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Discussion on Formation Fluid Density Measurements and Their Applications

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Abstract

Knowledge of formation fluid density is necessary for a variety of applications. It provides information on pressure gradient, zonal compartmentalization, transition zone characterization, thin beds analysis, and other reservoir qualities. It also contributes to estimates of the commercial value of the produced fluid and is a critical parameter used in modeling of the reservoir fluids through the equation of state (EOS) to obtain a better representation of fluid Pressure/Volume/Temperature (PVT) properties. Various techniques exist today for the measurement of formation fluid density. These measurements can be taken either at surface on captured fluid samples or downhole in real time using formation tester tools. The different techniques include laboratory PVT analysis of a fluid sample brought to surface, pressure gradients, downhole optical spectroscopy, and, recently developed, density measurements with the in-situ densimeter, which determines density by measuring the resonance characteristics of a vibrating object immersed in the fluid.

Although PVT analyses have excellent accuracy, downhole measurements have an advantage over surface measurements as they provide in-situ measurements under reservoir conditions without depending on the quality of the fluid from the sample bottle and sample transfer. They also allow better reservoir characterization without the need for an extensive sampling program. Pressure gradient surveys have been successfully used for decades to provide density measurements of the formation fluids. Although the measurement depends on the accuracy of both pressure measurement and depth, it provides density unaffected by flowline condition of formation testers and mud filtrate contamination. Downhole flowline sensors, such as spectroscopic sensors and vibrating rods, have the advantage of providing density measurements of the fluid itself rather than relying on other parameters such as depth, but they are sensitive to flowline conditions. Whereas the estimation of density from the spectroscopic method relies on an empirical model that cannot be used in every condition, the vibrating rod in-situ density sensor gives a direct physical measurement and is thus the preferred method of measurement whenever available.

Introduction

Precise fluid characterization provides vital information for reservoir evaluation, flow assurance, facility design, reservoir management, production strategies and reserves definition. Many applications benefit from a precise knowledge of the formation fluid density. Measurements are performed by various techniques at surface or downhole, where some can be intercorrelated to enhance reservoir characterization. Surface measurements include PVT analysis on the formation fluid samples at the wellsite or in a laboratory. Downhole measurements include pretest pressure surveys, molecular spectroscopy measurements and in-situ flowline measurements with vibrating object densimeters. These results are then used for the fluid gradient determination, thin bed analysis, reserve estimation, fluid modeling, zonal connectivity, compositional gradients, contamination estimation, transition zones, compressibility, etc.

Pretest pressure gradient surveys obtained with a wireline-conveyed formation tester have long been used as an important tool to determine downhole formation fluid density along with fluid contact and layer connectivity (Steward and Wittman, 1979). These approaches have been extended to logging-while-drilling (LWD) surveys (Pop et al. 2005). However, the uncertainty of the density determined from pressure gradients depends on the number and depth accuracy of the locations at which pressure is measured (Dubost et al. 2007), combined with the accuracy of the pressure measurement (Jackson et al. 2007). Moreover, the pressure measurements could be affected by depletion, capillary forces and rock wettability (Elshahawi et al. 1999), and supercharging effects. Precise measurements of the fluid density, such as those provided by inline sensors or from sampling, can complement pressure gradient surveys and in many cases decrease the uncertainty of the fluid contacts.