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Uranium Enrichment Measurement for a UF_6 Cylinder Verification using the Quad-CZT Array

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1. Introduction

The verification of UF_6 cylinder is an important activity in routine safeguards inspection in the field so International Atomic Energy Agent (IAEA) pursues technologies providing information on uranium enrichment classification of UF_6 cylinder, quickly and accurately.

With that purpose, the present authors designed and built a new portable gamma spectrometry system utilizing the quad-CZT array. A CZT was selected due to better resolution and simpler experimental setups than other gamma-ray detectors such as a HPGe and NaI. The quad-CZT array is then applied to the verification of UF_6 cylinder at the KEPCO Nuclear Fuel (KNF).

2. A New Portable Gamma Spectrometry System

A CZT is operable at room temperature and has medium-level energy resolution due to its high atomic number, wide band-gap, and low electron-hole production energy. However, its limited physical size typically leads to low detection efficiency so longer measuring time is finally required [1].

To address this drawback of the CZT, a quad-CZT array which consists of four CZT detectors, a lead collimator, and the related DAS (Data Acquisition System) is designed and built. All components are placed in a field case (H23.5 x W51 x L38 cm). The total weight of the system, including all components and field case, is 28 kg. The operating program and analysis algorithm are also developed.

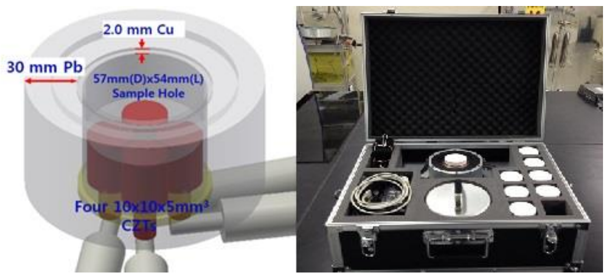

Fig. 1. Structure of the quad-CZT array (left) and a picture of the portable gamma spectrometry system (right).

The digital signal processing circuit consists of four ADCs, a FPGA (Filed Programmable Gate Array) and a MCU (Micro Control Unit). Each ADC digitizes the voltage signal from an analog circuit for four detectors [Figure. 2].

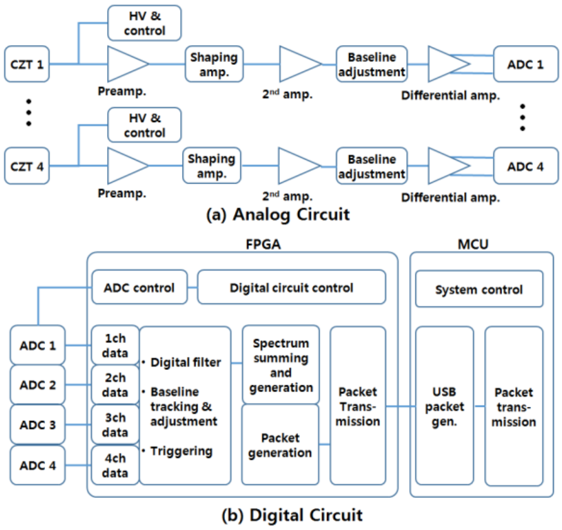

Fig. 2. A block diagram of analog and digital circuits for the portable gamma spectrometry system.

3. Experimental Work and Results

3.1 Detector Setups

Since the new portable gamma spectrometry system was designed for a pellet or cylindrical sample, the whole system was placed as closer as possible to a UF_6 cylinder [Figure. 3].

Fig. 3. Experimental setups and data acquisition for the verification of UF_6 cylinder at the KEPCO Nuclear Fuel (KNF).

The acquisition time was equally set up 300 sec for all measurements. The obtained spectra from three cylinders are shown in Figure 4.

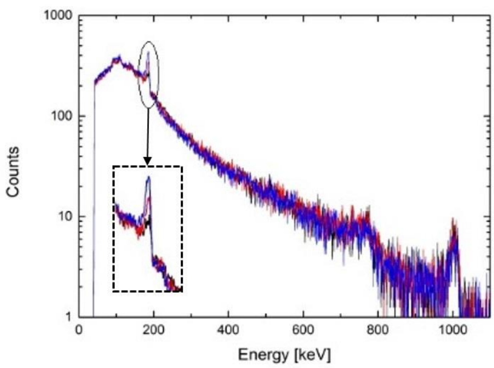

Fig. 4. Obtained spectra from three UF_6 cylinders at the KEPCO Nuclear Fuel (KNF).

3.2 Enrichment Calculation

The derivations in this subchapter assume that the first UF_6 cylinder is known certified source and other two cylinders are unknown samples since there is no certified UF_6 cylinder. The declared enrichment value of the certified UF6 cylinder (first cylinder) was 3.14%.

The enrichment values of unknown samples are then calculated based on the following equation:

$$A_{sam} = A_{cer} \times \frac{C_{sam}}{C_{cer}}$$

A_{sam} and A_{cer} respectively indicates U-235 activity of the sample and certified source. The C_{sam} and C_{cer} are the total net counts in the 185.7 keV gamma photopeak of U-235 of the sample and certified source [2].

Table. 1. The predicted enrichment values of the unknown samples (2^{nd} and 3^{rd} cylinders).

Sample No.	Declared	Net Counts	Predicted
1 (known)	3.14	2319	-
2 (unknown)	-	1573	2.13
3 (unknown)	-	3324	4.50

3.3 Results

The predicted values for two cylinders, previously assumed as the unknown samples, were compared with the actual enrichment values. The actual enrichment values for 2^{nd} and 3^{rd} cylinder were 1.71% and 4.65%, respectively. The result shows that the new portable gamma spectrometry system little overestimated the enrichment values in field.

3. Conclusions

The present authors utilized a simple and fast technique for verification of UF_6 cylinders. As a result, the new portable gamma spectrometry system seems to overestimate the enrichment values in field.

This overestimation might be caused by the inappropriate design parameters, changes in geometry, or container wall thickness. Thus, further steps will optimize the whole system and design, and repeat measurement under the same condition.

REFERENCES

[1] S. Kwak, J. Shin, S. Park, Y. Kim, Multi-Element CZT Array for Nuclear Safeguards Application, Proceedings of the Advancements in Nuclear Instrumentation Measurement Methods and their Application (ANIMMA 2015), April 20-24, 2015, Lisbon, Portugal.

[2] S. A. El-Mongy and H. A.I, Depleted, Natural and Low Enriched Uranium Verification by Recent Portable Passive Non-destructive Assay Tools, Journal of Nuclear and Radiation Physics, Vol. 2, No. 2, p. 79-87, 2007.