An Improved U-Pu System for Field Pu Measurements

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Abstract

Plutonium is a special nuclear material that must be accurately measured and accounted for at all times. Canberra's solution to field measurements of plutonium materials is the U-Pu system. It produces fast and accurate results and can be operated with minimal training. However, the precision and accuracy of the measurement does depend on how well the system hardware matches the requirements of the analysis software. The most critical parameter is the resolution. In this paper, we discuss two separate enhancements to the original U-Pu system. Test results show a resolution improvement of up to 50-70 eV at the 122 keV Co-57 energy.

1. Introduction

New safeguards requirements make the faster and more accurate determination of uranium enrichment and/or isotopic composition of plutonium essential. The measurement of uranium enrichment has traditionally been accomplished by use of the "enrichment meter" method[1]. This method requires carefully calibrating a spectrometer with the 185 keV line from the decay of ^{235}U[2]. But the “enrichment meter” technique is limited to cases where both the sample and standard meet the so-called infinite thickness criterion, and have a known container wall composition and thickness. Furthermore, the chemical composition of the uranium-bearing material must be known. The calibrations are generally valid only if the same detector and analyzer are used.

To eliminate the calibration and detector-to-MCA matching problems for uranium enrichment measurements, Dr. Gunnink and his co-workers have developed a Multi-Group Analysis program for uranium analysis (MGAU)[3]. The MGAU program is designed for high resolution gamma spectrometry and determines the amount of attenuation in the container walls and in the uranium-bearing matrix directly from the spectral data. Careful calibrations with standards that resemble the samples are not required. However, MGAU requires that the sample be at least about six months old, and is therefore not suitable for measuring freshly processed materials.

The determination of the isotopic composition of plutonium has historically been somewhat easier. With high resolution gamma spectrometry using the original Multi Group Analysis (MGA) code[4], the results are generally reasonably accurate regardless of sample age, geometry, chemical composition or attenuation between the sample and detector. However, older versions of MGA often required skilled and highly qualified personnel to correctly set up the instrument and to interpret the results and messages.

To address the ease of use issue with MGA, as well as MGAU, Canberra has developed the U-Pu InSpector system[5]. In addition, together with Dr. Gunnink, we have enhanced the MGA code to be more robust for situations where the counting statistics are far from ideal[6]. Although the U-Pu system had an adequate performance for these types of measurements, two seperate hardware improvements were recently incorporated to improve its overall performance, a new shaping time and an improved baseline restorer. In the following, we report test results obtained using these improvements. The test results show resolution improvements of up to about 50-70 eV at the 122 keV Co-57 energy. We have also compared this improved U-Pu system against standard bench top NIM systems and found that the results are very comparable.

2. Materials and Methods

Previously all U-Pu MCAs were shipped with a combination of two shaping time constants, 1ms and 4ms. Experience has shown that the resolution deteriorates very quickly as a function of count rate when using the 4ms shaping time. The resolution response for a 1ms shaping time is nearly independent of count rate but generally not nearly as good as desired for MGA and MGAU analysis. We have since established that a 2 ms shaping time, compared to the 1ms shaping time, significantly improves the detector resolution at low count rates while maintaining good resolution for higher count rates.

In addition, it has been shown that the presence of other sources tended to make the resolution of the U-Pu system worse than expected. This latter effect was eventually traced to a baseline restoration circuit that was not providing enough stability under such conditions.

Canberra has subsequently started manufacturing all U-Pu MCAs with a combination of 1ms and 2ms shaping time and with a modified baseline restoration circuitry.

During the transition from one type of a system to another, we have measured a large number of U-Pu detector/InSpector MCA combinations for their resolution and high side peak tailing characteristics as a function of count rate using a Co-57 source.

For each system, we first established the amplifier gain setting required to obtain the 0.075 keV/channel energy calibration used by MGA. This places the 122 keV Co-57 peak in a 4K spectrum at approximately channel 1627. We then placed a Co-57 in front of the detector so that the system dead time was approximately 10% and set the pole-zero using the automatic pole-zero mechanism in the InSpector MCA. After adjusting the gain setting again and repeating the pole-zero adjustment, we measured the Co-57 source until we had about 20,000 counts per channel in top channel of the 122 keV peak. We then moved the source closer until we obtained about a 65-70% dead time and repeated the measurement.

We then placed the source in the low count rate position again, changed the amplifier gain to place the 122 keV above channel 3000 and re-did the automatic pole-zero adjustment. After reducing the amplifier gain back to 0.075 keV/channel, we repeated the measurements with the Co-57 source at the low count rate and the high count rate.

We analyzed the 122 keV peak from each of these four spectra for its resolution and high side peak tailing as a function of dead time. In some cases, we were able to measure these characteristics for a system before and after the InSpector MCA was modified for its shaping time constants and baseline restoration circuit. In other cases, the comparative measurements were done with one MCA already modified against another one that was not. In all cases, the same detector was always used for the comparative analyses.

For comparison, some of the InSpector-based systems were also compared against a NIM-based system that consisted of a Canberra model 3102 or model 3105 High Voltage Power Supply module, a Canberra model 2025 spectroscopy amplifier module, a Canberra model 8701 100 MHz Wilkinson ADC

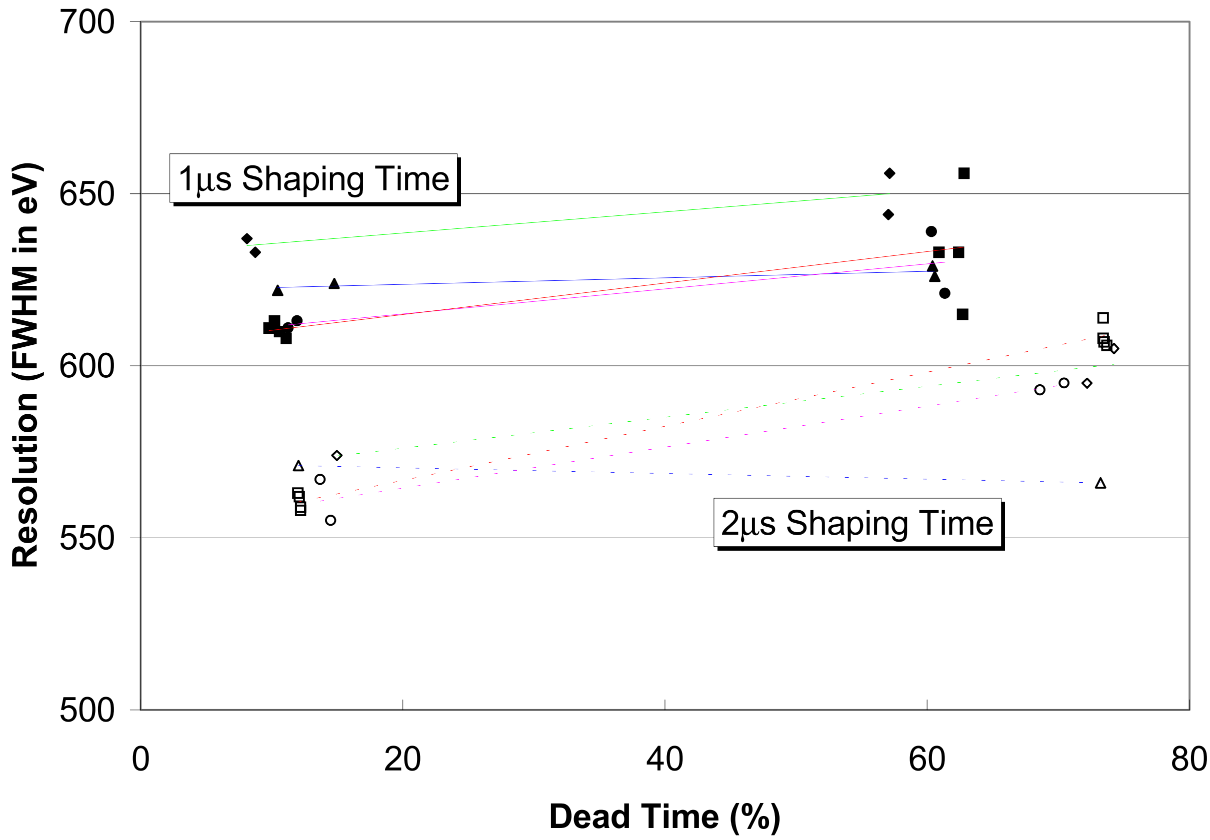

Figure 1 System resolution in eV at the 122 keV peak of Co-57 as a function of dead time and shaping time. The solid lines and filled symbols represent the 1ms shaping time and the dashed lines and open symbols the 2ms shaping time. Note that the lines are a linear interpolation through the data points.

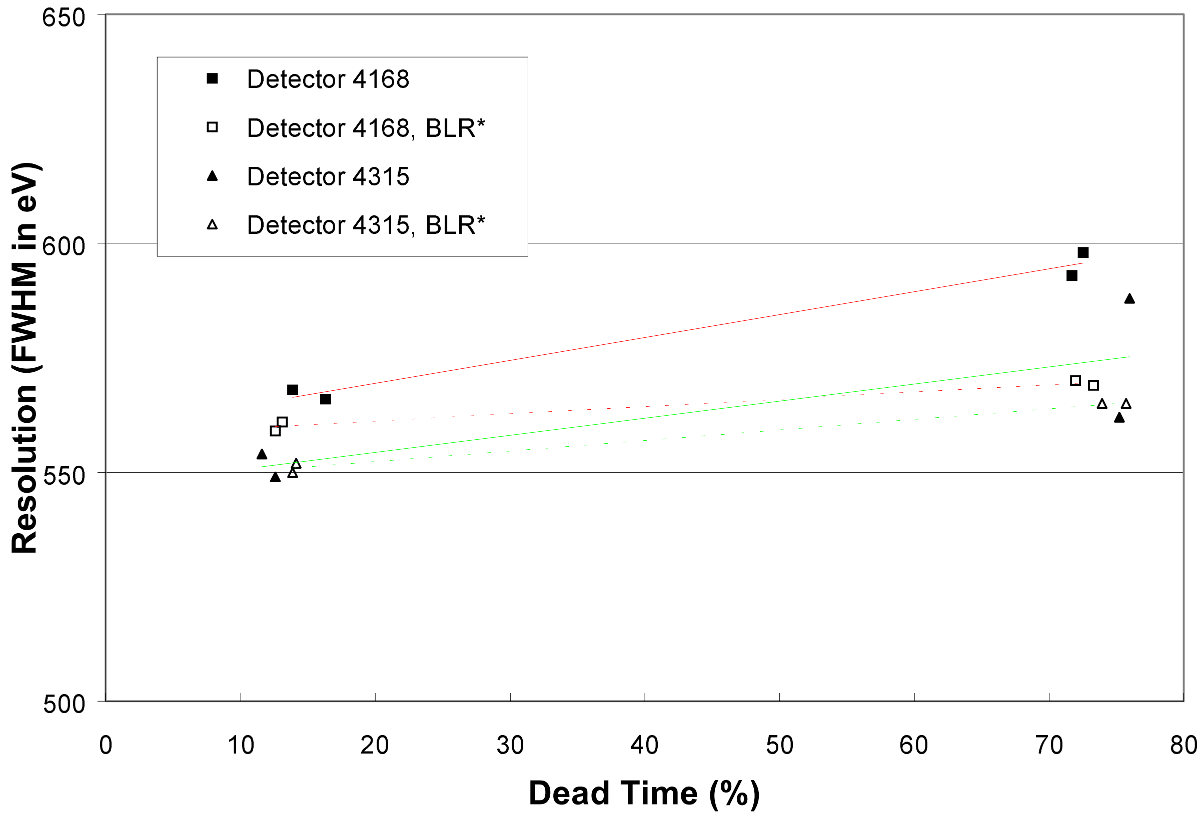

Figure 2 Resolution at the 122 keV in eV as a function of the system dead time and the baseline restoration modification. The solid lines and filled symbols represent the resolution without the modification and the dashed lines and open symbols with the modification.

module, and a Canberra model 556 Acquisition Interface Module (AIM) MCA. This particular combination of amplifier and ADC was specifically selected because it matches the capabilities of the internal amplifier and ADC in the InSpector MCA. In all cases, the four test measurements that were done with the InSpector MCA were also performed with the same detector connected to the NIM hardware.

3. Results

Figure 1 shows a comparison of the FWHM in eV at 122 keV for several detectors with both a 1ms shaping time and a 2 ms shaping time. The upper grouping of solid lines and filled symbols represents the results at 1ms shaping time and the lower grouping with dashed lines and open symbols the results with 2ms shaping time. Note that the lines in this figure, as well as in all the other figures, represent a linear interpolation through the data points. The detectors that were used in these tests are identified in the legend by their serial numbers. Note also that in each case the same detector was measured with both shaping time constants. The improvement from 1ms to 2ms is quite obvious and significant. These results are also in good agreement with the IAEA findings in this regard, and thus make the new InSpector-based systems suitable for the IAEA requirements for use with MGA and MGAU.

The difference in the resolution as a function of the dead time and the baseline restoration change is shown in Figure 2. The solid lines and the filled symbols represent the results without the baseline restoration change and the dashed lines and the open symbols the results with the change in place. As can be seen from the graph, the improvement in resolution is not quite as dramatic as it is with the change in shaping time. In fact, at low count rates, there is very little difference. At higher count rates, the difference between having the baseline restoration modification and not having it, improves the resolution approximately 10-20 eV.

The resolution results from InSpector based systems are compared to the results measured with the same detectors using a NIM-based system in Figure 3. The solid lines and filled symbols represent the data from the InSpector systems and the dashed lines and open symbols the data from the NIM-based systems. As can be seen from the graph, the results between the two

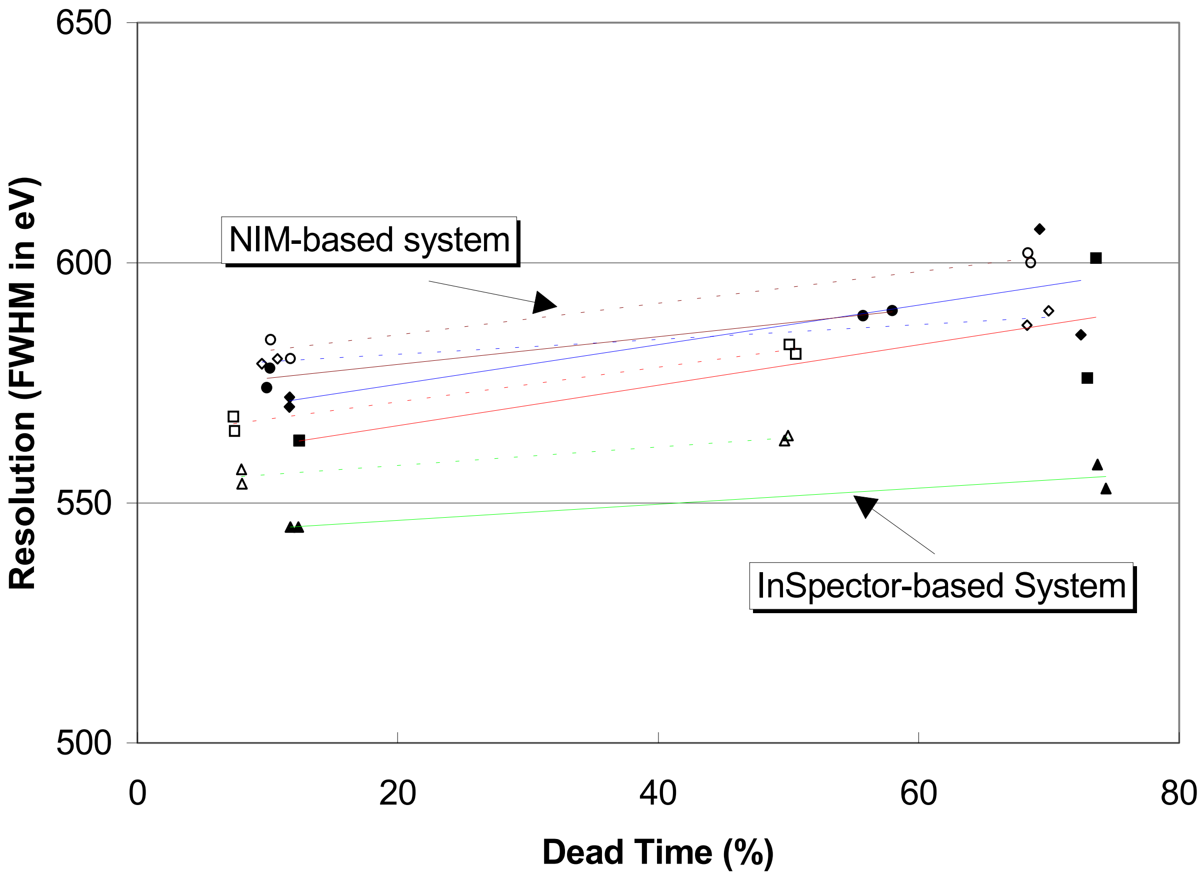

Figure 3 System resolution as a function of dead time for InSpector and NIM based systems. The solid lines and filled symbols represent the results obtained with InSpector-based systems, the dashed lines and open symbols the results obtained with NIM-based systems.

systems are very comparable. In fact, where there is a difference between the two systems, the InSpector results seem to be better than the NIM results. In some cases the difference is as little as less than 5 eV, in other cases as much as about 15 eV.

In evaluating the behavior of the peak high side tailing, we were able to establish that there was no dependence on the shaping time constant, i.e. the amount of peak high side tailing was approximately the same for both shaping times for a given detector, although it varied from detector to detector.

Likewise, there does not appear to be any difference in the peak high side tailing between an InSpector-based system and a NIM-based system.

A comparison of the results of the peak high side tailing analysis for InSpector MCAs with and without the baseline restoration change is shown in Figure 4. The solid lines and the filled symbols represent the situation without the change and the dashed lines and open symbols the situation with the change.

4. Conclusions

Based on the data presented here, the improved U-Pu system based on the InSpector MCA appears to provide system characteristics that are quite suitable for plutonium isotopics analysis in the field. A comparison to the previous revision of the hardware shows an obvious improvement. Furthermore, a comparison between the portable InSpector system and a NIM-based system shows that the results are as good as those obtainable using the lab bench NIM system.

5. Acknowledgements

We gratefully acknowledge the assistance of Dr. Ray Gunnink who provided us with the test program that we used to determine the peak resolution and high side tailing in this study. While Canberra has other programs that provide the same information, his test

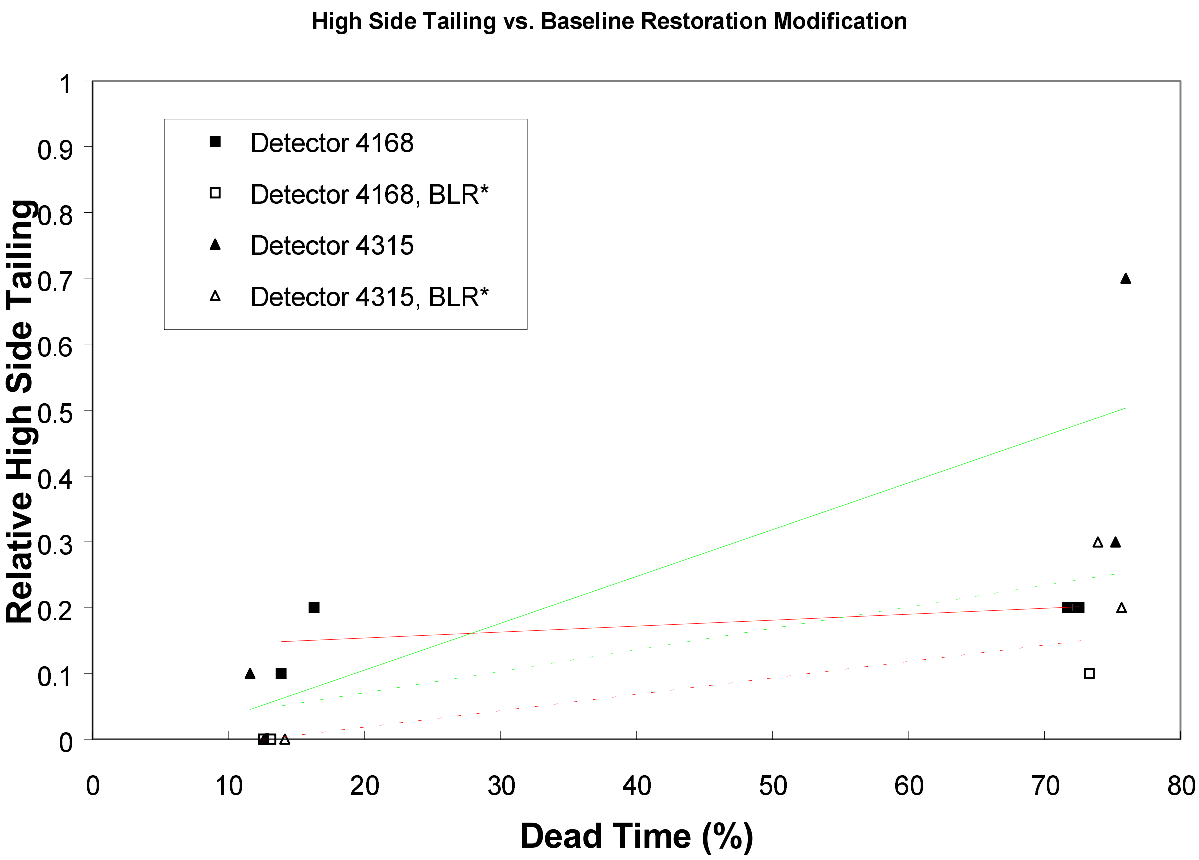

Figure 4 Relative peak high side tailing as a function of the system dead time and with and without the change in the baseline restoration circuitry. The solid lines and filled symbols represent the results without the change, the dashed lines and open symbols the results with the change.

program provided us with a model that matches the peak model used in the MGA code and thus is the most appropriate for the study. We also gratefully acknowledge the help of Dr. Wayne Ruhter, of Lawrence Livermore National Laboratory, who worked with us on the design of the baseline restoration modification.

6. References

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