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N451 γ Spectrometry Logging Probe and Logging Techniques

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1 Introduction

In 21st Century, to meet the demands of nuclear power industries in China for uranium resources, the hydrothermal uranium deposit becomes the key type of deposits in uranium exploration again. For hydrothermal uranium deposits mixed with thorium, the contents of uranium and thorium in the layer could be accurately measured only by γ spectrometry logging method. At present, γ spectrometry logging instruments are mainly used in coal and oil-gas field exploration in the world, but only uranium of low content in the layer could be measured, so the instruments are not suitable for measuring uranium of high content in the layer. So the invention of γ spectrometry logging instruments for uranium exploration is of important significance.

2 N451 γ Spectrometry Logging Probe

N451 γ spectrometry logging probe is designed with 1024 channels based on pulse-amplitude analysis (Jiao et al., 2009), and the schematic diagram is shown below (Fig.1). The main characteristic is that the design adopts the construct of dual microprocessors responsible for data acquisition and transmission. That makes the maximum data transmission rate up to 333 kb/s which lays the foundation for full spectrum acquisition and transmission on the condition of the high count rate of the nuclear pulse.

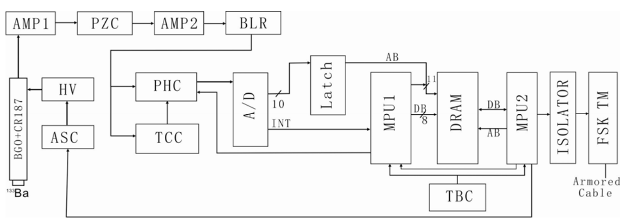

Fig. 1. Schematic of N451 γ spectrometry logging probe.

BGO crystal（φ30mm×100mm） is used in the probe to enhance the detection efficiency. By detecting the full energy peak (358keV) of the reference source ^{133}Ba, the function of automatic spectrum stabilization is realized by adjusting the value of the high voltage of the photomultiplier on the basis of four-window-spectrum-stabilization method (Lu and Zhang, 2008). The result of the test on the benchmark logging well models shows that the peak drift of the energy peak 2614keV is only 0.96%.

3 γ Spectrometry Logging Techniques

3.1 Optimal energy windows

A set of optimal energy windows is selected to accurately measure the content of uranium and thorium. According to the test made on the benchmark logging well models, the scheme of 2 wide energy windows is adopted finally which includes U window (1.05～2.00 MeV) and Th Window (2.00～2.90 MeV).

3.2 Calibration method

There are two steps for the calibration to the N451 logging instrument. Step1: After the count rates of U and Th window have been corrected with their respective dead time, calibration coefficients are calculated by the count rates and the contents of uranium and thorium in the models; Step2: the contents of uranium and thorium in the uranium-thorium mixed logging models are calculated. The test results about the comparison between the calculated content and the nominal content of uranium and thorium in the mixed logging models, all of the relative errors are below 10% (Table 1). That proves the calibration method is correct and adaptive.

3.3 Absorption coefficients of water and iron pipe

For γ spectrometry logging, the absorption coefficients

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Table 1 Test results in the mixed models

Model Code	Element	Nominal content （%）	Measured content （%）	Relative error （%）
U-Th-1	U	0.2047	0.1871	-8.60
	Th	0.0709	0.07401	4.37
U-Th-2	U	0.0096	0.0090	-6.09
	Th	0.0319	0.0300	-6.18

of water and iron pipe should be measured for U and Th windows respectively. In Metrology Station of Radio Geological Survey of CNNC, well models are built with the building blocks, and the absorption coefficients are measured in the models.

3.4 Data processing method

The procedures of data processing are as follows (Cardoso et al., 2004): ① dead time correction, and water and iron absorption correction for the count rates of U and Th windows; ② calculation of primary contents of uranium and thorium; ③ calculation of contents of uranium and thorium of each unit layer with 5-poin-deconvolution method.

3.5 Working procedure in the field

First, the depth of each anomaly segment is confirmed when the probe moves downwards at the speed lower than 5m/min. Then the probe is lift upwards to the anomaly segment at a fast speed after the probe has reached the bottom of the well, and the probe is lift upwards on the anomaly segment at the speed of 1～1.5m/min.

4 Field Logging Test

In 2012, test was done in uranium deposit mixed with thorium in the west of Xiangshan where logging data of 4 drilling holes was acquired. Comparison is made between the results made by γ logging method with FD-3019 performed by Geological Party 261 and that made by γ spectrometry logging method with N451 γ spectrometry logging instrument. There are industrial ore block (U≥0.05%; 32.6m), mineralized block (0.03%≤U≤0.05%; 7.5m) and anomaly block (0.01%≤U≤0.03%; 31.4m). By calculation, the relative error of total uranium linear reserves is -4.23%. Cores acquired from the anomaly segment with the total length of 31.7m in 4 drilling holes are analyzed with neutron activation analysis method, and compared to the results of γ logging and γ spectrometry logging, the relative error of total uranium linear reserves is 33.65% (FD-3019) and 26.18% (N451). Maybe that is caused by the fact that the uranium is not well distributed in the ore body, so the scope of the same ore-body reflected by the core is different from the scope reflected by γ survey.

5 Conclusions

N451 γ spectrometry logging probe is designed and produced which could work normally and stably in the temperature of the drilling hole from 10℃ to 50℃. The maximum uranium and thorium content measured could reach to 1.093% and 1.5% separately. The correspondent γ spectrometry logging techniques are set up, so the probe could be used to continuously and effectively measure the content of uranium and thorium of the layer around the borehole in uranium exploration. Above all, continuous γ spectrometry logging is performed in the domain of uranium exploration in China.

Acknowledgements

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