Transactions of the Korean Nuclear Society Spring Meeting
Jeju, Korea, May 12-13, 2016

Development of the 2nd Generation of a Quad-CZT Array Based Uranium Enrichment Measurement Equipment

Ae-Ri Lee [a], Jung-Ki Shin[b], Uk Ryang Park [a], Seunghoon Park [a], Heejun Chung [a], Yongkwon Kim [c], Sung-Woo Kwak [a*]
[a] *Korea Institute of Nuclear Non-proliferation and Control, Yuseong-daero, Yuseong-gu, Daejeon, Korea 305-348*
[b] *Korea Institute of Nuclear safety, 62, Gwahak-ro, Yuseong-gu, Daejeon, Korea 34142*
[c] *NuCare Medical Systems, INC., 30 Songdo Miraero, Yeonsu-gu, Incheon, Korea 406-840*
[*] *Corresponding author: swkwak@kinac.re.kr*

1. Introduction

A CZT (CdZnTe) semiconductor detectors are capable of providing superior energy resolution and gamma ray interactions in several fields, including nuclear physics, medicine and gamma-ray imaging at room temperature. [1] CZT has been used to verify U-235 in fresh fuel and to identify Cs-137 in old spent fuel for nuclear safeguards measurements.

With the purpose of verification for UF_6 cylinder and fast uranium enrichment screening at the KEPCO Nuclear Fuel (KNF), the present authors was developed portable gamma spectrometry system utilizing the Quad-CZT array in 2014. In this study, new equipment system was developed to improve the drawback of 1st Quad-CZT array system. The goal of this study is to experimentally evaluate the new equipment system performance.

2. Materials and Methods

In this paper, the first developed equipment and newly developed equipment were represented as 1st Quad-CZT array system and 2nd Quad-CZT array system, respectively.

2.1 The 1st Generation of a Quad-CZT Array Based Equipment

A single CZT limited physical size results in low detection efficiency and finally leads to measurement time [2]. To Compensate for this drawback of the CZT, portable gamma spectrometry system, which consists of four daisy chained CZT detectors (10 × 10 × 5 mm, Ritec), a lead collimator, multichannel analyzer, and related electronics.

The 1st Quad-CZT array system are placed inside a field case of H23.5 × W51 × L38 cm and its total weight is 28kg as Figure 1 shows.

Fig. 1. Picture of the 1st Quad-CZT array system

2.2 The 2nd Generation of a Quad-CZT Array Based Equipment

The 2nd Quad-CZT array was designed as figure 2 shows.

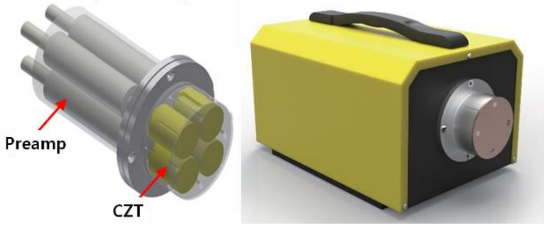

Fig. 2. The Inner Structure of the 2nd Quad-CZT array (left) and a figure of the 2nd Quad-CZT array system (right).

In spite of 1st Quad-CZT array system is a portable equipment, it has drawback of size and weight. In addition to, 1st Quad-CZT is hard to approach UF_6 cylinder at KNF, as figure 3 shows. The 2nd Quad-CZT was designed and developed to compensate for this drawback.

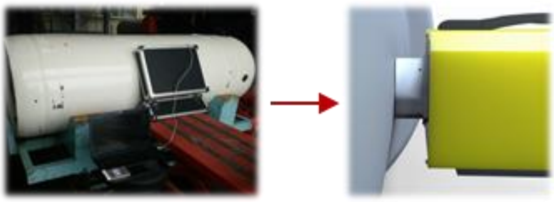

Fig. 3. The Picture of actual Measurement using the 1st Quad-CZT array system (left) and a figure of design using the 2nd Quad-CZT array system (right).

The equipment size of 2nd Quad-CZT array system is H18.2 × W19.2 × L32.4 cm^3 without a case and a shielding material (Pb) case, and its total weight is 12 kg. The 2nd Quad-CZT array system is composed of CZT hardware, measurement software, shielding material (Pb) as figure 4 shows.

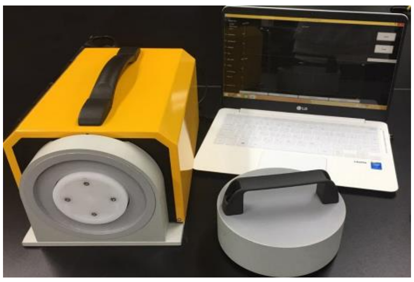

Fig. 4. Picture of the 2nd Quad-CZT array system.

3. Results and Discussion

The performance evaluation of 2nd Quad-CZT array system is carried out through two experiments. First, we compared with the results measuring the same sample by 1st Quad-CZT array system and 2nd Quad-CZT array system, respectively. The sample enrichment of UO_2 pellets is 3.8%. The result shows the peak occurred at the same location, and the counter efficiency of the 2nd Quad-CZT array system were more highly measured as shown in figure 5.

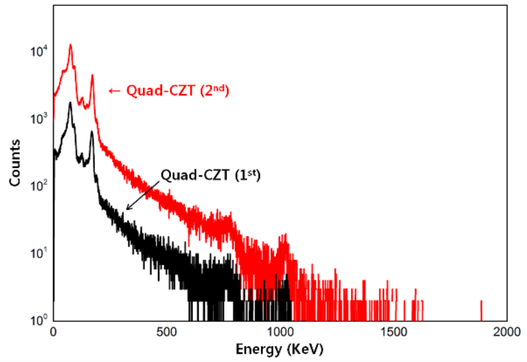

Fig. 5. Picture of the 2nd Quad-CZT array system.

Second, to measure of the enrichment for unknown sample, three certified uranium sources were employed as drawing the best-fit line in this study and their declared enrichment values are 1.28, 2.34, and 4.10%, respectively.

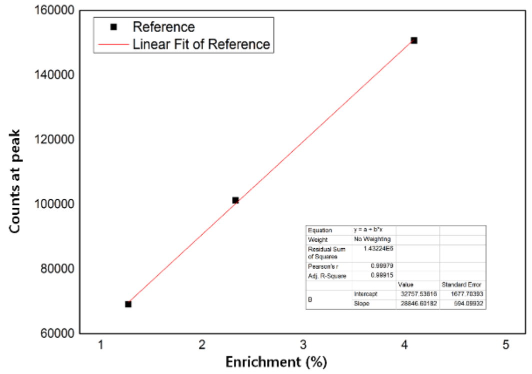

Fig. 6. The reference line of three sources (1.28, 2.34 and 4.10%)

This figure shows the linear correlation (R^2=0.99979) and the equation of the line of the best fit is:

$$\frac{(Counts - 32757.54)}{28846.60} = Enrichment\ (\%)$$

The total counts in the 185.7 keV gamma ray peak of U-235 of the unknown sample were measured and then the enrichment can be predicted through the above equation. [3]

The UO_2 pellets, assumed as the unknown samples, were compared with the actual enrichment values using the 2nd Quad-CZT array system. The measurement was repeated five times on same sample. The actual enrichment value of sample is 3.8%. The result shows Table I.

Table I: The Predicted enrichment value of the unknown samples.

Sample No.	Net Counts	Predicted Enrichment (%)	Standard deviation
1	141651	3.81	3.804 ±0.008
2	141511	3.81	
3	141139	3.79	
4	141713	3.81	
5	141401	3.80	

The result shows the enrichments were estimated very closely to actual concentration of sample. The standard deviation of the experimental values is 3.804±0.008%. Thus, we confirmed that the 2nd Quad-CZT array system have no problem on the enrichment measurement.

4. Conclusion and Future Study

We developed new equipment system (2nd Quad-CZT array system) to improve the drawback of 1st Quad-CZT array system and experimentally evaluated the new equipment system performance.

Future study is scheduled to optimize the whole system and repeat measurement under the same condition. Also, in order to perform a field test of the system, the measurement of U-235 enrichment for nuclear fuel pellets and UF_6 cylinders will be scheduled at the KEPCO Nuclear Fuel (KNF).

REFERENCES

[1] Z. Xiaoqing, C. Zeng, D. M. Jamal, P. Hao, Improving the spatial resolution in CZT detectors using charge sharing effect and transient signal analysis: Simulation study, Nuclear Inst. And Method in Physics Research, Vol.808, p. 60, 2015.

[2] 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.

[3] 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.