

Research Article

PERFORMANCE EVALUATION OF EXPERIMENTAL AND SIMULATED PVT TESTS OF OIL SAMPLES FOR LOWER GURU FORMATION

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ABSTRACT

In the petroleum industry pressure-volume-temperature (PVT) analysis and behavior of oil & gas condensate reservoirs depend on pressure, volume, fluid composition, temperature, and behavior in the phase envelope. The best way to calculate the performance of a reservoir, one of the key parameters for performance of any reservoir is the PVT properties, which are either important for the material balance, reserves estimation, reservoir performance prediction, enhanced oil recovery scheme, production system design and optimization. Through the laboratory experiment of reservoir fluids, the PVT properties can be calculated, but this laboratory experimental work can be expensive and it is not available easily all the time during the evaluation of reservoir fluids. So we have an alternate way to calculate various reservoir fluid properties through the use of available existing empirical correlations. This study adopts the most frequently used pressure-volume-temperature (PVT) empirical correlations used in industry. These correlations were evaluated based on performance for oil samples of the Lower Guru Formation located in Pakistan. A total of 09 PVT reports were used in this work to study the performance of the popular PVT correlations to estimate some of the PVT properties for Pakistani based light oil such as bubble point pressure (Pb), gas solubility (Rs), and formation volume factor (Bo), at and below the bubble point pressure. The samples were originally collected from three different wells of a single field. The field is located in the upper guru formation. And data were obtained from laboratory analysis (PVT routine tests) Constant Composition Expansion and Differential Liberation tests respectively. The experimental results were then used in available empirical correlations. Finally, the evaluation is performed based on statistical error analysis (SEA), suitable correlations for field applications are recommended for estimating gas solubility, bubble point pressure, and oil formation volume factor (FVF).

Keywords: Physical fluid properties, PVTcell tests, Empirical correlations; statistics.

INTRODUCTION

The fluids found in the hydrocarbon reservoir are in varying quantities, mainly (water, oil and gas). Some may be saturated with only water and oil, water and gas, or water, oil and gas, collecting a representative sample of these fluids and investigating their phase behavior in the laboratory are very important for characterizing fluids or reservoirs, economic evaluations (Igwe and Ujile, 2015). It is necessary to obtain the accurate results of the reservoir rock structure, hydrocarbon fluid properties and their interaction inside the reservoir for the purpose to analyze characteristics of the reservoir fluid. PVT data is very important for the reservoir engineers to test the reservoir (Ashrafi *et al.*, 2011). Study of pressure-volume-temperature (PVT) is the analysis of the liquid and/or vapor behavior in petroleum reservoirs which depends on pressure, volume, fluid composition temperature and behavior in the phase envelope. The best way to calculate the output of a reservoir, one of the key input data is the PVT properties, which are important in the material balance, reserves estimation, reservoir performance prediction, enhanced oil recovery scheme, production system design and optimization. It is therefore assumed that the calculation of the reserves and the design of the best depletion strategy are only feasible where reasonable and realistic values of the reservoir fluid properties are available. Consequently, obtaining reliable measurements of PVT data can be difficult or economically impractical at the earlier stages of a well. In a case where the fluid samples are available, they may be subjected to

PVT analysis in order to determine their properties, but samples are Also suspected and PVT analysis typically only occurs at reservoir temperature. Through the laboratory experiment of reservoir fluids the PVT properties can be calculated, but this laboratory experimental work can be expensive and it is not available easily in all the time during the evaluation of reservoir fluids. So we have an alternate way to calculate various reservoir fluid properties through the use of available existing empirical correlations (Sylvester, 2018). Differential Liberation (DL) test also known as Differential Vaporization or Differential Expansion is one of the standard tests performed on reservoir fluid samples by the Pressure-Volume-Temperature (PVT) laboratories. The DL test is performed to evaluate the depletion process of oil reservoir and to simulate the behavior of hydrocarbon fluid at conditions above the critical gas saturation. In DL process, the solution gas which is initially mixed with the oil and acts as a single phase under reservoir conditions, when production of hydrocarbons starts the resulting drop in pressure will cause two phase flow as the gas is starts to evaporate from the solution. As the saturation of these released gases exceeds critical gas saturation, the liberated gas starts to flow and leaving the oil behind. This happens due to high gas as compared to oil. This is because gases have greater mobility than oils. The process of differential liberation may vary with respect to pressure under composition of the total hydrocarbon system (Igwe and Ujile, 2015). PVT correlations are essential tools for predicting PVT properties in cases where laboratory analysis is not accurate. In order to accurately estimate PVT properties for a specific geological area, a primary study should be carried out using laboratory data to determine the best set of correlations in representing that area's crude oil; this research examines the appropriate use of the existing correlations to estimate the FVF, solution GOR under below the

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bubble point pressure for Pakistan's Sindh based (Mohamed *et al.*, 2018).

RESEARCH METHODOLOGY

The proposed research methodology is described as follows, collecting various samples of oil from the fields of lower guru formation. Then analyses of those oil samples were performed at the PVT laboratory available in IPNGE M.U.E.T. Jamshoro. After the laboratory investigation of oil samples under different pressure and temperature conditions, the laboratory data is then incorporated in the existing frequently used empirical correlations with the help of the Petroleum Office. Finally, Comparative analyses were carried out for the laboratory data and empirical correlation results in terms of PVT parameters which include (R_{so}, P_b, B_o). In last suggested the best correlations for the proposed PVT parameters of this research work based on Statistical Error analysis for the specific wells of lower guru formation.

Laboratory Setup

The PVT cell is intended for studies of small volume PVT, thermodynamic properties, and phase behavior of black oil and gas condensate samples. The cell is made up of an efficient fluid mixer mounted on a piston, a dedicated visual head, two sampling valves, an accurate pressure transducer, and an electric heater that allows for uniform temperature control. Through the sapphire windows, a digital camera system monitors the liquid/gas interface. The removal of the gas phase during differential vaporization or flash liberation is aided by full visibility of the gas/oil interface through the cell window. The cell is upright for oil studies and inverted for gas condensate experiments.



Figure 1: Complete PVT Cell Profile with Gasometer

Laboratory Tests

The prime objective of PVT tests is to advance experimental information for the performance of subsurface fluids at reservoir conditions. The secondary purpose of the PVT test is to generate information on the volumetric changes that occur with the good stream when produced under standard conditions.

RESULTS AND DISCUSSION:

Experimental Results

Experimental results were observed from the laboratory using PVT cell, three different oil samples were collected from separator

conditions. Then collected samples were evaluated for saturations pressure (P_b), Gas solubility (R_{so}), and Oil formation volume factor (B_o) at different reservoir pressure and temperature conditions in the PVT cell laboratory. The constant composition expansion test (CCE)/(CME) and Differential Liberation (DL) tests were conducted for all three samples labeled as Sample-A, Sample-B, and Sample-C. The PVT test results show that due to depletion of reservoir pressure as a result of a decline of reservoir fluid (oil), the bubble point pressure or liquid saturation pressure (it is that pressure at which the first bubble of solution gas evolves from the oil). The oil formation volume factor is also known as the oil shrinkage factor or relative volume is the ratio of the volume of oil at reservoir conations to the volume of oil at stock tank conditions. The above table also shows that at the beginning of the experiment above the bubble point pressure, the oil formation volume factor increases gradually up the bubble point pressure, with decreasing pressure. The oil formation volume factor starts decreasing immediately after the bubble point pressure. The oil volume shrinks gradually. This is due to the liberation of dissolved gas and immediate removal of the same from contact with the oil. PVT cell tests were conducted for three different samples of lower guru fields at three temperature conditions to evaluate the impact of field conditions.

Table 1: Laboratory Data

Paramet ers	Sample-A			Sample-B			Sample-C		
Tempera ture, °F	140	158	176	104	140	176	104	122	158
API Gravity	40.0	40.0	40.0	44.5	44.5	44.5	44.	44.4	44.4
Sp. Gravity of Gas	0.85	0.85	0.85	0.85	0.85	0.85	0.8	0.85	0.85
Gas Solubility ,Rs	377.	297.	227.	346.	283.	255.	60.	57	31
Bubble Point Pressure ,Pb	34	67	34	24	56	87	23		
	134	117	100	111	100	998	305	300	297
Oil FVF, Bo	0	7	0	1	0				
	1.22	1.21	1.19	1.20	1.19	1.20	1.0	1.05	1.08
	8	72	01	04	12	45	41	03	04

Evaluation Procedure

The fundamental criteria adopted for this study; are based on statistical and graphical error analyses. Existing empirical correlations are used for the acquired data points, and their comprehensive error analysis is performed based on a comparison of the simulation results and original laboratory experimental results. For an in-depth analysis of the accuracy of the correlations tested, error analysis based on different oil samples of lower guru formation is also carried out graphically. An error analysis based on different temperature ranges is considered an effective tool for determining the suitability of the correlation for oil samples of lower guru formation. The following statistical means are used to determine the accuracy of correlations to be evaluated. Average Absolute Percent Relative Error (E_a) and Standard Deviation (σ) are important indicators for the accuracy of an empirical model. It is used here for Gas Solubility (R_{so}), Bubble Point Pressure (P_b), and Oil FVF (B_o) respectively as a comparative criterion for testing the accuracy of existing correlations.

Statistical Accuracy (E_a) of Gas Solubility

Table 2: Average Absolute Percent Relative Error (Ea) of Gas Solubility (Rso)

Rso (Standing)	Rso(Vesquez Begs)	Rso(Glaso`s)	Rso (Al-Marhoun`s)
Ea	Ea	Ea	Ea
17.38609	5.645532	6.840110	0.85994
23.36919	14.43069	7.477402	1.28267
52.01057	44.51927	89.05944	3.58300

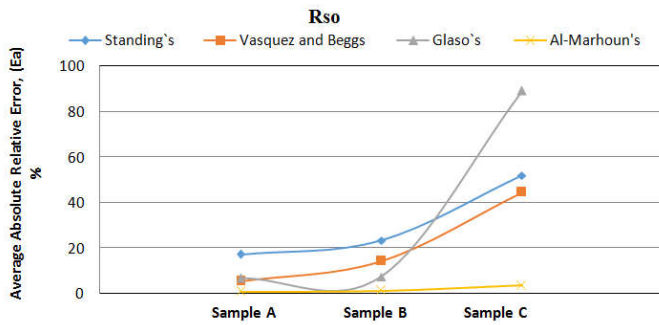


Figure 2: Statistical Accuracy (Ea) of Gas Solubility correlation grouped by sample wise

Another effective comparison of correlations is performed through graphical representation of error as given in Figure 2. From the graph we can see that the least absolute error is given by Al-Marhouns correlation of gas solubility for all samples and it shows strait line. Again the Galso`s correlation also showing the minimum absolute error at sample-1 and sample 2 only.

Statistical Accuracy (Ea) of Bubble Point Pressure

Table 3: Average Absolute Percent Relative Error (Ea) of Bubble Point Pressure (Pb)

Pb (Standing)	Pb (VesquezBeggs)	Pb (Al Marhoun`s)	Pb (Dokla Osman)
Ea	Ea	Ea	Ea
15.00618732	4.462685699	0.621212318	8.597040831
17.79738	10.733088	6.88257551	0.931472
37.23614954	26.66290353	2.661080846	36.26877503

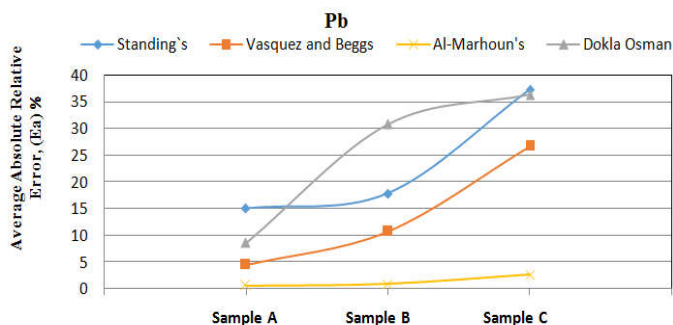


Figure 3: Statistical Accuracy (Ea) of Bubble Point correlation grouped by sample wise

Figure 3, shows that the least absolute error is given by the Al-Marhouns correlation of bubble point pressure for all samples and it shows a straight line increasing slightly at sample 3. Again the Vasquez and Beggs correlation also shows the minimum absolute error at sample-1 and sample 2 only.

Statistical Accuracy (Ea) of Oil Formation Volume Factor

Table 4: Average Absolute Percent Relative Error (Ea) of Oil Formation Volume Factor (Bo)

Bo (Standing)	Bo (VesquezBeggs)	Bo (Glaso`s)	Bo (Al Marhoun`s)
Ea	Ea	Ea	Ea
0.01663728	0.21394555	0.0415192	0.00739584
0.013670063	0.003392185	0.03656724	0.004034201
0.004496222	0.01011745	0.02120234	0.005809729

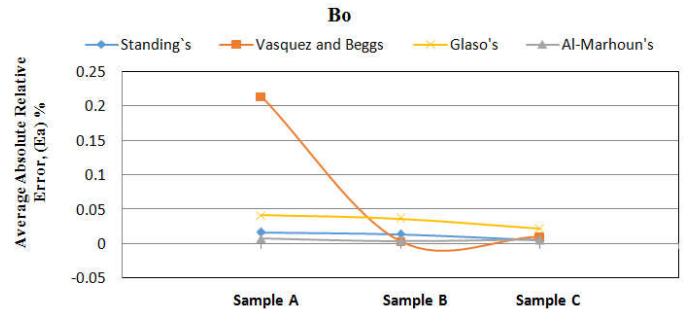


Figure 4: Statistical Accuracy (Ea) of (OFVF) correlation grouped by sample wise

It is clear in figure 4, that the least absolute error is observed in the Al-Marhouns correlation of oil formation volume factor for all samples and it shows a straight line. Again the Standing`s correlation also shows the minimum absolute error.

Statistical Accuracy (σ) of Gas Solubility

Table 5: Standard deviation (σ) of Gas Solubility(Rso)

SD (Standing)	SD (VesquezBeggs)	SD (Glaso`s)	SD (Al-Marhoun`s)
6.9483255	6.607901162	36.0365287	0.20449559
3.713111091	0.298470174	26.43703965	0.482040549
0.335741257	2.569332604	16.83811339	1.962191851

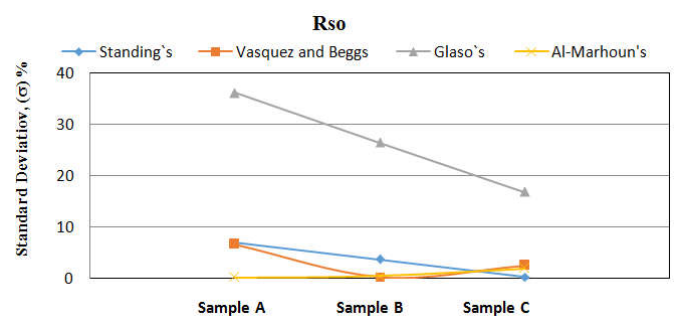


Figure 5: Statistical Accuracy (σ) of Gas Solubility correlation grouped by sample wise

From figure 5, we may observe that the least standard deviation is observed in the Al-Marhouns correlation of gas solubility for all three samples and it shows a straight line almost. Again the Vasquez and Beggs correlation also shows the minimum standard deviation error at sample 2 only.

Statistical Accuracy (σ) of Bubble Point Pressure (Pb)

Table 6: Standard deviation (σ) of Bubble Point Pressure (Pb)

SD (Standing)	SD (VesquezBeggs)	SD (Al Marhoun's)	SD (Dokla Osman)
9.255691556	3.851526059	0.108390573	26.46484836
1.453777584	0.129840393	0.256918545	147.5436321
0.046266804	0.463616649	1.126280477	77.38979553

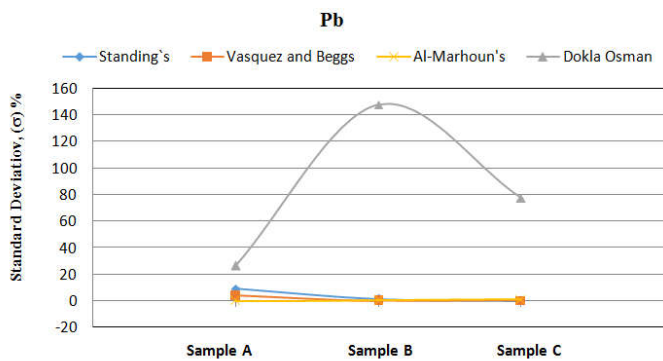


Figure 6: Statistical Accuracy (σ) of Bubble Point correlation grouped by sample wise

In figure 6 it is clear here that the least standard deviation is observed in the Al-Marhouns correlation of bubble point pressure for all three samples and it shows a straight line. Again the standing's and Vasquez Beggs correlations also show the minimum standard deviation error for all three samples.

Statistical Accuracy (σ) of Oil Formation Volume Factor

Table 7: Standard deviation (σ) of Oil Formation Volume Factor (Bo)

SD (Standing)	SD (VesquezBeggs)	SD (Glaso's)	SD (Al Marhoun's)
3.92773E-05	0.000119679	5.7966E-05	1.18944E-05
2.03552E-05	1.31196E-06	5.5557E-05	1.82737E-06
2.50317E-05	1.91517E-05	5.96E-05	2.13764E-06

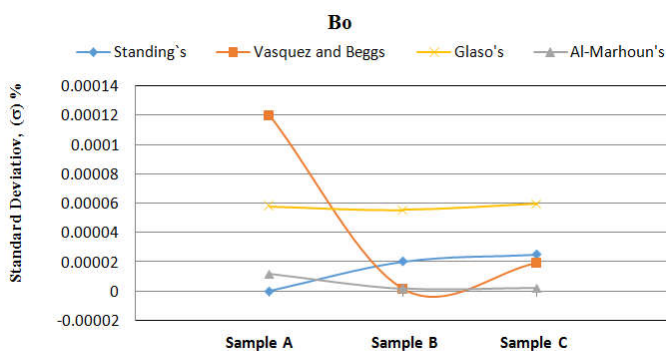


Figure 7: Statistical Accuracy (σ) of (OFVF) correlation grouped by sample wise

From figure 7, we can see that the least standard deviation is observed in the Al-Marhouns correlation of oil formation volume factor for all three samples. Again the standing's correlation shows the minimum standard deviation error at sample-1 which has the least error but again increases accordingly for samples 2 and 3.

CONCLUSION

Followings are the conclusions of this study.

- For gas solubility, the least average absolute relative error (Ea) is observed in Al-Marhouns correlation for all three oil samples of lower guru formation. Although for more convenient results another method is used and again Al-Marhouns gas solubility correlation shows the least standard deviation (σ) error. But the maximum standard deviation is observed in Glaso's correlation. So it is concluded that Al-Marhouns gas solubility correlation results the best and should be used for the lower guru formation.
- Bubble point pressure correlations were observed to check their accuracy in terms of errors, and the least average absolute relative error is observed in Al-Marhouns bubble point correlation. Again for the more accurate results of bubble point correlations, another method is used here to check their accuracy for a particular field, which again shows the same Al-Marhouns correlation having the least standard deviation error. Although Vasquez and Beggs also shows minimum standard deviation error, it can be used at some conditions if required.
- The least average absolute percent relative error (Ea) of Oil Formation Volume Factor is observed in Al-Marhouns correlation, the given correlation should be used for the lower guru formation which leads to minimum error. Again the Standing's correlation of OFVF shows the minimum average absolute percent relative error (Ea). But for the particular lower guru formation it is best to use Al-Marhouns OFVF correlation which has least standard deviation.

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