A Field Test of the New Portable Gamma Spectrometry System

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1. Introduction

With the purpose of fast uranium enrichment screening, a new portable gamma spectrometry system utilizing the quad-CdZnTe (CZT) array was recently developed by the present authors. In order to perform a field test of the system, the measurement of U-235 enrichment for nuclear fuel pellets was conducted along with the IAEA Physical Inventory Verification (PIV) inspection at the KEPCO Nuclear Fuel (KNF).

The enrichment value of U-235 was calculated based on the total counts of the 185.7 keV photopeak and compared with the reference line, drawn by certified sources. The goal of this study is to experimentally evaluate the system performance of the developed system.

2. Fast Uranium Enrichment Screening

To apply this fast screening method, the exactly same measuring environment and a certified (standard) uranium source must be required. U-235 enrichment of an unknown (random) sample can be calculated based on the counts of the 185.7 keV photopeak and compared with the certificated values (declared enrichment values).

Under the same measuring environment, U-235 activity in the unknown samples can be calculated by using the following equation:

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

where A_{sam} and A_{cer} are U-235 activity of the sample and certified source. The C_{sam} and C_{cer} are the total counts in the 185.7 keV gamma photopeak of U-235 of the sample and certified source [1]. If two or more certified sources are available, the best-fit line can be drawn and then used to predict the enrichment values in the unknown samples.

3. Description of the Equipment

Mostly, CZT has been used to verify U-235 in nuclear fresh fuel and to identify Cs-137 in old spent fuel for nuclear safeguards measurements. However, its limited physical size results in low detection efficiency and finally leads to longer measuring time [2]. To address this drawback of the CZT, portable gamma spectrometry system, which consists of four daisy-chained CZT detectors (10 x 10 x 5 mm, Ritec), a lead collimator, multichannel analyzer, and related electronics.

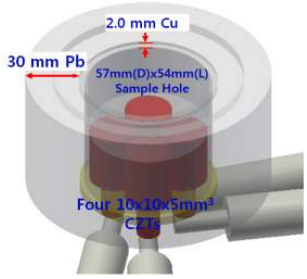

Fig. 1. The schematic diagram of the quad-CZT array with the lead collimator.

All components are placed inside a field case of H23.5 x W51 x L38 cm and its total weight is 28 kg.

Fig. 2. The portable gamma spectrometry system, developed in this study.

An algorithm to operate this system and analyze the output signals was also developed in this study. The output signals from the CZT array are delivered to the personal computer through a USB port for display and analysis.

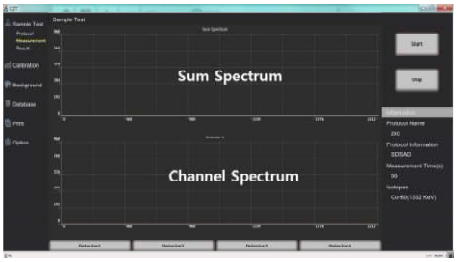

Fig. 3. A picture of user interface, developed in this study. The sum spectrum is displayed on the top screen and each individual spectrum is selectively displayed on the bottom

screen.

4. Results

4.1 Construction of a Reference Line

Three certified uranium sources were employed in order to draw the best-fit line in this study and their declared enrichment values are 0.2, 2.64, and 4.65 %, respectively.

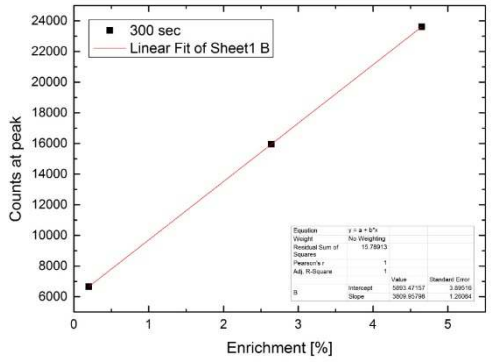

Fig. 4. The reference (best-fit) line drawn by three declared sources.

This figure shows the strong correlation (R^2=1) and the equation of the line of the best-fit was:

$$\frac{(Counts - 5893.47)}{3809.96} = Enrichment(\%)$$

4.2 Enrichment Calculation for the Unknown Samples

The total counts in the 185.7 keV gamma photopeak of U-235 of the three unknown samples, randomly chosen, were measured and then their enrichment values were predicted through the above equation. The measured values from IAEA PIV inspection are also shown and compared in Table 1.

IAEA respectively employed a $LaBr_3$ and NaI detector for low enriched sample [No. 2] and higher enriched samples [No. 1 and 3]. The obtained signals from those two detector were analyzed through the IMCA (Inspection Multi-Channel Analyzer) [3].

Table. 1. The predicted enrichment values of the selected three unknown samples.

Sample No.	1	2	3
Predicted Enrichment (%)	4.42	2.53	5.10
IAEA PIV Inspection (%)	4.12	2.36	4.63

The experiments were conducted under the exact same environment in order to cut off the perturbation from the background radiation. The acquisition time was equally set up for all measurements (300 sec).

4.3 Analysis

After acquisition, the actual declared enrichment value for the above three samples were obtained and compared with the measurement date.

Table. 2. Comparison between the actual declared and measured values for five samples, randomly chosen.

Sample No.	1	2	3
Predicted Enrichment (%)	4.42	2.53	5.10
IAEA PIV Inspection (%)	4.12	2.36	4.63
Actual Declared Enrichment (%)	4.09	2.20	4.67

5. Conclusions

The new portable gamma spectrometry system has been designed and built by the present authors. It has the ability to rapidly analyze uranium enrichment from a suspicious sample and easily transfer a portable gamma field case to any inspection points.

In this study, the new portable gamma spectrometry system showed a good linearity (R^2=1) but overestimated the enrichment values than IAEA inspection device. It could be caused by the stability of the new system since it found, right after this measurement, that the accuracy of the system gradually increases and becomes stable over time.

Further steps will optimize the design parameter based on these results and repeat measurement with the same samples under the same environment.

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