Impact of Methane Loss on Bitumen Viscosity - Joint Industry Project

Roy Coates
Gerry Pierce
Hugh Fung

REPORT PREPARED FOR
AERI
PARAMOUNT RESOURCES LTD.
ENCANA CORP.
PETRO-CANADA
CONOCOPHILLIPS CANADA CORP.
NEXEN INC.
BY ALBERTA RESEARCH COUNCIL INC.

HEAVY OIL AND OIL SANDS
250 KARL CLARK ROAD
EDMONTON, ALBERTA T6N 1E4
CANADA

CONFIDENTIAL

December, 2005

EXECUTIVE SUMMARY

This report describes a Joint Industry Project (JIP) commissioned to examine the impact of de-methanization on the viscosity of bitumen. The experimental study was carried out by the Alberta Research Council's (ARC) Heavy Oil and Oil Sands (HOOS) research department. Members of the JIP are AERI, Paramount Resources Ltd., EnCana Corp., Petro-Canada, ConocoPhillips Canada Corp., and Nexen Inc. The impetus for conducting the study was to provide industry with detailed data which could then be used in examining the effect that reservoir depressurization and degasification has on the recovery process. This has a direct application to the gas over bitumen issue in the Alberta oil sands.

The study involved the designing and construction of an experimental set up which enabled the preparation of different mixtures of methane and bitumen, and the measurement of the live bitumen viscosity and methane solubility at temperatures (30 °C – 220 °C) and pressures (500 kPa – 4,000 kPa) representative of a SAGD operation. Bitumen from two different sources, Petro-Canada's MacKay River lease and EnCana's Christina Lake lease, was obtained and tested. A series of 18 viscosity and solubility measurements were taken over the specified temperature and pressure range on each bitumen in a fully methane saturated state. For each bitumen, an additional 4 viscosity measurements were taken in an undersaturated state. Also the viscosity of each bitumen in a degassed dead state was measured over the specified temperature range.

Once the measurements were taken on each bitumen, they were then used to assess the effectiveness of the different methods to predict live oil viscosity. The three approaches assessed were;

- Mehrotra & Svrcek generalized empirical correlations for the viscosity of fully methane saturated bitumen and methane solubility developed from their experimental measurements.
- Equations developed by Butler from Mehrotra & Svrcek's data for predicting live oil viscosity and methane solubility. The values of the constants in Butler's equations are determined for both bitumens in the present study.
- Approach used by the CMG STARS numerical simulator. Values for liquid methane pseudo-viscosity required by this approach are determined for both bitumens in the present study. Values for the constants required in the equation to calculate methane gas/liquid K-value (from which methane solubility can be calculated) were also determined for both bitumens in this study.

The experimental measurements showed that temperature has a much greater effect on oil viscosity then the degree of saturation of methane. Conversely pressure had a greater influence on methane solubility then temperature

The Mehrota & Svrcek correlations with their suggested coefficients, under predicted both methane solubility and live oil viscosity for both bitumens. Under prediction of methane solubility was about 30% for both bitumens. Live oil viscosity was under predicted by a larger degree with Christina Lake bitumen then MacKay River; on average by 20% at low viscosity

and 60% at high viscosity for MacKay River versus 40% at low viscosity and 80% at higher viscosities for Christina Lake.

Both the Butler and STARS methods were effective at predicting the methane solubility and live oil viscosity at fully saturated conditions. Both approaches were also effective at predicting the live oil viscosity at undersaturated conditions if the methane solubility was known. Both approaches predicted live oil viscosity within 10% for MacKay River bitumen and 15% for Christina Lake bitumen.

The experimental measurements of methane solubility at fully saturated conditions were very similar for both bitumens as were the values of the constants in both the Butler and STARS equations for calculating methane solubility.

The study showed that the methane pseudo-viscosity of the STARS approach could be effectively characterized by equations similar to those that characterize the viscosity of degassed bitumen. Both bitumens show a similarity in the magnitude of the methane pseudo-viscosity and its relationship with temperature.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

IMPACT OF METHANE LOSS ON BITUMEN VISCOSITY - JOINT INDUSTRY PROJECT

ROY COATES, GERRY PIERCE, HUGH FUNG

1.0 INTRODUCTION

There is major concern in Alberta regarding the situation where exploitable gas reserves overlay oil sand deposits that are recoverable by a SAGD process. The fear is that the development of either resource autonomously, may have a detrimental effect on the exploitation of the other. A case in point is the Surmount Steam Assisted Gravity Drainage (SAGD) pilot operated by Conoco. The lease has a top gas zone overlying the oil sand pay zone. An observation well indicates that the gas cap pressure at the pilot site fell from 1327 kPa to 858 kPa over 3 years due to production of gas. It is estimated that the pressure may fall to less than 300 kPa by the time the gas wells are abandoned. A reduction in pressure within of the oil sand zone brings about a degasification (methane) of the oil phase, which in turn results in an increase in the oil phase viscosity. The degree of degasification and viscosity increase may have an important effect on the ultimate performance of the SAGD process.

The Alberta Research Council (ARC) has the capability to saturate heavy crude oil with methane to different degrees of saturation at different conditions of temperature and pressure, and has the capability to determine properties (viscosity and composition) of the bitumen/methane blend at these conditions. A joint industry project (JIP) was initiated that enlisted ARC to measure the viscosity of two different methane saturated bitumens at temperature and pressure conditions encountered during a SAGD operation. One bitumen was from Petro-Canada's MacKay River lease and the other bitumen was from EnCana's Christina Lake lease. The project also aimed to establish a suitable relationship (existing or new) that would enable industry to predict the effect of methane degasification on oil phase viscosity. Members of the JIP are AERI, Paramount Resources Ltd., EnCana Corp., Petro-Canada, ConocoPhillips Canada Corp., and Nexen Inc. This report describes the experimental study and ensuing results.

It is well established that along with temperature (and to a minor degree pressure), the viscosity of crude oil is significantly affected by the amount of gas dissolved in the oil. The viscosity of the oil decreases with increasing gas content. In turn the amount of gas that can be dissolved in the oil is a function of pressure and temperature. The solubility of methane in oil decreases with increasing temperature and increases with increasing pressure. It is apparent that any correlation to determine live oil viscosity must include effects of temperature and pressure on the dead oil viscosity and the effect of the amount of gas dissolved in the oil. Three approaches to predicting methane solubility and live oil viscosity are examined in this report. They are denoted as Mehrotra and Svrcek (referred to in this report as M&S) approach, Butler approach and STARS (CMG's thermal numerical simulator) approach.

Mehrotra and Svrcek[1,2] et al. carried out extensive measurements of the solubility of different gases in Athabasca bitumen along with density and viscosity measurements. From this work two empirical correlations were produced:

$$\mathrm{sol} = a_1 + a_2 \times P + a_3 \times \frac{P}{T} + a_4 \times \left(\frac{P}{T}\right)^2 \qquad (1)$$

where:

sol = solubility [cm³(@NTP)/cm³]
P = pressure [MPa]
T = temperature [°K]
a_1, a_2, a_3, a_4 = correlation coefficients for specific gases

and

$$\log\log(\mu) = b_1 + b_2 \times T + b_3 \times P + b_4 \times \left(\frac{P}{T}\right) \qquad (2)$$

where:

μ = viscosity [mPa.s]
T = temperature [°K]
P = pressure, [MPa]
b_1, b_2, b_3, b_4 = correlation coefficients for specific gases

The respective correlation coefficients for methane are presented in Table 1

Table 1. M&S Correlation Coefficients

Solubility (a_1,a_2,a_3,a_4)	-0.018931	-0.085048	827.26	-635.26
Viscosity (b_1,b_2,b_3,b_4)	0.777532	-0.00429448	-0.0175639	3.46902

Although these correlations adequately capture the trends associated with the effects of pressure and temperature they are only generalized equations. They do not take into account the variance in different bitumen dead oil viscosities due to compositional differences. Also the viscosity correlation is only for fully saturated bitumen and can not be used for under-saturated conditions. Additionally the correlations were based on measurements at <100 °C and cannot necessarily be extrapolated to elevated SAGD operating temperatures. An objective of this study will be to examine how well the above correlations predict the solubility and viscosity of the bitumens tested.

Butler[3] took another approach with Mehrotra and Svrcek's measurements by plotting dissolved methane versus log(dead oil viscosity)/log(live oil viscosity). He found the linear correlation:

$$\frac{\log(\mu_o)}{\log(\mu)} = 1 + m' \times \mathrm{sol} \qquad (3)$$

where:

μ_o = dead oil viscosity
μ = live oil viscosity
sol = methane solubility
m′ = slope

Also he found that their solubility measurements correlated against pressure and temperature by the equation:

$$\text{sol} = a \times P \times \exp\left(\frac{b}{T}\right) \quad (4)$$

where:

sol = methane solubility
P = pressure
T = temperature
a,b = correlation coefficients

By combining the two equations the following correlation predicts the viscosity of live oil as a function of temperature, pressure and the viscosity of the dead oil at the same pressure and temperature:

$$\mu = \exp\left\{\frac{\ln(\mu_o)}{1 + m' \times a \times P \times \exp\left(b/T\right)}\right\} \quad (5)$$

This correlation, however, is again based on measurements taken at temperatures <100 °C and at fully saturated conditions. An objective of this study is to determine the values of m′, a, and b for the bitumens used.

A third approach, which is used by the STARS numerical simulator, is based on a formula proposed by Shu[4] for determining the viscosity of a bitumen-liquid solvent mixture. The formula has the following logarithmic mixing form:

$$\ln(\mu_m) = \sum_{i=1}\left(X_i \times \ln(\mu_i)\right) \quad (6)$$

where:

μ_m = viscosity of mixture
X_i = mole fraction of component i in oil phase
μ_i = viscosity of pure component i

Methane is considered as the solvent and although at practical conditions it does not exist as a liquid, its pseudo properties can be determined by making a few live oil viscosity measurements. At a constant temperature, a plot of the measurements of the mole fraction of methane in oil versus ln(oil viscosity) produces a linear relationship. Extrapolation of the line to

X_{CH4} = 1 yields the pseudo-viscosity of pure liquid methane. One of the goals of the present study is to determine if this approach is also valid for undersaturated conditions.

The default equation used in STARS to calculate liquid component viscosities is the following exponential relationship between viscosity and temperature:

$$\mu = \text{avisc} \times \exp(\text{bvisc}/\text{T}) \qquad (7)$$

The STARS manual suggests 0.137849 cp and 114.14 °K as values for the constants avisc and bvisc for liquid methane.

Usually a better fit of the viscosity-temperature relationship for oil is represented by Walther's[5] equation:

$$\log\log(\mu + 0.8) = \text{m} \times \log(\text{T}) + \text{n}$$ (For heavy oil and bitumen the term 0.8 if often neglected.) (8)

Another objective of this study is to determine if the pseudo-viscosity of liquid methane, obtained through the Shu approach, can also be characterized by these equations and whether the methane viscosities are independent of the bitumen type.

The STARS numerical simulator uses a modified version of the Antoine equation to calculate methane solubility:

$$\text{K} = (\text{kv1}/\text{P} + \text{kv2} \times \text{P} + \text{kv3}) \times \exp(\text{kv4}/(\text{T} - \text{kv5})) \qquad (9)$$

where:

K = gas-liquid equilibrium factor = mole fraction of component in gas phase/mole fraction of component in oil phase. For a single gas component K=1/X.

P = pressure

T = temperature

kv1, kv2, kv3, kv4, kv5 = constants for specific gases

The STARS manual gives values of 5.4547x10^5 kPa, 0.0, 0.0, -879.84 °K, and 7.16 °K for kv1, kv2, kv3, kv4 and kv5 respectively for methane (from Reid et al[6]). In the study the constant are determined for the two bitumens.

2.0 OBJECTIVES

The objectives were to make solubility and viscosity measurements of mixtures of methane and two different Athabasca bitumens at temperatures and pressures encountered during a SAGD operation. The measurements were to be compared with the results from different methods for predicting solubility and viscosity.

3.0 EXPERIMENTAL

3.1. Experimental Set Up

An experimental set up was designed and constructed to enable measurement of live bitumen viscosity at temperatures (up to 220 °C) and pressures (up to 4000 kPa) representative of SAGD operations in Alberta. Incorporated into the set up was the ability to extract a sample of the bitumen and measure the methane dissolved in it. Figure 1 shows a simplified schematic of the set up.

The experimental set up consisted of two 5 l accumulators, shown in Figure 2, which were connected together at the top and connected at the bottom water side to a dual piston pump, shown in Figure 3. The accumulators were mounted within an oven to maintain test temperature. One accumulator was filled with live oil (piston at the bottom) while the other accumulator was partially filled with methane (piston near the top). At each new test condition of pressure and temperature, the oil was pumped back and forth between accumulators to expedite a state of equilibrium. The piston pump would displace the oil by pumping water into the bottom of the oil accumulator while the back pressure regulator would maintain system pressure by allowing water to flow from the bottom of other accumulator. When equilibrium conditions were established the fluid levels in the accumulators were adjusted so that only the oil phase was contained in one accumulator and the gas phase was contained in the other accumulator.

Viscosity measurements were made using a capillary tube viscometer positioned between the top of the two accumulators. The viscometer consisted of two 1 m long parallel tubes; a 0.125 inch diameter tube and a 0.0625 inch diameter tube, shown in Figure 4. The larger tube was used for high viscosity measurements and the smaller tube for low viscosity measurements. A differential pressure transmitter (one high range and one low range) measured the pressure drop across the tubes when oil was displaced through them by pumping water at a constant rate into the bottom of the accumulator from the piston pump. Determination of fluid viscosity from the capillary tube viscometer is based on Pouselle's Law which states that:

$$\Delta P = \frac{8 \times \mu \times L \times Q}{\pi \times r^4} \qquad (10)$$

where:

ΔP = pressure drop across capillary tube
μ = viscosity
L = length of capillary tube
Q = fluid flow rate (water rate from pump corrected for oven temperature)
r = radius of capillary tube

For a specific capillary tube, L and r are constant and the equation can be rewritten:

$$\mu = A \times \frac{\Delta P}{Q} \tag{11}$$

A is the calibration constant for a specific tube and is obtained by flowing fluids of known viscosity through the tubes at different flow rates and measuring the resulting pressure drops. Calibration constants for the two tubes were determined using four viscosity fluid standards and details of the calibration are presented in Appendix I. The calibration constants obtained were 16.08 and 15.14 for the 0.125 and 0.0625 inch tube respectively.

Once calibrated the viscometer was used to determine the viscosity of the bitumen by pumping the oil phase at several controlled rates, through the tubes and measuring the resulting pressure drop. A plot of pressure drop versus flow rate provides a slope which is then multiplied by the calibration constant to give viscosity.

Solubility measurements were made by extracting a sample of the oil phase through a back pressure regulator into a sealed sample jar. The lid of the sample jar was connected to a Brooks total volume meter, Figure 5, which measured the volume of gas that exsolved from the oil phase when flashed to atmospheric conditions. The volume of remaining oil was measured, volumes of gas and oil were corrected for standard conditions (15 °C & 1 atm.) and a gas/oil ratio (GOR) was determined.

3.2. Experimental Conditions

The run conditions were selected to span the conditions representative of SAGD operations in Alberta. Table 2 summarizes the conditions under which measurements were taken.

Table 2. Summary of Experimental Measurements

	Dead Oil (Viscosity)	Live Oil (GOR & Viscosity) Pressure (kPa gauge)			
Temperature (°C)		**4000**	**1500**	**500**	**1500[1]**
30	X	X	X	X	X
70	X	X	X	X	X
100	X	X	X	X	X
125	X	X	X	X	X
150	X	X	X	X	
200	X	X	X		
220[2]	X	X			

[1] Undersaturated

[2] The initial proposal specified an upper temperature of 250 °C; however, this value was relaxed because of equipment limitations.

The order in which measurements are taken was from conditions of highest GOR to conditions of lower GOR. For example the first measurement was at 30 °C and 4000 kPa. The bitumen mixture was then heated to drive off dissolved methane and measurements were taken at each specified temperature. The mixture was then cooled back to 30 °C and depressurized to 1500 kPa releasing additional dissolved methane. This procedure was continued over the experimental temperature and pressure range. The under saturated measurements were obtained by cooling oil saturated with CH_4 at 1500 kPa and 150 °C and taking viscosity measurements at 30 °C, 70 °C, 100 °C, and 125 °C. Cooling was carried out at constant 1500 kPa and in the absence of methane gas. GOR of the oil at undersaturated conditions was the same as at 1500 kPa and 150 °C.

3.3. Bitumen Properties

The two bitumens to be tested came from two locations in the Athabasca Oil Sands: Petro-Canada's MacKay River Lease and EnCana's Christina Lake lease. One of the chief differences between the two leases is the depth of the pay zone. MacKay River is relatively shallow, averaging 95 m and Christina Lake is deeper at 350 m. This difference may lead to differences in chemical composition and as a result different viscosity behavior. Another difference of importance to the present study is the location where the bitumen was collected at the respective plant sites. The operation and surface oil/water separation facilities at MacKay River require very little additives for efficient separation, so the bitumen supplied was sales oil that required no further processing for laboratory testing. However, the Christina Lake operation uses large amounts of additives which negated the use of sales oil in the study. The Christina Lake bitumen was obtained directly from the well head manifold. This produced a very stable oil/water emulsion that proved very difficult to separate. Several methods were attempted including; heating with long residence time, filtering with a hydrophilic paper filter and centrifugation. The method which was ultimately used and which provided viscosities similar to high speed centrifugation (this method was not practical because of the small volumes that could be processed) was removal of the water by a dean stark extraction and then removal of solvent by rotovap at low temperature. Table 3 gives the viscosity measurements made with a laboratory viscometer for a range of temperatures from 10 °C to 150 °C (the upper limit of the viscometer).

Table 3. Dead Oil Viscosity Measurements

Temperature	MacKay River Viscosity	Christina Lake Viscosity
°C	cp	cp
10	2,048,454	3,480,800
20	330,472	673,920
30	71,437	142,850
40	20,595	37,670
50	6,988	12,076
60	2,811	4,590
70	1,240	1,963
80	614	952
90	329	505
100	191	291
110	120	177
130	57.6	78.0
150	32.9	41.6

Dead oil viscosity data is plotted according to exponential equation 7 as ln(μ) versus 1/T in Figures 6 and 7 for MacKay River and Christina Lake bitumen respectively and according to Walther's equation 8 as lnln(μ) versus ln(T) in Figures 8 and 9 for MacKay River and Christina Lake bitumen respectively. Walther's equation produces the best fit to the data. For MacKay River bitumen avisc and bvisc of equation 7 are 2.75×10^{-9} cp and 9383.2 °K, and m and n of equation 8 are -3.583 and 22.889. For Christina Lake bitumen avisc and bvisc of equation 7 are 2.06×10^{-9} cp and 677.4 °K, and m and n of equation 8 are -3.504 and 22.489.

Table 4 presents the measured densities for the two bitumens.

Table 4. Bitumen Densities

Temperature	MacKay River Density	Christina Lake Density
°C	g/cm^3	g/cm^3
15	1.011	1.019
20	1.006	1.015
25	1.002	1.009

Additionally, measured molecular weights for the two bitumens were 611 g/mole for MacKay River and 640 g/mole for Christina Lake.

4.0 RESULTS

4.1. MacKay River Bitumen

4.1.1. Measurements

Appendix II presents the raw capillary tube pressure drop measurements for MacKay River bitumen at all the experimental test conditions. A summary of calculated viscosities is presented in Table 5.

Table 5. MacKay River Bitumen Viscosity Measurements

	Dead Oil Viscosity (cp)	Live Oil Viscosity (cp)			
		Pressure (kPa)			
Temperature (°C)		**4000**	**1500**	**500**	**1500[1]**
30	71,912	20,383	37,794	53,724	45,219
70	1,301	626	900	1,072	1,024
100	202	123	158	171	166
125	67.3	46.5	56.4	60.8	58.0
150	30.4	22.0	26.1	26.3	
200	9.7	8.4	9.44		
220	7.1	6.1			

[1] Undersaturated

Appendix III presents all the raw GOR measurements for MacKay River bitumen. Table 6 presents the methane solubility measurements. Mole fraction of methane in oil was derived from the GOR by the following equation:

$$X_{CH_4} = \frac{GOR \times 42.32}{\left(\rho / MW \times 1{,}000{,}000 \right) + GOR \times 42.32} \qquad (12)$$

where:

X_{CH4} = mole fraction of methane in oil phase
GOR = gas/oil ratio (@STP) [m^3/m^3]
ρ = density of oil at 15 °C [g/cm^3]
MW = molecular weight [g/mole]
42.32 = mole density of gas at standard conditions [$gmole/m^3$]
1,000,000 = units conversion factor [cm^3/m^3]

Table 6. MacKay River Bitumen Methane Solubility Measurements

	Methane Solubility					
	Pressure (kPa)					
	4000		1500		500	
Temperature (°C)	GOR	X	GOR	X	GOR	X
30	10.84	0.2172	4.34	0.1000	1.54	0.0378
70	9.12	0.1892	3.75	0.0876	1.23	0.0305
100	8.19	0.1732	2.91	0.0694	1.01	0.0252
125	7.30	0.1573	2.63	0.0631	0.98	0.0245
150	7.09	0.1536	2.62	0.0629	0.96	0.0629
200	6.82	0.1486	2.35	0.0567		
220	6.72	0.1467				

4.1.2. M&S Approach for Predicting MacKay River Bitumen Properties

Figures 10 and 11 compare the calculated methane solubilities and live oil viscosities from the M&S correlations (equations 1 and 2) to measured values. The graphs show that for the MacKay River bitumen, the M&S correlations under predict methane solubility; on average by 30% and under predict live oil viscosity on average by 20% at low viscosity but 60% at higher viscosities.

4.1.3. Butler Approach for Predicting MacKay River Bitumen Properties

Figure 12 presents a plot of the ln(GOR/P) versus 1/T for MacKay River bitumen. The data exhibits a reasonably good linear fit of the measurements. The slope of the regression equates to b and the exponential of the intercept equates to a in equation 4. By minimizing the sum of errors squared the values of a and b were refined to give 0.00073 and 382.64. Figure 13 shows that the calculated solubilities from equation 4 compare quite closely to the measured values.

Figure 14 presents a plot of the ln(dead oil μ)/ln(live oil μ) versus GOR for MacKay River bitumen. The data again exhibits a reasonably good linear fit. The slope of the regression, 0.0125, equates to m′ in equation 3. Using the values for a, b and m′, the live oil viscosities are calculated with equation 5 and the ratio of calculated values and measured values are shown in Figure 15. The Butler approach was effective at predicting MacKay River live oil viscosities at saturated conditions within 10%. Also shown on Figure 15 are the predictions at undersaturated conditions and these also fall within 10% of the measured values

4.1.4. STARS Approach for Predicting MacKay River Bitumen Properties

The Mackay River bitumen measured solubility and viscosity data are presented in Figure 16 in the form of ln(μ) versus mole fraction methane in oil. Dead oil viscosity is included at zero mole fraction methane. Each set of measurements at each test temperature produces a linear relationship that when extrapolated to X_{CH4} = 1 gives the pseudo-viscosity of pure liquid methane. Table 7 gives the values of the methane viscosity at each temperature and these values are plotted as ln(μ) versus 1/T in Figure 17 and lnln(μ) versus ln(T) in Figure 18.

Table 7. MacKay River Methane Pseudo-Viscosity

Temperature	Viscosity
°C	cp
30	231
70	30.5
100	13.3
125	7.00
150	5.07
200	3.73
220	2.72

The methane viscosity values are characterised quite well by equation 7 and equation 8 with avisc and bvisc equal to 0.0023 cp and 3335.1 °K, and m and n equal to -3.34 and 20.72 respectively. Note that these values for avisc and bvisc are very different from those suggested in the STARS manual.

Also plotted on Figure 16 are the undersaturated live oil viscosity measurements. As observed from the graph, the undersaturated values fall very closely on the linear trend connecting the measurements at each test temperature.

Figure 19 presents the MacKay River K value ($1/X_{CH4}$) measurements versus pressure for each test temperature. By minimising the sum of errors squared, values of kv1, kv2, kv3, kv4 and kv5 in equation 9 are determined as 4.0689×10^4 kPa, 4.8680×10^{-4} kPa^{-1}, -1.1616, -1.1836×10^2 °K, and 1.7368×10^2 °K respectively. Note that these kv values differ from those suggested in the STARS manual. The K values calculated from equation 9 are also plotted on Figure 19 and show a close match to measured values. Figure 20 also shows that the calculated methane solubilities (back calculated from the K values) compare quite closely to the measured values for MacKay River bitumen.

Using equation 8 with the derived values of m and n for MacKay River dead oil and for the pseudo-liquid methane to determine component viscosities, and using equation 9 with the derived values of kv1, kv2 kv3, kv4 and kv5 to determine the equilibrium mole fraction of methane in the oil phase, live oil viscosities at saturated conditions were calculated with equation 6. The predicted values are compared to measured values in Figure 21. The STARS approach was capable of predicting live oil viscosities within 10%. Also shown on Figure 21 are the predictions at undersaturated conditions and these also fall within 10% of the measured values.

4.2. Christina Lake Bitumen

4.2.1. Measurements

Appendix IV presents the raw capillary tube pressure drop measurements for Christina Lake bitumen at all the experimental test conditions. A summary of calculated viscosities is presented in Table 8.

Table 8. Christina Lake River Bitumen Viscosity Measurements

Temperature (°C)	Dead Oil Viscosity (cp)	Live Oil Viscosity (cp)			
		Pressure (kPa)			
		4000	1500	500	1500[1]
30	113,977	33,232	66,030	98,679	89,373
70	2,090	1,000	1,274	1,576	1,416
100	299	176	211	246	216
125	93.7	63.1	72.2	82.8	73
150	39.2	27.9	31.2	35.9	
200	11.9	9.3	10.9		
220	8.5	6.9			

[1] Undersaturated

Appendix V presents all the raw GOR measurements for Christina Lake bitumen. Table 9 presents the methane solubility measurements. Mole fraction of methane in oil was derived from the GOR by equation 12.

Table 9. Christina Lake Bitumen Methane Solubility Measurements

	Methane Solubility					
	Pressure (kPa)					
	4000		1500		500	
Temperature (°C)	GOR	X	GOR	X	GOR	X
30	10.57	0.2193	4.21	0.1007	1.94	0.0489
70	8.56	0.1853	3.60	0.0873	1.44	0.0368
100	8.10	0.1771	3.08	0.0757	1.19	0.0306
125	7.63	0.1687	2.70	0.0671	1.09	0.0283
150	7.48	0.1659	2.56	0.0638	0.92	0.0240
200	6.97	0.1564	2.38	0.0596		
220	6.65	0.1501				

4.2.2. M&S Approach for Predicting Christina Lake Bitumen Properties

Figures 22 and 23 compare the calculated methane solubilities and live oil viscosities from the M&S correlations (equations 1 and 2) to measured values. The graphs show that the M&S correlations significantly under predict both methane solubility and live oil viscosity for the Christina Lake bitumen; on average; by 30% for solubility, and by 40% for low viscosity and 80% for high viscosity.

4.2.3. Butler Approach for Predicting Christian Lake Bitumen Properties

Figure 24 presents a plot of the ln(GOR/P) versus 1/T for Christina Lake bitumen. The data exhibits a reasonably good linear fit. The slope of the regression equates to b and the exponential of the intercept equates to a in equation 4. By minimizing the sum of errors squared the values of a and b were refined to give 0.00073 and 379.26. Figure 25 shows that the calculated solubilities from equation 4 compare quite closely to the measured values.

Figure 26 presents a plot of the ln(dead oil μ)/ln(live oil μ) versus GOR for Christina Lake bitumen. The data again exhibits a reasonably good linear fit. The slope of the regression, 0.0142, equates to m′ in equation 3. Using the values for a, b and m′, the live oil viscosities are calculated with equation 5 and the ratio of calculated values and measured values are shown in Figure 27. The Butler approach was effective at predicting Christian Lake live oil viscosities at saturated conditions within 15%. Also shown on Figure 27 are the predictions at undersaturated conditions and these also fall within 15% of the measured values.

4.2.4. STARS Approach for Predicting Christina Lake Bitumen Properties

The Christina Lake bitumen measured solubility and viscosity data are presented in Figure 28 in the form of ln(μ) versus mole fraction methane in oil. Dead oil viscosity is included at zero mole fraction methane. Each set of measurements at each test temperature produces a linear relationship that when extrapolated to $X_{CH4} = 1$ gives the pseudo-viscosity of pure liquid methane. Table 10 gives the values of the methane viscosity at each temperature and these values are plotted as ln(μ) versus 1/T in Figure 29 and lnln(μ) versus ln(T) in Figure 30.

Table 10. Christina Lake Methane Pseudo-Viscosity

Temperature	Viscosity
°C	cp
30	222.58
70	44.14
100	17.26
125	9.74
150	5.41
200	2.45
220	2.07

The methane viscosity values are characterised quite well by equation 7 and equation 8 with avisc and bvisc equal to .00097 cp and 3696.1 °K, and m and n equal to -4.19 and 25.75 respectively. Note that the value of avisc and bvisc are very different from those suggested in the STARS manual.

Also plotted on Figure 28 are the undersaturated live oil viscosity measurements. As observed from the graph, the undersaturated values fall very closely on the linear trend connecting the measurements at each test temperature.

Figure 31 presents the Christian Lake K value ($1/X_{CH4}$) measurements versus pressure for each test temperature. By minimising the sum of errors squared, values of kv1, kv2, kv3, kv4 and kv5 in equation 9 are determined as 3.7404×10^4 kPa, -1.4046×10^{-3} kPa^{-1}, 1.0086×10^1, -2.1228×10^2 °K, and 1.2199×10^2 °K respectively. Note these kv values are different from those suggested in the STARS manual. The K values calculated from equation 9 are also plotted on Figure 31 and show a close match to measured values. Figure 32 also shows that the calculated methane solubilities (back calculated from the K values) compare quite closely to the measured values for Christina Lake bitumen.

Using equation 8 with the derived values of m and n for Christian Lake dead oil and for the pseudo liquid methane to determine component viscosities, and using equation 9 with the derived values of kv1, kv2 kv3, kv4 and kv5 to determine the equilibrium mole fraction of methane in the oil phase, live oil viscosities at saturated conditions were calculated with equation 6. The predicted values are compared to measured values in Figure 33. The STARS approach was capable of predicting live oil viscosities within 15%. Also shown on Figure 33 are the predictions at undersaturated conditions and these also fall within 15% of the measured values.

5.0 DISCUSSION

The experimental measurements showed that temperature has a much greater effect on oil viscosity then the degree of saturation of methane. For example for MacKay River bitumen, increasing the temperature from 30 °C to 220 °C at a constant methane content of 2.62 std. m^3/m^3, decreased the viscosity from 45,000 cp to 58 cp, where as; increasing the methane content from 1.11 std. m^3/m^3 to 10.84 std. m^3/m^3 at a constant temperature of 30 °C, only decreased the viscosity from 54,000 cp to 20,000 cp. Conversely pressure had a greater influence on methane solubility then temperature. For example for MacKay River Bitumen, increasing the pressure from 500 kPa to 4,000 kPa at a constant temperature of 30 °C increased methane solubility from 1.11 std. m^3/m^3 to 10.84 std. m^3/m^3, where as; increasing the temperature from 30 °C to 220 °C at a constant pressure of 4,000 kPa, only decreased solubility from 10.84 std. m^3/m^3 to 6.72 std. m^3/m^3.

The experimental study demonstrated that with the suggested constants, the use of Mehrotra & Svrcek correlations to provide absolute values for solubility and live oil viscosity were not accurate. Although the correlations capture the trends associated with the effects of pressure and temperature, they significantly under predicted both parameters of both bitumens. The correlations were developed for a specific bitumen which was not identified and make no allowance for the magnitude of the dead oil viscosity. From the degree of deviation between measured and calculated values it appears that the M&S correlations were developed from a bitumen that had a viscosity more closely matching Mackay River then Christina Lake. No assumption can be made of the solubility as both bitumens showed similar deviation. To obtain a better prediction with the M&S method, new correlation coefficients for each specific bitumen would need to be determined.

Both the Butler approach and STARS approach showed the ability to effectively predict the methane solubility and live oil viscosity at fully saturated conditions. Also both approaches can predict the live oil viscosity at undersaturated conditions if the methane solubility was known.

The experimental measurements of methane solubility at fully saturated conditions were very similar for both bitumens as shown in Figure 34. This is also confirmed by the similarity in the parameters in equation 4 and in equations 9 for both bitumens. It remains to be determined if this characteristic is true for other Athabasca bitumens.

The study has shown that the methane pseudo-viscosity can be effectively characterized by either the exponential equation 7 or by Walther's equation 8. Both bitumens show a similarity in the magnitude and relationship with temperature of the methane pseudo-viscosity. This similarity is shown in Figure 35 for all the derived methane viscosities of both bitumens. An overall linear regression of the data provides values of -3.76 and 23.24 respectively for parameters m and n in equation 9. Again it remains to be determined if this characteristic is true for other Athabasca bitumens, however, if it is true then the STARS approach has an advantage. In this approach to determine live oil viscosity at any temperature and pressure only the dead oil viscosity and methane solubility (either measured or by correlation) need to be known. In the Butler approach several live oil viscosity measurements need to be made in order to determine the value of parameter m' in equation 3.

6.0 CONCLUSIONS

1. An experimental set up was designed and constructed to measure live oil viscosity and methane solubility over a range of temperatures (30°C – 220 °C) and pressures (500 kPa-4,000 kPa) encountered during a SAGD operation.

2. Measurements of live oil viscosity and methane solubility were made over the SAGD operating temperature and pressure range for two different bitumens, MacKay River and Christina Lake. Measurements were made at fully methane saturated conditions and at under saturated conditions.

3. Three predictive approaches were examined for there ability to effectively determine methane solubility and live oil viscosity. The approaches were Mehrota & Svrcek correlations, Butler correlations and STARS numerical simulator correlations. Values for the correlation constants of both the Butler and STARS methods were determined for both MacKay River and Christina Lake bitumens.

4. The Mehrota & Svrcek correlations with their suggested constants, under predicted both methane solubility and live oil viscosity for both bitumens. Under prediction of methane solubility was about 30% for both bitumens. Live oil viscosity was under predicted by a larger degree with Christina Lake bitumen then MacKay River; on average by 20% at low viscosity and 60% at high viscosity for MacKay River versus 40% at low viscosity and 80% at higher viscosities for Christina Lake.

5. The liquid methane pseudo-viscosities determined in the STARS method could be effectively represented by either the exponential relationship or Walther's equation.

6. Both the Butler and STARS methods were effective at predicting the methane solubility and live oil viscosity at fully saturated conditions. Both approaches were also effective at predicting the live oil viscosity at undersaturated conditions if the methane solubility was known. Both approaches predicted live oil viscosity within 10% for MacKay River bitumen and 15% for Christina Lake bitumen.

7. Methane solubilities at fully saturated conditions were very similar for both bitumens.

8. The magnitude and temperature relationship of the liquid methane pseudo-viscosity determined in the STARS method was very similar for both bitumens.

7.0 REFERENCES

[1] Svrek, W.Y., Mehrotra, A.K., "Gas Solubility, Viscosity and Density Measurements for Athabasca Bitumen", Journal of Canadian Petroleum Technology, 21 (4), 31-38 (1982).

[2] Mehrotra, A.K., Svrek, W.Y., "Correlation for Properties of Bitumen Saturated with CO_2, CH_4 N_2 and Experiments with Combustion Gas Mixtures ", Journal of Canadian Petroleum Technology, 21 (6) 95-104 (1982).

[3] Butler, R.M., "Thermal Recovery of Oil & Bitumen", Englewoods Cliffs, New York, Prentice-Hall (1991).

[4] Shu, W.R., " A Viscosity Correlation for Mixtures of Heavy Oil, Bitumens and Petroleum Fractions", SPE 11280 (1982).

[5] Walther, C., From Proceedings of the World Petroleum Congress, London (1933).

[6] Reid, J.M., Prausnitz, J.M., Sherwood, T.K., "The Properties of Gases and Liquids", 3rd Editions, McGraw-Hill (1977).

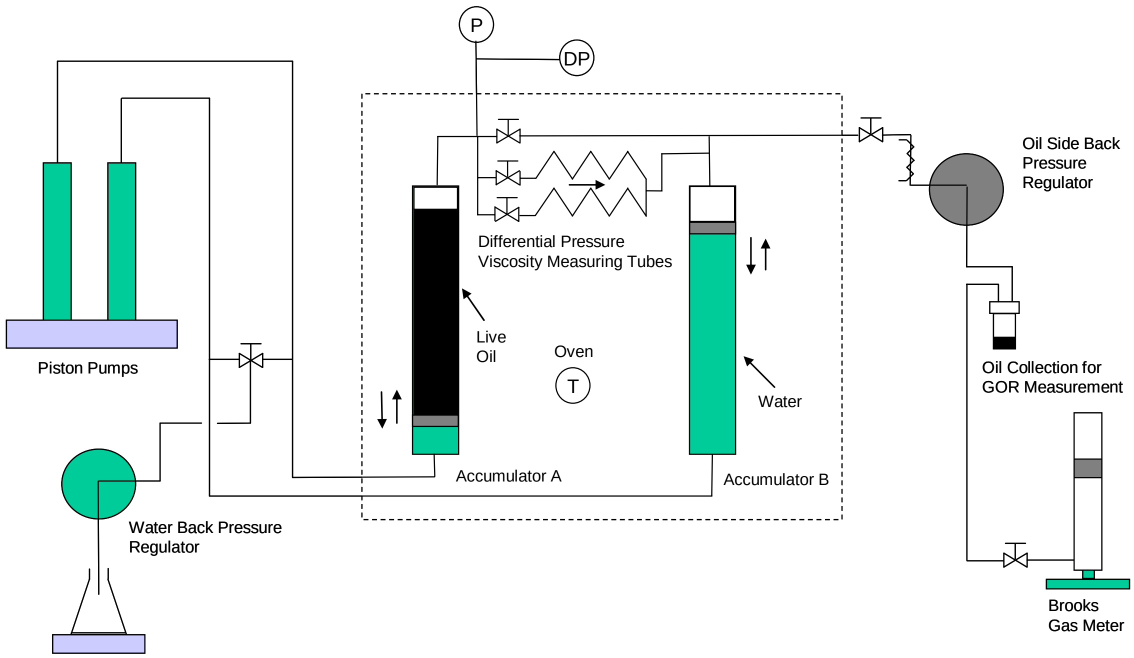


Figure 1. Schematic of Experimental Set Up

Figure 2. Photograph of Fluid Accumulators

Figure 3. Photograph of Piston Pump

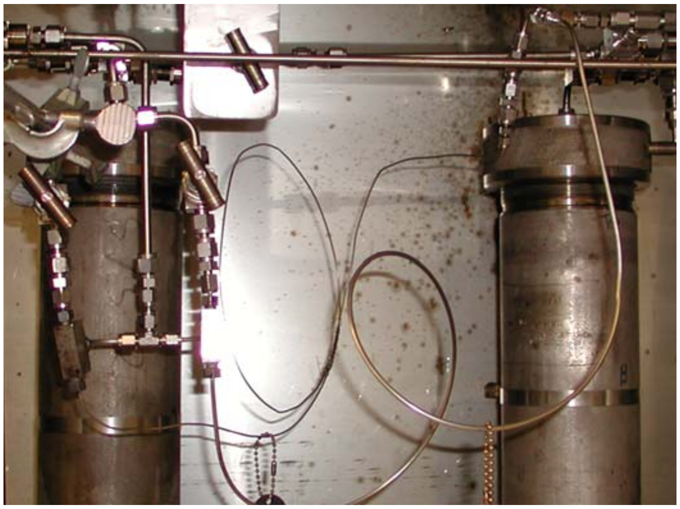


Figure 4. **Photograph of Capillary Tubes**

Figure 5. **Photograph of Brooks Gas Meter**

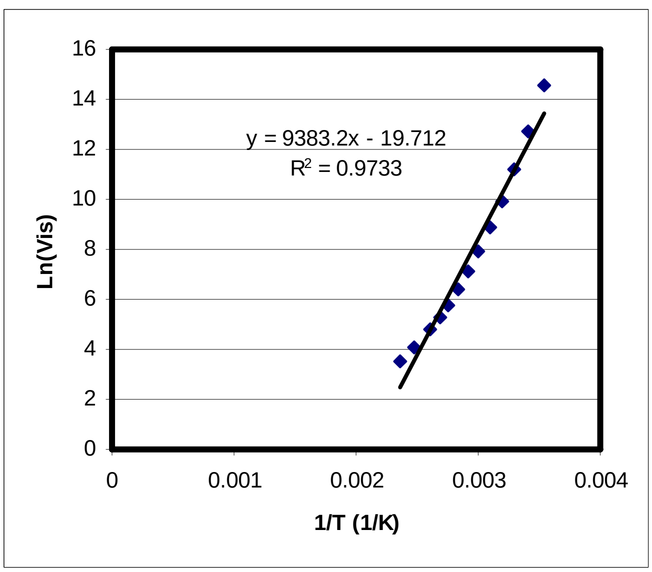


Figure 6. MacKay River Dead Oil Viscosity – Exponential Relationship

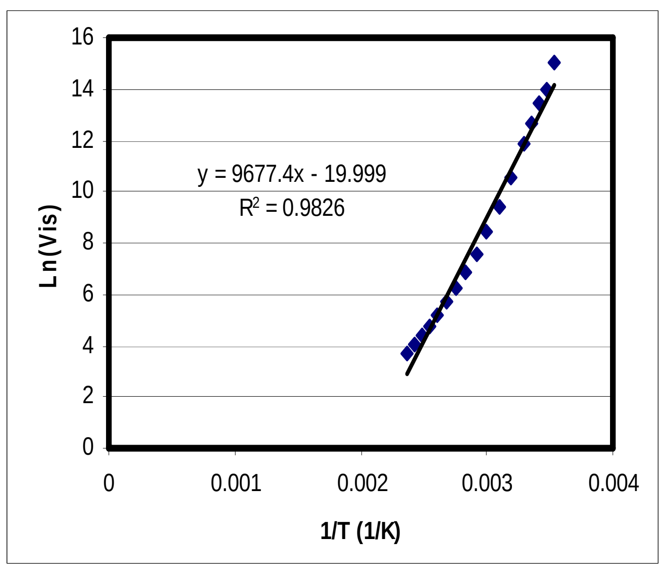


Figure 7. Christina Lake Dead Oil Viscosity – Exponential Relationship

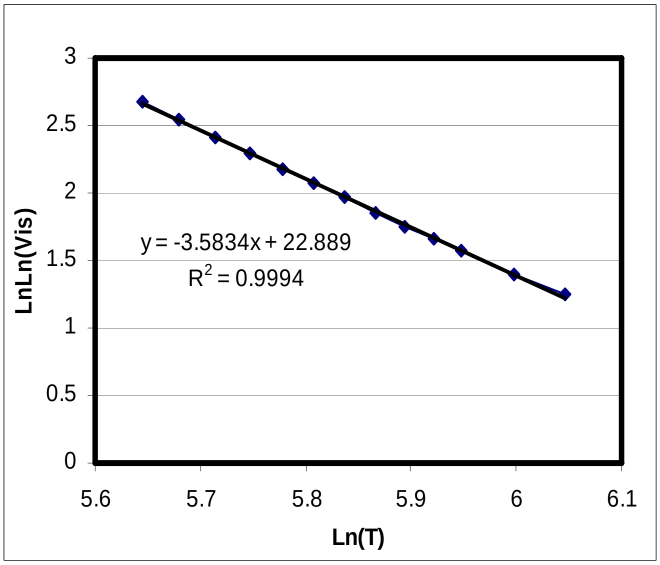


Figure 8. MacKay River Dead Oil Viscosity – Walther's Equation

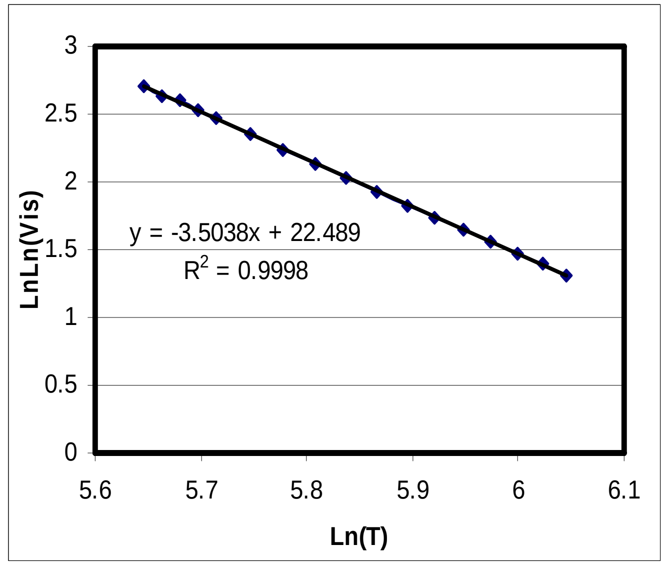


Figure 9. Christina Lake Dead Oil Viscosity – Walther's Equation

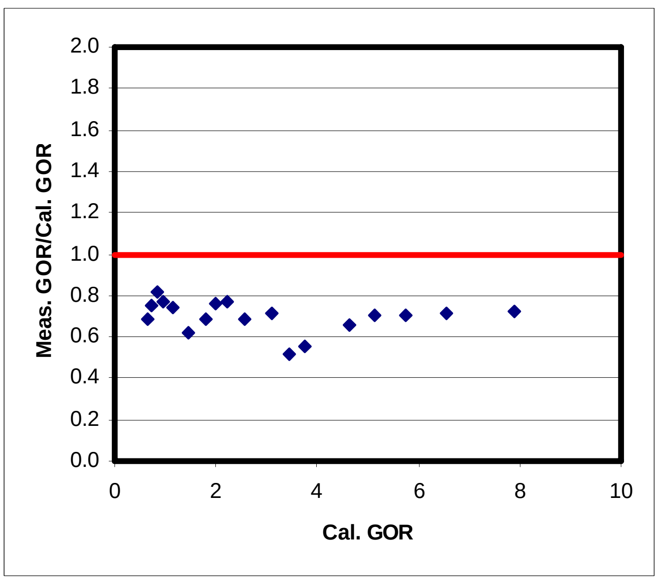


Figure 10. M&S Calculated Solubility Compared to MacKay River Measured Solubility

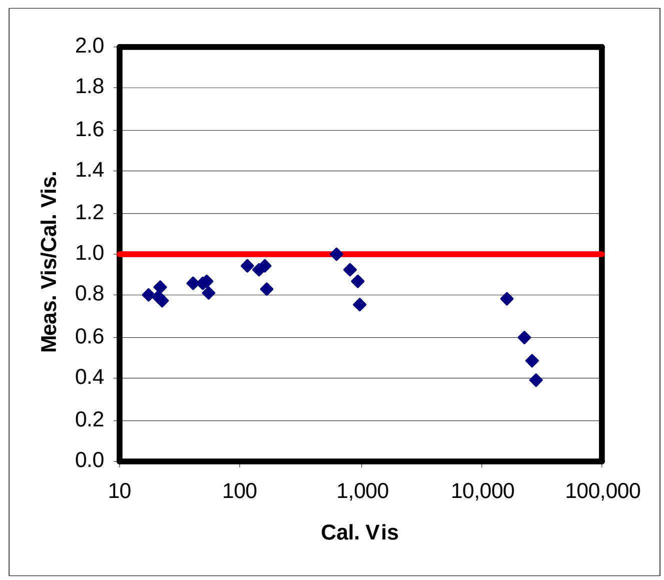


Figure 11. M&S Calculated Viscosity Compared to MacKay River Measured Viscosity

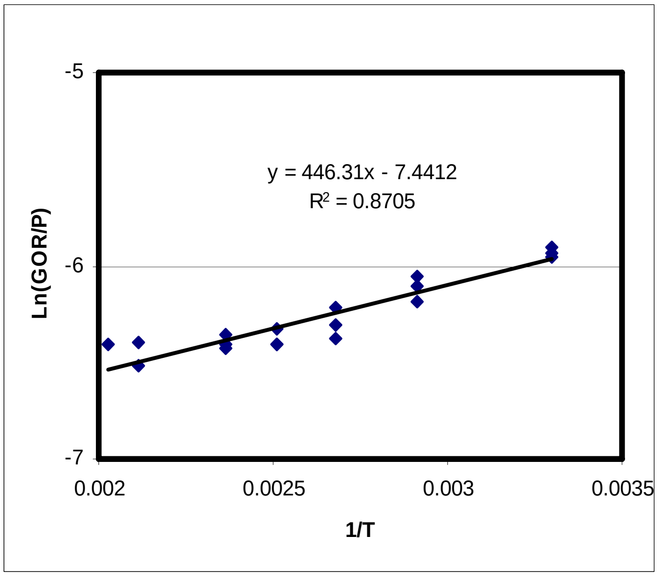


Figure 12. Ln(GOR) versus 1/T for MacKay River Bitumen

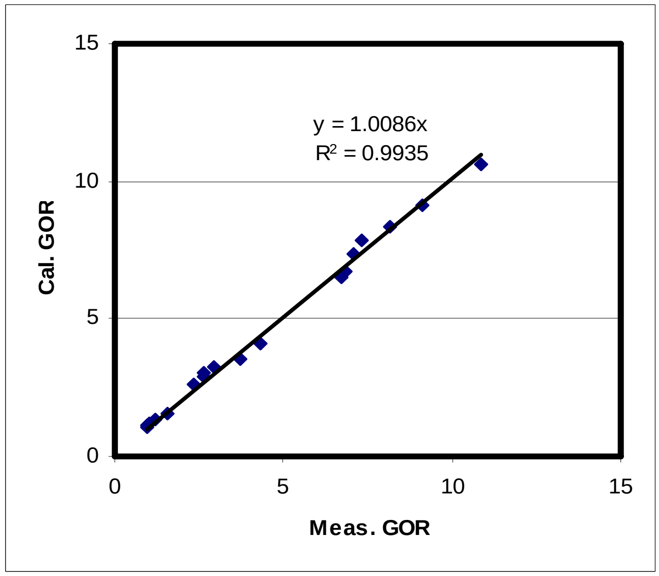


Figure 13. Butler Calculated Solubility versus MacKay River Measured Solubility

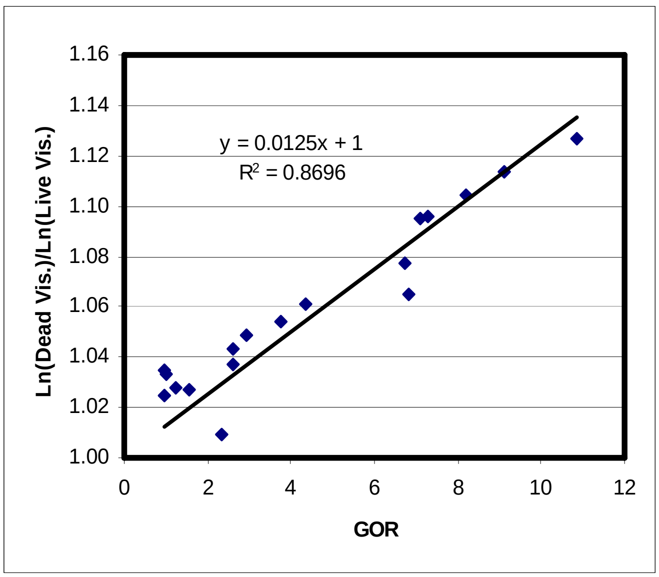


Figure 14. Ln(Dead Oil Vis.)/Ln(Live Oil Vis.) versus GOR for MacKay River Bitumen

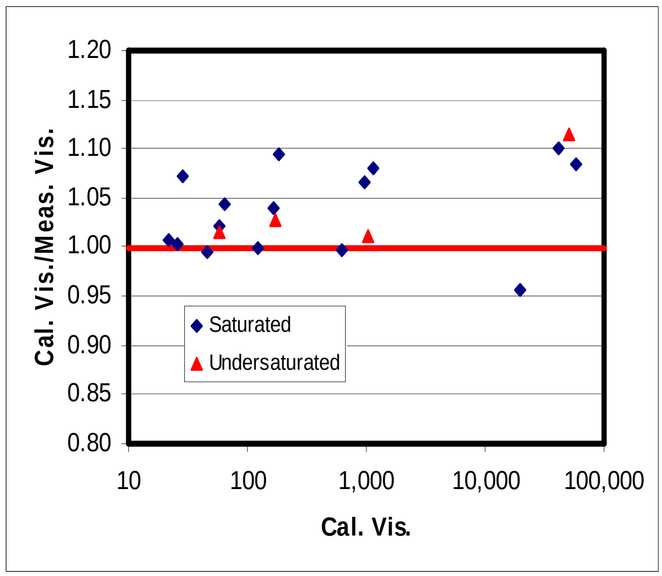


Figure 15. Butler Calculated Viscosity compared to MacKay River Measured Viscosity

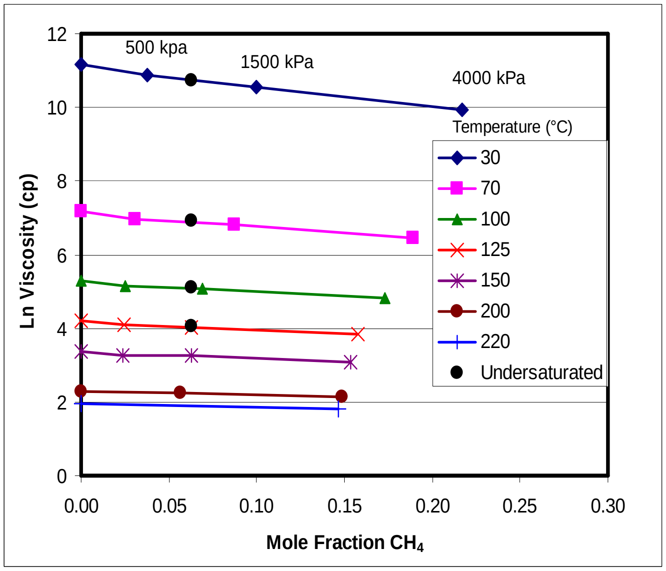


Figure 16. Ln(Viscosity) versus Mole Fraction Methane for MacKay River Bitumen

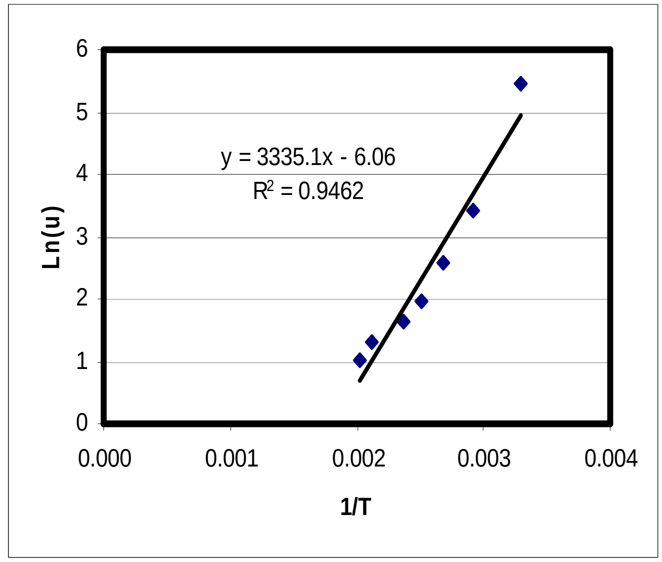


Figure 17. Methane Pseudo-Viscosity Values for MacKay River Bitumen – Exponential Relationship

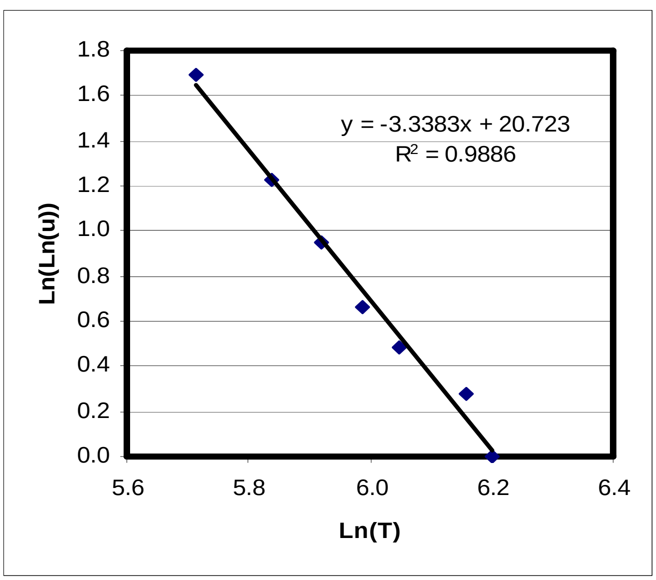


Figure 18. Methane Pseudo-Viscosity Values for MacKay River Bitumen – Walther's Equation

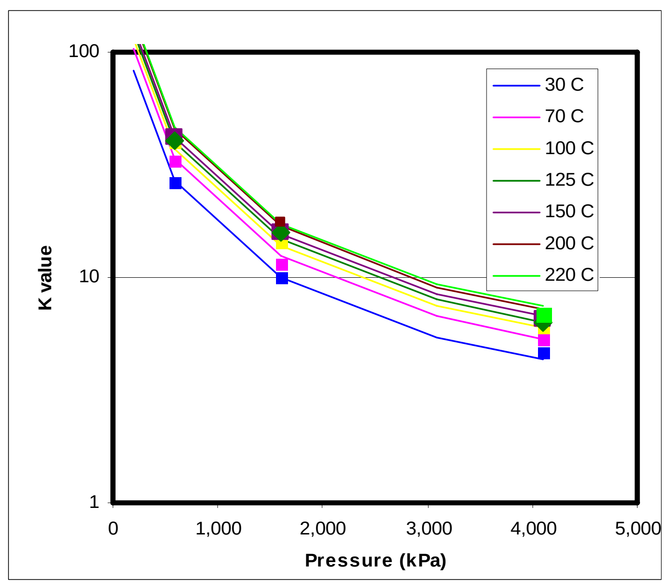


Figure 19. K-Values for MacKay River Bitumen

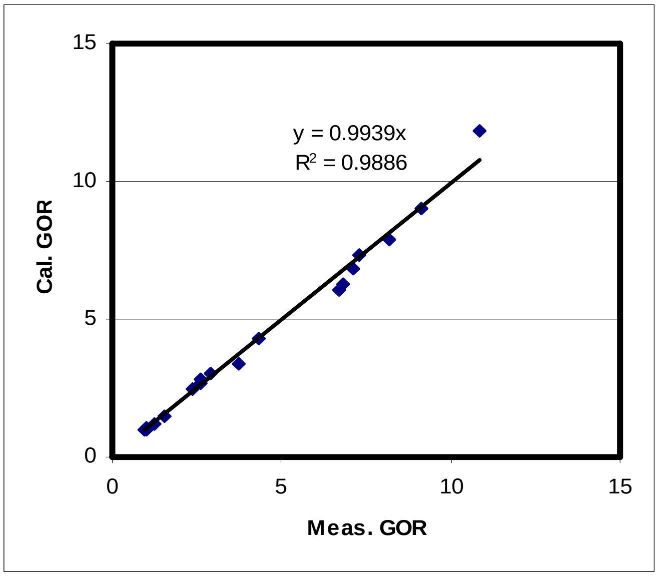


Figure 20. STARS Calculated Solubility versus MacKay River Measured Solubility

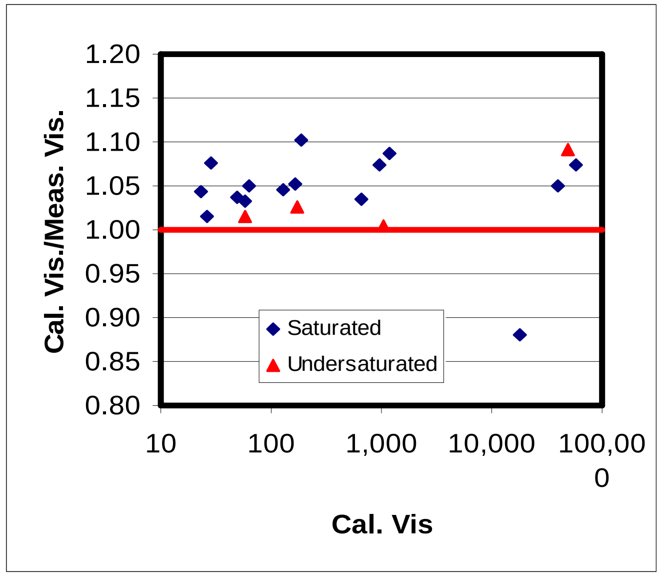


Figure 21. STARS Calculated Viscosity versus MacKay River Measured Viscosity

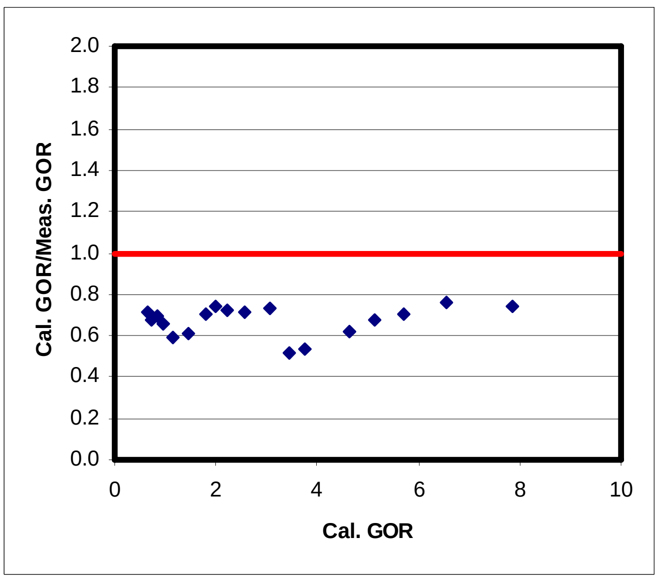


Figure 22. M&S Calculated Solubility Compared to Christina Lake Measured Solubility

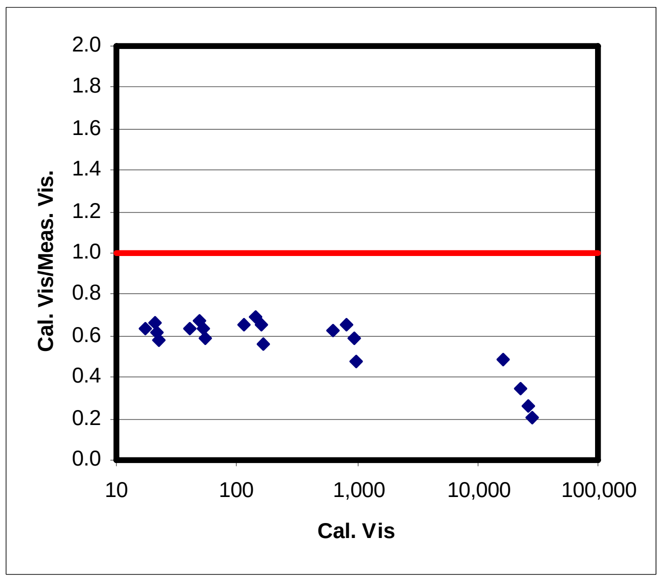


Figure 23. M&S Calculated Viscosity Compared to Christina Lake Measured Viscosity

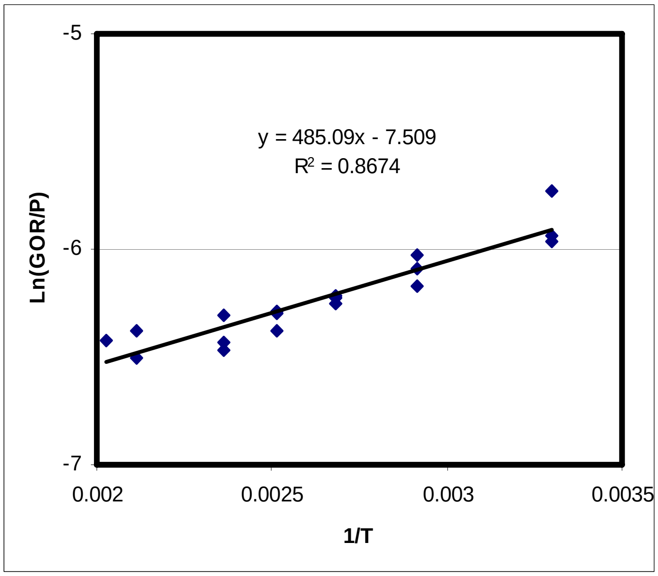


Figure 24. Ln(GOR/P) versus 1/T for Christina Lake Bitumen

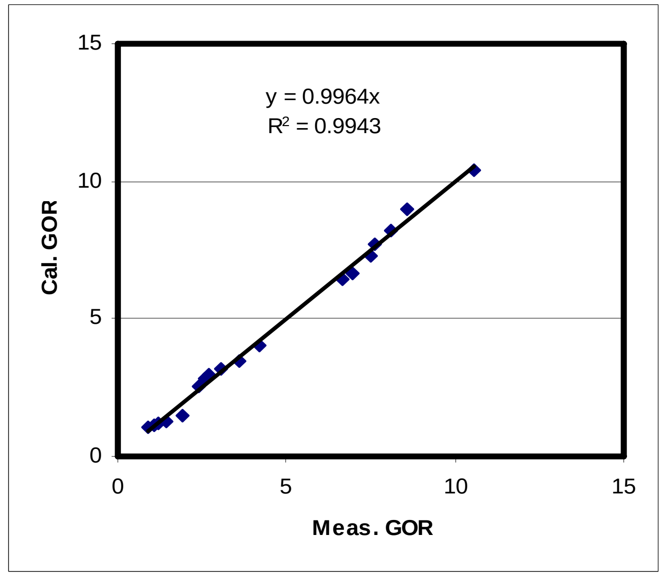


Figure 25 Butler Calculated Solubility versus Christian Lake Measured Solubility

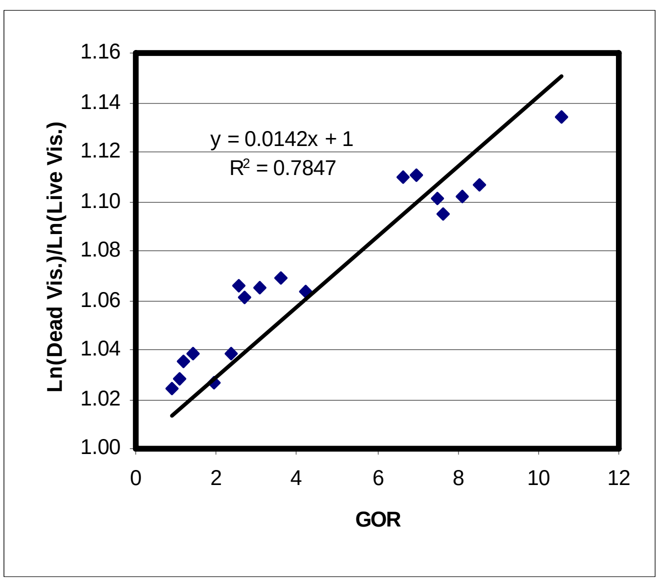


Figure 26. Ln(Dead Oil Vis.)/Ln(Live Oil Vis.) versus GOR for Christina Lake Bitumen

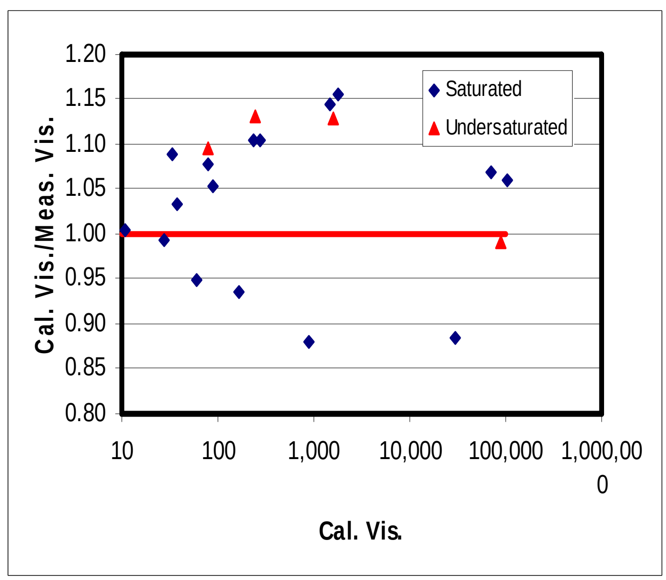


Figure 27. Butler Calculated Viscosity compared to Christina Lake Measured Viscosity

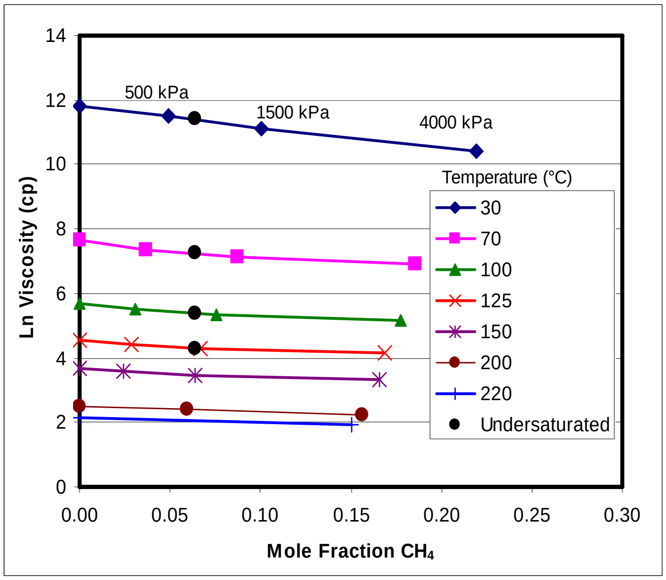


Figure 28. Ln(Viscosity) versus Mole Fraction Methane for Christina Lake Bitumen

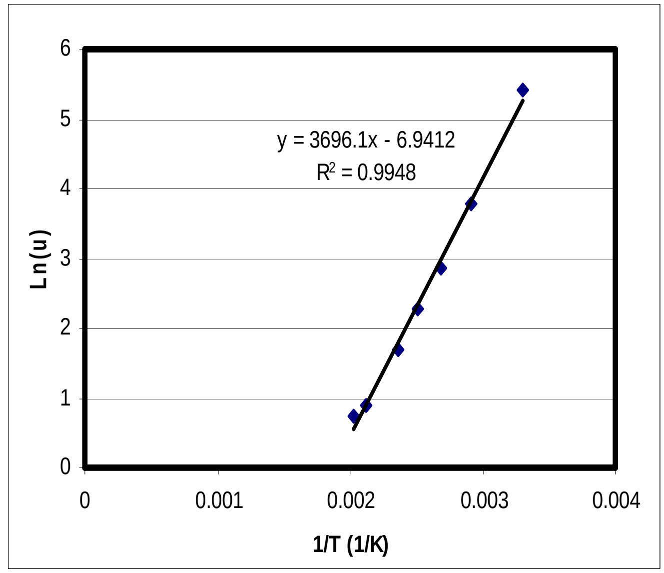


Figure 29. Methane Pseudo-Viscosity Values for Christian Lake Bitumen - Exponential Relationship

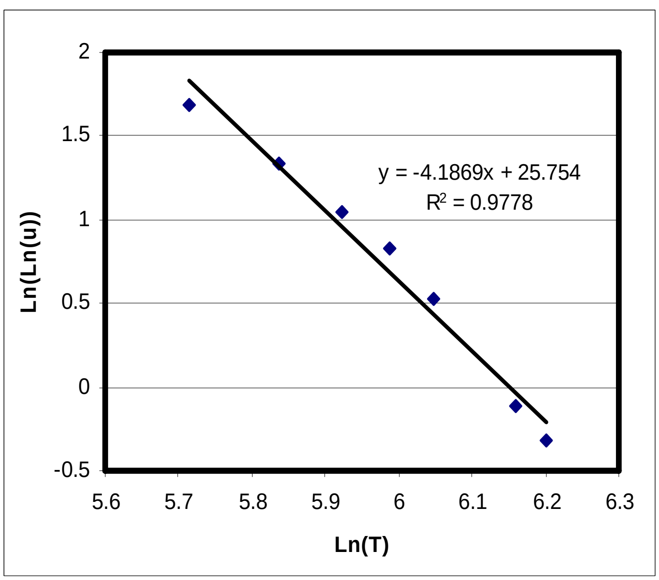


Figure 30. Methane Pseudo-Viscosity Values For Christian Lake Bitumen – Walther's Equation

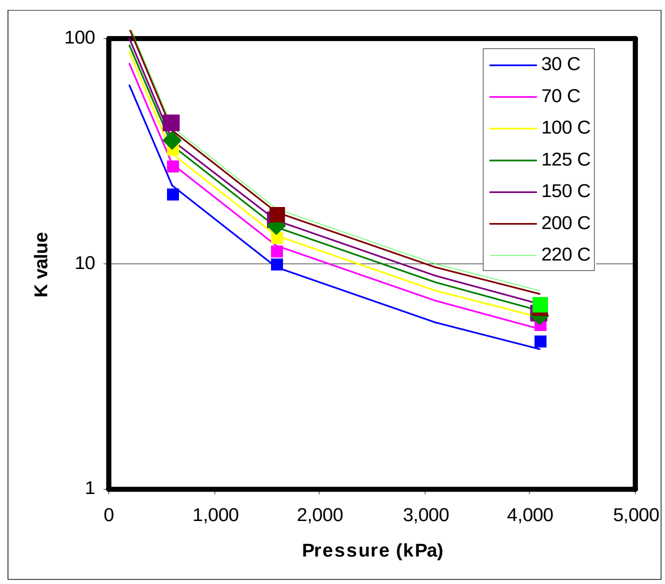


Figure 31. K-Values for Christian Lake Bitumen

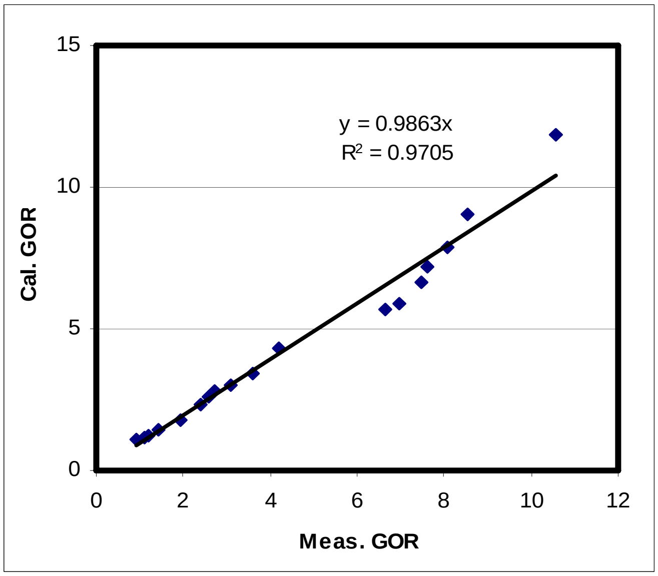


Figure 32. Stars Calculated Solubility versus Christian Lake Measured Solubility

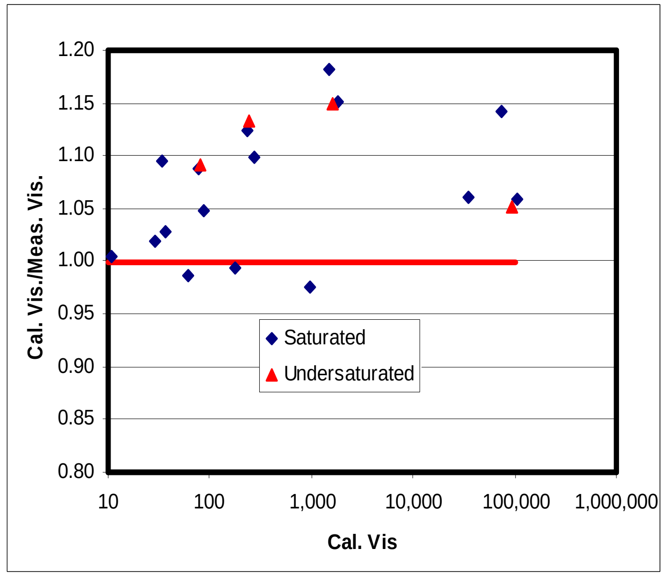


Figure 33. STARS Calculated Viscosity Compared to Christina Lake Measured Viscosity

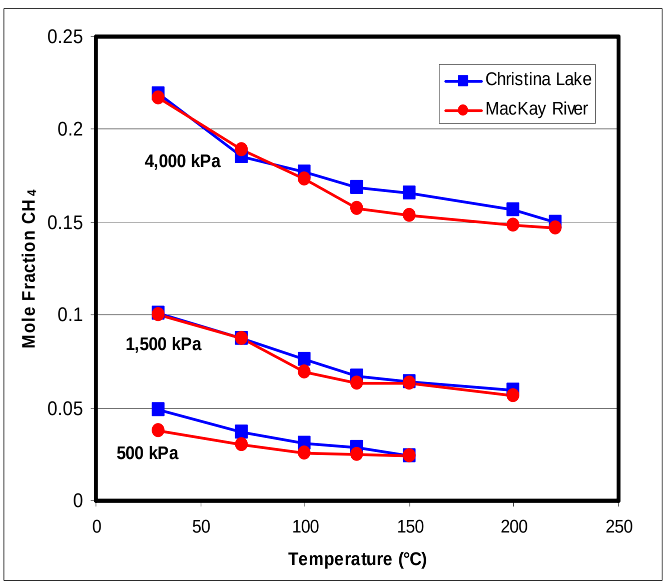


Figure 34. MacKay River Methane Solubility Compared to Christina Lake Methane Solubility

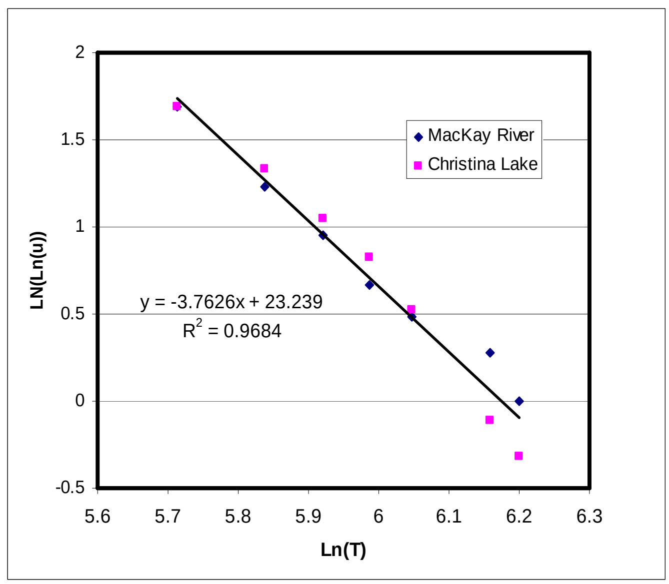


Figure 35. MacKay River Methane Pseudo-Viscosity Compared to Christina Lake Methane Pseudo-Viscosity

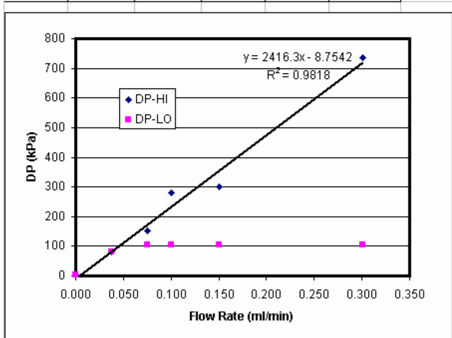
8.0 APPENDICES

Appendix I Capillary Tube Calibration Data

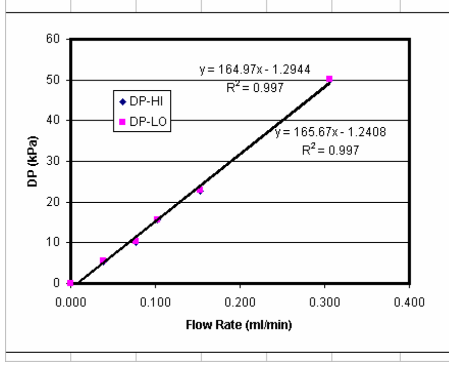
Table 11. Calibration Measurements

	Oil Standards			
	S30000	S8000	S2000	S600
Temp	Viscosity	Viscosity	Viscosity	Viscosity
C	cp	cp	cp	cp
22	104,334.48	31,414.65	6,641.21	1,908.51
30	47,776.21	14,457.06	3,194.09	975.24
70	2,416.16	793.26	220.50	87.47
100	521.06	186.80	60.97	28.22
125	196.28	75.93	27.94	14.37
150	90.19	37.57	15.37	8.64
200	28.82	13.72	6.70	4.31
		1/8 " Tube		
		1/16" Tube		
		Both		

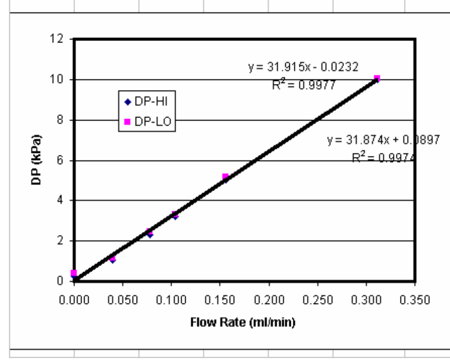
Oil	S30000	Viscosity	45364.59	cp	
Temp.	30	C			
Line Dai.	0.125	"			Actual
Flow Rate	DP-HI	DP-LO	Temp	Rm Temp	Flow Rate
ml/min	kPa	kPa	°C	°C	ml/min
0	4.61	4.86	30.59	22.02	0.000
0.038	81.35	81.75	30.26	21.91	0.038
0.075	151.76	105.07	30.91	22.09	0.075
0.1	280.72	105.07	30.38	22.02	0.100
0.15	300.11	105.07	30.99	22.10	0.150
0.3	734.99	105.06	30.22	22.02	0.301



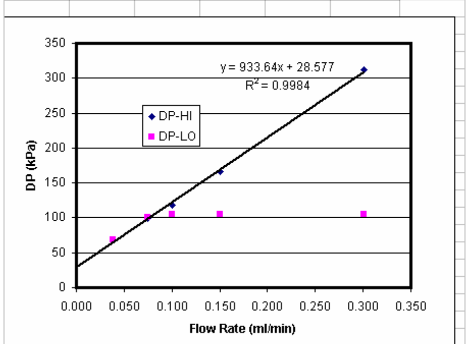
Oil	S30000	Viscosity	2304.864	cp	
Temp.	70	C			
Line Dai.	0.125	"			Actual
Flow Rate	DP-HI	DP-LO	Temp	Rm Temp	Flow Rate
ml/min	kPa	kPa	°C	°C	ml/min
0	-0.16	-0.11	70.74	22.03	0.000
0.038	5.38	5.50	70.81	22.18	0.039
0.075	10.15	10.30	70.83	22.20	0.077
0.1	15.65	15.73	70.83	22.15	0.102
0.15	22.80	22.91	71.00	22.09	0.153
0.3	49.99	50.27	70.58	22.25	0.306



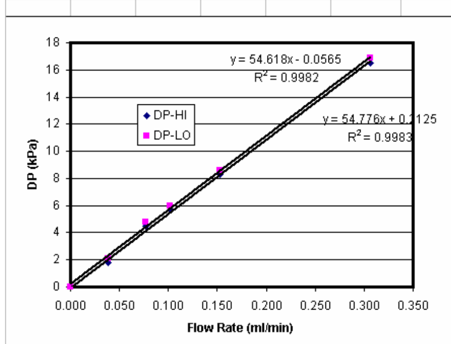
Oil	S30000	Viscosity	514.6024	cp	
Temp.	100	C			
Line Dai.	0.125	"			Actual
Flow Rate	DP-HI	DP-LO	Temp	Rm Temp	Flow Rate
ml/min	kPa	kPa	°C	°C	ml/min
0	0.25	0.38	100.49	22.44	0.000
0.038	1.06	1.13	100.23	22.39	0.039
0.075	2.32	2.44	100.27	22.34	0.078
0.1	3.21	3.34	100.22	22.33	0.104
0.15	5.04	5.15	100.15	22.39	0.156
0.3	9.97	10.06	100.35	22.38	0.312



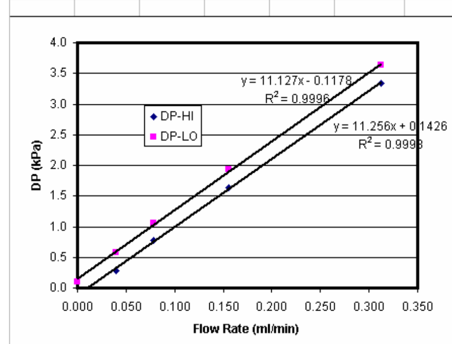
Oil	S8000	Viscosity	13357.86	cp	
Temp.	30	C			
Line Dai.	0.125	"			Actual
Flow Rate	DP-HI	DP-LO	Temp	Rm Temp	Flow Rate
ml/min	kPa	kPa	°C	°C	ml/min
0					0.000
0.038	68.74	69.03	30.59	22.27	0.038
0.075	99.71	100.17	30.94	22.29	0.075
0.1	117.61	105.07	31.01	22.22	0.100
0.15	165.67	105.07	30.88	22.26	0.150
0.3	311.75	105.07	30.90	22.45	0.301



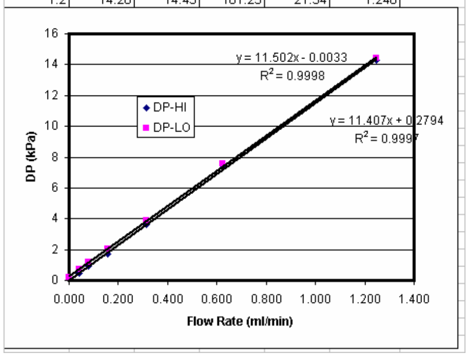
Oil	S8000	Viscosity	753.7892	cp	
Temp.	70	C			
Line Dai.	0.125	"			Actual
Flow Rate	DP-HI	DP-LO	Temp	Rm Temp	Flow Rate
ml/min	kPa	kPa	°C	°C	ml/min
0	-0.23	0.03	70.85	22.03	0.000
0.038	1.78	2.08	70.95	22.38	0.039
0.075	4.51	4.79	70.84	22.15	0.077
0.1	5.71	5.98	70.94	22.30	0.102
0.15	8.29	8.59	70.95	22.47	0.153
0.3	16.54	16.85	70.89	22.43	0.306



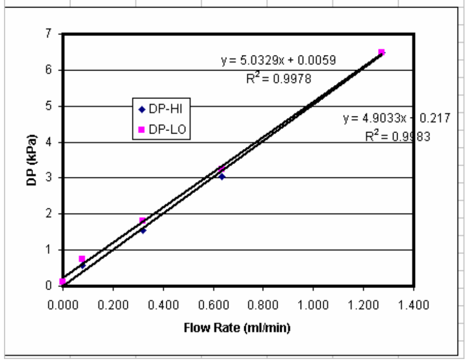
Oil	S8000	Viscosity	176.8948	cp	
Temp.	100	C			
Line Dai.	0.125	"			Actual
Flow Rate	DP-HI	DP-LO	Temp	Rm Temp	Flow Rate
ml/min	kPa	kPa	°C	°C	ml/min
0	-0.11	0.10	101.45	21.25	0.000
0.038	0.28	0.58	101.10	21.72	0.040
0.075	0.78	1.05	101.18	21.77	0.078
0.1					0.100
0.15	1.63	1.94	101.49	21.30	0.156
0.3	3.35	3.63	101.48	21.34	0.312



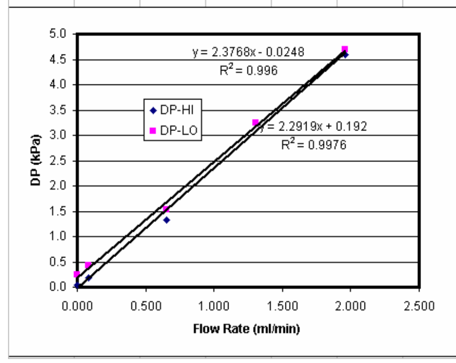
Oil	S8000	Viscosity	176.5701	cp	
Temp.	100	C			
Line Dai.	0.0625	"			Actual
Flow Rate	DP-HI	DP-LO	Temp	Rm Temp	Flow Rate
ml/min	kPa	kPa	°C	°C	ml/min
0	-0.08	0.18	101.35	21.23	0.000
0.038	0.46	0.72	101.25	21.48	0.040
0.075	0.91	1.19	101.54	21.36	0.078
0.15	1.73	2.04	101.34	21.41	0.156
0.3	3.63	3.89	101.40	21.31	0.312
0.6	7.32	7.55	101.44	21.42	0.624
1.2	14.28	14.43	101.25	21.34	1.248



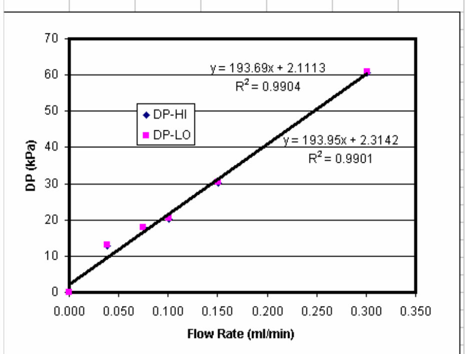
Oil	S8000	Viscosity	73.50909	cp	
Temp.	125	C			
Line Dai.	0.0625	"			Actual
Flow Rate	DP-HI	DP-LO	Temp	Rm Temp	Flow Rate
ml/min	kPa	kPa	°C	°C	ml/min
0	-0.03	0.12	126.05	21.39	0.000
0.075	0.57	0.75	126.13	21.64	0.080
0.3	1.55	1.80	126.16	21.44	0.318
0.6	3.05	3.24	125.86	21.38	0.637
1.2	6.49	6.50	125.94	21.51	1.273



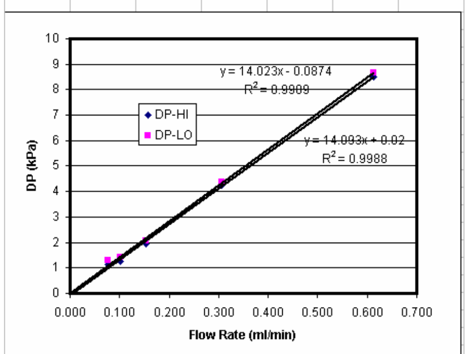
Oil	S8000	Viscosity	36.58066	cp	
Temp.	150	C			
Line Dai.	0.0625	"			Actual
Flow Rate	DP-HI	DP-LO	Temp	Rm Temp	Flow Rate
ml/min	kPa	kPa	°C	°C	ml/min
0	0.04	0.24	151.00	21.46	0.000
0.075	0.19	0.42	151.35	22.01	0.082
0.6	1.33	1.52	151.16	21.99	0.652
1.2	3.21	3.24	150.78	21.42	1.304
1.8	4.59	4.69	151.05	21.63	1.956



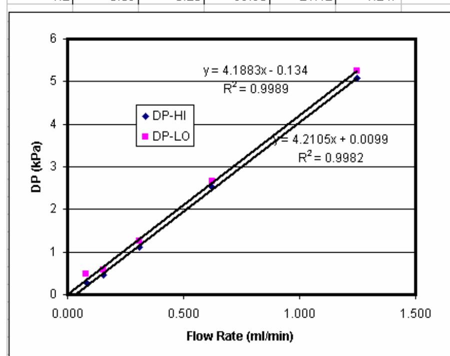
Oil	S2000	Viscosity	3018.606	cp	
Temp.	30	C			
Line Dai.	0.125	"			Actual
Flow Rate	DP-HI	DP-LO	Temp	Rm Temp	Flow Rate
ml/min	kPa	kPa	°C	°C	ml/min
0	-0.30	-0.13	30.64	20.71	0.000
0.038	12.80	13.08	30.58	21.04	0.038
0.075	17.82	18.05	30.33	20.79	0.075
0.1	20.29	20.48	31.01	20.60	0.100
0.15	30.25	30.49	30.72	20.64	0.150
0.3	60.60	60.89	30.65	20.64	0.301



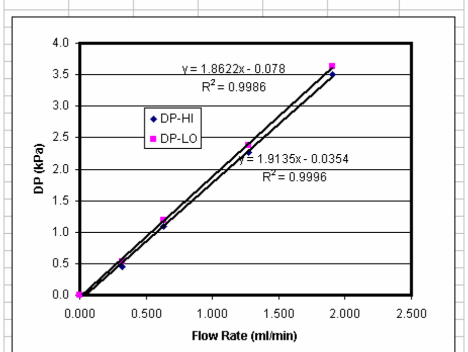
Oil	S2000	Viscosity	210.5323	cp	
Temp.	70	C			
Line Dai.	0.125	"			Actual
Flow Rate	DP-HI	DP-LO	Temp	Rm Temp	Flow Rate
ml/min	kPa	kPa	°C	°C	ml/min
0	-0.09	-0.04	71.04	20.67	0.000
0.075	1.15	1.30	71.08	20.68	0.077
0.1	1.26	1.40	70.95	20.76	0.102
0.15	1.93	2.06	70.74	20.83	0.153
0.3	4.25	4.36	70.78	20.83	0.306
0.6	8.50	8.65	70.86	20.84	0.612



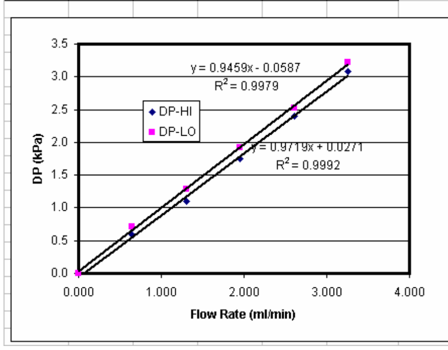
Oil	S2000	Viscosity	60.60791	cp	
Temp.	100	C			
Line Dai.	0.0625	"			Actual
Flow Rate	DP-HI	DP-LO	Temp	Rm Temp	Flow Rate
ml/min	kPa	kPa	°C	°C	ml/min
0	-0.15	-0.03	100.30	20.84	0.000
0.075	0.30	0.49	100.28	21.03	0.078
0.15	0.46	0.58	100.32	21.09	0.156
0.3	1.11	1.27	100.12	21.14	0.312
0.6	2.51	2.66	99.99	21.05	0.624
1.2	5.09	5.26	99.98	21.12	1.247



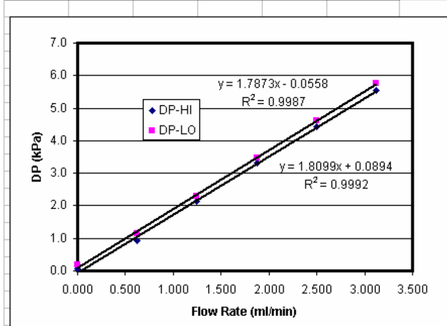
Oil	S2000	Viscosity	27.78052	cp	
Temp.	125	C			
Line Dai.	0.0625	"			Actual
Flow Rate	DP-HI	DP-LO	Temp	Rm Temp	Flow Rate
ml/min	kPa	kPa	°C	°C	ml/min
0	-0.01	0.00	125.39	21.08	0.000
0.3	0.45	0.53	125.39	21.19	0.318
0.6	1.09	1.19	125.32	21.21	0.636
1.2	2.27	2.38	125.05	21.15	1.272
1.8	3.51	3.63	124.89	21.28	1.908



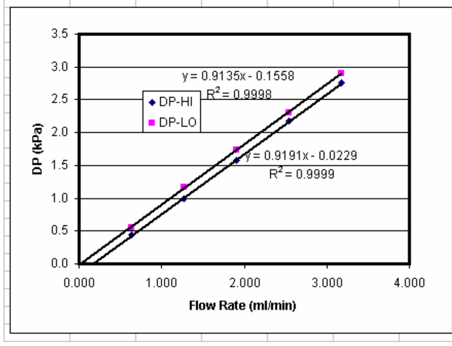
Oil	S2000	Viscosity	15.31354	cp	
Temp.	150	C			
Line Dai.	0.0625	"			Actual
Flow Rate	DP-HI	DP-LO	Temp	Rm Temp	Flow Rate
ml/min	kPa	kPa	°C	°C	ml/min
0	-0.02	0.00	150.62	21.22	0.000
0.6	0.59	0.72	150.40	21.25	0.652
1.2	1.09	1.28	150.24	21.29	1.303
1.8	1.76	1.92	149.92	21.30	1.954
2.4	2.39	2.53	150.09	21.35	2.605
3	3.08	3.21	149.86	21.40	3.256



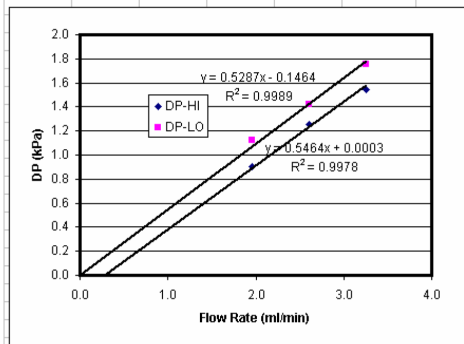
Oil	S600	Viscosity	27.04092	cp	
Temp.	100	C			
Line Dai.	0.0625	"			Actual
Flow Rate	DP-HI	DP-LO	Temp	Rm Temp	Flow Rate
ml/min	kPa	kPa	°C	°C	ml/min
0	0.05	0.18	101.89	21.47	0.000
0.6	0.94	1.15	101.60	21.44	0.624
1.2	2.14	2.29	101.43	21.47	1.248
1.8	3.31	3.48	101.35	21.69	1.872
2.4	4.42	4.60	101.14	21.65	2.496
3	5.54	5.77	100.87	21.69	3.120



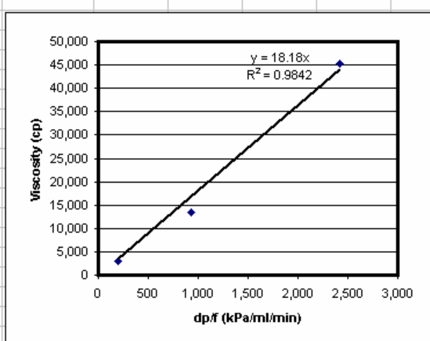
Oil	S600	Viscosity	13.91224	cp	
Temp.	125	C			
Line Dai.	0.0625	"			Actual
Flow Rate	DP-HI	DP-LO	Temp	Rm Temp	Flow Rate
ml/min	kPa	kPa	°C	°C	ml/min
0	-0.16	-0.03	127.10	21.49	0.000
0.6	0.45	0.56	126.87	21.55	0.637
1.2	0.99	1.17	126.60	21.50	1.274
1.8	1.58	1.73	126.22	21.79	1.910
2.4	2.18	2.31	125.96	22.14	2.546
3	2.76	2.90	125.69	22.29	3.181



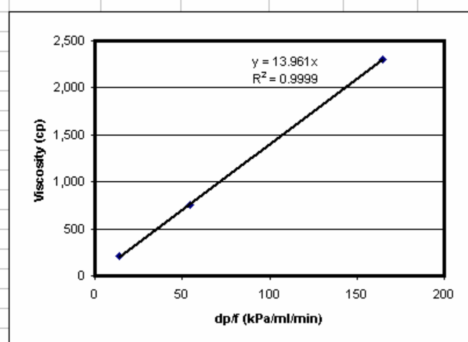
Oil	S600	Viscosity	8.380193	cp	
Temp.	150	C			
Line Dai.	0.0625	"			Actual
Flow Rate	DP-HI	DP-LO	Temp	Rm Temp	Flow Rate
ml/min	kPa	kPa	°C	°C	ml/min
0	-0.16	-0.02	152.55	21.56	0.000
1.8	0.90	1.12	151.88	21.66	1.958
2.4	1.26	1.42	151.44	21.73	2.609
3	1.55	1.75	151.05	21.67	3.260



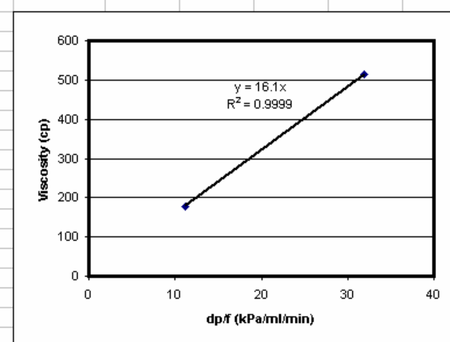
Tube ID	0.125	"	
Temperature	30	C	
Vis	dp/f		
cp	kPa/ml/min		
45,364.59	2416.262		Cal. Cont.
13,357.86	933.6368		18.17985
3,018.61	193.6891		



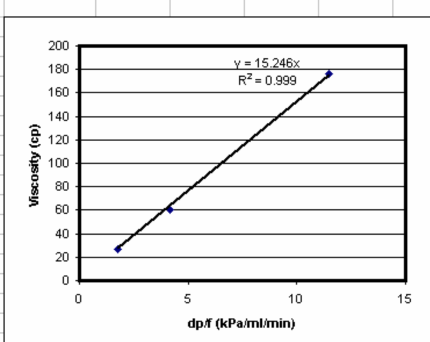
Tube ID	0.125	"	
Temperature	70	C	
Vis	dp/f		
cp	kPa/ml/min		
2,304.86	164.97439		Cal. Cont.
753.79	54.618425		13.96109
210.53	14.023341		



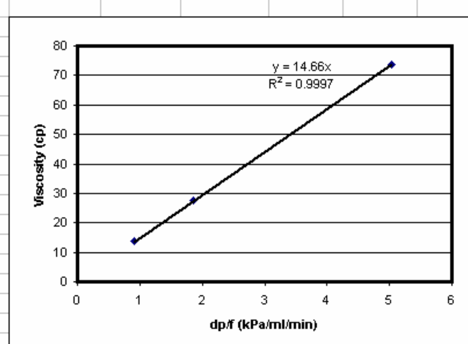
Tube ID	0.125	"	
Temperature	100	C	
Vis	dp/f		
cp	kPa/ml/min		
514.60	31.91502		Cal. Cont.
176.89	11.12748		16.09954



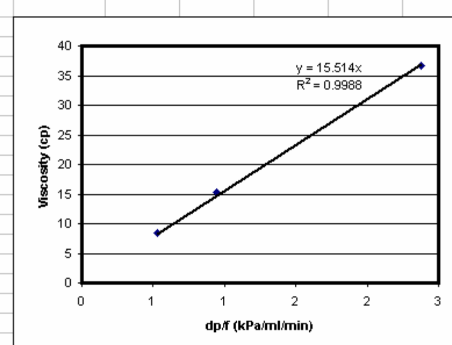
Tube ID	0.0625	"	
Temperature	100	C	
Vis	dp/f		
cp	kPa/ml/min		
176.57	11.5021		Cal. Cont.
60.61	4.188325		15.24557
27.04	1.787281		



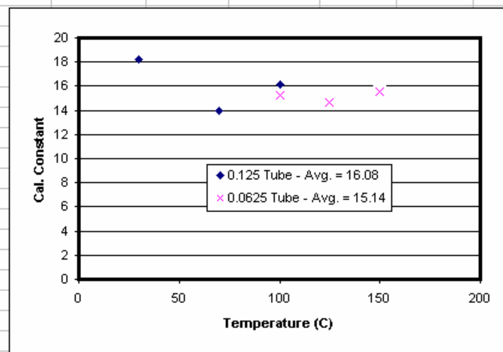
Tube ID	0.0625	"	
Temperature	125	C	
Vis	dp/f		
cp	kPa/ml/min		
73.51	5.0328561		Cal. Cont.
27.78	1.862236		14.6599
13.91	0.9135356		



Tube ID	0.0625	"	
Temperature	150	C	
Vis	dp/f		
cp	kPa/ml/min		
36.58	2.376804		Cal. Cont.
15.31	0.945907		15.51427
8.38	0.528679		

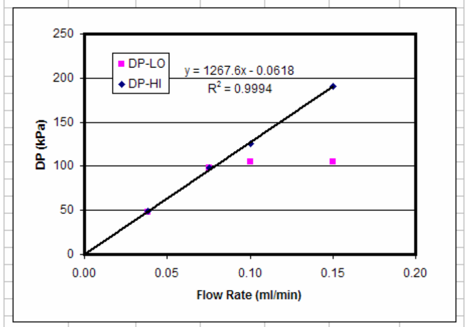


Tube	0.125		0.0625
Temp	Cal. Const.	Temp	Cal. Const.
30	18.179847	100	15.24557
70	13.961093	125	14.6599
100	16.099536	150	15.51427
Average	16.080159		15.13992

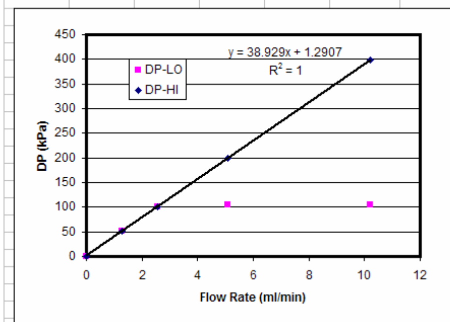


Appendix II MacKay River Bitumen Capillary Tube Measurements

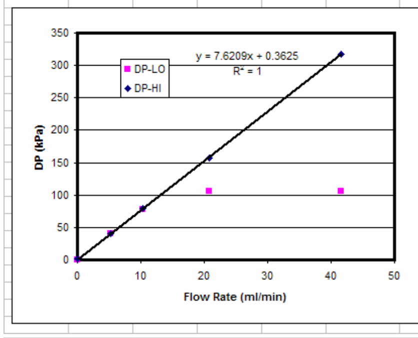
MacKay River Live Oil					
Temp	30	C			
Pressure	4000 kPa				
Line Dia.	0.125	"			Actual
Flow Rate	DP-HI	DP-LO	Temp	Rm Temp	Flow Rate
ml/min	kPa	kPa	°C	°C	ml/min
0	-1.20	-0.62	30.50	21.76	0.000
0.038	48.69	47.99	30.42	21.86	0.038
0.075	98.11	97.72	30.42	21.98	0.075
0.1	125.14	105.07	30.66	21.85	0.100
0.15	190.29	105.07	30.47	21.80	0.150



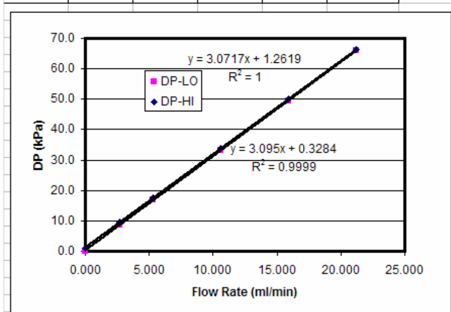
MacKay River Live Oil					
Temp	70	C			
Pressure	4000	kPa			
Line Dia.	0.125	"			Actual
Flow Rate	DP-HI	DP-LO	Temp	Rm Temp	Flow Rate
ml/min	kPa	kPa	°C	°C	ml/min
0	0.93	-0.06	71.09	22.08	0.000
1.25	51.35	50.85	70.92	22.26	1.275
2.5	100.98	100.80	70.78	22.19	2.550
5	199.24	105.07	70.60	22.05	5.100
10	398.51	105.07	70.36	21.93	10.200



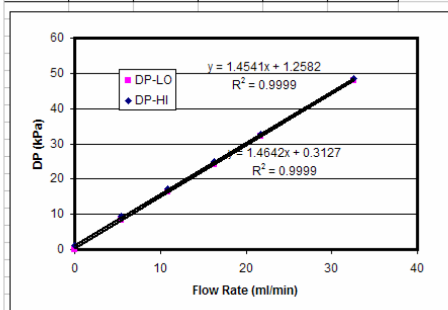
MacKay River Live Oil					
Temp	100	C			
Pressure	4000	kPa			
Line Dia.	0.125	"			Actual
Flow Rate	DP-HI	DP-LO	Temp	Rm Temp	Flow Rate
ml/min	kPa	kPa	°C	°C	ml/min
0	1.03	0.04	102.11	22.03	0.000
5	40.46	39.83	100.99	21.97	5.199
10	78.83	78.53	100.49	21.94	10.395
20	157.70	105.07	99.96	22.05	20.782
40	317.67	105.07	99.59	22.10	41.552



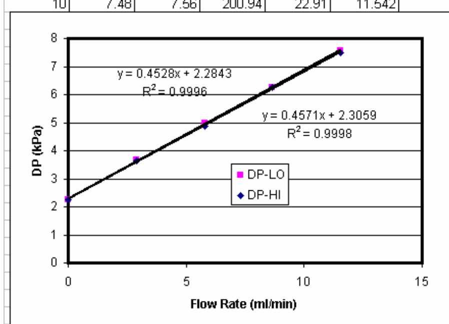
MacKay River Live Oil					
Temp	125	C			
Pressure	4000	kPa			
Line Dia.	0.0625	"			Actual
Flow Rate	DP-HI	DP-LO	Temp	Rm Temp	Flow Rate
ml/min	kPa	kPa	°C	°C	ml/min
0	1.03	0.05	125.82	21.53	0.000
2.5	9.64	8.77	125.66	21.78	2.651
5	17.68	16.92	125.60	21.79	5.302
10	33.77	33.12	125.63	21.76	10.605
15	49.99	49.40	125.68	21.91	15.908
20	66.49	66.04	125.71	21.87	21.211



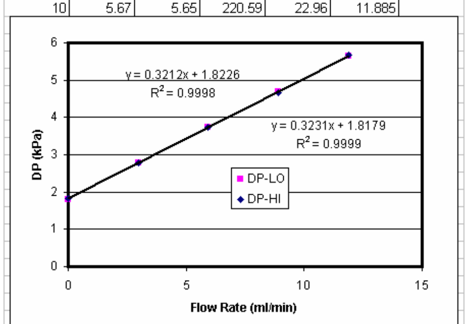
MacKay River Live Oil					
Temp	150	C			
Pressure	4000	kPa			
Line Dia.	0.0625	"			Actual
Flow Rate	DP-HI	DP-LO	Temp	Rm Temp	Flow Rate
ml/min	kPa	kPa	°C	°C	ml/min
0	1.05	0.10	150.40	21.70	0.000
5	9.33	8.44	150.59	21.83	5.430
10	17.15	16.31	150.67	21.79	10.861
15	24.98	24.22	150.58	21.85	16.290
20	32.78	32.05	150.78	21.88	21.725
30	48.61	47.99	150.68	21.76	32.585



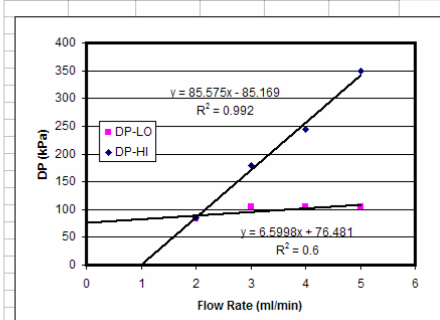
MacKay River Live Oil					
Temp	200	C			
Pressure	4000	kpa			
Line Dia.	0.125	"			Actual
Flow Rate	DP-HI	DP-LO	Temp	Rm Temp	Flow Rate
ml/min	kPa	kPa	°C	°C	ml/min
0	2.24	2.27	200.78	22.80	0.000
2.5	3.64	3.66	200.83	22.82	2.885
5	4.89	4.98	200.92	22.76	5.771
7.5	6.24	6.26	200.91	22.88	8.657
10	7.48	7.56	200.94	22.91	11.542



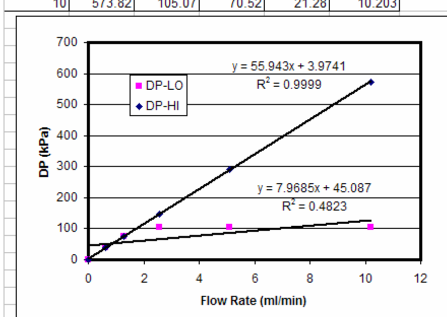
MacKay River Live Oil					
Temp	220	C			
Pressure	4000	kpa			
Line Dia.	0.125	"			Actual
Flow Rate	DP-HI	DP-LO	Temp	Rm Temp	Flow Rate
ml/min	kPa	kPa	°C	°C	ml/min
0	1.83	1.80	220.62	22.86	0.000
2.5	2.78	2.80	220.65	22.93	2.972
5	3.73	3.75	220.53	22.90	5.942
7.5	4.65	4.69	220.50	22.95	8.912
10	5.67	5.65	220.59	22.96	11.885



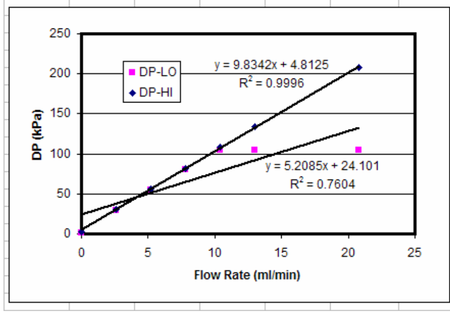
MacKay River Live Oil					
Temp	30	C			
Pressure	1500	kpa			
Line Dia.	0.125	"			Actual
Flow Rate	DP-HI	DP-LO	Temp	Rm Temp	Flow Rate
ml/min	kPa	kPa	°C	°C	ml/min
0	0.44	0.73	30.50	20.71	0.000
0.038	84.82	83.08	30.66	21.55	0.038
0.075	180.08	105.08	30.50	21.25	0.075
0.1	243.56	105.08	30.37	21.27	0.100
0.15	348.91	105.08	30.40	21.24	0.150



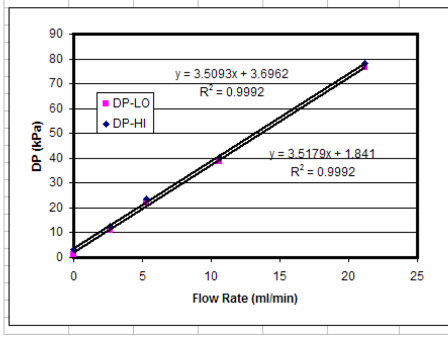
MacKay River Live Oil					
Temp	70	C			
Pressure	1500	kpa			
Line Dia.	0.125	"			Actual
Flow Rate	DP-HI	DP-LO	Temp	Rm Temp	Flow Rate
ml/min	kPa	kPa	°C	°C	ml/min
0	0.92	-0.61	70.49	21.01	0.000
0.625	40.23	38.54	70.38	21.28	0.638
1.25	76.39	74.87	70.37	21.21	1.275
2.5	148.30	105.08	70.41	21.18	2.551
5	290.04	105.08	70.45	21.18	5.101
10	573.82	105.07	70.52	21.28	10.203



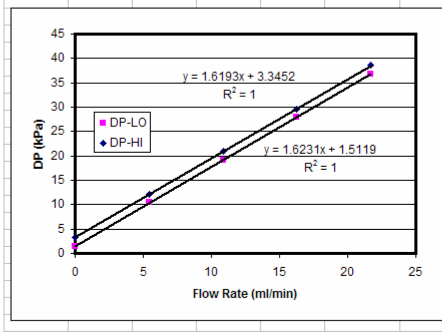
MacKay River Live Oil					
Temp	100	C			
Pressure	1500	kpa			
Line Dia.	0.125	"			Actual
Flow Rate	DP-HI	DP-LO	Temp	Rm Temp	Flow Rate
ml/min	kPa	kPa	°C	°C	ml/min
0	2.80	0.93	100.71	21.39	0.000
2.5	30.76	28.97	100.69	21.50	2.599
5	56.44	54.74	100.70	21.47	5.199
7.5	81.82	80.20	100.66	21.57	7.798
10	108.09	105.08	100.58	21.52	10.397
12.5	134.18	105.08	100.64	21.55	12.997
20	207.54	105.08	100.64	21.46	20.795



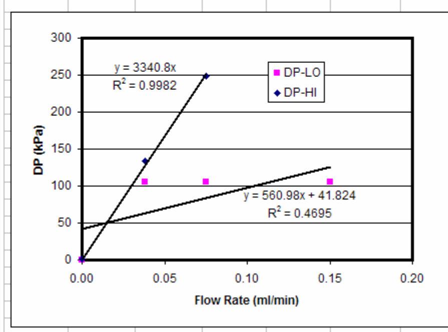
MacKay River Live Oil					
Temp	125	C			
Pressure	1500	kpa			
Line Dia.	0.125	"			Actual
Flow Rate	DP-HI	DP-LO	Temp	Rm Temp	Flow Rate
ml/min	kPa	kPa	°C	°C	ml/min
0	3.10	1.24	125.60	21.40	0.000
2.5	12.72	10.92	125.53	21.70	2.651
5	23.74	21.94	125.54	21.70	5.302
10	40.43	38.63	125.68	21.55	10.606
20	78.05	76.38	125.56	21.60	21.210



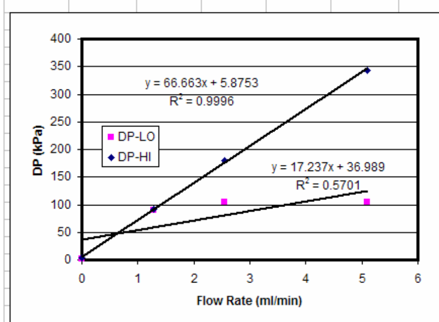
MacKay River Live Oil					
Temp	150	C			
Pressure	1500	kpa			
Line Dia.	0.125	"			Actual
Flow Rate	DP-HI	DP-LO	Temp	Rm Temp	Flow Rate
ml/min	kPa	kPa	°C	°C	ml/min
0	3.32	1.48	150.18	21.58	0.000
5	12.20	10.39	150.31	21.50	5.429
10	20.93	19.15	150.16	21.64	10.856
15	29.63	27.85	150.26	21.63	16.286
20	38.55	36.80	150.16	21.57	21.713



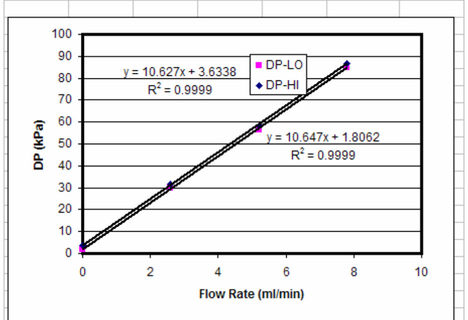
MacKay River Live Oil					
Temp	30	C			
Pressure	500	kpa			
Line Dia.	0.125	"			Actual
Flow Rate	DP-HI	DP-LO	Temp	Rm Temp	Flow Rate
ml/min	kPa	kPa	°C	°C	ml/min
0	1.89	0.02	30.67	20.91	0.000
0.038	133.76	105.08	30.44	20.90	0.038
0.075	248.02	105.08	30.43	20.64	0.075
0.15	455.19	105.07	30.61	20.92	0.150



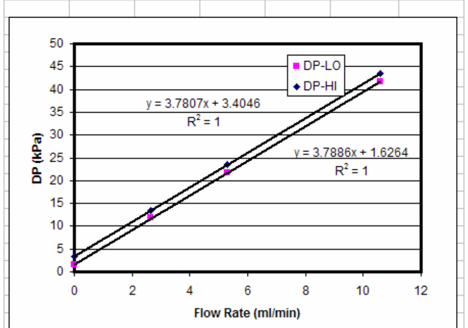
MacKay River Live Oil					
Temp	70	C			
Pressure	500	kpa			
Line Dia.	0.125	"			Actual
Flow Rate	DP-HI	DP-LO	Temp	Rm Temp	Flow Rate
ml/min	kPa	kPa	°C	°C	ml/min
0	3.49	1.65	70.33	21.19	0.000
1.25	91.56	90.00	70.20	21.11	1.275
2.5	179.62	105.08	70.11	21.10	2.550
5	343.84	105.08	70.14	21.17	5.100



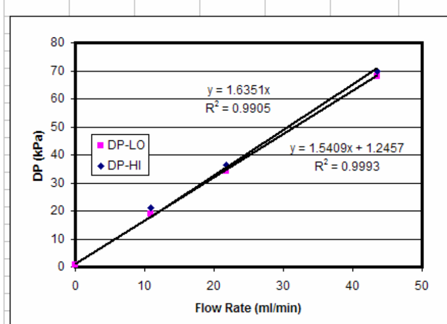
MacKay River Live Oil					
Temp	100	C			
Pressure	500	kpa			
Line Dia.	0.125	"			Actual
Flow Rate	DP-HI	DP-LO	Temp	Rm Temp	Flow Rate
ml/min	kPa	kPa	°C	°C	ml/min
0	3.55	1.71	101.54	21.11	0.000
2.5	31.65	29.89	100.30	21.35	2.599
5	58.31	56.59	100.41	21.28	5.198
7.5	86.73	85.05	100.36	21.33	7.797



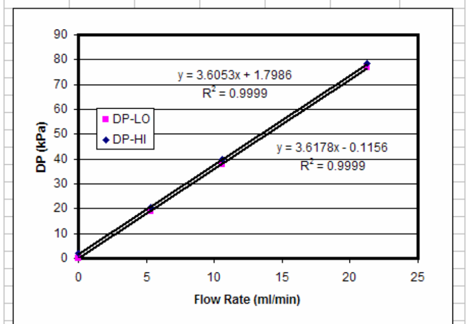
MacKay River Live Oil					
Temp	125	C			
Pressure	500	kpa			
Line Dia.	0.125	"			Actual
Flow Rate	DP-HI	DP-LO	Temp	Rm Temp	Flow Rate
ml/min	kPa	kPa	°C	°C	ml/min
0	3.31	1.54	125.21	21.28	0.000
2.5	13.51	11.77	125.34	21.31	2.651
5	23.50	21.74	125.33	21.39	5.302
10	43.45	41.76	125.31	21.33	10.603



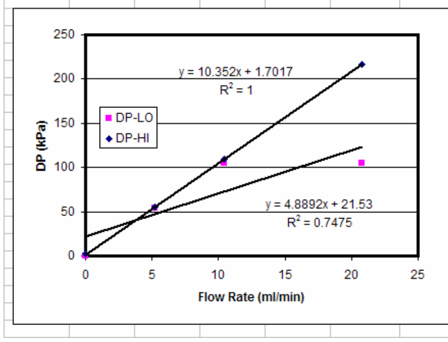
MacKay River Live Oil					
Temp	150	C			
Pressure	500	kpa			
Line Dia.	0.125	"			Actual
Flow Rate	DP-HI	DP-LO	Temp	Rm Temp	Flow Rate
ml/min	kPa	kPa	°C	°C	ml/min
0	2.59	0.64	151.14	21.50	0.000
10	20.96	19.08	151.19	21.63	10.868
20	36.19	34.32	151.21	21.62	21.736
40	69.95	68.16	151.09	21.71	43.465



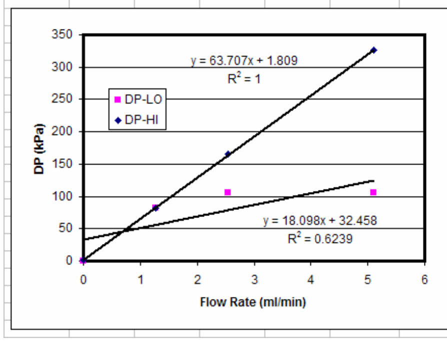
MacKay River Undersaturated Live Oil					
Temp	125	C			
Pressure	1500	kpa			
Line Dia.	0.125	"			Actual
Flow Rate	DP-HI	DP-LO	Temp	Rm Temp	Flow Rate
ml/min	kPa	kPa	°C	°C	ml/min
0	2.10	0.18	125.74	21.26	0.000
5	20.74	18.91	125.74	21.39	5.304
10	39.69	37.91	125.69	21.35	10.607
20	78.50	76.85	125.69	21.39	21.214



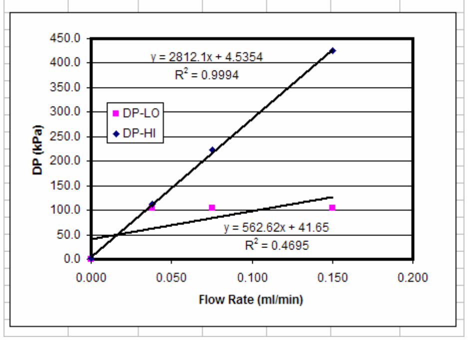
MacKay River Undersaturated Live Oil					
Temp	100	C			
Pressure	1500	kpa			
Line Dia.	0.125	"			Actual
Flow Rate	DP-HI	DP-LO	Temp	Rm Temp	Flow Rate
ml/min	kPa	kPa	°C	°C	ml/min
0	1.93	0.03	100.26	21.20	0.000
5	55.42	53.79	100.08	21.34	5.197
10	108.96	105.08	99.98	21.21	10.393
20	217.08	105.08	100.01	21.32	20.787



MacKay River Undersaturated Live Oil					
Temp	70	C			
Pressure	1500	kpa			
Line Dia.	0.125	"			Actual
Flow Rate	DP-HI	DP-LO	Temp	Rm Temp	Flow Rate
ml/min	kPa	kPa	°C	°C	ml/min
0	1.76	-0.08	70.13	21.14	0.000
1.25	82.74	81.26	69.88	21.20	1.275
2.5	164.79	105.08	69.86	21.21	2.550
5	326.49	105.08	69.84	21.13	5.100



MacKay River Undersaturated Live Oil					
Temp	30	C			
Pressure	1500	kpa			
Line Dia.	0.125	"			Actual
Flow Rate	DP-HI	DP-LO	Temp	Rm Temp	Flow Rate
ml/min	kPa	kPa	°C	°C	ml/min
0	1.61	-0.26	30.08	20.93	0.000
0.038	111.53	105.08	30.47	21.41	0.038
0.075	222.09	105.08	30.45	21.27	0.075
0.15	424.51	105.08	30.40	21.18	0.150



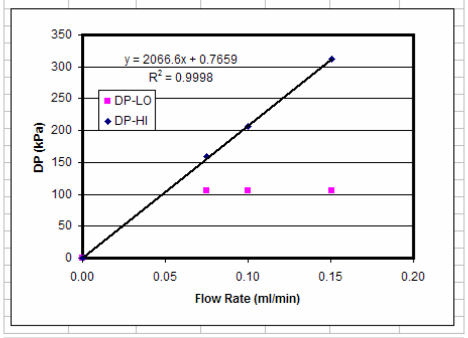
Appendix III MacKay River Bitumen GOR Measurements

MacKay River Bitumen mixed with methane (C1) gas oil ratio (GOR) measurement Data

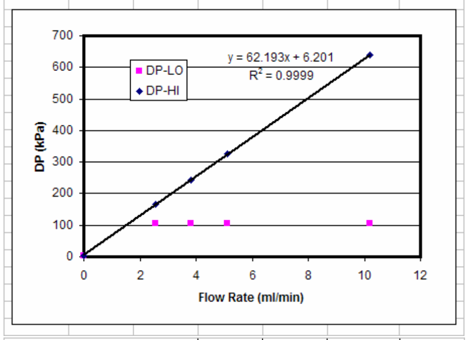
Date	Time	Type of gas mixed with Mackay R. B.	Equilibrium pressure Kpag	System Temperature C	Dead oil density g/ml	Oil Volume Rm. Temp. cc	Gas Meter Vol. Rm. Temp. cc	Corrected Gas Meter Vol Rm. Temp. cc	Oil Volume 15 C cc	Gas Vol.@ standard condition cc	Gas oil ratio @ standard condition Vol G./Vol OIL ml/ml	Average GOR	Trial #	# of Time heating up Glass jar	Weight Tare Jar g	Weight Jar+ D. oil g	net D. oil g	Room Temp. ^{0}C	Average Room Temp	Barometer mm Hg	Average Barometric Pres. kPa
06-May-05	8:47	Methane	4000.00	30.00	1.0057	3.6343	51.00	47.4	3.6142	42.3	11.7037		1	0	148.433	152.088	3.655	22.0		695.2	
06-May-05	11:34	Methane	4000.00	30.00	1.0057	4.9548	61.00	56.0	4.9273	50.1	10.1606		2	0	148.351	153.334	4.983	22.0		695.4	
06-May-05	14:59	Methane	4000.00	30.00	1.00594	4.2219	64.50	60.3	4.1995	53.9	12.8422		3	0	149.63	153.877	4.247	21.7		695.8	
06-May-05	16:10	Methane	4000.00	30.00	1.00578	5.0528	65.00	59.9	5.0252	53.6	10.6660	10.8434	4	0	148.17	153.252	5.082	21.9	21.9	695.8	92.7
11-May-05	15:28	Methane	4000.00	70.00	1.00474	5.8513	61.50	55.6	5.8133	50.1	8.6206		1	0	149.228	155.107	5.879	23.2		703.9	
11-May-05	16:08	Methane	4000.00	70.00	1.00458	5.6710	62.00	56.3	5.6333	50.6	8.9871		2	0	149.235	154.932	5.697	23.4		703	
12-May-05	11:49	Methane	4000.00	70.00	1.00506	5.8832	64.50	58.6	5.8469	52.5	8.9800		4	0	149.51	155.423	5.913	22.8		699.2	
12-May-05	15:35	Methane	4000.00	70.00	1.0045	5.8248	70.00	64.2	5.7856	57.3	9.9023		5	0	148.677	154.528	5.851	23.5		698.5	
13-May-05	10:10	Methane	4000.00	70.00	1.00554	9.5789	105.25	95.7	9.5244	86.7	9.1023	9.1185	6	0	149.784	159.416	9.632	22.2	23.0	705.9	93.6
20-May-05	11:12	Methane	4000.00	101.00	1.0061	10.1481	101.25	91.1	10.0959	81.8	8.1046		1	0	148.478	158.688	10.210	21.5		698.0	
20-May-05	12:39	Methane	4000.00	101.00	1.00626	9.9845	101.25	91.3	9.9347	82.0	8.2541		2	0	147.582	157.629	10.047	21.3		697.8	
20-May-05	13:50	Methane	4000.00	101.00	1.0061	9.8579	101.25	91.4	9.8072	82.0	8.3650		3	0	148.811	158.729	9.918	21.5		697.6	
20-May-05	14:50	Methane	4000.00	101.00	1.00618	10.2228	101.25	91.0	10.1711	81.7	8.0328	8.1891	4	0	148.854	159.14	10.286	21.4	21.4	697.3	93.0
26-May-05	15:39	Methane	4000.00	125.70	1.00602	11.1847	100.25	89.1	11.1263	81.2	7.2984		1	0	149.003	160.255	11.252	21.6		708.8	
26-May-05	16:15	Methane	4000.00	125.70	1.0061	11.5575	101.00	89.4	11.4981	81.6	7.0937		2	0	147.094	158.722	11.628	21.5		708.7	
26-May-05	16:49	Methane	4000.00	126.00	1.00602	11.7334	101.25	89.5	11.6721	81.6	6.9894		3	0	148.83	160.634	11.804	21.6		708.5	
27-May-05	14:25	Methane	4000.00	125.70	1.0061	11.3587	100.50	89.1	11.3003	80.9	7.1580		1	0	148.699	160.127	11.428	21.5		705.2	
27-May-05	14:48	Methane	4000.00	125.80	1.0061	11.3199	100.50	89.2	11.2617	80.9	7.1857		2	0	148.456	159.845	11.389	21.5		705.2	
27-May-05	15:17	Methane	4000.00	126.00	1.0061	11.2553	100.00	88.7	11.1975	80.5	7.1916		3	0	148.773	160.097	11.324	21.5		705.2	
27-May-05	16:10	Methane	4000.00	125.70	1.0061	11.3040	100.25	88.9	11.2459	80.7	7.1759	7.1324	4	0	149.765	161.138	11.373	21.5	21.5	705.1	94.2
02-Jun-05	10:34	Methane	4000.00	150.60	1.00586	11.8396	100.50	88.7	11.7759	79.4	6.7446		1	0	148.084	159.993	11.909	21.8		696.9	
02-Jun-05	11:07	Methane	4000.00	150.50	1.00578	11.7302	100.50	88.8	11.6662	79.5	6.8141		2	0	148.329	160.127	11.798	21.9		696.9	
02-Jun-05	11:41	Methane	4000.00	150.70	1.00586	11.4917	100.50	89.0	11.4298	79.7	6.9741		3	0	147.048	158.607	11.559	21.8		696.7	
02-Jun-05	12:14	Methane	4000.00	150.60	1.00594	11.3188	100.50	89.2	11.2588	79.9	7.0942		4	0	147.73	159.116	11.386	21.7		696.5	
02-Jun-05	12:55	Methane	4000.00	150.50	1.00602	13.6618	120.50	106.8	13.5904	95.7	7.0400		5	0	148.417	162.161	13.744	21.6		696.2	
02-Jun-05	13:30	Methane	4000.00	150.80	1.00594	11.3367	100.50	89.2	11.2766	79.8	7.0765	6.9573	6	0	147.874	159.278	11.404	21.7	21.8	696.0	92.8
27-Jun-05	11:10	Methane	1500.00	30.40	1.00634	12.3716	71.75	59.4	12.3109	53.8	4.3669		1	0	147.349	159.799	12.450	21.2		702.9	
27-Jun-05	11:47	Methane	1500.00	30.40	1.00642	12.6160	72.25	59.6	12.5551	54.0	4.3000		2	0	148.115	160.812	12.697	21.1		702.6	
27-Jun-05	14:00	Methane	1500.00	30.40	1.00642	17.8693	103.50	85.6	17.7831	77.5	4.3587		3	0	147.618	165.602	17.984	21.1		702.5	
27-Jun-05	14:51	Methane	1500.00	30.40	1.00626	17.5313	102.50	85.0	17.4439	76.8	4.4054		4	0	147.517	165.158	17.641	21.3		702.4	
27-Jun-05	15:49	Methane	1500.00	30.50	1.00634	17.8767	102.00	84.1	17.7890	76.1	4.2784	4.3419	5	0	147.024	165.014	17.990	21.2	21.2	702.4	93.7
30-Jun-05	9:42	Methane	1500.00	70.10	1.00626	16.5444	101.50	85.0	16.4620	76.6	4.6555		1	0	148.069	164.717	16.648	21.3		700.6	
30-Jun-05	10:42	Methane	1500.00	70.40	1.00626	11.8627	60.75	48.9	11.8036	44.1	3.7363		2	0	147.093	159.03	11.937	21.3		700.6	
30-Jun-05	11:37	Methane	1500.00	70.30	1.00626	13.6565	70.50	56.8	13.5885	51.2	3.7716		3	0	148.058	161.8	13.742	21.3		700.2	
30-Jun-05	12:58	Methane	1500.00	70.20	1.00634	25.4338	125.50	100.1	25.3090	90.2	3.5629		4	0	148.357	173.952	25.595	21.2		699.6	
30-Jun-05	13:40	Methane	1500.00	70.30	1.00618	11.4572	61.00	49.5	11.3992	44.6	3.9138	3.7461	5	0	147.483	159.011	11.528	21.4	21.3	699.6	93.3
06-Jul-05	10:58	Methane	1500.00	100.60	1.0061	15.9587	71.00	55.0	15.8766	49.0	3.0865		1	0	146.995	163.051	16.056	21.5		691.9	
06-Jul-05	12:09	Methane	1500.00	100.50	1.0061	20.5218	80.50	60.0	20.4163	53.4	2.6132		2	0	149.69	170.337	20.647	21.5		691.3	
06-Jul-05	13:10	Methane	1500.00	100.50	1.00602	23.3514	101.50	78.1	23.2295	69.4	2.9889		3	0	149.591	173.083	23.492	21.6		690.7	
06-Jul-05	14:04	Methane	1500.00	100.50	1.00602	16.6269	71.25	54.6	16.5401	48.5	2.9337		4	0	148.868	165.595	16.727	21.6		690.6	
06-Jul-05	15:20	Methane	1500.00	100.50	1.00602	24.3037	104.00	79.7	24.1768	70.9	2.9334		5	0	148.024	172.474	24.450	21.6		691.8	
06-Jul-05	16:11	Methane	1500.00	100.70	1.00618	16.8181	71.75	54.9	16.7329	49.0	2.9267	2.9137	6	0	147.266	164.188	16.922	21.4	21.5	692.6	92.2
11-Jul-05	12:43	Methane	1500.00	125.40	1.00594	26.3952	100.75	74.4	26.2553	67.1	2.5557		1	0	147.947	174.499	26.552	21.7		701.8	
11-Jul-05	13:45	Methane	1500.00	125.40	1.00602	18.2829	73.00	54.7	18.1875	49.4	2.7166		2	0	148.135	166.528	18.393	21.6		702	
11-Jul-05	14:44	Methane	1500.00	125.50	1.00602	18.3754	70.50	52.1	18.2794	47.1	2.5742		3	0	148.508	166.994	18.486	21.6		701.8	
11-Jul-05	15:33	Methane	1500.00	125.70	1.0061	18.2437	72.25	54.0	18.1499	48.7	2.6859	2.6331	4	0	148.181	166.536	18.355	21.5	21.6	701.5	93.5
14-Jul-05	15:55	Methane	1500.00	150.40	1.00586	16.1563	60.13	44.0	16.0694	39.7	2.4736		2	0	148.722	164.973	16.251	21.8		703.3	
14-Jul-05	16:45	Methane	1500.00	150.10	1.00586	15.4674	60.13	44.7	15.3842	40.4	2.6243		3	0	149.134	164.692	15.558	21.8		703.3	
15-Jul-05	9:30	Methane	1500.00	150.30	1.00602	18.3227	65.00	46.7	18.2270	42.0	2.3069		4	0	148.538	166.971	18.433	21.6		700.3	
15-Jul-05	10:34	Methane	1500.00	150.40	1.00602	19.4430	70.00	50.6	19.3414	45.5	2.3546		5	0	148.513	168.073	19.560	21.6		700.3	
15-Jul-05	11:27	Methane	1500.00	150.40	1.00594	18.8779	65.00	46.1	18.7778	41.5	2.2115	2.3942	6	0	147.428	166.418	18.990	21.7	21.6	700.2	93.3
26-Jul-05	15:59	Methane	500.00	30.30	1.0065	22.6110	60.00	37.4	22.5037	34.0	1.5121		1	0	148.737	171.495	22.758	21		706.1	
26-Jul-05	16:45	Methane	500.00	30.50	1.00658	18.4138	50.00	31.6	18.3279	28.7	1.5686		2	0	148.261	166.796	18.535	20.9		705.9	
26-Jul-05	17:44	Methane	500.00	30.70	1.0065	22.4292	60.00	37.6	22.3228	34.2	1.5316	1.5374	3	0	148.677	171.252	22.575	21	21.0	706	94.1
28-Jul-05	12:01	Methane	500.00	70.30	1.00618	24.3396	55.00	30.7	24.2164	27.7	1.1432		1	0	147.767	172.257	24.490	21.4		701.5	
28-Jul-05	13:10	Methane	500.00	70.30	1.00618	25.5491	60.00	34.5	25.4198	31.1	1.2229		2	0	147.666	173.373	25.707	21.4		701	
28-Jul-05	13:52	Methane	500.00	70.00	1.00626	17.0373	40.00	23.0	16.9524	20.7	1.2226		3	0	148.668	165.812	17.144	21.3		701	
28-Jul-05	14:15	Methane	500.00	70.30	1.00626	51.5533	126.00	74.4	51.2964	67.2	1.3092	1.2245	4	0	147.711	199.587	51.876	21.3	21.4	700.6	93.4
29-Jul-05	11:58	Methane	500.00	100.30	1.00618	28.3071	50.00	21.7	28.1637	19.6	0.6946		1	0	147.272	175.754	28.482	21.4		700.6	
29-Jul-05	13:25	Methane	500.00	100.20	1.0061	34.8087	75.00	40.2	34.6297	36.2	1.0457		2	0	147.737	182.758	35.021	21.5		700.2	
29-Jul-05	14:24	Methane	500.00	100.20	1.0061	24.0374	50.00	26.0	23.9138	23.4	0.9779	1.0118	3	0	147.902	172.086	24.184	21.5	21.5	700	93.3
02-Aug-05	13:50	Methane	500.00	125.50	1.0061	18.3660	36.00	17.6	18.2715	15.9	0.8712		1	0	147.97	166.448	18.478	21.5		701.5	
02-Aug-05	15:22	Methane	500.00	125.50	1.0061	17.4197	36.00	18.6	17.3302	16.8	0.9687		2	0	148.61	166.136	17.526	21.5		702.2	
02-Aug-05	16:10	Methane	500.00	125.50	1.0061	17.1514	36.00	18.8	17.0632	17.0	0.9985	0.9836	3	0	148.151	165.407	17.256	21.5	21.5	702.5	93.6
04-Aug-05	13:15	Methane	500.00	151.40	1.00594	24.8305	50.00	25.2	24.6989	22.8	0.9239		1	0	148.036	173.014	24.978	21.7		705.1	
04-Aug-05	14:00	Methane	500.00	151.40	1.00586	23.9139	50.00	26.1	23.7852	23.6	0.9935		2	0	147.641	171.695	24.054	21.8		704.7	
04-Aug-05	15:42	Methane	500.00	151.40	1.00578	53.1160	110.00	56.9	52.8261	51.5	0.9744	0.9639	3	0	148.395	201.818	53.423	21.9	21.8	704.2	93.9
29-Nov-05	11:54	Methane	4000.00	201.20	1.00506	10.4143	90.00	79.6	10.3500	71.7	6.9281		1	0	153.13	163.597	10.467	22.8		703.3	
29-Nov-05	12:21	Methane	4000.00	201.40	1.00514	10.0474	90.00	80.0	9.9862	72.1	7.2151		2	0	154.06	164.159	10.099	22.7		703.2	
29-Nov-05	12:54	Methane	4000.00	201.00	1.00514	10.5916	90.00	79.4	10.5270	71.6	6.7978		3	0	153.432	164.078	10.646	22.7		703.2	
29-Nov-05	13:22	Methane	4000.00	200.80	1.00506	11.2570	90.00	78.7	11.1876	70.9	6.3398	6.8202	4	0	153.063	164.377	11.314	22.8	22.7500	703.1	703.2000
01-Dec-05	14:45	Methane	4000.00	220.80	1.00482	11.0806	100.03	88.9	11.0096	80.3	7.2902		1	0	153.082	164.216	11.134	23.1		705.1	
01-Dec-05	15:19	Methane	4000.00	220.80	1.0049	11.9086	100.03	88.1	11.8333	79.5	6.7209		2	0	153.399	165.366	11.967	23		705	
01-Dec-05	15:48	Methane	4000.00	220.40	1.0049	11.9465	100.03	88.1	11.8709	79.5	6.6968		3	0	153.068	165.073	12.005	23		705	
01-Dec-05	16:23	Methane	4000.00	220.40	1.0049	12.8092	100.03	87.2	12.7282	78.7	6.1828	6.7226	4	0	153.255	166.127	12.872	23	23.0250	704.8	704.9750
05-Dec-05	14:44	Methane	1500.00	200.50	1.0049	10.8867	40.00	29.1	10.8178	26.5	2.4497		1	0	148.438	159.378	10.940	23		711	
05-Dec-05	15:14	Methane	1500.00	200.60	1.0049	11.1772	40.00	28.8	11.1065	26.2	2.3632		2	0	148.415	159.647	11.232	23		711.3	
05-Dec-05	15:44	Methane	1500.00	200.60	1.00498	11.5574	40.00	28.4	11.4852	25.9	2.2568		3	0	153.398	165.013	11.615	22.9		711.6	
05-Dec-05	16:22	Methane	1500.00	200.80	1.00498	14.1406	50.00	35.9	14.0522	32.7	2.3262	2.3490	4	0	152.795	167.006	14.211	22.9	22.9500	711.8	711.4250

Appendix IV Christina Lake Capillary Tube Measurements

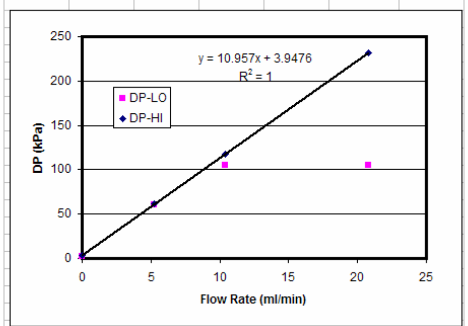
Christina Lake Live Oil					
Temp	30	C			
Pressure	4000	kPa			
Line Dia.	0.125	"			Actual
Flow Rate	DP-HI	DP-LO	Temp	Rm Temp	Flow Rate
ml/min	kPa	kPa	°C	°C	ml/min
0	0.25	-0.62	30.94	20.27	0.000
0.075	158.74	105.08	30.68	20.95	0.075
0.1	205.81	105.08	30.73	20.60	0.100
0.15	311.93	105.08	30.70	20.59	0.150



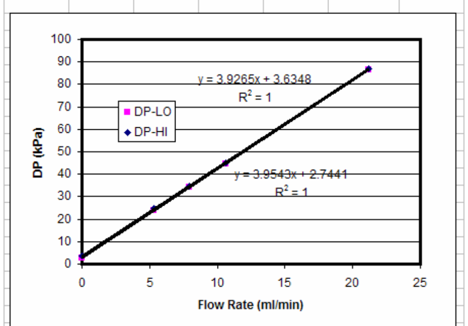
Christina Lake Live Oil					
Temp	70	C			
Pressure	4000	kPa			
Line Dia.	0.125	"			Actual
Flow Rate	DP-HI	DP-LO	Temp	Rm Temp	Flow Rate
ml/min	kPa	kPa	°C	°C	ml/min
0	3.99	2.98	70.41	20.56	0.000
2.5	167.31	105.08	70.52	20.55	2.551
3.75	243.05	105.08	70.60	20.61	3.827
5	325.72	105.08	70.47	20.56	5.102
10	639.56	105.07	70.47	20.54	10.204



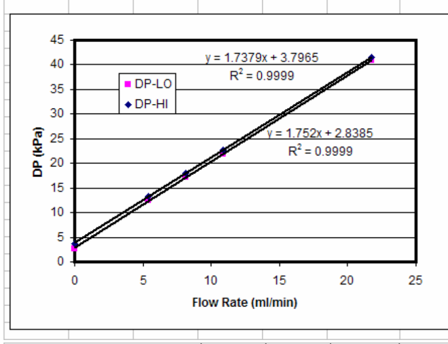
Christina Lake Live Oil					
Temp	100	C			
Pressure	4000	kPa			
Line Dia.	0.125	"			Actual
Flow Rate	DP-HI	DP-LO	Temp	Rm Temp	Flow Rate
ml/min	kPa	kPa	°C	°C	ml/min
0	3.76	2.80	100.67	20.55	0.000
5	61.37	60.87	100.51	20.78	5.199
10	117.58	105.08	100.57	20.77	10.399
20	231.87	105.08	100.59	20.72	20.799



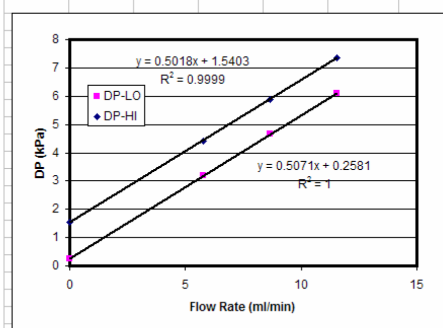
Christina Lake Live Oil					
Temp	125	C			
Pressure	4000	kPa			
Line Dia.	0.125	"			Actual
Flow Rate	DP-HI	DP-LO	Temp	Rm Temp	Flow Rate
ml/min	kPa	kPa	°C	°C	ml/min
0	3.67	2.76	125.32	21.56	0.000
5	24.63	23.93	125.25	21.64	5.301
7.5	34.72	34.06	125.30	21.70	7.952
10	45.11	44.45	125.31	21.59	10.603
20	86.99	86.70	125.32	21.45	21.207



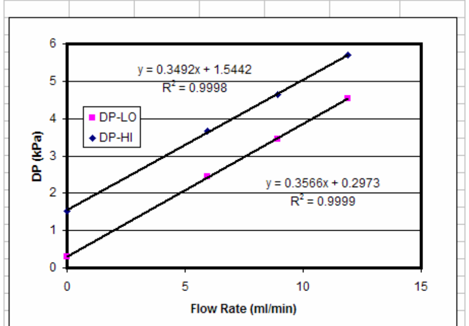
Christina Lake Live Oil					
Temp	150	C			
Pressure	4000	kPa			
Line Dia.	0.125	"			Actual
Flow Rate	DP-HI	DP-LO	Temp	Rm Temp	Flow Rate
ml/min	kPa	kPa	°C	°C	ml/min
0	3.65	2.66	151.41	21.21	0.000
5	13.39	12.54	151.04	21.72	5.433
7.5	18.03	17.20	151.09	21.90	8.149
10	22.66	21.86	151.13	21.78	10.867
20	41.51	40.85	151.05	21.79	21.731



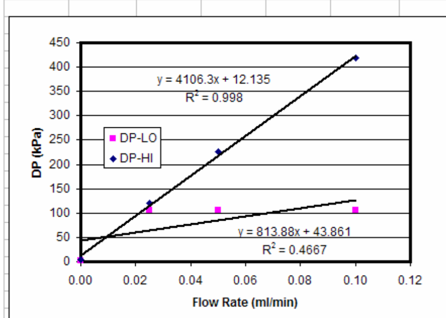
Christina Lake Live Oil					
Temp	200	C			
Pressure	4000	kPa			
Line Dia.	0.125	"			Actual
Flow Rate	DP-HI	DP-LO	Temp	Rm Temp	Flow Rate
ml/min	kPa	kPa	°C	°C	ml/min
0	1.56	0.26	201.24	21.50	0.000
5	4.42	3.18	201.16	21.64	5.775
7.5	5.87	4.65	201.22	21.63	8.663
10	7.36	6.12	201.23	21.59	11.551



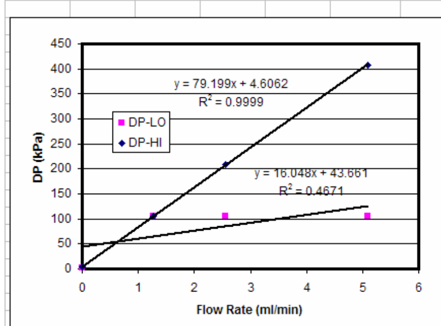
Christina Lake Live Oil					
Temp	220	C			
Pressure	4000	kPa			
Line Dia.	0.125	"			Actual
Flow Rate	DP-HI	DP-LO	Temp	Rm Temp	Flow Rate
ml/min	kPa	kPa	°C	°C	ml/min
0	1.53	0.29	220.45	22.75	0.000
5	3.66	2.44	220.50	22.58	5.942
7.5	4.63	3.46	220.59	22.71	8.914
10	5.69	4.54	220.42	22.76	11.882



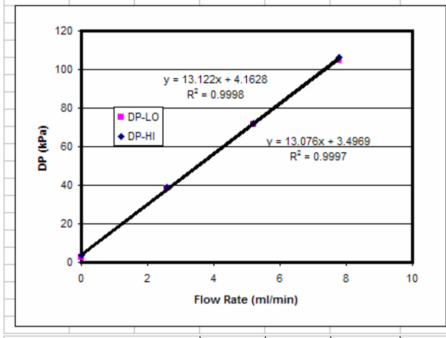
Christina Lake Live Oil					
Temp	30	C			
Pressure	1500	kPa			
Line Dia.	0.125	"			Actual
Flow Rate	DP-HI	DP-LO	Temp	Rm Temp	Flow Rate
ml/min	kPa	kPa	°C	°C	ml/min
0	3.91	3.05	30.34	20.16	0.000
0.025	121.19	105.08	30.26	20.22	0.025
0.05	225.35	105.08	30.14	20.31	0.050
0.1	418.79	105.08	30.80	21.02	0.100



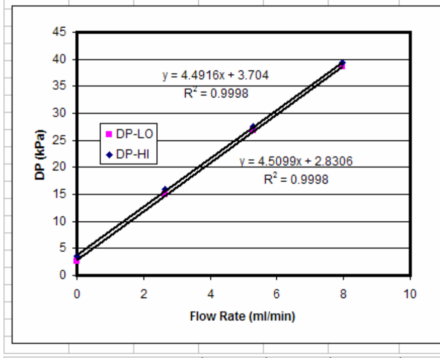
Christina Lake Live Oil					
Temp	70	C			
Pressure	1500	kPa			
Line Dia.	0.125	"			Actual
Flow Rate	DP-HI	DP-LO	Temp	Rm Temp	Flow Rate
ml/min	kPa	kPa	°C	°C	ml/min
0	3.55	2.76	70.83	20.66	0.000
1.25	105.71	105.02	70.93	21.01	1.276
2.5	208.68	105.08	70.87	21.06	2.551
5	407.69	105.08	70.79	21.03	5.102



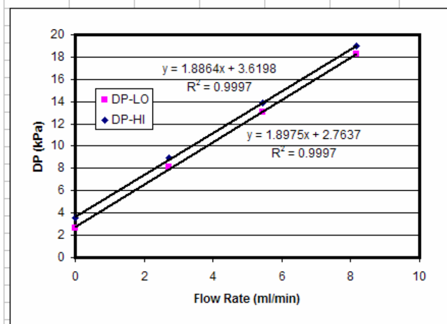
Christina Lake Live Oil					
Temp	100	C			
Pressure	1500	kPa			
Line Dia.	0.125	"			Actual
Flow Rate	DP-HI	DP-LO	Temp	Rm Temp	Flow Rate
ml/min	kPa	kPa	°C	°C	ml/min
0	3.58	2.73	100.71	21.20	0.000
2.5	39.20	38.52	100.79	21.69	2.600
5	72.28	71.71	100.77	21.46	5.199
7.5	106.27	104.98	100.91	21.66	7.799



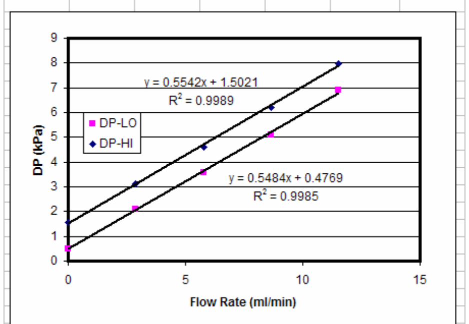
Christina Lake Live Oil					
Temp	125	C			
Pressure	1500	kPa			
Line Dia.	0.125	"			Actual
Flow Rate	DP-HI	DP-LO	Temp	Rm Temp	Flow Rate
ml/min	kPa	kPa	°C	°C	ml/min
0	3.50	2.62	125.76	22.03	0.000
2.5	15.87	15.06	125.80	21.96	2.652
5	27.60	26.84	125.74	21.89	5.303
7.5	39.29	38.55	125.84	22.04	7.955



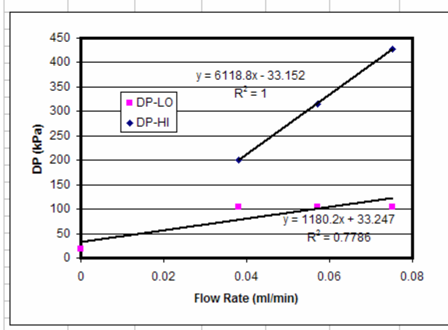
Christina Lake Live Oil					
Temp	150	C			
Pressure	1500	kPa			
Line Dia.	0.125	"			Actual
Flow Rate	DP-HI	DP-LO	Temp	Rm Temp	Flow Rate
ml/min	kPa	kPa	°C	°C	ml/min
0	3.53	2.67	151.87	21.51	0.000
2.5	8.91	8.08	151.79	21.24	2.719
5	13.84	13.03	151.94	21.20	5.439
7.5	18.98	18.22	151.89	21.29	8.157



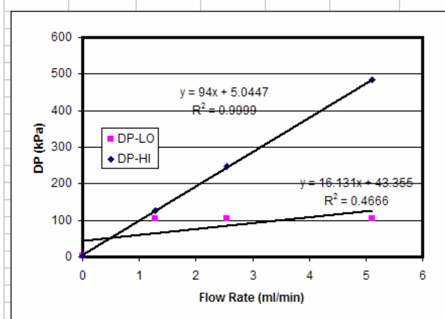
Christina Lake Live Oil					
Temp	200	C			
Pressure	1500	kPa			
Line Dia.	0.125	"			Actual
Flow Rate	DP-HI	DP-LO	Temp	Rm Temp	Flow Rate
ml/min	kPa	kPa	°C	°C	ml/min
0	1.54	0.50	199.84	22.64	0.000
2.5	3.13	2.11	199.90	22.64	2.882
5	4.61	3.58	199.99	22.60	5.764
7.5	6.21	5.08	199.84	22.59	8.644
10	7.99	6.92	199.91	22.62	11.527



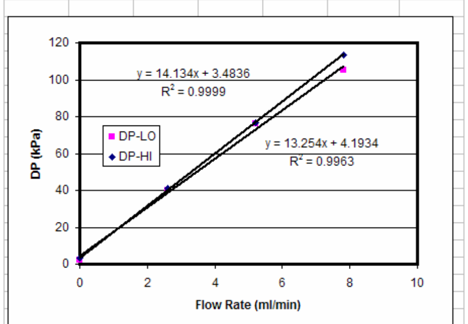
Christina Lake Live Oil					
Temp	30	C			
Pressure	500	kPa			
Line Dia.	0.125	"			Actual
Flow Rate	DP-HI	DP-LO	Temp	Rm Temp	Flow Rate
ml/min	kPa	kPa	°C	°C	ml/min
0	19.76	18.94	30.07	22.64	0.000
0.038	200.32	105.08	30.53	20.90	0.038
0.057	315.97	105.08	30.24	21.15	0.057
0.075	427.39	105.08	30.85	21.17	0.075



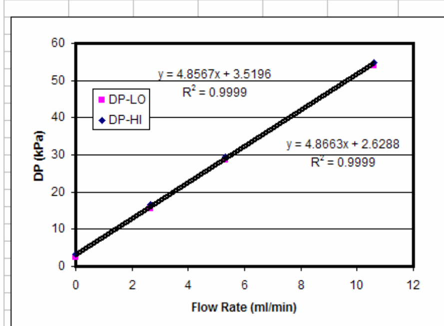
Christina Lake Live Oil					
Temp	70	C			
Pressure	500	kPa			
Line Dia.	0.125	"			Actual
Flow Rate	DP-HI	DP-LO	Temp	Rm Temp	Flow Rate
ml/min	kPa	kPa	°C	°C	ml/min
0	3.15	2.21	70.19	20.62	0.000
1.25	126.20	105.08	70.38	20.64	1.275
2.5	246.74	105.08	70.42	20.57	2.551
5	483.32	105.07	70.31	20.72	5.101



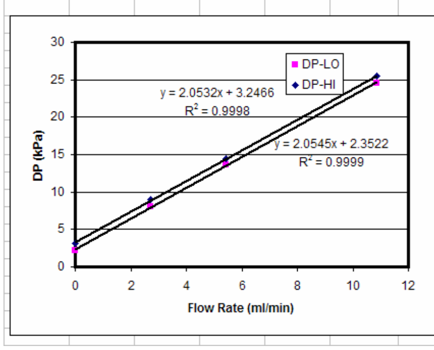
Christina Lake Live Oil					
Temp	100	C			
Pressure	500	kPa			
Line Dia.	0.125	"			Actual
Flow Rate	DP-HI	DP-LO	Temp	Rm Temp	Flow Rate
ml/min	kPa	kPa	°C	°C	ml/min
0	3.07	2.18	101.10	20.64	0.000
2.5	40.92	40.16	101.02	20.68	2.601
5	76.89	76.16	101.02	20.66	5.201
7.5	113.60	105.08	101.00	20.70	7.802



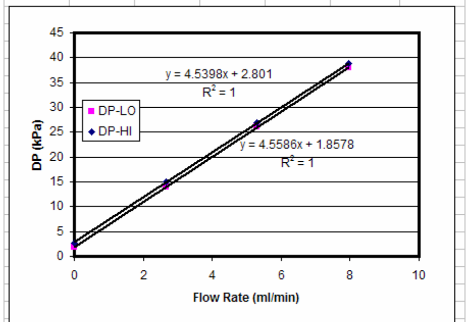
Christina Lake Live Oil					
Temp	125	C			
Pressure	500	kPa			
Line Dia.	0.125	"			Actual
Flow Rate	DP-HI	DP-LO	Temp	Rm Temp	Flow Rate
ml/min	kPa	kPa	°C	°C	ml/min
0	3.27	2.41	125.38	21.09	0.000
2.5	16.56	15.66	125.18	21.15	2.651
5	29.51	28.68	125.22	21.10	5.302
10	54.86	54.07	125.29	21.05	10.604



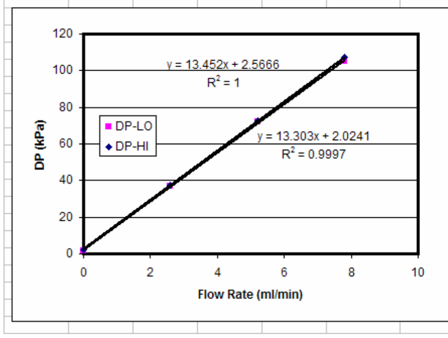
Christina Lake Live Oil					
Temp	150	C			
Pressure	500	kPa			
Line Dia.	0.125	"			Actual
Flow Rate	DP-HI	DP-LO	Temp	Rm Temp	Flow Rate
ml/min	kPa	kPa	°C	°C	ml/min
0	3.10	2.23	150.63	21.31	0.000
2.5	8.94	8.03	150.72	21.35	2.716
5	14.50	13.60	150.72	21.36	5.432
10	25.47	24.60	150.63	21.33	10.862



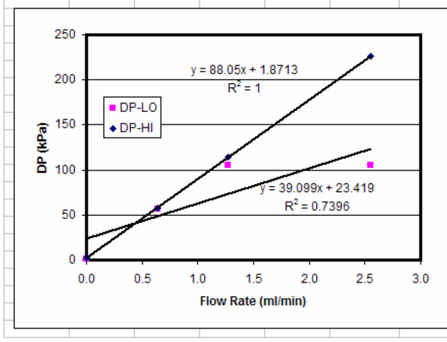
Christina Lake Undersaturated Live Oil					
Temp	125	C			
Pressure	1500	kPa			
Line Dia.	0.125	"			Actual
Flow Rate	DP-HI	DP-LO	Temp	Rm Temp	Flow Rate
ml/min	kPa	kPa	°C	°C	ml/min
0	2.73	1.80	125.44	21.05	0.000
2.5	14.94	14.03	125.36	21.17	2.651
5	26.86	26.01	125.36	21.18	5.302
7.5	38.88	38.10	125.41	21.11	7.954



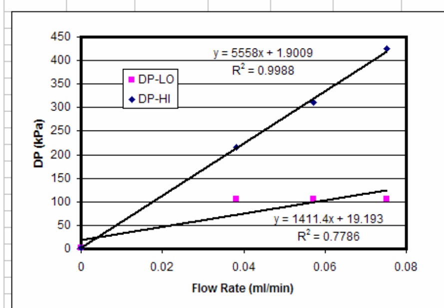
Christina Lake Undersaturated Live Oil					
Temp	100	C			
Pressure	1500	kPa			
Line Dia.	0.125	"			Actual
Flow Rate	DP-HI	DP-LO	Temp	Rm Temp	Flow Rate
ml/min	kPa	kPa	°C	°C	ml/min
0	2.40	1.51	100.35	20.83	0.000
2.5	37.70	36.94	100.41	20.87	2.599
5	72.66	72.05	100.44	20.76	5.199
7.5	107.30	105.08	100.42	20.94	7.798



Christina Lake Undersaturated Live Oil					
Temp	70	C			
Pressure	500	kPa			
Line Dia.	0.125	"			Actual
Flow Rate	DP-HI	DP-LO	Temp	Rm Temp	Flow Rate
ml/min	kPa	kPa	°C	°C	ml/min
0	1.93	1.00	70.17	20.50	0.000
0.625	57.70	57.05	70.29	20.61	0.638
1.25	114.53	105.08	70.21	20.43	1.275
2.5	226.37	105.08	70.22	20.49	2.551



Christina Lake Undersaturated Live Oil					
Temp	30	C			
Pressure	1500	kPa			
Line Dia.	0.125	"			Actual
Flow Rate	DP-HI	DP-LO	Temp	Rm Temp	Flow Rate
ml/min	kPa	kPa	°C	°C	ml/min
0	3.09	2.09	29.96	20.97	0.000
0.038	215.51	105.08	30.10	21.42	0.038
0.057	310.74	105.08	30.17	21.64	0.057
0.075	425.57	105.08	29.97	21.17	0.075



Appendix V Christina Lake GOR Measurements

Christina Lake Bitumen mixed with methane (C1) gas oil ratio (GOR) measurement data

Date	Time	Type of gas mixed with Bitumen	Equilibrium pressure Kpag	System Temperature C	Dead oil density g/ml	Oil Volume Rm. Temp. cc	Measured Gas Meter Vol. Rm. Temp. cc	Corrected Gas Meter Vol Rm. Temp. cc	Oil Volume 15 C cc	Gas Vol.@ standard condition cc	Gas oil ratio @ standard condition ml/ml	Average GOR	Trial #	Weight Tare Jar g	Weight Jar+ oil g	net oil g	Room Temp. ^{0}C	Average Room Temp	Barometer mm Hg	Average Barometric Pres. kPa
07-Sep-05	14:28	Methane	4000	30.40	1.0127	7.6015	100.05	92.4485	7.5589	83.8	11.0872		1	148.605	156.303	7.698	20.7		702.6	
07-Sep-05	15:13	Methane	4000	30.40	1.0127	8.2166	100.03	91.8084	8.1707	83.2	10.1847		2	148.866	157.187	8.321	20.7		702.5	
07-Sep-05	15:40	Methane	4000	30.40	1.0127	8.0419	101.00	92.9581	7.9969	84.2	10.5318		3	148.348	156.492	8.144	20.7		702.2	
07-Sep-05	16:07	Methane	4000	30.30	1.0127	8.1801	100.00	91.8199	8.1343	83.2	10.2241		4	147.578	155.862	8.284	20.7		702	
07-Sep-05	16:33	Methane	4000	30.40	1.0126	7.7661	100.00	92.2339	7.7219	83.5	10.8151	10.5686	5	148.139	156.003	7.864	20.8	20.7	702	93.6
12-Sep-05	15:33	Methane	4000	71.30	1.0126	10.4523	100.05	89.5977	10.3928	80.9	7.7838		1	148.174	158.758	10.584	20.8		700	
12-Sep-05	15:58	Methane	4000	71.30	1.0126	8.9591	100.05	91.0909	8.9081	82.2	9.2324		2	148.18	157.252	9.072	20.8		700	
12-Sep-05	16:25	Methane	4000	71.40	1.0124	9.5397	100.03	90.4853	9.4835	81.7	8.6112		3	148.345	158.003	9.658	21		700.2	
12-Sep-05	16:52	Methane	4000	71.30	1.0124	9.6365	101.00	91.3635	9.5797	82.5	8.6074	8.5587	4	148.512	158.268	9.756	21	20.9	700.2	93.3
14-Sep-05	12:31	Methane	4000	100.50	1.0124	9.9931	100.00	90.0069	9.9342	81.0	8.1513		1	147.81	157.927	10.117	21		698	
14-Sep-05	13:00	Methane	4000	100.50	1.0126	12.0363	120.00	107.9637	11.9678	97.2	8.1228		2	147.694	159.882	12.188	20.8		698.1	
14-Sep-05	13:35	Methane	4000	100.40	1.0125	10.0652	100.05	89.9848	10.0069	81.0	8.0976		3	147.986	158.177	10.191	20.9		698.4	
14-Sep-05	14:05	Methane	4000	100.50	1.0126	9.9407	100.05	90.1093	9.8841	81.2	8.2134		4	148.484	158.55	10.066	20.8		698.5	
14-Sep-05	14:37	Methane	4000	100.70	1.0126	10.2815	100.05	89.7685	10.2229	80.9	7.9135	8.0997	5	148.587	158.998	10.411	20.8	20.9	698.7	93.1
19-Sep-05	12:32	Methane	4000	125.40	1.0122	13.0468	123.00	109.9532	12.9674	98.9	7.6234		1	147.566	160.772	13.206	21.2		698	
19-Sep-05	13:05	Methane	4000	125.20	1.0122	12.7218	120.00	107.2782	12.6443	96.5	7.6290		2	148.758	161.635	12.877	21.2		698.1	
19-Sep-05	13:39	Methane	4000	125.10	1.0121	12.7685	120.05	107.2815	12.6895	96.4	7.6006		3	148.11	161.033	12.923	21.3		698.2	
19-Sep-05	14:12	Methane	4000	125.30	1.0121	12.6638	120.00	107.3362	12.5854	96.5	7.6663		4	147.677	160.494	12.817	21.3		698.1	
19-Sep-05	14:48	Methane	4000	125.20	1.012	12.6877	120.00	107.3123	12.6080	96.4	7.6482	7.6335	5	147.578	160.418	12.840	21.4	21.3	698.1	93.1
21-Sep-05	10:54	Methane	4000	151.40	1.012	10.8666	100.03	89.1584	10.7983	80.9	7.4927		1	154.937	165.934	10.997	21.4		705	
21-Sep-05	11:24	Methane	4000	151.40	1.012	10.8053	100.05	89.2447	10.7374	81.0	7.5403		2	155.121	166.056	10.935	21.4		704.8	
21-Sep-05	11:54	Methane	4000	151.40	1.012	10.9209	100.05	89.1291	10.8523	80.8	7.4498		3	148.67	159.722	11.052	21.4		704.7	
21-Sep-05	12:26	Methane	4000	151.60	1.012	10.8943	100.05	89.1557	10.8258	80.9	7.4692		4	147.417	158.442	11.025	21.4		704.6	
21-Sep-05	13:04	Methane	4000	151.60	1.0119	13.9658	128.20	114.2342	13.8767	103.5	7.4615	7.4827	5	148.518	162.65	14.132	21.5	21.4	704.4	93.9
27-Sep-05	15:43	Methane	1500	30.10	1.013	11.0760	60.00	48.9240	11.0173	44.7	4.0613		1	154.89	166.11	11.220	20.4		708.1	
27-Sep-05	16:15	Methane	1500	30.10	1.0128	10.7859	61.00	50.2141	10.7266	45.9	4.2784		2	155.306	166.23	10.924	20.6		708.1	
27-Sep-05	16:45	Methane	1500	30.20	1.0128	10.5737	60.00	49.4263	10.5155	45.2	4.2958	4.2118	3	154.228	164.937	10.709	20.6	20.5	708.1	94.4
30-Sep-05	15:14	Methane	1500	70.90	1.0123	13.8072	60.05	46.2428	13.7245	41.2	3.0051		1	154.738	168.715	13.977	21.1		692.2	
30-Sep-05	15:50	Methane	1500	71.10	1.0125	13.0617	61.00	47.9383	12.9861	42.8	3.2923		2	154.386	167.611	13.225	20.9		691.7	
30-Sep-05	16:21	Methane	1500	71.30	1.0125	11.9141	60.00	48.0859	11.8451	42.8	3.6174		3	155.111	167.174	12.063	20.9		691.1	
30-Sep-05	16:45	Methane	1500	71.30	1.0125	8.0089	40.00	31.9911	7.9625	28.5	3.5796	3.5985	4	154.471	162.58	8.109	20.9	21.0	691	92.1
03-Oct-05	15:01	Methane	1500	101.10	1.0117	11.2207	50.00	38.7793	11.1469	35.3	3.1654		1	154.831	166.183	11.352	21.7		707.6	
03-Oct-05	15:33	Methane	1500	101.10	1.0118	11.3698	50.03	38.6552	11.2962	35.2	3.1151		2	154.913	166.417	11.504	21.6		707.7	
03-Oct-05	16:04	Methane	1500	101.00	1.0118	11.8383	50.00	38.1617	11.7616	34.7	2.9536		3	155.042	167.02	11.978	21.6		707.7	
03-Oct-05	16:35	Methane	1500	101.00	1.0118	11.4390	50.00	38.5610	11.3649	35.1	3.0887	3.0807	4	154.41	165.984	11.574	21.6	21.6	707.7	94.3
05-Oct-05	12:42	Methane	1500	126.10	1.0121	12.6914	50.00	37.3086	12.6129	34.1	2.7004		1	154.309	167.154	12.845	21.3		709	
05-Oct-05	13:14	Methane	1500	126.20	1.0123	12.6484	50.00	37.3516	12.5727	34.1	2.7136		2	154.113	166.917	12.804	21.1		708.9	
05-Oct-05	13:48	Methane	1500	125.80	1.0114	13.0166	51.50	38.4834	12.9271	35.0	2.7101		3	154.683	167.848	13.165	22		708.7	
05-Oct-05	14:24	Methane	1500	126.20	1.0114	12.7032	50.03	37.3218	12.6159	34.0	2.6920	2.7040	4	155.643	168.491	12.848	22	21.6	708.4	94.5
07-Oct-05	12:23	Methane	1500	152.00	1.0112	12.4842	50.00	37.5158	12.3959	33.3	2.6889		1	153.792	166.416	12.624	22.2		692.1	
07-Oct-05	12:56	Methane	1500	151.90	1.0112	12.4268	50.03	37.5982	12.3390	33.4	2.7072		2	154.94	167.506	12.566	22.2		692.1	
07-Oct-05	13:29	Methane	1500	152.20	1.0114	12.5153	50.03	37.5097	12.4293	33.3	2.6830		3	154.988	167.646	12.658	22		692.1	
07-Oct-05	14:06	Methane	1500	151.90	1.0121	12.9740	50.03	37.0510	12.8938	33.0	2.5623	2.5623	4	154.684	167.815	13.131	21.3	21.9	692.5	92.3
27-Oct-05	11:27	Methane	500	30.20	1.0123	18.4471	55.25	36.8029	18.3366	33.3	1.8154		1	154.153	172.827	18.674	21.1		702	
27-Oct-05	12:29	Methane	500	30.20	1.0123	21.0056	67.50	46.4944	20.8798	42.0	2.0127		2	154.679	175.943	21.264	21.1		701.5	
27-Oct-05	13:23	Methane	500	30.50	1.0123	20.4159	65.00	44.5841	20.2936	40.2	1.9790		3	153.938	174.605	20.667	21.1		699.1	
27-Oct-05	14:25	Methane	500	30.40	1.0121	22.3199	70.00	47.6801	22.1819	42.9	1.9352	1.9356	4	148.045	170.635	22.590	21.3	21.2	699.2	93.4
28-Oct-05	14:37	Methane	500	70.20	1.0127	20.5757	50.00	29.4243	20.4605	26.4	1.2926		1	148.138	168.975	20.837	20.7		696.6	
28-Oct-05	15:36	Methane	500	70.20	1.0128	21.6726	50.00	28.3274	21.5534	25.5	1.1817		2	147.938	169.888	21.950	20.6		696.6	
28-Oct-05	16:31	Methane	500	70.30	1.0128	21.4386	50.00	28.5614	21.3207	25.7	1.2039	1.2260	3	148.293	170.006	21.713	20.6	20.6	696.3	92.8
31-Oct-05	13:39	Methane	500	101.10	1.0127	23.0137	55.00	31.9863	22.8849	28.6	1.2501		1	148.343	171.649	23.306	20.7		693.2	
31-Oct-05	14:41	Methane	500	101.00	1.0127	23.7168	55.00	31.2832	23.5841	28.0	1.1872		2	147.871	171.889	24.018	20.7		693.7	
31-Oct-05	15:45	Methane	500	101.20	1.0126	24.4963	55.00	30.5037	24.3568	27.3	1.1217	1.1863	3	147.548	172.353	24.805	20.8	20.7	694.4	92.5
02-Nov-05	11:50	Methane	500	125.30	1.0119	25.3533	60.00	34.6467	25.1915	31.0	1.2317		1	148.022	173.677	25.655	21.5		696	
02-Nov-05	13:13	Methane	500	125.00	1.0121	32.1006	70.00	37.8994	31.9020	33.9	1.0639		2	148.149	180.638	32.489	21.3		695.5	
02-Nov-05	14:26	Methane	500	125.00	1.0121	27.7463	60.00	32.2537	27.5746	28.9	1.0471		3	149.086	177.168	28.082	21.3		695.2	
02-Nov-05	15:40	Methane	500	125.10	1.0121	27.9083	60.00	32.0917	27.7357	28.7	1.0353	1.0945	4	149.001	177.247	28.246	21.3	21.4	694.9	92.7
04-Nov-05	11:49	Methane	500	150.60	1.012	28.2490	60.0000	31.7510	28.0715	28.2	1.0036		1	147.754	176.342	28.588	21.4		689.3	
04-Nov-05	13:05	Methane	500	150.60	1.0121	29.6789	60.0000	30.3211	29.4953	26.9	0.9128		2	148.357	178.395	30.038	21.3		689.6	
04-Nov-05	14:24	Methane	500	150.40	1.0121	29.9259	60.0000	30.0741	29.7408	26.7	0.8988		3	147.542	177.83	30.288	21.3		690.3	
04-Nov-05	15:42	Methane	500	150.80	1.0121	30.2678	60.0000	29.7322	30.0805	26.4	0.8787	0.9235	4	148.89	179.524	30.634	21.3	21.325	690.4	92.0
14-Nov-05	15:07	Methane	4000	201.40	1.0117	10.5733	90.0000	79.4267	10.5037	72.8	6.9280		1	147.608	158.305	10.697	21.7		712.5	
14-Nov-05	15:38	Methane	4000	201.50	1.0117	10.4725	90.0000	79.5275	10.4036	72.9	7.0065		2	148.092	158.687	10.595	21.7		712.8	
14-Nov-05	16:06	Methane	4000	201.50	1.0118	10.4141	90.0000	79.5859	10.3466	73.0	7.0566		3	153.727	164.264	10.537	21.6		713.2	
14-Nov-05	16:36	Methane	4000	201.50	1.0118	10.6207	90.0000	79.3793	10.5518	72.8	6.9033	6.9736	4	148.742	159.488	10.746	21.6	21.65	713.4	95.0
16-Nov-05	11:14	Methane	4000	220.60	1.0106	11.4358	100.0500	88.6142	11.3482	79.7	7.0225		1	153.422	164.979	11.557	22.8		702	
16-Nov-05	11:50	Methane	4000	220.70	1.0106	12.0898	100.0000	87.9102	11.9973	79.0	6.5880		2	154.655	166.873	12.218	22.8		701.8	
16-Nov-05	12:27	Methane	4000	220.70	1.0106	12.3669	100.0500	87.6831	12.2722	78.8	6.4228		3	153.478	165.976	12.498	22.8		701.7	
16-Nov-05	13:05	Methane	4000	220.50	1.0106	14.5122	120.0000	105.4878	14.4010	94.8	6.5848		4	153.672	168.338	14.666	22.8		701.7	
16-Nov-05	13:37	Methane	4000	220.50	1.0107	12.0629	100.0500	87.9871	11.9717	79.1	6.6100	6.6456	5	154.011	166.203	12.192	22.7	22.78	701.8	93.5
17-Nov-05	15:27	Methane	1500	199.70	1.0108	12.1448	40.0000	27.8552	12.0542	25.1	2.0790		1	153.115	165.391	12.276	22.6		701.8	
17-Nov-05	16:03	Methane	1500	199.70	1.0108	14.2076	40.0000	25.7924	14.1015	23.2	1.6453		2	154.512	168.873	14.361	22.6		701.7	
17-Nov-05	16:54	Methane	1500	200.20	1.0108	21.5255	60.0500	38.5245	21.3649	34.6	1.6211	2.0790	3	154.405	176.163	21.758	22.6	22.6	701.3	93.5