Comparing downhole chemical source neutron porosity tool calibrations with a new deuterium-deuterium downhole neutron generator tool

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Pore volume and movement of fluids through near surface geological formations can be estimated semi-quantitatively with borehole geophysical logs and has become increasingly important over the years. Several methods are used to estimate in-situ porosity and permeability, including resistivity ratios, full waveform sonic porosity and tube-wave attenuation, density porosity, borehole magnetic resonance (BMR) for bound-capillary-free water volume & hydraulic conductivity estimates, neutron porosity, along with a few other borehole logging techniques. This manuscript will focus and compare chemical source neutron-thermal-neutron and pulsed neutron methods and results from models of known porosity.

Historically, chemical source neutron tools utilizing one or two 3He detectors at a known distance from the Am241Be chemical source have been deployed. The source (1 – 5 Curie typically, higher for oil industry applications), usually mounted at the bottom of a downhole logging tool bombards the formation with fast neutrons. These neutrons, with similar molecular mass as water, slow down through elastic scattering in the fluid-filled, or partially fluid-filled formations. The rate of return to the 3He detector depends on lithology, porosity percentage, and gas-water-oil-mineral content. Count rate is generally inversely proportional to porosity. Although a very good measurement to estimate porosity, regulations, risk and cost constraints, and operational limitations often limit the use of neutron logging at many well sites and applications.

A newly developed neutron generator downhole tool does not require the Am241Be source, instead generating fast neutrons via a deuterium-deuterium (D-D) fusion reaction, thus easing historical constraints from using this methodology. The new 50mm OD (2”) tool, de-centralized in a borehole, includes a wireline power and telemetry section, the slimline neutron generator, and optimized near and far detectors and associated electronics. Neutron energy flux produced by today’s commonly used AmBe tools ranges from 1 – 6 MeV. At 2.5 MeV or so, the D-D produced neutron energy is suitable for most slimline borehole geophysics applications, including groundwater & hydrogeology, lithostratigraphic porosity, mine de-watering projects, moisture content profiling and pore/grain size analysis, along with many other possibilities. The new tool design uses array domino detectors, replacing prior generation 3He detectors.

MCNP simulations for the D-D neutron porosity tool will be presented and compared to AmBe tool results. These results allow us to optimize detector spacing and ultimate D-D tool performance, while establishing a market gap solution for non-hydrocarbon applications where chemical neutron sources are discouraged. Preliminary data indicates excellent limestone porosity response compared to 16 Curie AmBe source.