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^{235}U Holdup Measurements in the 321-M Lathe HEPA Banks

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ABSTRACT

The Analytical Development Section of Savannah River Technology Center (SRTC) was requested by the Facilities Decommissioning 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 holdup. One is a portable HPGe detector and EG&G Dart™ system that contains the high voltage power supply and signal processing electronics. A personal computer with Gamma-Vision software was used to control the Dart™ multichannel analyzer (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 six high efficiency particulate air (HEPA) filter banks of the A-lathe and B-lathe exhaust systems of the 321-M facility. Our results indicated that the HEPA banks contain a total of 66 ± 5 g enriched uranium. This report discusses the non-destructive assay measurements, assumptions, calculations, and results of the uranium holdup in these six items.

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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 analyses. Therefore Facilities Decommissioning 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 highly enriched uranium (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. 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 the A-lathe and B-lathe high efficiency particulate air (HEPA) filter banks of building 321- M. There are three filter banks for each lathe. The HEPA banks were located on the roof of 321-M and were assayed in place in 1995. Our current assays were performed with the filter banks cut out of the line and assayed one at a time. Similar off-line holdup measurements were made previously on the elbows of the exhaust system leading from the lathes to these HEPA

filter housing units and on the cooling hut HEPA housing unit.[5,6] Because holdup values are extremely difficult to determine, conservative assumptions are usually made to report the ^{235}U gram values. Relative uncertainties for this kind of measurements are generally quoted as +100% and -50%.[2] But because our assays were conducted off line, we could obtain optimum acquisition conditions and better uncertainty. Our results indicated that the HEPA banks contain 66 ± 5 g enriched uranium.

2. EXPERIMENTAL

A portable 2" x 2" NaI detector system and a portable high purity germanium (HPGe) detector system were used to conduct γ-pulse height analysis (PHA) nondestructive assay (NDA) measurements of HEU holdup on the six 321-M HEPA filter units. The NaI detector system uses a 2" x 2" crystal with a multichannel analyzer (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.[7] For the NaI acquisitions and analyses we used Canberra Genie-2000 software. The HPGe detector 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 8 and has been used extensively in HEU holdup measurements for FDD.

All of the HPGe acquisitions were obtained in the far field point source configuration, and all of the NaI acquisitions were obtained in the close field configuration. A photograph of a far field HPGe acquisition in progress is shown in Figure 1. The numerals 1 – 4 in Figure 1 designate the close field acquisition points obtained on this item using the NaI detector. To accomplish the HEPA filter housing assays, we obtained nineteen HPGe acquisitions and sixteen NaI acquisitions. All six of the housing items had dimensions of
90" x 30" x 30". To obtain a full view far field acquisition, the HPGe spectra were acquired at distances of 86" to 168". With these nineteen transmission-corrected point source acquisitions we intended to obtain an assay of the HEU content of the entire item.

Some of the HPGe acquisitions were obtained from a side view of the component, and some were obtained from an end view. We performed a separate transmission correction measurement for each of these two views. The HPGe acquisitions and measured data in the 185-keV γ-ray are listed in Table 1. We describe the treatment of data in the next section.

We obtained multiple quality control (QC) checks on the HPGe system. At the beginning of each day of acquisition a QC check with a ^{137}Cs source placed in a fixed geometry as described in reference 9 was performed. We also performed two QC checks using the T_0 and T_{0end} acquisitions of Table 1. Both of these acquisitions were obtained with a ^{235}U source of 4.41 g placed at a known distance. Spectrum T_0 is shown in Figure 2. Using the data from acquisition T_0 we can calculate the content of the ^{235}U source using equation (1).

Figure 1. A photograph of the HPGe detection system and one of the six HEPA banks (2639).

$$[\text{HEU}] = (2.36\text{x}10^{-5}\text{g-sec/cm}^2)(\text{cps})(\text{d})^2 \qquad (1)$$

$$= (2.36\text{x}10^{-5})(\{260\pm24\}/203.14)(158\text{x}2.54)^2 = 4.86\pm0.45 \text{ g.}$$

These represented additional satisfactory QC checks of the system.[9] A typical component HPGe far field spectrum is shown in Figure 3.

Table 1 also lists the sixteen NaI acquisitions that we obtained in the close field configuration. Each of these acquisitions was intended to view a portion of the component, and the HEU content for that portion was calculated from the acquired data. We obtained four NaI close field acquisitions for four of the six HEPA housing components. The four separate NaI views that we obtained on component 2639 are denoted in Figure 1. In that example, views 1 and 2 were acquired to obtain one sum of the HEU content of 2639, and views 3 and 4 were acquired to obtain a second independent sum. The NaI close view calculations are described in the next section. A typical spectrum is shown in Figure 4.

The NaI detector was also QC-checked with the Cs-137 source daily both before and after each set of acquisitions as prescribed in reference 10. We also performed frequent QC checks with the U-235 source identical to those described for the HPGe detector. These are documented in reference 11, pages 71 and 72 using equation (2).

$$[HEU] = (2.10 \times 10^{-6})(cpm)(d)^2. \quad (2)$$

A typical HEU source spectrum acquired with the NaI detector is shown in Figure 5.

Table 1. Acquisitions from both HPGe and NaI detectors.

		HPGe			NaI		
	Item Number	Count Time (s)	185 KeV peak area	Distance (inches)	Count Time (s)	185 KeV peak area	Distance (inches)
A-Lathe	88BKG	600	-30±28		600	266±54%	
	2624	600	2571±64	97			
	T2624	501.08	2266±61	97			
	T_0	203.14	260±24	158			
	2624end	479.38	3225±66	86			
	T2624end	482.76	3449±69	86			
	T_0end	384.38	394±31	168			
	2624out	600	1515±51	100			
	2624-1				60	460±14.5%	30
	2624-2				60	4085±3%	30
	2624-3				60	945±7.3%	30
	2624-4				60	3630±3.4%	30
	2629in				99.53	4436±3%	24
	2629out				100	1411±5.9%	21
	2629side				100	750±10.4%	57
	2629side2				100	1130±7.5%	57
	2630in				100	5091±2.9%	24
	2630out				100	1739±5.6%	31
	2630side				100	1267±7.%	62
	2630side2				100	1275±6.6%	58
	2629in	600	3512±69	96			
	2629sid	600	1564±51	113			
	2630in	600	3529±72	97			
	2630sid	600	1973±58	116			
	2637in	600	2994±67	98			
	2637sid	600	1738±55	113			
B-Lathe	2637-1				60	1219±6%	57
	2637-2				60	52±103%	57
	2637-3				60	3519±3.4%	24
	2637-4				60	724±8.8%	31
	2638in	600	1686±52	90			
	2638sid	600	926±43	110			
	2638sid2	600	762±70	118			
	2639in	600	2080±55	94			
	2639sid	600	1041±44	113			
	2639sid2	600	990±44	116			

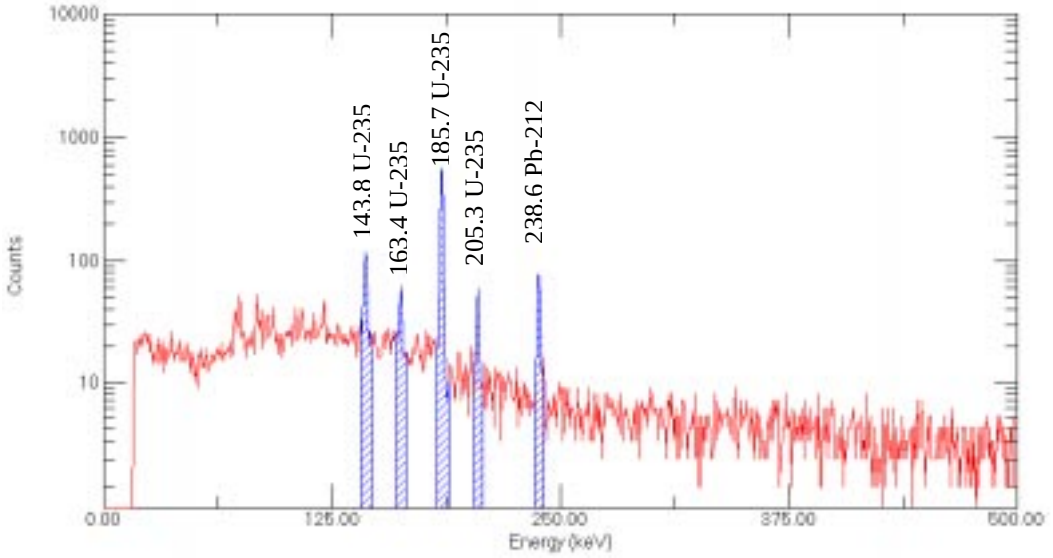

Figure 2. HPGe spectrum of HEU source T_0 at 158 inches from the detector.

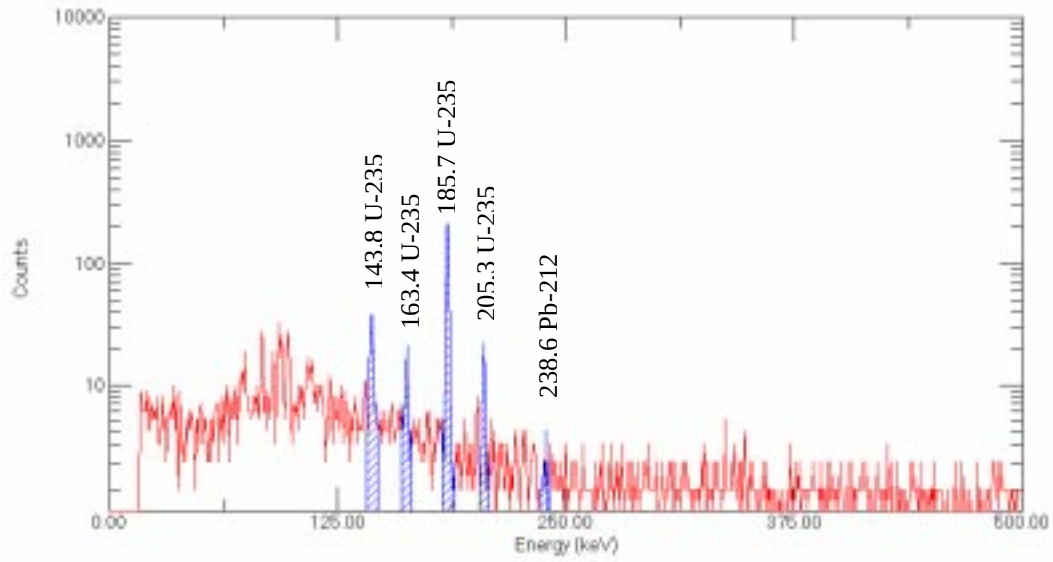

Figure 3. HPGe spectrum of one of the items (2629).

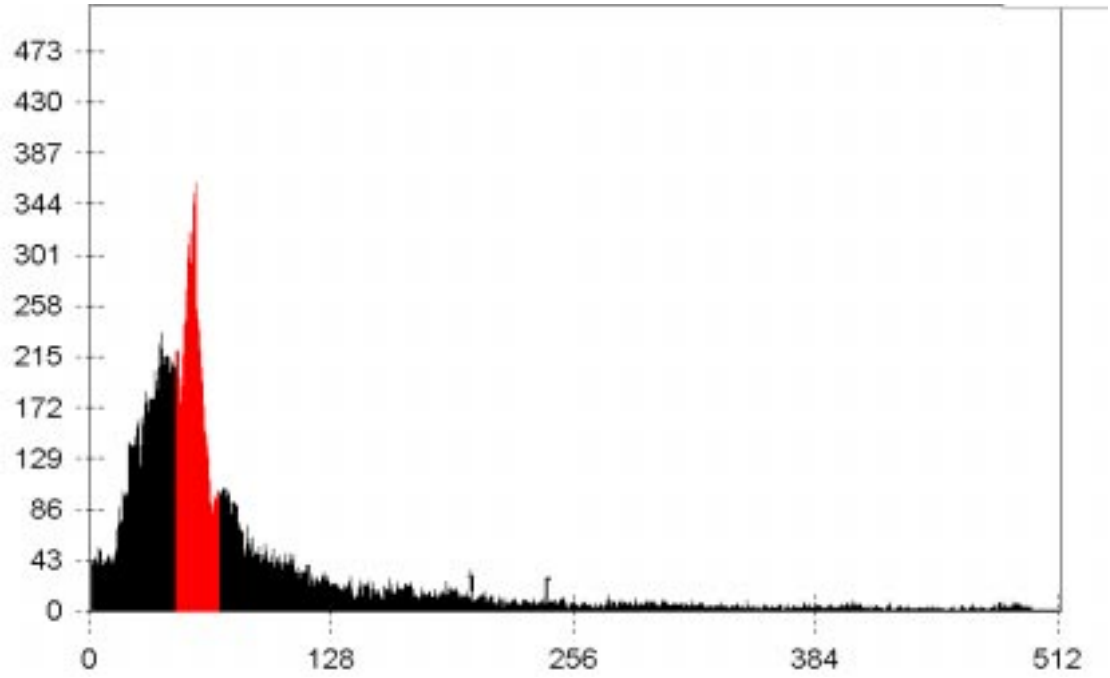

Figure 4. NaI spectrum of one of the items (2629).

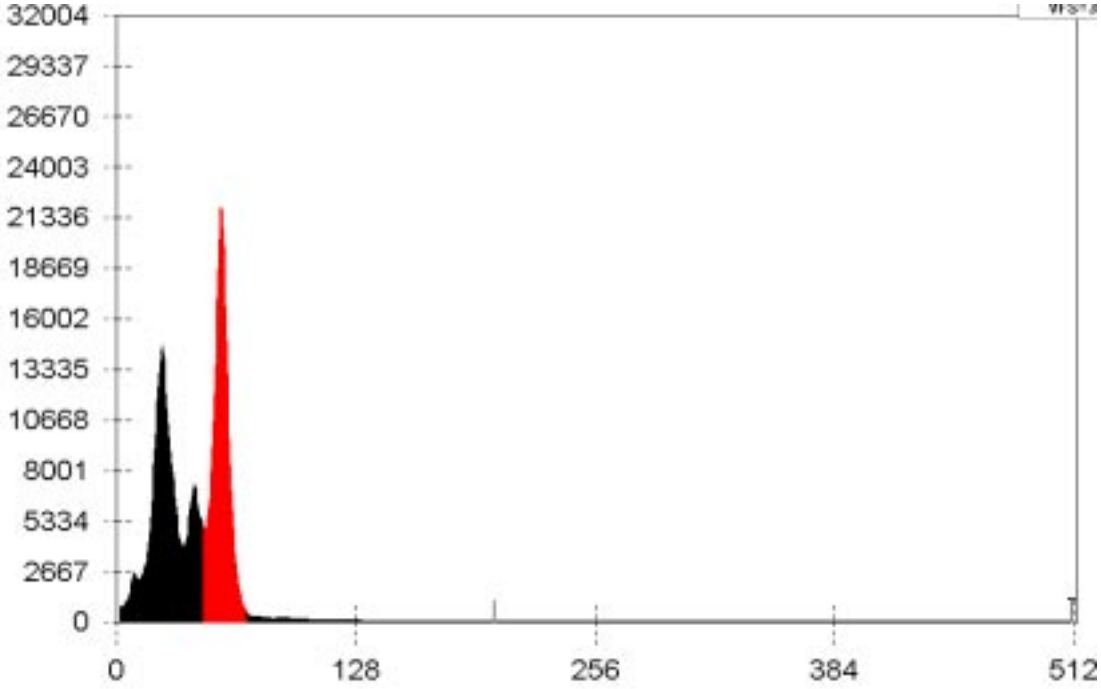

Figure 5. NaI spectrum of the HEU source QC check.

3. CALCULATIONS

The holdup of each individual component observed in the nineteen HPGe measurements was determined from equation (1).

$$[HEU] = (2.36x10^{-5})(cps)(Cf_{trans})(d)^2, \quad (1)$$

where the first factor is the point source calibration constant of reference 8 in units of g-sec/cm^2, cps is the measured detection rate in the 185-KeV peak, Cf_{trans} is the transmission correction factor, and d is the acquisition distance in centimeters. For each HPGe acquisition the distance in inches is listed in column four of Table 1.

The transmission correction factor Cf_{trans} for each HPGe side acquisition was determined from the detection rates of the 185 keV γ-ray in the three spectra *2624*, *T2624*, and T_0 listed in Table 1. From these three spectra the measured transmission of the 185 keV γ-ray through the side of each HEPA filter-housing unit was determined by equation (3).

$$T = \{cps(T2624) - cps(2624)\}/cps(T_0) \quad (3)$$

$$= \{4.522 - 4.285\}/1.28 = 0.185 \pm 0.129.$$

The correction factor for all of the side acquisitions is then taken to be $(1/T_s)^{1/2} = 2.3^{+1.6}_{-0.5}$.

The transmission correction factor Cf_{trans} for each HPGe end acquisition was determined from the detection rates of the 185 keV γ-ray in the three spectra *2624end*, *T2624end*, and *T_0end* listed in Table 1. From these three spectra the measured transmission of the 185 keV γ-ray through the end of each HEPA filter-housing unit was determined by

$$T = \{cps(T2624end) - cps(2624end)\}/cps(T_0end)$$

$$= \{7.144 - 6.727\}/1.03 = 0.405 \pm 0.195.$$

The correction factor for all of the end acquisitions is then taken to be $(1/T_e)^{1/2} = 1.6^{+0.6}_{-0.3}$. Using these transmission correction factors we were able to perform the HPGe assay calculations for each of the fifteen acquisitions. We obtained seven acquisitions from the sides of the six components. Each of these was a point source acquisition that we assumed was able to view the entire component. The HEU content was calculated by (1) with the correction factor $Cf_{trans} = 2.3$. Because the backgrounds in both detection systems were very low, we did not include them in our calculations. For the content in component 2624 using the acquisition obtained from the side, we determined

$$[HEU] = (2.36x10^{-5})(4.285)(97x2.54)^2(2.3) = 14 \pm 3 \text{ g}. \quad (4)$$

For component 2624 we obtained two end acquisitions that are listed in Table 1 as *2624end* and *2624out*. Each of these was assumed to view only the HEPA filter inside of

component that was closer to the end being viewed. That is, *2624end* was assumed to view only the inlet HEPA filter inside component 2624 from a range of 86 inches. While the HEPA filter from the outlet end was within the view of the detector, it was so far away, we assumed it made a negligible contribution to the spectrum. (Referring to Figure 1, the reader should note that the end we designate with 3 is the inlet end of the component, and the end we designate as 4 is the outlet end.)

The HEU holdup on the inlet end HEPA filter of component 2624 was determined by

$$[\text{HEU}] = (2.36\text{x}10^{-5})(6.727)(86\text{x}2.54)^2(1.6) = 12\pm3 \text{ g.} \qquad (5)$$

The HEU holdup on the outlet end HEPA filter of component 2624 was determined from acquisition *2624out* by

$$[\text{HEU}] = (2.36\text{x}10^{-5})(2.525)(100\text{x}2.54)^2(1.6) = 6\pm2 \text{ g.} \qquad (5)$$

The calculations for each of the fifteen HPGe acquisitions are summarized in Table 2 using equations (4) and (5). For component 2624 the HPGe measurements yield two separate determinations of HEU content. The side view acquisition yields one measure of 14±3 g, and the two end views are summed to yield a second determination of 18±4 g. The NaI acquisitions are treated separately.

Each of the sixteen point source NaI acquisitions is listed in Table 1. We obtained NaI acquisitions only on components 2624, 2629, 2630, and 2637. Each HEU determination was calculated from equation (6) by

$$[\text{HEU}] = (2.10\text{x}10^{-6})(\text{cpm})(\text{Cf}_{\text{trans}})(\text{d})^2, \qquad (6)$$

where the first term is the point source calibration constant in units of g-min/in^2.[7] We describe the NaI calculations using component 2624 as an example.

We obtained the acquisitions labeled *2624-1* and *2624-2* in the close field point source configuration from the same side of component 2624. Acquisition *2624-1* was designed to view the outlet HEPA filter inside of 2624, and acquisition *2624-2* was designed to view the inlet HEPA filter. Each was acquired at the close field distance of 30 inches. The HEU content from *2624-1* was calculated by

$$[\text{HEU}] = (2.10\text{x}10^{-6})(460)(2.3)(30)^2 = 2\pm1\text{g,}$$

and the content from *2624-2* is

$$[\text{HEU}] = (2.10\text{x}10^{-6})(4085)(2.3)(30)^2 = 18\pm8 \text{ g.}$$

These two results are tabulated in Table 2. Together these two calculations yield a third separate sum of the HEU content in component 2624.

Table 2. Results in grams of HEU for each acquisition.

Acquisition Number	HPGe Full View (g)	HPGe Inlet & Outlet View (g)	NaI Full View (g)	NaI Individual View (g)	NaI Sum (g)
2624	14±3				
2624end		12±3			
2624out		6±2			
2624-1				2±1	
2624-2				18±8	20±8
2624-3				3±1	
2624-4				11±5	14±5
2629in	13±4				
2629sid	12±5				
2629in				6±2	
2629out				3±1	10±2
2629sid			9±4		
2629sid2			13±6		
2630in	13±4				
2630sid	15±7				
2630in				6±2	
2630out				3±1	9±2
2630sid			15±7		
2630sid2			12±6		
2637in	12±3				
2637sid	13±6				
2637-1				19±9	
2637-2				0.8±0.9	20±9
2637-3				7±2	
2637-4				2±1	9±2
2638in	6±2				
2638sid	7±3				
2638sid2	6±3				
2639in	7±2				
2639sid	8±4				
2639sid2	8±4				

Similarly, acquisitions labeled *2624-3* and *2624-4* were obtained in the close field point source configuration from the opposite ends of component 2624 from a distance of 30 inches. Like the two HPGe acquisitions obtained from the ends of this component, these two acquisitions were designated to obtain individual assays of the two HEPA filters inside of 2624. The HEU content for these two acquisitions were calculated by

$$[HEU]_{2624\text{-}3} = (2.10\text{x}10^{-6})(945)(1.6)(30)^2 = 3\pm1\text{g},$$

and the content from *2624-4* is

$$[HEU]_{2624\text{-}4} = (2.10\text{x}10^{-6})(3630)(1.6)(30)^2 = 11\pm5\text{ g}.$$

These two results are also tabulated in Table 2. Together these two calculations yield a fourth separate sum of the HEU content in component 2624. All together we obtained four separate measurements of the content in component 2624. These four measurements yield the adopted value of 16±3 g. That result is listed in Table 3. All of the individual NaI acquisition results were calculated by the same techniques. The individual results are all tabulated in Table 2 along with the HPGe results.

Table 3. HEU gram value for each of the six HEPA banks.

Item Number	Lathe	HEU holdup (grams)
2624	A-Lathe	16±3
2629	A-Lathe	10±2
2630	A-Lathe	13±2
2637	B-Lathe	13±5
2638	B-Lathe	6±1
2639	B-Lathe	8±1

4. RESULTS AND DISCUSSION

The results of the assays for each of the six HEPA filter banks are listed in Table 3. Each reported value is a result from the average of at least three transmission-corrected calculations that yield excellent agreement. Each of the six components was measured by two to four far field point source HPGe acquisitions that were averaged together to yield a single HPGe result. Four of the components were measured by four separate close field point source NaI acquisitions. For these four components, the close field point source measurements were summed to yield a single NaI result. For these four, the HPGe and NaI results were then averaged for a single reported value with one sigma uncertainty. For the remaining two that received no NaI acquisitions, we report the value from the HPGe result with its one sigma uncertainty.

As seen in Table 3, the values we report range from 6 to 16 grams with uncertainties that range from 12% to 38%. These values are in excellent agreement with the predicted holdup contents for process filters listed in Table 20-3 of reference 12. Thomason reports holdup contents of 14 g for the A-lathe filter bank that corresponds to item 2624 in this report and holdup contents of 9 g for the B-lathe filter bank that corresponds to item 2637 in this report.[2] The two reports agree very well. Our uncertainties are somewhat better than those predicted by Table 20-6 of reference 12. However, that table assumes the holdup measurements are made in-line, where obtaining an isolated background and good counting geometry is very difficult. Our assays were performed on items that had been cut out of the building process. Therefore we were able to obtain a stable and low background, and we were able to obtain an optimum acquisition geometry in two counting configurations. We believe our uncertainties are realistic.

5. CONCLUSION

We have performed transmission-corrected γ-PHA measurements of the ^{235}U holdup content in six 321-M HEPA filter-housing units from the A-lathe and B-lathe exhaust systems. The reported content of ^{235}U holdup in the six units ranged from 6 g to 16 g with a total content of 66 ± 5 g HEU. Since our measurements were performed off line, with the HEPA filter units cut out of the process, we believe that our total uncertainty of only 8% is realistic.

The measurements use two detection systems that acquired the necessary data in two distinct counting configurations. All of the HPGe acquisitions were obtained in duplicate in the far field point source configuration in which we attempted to view the entire component. The NaI acquisitions were obtained in the close field point source configuration in which we attempted to isolate segments of the component in each view. The NaI results were then summed to represent the entire component. The two methods of determination of HEU holdup yielded excellent agreement, and the total measured holdup in these six components is in very good agreement with the content of HEU predicted for this kind of equipment.

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