PVT Investigation of an Iraqi Reservoir

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Abstract

This investigation was made to clarify the type of reservoir fluids in an Iraqi field reservoir regarding the controversy about its type. It was known for many years as a condensate field, but in this study a different theory was investigated and proved using Winprop of CMG$^{®}$ software.

Two equations of state (EOS) were tested and the one with minimum error percentage was used. Also, three correlations were tested to calculate the original C_6^+ properties, which are: Lee-Kesler , Twu and Riazi . Twu`s correlation prevailed because the results of this correlation were the nearest to the original data, and it permits using a wide range of pressures (from zero to infinite pressure values), which minimizes the discrepancies between the results of any equation of state, which was investigated.

After achieving the closest possible match of all available properties, the envelopes were constructed. Winprop of CMG needs a full set of oil and gas properties from a single sample. Therefore, a recombination for the available gas and oil samples were made to construct the phase envelopes for the field system in addition to individual gas and oil phase envelopes

The result of this investigation and analysis is that the reservoir is actually a black oil field with a gas cap, despite what was believed earlier as being a condensate field.

Keywords: EOS, Correlation, Plus fraction properties (C_6^+), Regression, Phase Envelopes, Black Oil (not condensate) reservoir.

Introduction

PVT analysis (which means pressure, volume, and temperature) is an examination of hydrocarbon reservoir fluids in a laboratory under various pressures, volumes, temperatures and compositions to determine the physical characteristics and behavior of the fluid [1].

The PVT analyses are first steps in any reservoir study and are important to determine the type of the fluids concerned with the study, and to predict their physical properties in order to select an appropriate simulator to build the reservoir model of that field for history matching and/or forecasting.

Winprop of CMG software is one of the most up-to-date programs in analyzing PVT data. It uses two equations of state and correlations for original properties and C+ properties.

The two equations of states that were tested are: Peng-Robinson (PR) [2] and Soave Redlich Kwang (SRK) [3]. Choosing the equation of state and correlations depends on the minimum error percentage result in each step.

The EOS needs very accurate properties of C_6^+ in order to give correct results, and because there are no C_6^+ data, a tuning process must be made.

A regression method [4] which is an option in the Winprop program was used to calculate the properties of the C_6^+ analysis and many factors.

The tuning process or "Regression analysis" is useful when the model parameters arising from the basic characterization procedure do not result in the desired agreement with PVT data, which is basically because there are no specific properties for the plus hydrocarbon fractions (C_6^+), so the regression minimizes the deviation between the measured data and the simulated results of the PVT experiments by varying a selection of model parameters.

It is important to note that the three correlations were tested to calculate the original C_6^+ properties, which are: Lee-Kesler [5] , Twu [6] and Riazi [7]

Using all the previous steps and information, a phase envelop can be constructed. Based on the resulting phase envelopes, the types of the fluids in the field can be identified. Oil, gas, and recombination phases can be constructed based on the available data and the particular needs of each reservoir study [8].

Phase Behavior Investigation

The available PVT data of the reservoir for wells X-5, X-8, X-2, X-43, X-47, X-52 and X-26 are: Bo (oil formation-volume factor), Bg (gas formation-volume factor), GOR (solution gas-oil ratio) and ROV (relative oil volume) vs. P (pressure) are shown in Figures (1-4) , and the values of hydrocarbon weight percent as listed in Tables (1&2). Also, values of bubble-point pressure and the reservoir temperature must be prepared in order to export them to Winprop of CMG.

Other available information used for both oil and gas wells were as follows; for oil wells: the saturation pressure is 3750 psia and the reservoir temperature is 146 ^oF, the sampling conditions are 3600 psia pressure and 146 ^oF temperature, the production conditions (separators) are 70 psia for pressure and 70 ^oF for temperature.

The reservoir conditions for gas wells are 3750 psia saturation pressure and 145 ^oF reservoir temperature, the sampling conditions are 3680 psia pressure and 145 ^oF temperature, the production conditions (separators) are 80 psia pressure and 80 ^oF temperature.

The SRK EOS has less error percentage in matching the real data of the field, because the PR EOS fails in determining the correct Bp pressure for the reservoir. Using Twu`s correlation to calculate the C_6^+ properties also gives the nearest values to the original properties. Evaluation of the final properties is the regression method as shown in Tables (3&4).

Eight phase envelopes for the reservoir were obtained using the recombination of available PVT reports of oil and gas, and a ninth phase envelop was determined from the composition of reservoir crude of the PVT report for well X-26.

All nine phase envelopes were identical, and the result was that the reservoir is not a condensate fluid, but it is a saturated black-oil field with a gas cap having high percentage of C_1.

Figure (1) to Figure (4) is comparisons between PR and SRK matching regarding GOR, ROV, Oil and Gas viscosity. Figure (5) through Figure (7) represents the phase envelopes for the reservoir, oil and gas respectively.

Gas wells phase envelopes indicate that the gas is dry with a high percentage of C_1, and the oil phase envelope indicates that the fluid is black oil.

The matching between the real and resulting data was very similar to the recombination results with a highest error percentage of 3.7% for all the relations according to the SRK method, as shown in Table (5).

Table (1) Hydrocarbon weight percentage for gas wells.

	X-5	X-8	X-26
Composition	Weight %	Weight %	Weight %
C1	75.08	79.4	75.000
C2	9.52	1.4	4.4027
C3	5.31	1.2	0.7562
iC4	3.62	3.6	2.320
nC4	1.07	5.3	4.8977
iC5	1.83	3.4	2.2399
nC5	1.65	3.9	3.5197
C6+	1.92	1.8	6.8653
Sum	100.00	100.0	100.000

Table (2) Hydrocarbon weight percentage for oil wells.

	X-2	X-43	X-47	X-52	X-26
Composition	Weight %	Weight %	Weight %	Weight %	Weight %
C1	0.53	0.30	0.56	0.7	1.22
C2	0.69	0.32	0.66	0.9	3.38
C3	0.77	0.51	0.73	1.1	3.72
iC4	1.23	0.97	1.27	1.8	1.87
nC4	1.99	4.86	1.91	1.9	2.46
iC5	5.47	7.75	5.79	5.5	1.87
nC5	7.37	9.40	7.36	10.8	9.73
C6+	81.95	75.89	81.72	77.3	75.75
Sum	100.00	100.00	100.00	100.0	100.00

Table (3) SRK parameters.

Component	Pc (atm)	Tc (k)	Acentric factor	Mole weight	volume shift	Z (rackett)	Vc (l/mol)	viscosity	Sg
C1	45.4	190.6	0.008	16.043	0	0.2876	0.099	0.099	0.300
C2	48.2	305.4	0.098	30.07	0	0.2789	0.148	0.148	0.356
C3	41.9	369.8	0.152	44.097	0	0.2763	0.203	0.203	0.507
IC4	36.0	408.1	0.176	58.124	0	0.2750	0.263	0.263	0.563
NC4	37.5	425.2	0.193	58.124	0	0.2728	0.255	0.255	0.584
IC5	33.4	460.4	0.227	72.151	0	0.2716	0.306	0.306	0.625
NC5	33.3	469.6	0.251	72.151	0	0.2685	0.304	0.304	0.631
C6+ (original)	32.86	489.5474	0.330048	85.99991	0.220455	0.27648	0.4128	0.344	0.69
C6+ (regression)	30.9463	480.0986	0.396058	85.99991	0.237644	0.268979	0.4128	0.344	0.69

Component	Omega A	Omega B	Enth. Coef. A	Enth. Coef. B	Enth. Coef. C	Enth. Coef. D	Enth. Coef. E	Enth. Coef. F
C1	0.42748	0.08664	0.00E+00	1.96E-01	3.89E-04	-5.13E-08	0.00E+00	0.00E+00
C2	0.42748	0.08664	0.00E+00	1.95E-01	3.90E-04	-5.13E-08	0.00E+00	0.00E+00
C3	0.42748	0.08664	0.00E+00	6.78E-02	4.11E-04	-5.13E-08	0.00E+00	0.00E+00
IC4	0.42748	0.08664	0.00E+00	4.35E-02	4.05E-04	-5.13E-08	0.00E+00	0.00E+00
NC4	0.42748	0.08664	0.00E+00	3.52E-02	4.02E-04	-5.13E-08	0.00E+00	0.00E+00
IC5	0.42748	0.08664	0.00E+00	2.28E-02	3.98E-04	-5.13E-08	0.00E+00	0.00E+00
NC5	0.42748	0.08664	0.00E+00	2.26E-02	3.98E-04	-5.13E-08	0.00E+00	0.00E+00
C6+ (original)	0.42700	0.08664	0.00E+00	-1.63E-02	4.12E-04	-5.77E-08	0.00E+00	0.00E+00
C6+ (regression)	0.60098	0.077182	0.00E+00	-1.63E-02	4.12E-04	-5.77E-08	0.00E+00	0.00E+00

Table (4) PR parameters

Component	Pc (atm)	Tc (k)	Acentric factor	Mole weight	volume shift	Z (rackett)	Vc (l/mol)	(viscosity)	Sg
C1	45.4	190.6	0.008	16.043	0	0.2876	0.099	0.099	0.300
C2	48.2	305.4	0.098	30.07	0	0.2789	0.148	0.148	0.356
C3	41.9	369.8	0.152	44.097	0	0.2763	0.203	0.203	0.507
IC4	36.0	408.1	0.176	58.124	0	0.2750	0.263	0.263	0.563
NC4	37.5	425.2	0.193	58.124	0	0.2728	0.255	0.255	0.584
IC5	33.4	460.4	0.227	72.151	0	0.2716	0.306	0.306	0.625
NC5	33.3	469.6	0.251	72.151	0	0.2685	0.304	0.304	0.631
C6+ (original)	32.86	489.5474	0.330048	85.99991	0.220455	0.27648	0.4128	0.344	0.69
C6+ (regression)	32.86	533.7999	0.396058	85.99991	0.215828	0.268317	0.4128	0.344	0.69

Component	Omega A	Omega B	Enth. Coef. A	Enth. Coef. B	Enth. Coef. C	Enth. Coef. D	Enth. Coef. E	Enth. Coef. F
C1	4.57E-01	7.78E-02	0.00E+00	1.96E-01	3.89E-04	-5.13E-08	0.00E+00	0.00E+00
C2	4.57E-01	7.78E-02	0.00E+00	1.95E-01	3.90E-04	-5.13E-08	0.00E+00	0.00E+00
C3	4.57E-01	7.78E-02	0.00E+00	6.78E-02	4.11E-04	-5.13E-08	0.00E+00	0.00E+00
IC4	4.57E-01	7.78E-02	0.00E+00	4.35E-02	4.05E-04	-5.13E-08	0.00E+00	0.00E+00
NC4	4.57E-01	7.78E-02	0.00E+00	3.52E-02	4.02E-04	-5.13E-08	0.00E+00	0.00E+00
IC5	4.57E-01	7.78E-02	0.00E+00	2.28E-02	3.98E-04	-5.13E-08	0.00E+00	0.00E+00
NC5	4.57E-01	7.78E-02	0.00E+00	2.26E-02	3.98E-04	-5.13E-08	0.00E+00	0.00E+00
C6+ (original)	4.57E-01	7.78E-02	0.00E+00	-1.63E-02	4.12E-04	-5.77E-08	0.00E+00	0.00E+00
C6+ (regression)	0.60098	7.78E-02	0.00E+00	-1.63E-02	4.12E-04	-5.77E-08	0.00E+00	0.00E+00

Table (5) Error percentage in fluid properties between PR and SRK EOS

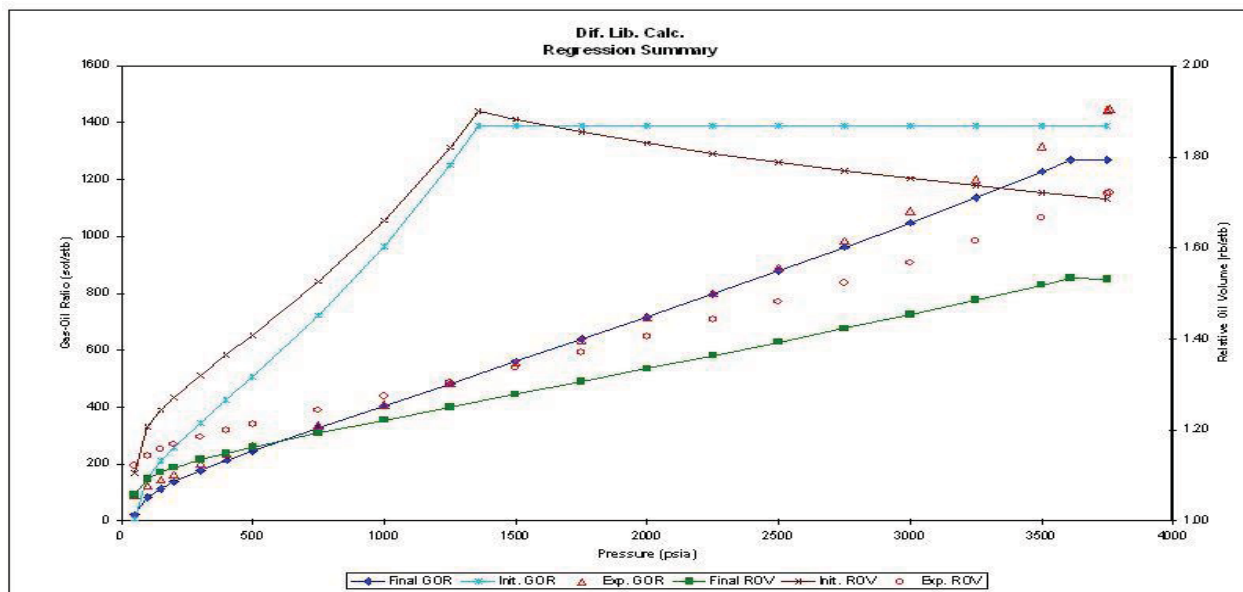|	GOR	ROV	Gas FVF	Oil Viscosity	Gas Viscosity
PR (avg.)	7%	6%	5%	6%	4%
PR (highest)	11%	9%	6%	10%	10%
SRK (avg.)	2%	1%	3%	2%	1%
SRK (highest)	4%	2%	4%	4%	3%

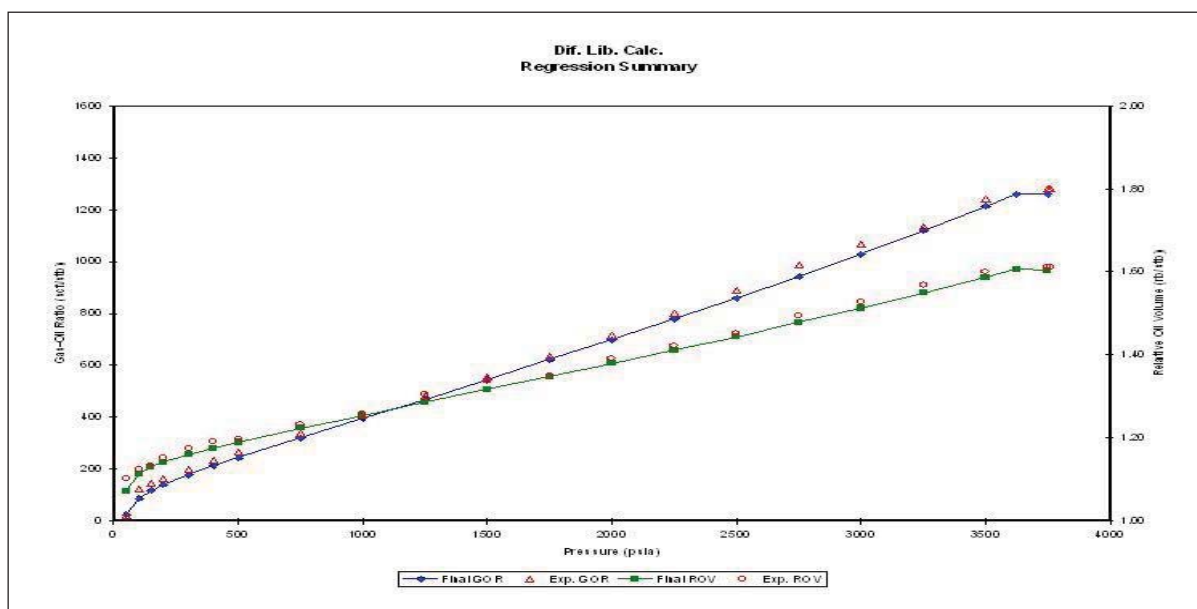**Fig.(1) GOR, ROV vs. P (PR method)**
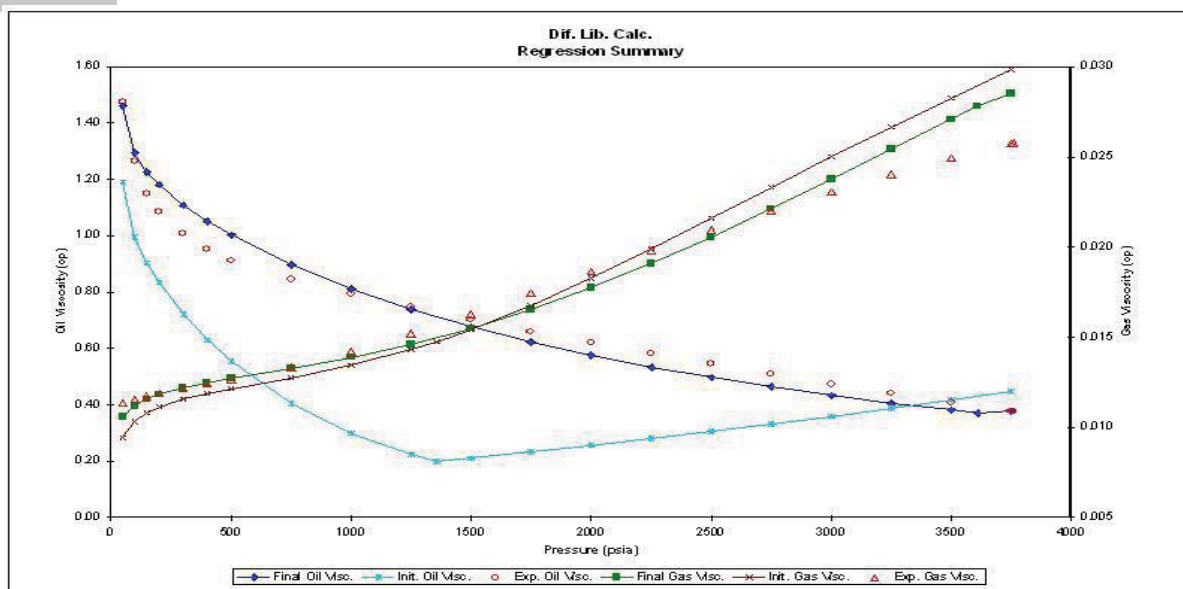

Fig.(2) GOR, ROV vs. P (SRK method)

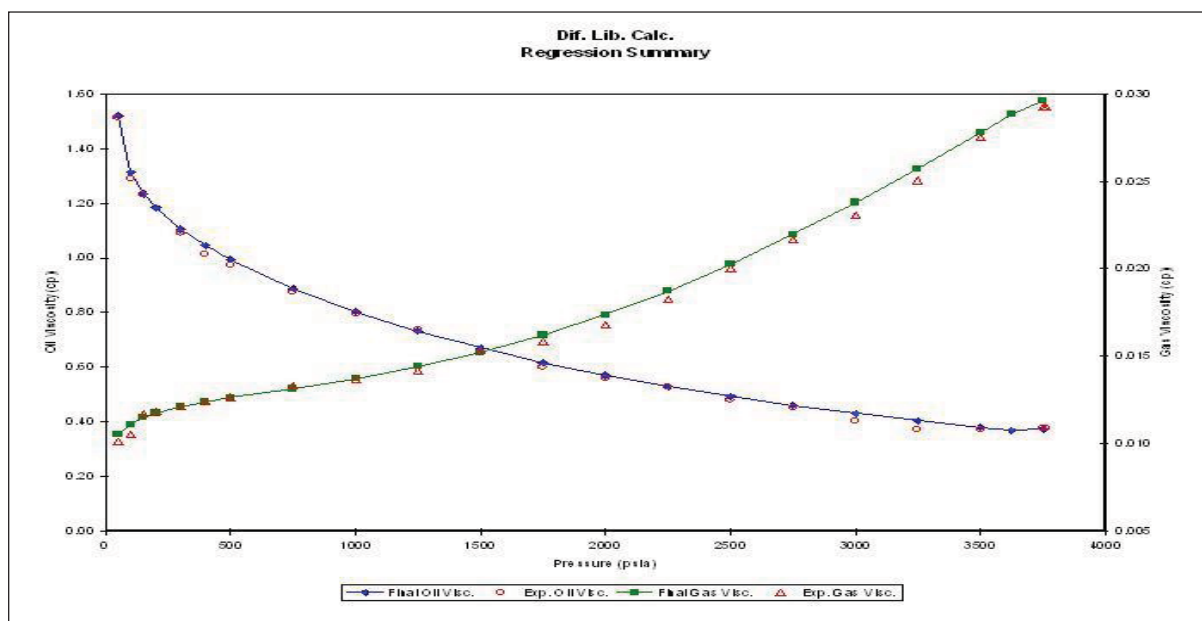**Fig. (3) Oil Viscosity, Gas Viscosity vs. P (PR method)**

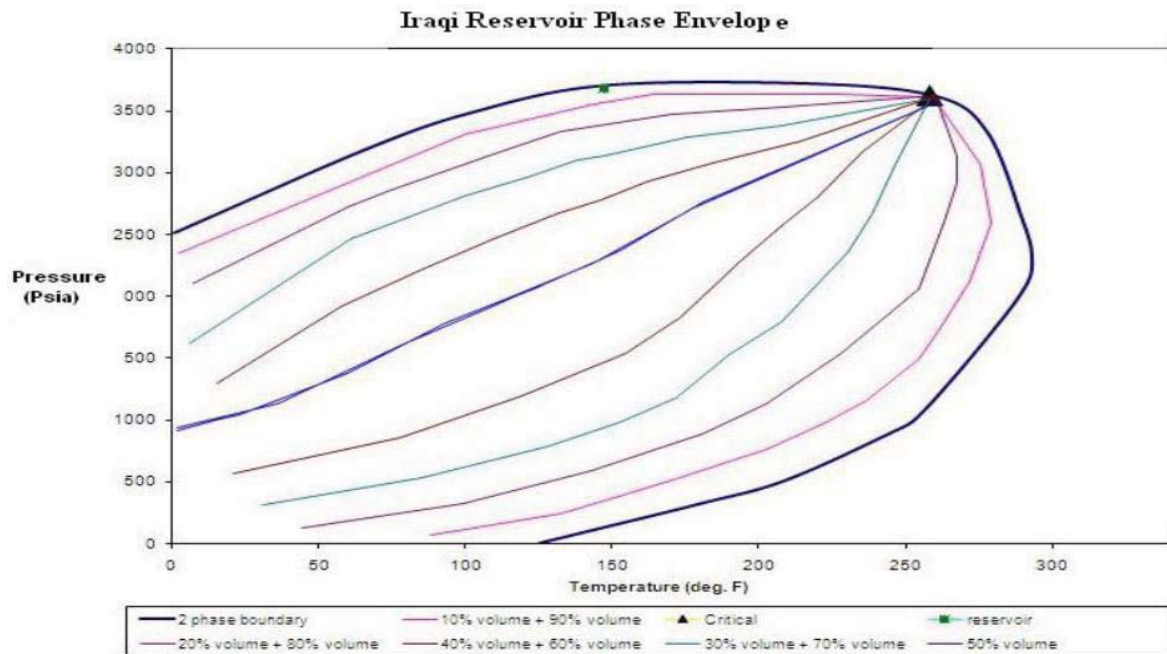**Fig. (4) Oil Viscosity, Gas Viscosity vs. P (SRK method)**
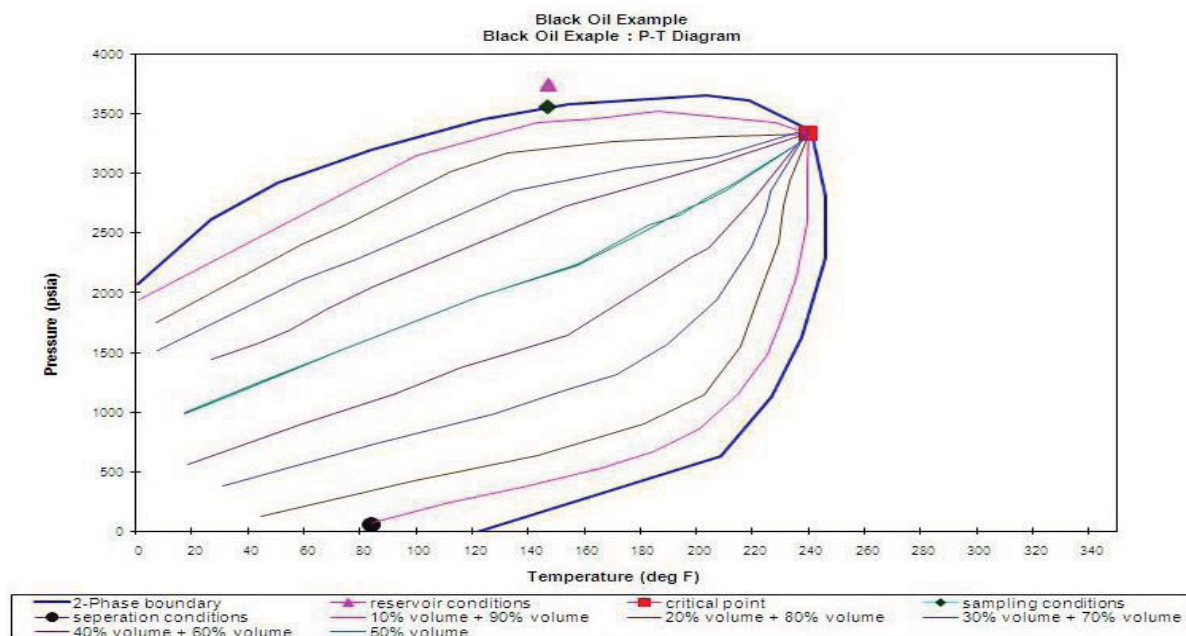
Fig.(5) Phase Envelop of an Iraqi Reservoir

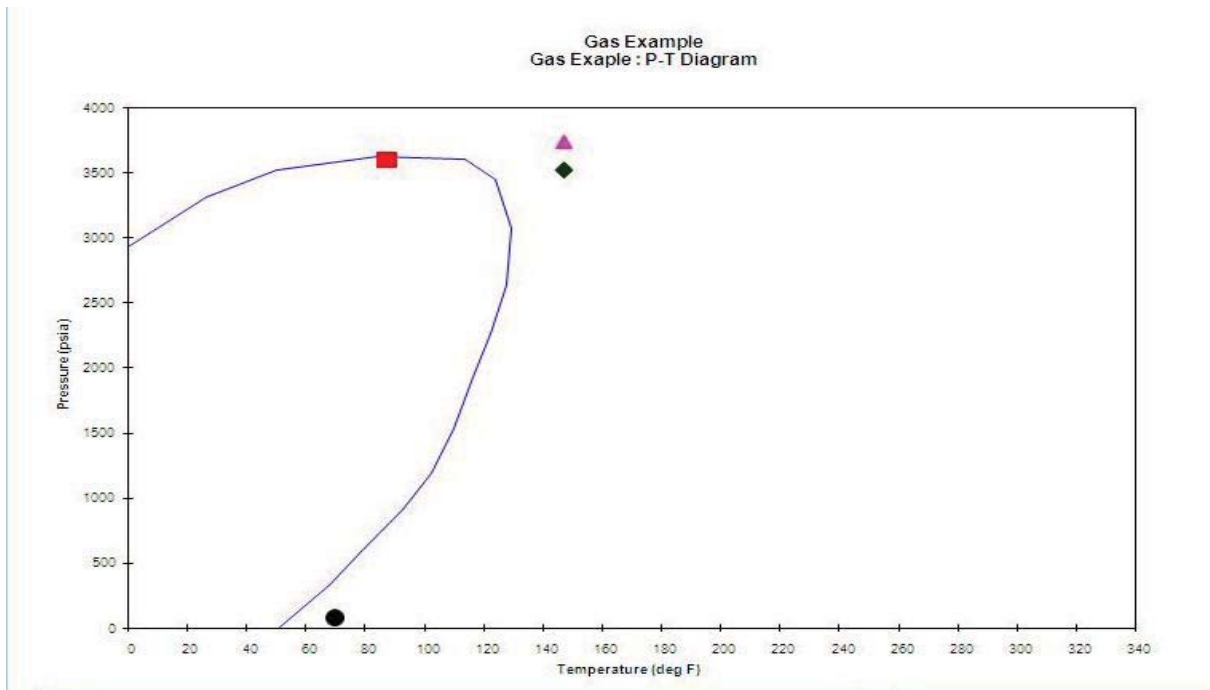**Fig.(6) Oil phase Envelopes**

Fig.(7) Gas Cap Phase Envelope for an Iraqi Reservior

Conclusions

1-The type of the reservoir fluid was determined from the PVT investigation, as this Iraqi field is a black-oil reservoir with a gas cap, with a high percentage of C1 hydrocarbons.

2-The SRK was best based on achieving the minimum error percentage comparing its results with the original data

Nomenclature

B0 = Formation-volume factor, STB/bbl.

Bg = Gas formation-volume factor ft3/Scf

GOR = Gas-oil ratio, Scf/STB

P = Pressure, pisa

T = Temperature oF

Pc = critical pressure

Tc = critical temperature

Vc = critical volume

Sg = specific gravity

Enth. Coef. = enthalpy coefficient

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