2.1 Introduction

Properties of crude oil and natural gas are fundamental for designing and analyzing oil and gas production systems in petroleum engineering. This chapter presents definitions of these fluid properties and some means of obtaining these property values other than experimental measurements. Applications of the fluid properties appear in subsequent chapters.

2.2 Properties of Oil

Oil properties include solution gas–oil ratio (GOR), density, formation volume factor, viscosity, and compressibility. The latter four properties are interrelated through solution GOR.

2.2.1 Solution Gas–Oil Ratio

"Solution GOR" is defined as the amount of gas (in standard condition) that will dissolve in unit volume of oil when both are taken down to the reservoir at the prevailing pressure and temperature; that is,

$$R_s = \frac{V_{gas}}{V_{oil}}, \tag{2.1}$$

where

R_s = solution GOR (in scf/stb)
V_{gas} = gas volume in standard condition (scf)
V_{oil} = oil volume in stock tank condition (stb)

The "standard condition" is defined as 14.7 psia and 60 °F in most states in the United States. At a given reservoir temperature, solution GOR remains constant at pressures above bubble-point pressure. It drops as pressure decreases in the pressure range below the bubble-point pressure.

Solution GOR is measured in PTV laboratories. Empirical correlations are also available based on data from PVT labs. One of the correlations is,

$$R_s = \gamma_g \left[\frac{p}{18} \frac{10^{0.0125(°API)}}{10^{0.00091t}} \right]^{1.2048} \tag{2.2}$$

where γ_g and °API are defined in the latter sections, and p and t are pressure and temperature in psia and °F, respectively.

Solution GOR factor is often used for volumetric oil and gas calculations in reservoir engineering. It is also used as a base parameter for estimating other fluid properties such as density of oil.

2.2.2 Density of Oil

"Density of oil" is defined as the mass of oil per unit volume, or lb_m/ft^3 in U.S. Field unit. It is widely used in hydraulics calculations (e.g., wellbore and pipeline performance calculations [see Chapters 4 and 11]).

Because of gas content, density of oil is pressure dependent. The density of oil at standard condition (stock tank oil) is evaluated by API gravity. The relationship between the density of stock tank oil and API gravity is given through the following relations:

$$°API = \frac{141.5}{\gamma_o} - 131.5 \tag{2.3}$$

and

$$\gamma_o = \frac{\rho_{o,st}}{\rho_w}, \tag{2.4}$$

where

°API = API gravity of stock tank oil
γ_o = specific gravity of stock tank oil, 1 for freshwater
$\rho_{o,st}$ = density of stock tank oil, lb_m/ft^3
ρ_w = density of freshwater, 62.4 lb_m/ft^3

The density of oil at elevated pressures and temperatures can be estimated on empirical correlations developed by a number of investigators. Ahmed (1989) gives a summary of correlations. Engineers should select and validate the correlations carefully with measurements before adopting any correlations.

Standing (1981) proposed a correlation for estimating the oil formation volume factor as a function of solution GOR, specific gravity of stock tank oil, specific gravity of solution gas, and temperature. By coupling the mathematical definition of the oil formation volume factor with Standing's correlation, Ahmed (1989) presented the following expression for the density of oil:

$$\rho_o = \frac{62.4\gamma_o + 0.0136 R_s \gamma_g}{0.972 + 0.000147\left[R_s \sqrt{\frac{\gamma_g}{\gamma_o}} + 1.25t\right]^{1.175}}, \tag{2.5}$$

where

t = temperature, °F
γ_g = specific gravity of gas, 1 for air.

2.2.3 Formation Volume Factor of Oil

"Formation volume factor of oil" is defined as the volume occupied in the reservoir at the prevailing pressure and temperature by volume of oil in stock tank, plus its dissolved gas; that is,

$$B_o = \frac{V_{res}}{V_{st}}, \tag{2.6}$$

where

B_o = formation volume factor of oil (rb/stb)
V_{res} = oil volume in reservoir condition (rb)
V_{st} = oil volume in stock tank condition (stb)

Formation volume factor of oil is always greater than unity because oil dissolves more gas in reservoir condition than in stock tank condition. At a given reservoir temperature, oil formation volume factor remains nearly constant at pressures above bubble-point pressure. It drops as pressure decreases in the pressure range below the bubble-point pressure.

Formation volume factor of oil is measured in PTV labs. Numerous empirical correlations are available based on data from PVT labs. One of the correlations is

$$B_o = 0.9759 + 0.00012\left[R_s \sqrt{\frac{\gamma_g}{\gamma_o}} + 1.25t\right]^{1.2}. \tag{2.7}$$

Formation volume factor of oil is often used for oil volumetric calculations and well-inflow calculations. It is also used as a base parameter for estimating other fluid properties.

2.2.4 Viscosity of Oil

"Viscosity" is an empirical parameter used for describing the resistance to flow of fluid. The viscosity of oil is of interest in well-inflow and hydraulics calculations in oil production engineering. While the viscosity of oil can be measured in PVT labs, it is often estimated using empirical correlations developed by a number of investigators including Beal (1946), Beggs and Robinson (1975), Standing (1981), Glaso (1985), Khan (1987), and Ahmed (1989). A summary of these correlations is given by Ahmed (1989). Engineers should select and validate a correlation with measurements before it is used. Standing's (1981) correlation for dead oil is expressed as

$$\mu_{od} = \left(0.32 + \frac{1.8 \times 10^7}{API^{4.53}}\right)\left(\frac{360}{t + 200}\right)^A, \tag{2.8}$$

Properties Of Petroleum Fluids 2ed Solution Manual

James A. Sullivan

Properties Of Petroleum Fluids 2ed Solution Manual:

Integrated Modeling of Reservoir Fluid Properties and Multiphase Flow in Offshore Production Systems Tobias R. Gessner,Jader R. Barbosa Jr.,2023-10-03 The book is intended for practicing engineers in the oil industry researchers and graduate students interested in designing and simulating offshore hydrocarbon production systems It approaches offshore oil production systems from an integrated perspective that combines the modeling of thermophysical properties of reservoir fluids and their flow as a multiphase mixture in wellbores flow lines and risers The first part of the book presents an internally consistent method to compute the critical parameters and acentric factor of Single Carbon Number SCN fractions of petroleum mixtures using state of the art multivariate fitting techniques The procedure is illustrated and validated using flash and differential liberation data from actual field samples In the second part of the book mechanistic multiphase flow models are discussed in light of their ability to predict the pressure temperature and phase holdup of production fluids in wellbores flow lines and risers Multivariate fitting procedures are again applied to evaluate the sensitivity of the results with respect to closure relationship parameters such as slug body gas holdup wall shear stress and wall roughness in pipelines and production tubing Finally the modeling framework is validated using actual field data from offshore production wells

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