541	0.0652	100.0000
350.000		0.8117	1.3127	0.0664	100.0000
159.000		1.4561	2.3410	0.0932	100.0000
0.000	@ Tres	6.5127	15.5454	0.8136	100.0000
0.000	@ Tstd				

Expt BUBBLE1 : Bubble Point Pressure Calculation

Peng-Robinson (3-Parm) on ZI with PR corr.
Lohrenz-Bray-Clark Viscosity Correlation

Specified temperature	Deg F	220.0000
Calculated bubble point pressure	PSIG	2547.5908
Observed bubble point pressure	PSIG	2516.7000

Fluid properties		Liquid Observed	Liquid Calculated	Vapour Calculated
Mole Weight			93.6557	22.3055
Z-factor			0.7397	0.8648
Viscosity			0.4979	0.0195
Density	LB/FT3	45.1100	44.4766	9.0606
Molar Vol	CF/LB-ML		2.1057	2.4618

Molar Distributions Components Mnemonic	Number	Total, Z Measured	Liquid,X Calculated	Vapour,Y Calculated	K-Values Calculated
CO2	1	0.9100	0.9100	1.2745	1.4006
N2	2	0.1600	0.1600	0.5362	3.3515
C1	3	36.4700	36.4700	78.1447	2.1427
C2	4	9.6700	9.6700	10.3949	1.0750
C3	5	6.9500	6.9500	4.9505	0.7123
IC4	6	1.4400	1.4400	0.7419	0.5152
NC4	7	3.9300	3.9300	1.7574	0.4472
IC5	8	1.4400	1.4400	0.4798	0.3332
NC5	9	1.4100	1.4100	0.4278	0.3034
C6	10	4.3300	4.3300	0.8774	0.2026
C7+	11	33.2900	33.2900	0.4148	0.0125
Composition Total		100.0000	100.0000	100.0000	

Appendix B
Black oil table from a DL experiment

```
ECHO
-- DENSITY created by PVTi
-- Units: lb /ft^3     lb /ft^3     lb /ft^3
DENSITY
--
-- Fluid Densities at Surface Conditions
--
         62.4244     62.4280      0.0709
/

-- Created from a Differential Liberation Experiment.
-- Using the method of Whitson and Torp.
--PVTi--Please do not alter these lines
--PVTi--as PVTi can use them to re-create the fluid model
--PVTiMODSPEC       ============================================================
--PVTiTITLE
--PVTiModified System: From Automatically created during keyword export
--PVTiVERSION
--PVTi  2005a   /
--PVTiNCOMPS
--PVTi       11 /
--PVTiEOS
--PVTi PR3  /
--PVTiPRCORR
--PVTiLBC
--PVTiOPTIONS
--PVTi  0  0  1  2  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
--PVTi/
--PVTiNOECHO
--PVTiMODSYS        ============================================================
--PVTiUNITS
--PVTi   FIELD       ABSOL         PERCENT      /
--PVTiDEGREES
--PVTi   Fahrenheit /
--PVTiSTCOND
--PVTi      60.0000      14.6959 /
--PVTiLNAMES
--PVTi CO2
--PVTi N2
--PVTi C1
--PVTi C2
--PVTi 1*
--PVTi 1*
--PVTi 1*
--PVTi 1*
--PVTi 1*
--PVTi 1*
--PVTi 1*
--PVTi 1*
--PVTi 1*
--PVTi /
--PVTiCNAMES
--PVTi 1*
--PVTi 1*
--PVTi 1*
--PVTi 1*
--PVTi C3
--PVTi IC4
--PVTi NC4
--PVTi IC5
--PVTi NC5
--PVTi C6
--PVTi C7+
--PVTi /
--PVTiTCRIT
--PVTi  8.878998547E+01 -2.325100060E+02 -1.165900091E+02  9.010398544E+01
--PVTi  2.030156425E+02  2.716496612E+02  3.022930481E+02  3.653718329E+02
--PVTi  3.818583335E+02  4.497755478E+02  7.591376503E+02                  /
--PVTiPCRIT
--PVTi  1.071331110E+03  4.923126500E+02  6.677816960E+02  7.083423800E+02
--PVTi  6.157582100E+02  5.290524000E+02  5.506553730E+02  4.915778550E+02
--PVTi  4.887856340E+02  4.366151890E+02  2.778916460E+02                  /
--PVTiVCRIT
--PVTi  1.505735240E+00  1.441661400E+00  1.569809080E+00  2.370732080E+00
--PVTi  3.203692000E+00  4.212854980E+00  4.084707300E+00  4.933685680E+00
--PVTi  4.981741060E+00  5.622479460E+00  1.361416812E+01                  /
--PVTiZCRIT
--PVTi  2.740777974E-01  2.911514044E-01  2.847294766E-01  2.846347951E-01
--PVTi  2.773957983E-01  2.839974373E-01  2.750764332E-01  2.739266526E-01
--PVTi  2.696356502E-01  2.515338791E-01  2.892530194E-01                  /
```

```
--PVTiPARACHOR
--PVTi  7.800000000E+01  4.100000000E+01  7.700000000E+01  1.080000000E+02
--PVTi  1.503000000E+02  1.815000000E+02  1.899000000E+02  2.250000000E+02
--PVTi  2.315000000E+02  2.710000000E+02  5.644000600E+02                  /
--PVTiHYDRO
--PVTi  N N H H H H H H H H
--PVTi /
--PVTiTHERMX
--PVTi    0.0002778 /
--PVTiBIC
--PVTi  -1.200000000E-02
--PVTi   1.000000000E-01  1.000000000E-01
--PVTi   1.000000000E-01  1.000000000E-01  0.000000000E+00
--PVTi   1.000000000E-01  1.000000000E-01  0.000000000E+00  0.000000000E+00
--PVTi   1.000000000E-01  1.000000000E-01  0.000000000E+00  0.000000000E+00
--PVTi   0.000000000E+00
--PVTi   1.000000000E-01  1.000000000E-01  0.000000000E+00  0.000000000E+00
--PVTi   0.000000000E+00  0.000000000E+00
--PVTi   1.000000000E-01  1.000000000E-01  0.000000000E+00  0.000000000E+00
--PVTi   0.000000000E+00  0.000000000E+00  0.000000000E+00
--PVTi   1.000000000E-01  1.000000000E-01  0.000000000E+00  0.000000000E+00
--PVTi   0.000000000E+00  0.000000000E+00  0.000000000E+00  0.000000000E+00
--PVTi   1.000000000E-01  1.000000000E-01  2.790000000E-02  1.000000000E-02
--PVTi   1.000000000E-02  0.000000000E+00  0.000000000E+00  0.000000000E+00
--PVTi   0.000000000E+00
--PVTi   1.000000000E-01  1.000000000E-01  5.121000000E-02  1.000000000E-02
--PVTi   1.000000000E-02  0.000000000E+00  0.000000000E+00  0.000000000E+00
--PVTi   0.000000000E+00  0.000000000E+00
--PVTi /
--PVTiSPECHA
--PVTi  8.289864000E+01  1.304188200E+02  8.059590000E+01  2.264640120E+01
--PVTi -1.768504320E+01 -5.819652000E+00  3.972017160E+01 -3.987927000E+01
--PVTi -1.518225790E+01 -1.847634840E+01  2.066931380E+01                  /

--PVTiSPECHB
--PVTi  3.074785920E-01 -5.681487600E-02  2.182160160E-01  7.456690800E-01
--PVTi  1.282416840E+00  1.610661960E+00  1.394623080E+00  2.121032880E+00
--PVTi  2.040227640E+00  2.436717600E+00  2.842733577E+00                /
--PVTiSPECHC
--PVTi -2.345445360E-04  1.122062400E-04  5.011599600E-05 -2.904801840E-04
--PVTi -6.640264800E-04 -7.728832800E-04 -4.638974400E-04 -1.142577720E-03
--PVTi -1.080194400E-03 -1.305862920E-03 -6.352136076E-04                /
--PVTiSPECHD
--PVTi  7.180362000E-08 -4.890182400E-08 -4.739457600E-08  3.647958840E-08
--PVTi  1.346056200E-07  1.212078600E-07 -1.181514960E-08  2.396105640E-07
--PVTi  2.221097400E-07  2.718907920E-07  0.000000000E+00                /
--PVTiHEATVAPS
--PVTi  1.802570424E+04  0.000000000E+00  0.000000000E+00  1.650621600E+04
--PVTi  3.603408601E+04  4.586099659E+04  6.166418764E+04  5.938211357E+04
--PVTi  6.289700021E+04  7.462523487E+04  1.859674392E+05                /
--PVTiCALVAL
--PVTi  0.000000000E+00  0.000000000E+00  1.891038000E+03  3.323854000E+03
--PVTi  4.754344000E+03  6.184834000E+03  6.184834000E+03  7.615324000E+03
--PVTi  7.615324000E+03  9.045814000E+03  2.299774350E+04                /
--PVTiSIMULATE     ====================================================
--PVTiUNITS
--PVTi   FIELD       ABSOL         PERCENT      /
--PVTiDEGREES
--PVTi   Fahrenheit /
--PVTiSTCOND
--PVTi      60.0000      14.6959 /
--PVTiEXP
--PVTi   1  ZI       DL         220.0000
--PVTi                        2531.3959    2364.6959    2114.6959    1864.6959
--PVTi                        1614.6959    1364.6959    1114.6959     864.6959
--PVTi                         614.6959     364.6959     173.6959      14.6959 /
--PVTi   2  ZI       SEPS        60.0000      14.6959  0  0 /
--PVTi /
--PVTi--End of PVTi generated section--
```

```
-- Column Properties are:
--       'Oil GOR'    'PSAT'    'Oil FVF'    'Oil Visc'
-- Units: Mscf /stb     psia     rb /stb     cp
PVTO
--
-- Live Oil PVT Properties (Dissolved Gas)
--
          0.0000     14.6959      1.1198     22.9146
                    173.6959      1.1188     23.2323
                    364.6959      1.1177     23.6113
                    614.6959      1.1163     24.1029
                    864.6959      1.1149     24.5895
                   1114.6959      1.1136     25.0711
                   1364.6959      1.1123     25.5479
                   1614.6959      1.1110     26.0198
                   1864.6959      1.1098     26.4870
                   2114.6959      1.1086     26.9495
                   2364.6959      1.1075     27.4074
                   2531.3959      1.1067     27.7102
                   2562.2867      1.1066     27.7660 /
          0.0612    173.6959      1.1648      2.3875
                    364.6959      1.1614      2.4802
                    614.6959      1.1571      2.6015
                    864.6959      1.1530      2.7227
                   1114.6959      1.1492      2.8437
                   1364.6959      1.1456      2.9646
                   1614.6959      1.1421      3.0852
                   1864.6959      1.1388      3.2056
                   2114.6959      1.1357      3.3257
                   2364.6959      1.1327      3.4455
                   2531.3959      1.1308      3.5251
                   2562.2867      1.1304      3.5399 /
          0.1465    364.6959      1.2181      1.9555
                    614.6959      1.2130      2.0600
                    864.6959      1.2082      2.1646
                   1114.6959      1.2037      2.2693
                   1364.6959      1.1994      2.3741
                   1614.6959      1.1954      2.4788
                   1864.6959      1.1915      2.5836
                   2114.6959      1.1879      2.6882
                   2364.6959      1.1844      2.7928
                   2531.3959      1.1822      2.8624
                   2562.2867      1.1817      2.8753 /
```

0.2402	614.6959	1.2733	1.6142
	864.6959	1.2675	1.7038
	1114.6959	1.2622	1.7937
	1364.6959	1.2571	1.8839
	1614.6959	1.2523	1.9742
	1864.6959	1.2478	2.0646
	2114.6959	1.2435	2.1552
	2364.6959	1.2394	2.2459
	2531.3959	1.2368	2.3063
	2562.2867	1.2363	2.3176 /
0.3284	864.6959	1.3232	1.3645
	1114.6959	1.3169	1.4423
	1364.6959	1.3110	1.5204
	1614.6959	1.3054	1.5989
	1864.6959	1.3001	1.6776
	2114.6959	1.2951	1.7566
	2364.6959	1.2904	1.8358
	2531.3959	1.2874	1.8887
	2562.2867	1.2869	1.8985 /
0.4167	1114.6959	1.3720	1.1646
	1364.6959	1.3650	1.2323
	1614.6959	1.3586	1.3004
	1864.6959	1.3525	1.3688
	2114.6959	1.3468	1.4376
	2364.6959	1.3413	1.5067
	2531.3959	1.3379	1.5530
	2562.2867	1.3373	1.5616 /
0.5073	1364.6959	1.4212	0.9993
	1614.6959	1.4136	1.0582
	1864.6959	1.4066	1.1176
	2114.6959	1.4000	1.1773
	2364.6959	1.3938	1.2374
	2531.3959	1.3899	1.2777
	2562.2867	1.3892	1.2852 /
0.6017	1614.6959	1.4718	0.8605
	1864.6959	1.4637	0.9118
	2114.6959	1.4561	0.9634
	2364.6959	1.4489	1.0155
	2531.3959	1.4444	1.0504
	2562.2867	1.4436	1.0569 /
0.7011	1864.6959	1.5247	0.7430
	2114.6959	1.5159	0.7875
	2364.6959	1.5077	0.8324
	2531.3959	1.5025	0.8626
	2562.2867	1.5016	0.8682 /
0.8066	2114.6959	1.5805	0.6428
	2364.6959	1.5710	0.6814
	2531.3959	1.5650	0.7073
	2562.2867	1.5639	0.7121 /
0.9196	2364.6959	1.6399	0.5570
	2531.3959	1.6330	0.5792
	2562.2867	1.6318	0.5833 /
0.9997	2531.3959	1.6819	0.5067
	2562.2867	1.6805	0.5104 /
1.0150	2562.2867	1.6899	0.4979
	2665.1580	1.6853	0.5103 /

/

```
-- Created from a Differential Liberation Experiment.
-- Using the method of Whitson and Torp.
--PVTi--Please do not alter these lines
--PVTi--as PVTi can use them to re-create the fluid model
--PVTiMODSPEC       ========================================================
--PVTiTITLE
--PVTiModified System: From Automatically created during keyword export
--PVTiVERSION
--PVTi  2005a   /
--PVTiNCOMPS
--PVTi       11 /
--PVTiEOS
--PVTi PR3  /
--PVTiPRCORR
--PVTiLBC
--PVTiOPTIONS
--PVTi  0  0  1  2  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
--PVTi/
--PVTiNOECHO
--PVTiMODSYS        ========================================================
--PVTiUNITS
--PVTi   FIELD       ABSOL         PERCENT      /
--PVTiDEGREES
--PVTi   Fahrenheit /
--PVTiSTCOND
--PVTi      60.0000      14.6959 /

--PVTiLNAMES
--PVTi CO2
--PVTi N2
--PVTi C1
--PVTi C2
--PVTi 1*
--PVTi 1*
--PVTi 1*
--PVTi 1*
--PVTi 1*
--PVTi 1*
--PVTi 1*
--PVTi /
--PVTiCNAMES
--PVTi 1*
--PVTi 1*
--PVTi 1*
--PVTi 1*
--PVTi C3
--PVTi IC4
--PVTi NC4
--PVTi IC5
--PVTi NC5
--PVTi C6
--PVTi C7+
--PVTi /
--PVTiTCRIT
--PVTi  8.878998547E+01 -2.325100060E+02 -1.165900091E+02  9.010398544E+01
--PVTi  2.030156425E+02  2.716496612E+02  3.022930481E+02  3.653718329E+02
--PVTi  3.818583335E+02  4.497755478E+02  7.591376503E+02                  /
--PVTiPCRIT
--PVTi  1.071331110E+03  4.923126500E+02  6.677816960E+02  7.083423800E+02
--PVTi  6.157582100E+02  5.290524000E+02  5.506553730E+02  4.915778550E+02
--PVTi  4.887856340E+02  4.366151890E+02  2.778916460E+02                  /
--PVTiVCRIT
--PVTi  1.505735240E+00  1.441661400E+00  1.569809080E+00  2.370732080E+00
--PVTi  3.203692000E+00  4.212854980E+00  4.084707300E+00  4.933685680E+00
--PVTi  4.981741060E+00  5.622479460E+00  1.361416812E+01                  /
--PVTiZCRIT
--PVTi  2.740777974E-01  2.911514044E-01  2.847294766E-01  2.846347951E-01
--PVTi  2.773957983E-01  2.839974373E-01  2.750764332E-01  2.739266526E-01
--PVTi  2.696356502E-01  2.515338791E-01  2.892530194E-01                  /
```

```
--PVTiVCRITVIS
--PVTi  1.505735240E+00  1.441661400E+00  1.569809080E+00  2.370732080E+00
--PVTi  3.203692000E+00  4.212854980E+00  4.084707300E+00  4.933685680E+00
--PVTi  4.981741060E+00  5.622479460E+00  1.361416812E+01                  /
--PVTiZCRITVIS
--PVTi  2.740777974E-01  2.911514044E-01  2.847294766E-01  2.846347951E-01
--PVTi  2.773957983E-01  2.839974373E-01  2.750764332E-01  2.739266526E-01
--PVTi  2.696356502E-01  2.515338791E-01  2.892530194E-01                  /
--PVTiSSHIFT
--PVTi -4.273033674E-02 -1.313342386E-01 -1.442656189E-01 -1.032683540E-01
--PVTi -7.750138148E-02 -6.198372515E-02 -5.422489699E-02 -4.177245672E-02
--PVTi -3.027789648E-02 -7.288775999E-03  1.585297707E-01                  /
--PVTiACF
--PVTi  2.250000000E-01  4.000000000E-02  1.300000000E-02  9.860000000E-02
--PVTi  1.524000000E-01  1.848000000E-01  2.010000000E-01  2.270000000E-01
--PVTi  2.510000000E-01  2.990000000E-01  7.039730240E-01                  /
--PVTiMW
--PVTi  4.401000000E+01  2.801300000E+01  1.604300000E+01  3.007000000E+01
--PVTi  4.409700000E+01  5.812398900E+01  5.812401100E+01  7.215098900E+01
--PVTi  7.215101100E+01  8.400000000E+01  2.180000000E+02                  /
--PVTiZI
--PVTi  9.100000000E-01  1.600000000E-01  3.647000000E+01  9.670000000E+00
--PVTi  6.950000000E+00  1.440000000E+00  3.930000000E+00  1.440000000E+00
--PVTi  1.410000000E+00  4.330000000E+00  3.329000000E+01                  /
--PVTiTBOIL
--PVTi -1.092100093E+02 -3.203500037E+02 -2.587900053E+02 -1.273900088E+02
--PVTi -4.369001102E+01  1.066998754E+01  3.118998700E+01  8.212998565E+01
--PVTi  9.688998526E+01  1.470199839E+02  5.607428168E+02                  /
--PVTiTREF

--PVTi  6.772998603E+01 -3.190900037E+02 -2.586100053E+02 -1.302700087E+02
--PVTi -4.387001101E+01  6.772998603E+01  6.772998603E+01  6.772998603E+01
--PVTi  6.772998603E+01  6.052998622E+01  5.999998631E+01                  /
--PVTiDREF
--PVTi  4.850653269E+01  5.019208788E+01  2.653188725E+01  3.421052756E+01
--PVTi  3.633307854E+01  3.477237929E+01  3.614579463E+01  3.870534140E+01
--PVTi  3.907990922E+01  4.276315945E+01  5.315741645E+01                  /
--PVTiPARACHOR
--PVTi  7.800000000E+01  4.100000000E+01  7.700000000E+01  1.080000000E+02
--PVTi  1.503000000E+02  1.815000000E+02  1.899000000E+02  2.250000000E+02
--PVTi  2.315000000E+02  2.710000000E+02  5.644000600E+02                  /
--PVTiHYDRO
--PVTi  N N H H H H H H H H H
--PVTi /
--PVTiTHERMX
--PVTi    0.0002778 /
--PVTiBIC
--PVTi  -1.200000000E-02
--PVTi   1.000000000E-01  1.000000000E-01
--PVTi   1.000000000E-01  1.000000000E-01  0.000000000E+00
--PVTi   1.000000000E-01  1.000000000E-01  0.000000000E+00  0.000000000E+00
--PVTi   1.000000000E-01  1.000000000E-01  0.000000000E+00  0.000000000E+00
--PVTi   0.000000000E+00
--PVTi   1.000000000E-01  1.000000000E-01  0.000000000E+00  0.000000000E+00
--PVTi   0.000000000E+00  0.000000000E+00
--PVTi   1.000000000E-01  1.000000000E-01  0.000000000E+00  0.000000000E+00
--PVTi   0.000000000E+00  0.000000000E+00  0.000000000E+00
--PVTi   1.000000000E-01  1.000000000E-01  0.000000000E+00  0.000000000E+00
--PVTi   0.000000000E+00  0.000000000E+00  0.000000000E+00  0.000000000E+00
--PVTi   1.000000000E-01  1.000000000E-01  2.790000000E-02  1.000000000E-02
--PVTi   1.000000000E-02  0.000000000E+00  0.000000000E+00  0.000000000E+00
--PVTi   0.000000000E+00
--PVTi   1.000000000E-01  1.000000000E-01  5.121000000E-02  1.000000000E-02
--PVTi   1.000000000E-02  0.000000000E+00  0.000000000E+00  0.000000000E+00
--PVTi   0.000000000E+00  0.000000000E+00
--PVTi /
--PVTiSPECHA
--PVTi  8.289864000E+01  1.304188200E+02  8.059590000E+01  2.264640120E+01
--PVTi -1.768504320E+01 -5.819652000E+00  3.972017160E+01 -3.987927000E+01
--PVTi -1.518225790E+01 -1.847634840E+01  2.066931380E+01                  /
--PVTiSPECHB
--PVTi  3.074785920E-01 -5.681487600E-02  2.182160160E-01  7.456690800E-01
--PVTi  1.282416840E+00  1.610661960E+00  1.394623080E+00  2.121032880E+00
--PVTi  2.040227640E+00  2.436717600E+00  2.842733577E+00                  /
```

```
--PVTiSPECHC
--PVTi -2.345445360E-04  1.122062400E-04  5.011599600E-05 -2.904801840E-04
--PVTi -6.640264800E-04 -7.728832800E-04 -4.638974400E-04 -1.142577720E-03
--PVTi -1.080194400E-03 -1.305862920E-03 -6.352136076E-04                  /
--PVTiSPECHD
--PVTi  7.180362000E-08 -4.890182400E-08 -4.739457600E-08  3.647958840E-08
--PVTi  1.346056200E-07  1.212078600E-07 -1.181514960E-08  2.396105640E-07
--PVTi  2.221097400E-07  2.718907920E-07  0.000000000E+00                  /
--PVTiHEATVAPS
--PVTi  1.802570424E+04  0.000000000E+00  0.000000000E+00  1.650621600E+04
--PVTi  3.603408601E+04  4.586099659E+04  6.166418764E+04  5.938211357E+04
--PVTi  6.289700021E+04  7.462523487E+04  1.859674392E+05                  /
--PVTiCALVAL
--PVTi  0.000000000E+00  0.000000000E+00  1.891038000E+03  3.323854000E+03
--PVTi  4.754344000E+03  6.184834000E+03  6.184834000E+03  7.615324000E+03
--PVTi  7.615324000E+03  9.045814000E+03  2.299774350E+04                  /
--PVTiSIMULATE      ========================================================
--PVTiUNITS
--PVTi   FIELD       ABSOL         PERCENT      /
--PVTiDEGREES
--PVTi   Fahrenheit /
--PVTiSTCOND
--PVTi      60.0000      14.6959 /
--PVTiEXP
--PVTi   1  ZI       DL         220.0000
--PVTi                        2531.3959    2364.6959    2114.6959    1864.6959
--PVTi                        1614.6959    1364.6959    1114.6959     864.6959
--PVTi                         614.6959     364.6959     173.6959      14.6959 /
--PVTi   2  ZI       SEPS        60.0000      14.6959  0  0 /
--PVTi /
--PVTi--End of PVTi generated section--

-- Column Properties are:
--     'Pressure'    'Gas FVF'    'Gas Visc'
-- Units: psia     rb /Mscf     cp
PVDG
--
-- Dry Gas PVT Properties (No Vapourised Oil)
--
         14.6959    230.5117      0.0103
        173.6959     18.6410      0.0118
        364.6959      8.7154      0.0126
        614.6959      5.0751      0.0132
        864.6959      3.5528      0.0138
       1114.6959      2.7217      0.0144
       1364.6959      2.2019      0.0150
       1614.6959      1.8488      0.0157
       1864.6959      1.5955      0.0165
       2114.6959      1.4064      0.0173
       2364.6959      1.2610      0.0182
       2531.3959      1.1819      0.0189
       2562.2867      1.1685      0.0190
/
```

Appendix C
Equilibration keyword

```
ECHO
--PVTi--Please do not alter these lines
--PVTi--as PVTi can use them to re-create the fluid model
--PVTiMODSPEC       ============================================================
--PVTiTITLE
--PVTiModified System: From Automatically created during keyword export
--PVTiVERSION
--PVTi  2005a   /
--PVTiNCOMPS
--PVTi       11 /
--PVTiEOS
--PVTi PR3  /
--PVTiPRCORR
--PVTiLBC
--PVTiOPTIONS
--PVTi  0  0  1  2  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
--PVTi/
--PVTiNOECHO
--PVTiMODSYS         ============================================================
--PVTiUNITS
--PVTi   FIELD       ABSOL         PERCENT      /
--PVTiDEGREES
--PVTi   Fahrenheit /
--PVTiSTCOND
--PVTi      60.0000      14.6959 /
--PVTiLNAMES
--PVTi CO2
--PVTi N2
--PVTi C1
--PVTi C2
--PVTi 1*
--PVTi 1*
--PVTi 1*
--PVTi 1*
--PVTi 1*
--PVTi 1*
--PVTi 1*
--PVTi 1*
--PVTi /
--PVTiCNAMES
--PVTi 1*
--PVTi 1*
--PVTi 1*
--PVTi 1*
--PVTi C3
--PVTi IC4
--PVTi NC4
--PVTi IC5
--PVTi NC5
--PVTi C6
--PVTi C7+
--PVTi /
--PVTiTCRIT
--PVTi  8.878998547E+01 -2.325100060E+02 -1.165900091E+02  9.010398544E+01
--PVTi  2.030156425E+02  2.716496612E+02  3.022930481E+02  3.653718329E+02
--PVTi  3.818583335E+02  4.497755478E+02  7.591376503E+02                  /
--PVTiPCRIT
--PVTi  1.071331110E+03  4.923126500E+02  6.677816960E+02  7.083423800E+02
--PVTi  6.157582100E+02  5.290524000E+02  5.506553730E+02  4.915778550E+02
--PVTi  4.887856340E+02  4.366151890E+02  2.778916460E+02                  /
--PVTiVCRIT
--PVTi  1.505735240E+00  1.441661400E+00  1.569809080E+00  2.370732080E+00
--PVTi  3.203692000E+00  4.212854980E+00  4.084707300E+00  4.933685680E+00
--PVTi  4.981741060E+00  5.622479460E+00  1.361416812E+01                  /
--PVTiZCRIT
--PVTi  2.740777974E-01  2.911514044E-01  2.847294766E-01  2.846347951E-01
--PVTi  2.773957983E-01  2.839974373E-01  2.750764332E-01  2.739266526E-01
--PVTi  2.696356502E-01  2.515338791E-01  2.892530194E-01                  /
```

```
--PVTiVCRITVIS
--PVTi  1.505735240E+00  1.441661400E+00  1.569809080E+00  2.370732080E+00
--PVTi  3.203692000E+00  4.212854980E+00  4.084707300E+00  4.933685680E+00
--PVTi  4.981741060E+00  5.622479460E+00  1.361416812E+01                  /
--PVTiZCRITVIS
--PVTi  2.740777974E-01  2.911514044E-01  2.847294766E-01  2.846347951E-01
--PVTi  2.773957983E-01  2.839974373E-01  2.750764332E-01  2.739266526E-01
--PVTi  2.696356502E-01  2.515338791E-01  2.892530194E-01                  /
--PVTiSSHIFT
--PVTi -4.273033674E-02 -1.313342386E-01 -1.442656189E-01 -1.032683540E-01
--PVTi -7.750138148E-02 -6.198372515E-02 -5.422489699E-02 -4.177245672E-02
--PVTi -3.027789648E-02 -7.288775999E-03  1.585297707E-01                  /
--PVTiACF
--PVTi  2.250000000E-01  4.000000000E-02  1.300000000E-02  9.860000000E-02
--PVTi  1.524000000E-01  1.848000000E-01  2.010000000E-01  2.270000000E-01
--PVTi  2.510000000E-01  2.990000000E-01  7.039730240E-01                  /
--PVTiMW
--PVTi  4.401000000E+01  2.801300000E+01  1.604300000E+01  3.007000000E+01
--PVTi  4.409700000E+01  5.812398900E+01  5.812401100E+01  7.215098900E+01
--PVTi  7.215101100E+01  8.400000000E+01  2.180000000E+02                  /
--PVTiZI
--PVTi  9.100000000E-01  1.600000000E-01  3.647000000E+01  9.670000000E+00
--PVTi  6.950000000E+00  1.440000000E+00  3.930000000E+00  1.440000000E+00
--PVTi  1.410000000E+00  4.330000000E+00  3.329000000E+01                  /
--PVTiTBOIL
--PVTi -1.092100093E+02 -3.203500037E+02 -2.587900053E+02 -1.273900088E+02
--PVTi -4.369001102E+01  1.066998754E+01  3.118998700E+01  8.212998565E+01
--PVTi  9.688998526E+01  1.470199839E+02  5.607428168E+02                  /

--PVTiTREF
--PVTi  6.772998603E+01 -3.190900037E+02 -2.586100053E+02 -1.302700087E+02
--PVTi -4.387001101E+01  6.772998603E+01  6.772998603E+01  6.772998603E+01
--PVTi  6.772998603E+01  6.052998622E+01  5.999998631E+01                  /
--PVTiDREF
--PVTi  4.850653269E+01  5.019208788E+01  2.653188725E+01  3.421052756E+01
--PVTi  3.633307854E+01  3.477237929E+01  3.614579463E+01  3.870534140E+01
--PVTi  3.907990922E+01  4.276315945E+01  5.315741645E+01                  /
--PVTiPARACHOR
--PVTi  7.800000000E+01  4.100000000E+01  7.700000000E+01  1.080000000E+02
--PVTi  1.503000000E+02  1.815000000E+02  1.899000000E+02  2.250000000E+02
--PVTi  2.315000000E+02  2.710000000E+02  5.644000600E+02                  /
--PVTiHYDRO
--PVTi  N N H H H H H H H H H
--PVTi /
--PVTiTHERMX
--PVTi    0.0002778 /
--PVTiBIC
--PVTi  -1.200000000E-02
--PVTi   1.000000000E-01  1.000000000E-01
--PVTi   1.000000000E-01  1.000000000E-01  0.000000000E+00
--PVTi   1.000000000E-01  1.000000000E-01  0.000000000E+00  0.000000000E+00
--PVTi   1.000000000E-01  1.000000000E-01  0.000000000E+00  0.000000000E+00
--PVTi   0.000000000E+00
--PVTi   1.000000000E-01  1.000000000E-01  0.000000000E+00  0.000000000E+00
--PVTi   0.000000000E+00  0.000000000E+00
--PVTi   1.000000000E-01  1.000000000E-01  0.000000000E+00  0.000000000E+00
--PVTi   0.000000000E+00  0.000000000E+00  0.000000000E+00
--PVTi   1.000000000E-01  1.000000000E-01  0.000000000E+00  0.000000000E+00
--PVTi   0.000000000E+00  0.000000000E+00  0.000000000E+00  0.000000000E+00
--PVTi   1.000000000E-01  1.000000000E-01  2.790000000E-02  1.000000000E-02
--PVTi   1.000000000E-02  0.000000000E+00  0.000000000E+00  0.000000000E+00
--PVTi   0.000000000E+00
--PVTi   1.000000000E-01  1.000000000E-01  5.121000000E-02  1.000000000E-02
--PVTi   1.000000000E-02  0.000000000E+00  0.000000000E+00  0.000000000E+00
--PVTi   0.000000000E+00  0.000000000E+00
--PVTi /
--PVTiSPECHA
--PVTi  8.289864000E+01  1.304188200E+02  8.059590000E+01  2.264640120E+01
--PVTi -1.768504320E+01 -5.819652000E+00  3.972017160E+01 -3.987927000E+01
--PVTi -1.518225790E+01 -1.847634840E+01  2.066931380E+01                  /
```

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--PVTiSPECHD
--PVTi  7.180362000E-08 -4.890182400E-08 -4.739457600E-08  3.647958840E-08
--PVTi  1.346056200E-07  1.212078600E-07 -1.181514960E-08  2.396105640E-07
--PVTi  2.221097400E-07  2.718907920E-07  0.000000000E+00                  /
--PVTiHEATVAPS
--PVTi  1.802570424E+04  0.000000000E+00  0.000000000E+00  1.650621600E+04
--PVTi  3.603408601E+04  4.586099659E+04  6.166418764E+04  5.938211357E+04
--PVTi  6.289700021E+04  7.462523487E+04  1.859674392E+05                  /
--PVTiCALVAL
--PVTi  0.000000000E+00  0.000000000E+00  1.891038000E+03  3.323854000E+03
--PVTi  4.754344000E+03  6.184834000E+03  6.184834000E+03  7.615324000E+03
--PVTi  7.615324000E+03  9.045814000E+03  2.299774350E+04                  /
--PVTiSIMULATE      ====================================================
--PVTiUNITS
--PVTi   FIELD       ABSOL         PERCENT      /
--PVTiDEGREES
--PVTi   Fahrenheit /
--PVTiSTCOND
--PVTi      60.0000      14.6959 /
--PVTiEXP
--PVTi   1  ZI       COMPG  OIL            220.0000    3594.6959    9200.0000   0.00000000
--PVTi                        9000.0003    9013.7934    9027.5865    9041.3796
--PVTi                        9055.1727    9068.9658    9082.7589    9096.5520
--PVTi                        9110.3451    9124.1382    9137.9313    9151.7244
--PVTi                        9165.5175    9179.3106    9193.1037    9200.0000
--PVTi                        9206.8968    9220.6900    9234.4831    9248.2762
--PVTi                        9262.0693    9275.8624    9289.6555    9303.4486
--PVTi                        9317.2417    9331.0348    9344.8279    9358.6210
--PVTi                        9372.4141    9386.2072    9400.0003              /
--PVTi   2  ZI       SEPS        60.0000      14.6959  0  0 /
--PVTi /
--PVTi--End of PVTi generated section--
-- Units: ft     Mscf /stb
RSVD
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```
-- Rs v Depth
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   9000.000012 1.04230005223793
   9013.79311155862 1.04036067782925
   9027.58621111724 1.03842976871228
   9041.37931067586 1.03650725653987
   9055.17241023448 1.03459307408644
   9068.9655097931 1.03268715471524
   9082.75860935172 1.03078943264239
   9096.55170891034 1.02889984287511
   9110.34480846897 1.02701832119901
   9124.13790802759 1.0251448041655
   9137.93100758621 1.0232792291457
   9151.72410714483 1.02142153398882
   9165.51720670345 1.01957165758959
   9179.31030626207 1.01772953960523
   9193.10340582069 1.01589512001063
   9199.99970560001 1.01498081175134
   9206.89650537931 1.01406833977752
   9220.68970493793 1.0122491273241
   9234.48280449655 1.01043745128114
   9248.27590405517 1.00863324135421
   9262.06900361379 1.00683644111373
   9275.86210317241 1.00504699477472
   9289.65520273103 1.00326484718549
   9303.44830228965 1.00148994381803
   9317.24140184828 0.999722230758537
   9331.0345014069 0.997961654698016
   9344.82760096552 0.99620816292316
   9358.62070052414 0.994461703307462
   9372.41380008276 0.992722224302363
   9386.20689964138 0.990989674928637
   9399.9999992 0.989264004767973
/
```