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Enhanced Characterization of Multi-Phase Downhole Fluid Samples Using a Full Spectrum Weighted Regression Analysis

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Abstract

Formation testers are commonly used to obtain fluid samples and measure formation pressure during openhole logging operations. Accurate identification of the produced fluid usually depends on the analysis of the sample chamber contents at the surface. An enhanced fluid characterization technique is now possible using the measurements of in-situ optical fluid density. This multi-phase fluid analysis can be used to determine the type formation fluids and to evaluate significant fluid characteristics.

The optical fluid analysis technique utilizes a visible and near-infrared absorption spectrometer for fluid discrimination. The spectrometer measures the light transmittance of a liquid at many different wavelengths and distinguishes between oil and water by comparing the resulting absorption spectra in the visible and near-infrared region. The spectrometer yields quantitative data on specific fluid phase volumes and qualitative data concerning fluid properties. Experiments were performed to catalog the optical fluid density characteristics of typical hydrocarbons, formation waters, filtrates, drilling mud systems, and mixtures of these fluids.

Utilizing this data base, optical density measurements can do an excellent job differentiating between oil, oil-base mud, and water. Hydrocarbon responses also show a strong correlation trend with optical fluid density measurements and can be used to estimate the in-situ oil gravity. Furthermore, quantitative differentiation between oil-base drilling fluid filtrates and hydrocarbons is possible. This outcome was observed with diesel, synthetic oil, and various other oil-base filtrates.

An enhanced technique has been developed, which performs a weighted regression analysis on the entire optical spectrum, to fully quantify the mud filtrate contamination, water, and formation hydrocarbon mixtures in real time. The advantage of this technique, over utilization of a single wavelength, is the ability to evaluate multi-phase fluids more precisely. Field examples are presented to illustrate the application of the optical density information to the interpretation of formation fluid characteristics. The technique reduces overall sampling time, minimizes sample contamination, improves sample quality, and provides basic characterization of the fluids.

Introduction

Modern wireline formation testers (WFT) are now designed with improved sampling, pressure, and permeability measurement capabilities. As part of the enhanced sampling capabilities, the use of an enhanced downhole spectroscopy module as shown in *Fig. 1* (working in conjunction with the pumpout module) allows the engineer to make intelligent decisions of when and where to take samples.¹⁻³

The optical spectroscopy module is typically placed in the WFT tool string between the probe and the sample chambers or pumpout module. It monitors the fluid flow in the flowline using two or more sensor systems spaced along the flowline; an optical spectrometer and an optical gas detector. The optical spectrometer allows differentiation between various liquids and is the topic of this paper. Differentiation between formation fluids and mud filtrates helps minimize the amount of sample contamination and provides a method for fluid identification.

The measurements are performed by passing light through a window opening onto the flowline; the transmitted light is received through a second window at the opposite side, and then separated into an array of filters and detectors. The transmitted light intensity at various wavelengths across the visible and near infrared range is recorded. The resulting spectrum depends on the composition of the sampled fluid. Optical fluid identification measurements are based on the considerably different light absorption spectra of water and oil in the near infrared region as shown in *Fig. 2*. Water has an absorption peak at 1450 nm and an absorption region from 1860 to 2080 nm. Oil has an absorption peak at 1720 nm.³ The longer wavelength part of the spectrum reveals information about the relative concentrations of the basic constituents (oil or