

# Evaluation of Hydrocarbon PVT Data for D2 Libyan Oil well

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## Abstract

High quality, precise PVT data can reduce uncertainty in reservoir fluid properties, provide a sound foundation for reservoir engineering studies, and improve investment efficiency. Poor quality PVT data can result in lost time due to rework and additional studies, insufficient or overly aggressive development plans, and inefficient investment. In this study complete PVT Lab experiments for D2 Libyan well which related to Libyan crude oil were evaluated and checked it by Buckley, FG, and material balance plots, then building a model for the PVT properties by PVTi software. After regression we have got an accurate and reliable model to use in reservoir simulator. The best EOS was PR3 (Peng Robinson) with the composition up to C15+.

**Keywords:** Black Oil, Bubble Point Pressure, PVT Experiments, PVT Properties

## 1. Introduction

Reservoir fluid properties play a key role in the design and optimization of injection/production strategies and surface facilities for efficient reservoir management To understand and predict the behavior of reservoirs oil and gas that function of pressure, determining of the physical properties of reservoir fluids must be gained to know how the hydrocarbons are going to flow from the well in its current state and allows the operator and its geologists to select the most cost effective extraction methods. [1]

The fluid properties are usually determined by laboratory experiments performed on samples of actual reservoir fluids, to gain the knowledge of producing best quality products in a most economical way under the changes of pressure and temperature of the reservoir. The main objective of a successful sampling campaign is to obtain representative samples with adequate volume and determine PVT properties, The concept of a representative sample is that sample correctly reflects the composition of reservoir fluid at the depth being tested, The most representative samples are usually obtained when the reservoir fluid is single phase at the point of sampling, be it the bottom hole or at

the surface, The selection of representative samples for the PVT analyses is mainly based on the well test data and separator conditions.[2]

These are several laboratory tests that can be made on a reservoir fluid sample the data collected from the PVT used to provide physical property data for well flow calculations,

Provide data for reservoir calculations and for surface facility design. In the absence of experimental analysis, the empirically PVT correlations are used but under conditions when we select the best correlation that be reliable to use with our reservoir to estimate reservoir fluid properties. [3]

PVT studies are usually based on one or more samples taken during a production test. Bottom-Hole samples can be obtained by wireline using a high pressure container, either during the production test or during a shut-in period. Separator samples may also be taken during a production test. All reservoir calculations require PVT data. Amount of the data required depends on the choice the separation process, surface separation optimization, Reserves estimate, reservoir simulation and material balance calculations, pressure transient testing, flow-line, wellbore hydraulics calculations, flow assurance, anticipated potential operating or environment problems and production allocation. To accurately determine the exact nature of a reservoir fluid is a challenge that calls for sampling and laboratory study with some factors affecting the reservoir fluid data such as leakage during Transport, calibration, vertical and lateral variation in fluid properties, sample size, mixture of fluid, recombination ratio, and stability of flow rate, temperature and pressure. [4]Figure (1) shows a diagram of the basic workflow in this study:

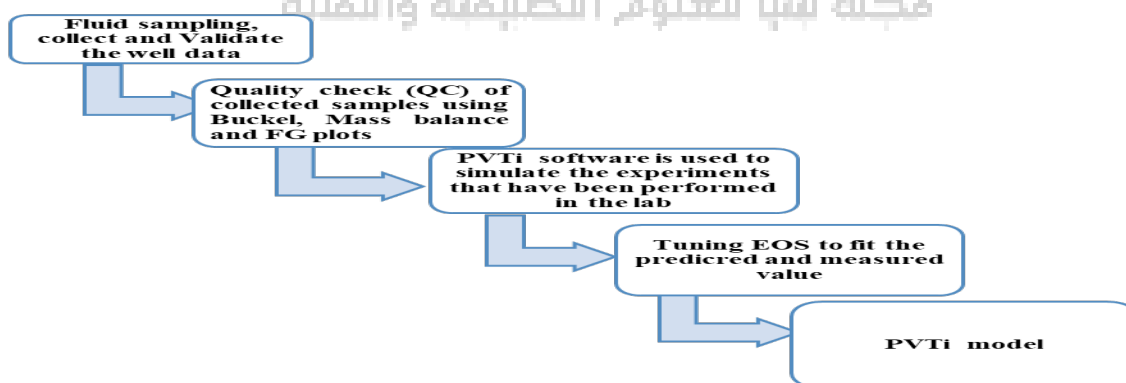


Figure1. PVT workflow

## 2. QC PVT Laboratory Data

D2 Libyan well were validated through their opening pressures and saturation pressure for quality control of samples, check for separator liquid and air contamination for separator gas. Also,

composition analysis for the reservoir fluids composition up to C15+ and physical recombination for field gas-oil ratio (GOR) correction to ensure that the fluid sample used in the PVT analyses is representative. Quality control (QC) of collected samples and data must be performed before, during and after sampling. Improper QC or any error in recorded data can be misleading in the next steps of fluid modeling, fluid properties measurement, and construction of thermodynamic model for representative reservoir fluid. Sometimes the measured value can be incorrect but a consistency check was performed before starting the tuning process which is almost impossible to match everything perfectly. It is worthy to not that when performing the PVT analysis, there are two major categories of the errors that happen, error sources due to the nature of reservoir fluid and due to human operations (error during sampling or transfer, contaminated sample containers and leaks during shipment). [5] [6] [7]

Validity of PVT samples can also be confirmed by generating Buckley and Mass Balance and FG plots, while the mass balance plot is a quantitative method, the Buckley plot is qualitative methods of assessing PVT data. A significant deviation from linearity its indication of errors in sampling and sample recombination. Validity of PVT samples can also be confirmed by generating Buckley and Mass Balance and FG plots, while the mass balance plot is a quantitative method, the Buckley plot is qualitative methods of assessing PVT data. A significant deviation from linearity its indication of errors in sampling and sample recombination. [8] [9]

#### a) Buckley Plot (or Campell Diagram)

The Buckley plot is expressed by the semi log plot of K-value versus the square of the critical temperature. Usually, the heavier component deviates downwards away from the straight line.

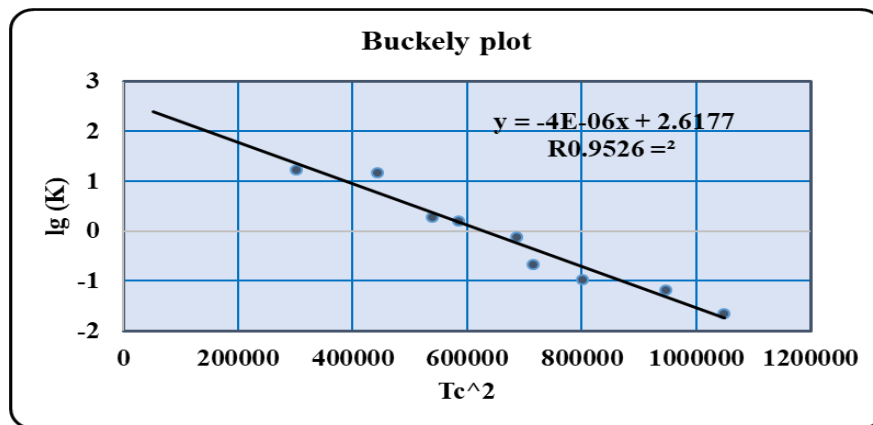


Figure2. D2 Libyan well Buckley plot.

The deviation from linearity due to non-equilibrium separation, thus indicating error in analysis or numerical data reporting.

### b) Mass Balance Diagram

This test is used to assess the feed composition and the separator vapour and liquid composition for consistency. The basis for the test is the mass balance criteria of the component. One mole of fluid of composition  $z$  is considered at a certain temperature and pressure ( $T, P$ ); it can be split into liquid and vapour of  $L$  moles and  $V$  moles of compositions respectively, Where  $F, L$  &  $V$  are the molar flow rates of feed, flashed liquid and flashed vapour respectively.

Equation 1 can be re-arranged as:

$$Y_i/Z_i = (-L/V) X_i/Z_i + F/V$$

This is a straight-line equation obtained by plotting  $Y_i/Z_i$  against  $X_i/Z_i$  to generate an intercept,  $F/V$  and a negative slope ( $L/V$ ); this negative slope is equivalent to the measured GOR. As shown in Figure.

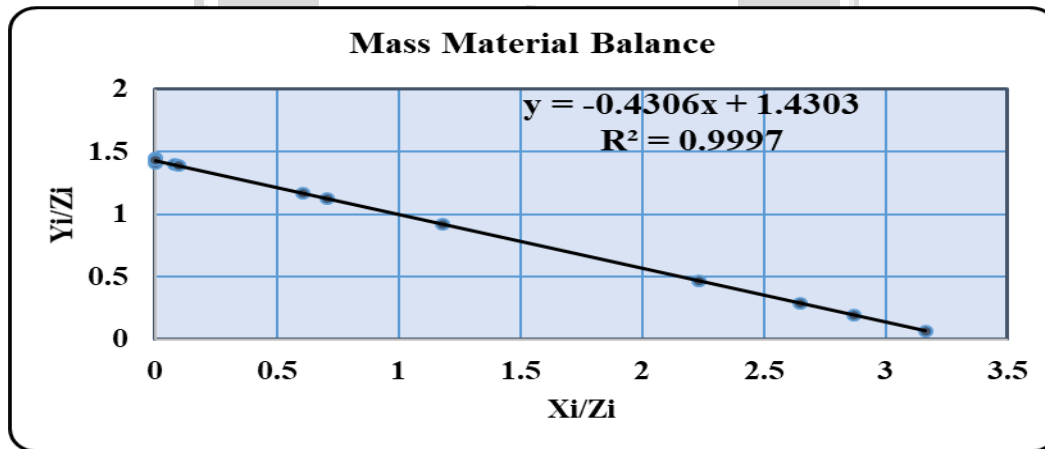


Figure 3. D2 Libyan well material balance plot.

No deviation in the material balance diagram (Figure 3); it indicates no arithmetic errors in the mathematical data recombination.

### c) FG Diagram

The FG plot is expressed by plot of  $(Z_i - X_i) / (Y_i - X_i)$ , which give a horizontal line, when the horizontal line fit with all the point that's give indication there is no deviation.

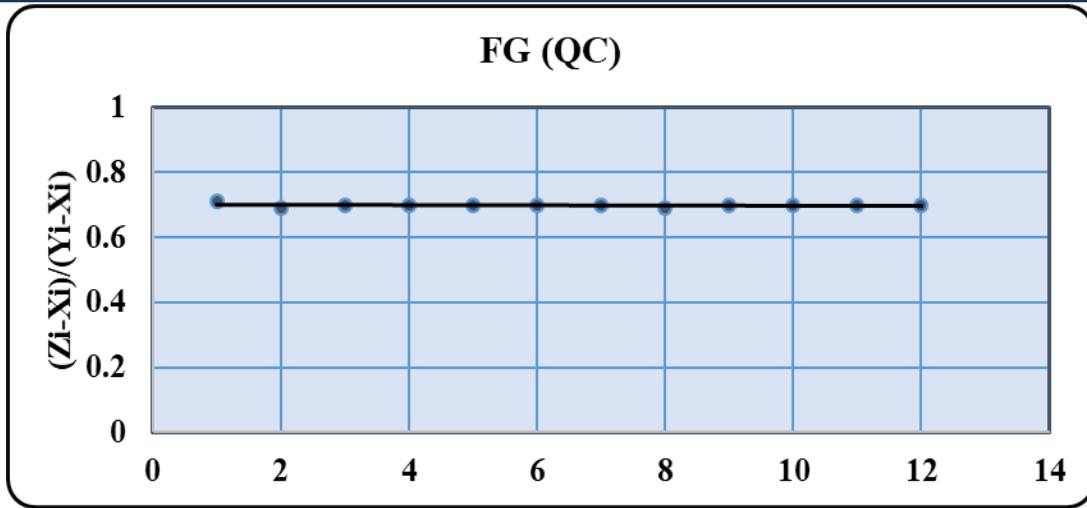


Figure 4. D2 Libyan well FG plot.

### 3. Well PVT data Availability:

The PVT analysis for *D2 oil Libyan well* has been carried out. This is in line with fitting an Equation of State (EOS) to the laboratory PVT experimental data and then using the EOS to produce ECLIPSE black oil PVT tables and EOS model for use in dynamic modeling of the reservoir dynamic simulation. Laboratory PVT Data reports were made available for the analysis. The reservoir fluid types and sampling points are depicted in the Table 1.

Table1. D2 oil Libyan well sampling date and point.

Reservoir Level	Fluid Type	Sampling Date	Sampling Point
D2 oil Libyan well	Volatile Oil	Feb 12, 2018	Bottom Hole

The experimental observations used in the analysis are:

1. Constant composition expansion (black oil and compositional)
  - (a) Saturation pressure (Bubble point) at reservoir temperature
  - (b) Relative volume

### 3. Differential Liberation/Vaporization (black oil only)

- (a) Vapour Z factor
- (b) Liquid density
- (c) Gas-Oil ratio
- (d) Relative volume (Formation volume factor)
- (e) Gas gravity
- (f) Liquid viscosity
- (g) Vapor viscosity

### 4. Data Analysis:

In **D2 oil well**, a total of Fifteen (15) components were defined in the characterization; eight (8) pure light hydrocarbons (from C1 to C6), two non-hydrocarbons (N2 and CO2) and heavy components lumped as C15+ fraction. Table 2 shows the fluid composition of the bottom Hole fluid sample.

Table 2. D2 well fluids compositions.

component	stock tank oil		Gas Mol%	Reservoir Fluid	
	Wt%	Mol%		Wt%	Mol%
N2			0.31	0.09	0.22
CO2			0.29	0.13	0.2
C1			46.93	7.56	32.79
C2	0.2	1.03	17.58	5.44	12.58
C3	0.31	1.09	15.96	7.29	11.49
iC4	0.92	2.45	4.71	3.37	4.03
nC4	1.66	4.43	7.02	5.22	6.24
Ic5	1.62	3.48	2.7	3.05	2.94
nC5	4.07	8.75	1.84	4.07	3.92
C6	8.03	14.75	1.57	6.76	5.45
C7	8.59	13.29	0.89	6.67	4.63
C8	6.57	8.92	0.2	4.64	2.82
C9	4.92	5.95		3.31	1.79
C10	4.92	5.36		3.31	1.62
C11	4.04	4.01		2.71	1.21
C12	2.85	2.59		1.92	0.78
C13	3.3	2.78		2.22	0.84
C14	2.62	2.05		1.76	0.62
C15+	45.38	19.37		30.48	5.83

## 5. Results

The PVT analysis for **D2 well** was carried out. This is in line with fitting an EOS to the laboratory PVT experimental data and then using the Equation of State to produce ECLIPSE black oil PVT tables and EOS model for use in dynamic modeling of the **D2 well** dynamic simulation.

### EOS Modeling

The fluid model was defined with the 3-Parameter Peng-Robinson (PR3). This 3-Parameter Peng Robinson (EOS) and Lohrenz-Bray-Clark (LBC) viscosity correlation were used to fit the simulated results to the experimental data. To improve the phase equilibrium by EOS, a number of regressions were carried out to choose EOS parameters to perform tuning on, the parameters that are used in this study tuning are, critical pressure ( $P_c$ ), critical temperature ( $T_c$ ), Omega A and volume shift (V. shift) of the changes within the C15+.

- Saturation pressure ( $P_b$ ) – Omega A
- Gas Oil Ratio (GOR) – Volume Shift
- Oil Formation Volume Factor –  $P_{cirt}$  and  $T_{crit}$
- Viscosity – Critical Z

A calculated bubble point pressure of 1866.1934psia (Lab experimentally determined = 1866 psia) is obtained at the end of tuning. The results and plots from the PVT analysis on the **D2 well** are depicted in Figure 6 to 20 and table from 3 to 7.

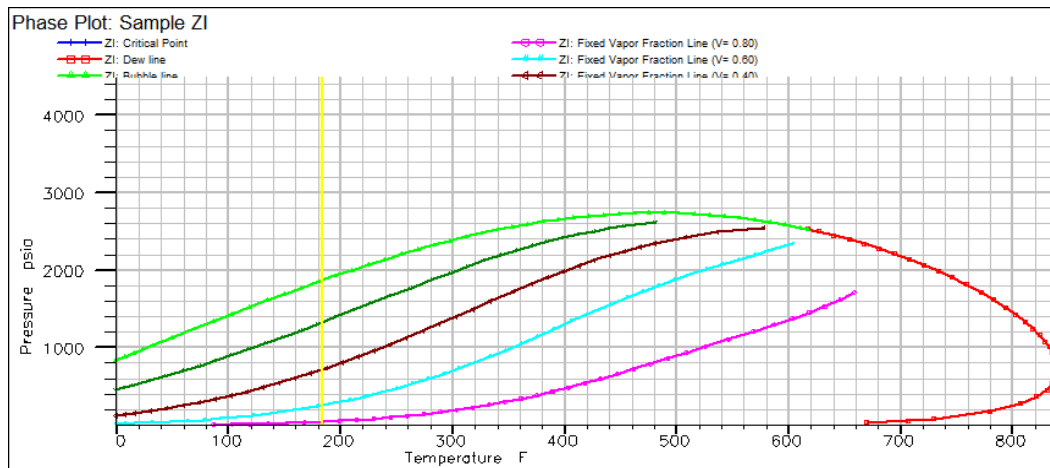


Figure 6. Phase behavior Plot

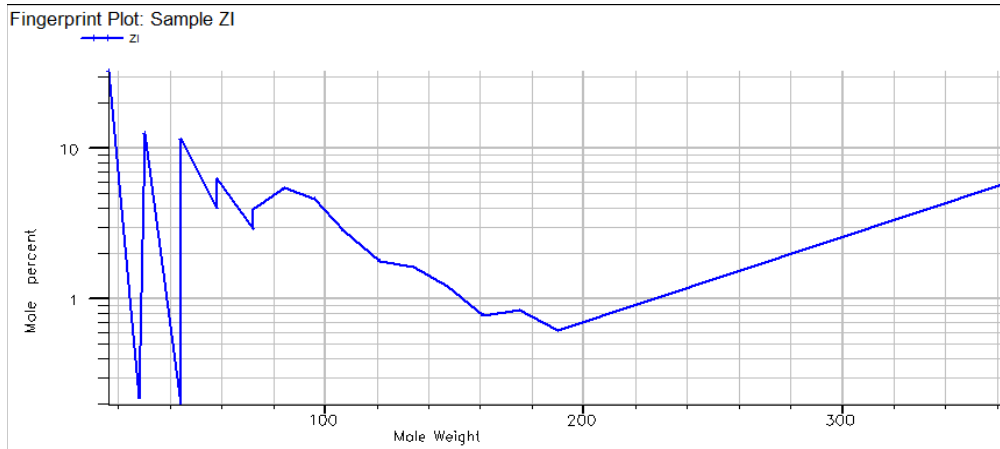


Figure 7. Fingerprint plot.

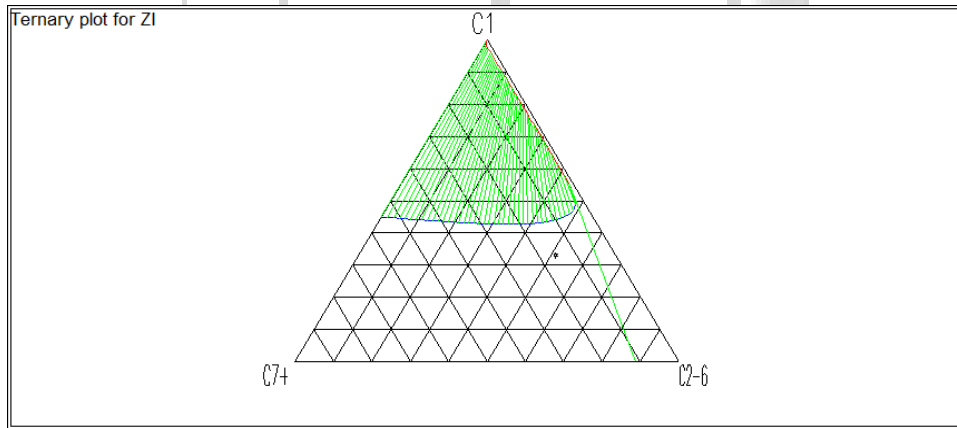


Figure 8. D2 Libyan well Final Phase plot.

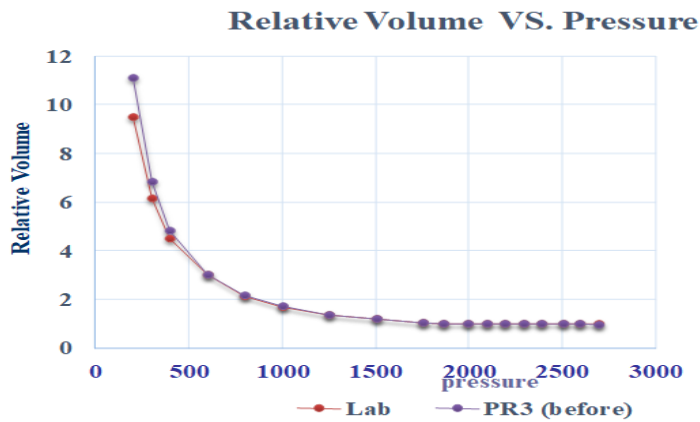


Figure 9. CCE Relative Volume (before regression).



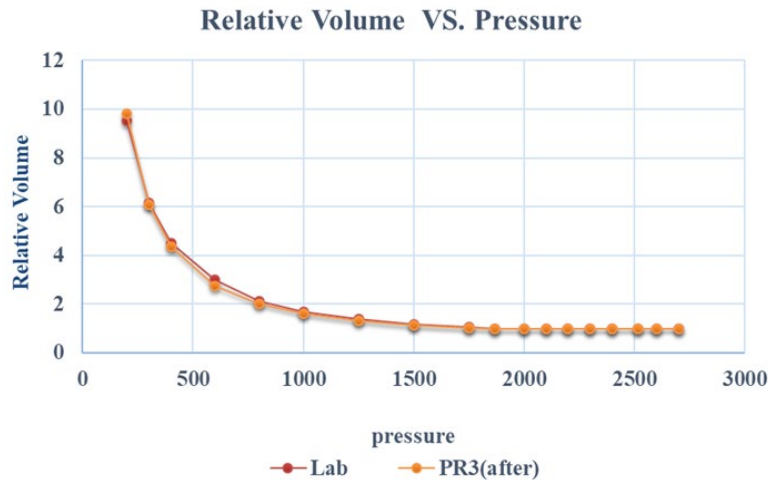


Figure 10. Relative Volume (after regression).

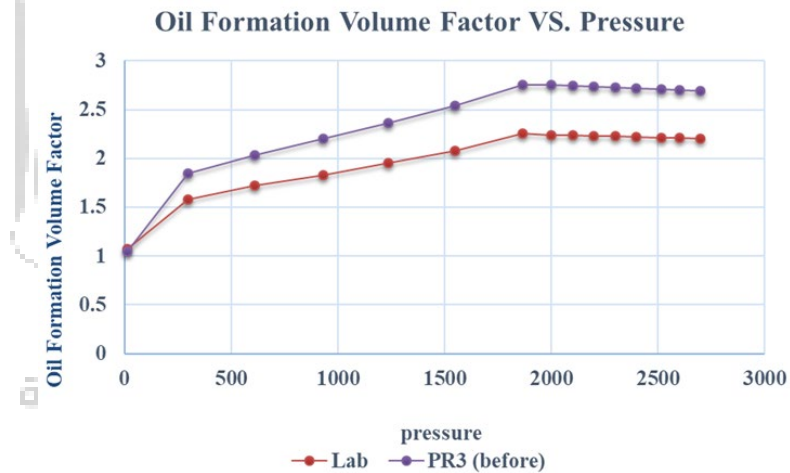


Figure 11. Oil Formation Volume Factor (before regression).

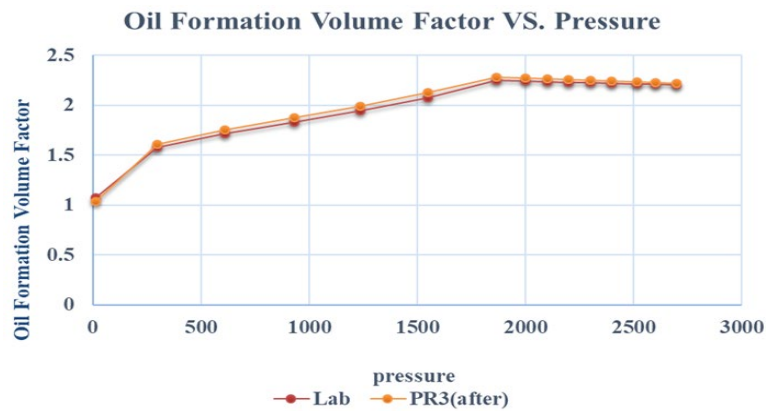
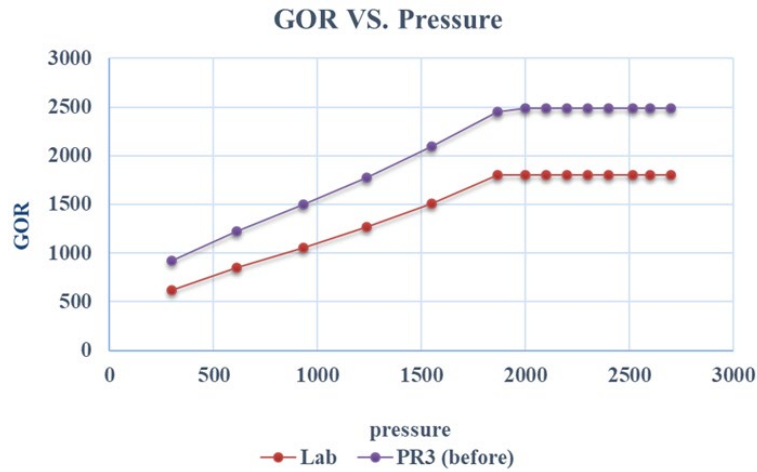
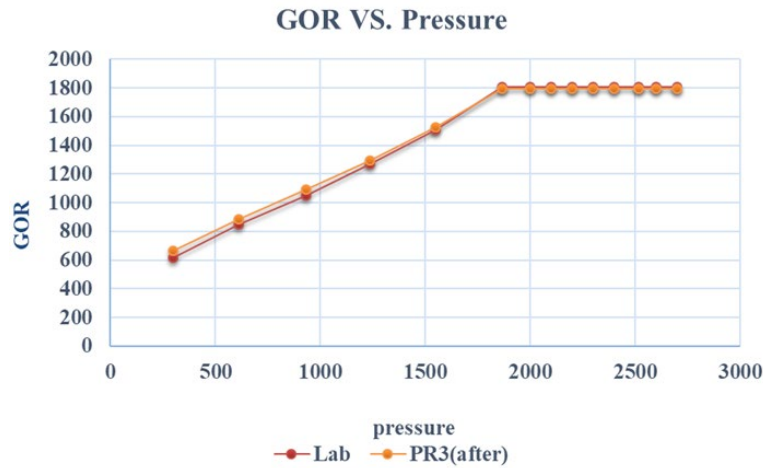


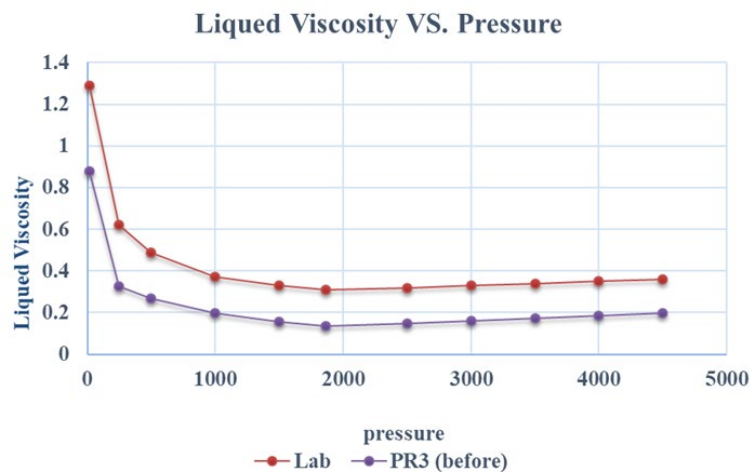
Figure 12. Oil Formation Volume Factor (after regression)



**Figure 13. Gas Oil Ratio (before regression)**



**Figure 14. Gas Oil Ratio (after regression)**



**Figure 15. Liqued Viscosity before regression.**

Liquid Viscosity VS. Pressure

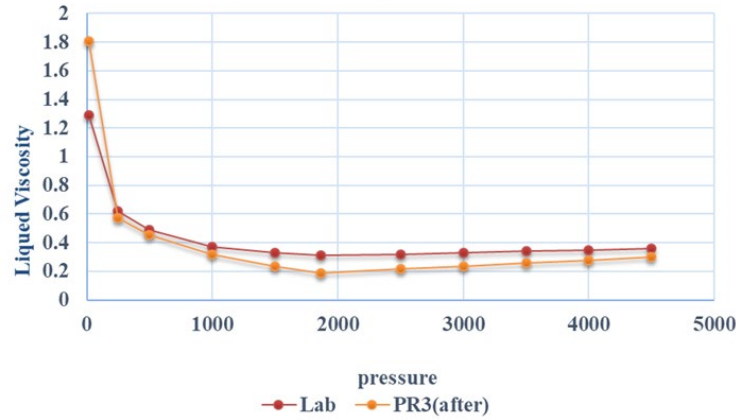


Figure 16. Liquid Viscosity (after regression)

Gas Gravity VS. Pressure

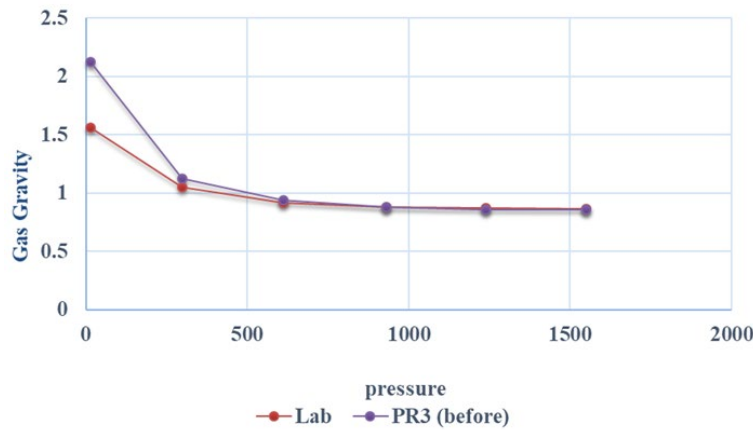


Figure 17. Gas Gravity before regression

Gas Gravity VS. Pressure

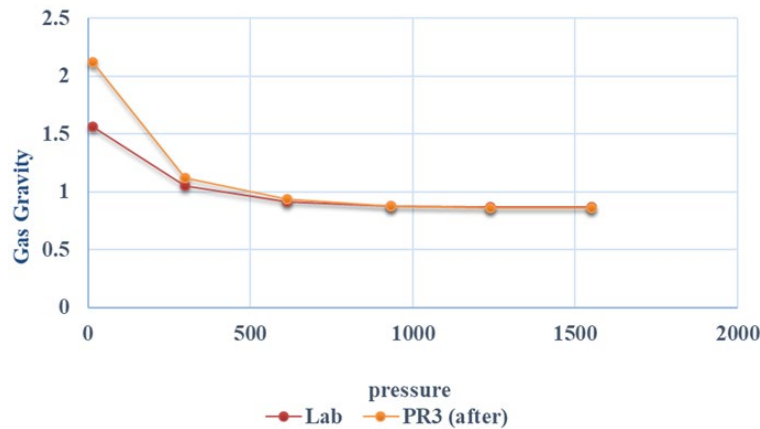


Figure 18. Gas Gravity after regression

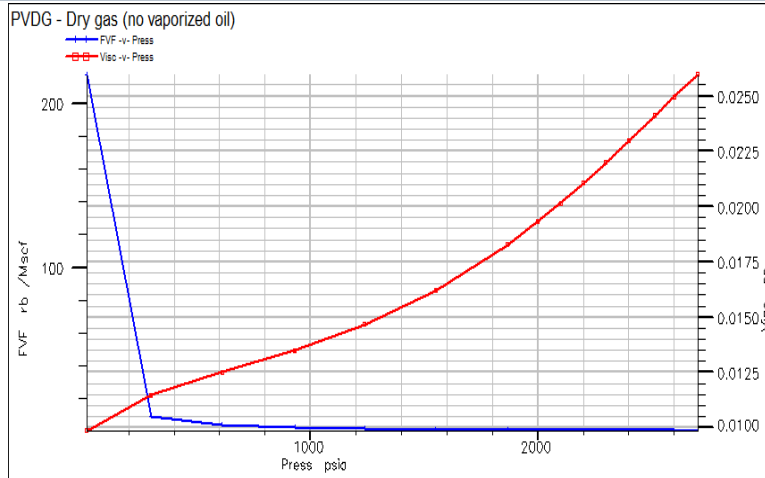


Figure 19. Dry Ga

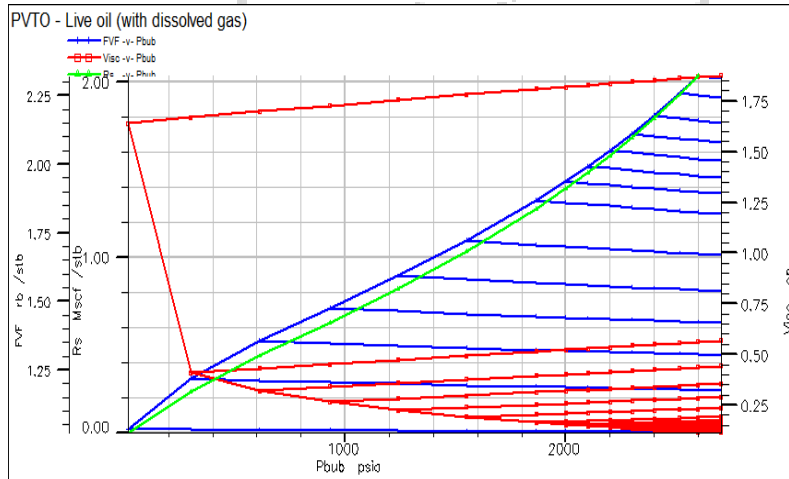


Figure 20. Live oil with dissolved gas.

Table 3. Relative Volume

Relative Volume					
Pressure(Psia)	Lab	Before regression		(After Regression)	
		PR3 (before)	Erorr %	PR3(after)	Erorr %
2700	0.98	0.9714	0.87755102	0.9736	0.653061224
2600	0.982	0.9745	0.76374745	0.9764	0.570264766
2515	0.985	0.9772	0.79187817	0.9788	0.629441624
2400	0.987	0.9811	0.59777102	0.9822	0.486322188
2300	0.989	0.9845	0.45500506	0.9853	0.374115268
2200	0.992	0.9881	0.39314516	0.9885	0.352822581
2100	0.994	0.9918	0.22132797	0.9918	0.221327968
2000	0.996	0.9956	0.04016064	0.9952	0.080321285
1866	1	1.0079	0.79	1.0001	0.01
1750	1.044	1.0499	0.5651341	1.0369	0.680076628
1500	1.173	1.175	0.17050298	1.1464	2.267689685
1250	1.371	1.3729	0.13858497	1.3195	3.756382203
1000	1.696	1.7044	0.49528302	1.6095	5.100235849
800	2.131	2.1601	1.36555608	2.0082	5.762552792
600	2.997	2.9913	0.19019019	2.7353	8.732065399
400	4.504	4.8315	7.27131439	4.3454	3.521314387
300	6.155	6.8263	10.90658	6.0909	1.041429732
200	9.505	11.0969	16.7480274	9.8281	3.399263546

**Table 4. Oil Formation Volume Factor**

Oil formation Volume factor					
		Before regression		(After Regression)	
Pressure(Psia)	Lab	PR3 (before)	Erorr %	PR3(after)	Erorr %
2700	2.204	2.6912	22.10526316	2.2234	0.880217786
2600	2.209	2.6999	22.22272522	2.2298	0.941602535
2515	2.214	2.7075	22.2899729	2.2353	0.962059621
2400	2.22	2.7181	22.43693694	2.2431	1.040540541
2300	2.225	2.7276	22.58876404	2.2501	1.128089888
2200	2.23	2.7375	22.75784753	2.2574	1.228699552
2100	2.236	2.7478	22.88908766	2.2649	1.292486583
2000	2.24	2.7584	23.14285714	2.2728	1.464285714
1866	2.254	2.7527	22.12511091	2.2836	1.313220941
1550	2.074	2.5443	22.67598843	2.1282	2.613307618
1238	1.949	2.3639	21.28783992	1.9944	2.329399692
932	1.828	2.2025	20.4868709	1.8752	2.582056893
612	1.72	2.0376	18.46511628	1.754	1.976744186
299	1.582	1.8434	16.52338812	1.612	1.896333755
14.7	1.077	1.0462	2.859795729	1.0338	4.011142061

**Table 5. Gas Oil Ratio**

GOR					
		Before regression		(After Regression)	
Pressure(Psia)	Lab	PR3 (before)	Erorr %	PR3(after)	Erorr %
2700	1806	2484.3	37.55813953	1792.5	0.747508306
2600	1806	2484.3	37.55813953	1792.5	0.747508306
2515	1806	2484.3	37.55813953	1792.5	0.747508306
2400	1806	2484.3	37.55813953	1792.5	0.747508306
2300	1806	2484.3	37.55813953	1792.5	0.747508306
2200	1806	2484.3	37.55813953	1792.5	0.747508306
2100	1806	2484.3	37.55813953	1792.5	0.747508306
2000	1806	2484.3	37.55813953	1792.5	0.747508306
1866	1806	2453.7	35.86378738	1792.4	0.753045404
1550	1507	2092.7	38.86529529	1524.9	1.187790312
1238	1271	1779.9	40.0393391	1294.3	1.833202203
932	1052	1502.2	42.79467681	1090.4	3.650190114
612	849	1225	44.28739694	887.6	4.546525324
299	616	920.6	49.44805195	665.9	8.100649351

**Table 6. Liquid Viscosity**

Liqued Viscosity					
		Before regression		(After Regression)	
Pressure(Psia)	Lab	PR3 (before)	Erorr %	PR3(after)	Erorr %
4500	0.36	0.1973	45.19444444	0.2984	17.11111111
4000	0.35	0.1848	47.2	0.2778	20.62857143
3500	0.34	0.1722	49.35294118	0.2572	24.35294118
3000	0.33	0.1597	51.60606061	0.2365	28.33333333
2500	0.32	0.1472	54	0.2158	32.5625
1866	0.31	0.1333	57	0.1895	38.87096774
1500	0.33	0.1563	52.63636364	0.2326	29.51515152
1000	0.37	0.1992	46.16216216	0.3152	14.81081081
500	0.49	0.2682	45.26530612	0.4522	7.714285714
250	0.62	0.3278	47.12903226	0.5734	7.516129032
14.7	1.29	0.8774	31.98449612	1.8088	40.21705426

Table 7. Gas Gravity

Gas Gravity					
		Before regression		(After Regression)	
Pressure(Psia)	Lab	PR3 (before)	Erorr %	PR3 (after)	Erorr %
1550	0.866	0.8598	0.715935335	0.8583	0.889145497
1238	0.869	0.8603	1.001150748	0.8592	1.127733026
932	0.878	0.8804	0.273348519	0.8794	0.159453303
612	0.914	0.9413	2.986870897	0.9403	2.877461707
299	1.052	1.1224	6.692015209	1.1211	6.568441065
14.7	1.562	2.1238	35.96670935	2.1232	35.92829706

In this study we get a good match between observed data and PR3 EOS model of component up to C15+ by tuning the uncertainty parameter ( $\Omega_a$ ,  $\Omega_b$ , critical pressure ( $P_c$ ), critical temperature ( $T_c$ ), acentric factor ( $\omega$ ) and binary interaction coefficients ( $\delta$ )), in case we didn't have satisfactory results by tuning the uncertainty we can use other techniques to get a good matching as:

### Grouping

The cost and resources required to simulate PVT phase behavior increases rapidly with an increasing number of components. The main reason for grouping components is to speed-up a compositional simulator, such as **ECLIPSE COMPOSITIONAL**, its used for large number of components, the computing time needed to solve the flash equations may be as great as the time needed to solve the flow equations.

The main basis for grouping is to group components with similar molecular weights. We would for instance group  $C_7$  with  $C_8$  rather than with  $C_2$ , as we would expect their properties of  $C_7$  and  $C_8$  to be similar, while the properties of  $C_7$  and  $C_2$  would be very different. Obvious candidates are to group  $iC_4$  with  $nC_4$ , and to group  $iC_5$  with  $nC_5$  as shown in table 8.

An exception to this rule is that  $N_2$  is usually added to  $C_1$  and  $CO_2$  is usually added to  $C_2$ .

Table 8. Reservoir Fluid Composition in Mole Fractions (after Grouping process)

component	Reservoir Fluid Mol%
X1+	33.007
X2+	12.779
C3	11.489
C4+	10.279
C5+	6.8593
C6	5.4495
C7+	7.4493
C9	1.7898
C10	1.6198
c11	1.2099
C12	0.77992
C13	0.83992
C14	0.61994
C15+	5.8294
<b>SUM</b>	<b>100</b>

## 6. Conclusion

*Based on the analysis of D2 Libyan well PVT Reports, the following conclusions were drawn:*

- The quality of the data is importance for a reasonable tuning effort.
- The fluid sample of D2 Libyan well after the Q.C with Buckley, FG and material balance plots, the composition give a good result, that mean it's a reprehensive sample of a reservoir.
- In the validated of a sample in the Buckley plot, the deviation from linearity indicate of non-equilibrium separation which indicates error in analysis or numerical data reporting due to the heavier component that deviates downwards away from the straight line It should be noted that as components become less paraffinic in nature their deviation from linearity increases.
- Before regression we have got unsatisfactory results of observed data, which indicate the E.O.S needs tuning. After regression we have got a good match with lab results.

## 7. Recommendations

- In this study we use just one sample which not enough and didn't represent the reservoir, so that this work should be continue with more samples in the same area.
- When use any simulator to get PVT properties, we have to choose the best scenario that give the best result.
- We recommend not using Tc, Pc and omega B in regression because we have got unsatisfactory results.
- The bubble point pressure is very sensitive to the omega A.

- After we have a good match between the simulated and experimental data. The EOS model is then exported into any reservoir simulator such as Eclipse software.

## 8. Nomenclature

API =American Petroleum Institute.

A, B =Parameter in various equations of state, dimensionless.

BHP = Bottom hole pressure, psia.

BIP = binary interaction coefficient.

Bo =Oil FVF, bbl/STB.

EOS=Equation of state.

FVF =Formation Volume Factor.

GOR =Gas-Oil Ratio, cf / STB.

MW = Molecular weight, lb./lb. Mole.

P = Pressure, Psia.

Pb = bubble point Pressure, psia.

PR =Peng-Robinson.

PVT=Pressure, Volume, Temperature.

Rs = Solution gas oil ratio.

SRK = Soave-Redlich-Kwong.

$\omega$ =Acentric factor, dimensionless.

## 9. References

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