

Investigation of Neutron Detector Response to Varying Temperature and Water Content for Geothermal Applications

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INTRODUCTION

Nuclear logging techniques have been used for oil well logging applications for decades [1]. The basic principle is to use a neutron and/or photon source and neutron and photon detectors for characterization purposes. Although the technology has matured, it is not directly applicable to geothermal logging due to even more challenging environmental conditions, both in terms of temperature and pressure. For geothermal logging, the operating temperature can go up to 376°C for depths up to 10,000 km [2,3].

In this paper, the preliminary computational results for thermal neutron detector response for varying temperature and water content for geothermal applications are presented.

NEUTRON DETECTOR RESPONSE TO VARYING TEMPERATURE AND WATER CONTENT

In nuclear logging, combined neutron and photon measurements are used to determine formation properties including porosity, density, liquid content (water in this case), and composition of the formation. Neutron detector measurements are used to estimate porosity, density, and water content of the formation. The results from photon spectroscopy are used to determine the composition of the formation.

The neutron detector measurements can be performed using either a steady-state neutron source (e.g., AmBe) or a time dependent source, for example a pulsed neutron generator (PNG) with 14 MeV neutrons and varying burst on-off times to determine the decay time. From these decay curves, the density and porosity of the formation are determined.

In this study, the preliminary analysis was performed to determine the neutron detector response for varying porosity, water content, and temperature. This initial analysis was performed using a generic tool. Currently, the tool is not yet being optimized for this specific application. For this purpose, input 12 of the MCNP [4] sample problems, distributed with the code, was modified. The analyses were performed using both a steady state neutron source (AmBe) and a pulsed neutron generator. The formation was defined as a sandstone rock formation and the density of a dry formation was taken as 2.69 g/cm³. For this analysis the porous volume was filled with water and the density was adjusted accordingly. Two

He-3 neutron detectors at 10 atm pressure were used to determine tool response for varying environmental conditions. The computations were performed using MCNP5 with ENDF/B-VII nuclear data libraries.

The neutron detector response as a function of temperature for two different porosities is shown in Fig. 1. In this case, the source is a steady state AmBe neutron source. As can be seen from the figure, the counts in the detector increase with increasing temperature for both porosities with varying slope. The increase in counts with increasing temperature is linear.

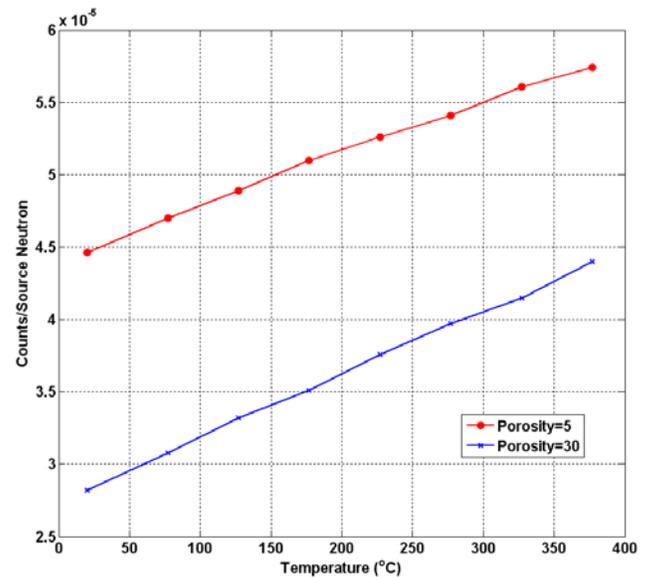


Fig. 1. Change in neutron counts, per source neutron, as a function of temperature for 5% and 30% porosity. The porous volume is filled with water. The neutron source is AmBe.

The same analysis has been performed for time dependent measurements. The 14 MeV neutron source is assumed to be on from 0 to 100 μ s. The decay of the neutrons is observed up to 800 μ s. Neutron decay curves for 5% and 30% porosity at 20°C and 376°C are shown in Fig. 2. As evident from the figure, there is a change in the detector response not only for varying water content but also for the varying temperature.

It should be noted that, at this time, the optimization for burst on-off times for the source has not been performed yet.

An earlier study showed that for decay time measurements, there is a very good agreement between the measured and computed values for a real oil-well logging tool [5]. The results reported in Ref. 5 were for room temperature measurements and computations using photon detectors.

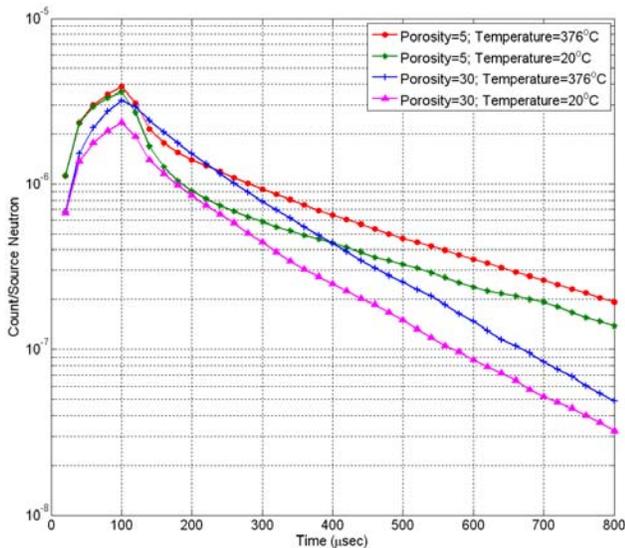


Fig. 2. Decay curve for formation with 5% and 30% porosity and temperatures of 20°C and 376°C. Source is 14 MeV neutrons from pulsed neutron generator and it is on for 100 μ s.

SUMMARY AND FUTURE WORK

In this summary, preliminary results for neutron detector response for varying formation temperature and water content are presented. The analysis is performed for a steady state source (AmBe) and time dependent source (PNG) in pulsed mode. The computational results show significant sensitivity to water content as well as temperature changes for both steady state and time dependent measurements. As expected, the most

significant change is due to the temperature change for $S(\alpha, \beta)$ nuclear data instead of individual isotope cross sections for the formation. Clearly, this is partially because of the fact that strong absorbers (i.e., chlorine) are not taken into account for the analysis at this time. The computational analysis was performed using the temperature dependent data in the ENDF/B-VII libraries, supplied with MCNP. Currently, the data for intermediate temperatures are being generated using NJOY and validated.

A series of measurements are planned to validate the computational results. Further measurements are planned to determine the neutron and photon detector response as a function of temperature. The tests will be performed for temperatures up to 400°C.

ACKNOWLEDGEMENT

This work is funded by the Department of Energy's Geothermal Office.

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