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^{235}U Holdup Measurements in the 321-M Exhaust Elbows

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ABSTRACT

The Analytical Development Section of Savannah River Technology Center (SRTC) was requested by the Facilities Disposition Division (FDD) to determine the holdup of enriched uranium in the 321-M facility as part of an overall deactivation project of the facility. The 321-M facility was used to fabricate enriched uranium fuel assemblies, lithium-aluminum target tubes, neptunium assemblies, and miscellaneous components for the production reactors. The facility also includes the 324-M storage building and the passageway connecting it to 321-M. The results of the holdup assays are essential for determining compliance with the Waste Acceptance Criteria, Material Control & Accountability, and to meet criticality safety controls. Two measurement systems were used to determine highly enriched uranium (HEU) holdup: One is a portable HPGe detector and EG&G Dart system that contains high voltage power supply and signal processing electronics. A personal computer with Gamma-Vision software was used to control the DART MCA and provide space to store and manipulate multiple 4096-channel γ-ray spectra. The other is a 2" x 2" NaI crystal with an MCA that uses a portable computer with a Canberra NaI+ card installed. This card converts the PC to a full function MCA and contains the ancillary electronics, high voltage power supply, and amplifier required for data acquisition. This report covers holdup measurements of uranium residue in the exhaust piping elbows removed from the roof the 321-M facility. Our results indicate that each of these elbows contained ^{235}U gram values ranging from 0.7 – 3.8 g and that all the elbows contain 14±1 g enriched uranium. This report will discuss the methodology, non-destructive assay (NDA) measurements, assumptions, and results of the uranium holdup in this item.

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TABLE OF CONTENTS

1. INTRODUCTION 7

2. EXPERIMENTAL 8

3. CALCULATIONS 11

3.1 HPGe SPECTRA 11

3.2 NaI SPECTRA 13

4. RESULTS 14

5. CONCLUSION 15

6. REFERENCES 16

LIST OF FIGURES

Figure 1. A photograph of HPGe and NaI acquisitions in progress 9
Figure 2. Spectrum of ^{235}U source check (T0) 9
Figure 3. HPGe spectrum of one of the items (2620) 10
Figure 4. NaI spectrum of HEU source at 8 inches from the detector 10
Figure 5. NaI spectrum of one of the items (2612) 11
Figure 6. Photograph of item 2612 being loaded in M-Area's Q^2 15

LIST OF TABLES

Table 1. Acquisitions from both HPGe and NaI detectors 12
Table 2. List of reported ^{235}U gram values 14

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1. INTRODUCTION

The 321-M facility was used to fabricate enriched uranium fuel assemblies, lithium-aluminum target tubes, neptunium assemblies, and other components for the production reactors. The facility also includes the 324-M storage building and the passageway connecting it to 321-M. The facility operated for 25 years. During this time thousands of uranium-aluminum-alloy (U-Al) fuel tubes were produced. After the facility ceased operations in 1995 all of the easily accessible U-Al was removed from the building, and only residual amounts remained. The bulk of this residue is located in the equipment that generated and handled small U-Al particles and in the exhaust systems for this equipment (e.g., Chip compactor, casting furnaces, log saw, lathes A & B, cyclone separator, Freon™ cart, riser crusher, …etc). [1]

^{235}U holdup measurements were performed in 1995 and documented in technical report WSRC-TR-95-0492.[2] The holdup values reported in WSRC-TR-95-0492 were best estimates only, due to lack of time for conducting the measurements and analysis. Therefore Facilities Disposition Division (FDD) has requested technical assistance from the Analytical Development Section (ADS) of the Savannah River Technology Center (SRTC) to determine the holdup of enriched uranium in the 321-M facility as part of an overall deactivation project of the facility.[3] This project includes the dismantling and removal of all held-up HEU to the extent practical. ADS was tasked to conduct holdup assays to quantify the amount of HEU on all components removed from the facility prior to placement in B-25 containers. The ^{235}U holdup in any single component of process equipment must not exceed 50 g in order to meet the B-25 limit.[4] This limit was imposed to meet criticality requirements of the E-Area Low Level Vaults. Thus the holdup measurements are used as guidance to determine if further decontamination of equipment is needed to ensure that the quantity of ^{235}U does not exceed the 50 g limit. In summary, the results of the holdup assays are essential for determining compliance with the Waste Acceptance Criteria, Material Control & Accountability, and to ensure that criticality safety controls are not exceeded.

This report covers holdup measurements of uranium residue in eight pieces of piping and elbows associated with the A and B lathe exhaust systems of the 321- M facility. The measurements were performed using γ-PHA acquisitions with two detection systems. In this report we describe the detector systems, the data acquisitions, and the techniques used to model the data from two different configurations. Our results indicate that these elbows

contained ^{235}U gram values ranging from 0.7 – 3.8 g and that all the elbows contain 14±1 g enriched uranium. These type of measurements are generally quoted as +100% and –50%.[2]

2. EXPERIMENTAL

A 2" x 2" sodium iodide (NaI) detector system and a portable high purity germanium (HPGe) detection system were used to conduct NDA measurements of HEU holdup on eight 321-M exhaust duct components. The NaI detector system uses a 2" x 2" crystal with an MCA that uses a portable computer with a Canberra NaI+ card installed. This card converts the PC to a full function MCA and contains the ancillary electronics, high voltage power supply and amplifier required for data acquisition.[5] For the NaI acquisitions and analyses we used Canberra Genie-2000 software. The HPGe detection system uses an EG&G Dart package that contains a high voltage power supply and signal processing electronics. A personal computer with Gamma-Vision acquisition software was used to provide space to store and manipulate multiple 4096-channel γ-ray spectra. This system is described in reference 6 and has been used extensively in HEU holdup measurements for FDD.

To accomplish the 321-M exhaust component assays, we obtained 22 HPGe acquisitions in the far field point source configuration and seventeen NaI acquisitions in the near field point source configuration. A photograph of both an HPGe acquisition and a NaI acquisition in progress is shown in Figure 1. Most of the exhaust components were short pieces of elbow piping from which we could obtain two HPGe transmission-corrected spectra from opposite sides. These acquisitions were taken at ranges of 35" or 48", and the ^{235}U HEU contents were calculated from equation (1) below. The close field NaI acquisitions were not taken to obtain an actual HEU content of the whole component, but were simply to obtain localized spectra to search for hot spots and to obtain a correlation of NaI detection rate with calculated HPGe content. All of the NaI spectra were acquired at a distance of eight inches. In each NaI case we determine a local, point content of HEU using equation (3) below. The local, point contents of HEU are discussed along with the overall HPGe determination for each component.

The data obtained in the 22 HPGe acquisitions are summarized in Table 1. The sixth column in Table 1 lists the transmission-corrected HEU content calculated from equation (1) for each acquisition. Table 1also lists the seventeen NaI acquisitions. The eleventh column in Table 1 lists the local, point content calculated for each acquisition using equation (3). Equation (3) applies the same transmission correction as (1).

Both detection systems were checked before and after each day's acquisitions with a ^{137}Cs source and with a ^{235}U source. The HPGe system Quality Control (QC) check is described in reference 7. A typical HPGe QC spectrum acquired with a 4.41-g ^{235}U source is shown in Figure 2, and a typical sample spectrum is shown in Figure 3. A typical NaI QC spectrum is shown in Figure 4, and a typical sample spectrum is shown in Figure 5.

Figure 1. A photograph of HPGe and NaI acquisitions in progress.

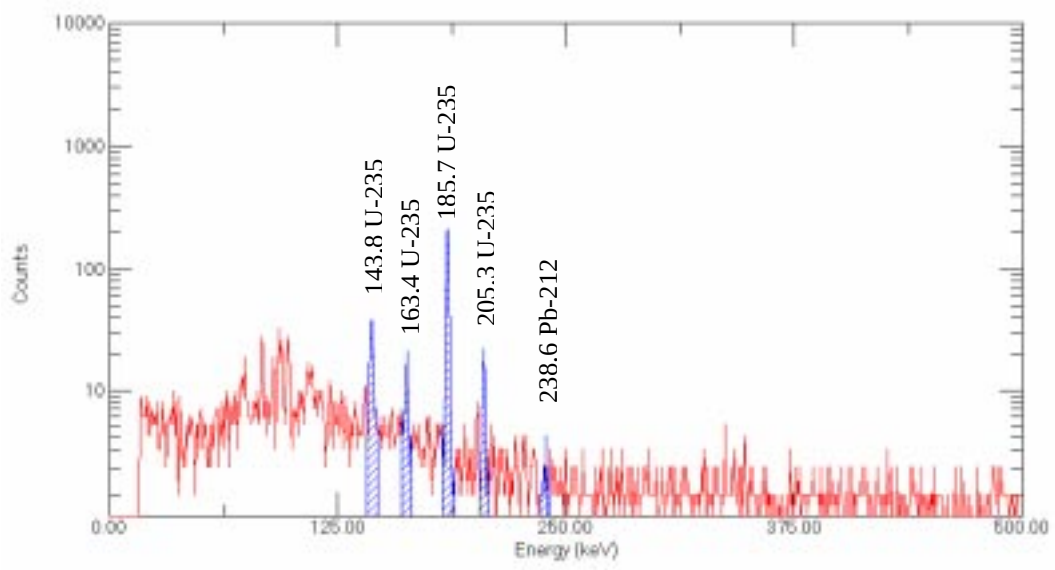

Figure 2. Spectrum of ^{235}U source check (T0).

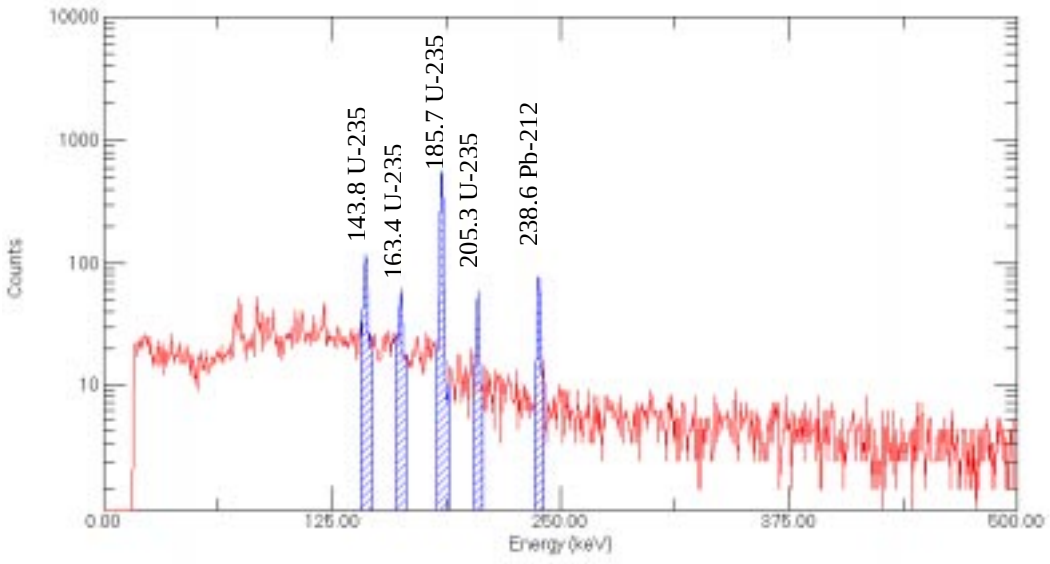

Figure 3. HPGe spectrum of one of the items (2620).

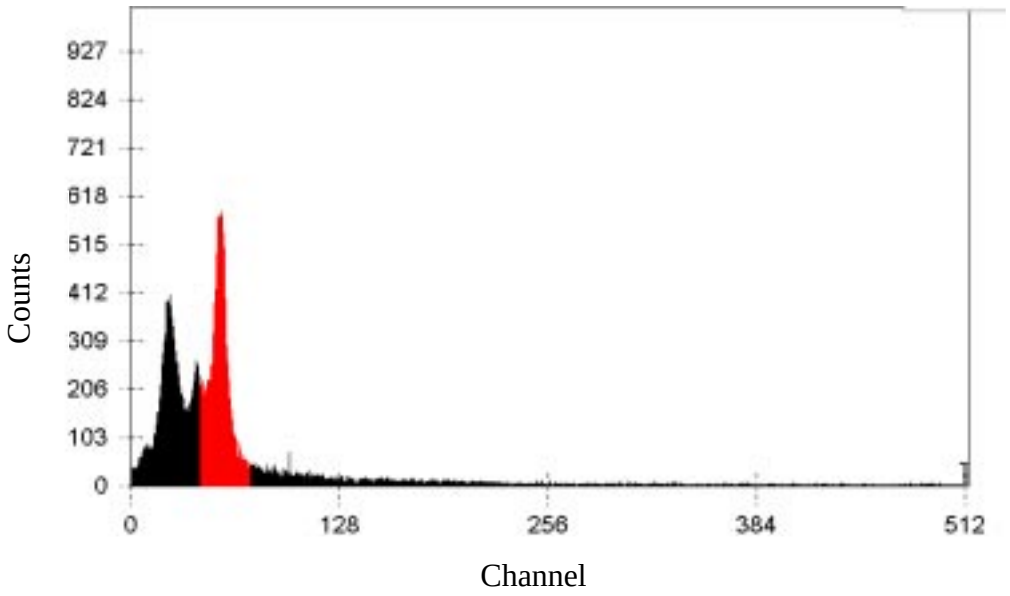

Figure 4. NaI spectrum of HEU source at 8 inches from the detector.

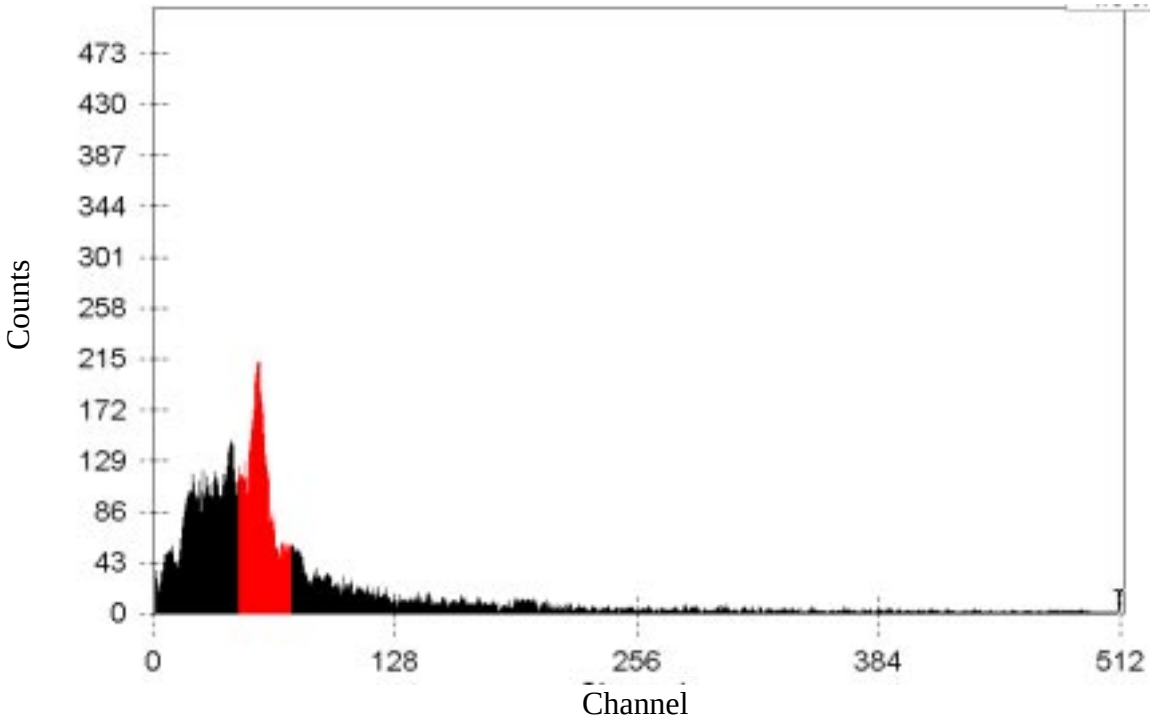

Figure 5. NaI spectrum of one of the items (2612).

3. CALCULATIONS

3.1 HPGe Spectra

The HEU holdup of each individual component observed in the HPGe measurements and listed in the sixth column of Table 1 was calculated from

$$[\text{HEU}] = (2.36\text{x}10^{-5})(\text{cps})(\text{d})^2(\text{T}_{\text{corr}}), \qquad (1)$$

where the first factor is the point source calibration constant of reference 6 in units of g-sec/cm^2, cps is the detection rate of the 185-keV γ-ray, d is the source to detector distance, and T_{corr} is the transmission correction factor. The transmission correction factor was calculated from the experimental spectra *2612back*, *2612Tback*, and T_0. The first is the spectrum taken from the back side of component 2612, the second is the spectrum taken in the identical configuration but with a 4.41-g ^{235}U source placed in the field of view of the detector but behind the source, and the third spectrum is that of the source alone. Transmission of the source 185 keV γ-rays through component 2612 is measured by

$$\text{T} = \{\text{cps}(\textit{2612Tback}) - \text{cps}(\textit{2612back})\}/\text{cps}(T_0) \qquad (2)$$

$$= \{12.530 - 4.733\}/11.955 = 0.6522.$$

Table 1. Acquisitions from both HPGe and NaI detectors.

HPGe Spectrum	HPGe 185 KeV Area	Count time (sec)	d (in)	cps	HEU	NaI Spectrum	NaI 185 KeV Area	d (in)	count time (sec)	HEU Rel.	$\frac{HEU(Rel)}{HEU(HPGe)}$
2612	1197	300	35	3.99	0.92	A2612	649	8	60	0.108	0.117
2612back	1420	300	35	4.73	1.09	B2612	777	8	60	0.129	0.118
T0	686	57.38		11.9							
2612Tback	1059	84.52		12.5							
2613	1319	300	35	4.40	1.02	2613A	1033	8	60	0.172	0.169
2613back	1041	300	35	3.47	0.80	2613B	1533	8	60	0.255	0.318
2614	2953	300	35	9.84	2.28	2614B	1641	8	60	0.273	0.120
2614back	2171	300	35	7.24	1.67	2614BB	2088	8	60	0.348	0.208
2615	2222	300	48	7.41	3.22	2615B	3686	9	60	0.777	0.241
2615back	2096	300	48	6.99	3.04	2615BB	3297	8	60	0.549	0.181
2620	2194	300	48	7.31	3.18	2620B	2054	8	60	0.342	0.108
2620back	1866	300	48	6.22	2.70	2620BB	3022	8	60	0.504	0.186
2621	742	300	48	2.47	1.08	2612	1143	8	60	0.190	0.177
2621back	868	300	48	2.89	1.26	2612back	1400	8	60	0.233	0.185
2621sid						2622sid	2012	8	60		
2622	1525	300	48	5.08	2.21	2622	2120	8	60	0.353	0.160
2622back	1557	300	48	5.19	2.26	2622BB	2037	8	60	0.339	0.150
2623	2306	300	48	7.69	3.34	2623	1896	8	60	0.316	0.094
2623back	2532	300	48	8.44	3.67	2623back	1391	8	60	0.232	0.063
801QC	2180	60	29	36.3	4.65						
Usource48	3682	300	48	12.3	4.30						
Usource35	1343	60	35	22.4	4.17						

The correction factor is then taken to be $\sqrt{\frac{1}{T}} = 1.238$. Since all of the measured components of Table 1 are very similar, we used this transmission correction factor in all of the HPGe calculations of equation (1). In Table 1 we have two measured values for each component. The reported value is listed in Table 2, where we have taken the average with one sigma standard deviation as the adopted content for each component.[8]

3.2 NaI Spectra

The NaI acquisitions of Table 1 were each taken at a source to detector distance of eight inches (with one exception). These acquisitions were not intended to yield a full view of the component, and can not be expected to render an assay of the HEU content of the component. Rather we used these acquisitions to look at some of the exhaust component ends and elbows to observe for possible hot spots that might require closer attention. In each of the NaI acquisitions of Table 1 we determined a localized, point HEU content using the point source configuration of equation (3).[5]

$$[\text{HEU}] = (2.10\text{x}10^{-6})(\text{cpm})(\text{d})^2(T_{corr}), \qquad (3)$$

where the first term is the NaI point source calibration constant in units of g-min/in^2. The distance d was 8 or 9 inches, and we used the transmission correction factor of 1.238 cited above. For these calculations we might justifiably have used the area source configuration. Either selection of configuration is reasonable, since neither quite applies, and we seek only relative rates.

We use acquisition A2612 as an example. Note that we obtained a detection rate of 649 cpm, which by (3) yields an apparent content of 0.108 g of ^{235}U in the limited field of view of the NaI detector. At a range of 8 inches, the detector has an effective field of view of approximately 100 in^2, or approximately a circle of radius 5.6 inches.[9] This limited field of view approximately matches the width of the exhaust components, but does not include the length of the component. Therefore the NaI acquisitions can be thought of as viewing something like 1/6th of each component.

The measured content of 0.108 g ^{235}U in the field of view of acquisition A2612 is shown in column eleven of Table 1. Even though the results listed in column eleven have units of (g ^{235}U), we have listed that column as HEU(rel) to designate that the measurements are of a limited field of view. In column twelve we have tabulated the value HEU(rel)(column 11)/HEU(column 6). This column shows the ratio of measured content in the limited field of view of the NaI detector relative to the total measured value in the point source field of view of the HPGe detector.

If our estimate that the NaI field of view allows it to view about 1/6th of each exhaust component, then the ratio in column twelve should be near 0.167 in each case. Applying the general rule for uncertainty in holdup measurements of +100%,-50% we would expect the ratio in column twelve to range from 0.083 up to 0.333.[10] With one exception, all of the ratios of column twelve fall in that range. We interpret that to indicate there were no

observable hot spots in any of the exhaust components. There was perhaps one relative "cold" spot in component 2623 in our very last NaI acquisition. Thus the NaI and HPGe data lend very good mutual support.

4. RESULTS

We have taken the average of the two transmission corrected HPGe measurements as the adopted value for HEU content in each exhaust elbow component. The reported values are listed in Table 2 and in reference 8. The NaI spectra of each component were obtained to search for possible inconsistencies in what we believed were likely places. No other weight was given the NaI spectra.

As an additional check on our results we counted one of the components in the 313-M Q^2 solid waste assay system (Figure 6). This system is designed for 55-gallon drums, so the elbow we counted did not have a favorable geometry. We counted elbow component 2612 in the Q^2 using both the direct count as intended by the vendor and the adapted segmented gamma-scan type count that we have reported previously for very high density solid waste.[11] Component item 2612 was the first item we counted by HPGe, and was the item on which we had performed a careful transmission measurement. Assay of this item using the Q^2 seemed to be an excellent test of our far field HPGe assay technique.

Table 2. List of reported ^{235}U gram values.

Component	^{235}U Reported (g)	Uncertainty (g)
2612	1.00	0.12
2613	0.91	0.16
2614	1.98	0.42
2615	1.66	0.31
2620	1.56	0.27
2621	1.17	0.13
2622	2.24	0.17
2623	3.50	0.26

We performed a very thorough analysis of the Q^2 data that we obtained from the adapted technique. This analysis is documented in reference 12. We do not address the analysis of the adapted Q^2 data in this report. The direct Q^2 results provide a very good support of our far field HPGe assays. As documented in reference 12, the direct measurements demonstrated a transmission correction factor of 1.08±0.05 and a ^{235}U content of 0.92±0.08. These are in good agreement with our results of 1.24±0.09 for the correction factor and 1.00±0.12 for the ^{235}U content. Note our transmission correction factor was determined by the traditional direct measure from a ^{235}U source, while the Q^2 transmission correction is obtained from a simple measure of total mass.

Figure 6. Photograph of item 2612 being loaded in M-Area's Q^2.

5. CONCLUSION

We have performed two transmission corrected γ-PHA assays on each of eight exhaust piping components from the 321-M process lathes. The assays were conducted in the far field point source acquisition configuration using a portable HPGe detection system. The HPGe assays were backed up using point by point checks with a NaI detection system in the close field acquisition configuration. The measured values for the eight components were all in the range of 0.7 – 3.8 g of HEU, which is consistent with the values predicted for exhaust duct holdup in Table 20-3 of reference 13. The measured total value for all eight components is 14±1 g HEU.

An additional check on the HPGe assays was performed using the 313-M Q^2 assay instrument. The Q^2 was used to perform a modified-segmented γ-PHA scan on one of the eight components. Like the supporting NaI data, this instrument yielded results in good agreement with the HPGe assay.

The results of these assays allowed all eight of the 321-M lathe exhaust components to be released as low activity solid waste and were an important contribution to completion of the FDD FY01 AOP milestone SC-FDD00-008. This FY01 milestone was for disassembly and decontamination of the 321-M ventilation and exhaust system for the deactivation and decontamination of Building 321-M in order to reclassify it as "Other Industrial".

6. REFERENCES

1. D. L. Honkonen, "Nuclear Criticality Safety Evaluation (NCSE): Enriched Uranium Removal From Building 321-M," N-NCS-G-00051, February 2000.
2. R. S. Thomason, "^{235}U Holdup in Building 321-M Contamination Areas and Associated Exhaust Systems," WSRC-TR-95-0492, December 1995.
3. Deactivation Project Plan 321-M Fuel Fabrication Facility, V-PMP-M-00004, January 2000.
4. WSRC 1S Manual, Procedure 3.17, Section A.3.a, "E-Area Vaults Nuclear Safety," July 2000.
5. R. A. Dewberry and S. R Salaymeh, "Efficiency Calibration Using HEU Standards of 2" x 2" NaI Detector," WSRC-TR-2000-00269, July 2000.
6. S. R Salaymeh and R. A. Dewberry, "Efficiency Calibration of the Portable High Purity Germanium Detection System for use in the M-Area Deactivation Assays," WSRC-TR-2000-00317, September 2000.
7. R. A. Dewberry and S. R. Salaymeh to Danny Smith, "Method Development Report for use of the Portable HPGe Detection System for Assay of Highly Enriched Uranium," SRT-ADS-2001-00388, September 2001.
8. R. A. Dewberry to Henry Burruss, SRT-ADS-2001-0376, August 2001.
9. Raymond A. Dewberry, Saleem R. Salaymeh, and Frank S. Moore, "K_a For a NaI Detector Using Two Methods", WSRC-TR-2001-00490, October 2001.
10. D. R. Rogers, ed., Handbook of Nuclear Safeguards Measurement Methods, National Technical Information Service, (Springfield, VA) 1983.
11. S. R Salaymeh and R. A. Dewberry, "Adapting the CANBERRA Q^2 to Assay High-Density Solid Waste from 321-M," WSRC-TR-2001-00004, January 2001.
12. R. A. Dewberry, Laboratory Notebook, WSRC-NB-2000-00086, pages 52, 61.
13. Doug Reilly, et. al., Passive Nondestructive Assay of Nuclear Materials (NUREG/CR-5550, Washington, DC 1991).