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Field Testing of Acoustic Fluid Level Instrument and Software Tools to Determine Nitrogen-Oil Interface Depths

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Abstract

Simultaneous measurements of Nitrogen/Oil interface depth using an acoustic liquid level instrument and conventional wireline density tools were performed during a routine Mechanical Integrity Test (MIT) in two oil-filled wells, a brine string well and a slick well. The acoustic tool provides a non-invasive technique by generating a pressure differential (pulse) which travels downhole through the gas at the speed of sound. Echoes are continuously reflected by wellbore discontinuities (including the gas/liquid interface) to a microphone at the surface. The reflected acoustic pulses are converted into an electronic signal and digitized, which is monitored by data acquisition and analysis computer software. The nitrogen-oil interface generates an acoustic reflection which is used to determine the movement of the interface depth over time. The purpose of the field test was to establish the accuracy of the tool as the nitrogen-oil interface depth in the well changed during nitrogen injection from the wellbore into the chimney of the cavern. At different time intervals, the nitrogen-oil interface depths were measured, using both the wireline density tool and the Echometer acoustic tool. The Echometer tool can use different initial pressure pulses to make a clear determination of nitrogen-oil interface depths down-hole using enhanced data processing software. Additionally the surface pressures were acquired and the Nitrogen/Oil interface displacement was determined in real time using a new material balance software application. The position of the Nitrogen/Oil interface based on material balance is determined using surface pressure, oil gradient, Nitrogen pressure-volume-temperature correlations and mass flow meter data.

Results indicate that both the acoustic system and the material balance software determined accurately the displacement of the interface within the well bore. The point when the interface moved past the casing shoe can be identified in the acoustic data using the polarity of the reflected signal based on the position of the interface above or below the casing shoe. The point when the interface moved past the casing shoe can also be accurately identified by the decrease in pressure buildup rate versus time when additional injected Nitrogen gas volume is required to depress the interface into the larger area below the casing shoe. The depth and cumulative volumes were used to identify cross sectional area of borehole, when the interface is above or below the casing shoe.

Acoustic liquid/gas interface tests are performed successfully in many different applications throughout the world. Technology for acoustically determining the depth to the interface is continually evolving and is improving the accuracy of acoustically determined downhole measurements. The combination of determining the interface depth using the acoustic liquid level instrument along with continuously acquired surface casing pressures provides a new accurate and low cost method to identify when the interface is depressed from above to below the casing shoe. Determination of the location of the Nitrogen/Oil interface with respect to the casing shoe points toward developing a new procedure for MIT using measured surface pressures and acoustic liquid level technology.

Key words: Caverns for Oil Storage, Caverns for Liquid Storage, Interface displacement, Acoustic Measurements, Nitrogen interface, Material Balance.