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Bubblepoint for Oil Reserves in the Absence of PVT Analysis

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Abstract

A modern method is further improved in order to estimate the bubblepoint pressure and the bubblepoint petroleum formation volume factor for petroleum reserves. The above high technology method requires that the value of the bubblepoint solution for oil/gas ratio be one of the input variables. Most of the known bubblepoint solution oil/gas ratio correlations are functions of bubblepoint pressure and gas gravity, which can be obtained either experimentally by using PVT (pressure-volume-temperature) analysis, or estimated from the existing correlations. Thus, it is not easy to apply the correlations in the absence of a PVT analysis. By the current paper, a modern technology is proposed in order to develop two novel correlations to estimate the bubblepoint solution oil/gas ratio and stock-tank vent oil/gas ratio in the absence of a PVT analysis. Hence, the proposed correlations can be directly applied by using several available field data and therefore there is no need for additional PVT analysis. The above proposed bubblepoint solution oil/gas ratio correlation is related to the separator gas-oil ratio, to the separator pressure, and to the stock-tank oil specific gravity. In addition, a very important application of the proposed stock-tank vent oil/gas ratio correlation is to estimate the stock-tank vent gas flow rate. Thus, the proposed bubblepoint solution oil/gas ratio correlation consists as the mean value of several other solutions.

Key Word and Phrases

PVT Analysis, PVT Correlations, Bubblepoint Oil/Gas Ratio, Stock-Tank Vent Oil/Gas Ratio, Bubblepoint Pressure.

1. Introduction

Reservoir fluid pressure-volume-temperature (PVT) tests are designed to simulate the simultaneous fluid flow of petroleum and gas from the reservoir to the surface. Thus, in the pressure-volume-temperature (PVT) lab, researchers are using several instruments to determine reservoir fluid behavior and properties from petroleum and gas samples. According to the above test a simulation is done of what takes place in the reservoir and at the surface during production. Hence, the main aspect of PVT analysis is how gas evolves from oil when pressure falls below the bubblepoint.

The bubblepoint is determined during a flash liberation test on a small amount of reservoir fluid which is sampled downhole, or is recombined from surface gas and oil samples taken from the separator. Then after transferring the sample to a high pressure cell at reservoir temperature and above reservoir pressure, then the cell pressure is decreased by removing mercury from the cell. Hence, for each volume change, cell pressure is recorded. Upon reaching therefore the bubblepoint, gas comes out of solution and so any subsequent mercury removal causes small pressure reductions.

Besides, the bubblepoint is crucial for understanding how petroleum behaves within the reservoir and indicates the probable drive mechanisms. In a reservoir producing below the bubblepoint, gas coming out of solution may either be produced, or if production is slow and vertical permeability is high, it may migrate upward and form a secondary gas cap that helps drive the reservoir. On the other hand, if initial reservoir pressure is much higher than the bubblepoint, which means that the oil is undersaturated (contains little dissolved gas), then the only drive will be monophasic liquid expansion, resulting in poor recovery.

Moreover, the bubblepoint oil/gas ratio (R_{sob}) is a key parameter in reservoir and in production engineering calculations. Thus, the oil/gas ratio refers to the amount of gas dissolved in the oil at any given pressure. In addition, the oil/gas ratio increases with pressure until the attainment of the bubblepoint pressure, after which it remains constant and reaches the bubblepoint oil/gas ratio. Bubblepoint pressure (p_b) for reservoir oil is the pressure at which the gas begins to come out of solution at constant temperature. The above parameters are usually obtained experimentally, through PVT analysis. Furthermore, the bubblepoint solution gas/oil ratio is a basic parameter in many PVT correlations used to estimate other fluid properties such as the bubblepoint pressure, and the bubblepoint oil formation volume factor (B_{ob}).

Many expressions are available in the oil and gas industry used to estimate reservoir oil bubblepoint pressure (p_b) and bubblepoint oil formation volume factor (B_{ob}), which require a value of the bubblepoint oil/gas ratio (R_{sob}) as an input variable. Several studies has been published over the past years by proposing expressions in order to obtain the bubblepoint oil/gas ratio. Among them we will mention Standing [16], Vasques and Beggs [17], Petrosky and Farshad [23], Frashad et al. [27], Elsharkawy and Alikhan [29], Boukadi et al. [34], Hemmati and Kharrat [36], Mazandarani and Asghari [37] and Khamehchi et al. [38]. Hence, in the proposed expressions the bubblepoint oil/gas ratio (R_{sob}) is a function of the following variables : reservoir oil bubblepoint pressure (p_b), gas specific gravity (γ_g), API stock tank oil gravity and reservoir temperature (T_R).

Consequently, in order to apply the above expressions in the absence of a PVT analysis, then the values of p_b and γ_g should be known. So, the difficulty of measuring parameters p_b and γ_g as field data leave engineers with the resort to perform additional calculations to estimate those parameters. Such methods were proposed by scientists like Standing [16], Vazquez and Beggs [17], Glaso [18], Al-Marhun [19], McCain [20], Dokla and Osman [22], Petrosky and Farshad [23], Omar and Todd [24], De Ghetto and Villa [25], Kartoatmodjo and Schmidt [26], Frashad et al. [27], Almehaideb [28], Hanafy et al. [30], Boukadi et al. [34], Al-Shammasi[32], Dindoruk and Christman [33], Hemmati and Kharrat [36], and Moradi et al. [40].

On the othe hand, the energy demand for petroleum will increase up to 2030 by 50-60%, as it is increasing worldwide yearly at a pace of 1.5 to 2.0%. So, for the on-shore and off-shore petroleum and gas reserves exploration was proposed by E.G.Ladopoulos [1]-[15] the new theory of *"Non-linear Real-Time Expert Seismology".* According to the above modern technology a non-linear 3-D elastic waves real - time expert system was proposed for the exploration of petroleum and gas resources all over the world, including the off-shore petroleum reserves, of the seas and oceans in the whole world in deep waters ranging from 300 to 3000 m, or even much more. Furthermore, the above technology is the best device for searching the on-shore and off-shore hydrocarbon resources in very deep depths, even approaching 20,000 m or 30,000 m.

Thus, for the new and the existing oilfields there is an absolute need for the improvement of the existing methods of well development. For this reason, by the present paper the *"Determination of Bubblepoint for Oil & Gas Reserves in the Absence of PVT Analysis"* is proposed and introduced. According to the above new technology the bubblepoint for petroleum reserves is determined by analytical method in the absence of an experimental PVT analysis.

By the current research, it will become possible to develop two novel correlations to estimate the bubblepoint solution oil/gas ratio and stock-tank vent oil/gas ratio in the absence of a PVT analysis. Thus, the proposed correlations can be directly applied by using several available field data and so there is no need for additional PVT analysis. Furthermore, the proposed bubblepoint solution oil/gas ratio correlation is related to the separator gas-oil ratio, to the separator pressure, and to the stock-tank oil specific gravity. In addition, a very important application of the proposed stock-tank vent oil/gas ratio correlation is to estimate the stock-tank vent gas flow rate. Hence, the proposed bubblepoint solution oil/gas ratio correlation consists as the mean value of several other solutions.

From the above described analysis it is clear the evidence of the applicability of the modern method of *"Determination of Bubblepoint for Oil & Gas Reserves in the Absence of PVT Analysis"*. Also its novelty, as it is based mostly on a theoretical and very sophisticated model and not to experimental tools like the existing methods. Hence, the new method will be the best technology for well development.

2. Bubblepoint Determination for Petroleum & Gas Reserves by Analytical Methods

In general, up to now there is very little research done on the determination of petroleum reserves properties in the absence of an experimental PVT analysis. For example Elmabrouk et al.[39] proposed two formulas to estimate the bubblepoint pressure (p_b) for reservoir petroleum and the bubblepoint oil formation volume factor (B_{ob}) in the absence of a PVT analysis. Consequently, they used measured field parameters as input variables without the further requirement of additional correlations or a PVT experimental analysis.

Furthermore, Vazquez and Beggs [17], Elsharkawy and Alikhan [29], Boukadi et al. [34], Hemmati and Kharrat [36], Mazandarani and Asghari [37], and Khamehchi et al. [38], treated the bubblepoint oil/gas ratio (R_{sob}) as an independent variable. On the other hand, most of the available R_{sob} expressions are impractical in the absence of an experimental PVT analysis, as the R_{sob} expressions require knowledge of p_b and γ_g values. Hence, it is difficult to apply the expressions in the absence of a PVT analysis.

Moreover, an indirect way of obtaining the R_{sob} is to add the estimated stock-tank vent oil/gas ratio R_{ST} , to the field measured separator oil/gas ratio R_{SP} as following:

$$R_{sob} = R_{SP} + R_{ST} \tag{2.1}$$

In addition, Rollins et al. [21] proposed the following expression in order to estimate the R_{ST} as a function of the stock-tank oil specific gravity γ_{oST} , separator gas specific gravity γ_{gSP} , separator pressure P_{SP} and separator temperature T_{SP} :

$$\ln ST = 0.2126 - 4.916 \ln \gamma_{oST} + 3.469 \ln \gamma_{gSP} + 1.501 \ln P_{SP} - 0.9213 \ln T_{SP} \tag{2.2}$$

The above equation has a practical limitation in the absence of a PVT analysis due to the difficulty in determining the separator gas specific gravity γ_{gSP} .

Beyond the above, Valko and McCain [35] proposed an expression in order to estimate the stock-tank vent oil/gas ratio R_{ST} as a function of the separator pressure P_{SP} , the separator temperature T_{SP} and API stock tank oil gravity. They studied a non-parametric regression analytical method, with 881 data points, and proposed the following equation:

$$\ln R_{ST} = 3.955 + 0.83z - 0.024z^2 + 0.075z^3 \tag{2.3}$$

in which:

$$z = \sum_{n=1}^{3} z_n \tag{2.4}$$

$$z_1 = -8.005 + 2.7 \ln P_{SP} - 0.161(\ln P_{SP})^2 \quad (2.5)$$

$$z_2 = 1.224 - 0.5 \ln T_{SP} \quad (2.6)$$

$$z_3 = -1.587 + 0.0441 API - 2.29(API)^2 \quad (2.7)$$

On the other hand, Valko and McCain [35], estimated the R_{sob} indirectly by using eqn (2.1). They further proposed an additional expression, to estimate the R_{sob} directly when the separator conditions are unknown:

$$R_{sob} = 1.1617 R_{SP} \quad (2.8)$$

3. Bubblepoint Determination for Oil Reserves by further Analytical Methods

Elmabrouk and Shirif [41] proposed two multiple regression analysis models for the estimation of the bubblepoint oil/gas ratio (R_{sob}) in the absence of a PVT analysis. The above expressions were proposed as a function of readily available field data without the need for additional formulas or an experimental PVT analysis.

Hence, 480 separator tests, measured at the p_b, were obtained from 118 PVT reports and collected from various Libyan oil reservoirs located in the Sirte Basin. Furthermore, most of the data points were taken from a two-stage separation test. Then, the volume of gas liberated at each stage and the volume of remaining liquid were measured. The first-stage separator pressure was generally varied to include at least four possible separator pressures at ambient temperature. Moreover, the second stage was carried out under stock tank conditions of 14.7 psia (1 atmosphere) at ambient temperature. Besides, in single-stage separation, the test was carried out under separator conditions of 14.7 psia at ambient temperature. In such case, R_{ST} is equal to zero.

In addition, by the same scientists [41] was proposed a new expression in order to estimate the bubblepoint oil/gas ratio (R_{sob}). The data were correlated in terms of the separator oil/gas ratio (R_{SP}), the separator pressure (p_{SP}) and the stock-tank oil specific gravity (γ_{oST}) after the forward-backward search algorithm was carried out to select the best subset input variables. The formula which was proposed is the following:

$$R_{sob} = -152 + 0.99 R_{SP} + 0.256 p_{SR} + 19.543 \ln p_{SR} - 557.2 \ln \gamma_{oST} \quad (3.1)$$

On the other hand, the R_{SP} is usually a field measurement, unlike the stock-tank vent oil/gas ratio (R_{ST}) which rarely is measured in the field. Thus, in order to obtain the R_{sob} indirectly firstly the R_{ST} should be estimated, and then to be added in the field measured R_{SP}. So, an expression has been proposed for the calculation of R_{ST} with independent variables the the separator pressure (p_{SP}), the separator temperature (T_{SP}) and the stock-tank oil specific gravity (γ_{oST}). Hence, the following equation has been obtained:

$$R_{ST} = p_{SP}{}^{1.02} \cdot \gamma_{oST}{}^{-9.47} \cdot T_{SP}{}^{-0.524} \quad (3.2)$$

Consequently, the above model was sufficient enough for describing data

4. Mean Value Determination of the Bubblepoint for Oil Reservoir

A new approach is proposed for the calculation of the bubblepoint oil/gas ratio (R_{sob}) which results as the mean value of the empirical equations (2.1), (2.8) and (3.1):

$$R_{sob} = \frac{\sum_{i}^{3} R_{sob_i}}{3} \tag{4.1}$$

where the values of R_{sob_i} , $i = 1,2,3$ are calculated form equations (2.1), (2.8) and (3.1).

By the same way the calculation of the stock-tank vent oil/gas ratio (R_{ST}), results as the mean value of the empirical equations (2.2), (2.3) and (3.2):

$$R_{ST} = \frac{\sum_{i}^{3} R_{ST_i}}{3} \tag{4.2}$$

in which the values of R_{ST_i} , $i = 1,2,3$ are calculated from equations (2.2), (2.3) and (3.2).

5. Conclusions

By the current paper a new method has been proposed in order to estimate the bubblepoint pressure and the bubblepoint oil formation volume factor for petroleum and gas reservoir. The above method was based on three novel and simple empirical correlations, based on a multiple regression analysis, to estimate the bubblepoint oil/gas ratio (R_{sob}) and the stock-tank vent oil/gas ratio (R_{ST}) in the absence of a PVT analysis. The above formulas were developed as a function of field data readily available. Hence, these expressions can be applied straightforwardly in the absence of a PVT analysis without the need for any additional correlations or experimental measurements.

Beyond the above, the proposed bubblepoint solution oil/gas ratio correlation consists as the mean value of the above mentioned three different solutions. Consequently, by the proposed sophisticated technology for energy applications it will be established a strong scientific and technical base for the Science & Technology worldwide in the emerging areas of well development in the energy field. So, through the new technology of *"Bubblepoint Determination for Oil and Gas Reserves in the Absence of PVT Analysis"*, then the fast estimation of the properties of a petroleum reservoir will become possible.

The petroleum markets are multi-billion markets all over the world. Thus, such a contribution requires an international approach, rather than a local approach, as it is referred to a market all over the world with value of many billions. It is therefore expected in order the big petroleum companies to keep and to improve their leading role in the worldwide Science & Technology in the oil & gas field, to get involved in the new and groundbreaking technology in the area of Energy, which is proposed by the present investigation.

Finally, as the proposed new method *" Bubblepoint Determination for Oil and Gas Reserves in the Absence of PVT Analysis"*, is based on a very sophisticated modern technology, then it is expected to get the best results.

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