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An approach to derive some simple empirical equations to calibrate nuclear and acoustic well logging tools

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HIGHLIGHTS

- Three concrete pads were constructed from primary building materials to calibrate the density tools.
- The calibration process for neutron tool completed depending on the (18%) and 100-percent.
- The application of empirical equations illustrates very good result.

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ABSTRACT

A set of three pads was constructed from primary materials (sand, gravel and cement) to calibrate the gamma-gamma density tool. A simple equation was devised to convert the qualitative cps values to quantitative g/cc values. The neutron-neutron porosity tool measures the qualitative cps porosity values. A direct equation was derived to calculate the porosity percentage from the cps porosity values.

Cement-bond log illustrates the cement quantities, which surround well pipes. This log needs a difficult process due to the existence of various parameters, such as: drilling well diameter as well as internal diameter, thickness and type of well pipes. An equation was invented to calculate the cement percentage at standard conditions. This equation can be modified according to varying conditions.

1. Introduction

Calibration process of geophysical well-logging tools is an essential step in quantitative evaluation of the data. Nevertheless, it is most an ignored aspect in well-log analysis (Richard E. Hodges, 1988).

Technology experts is a specialized company in well-logging for groundwater exploration. It owns a well-logging system that contains different tools or probes. The two nuclear porosity tools (density and neutron) record the densities of rocks and formation porosities respectively in cps values. These values give only a qualitative information about both density and porosity.

Porosity determination, evaporate deposit identification, gas detection, hydrocarbon density determination, shaly sand lithology evaluation and rock mechanical properties represent the main uses of density logs (Schlumberger, 1989a)

The density probe needs a radioactive Cesium-137 source to emit gamma rays to the formation and a detector to receive the unabsorbed gamma rays. Since Cesium-137 has a half-life of about 30.17 years (NIST, 2011), thus, the calibration of density probe must be done at frequent intervals.

Porosity can be determined quantitatively on the basis of neutron logging. Meanwhile, qualitatively, excellent discriminator can be obtained between gas and oil. Neutron log can also be used to identify the gross lithology, evaporates, hydrate minerals and volcanic rocks (Reider, 1996).

The Americum Beryllium (AmBe, 432.2 year half-life) neutron source emits neutrons at the same size of hydrogen atoms, which are an essential component in water and hydrocarbons. According to this accident between neutrons and hydrogen atoms, the neutrons loose their activities and change from fast to thermal neutrons. A neutron detector receives the remnant fast neutrons again.

Early Cement-Bond Log (CBL) designs (1960s) used a single transmitter and a single receiver for an amplitude measurement. CBL log evaluation is similar to that of openhole sonic logs (Pilkington, 1992). It gives a continuous measurement of the amplitude of sound pulses from transmitter to receiver. This amplitude is maximum in less fixed pipes, and minimum in well-cemented casing.

2. Problems

The geophysical well-logging tools in Technology Experts Company in Saudi Arabia (TECSA) especially density, neutron and CBL measure

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the physical quantities only apparently, such as:

1. The density tool measures the values in cps units. This unit can give an idea about the high, moderate and low bulk density zones along the well and don't give any idea about the accurate rock density values, in g/cc. The (TECSA) company has only one molted Aluminum pad, which has a density value of 2.56 g/cc for calibration.
2. The measure cps values represent the results of neutron – neutron tools. These values suit is reversibly proportional with porosity percentage values. This is due to the fact that the detector kind is a neutron detector. The (TECSA) company has only one calibration box that has a known porosity percentage value.
3. μs/ft is the measurement unit used in CBL log. This unit can illustrate the cementation value qualitatively but not quantitatively. It cannot measure accurately the cement bond percentage.

3. Methodology

Calibration processes for the three tools (density, neutron and PDEL) were executed after conducting many trials and several tests to reach suitable empirical equations that can be applied to give accurate and standard values for each tool.

3.1. Calibration of density tools

There are two probes that can measure bulk density values named Formation Sidewall Density probe for GeoVista company (FDSB**)** and Density/ Gamma probe for Robertson Geologging Company (GDDS)**.** The density values are measured in cps units using these probes. One molted aluminum pad possessing a density value of 2.56 g/cc is present. The calibration process cannot be completed depending on one calibration pad. Thus, three steps will be followed to complete the calibration process successfully. These steps include the following.

3.1.1. Construction of the calibration pads

Three pads were constructed from three primary materials. These include sand, gravels and cement. The amounts of cement were stable in the three pads. However, the amounts of gravel and sand were different from one pad to anther. More gravel and less sand gives a high-density pad but more sand and less gravel yield a low-density pad. The third one was constructed from equal amounts of sand and gravel. The dry primary materials (sand, gravels and cement) for each pad were blended using a suitable blender during one hour for a homogenous mixture. The three concrete pads were constructed similar to the molted aluminum one both in size (80 cm length, 25 cm width and 30 cm height) and shape. Three cubic samples (10 × 10 × 10) cm also constructed one for each pad

After dryness of the three pads and cubic samples, the density of each cubic sample was calculated, we own now four pads with different densities. These densities reach 2.56, 2.27, 2.11 and 1.98 g/cc for molted aluminum, high concrete, moderate concrete and low concrete pads respectively. Fig. 1 illustrates the four density calibration pads.

3.1.2. Data acquisition on pads

After fixing the gamma-gamma source at the end of the density probe, it must be installed on the surface of each pad. Then, a suitable number of readings is taken that amount more than 10,000 cps for each pad. The average cps value is calculated for every pad.

3.1.3. Derivation of the equation

Plotting the results of source measurements, in cps against the known pad density values on a semi-logarithmic paper in relation to the FDSB density tool which have distance about 47 cm between the source and detector. The derived equation from this linear relationship is shown on Fig. 2. This empirical equation can be used to convert the cps values to g/cc values. This equation can be applied along the recorded well.

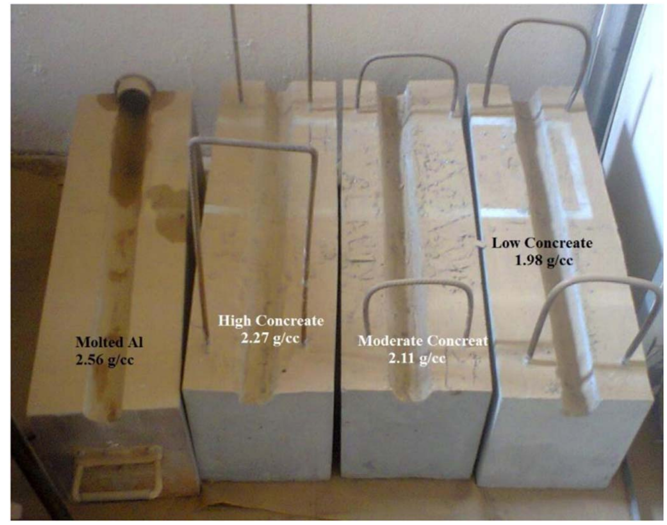

Fig. 1. Various density calibration pads, including 2.56, 2.27, 2.11 and 1.98 g/cc.

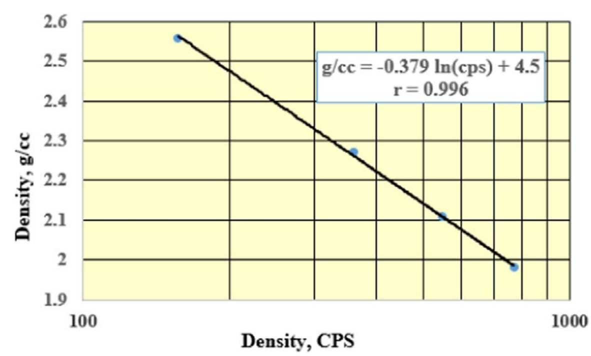

Fig. 2. Relationship between source measurements in (CPS) and real densities of the four pads for FDSB density tool.

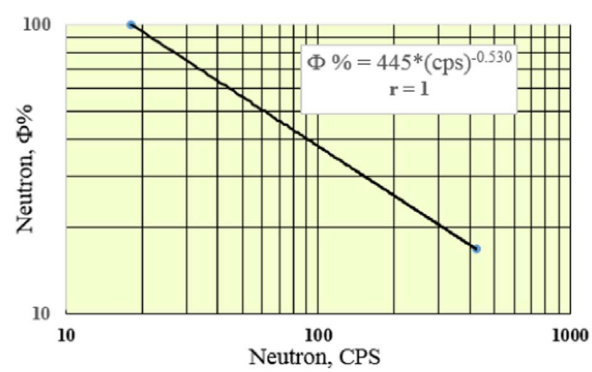

Fig. 3. Relationship between measurements in (CPS) and the standard porosity calibration box in %, for the neutron tool.

3.2. Calibration of neutron tool

Only one standard porosity calibration box was found to calibrate the neutron tool. So, it is impossible to carry out the calibration process depending on one reading. Thus at least another reading with a different porosity value is needed.

A reference box having 100% porosity can be used, when the neutron probe is lowered into the center of a container processing sides of 2*2*2 m, filled with water.