SIMULATION OF DENSITY CURVE FOR SLIM BOREHOLE USING THE MONTE CARLO CODE MCNPX

Edmilson Monteiro de Souza, emonteiro@nuclear.ufrj.br
Programa de Engenharia Nuclear, COPPE, Universidade Federal do Rio de Janeiro (UFRJ)
Ilha do Fundão, Caixa Postal 68509, 21945-970, Rio de Janeiro, RJ, Brasil.
Centro Universitário Estadual da Zona Oeste (UEZO)
Avenida Manuel Caldeira de Alvarenga, 1203, 23070-200, Rio de Janeiro, RJ, Brasil.
Samanda Cristine Arruda Correa, scorrea@nuclear.ufrj.br
Centro Universitário Estadual da Zona Oeste (CCMAT/UEZO)
Avenida Manuel Caldeira de Alvarenga, 1203, 23070-200, Rio de Janeiro, RJ, Brasil.
Ademir Xavier da Silva, ademir@nuclear.ufrj.br
Programa de Engenharia Nuclear, COPPE, Universidade Federal do Rio de Janeiro (UFRJ)
Ilha do Fundão, Caixa Postal 68509, 21945-970, Rio de Janeiro, RJ, Brasil.
Inaya C.B. Lima, inaya@lin.ufrj.br
Instituto Politécnico do Rio de Janeiro, Universidade Estadual do Rio de Janeiro (IPRJ/UERJ)
Rua Alberto Rangel, s/n, Parque Ambiental Luiz Simões Lopes, Nova Friburgo, Rio de Janeiro, RJ, Brasil.
Paula L.F. Rocha, ferrucio@acd.ufrj.br
Departamento de Geologia, Universidade Federal do Rio de Janeiro (UFRJ)
Ilha do Fundão, CCMN, Bloco F, Rio de Janeiro, RJ, Brasil.
Ricardo Tadeu Lopes, ricardo@lin.ufrj.br
Programa de Engenharia Nuclear, COPPE, Universidade Federal do Rio de Janeiro (UFRJ)
Ilha do Fundão, Caixa Postal 68509, 21945-970, Rio de Janeiro, RJ, Brasil.

Abstract. *Borehole logging for formation density has been an important geophysical measurement in oil industry. For calibration of the Gamma Ray nuclear logging tool, numerous rock models of different lithology and densities are necessary. However, the full success of this calibration process is determined by a reliable benchmark, where the complete and precise chemical composition of the standards is necessary. Simulations using the Monte Carlo MCNP have been widely employed in well logging application once it serves as a low-cost substitute for experimental test pits, as well as a means for obtaining data that are difficult to obtain experimentally. Considering this, the purpose of this work is to use the code MCNP to obtain density curves for slim boreholes using Gamma Ray logging tools. For this, a Slim Density Gamma Probe, named TRISOND^R, and a 100 mCi Cs-137 gamma source has been modeled with the new version of MCNP code MCNPX.*

Keywords*: Borehole logging, nuclear logging, MCNP, MCNPX.*

1. INTRODUCTION

Borehole logging for formation density has been an important geophysical measurement in oil industry. In general, the gamma density tool consists of a gamma-ray source, and two gamma detectors placed to different distance from the source, where the gamma radiation from the source is backscattered by the formation (Compton Effect) and reaches the two detectors where the relative count-rates provide a measure of formation bulk density (Bertozzi et al, 1981). For calibration of the Gamma Ray nuclear logging tool, numerous rock models of different lithology and densities are necessary. However, the full success of this calibration process is determined by a reliable benchmark, where the complete and precise chemical composition of the standards is necessary, and the calibration curves should take account the borehole casing and the presence of liquid inside the hole for data correction (Gardner et al, 1980).

Simulations using the Monte Carlo code MCNP have been widely employed in well logging application once it serves as a low-cost substitute for experimental test pits, as well as a means for obtaining data that are difficult to obtain experimentally (Gardner et al, 2010). Considering this, the purpose of this work is to use the code MCNP to obtain Density Curves for Gamma Ray logging tools. For this, a Slim Density Gamma Probe, named TRISOND^R, and a 100 mCi Cs-137 gamma source with a 0.662 MeV gamma-ray has been modeled with the new version of MCNP code MCNPX (Pelowitz, 2005). The effects of casing material composition and the presence of liquid inside the hole in the detectors count rates will be considered.

2. COMPUTER MODEL

The simulated probe in this work was a model of the *Density Gamma Probe – TRISOND^R*, produced by *Robertson Geolloging Limited*. The tool is a 3.8cm diameter slim probe, which contain two high-sensitivity NaI(Ta) scintillation gamma detectors with different sizes, named *Long-spacing detector (LSD)*, used for low count rate and *High-resolution detector (HRD)*, used for higher count rat, placed inside a steel shield (probe body). On probe top some space is reserved for the data acquisition systems. A Cs-137 gamma source is housed in a steel holder, and attached to the probe body. The source-detector distances are respectively 48cm (*LSD*) and 24cm (*HRD*). Figure 1 shows the probe modeled. The images were obtained using the software MORITZ[R] geometry tool.

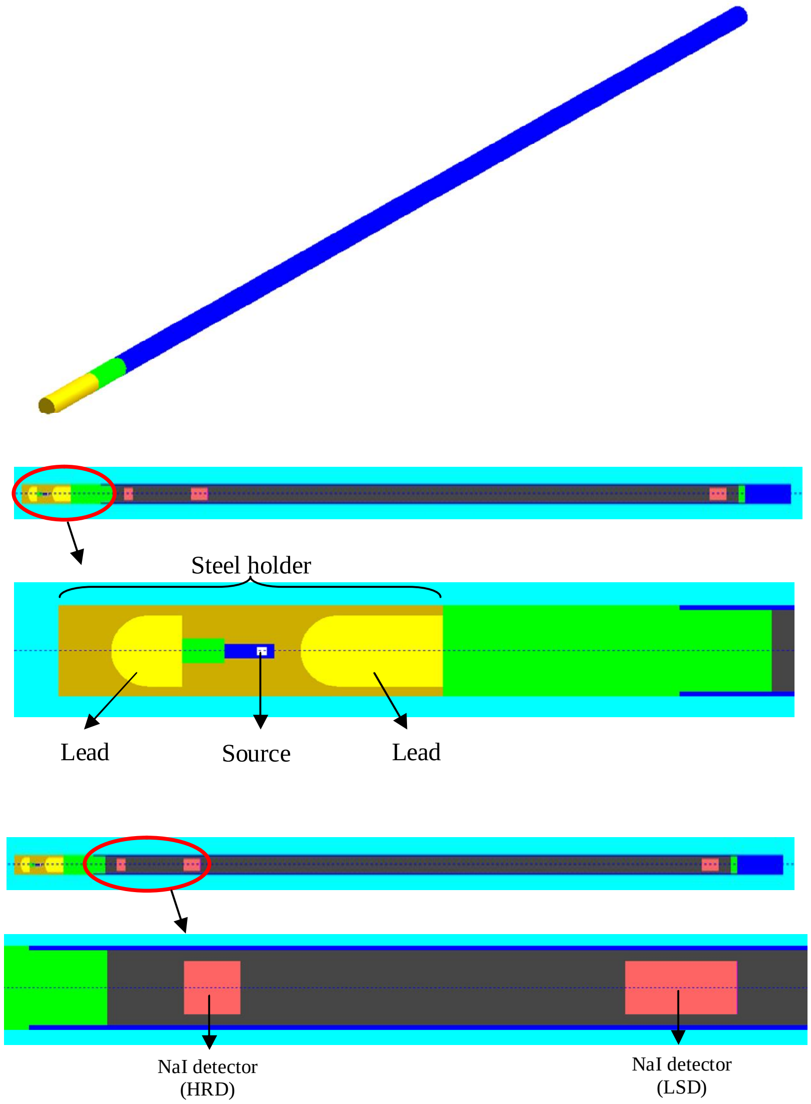

Figure 1. The MORITZ geometry of the *Density Gamma Probe – TRISOND*[R]

The calculations were done simulating the probe inside a 7.5cm diameter *slim borehole*. For analyze the influence of the casing in the gamma detector count rate, the borehole was cased with steel casing and after with PVC (*Polyvinyl chloride*) casing. In both situations the thickness of casing is set 0.3cm. A section of the tool inside the borehole is shown in Figure 2. The probe is placed against the borehole wall. The rest of the borehole is filled with fresh water (ρ = 1 g/cc).

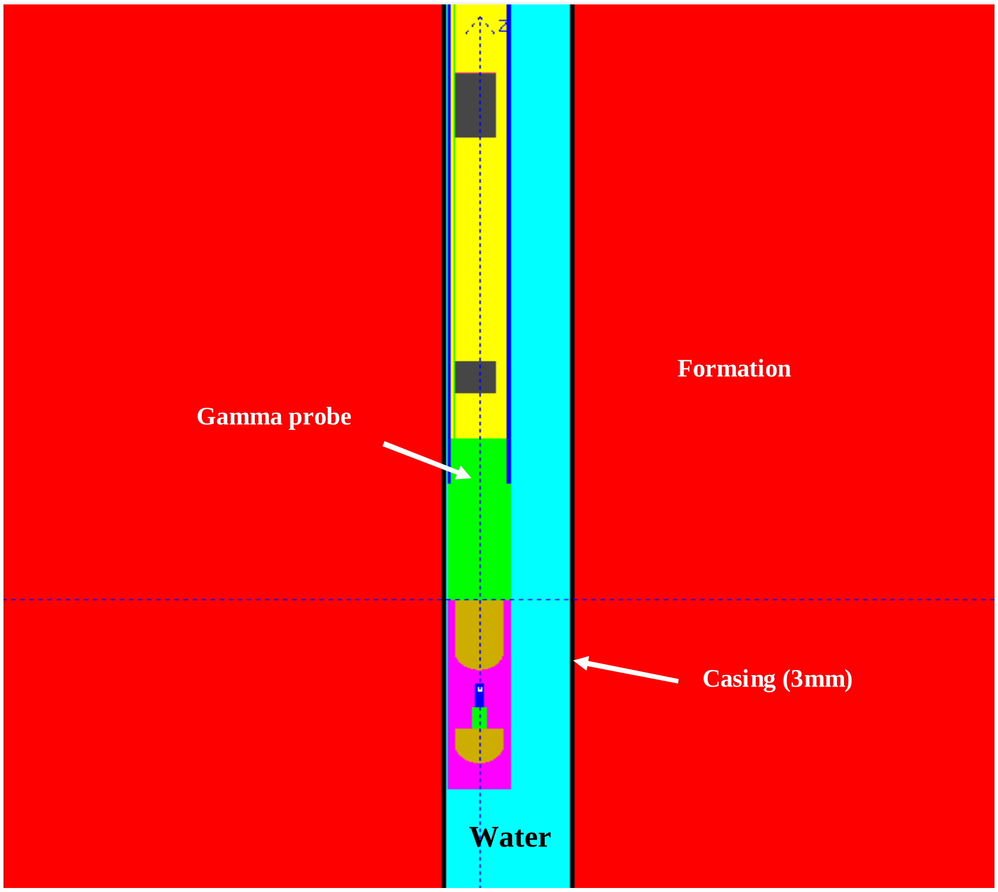

Figure 2. MCNP geometry of the probe inside the borehole

Surrounding the borehole is the formation. In the simulation, the formation thickness is 120cm and the formation radius is 60cm. Several rocks with porosity of zero and different densities values were used for obtaining the density curve. The Chemical composition of the rocks and their respective densities are shown in Table 1.

Table 1. Rock formations and densities values

Formation	Density (g/cc)
Silvite (KCl)	1.984
Gypsite ($CaSO_4 2H_2O$)	2.320
Calcite ($CaCO_3$)	2.710
Anhydrite ($CaSO_4$)	2.960

The calculations were made using the Monte Carlo Code MCNPX version 2.6. In order to reproduce the real count in the detectors, a 100 mCi source power with gamma abundance of 85% was considered (Knoll, 1999). Several borehole configurations were considered for density curve determination. The MCNPX tally F4 was used to get the flux of photons in the NaI(Ta) detectors. The number of histories has been estimated according to the accuracy assumed less than 1% for the detectors cells.

3. RESULTS

3.1 Influence of the casing material composition in the detector count rate

Figure 3 shows the effect of different casing material in the HRD detector counts rate.

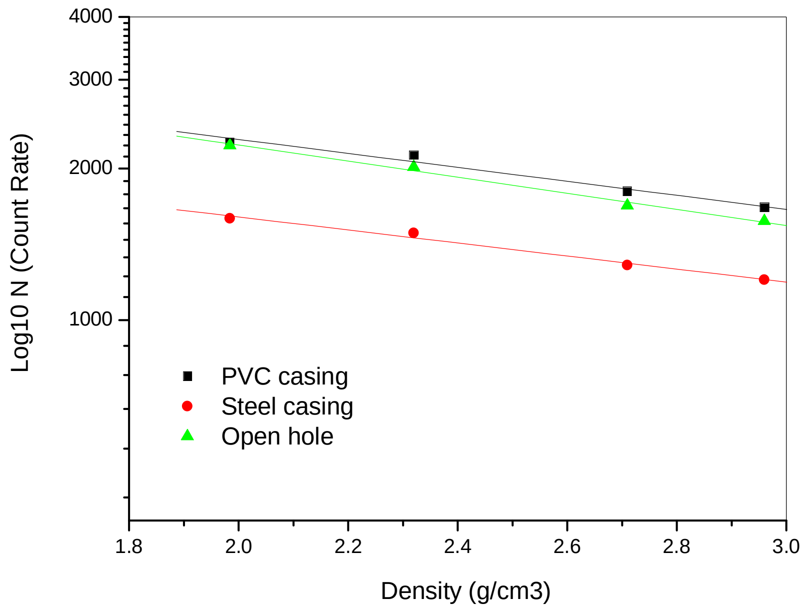

Figure 3. Comparison of HRD detector counts rate for open hole and steel and PVC cased hole. The material inside the hole was considered air

Figure 3 shows that the density counts are symmetric, but the presence of steel casing decreases the detector counts about 482 units with relation to PVC cased hole and opened hole due the high cross section of the back scattered photon in the formation for steel material. In the other hand, the figure shows that the PVC material is ideal for this kind of borehole, once that the detector counts were similar to open hole counts. The same behavior can be seen in Figure 4 to LSD detector counts. However, the influence of the steel casing in the LSD detector counts is lower than HRD detector, once that the difference between the counts was about 47 units.

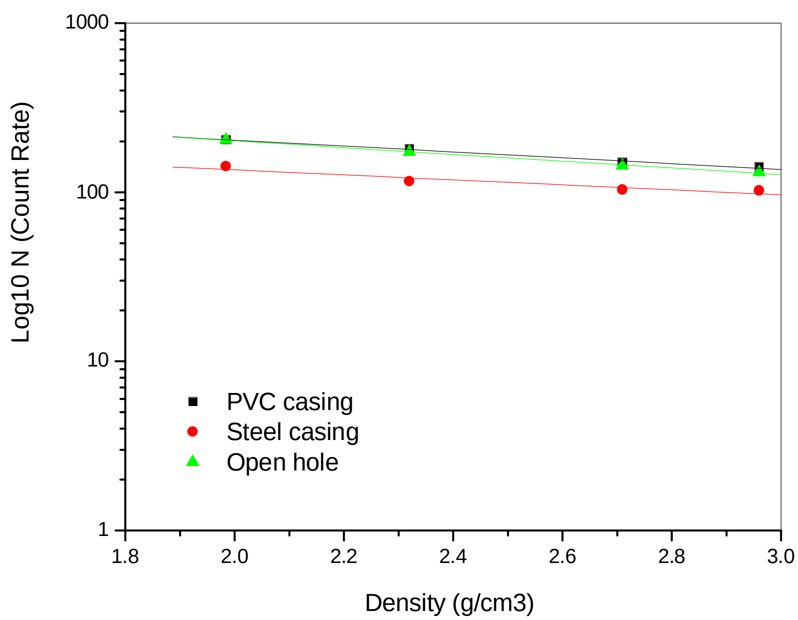

Figure 4. Comparison of LSD detector counts rate for open hole and steel and PVC cased hole. The material inside the hole was considered air

3.2 Influence of the liquid inside the borehole in the detector counts rate

The influence of the liquid inside the borehole in the HRD and LSD detector counts is shown in Figure 5.

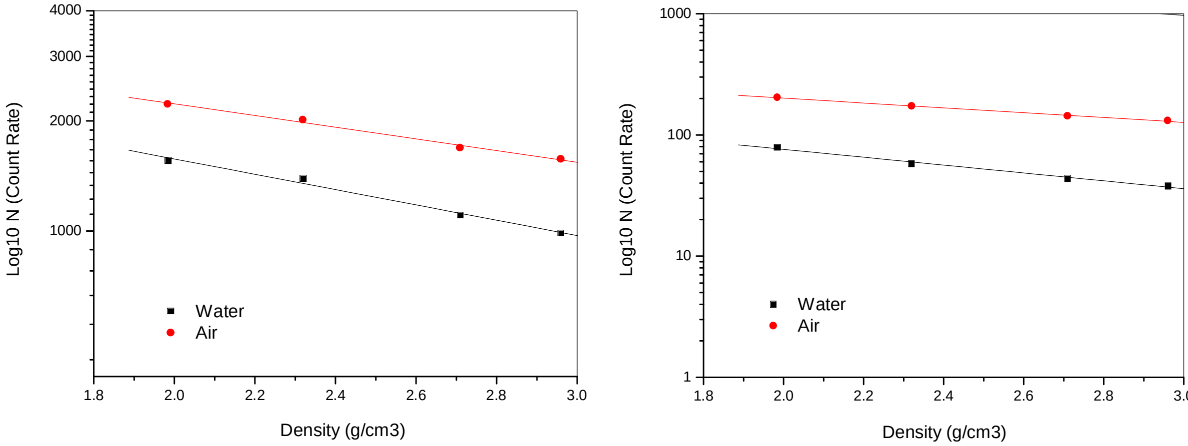

Figure 5. Density curves considering water and air inside the borehole for: (a) HRD detector and (b) LSD detector

Through the figure 5 is observed that the presence of water inside the hole influences significantly the detector counts. For HDR detector the decrease of the counts was about 613 units, while for LSD detector it was about 108 units. In the case of the *slim borehole*, the gamma rays are backscattered for all formation surrounding the borehole. Consequently, the presence of water inside the hole works just like a shield to the low energy backscattered gamma ray, decreasing the counts in the detectors. Figure 6 shows this behavior.

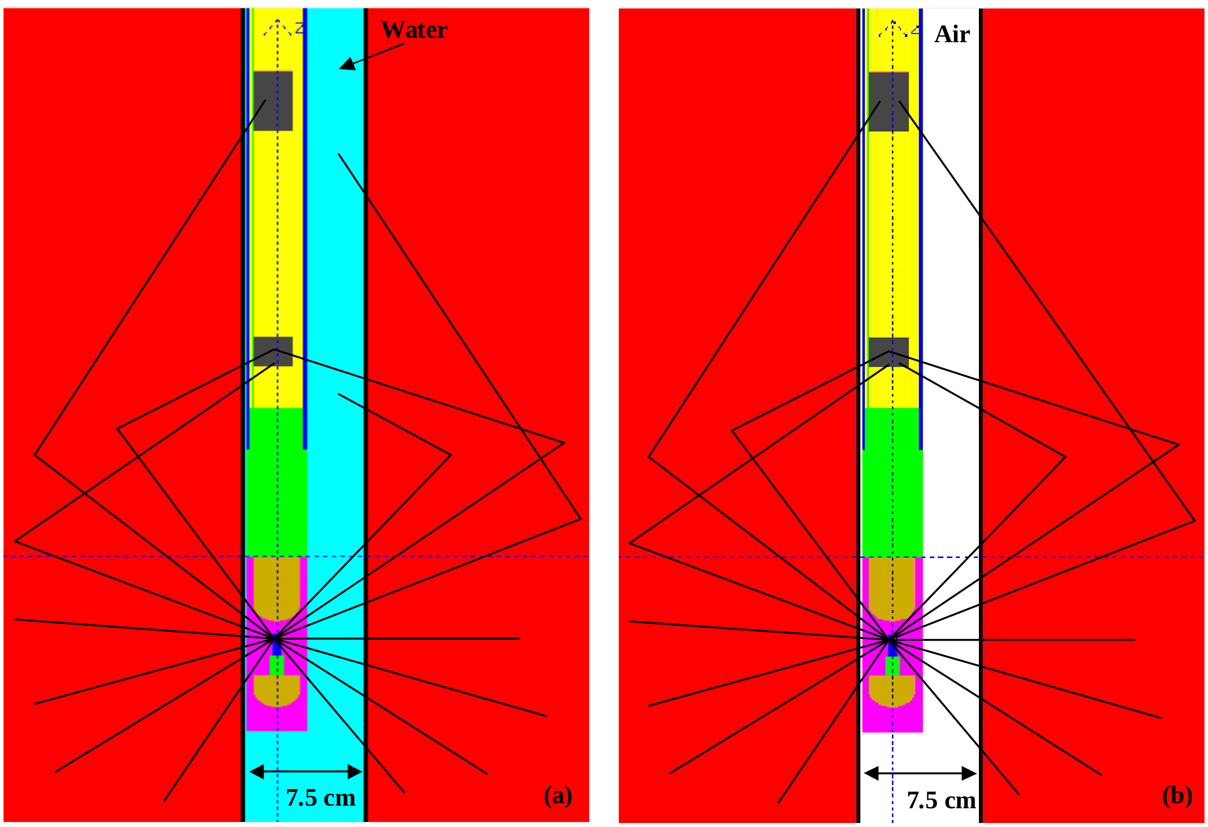

Figure 6. Schematic representation of the backscatter radiation in the formation for (a) water inside de hole and (b) air inside the hole

4. CONCLUSIONS

The results obtained in this work suggest that the determination of density curves for *slim borehole* should take account parameters like type of casing material and presence of liquid inside the hole. In this kind of borehole, the detector counts depend not only the radiation backscattered from the formation against the probe, but also the radiation from all formation surrounding the hole, and the presence of the gamma absorbers materials can prevent the multiple scatter photons reaching the detectors. Finally, the results also confirmed that the MCNPX code is very useful in well logging studies.

5. ACKNOWLEDGEMENTS

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