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Qualification of SRS's KAMS NMC and GIS Systems

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Abstract

The Savannah River Site's KAMS facility was designed for the receipt and storage of incoming SNM shipments. MC&A requires confirmation and verification on these items. These items normally arrive packaged in a 9975. The KAMS facility has a Neutron Multiplicity Counter (NMC) and a Gamma Isotopic System (GIS) to support these measurements.

This report will discuss the qualification of the NMC and GIS for KAMS receipts. The task was made significantly more difficult as the items contain a whole host of materials from Pu metal to mixed Pu/EU and from items relativity free from impurities to items containing significant amounts of impurities as they affect NMC assay. The 9975 container itself has proved to be a challenge for NDA work as it contains at least a ½" of heavy metal shielding as well as hydrogenous materials.

Typical MC&A issues will be addressed in this paper apply to the unique application posed by the KAMS environments. These include choice of appropriate standards, qualification of instrumentation, Measurement control program (MCP), Shipper-Receiver reconciliation, and receipts verification measurements.

SYSTEM DESCRIPTION

The Neutron Multiplicity Counter (NMC)[1]

The NMC is a passive neutron coincidence counter intended for use with multiplicity counting of samples up to 220 liters (55 gallons) in volume. The assay cavity is hexagonal with nominal minor diameter 78 cm (28") and 119 cm (47") tall. The counter was purchased primarily to verify incoming shipments to the KAMS facility. These shipments are part of the DOE Complex-wide D&D effort resulting in the shipment to KAMS of a wide variety of isotopic mixtures and impurities. The

Figure 1 -- Photograph of the NMC

counter was designed for efficiency, ability to minimize the effects of non-Pu contributions to the assay, and minimize the effects of impurities.

The counter utilizes 198 ^{3}He proportional tubes arranged in three concentric rings about the

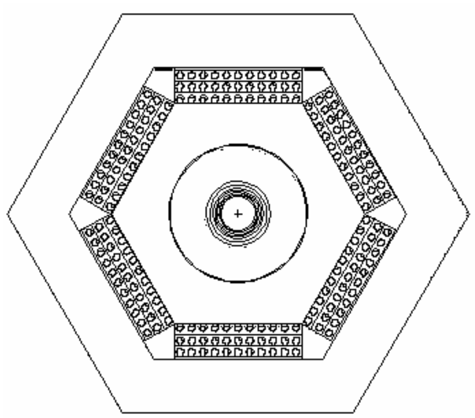

Figure 2 – Drawing of the NMC as Seen From the Top

assay cavity. The basic configuration and detection properties of the six sides of the counter are identical. The counter utilizes graphite reflectors located at the top and bottom of the cavity to improve linearity in response and increased efficiency.

Each detector module (each side) contains 33 ^{3}He tubes arranged in 3 parallel rows of 11 tubes each. The 33 tubes are divided into 9 banks and connected to a pre-amp/amp/ discriminator board.

Each junction box contains a 20 MHz de-randomizer board. The de-randomizer takes the TTL signals from the nine JAB-01 boards and provides three outputs from the detector module, one corresponding to each row of tubes.

The signals from the 6 detector modules are input to a seventh de-randomizer board located in the panel mounted on the counter. This de-randomizer provides 4 outputs, 1 from each of the three rings plus a summed output from all boards. The number of detectors,

Figure 3 – Top and Front Photographs of a Single NMC Detector Bank Showing Neutron Shielding, Detector Layout, and Detector Density

pre-amps, and de-randomizer boards coupled with the their configuration was specifically tailored to minimize deadtime and increase efficiency. This arrangement of amplifier and de-randomizer circuits results in a counter dead-time of less than 20 nanoseconds and a counting efficiency of ~54%.

Figure 4 - Photograph of the Gamma Isotopic System

The Gamma Isotopic System (GIS)[2]

The Gamma Isotopic System (GIS) procured for KAMS is typical of such systems throughout the Complex. Figure 4 is a photograph of the system. It employs a >42% HpGe coaxial detector and lead/cadmium/copper shield and collimator. Items are placed directly in front of the collimator that can be adjusted in height to maximize signal strength.

MGA was the software front end of choice. MGA's decision rules on how to perform the analysis are inside the program. That is, MGA uses selected peaks in the unknown sample spectrum to provide an energy calibration, a peak resolution (FWHM) calibration, and a peak tailing calibration. The MGA code contains all the logic of what peaks to use and how to analyze them inside the code and does not depend on tables that are outside the source code. The latter situation, the use of tables outside of the source code, has the benefit that even very special situations can be accommodated, but the disadvantage that there are fewer automatic rules to direct the flow of calculations. In addition, the MGA code has been enhanced to be more robust for situations where the counting statistics are far from ideal, such as with the 9975 shipping container.

Recently, a new analysis mode has been added to MGA to allow a complete analysis based on only the high-energy region of a spectrum. Of all the codes, the traditional low energy MGA results seem to provide the smallest deviation from the known isotopics. Additionally, MGA allows a complete analysis to be made based on only the high-energy region of a spectrum.

System Qualification[3]

NMC[4]

The instrument was initially qualified by the vendor at their site[5]. It was demonstrated to exceed performance specifications.

Qualification of instrumentation for MC&A use at SRS is subject to DOE orders as interpreted by local site regulations[6]. This nominally includes the title and description of instrument to be qualified (type of assay: gamma, neutron, or other techniques; detector specifics; item descriptions: drums, boxes, etc), the reason for qualification (application specifics: use, calibration ranges, containers, etc.), Process specifics (intended use of assay, isotopes qualified, assay time, accuracy), and description of the item materials used to qualify the application (standards description and pedigrees).

Initially, eighteen items were selected by consensus between the shipper and SRS to be used as qualification sources ("pseudo-standards"). The "true" values of these items were determined by calorimeter/gamma isotopic assay as performed by the shipper. These "pseudo-standards" were used as the qualification standards for the NMC.

Multiple data points were obtained from the NMC over the mass ranges and material types specified. Additional data was acquired for selected items to quantify the NMC's statistics and to better understand bias, reproducibility, and LEID (limits of error) issues. All items were measured in their original "9975" shipping containers.

Background data and measurement control data were obtained throughout this effort and monitored for consistency and instrument stability. One item was measured at selected assay times to determine the relationship between assay time and measurement error.

The data was tabulated, statistics calculated, and limits of errors established based on these observations. These limits are presently applied as acceptability criteria for interpreting receipt measurements.

The most prominent observation during this qualification was a need for correction of metal samples. Assumptions for oxides are not properly extrapolated to high-density materials such as metals. Therefore, a metal correction factor was developed and applied to all material characterized as Pu metal.

The conclusions reached during the initial calibration were:

- As demonstrated by repeated background measurements and the Measurement Control Program (MCP), the NMC is stable and performs within required specifications,
- a metal correction factor be used for metals,
- assay times of 15 minutes be utilized,
- an active MCP be maintained and actively monitored, and
- that measurement uncertainty be bounded by **+5% to –8%** for normal assays (oxides and metals as corrected).

GIS[7]

Data was collected in similar manner for the GIS. However, the issues with GIS are different. Whereas the NMC is a quantitative instrument (quantifying ^{240}Pu), the GIS is strictly a qualitative instrument (measuring relative isotopic abundance). The issue with container self-shielding, discussed below, significantly affected results and consequentially measurement uncertainly and the establishment of acceptance criteria.

Multiple assays were acquired for each item to quantify the GIS's statistics and to better understand basis, reproducibility, and LEID issues. All items were measured in their original "9975" shipping containers.

The preliminary data was collected to compare KAMS GIS results with that obtained at RFETS. After adaptations and allowances for the 9975 container, the results compared favorably (i.e. within specified limits).

The calculated percent $^{240}Pu_{effective}$, its uncertainty, and the effect on total calculated Pu between each KAMS GIS measurement and the declared values was presented for each material category.

As with the NMC, one standard was selected and assayed at different assay times to determine the relationship between assay time and measurement error. Once the optimal assay time was determined, this same standard was measured repeatedly at the optimal assay time to determine measurement control limits. It was determined that the best way to present the data was to compare the calculated percent $^{240}Pu_{effective}$ as this is the final number that is used in the calculation of total mass when coupled to the NMC.

The KAMS GIS responded remarkably well considering the item packaging as discussed below (the 9975 package). On average, the KAMS GIS produced a measured percent $^{240}Pu_{effective}$ resulting in total calculated Pu within ~6% of RFETS's declared values given the same values for mass of $^{240}Pu_{effective}$. Recommendations arising from the qualification report are assay times of 4 hours and that a MCP assay should be obtained as often as reasonable to minimize impact on production. That is, the normal procedure of obtaining MCP data on a daily basis is not practical with 4-hour assays. KAMS GIS results should be bounded with valid MCP results, and a weekly MCP assay during instrument operation is reasonable. It was further suggested that a MCP check source, other than an item packaged in a 9975, be established. This will greatly reduce the time require to perform the MCP checks.

It was also recommended that this instrument analyze a NIST certified item and an appropriate comparative analysis be performed between the NIST reported values and those measured by the GIS. In this report, the GIS was compared only with items measured at another DOE site using similar methodologies and subject to similar errors. The analysis of a NIST certified sample would further the pedigree of this instrument confirming that the GIS produced accurate isotopic results as well as agreeing with other similar methodologies at other DOE sites.

Application Related Problems

The 9975 Package[8]

Perhaps the most unique and troublesome aspect of KAMS receipts measurements is the 9975 Package. The 9975 package was designed, among many other criteria, to minimize personnel radiation exposure. This is directly contradictory to conditions for good NDA measurements. Minimizing the radiation exposures also minimizes the very physical characteristic that the NDA specialist attempts to quantify. The fact that the 9975 designers did such a good job in this task severely limits the quality of the NDA measurement.

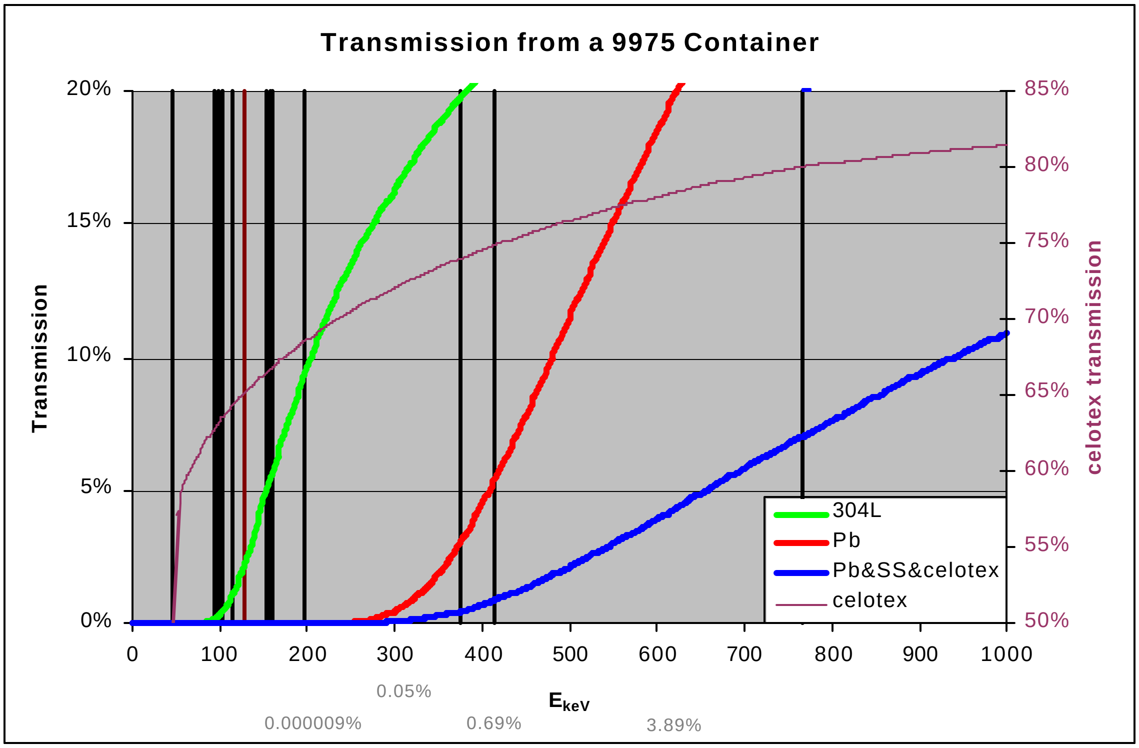

Figure 5 – Graphic Presentation of the Gamma-Ray Shielding Effects of the 9975 Demonstrating Almost Complete Shielding Below 300 KeV.

Figure 4 graphically demonstrates this issue. This is a plot of how a sample's gamma signature is attenuated by the 9975 package. The black vertical lines represent the peaks of primary interest to the GIS. Note that these peaks are, for all intents and purposes, are completely shielded and not available for use by the GIS. Therefore, the GIS measurement reverts to the analysis of the high-energy regions. The peaks in the high-energy regions are significantly weaker, resulting in requirements for substantially longer assay times and poorer measurement statistics. The 9975, on occasion, completely prohibited a valid GIS assay.

Outliers[9]

The investigation of outlier items was initiated, in part, to better understand the nucleonics of the NMC. A better understanding of the physics occurring within the NMC, the 9975 shipping container, the items assayed, and the limits of this application will lead to better assay results in the future and justification for items not well measured by this technique.

Conclusion

The KAMS NMC and GIS has been demonstrated to perform quantitative assays for Pu bearing items. The instruments are stable and perform within design specifications.

Many lessons have been learned regarding the 9957 shipping container and attempts at Gamma assay of material within it. The qualification NMC/GIS combination resulted in an overall uncertainly of the system of approximately 5% to -8%. Further work is in progress to further tune NMC calculations for items containing impure oxides.

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