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Engineering Calculations and Analysis

ECAR Title:	Examination of Graphite Fuel Compact Holders for the AGR-1 TRISO Experiment using Gamma Spectrometry
ECAR No.:	1709

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1. Confirmation of completeness, mathematical accuracy, and correctness of data and appropriateness of assumptions.
2. Concurrence of method or approach. See definition, LWP-10106.
3. Concurrence of procedure compliance. Concurrence with method/approach and conclusion.
4. Concurrence with the document's assumptions and input information. See definition of Acceptance, LWP-10200.

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REVISION LOG

Rev.	Date	Affected Pages	Revision Description
0	11/20/2011	All	Newly issued document

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1. Quality Level (QL) No.	QL-2	**Professional Engineer's Stamp**
2. QL Determination No.	MFC-001009X	
3. Engineering Job (EJ) No.	X	See LWP-10010 for requirements.
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8. Objective/Purpose:

The objective of this document is to describe the results of Precision Gamma Scanner (PGS) evaluation of the graphite holders used in the AGR-1 TRISO fuel experiment. Several scans of each graphite holder were performed to evaluate the distribution of various fission products that were released from the fuel, including Ag-110m. Gamma emitting activation products produced by impurities in the holder graphite or produced by other assorted experiment materials left in the holders was also examined. The distribution of Ag-110m in the holders is of particular interest because of its unique diffusion properties in the TRISO fuel system. The total Ag-110m activity in each holder is also evaluated from the PGS scans and compared to Analytical Laboratory counts of Ag-110m total activity in each holder. Holder inventories of other fission products detected at the Analytical Laboratory are also reported here.

9. Conclusions/Recommendations:

The collected PGS spectra were successfully analyzed to find the distribution of Ag-110m in the holders. The distribution of Ag-110m has been examined both through axial scans and horizontal traverses that produced activity intensity maps. The resulting Ag-110m activity intensity maps show Ag-110m tending to concentrate in lower temperature regions of the holders. However the relative releases among holders do not show any obvious link to compact temperature or neutron flux. Activation products and other fission products were also detected in the PGS scans. The total Ag-110m inventory measured by the PGS scans compares well with Analytical Laboratory measurements of the activity of different radionuclides present in the holders. The results of this analysis can be compared to results from microscopic analysis of TRISO fuel compacts and individual TRISO particles to help further explain the properties and mechanisms of Ag-110m release in TRISO fuel. A local Cs-134 distribution derived from PGS results is presented for one elevation of Holder 5 where one or more silicon carbide layers evidently failed. Looking for consistent, concurrent Cs-134 and Cs-137 signals in the holder, PGS scans should be useful tool in identifying compacts with defective TRISO particles during post-irradiation examination of future AGR compacts.

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Appendix A, Example PC-GAP Listing (.LIS) File

SCOPE AND BRIEF DESCRIPTION

Gamma-ray scans of the graphite fuel compact holders (holders) from the AGR-1 (Advanced Gas Reactor-1) TRISO fuel irradiation test have been collected using the Precision Gamma Scanner (PGS) system located in the Hot Fuel Examination Facility (HFEF) of the Materials and Fuels Complex (MFC) of the Idaho National Laboratory (INL). The AGR-1 test contained 72 TRi-structural ISOtropic (TRISO) fuel compacts that were irradiated in the Advanced Test Reactor for approximately 620 effective full power days (about 3 calendar years). This document details the configuration of the PGS system during these measurements along with the calibration of the PGS system for gamma-ray spectrum collection. Scans were completed of each holder to evaluate the distribution of fission and activation products present in the holders. Fission products can reach the graphite holders from any defective particles or when some fission products (e.g. Ag-110m) are able to diffuse through intact TRISO layers. The measured fission product distributions in the holders can be studied to better understand the migration of these fission products. The total activity of detected Ag-110m in each holder was also compiled from PGS measurements and compared to additional more quantitative evaluations of Ag-110m activity from gamma counts at the MFC Analytical Laboratory. Evidence of cesium fission products released through defective silicon carbide layers also was found in two holders. Additionally, activation products were detected in the holders. The most notable activation product is Co-60 produced from iron or cobalt impurities in the graphite; however, there were also some activation products detected from support material from the experiment left in the holders such as gas lines and thermocouples.

DESIGN OR TECHNICAL PARAMETER INPUT AND SOURCES

Data from the PGS system: R.P. Lind, “AGR-1 Holders Gamma Scan Data”, Data Transmittal 11PL013, NGNP project files INL EDMS, Idaho National Laboratory, (2011)

RESULTS OF LITERATURE SEARCHES AND OTHER BACKGROUND DATA

See Discussion/Analysis section

ASSUMPTIONS

Spectra received from the PGS system were examined to assure there were no obvious problems with the collected data. All activity calculations assume the spectra used in their derivation were collected under the same PGS conditions. Previous experience with PGS system behavior has shown the system is stable over long counting periods. The behavior of natural background peaks indicate no major deviations were observed during the course of scanning the holders.

COMPUTER CODE VALIDATION

Code 1:

a. Computer type: PC running Windows XP
b. Computer program name and revision: Maestro for Windows Version 6.08,
c. Inputs: PGS System
d. Outputs: See PGS formal data transmittal of collected spectra
e. Evidence of, or reference to, computer program validation: The data was generated by the PGS system, owned and managed by HFEF under their own software management controls. No software management to Maestro is documented in this ECAR.

Code 2:

a. Computer type: PC running Windows XP
b. Computer program name and revision: PC-GAP (Convert module) Version 01/16/2008
c. Inputs: See PGS formal data transmittal of collected spectra
d. Outputs: See Sample in Appendix A
e. Evidence of, or reference to, computer program validation: PCGAP is "legacy" software per LWP-13620, so, although software QA documentation for it is not complete, it has been accepted and is used under the terms of legacy software in LWP-13620. It is managed as documented in Lab Notebook LAB-764.

DISCUSSION/ANALYSIS

INTRODUCTION

Gamma-ray scans of the AGR-1 TRISO fuel irradiation experiment have been analyzed to examine the distribution of fission products in the structural graphite blocks that held the fuel compacts in place (i.e. the holders).[1] The AGR-1 experiment is part of a series of low-enriched uranium oxycarbide TRISO coated particle fuel experiments that are ongoing at several research facilities of Idaho National Laboratory (INL) and Oak Ridge National Laboratory. The experiment contained 6 temperature-controlled irradiation capsules that each held 12 cylindrical TRISO fuel compacts (1 inch long x 0.5 inch diameter) consisting of approximately 4100 individual TRISO particles per compact.[2] Inside each capsule, the fuel compacts were placed inside a graphite fuel holder in three vertical stacks each containing four compacts.[3] AGR-1 was irradiated for 620 Effective Full Power Days in the Advanced Test Reactor (ATR) located at the INL, and is estimated to have reached a peak burnup of 19.6% FIMA (Fissions of Initial Metal Atoms).[2] After irradiation the experiment was sent to the Materials and Fuels Complex (MFC) at INL for post-irradiation examination (PIE).

The graphite fuel holders were scanned after removal of the fuel compacts using the HFEF PGS system. The five available holders were examined with the PGS. The holder for Capsule 4 was damaged during disassembly of the experiment and was not measured with the PGS. Each holder was scanned in two off axial sweeps that examined half of the holder in each sweep. This allowed for the identification of axial regions where Ag-110m (the only prominent fission product) was concentrated. Horizontal scans were performed in two orthogonal directions at regions with elevated Ag-110m concentrations to identify cross-sectional locations of Ag-110m in a square grid pattern. A rudimentary tomography scheme was applied to the results of the orthogonal scans to map Ag-110m distributions (also Cs-134 at one elevation of one holder).

Additionally, holder scans detected the presence of activation products in holders from gas tubing, thermocouples, and flux wires. PGS scans were able to confirm the presence or absence of certain flux wire packages that needed to be removed from the holders for analysis. Fission product activities measured with the PGS system were also been compared to gamma-ray inventory results measured on a separate spectrometry system at the MFC Analytical Laboratory.

Gamma Scanning of AGR-1 Graphite Holders

One component of the AGR-1 post-irradiation examination is gamma scanning the available graphite holders from the 6 capsules of the AGR-1 test using the PGS system. The PGS system consists of a collimator that penetrates the HFEF main hot cell wall, a high purity germanium (HPGe) gamma spectrometry system, and a set of in-cell devices used to position samples for examination. The hot cell side of the collimator consists of tungsten alloy blocks that can be adjusted to create a slit height varying from 0.100 inches to 0.001 inches. The width of the collimator opening is fixed at 0.875 inches creating a rectangular viewing area for the PGS system. Gamma rays entering the collimator travel through the hot cell wall through a second tungsten alloy beam scraper and then to the HPGe detector. The entire collimator assembly can be rotated 90 degrees so that the collimator moves from a horizontal slot configuration where the long dimension of the collimator opening is parallel to the ground, to a vertical slot configuration. An assembly drawing of the PGS collimator is shown in Fig. 1.

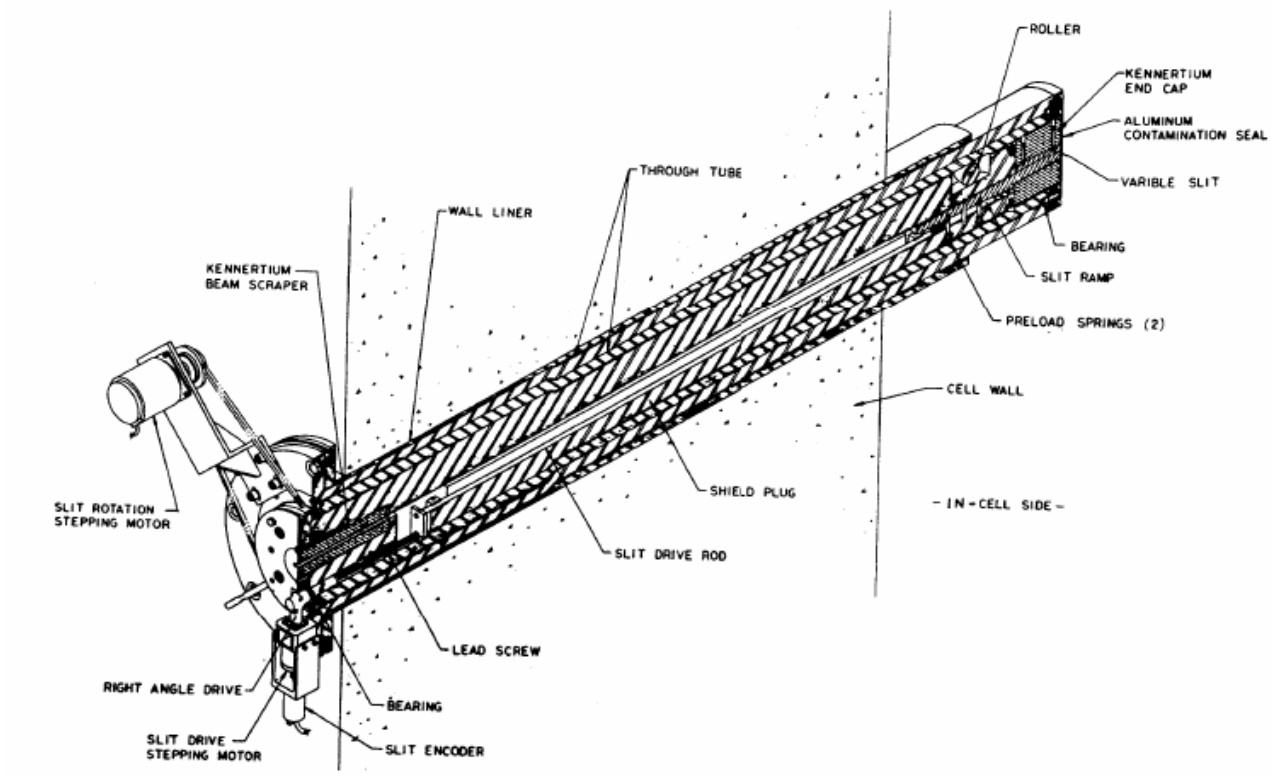

Fig. 1. Assembly drawing of PGS collimator[4]

The PGS uses a custom control software interface that controls both the collection of gamma-ray spectra and the movement of the sample in the hot cell. Spectroscopic control is achieved by communicating with an ORTEC 921 Multi-Channel Buffer (MCB). Once the sample is positioned the PGS collects a spectrum until the live time clock on the MCB reaches the desired limit. The contents of the buffer are then stored on the PGS control computer as a uniquely named ORTEC .CHN binary spectrum file. Additionally a corresponding .DAT file that contains position and system status

information related to the PGS during spectrum collection is also saved after each spectrum is collected. The control software then moves the sample to the next desired position and begins counting again.

For holder examination in the PGS, each holder was loaded into individual aluminum containers with fixtures that could be held by the PGS system.[5,6] These containers had positioning nubs that aligned each holder in a known azimuthal geometry in reference to the guide pin. The axial pattern used to scan the left side and right side of each holder is shown in the left part of Fig. 2. In order to find the center of the holder, the PGS collimator slit was turned vertical and the edges of the holders were found by moving the holder in small horizontal increments while monitoring Co-60 counts. After rotating the collimator to a horizontal orientation, the left and right sides of the holders were set by moving 7/16 inch off center, and each side was scanned in 0.1 inch increments from the top to the bottom of each holder with 2 hours live time per slice. After the initial scans, axial regions with appreciable Ag-110m concentrations received a second set of scans using the PGS collimator in a vertical slot position. The holder was scanned horizontally across the holder from edge to edge as seen in the right side of Fig. 2 using 30-minute counts for each slice. The holder was then rotated 90 degrees clockwise relative to the holder position in Fig. 2 and again scanned horizontally from edge to edge. By combining the results of all these scans, it was possible to construct rough tomographic maps showing where Ag-110m was concentrated in the holders (also Cs-134 within one holder).

Holders were scanned on separate dates. All reported activities were decay-corrected back to the end of irradiation unless otherwise noted. The date for decay correction for each holder is shown in Table 1. This date is the midpoint date of the left and right side scanning. Using this date introduces at most about 1.1% error into the activities calculated in this analysis for Ag-110m. This error is small compared to other uncertainties present in this analysis and is less for longer lived nuclides. These scans were performed for all available holders and were used to investigate the distribution of fission products as well as estimate the total end of irradiation activity of the observed fission products.

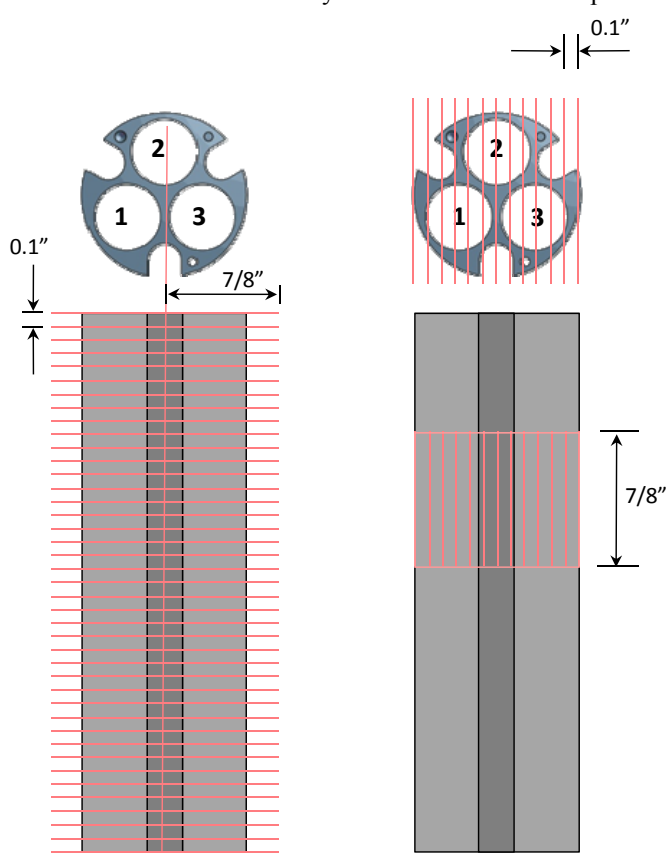

Fig. 2. Diagram showing the alignment of 7/8-inch x 0.1-inch collimator for adjacent axial slices on AGR-1 graphite holders (left diagram) as well as the alignment of the collimator (rotated 90 degrees) for the subsequent transverse slices at specific axial locations used to produce cross-sectional maps of the holders (right diagram).

Table 1. Collection start date of spectra for compacts from different capsules

Holder	Date
1	4/18/2011
2	3/14/2011
3	2/26/2011
4	N/A
5	3/8/2011
6	2/1/2011

The numbering system used to identify compacts has also been applied to the holders where appropriate. An illustration of the numbering system used to identify individual compacts can be found in Fig. 3 and further details can be found in Reference 3. The left side scans typically captured Stack 1 and part of Stack 2, while the right side scans captured Stack 3 and part of Stack 2. As shown later, fission products tended to be axially distributed in groupings that corresponded to compact Levels 1 through 4. The holder for Capsule 6 was loaded upside down and rotated 120 degrees clockwise. The result of this flip and rotation is the positions of stack 2 and stack 3 were switched in the PGS scans relative to the positions shown in Fig. 3. To make the axial distribution data similar between the Capsule 6 measurement and all other holder measurements, the axial slice measurements taken from Holder 6 are plotted in reverse order so that axial slices of a specific level correspond between the different graphite holders. This was done for all data that arose from Holder 6 measurements including the data presented in Fig. 5, Fig. 12, Fig. 13, and Fig. 14.

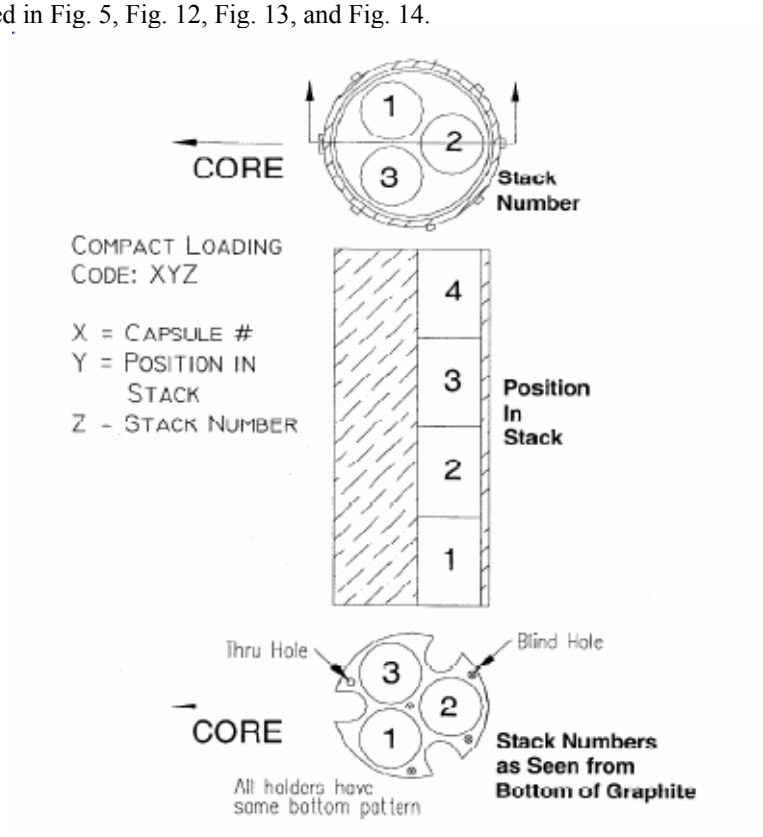

Fig. 3. Numbering system used to identify AGR-1 compacts

Calibration and Characterization of PGS system

The gamma scanning of the holders built upon the experience of gamma scanning the 72 AGR-1 fuel compacts with the PGS.[7] The collected gamma-ray spectra were analyzed using the PC-GAP software package that was developed at INL. Unlike the compact gamma scanning, no check source was scanned before and after each set of measurements. The PGS system was sufficiently well characterized that energy calibration of the scans could be accomplished by using known peaks in the spectrum that included fission products, activation products and naturally occurring radioisotopes. The same MCNP (Monte Carlo n-Particle) model that was used to derive the compact slice efficiency was also used to help determine the slice efficiency of the half-holder axial scans.[7] The MCNP model was modified from the compact geometry to the holder geometry. The source was assumed to be uniformly distributed throughout the graphite of the holder and restricted to the axial slice that the collimator was currently viewing. MCNP simulations showed very little contribution to the detector for fission products located in the slice above or below the slice viewed by the collimator. Changes in the efficiency from the compact to the holder were used to generate a new efficiency curve for the axial scans of the holder as shown in Fig. 4.

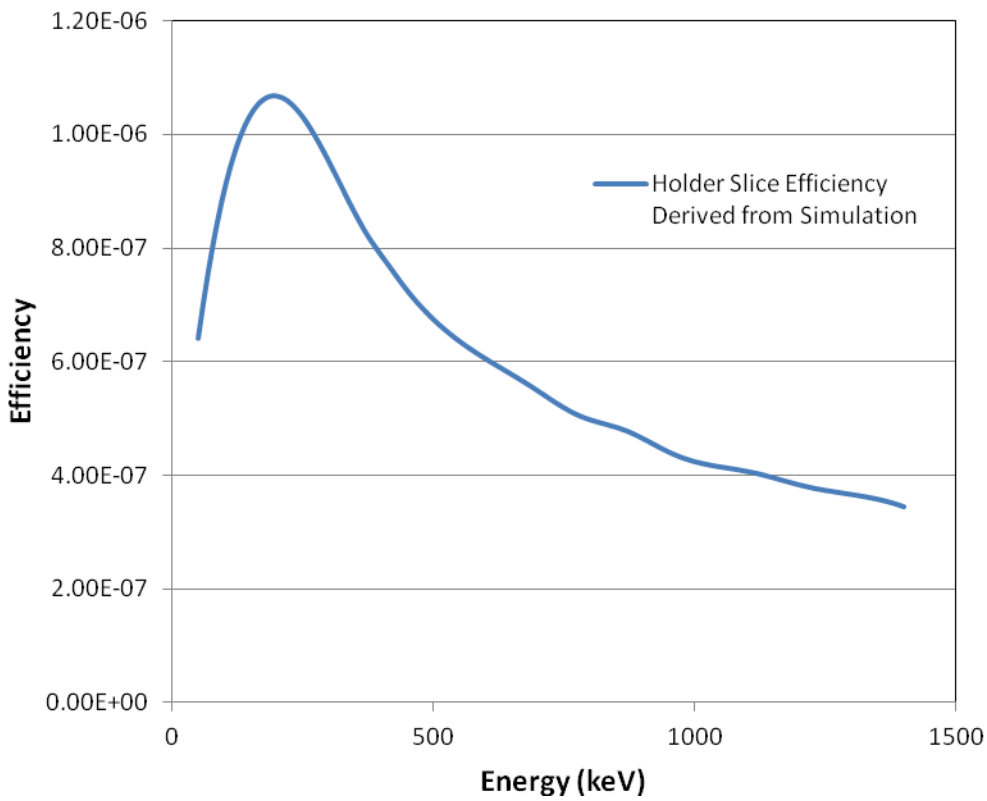

Fig. 4. Efficiency of gamma rays in the holder in the viewed slice of the collimator

The collected spectra were converted from their native Ortec .CHN format to the PC-GAP format and analyzed using the derived efficiency curve and the latest PC-GAP analysis libraries to find the activity of all radioisotopes present in the collected spectra. The same python script used to pull data from the PC-GAP .LIS output files for the analysis of AGR-1 compacts on the PGS was again used for the data from the holders.[7] Modifications were made to look for activation products in the holder scans that were not important and not present in the compact gamma scans. These activation products included Co-60, Nb-94, Nb-95, Hf-175, Hf-181, Ta-182, and Mn-54. The detected activity of the background, naturally occurring isotope K-40 was also pulled and examined to monitor for any unexpected changes in detector conditions that would be indicated by a change in K-40 activity. All the previously detected fission product activities from the compact gamma scans (Y-91, Zr-95, Ru-103, Rh-106 (the daughter of Ru-106), Sb-125, Cs-134, Cs-137, Ce-141, Ce-144, Eu-154, and Pr-144 (the

daughter of Ce-144)) and Ag-110m were also pulled by the python script and examined. Of all these radioisotopes, only a few were detected regularly in the holder gamma scans. The output summary table of detected activities and uncertainties from the python script was then analyzed and interpreted.

Detected Radioactivity in PGS Scans

The primary goal of these scans was to qualitatively identify any detectable fission product release into the holders and to identify the distribution of any released fission products (especially Ag-110m). The primary detected fission product in these scans was Ag-110m, but there were some isolated cases of Cs fission product detection. The other consistently detected radionuclide was Co-60 which is an activation product from trace amounts of Co, Ni, and Fe in the holder graphite. The Co-60 activity was fairly constant across any certain holder indicating even distribution of the trace metal impurities in the graphite. It was clearly evident in the activity numbers when a flux wire containing Co-60 was scanned. The decay-corrected activity would increase about an order of magnitude for a single scan and then return back to an activity that resembled previous activity measurements.

The axial distribution of Ag-110m for all the graphite holders is plotted in Fig. 5. This plot clearly illustrates the variation in measured Ag-110m activity in the holders. Silver fission product distribution in the graphite holders is highly varied and does not appear to follow any definite or consistent set of experimental conditions such as flux or temperature. However, higher Ag-110m concentrations are found near the ends of Holders 1 and 6 (both initially loaded with 5.5% boron carbide), while Holders 2, 3, and 5 (initially loaded with 7.0% boron carbide) exhibit higher Ag-110m concentrations away from their ends. The total Ag-110m decay corrected activity present in each holder was summed together and is shown in Table 2.

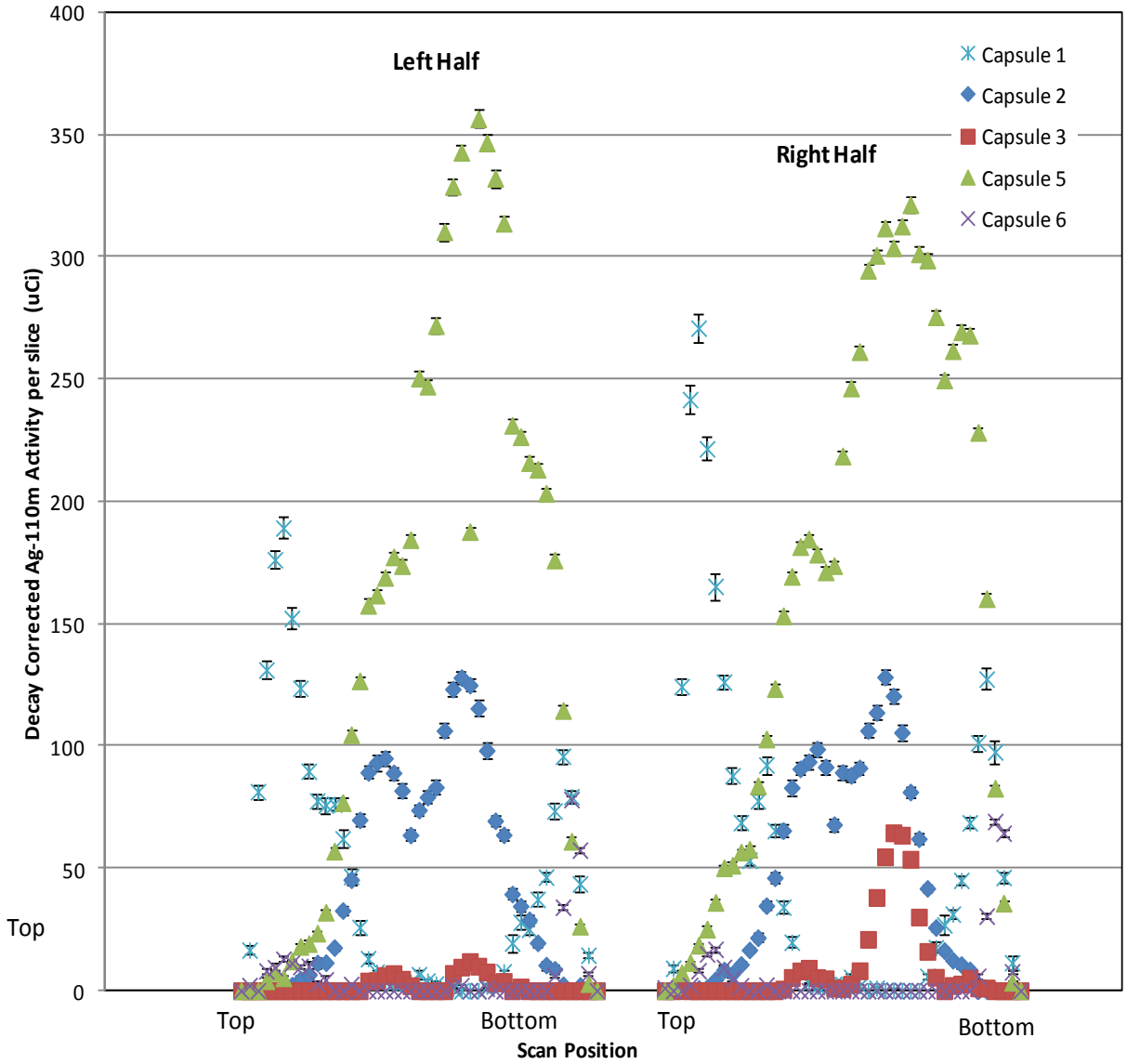

Fig. 5. Axial Ag-110m profiles along AGR-1 graphite holders.

Table 2. Total Ag-110m Activity in each Graphite Holder

Capsule	Activity (µCi)	Uncertainty (µCi)
1	4114	24
2	3772	18
3	489	6
4[+]	N/A	N/A
5	13116	20
6	500	6

[+] The holder from Capsule 4 was damaged during disassembly and cannot be scanned

The vertical slice scans were processed to create pseudo-colored concentration maps of specific levels in the graphite holders. Decay-corrected Ag-110m activities from each lateral slice were first divided by the graphite volume seen through the collimator to yield volumetric concentrations in each slice. The Ag-110m concentrations at one azimuth were then multiplied by slice concentrations after a 90-degree rotation, producing a 12 x 12 matrix of Ag-110m concentration products. (Concentrations were multiplied rather than added for enhanced contrast.) These values were then converted into pseudo-colors using a "cool-to-warm continuously diverging" colormap developed at Sandia National Laboratory (Fig. 6), producing the 12 x 12 square array at the left of Fig. 7. Finally, a digital mask was overlain to remove areas formerly filled by fuel compacts and molybdenum through-tubes. Note the red square with the highest concentration product was hidden in the process so the masked arrays do not necessarily cover the full range of the colormap. In cases such as the Fig. 7 example, the red square is a "virtual" hot spot.

Fig. 6. Sandia colormap used for pseudo-color displays (256 levels).

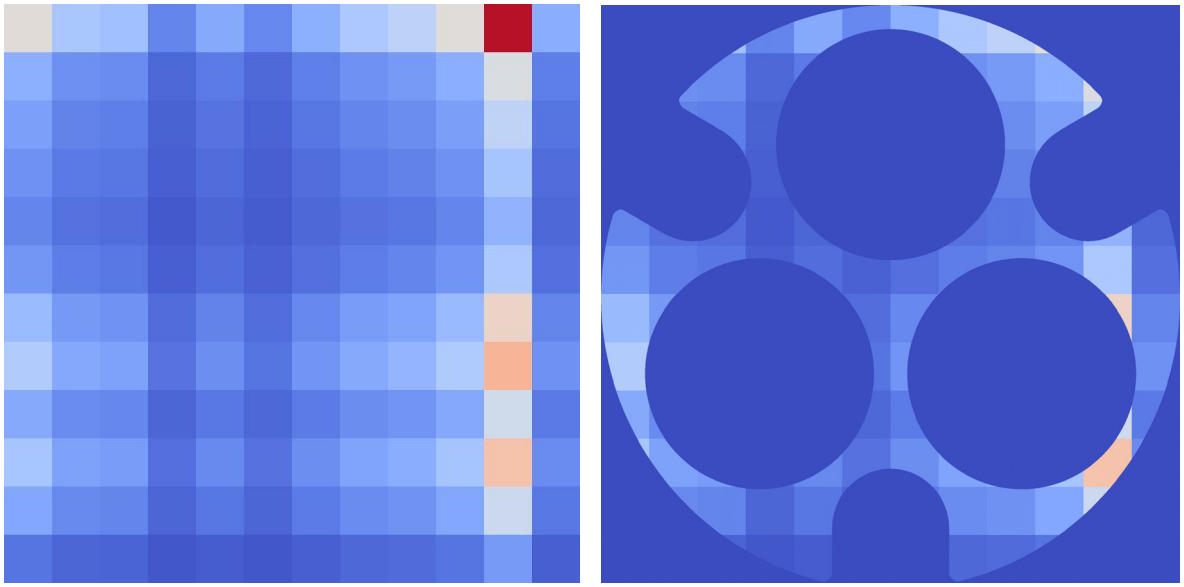

Fig. 7. Conversion of pseudo-colored concentration product array into cross-sectional Ag-110m distribution with a digital mask.

Fig. 8 through Fig. 12 respectively contain the axial Ag-110m distribution for each individual Holder 1 through 6 excluding Holder 4. In the individual holder plots the decay corrected Ag-110m activity per slice for the left and right half scans are plotted versus a distance from the top of each holder. The plots in Fig. 8 through Fig. 12 also contain the results of the tomographic analysis of the Ag-110m activity distributed throughout the holders. Axial features in the Ag-110m distribution tend to be grouped together in sets of 10 slices that roughly correspond to a single compact. In the plots the levels defined in Fig. 3 start at Level 4 (centered on 0.5 inches below the top of the holder) on the left and drop to 1 on the right (centered on 3.5 inches). This grouping is most obvious in Fig. 10 where Ag-110m is localized around compacts that correspond to Levels 2 and 3 in the compact numbering scheme and Fig. 12 where the peaks in the Ag-110m activity are localized around Levels 1 and 4. This effect can be seen even in the case of the highest general concentration of Ag-110m that occurred in Holder 5 where there appears to be very little silver in Level 4 while peaks are localized around Levels 1, 2, and 3.

Even more striking is that the concentration of Ag-110m within AGR-1 holders seems to be almost stochastic in nature. The amount of Ag-110m detected by the PGS looks to be independent of total neutron fluence. For example the highest Ag-110m concentration was found in Holder 5 while the lowest concentration was found in Holder 3 where the total neutron fluence was the highest. The temperature of the compacts also does not appear to have a direct correlation to the retention of Ag-110m in holders for any given compact. One key to interpreting this behavior is noting that holder retention of silver

does not necessarily equate to silver release in compacts, because appreciable silver probably diffused through the holders to collect on cooler metallic capsule components (stainless steel shell liners, molybdenum through-tubes, niobium gas lines, etc.).

Results of the tomography are presented in Fig. 8 through Fig. 12 for Holders 1, 2, 3, 5, and 6, respectively, where Ag-110m concentrations (μCi per cubic inch) are displayed adjacent to each slice and fuel compact identifiers are shown within each hole. These figures also indicate the specific 7/8-inch axial sections of the holders that were scanned to produce the cross-section maps (indicated by the green arrows overlaid on the axial activity plot). Please note that the concentration maps are each individually scaled over the intensity range collected for that map. To compare Ag-110m intensities of individual squares between different maps, the product of the Ag-110m concentrations displayed adjacent to each corresponding slice needs to be calculated for each square.

Fig. 8 through Fig. 12 generally reveal that the highest Ag-110m concentration products were located around the peripheries of the holders. Azimuths with especially large amounts of silver tend to be where the holder periphery is the thinnest, which is where fuel compacts were closest to the relatively cool capsule shells. Higher than average amounts of silver also are indicated in some squares where compacts were closest to relatively cool molybdenum through-tubes. Furthermore, somewhat smaller Ag-110m amounts typically are found near Hole 2, which faced away from the ATR core center and experienced lower temperature and neutron fluence, although there are a few exceptions in Holders 1 and 6.

Several features merit further explanation. Fig. 8 is unusual in that the red square with the highest Ag-110m concentration product (at the intersection of the horizontal and vertical slices with highest concentrations) is hidden by the mask in all three cross sections. As a circumstantial consequence, the colors in the unmasked squares are somewhat subdued in comparison to most cross sections in Fig. 9 through Fig. 12. Another artifact is evident in the Level 3 cross section in Figure 8, where only one square shows color. This results from the low Ag-110m activity at this elevation of Holder 3, where the 120-minute axial counts were able to find silver on the left half while the 30-minute lateral counts could not.

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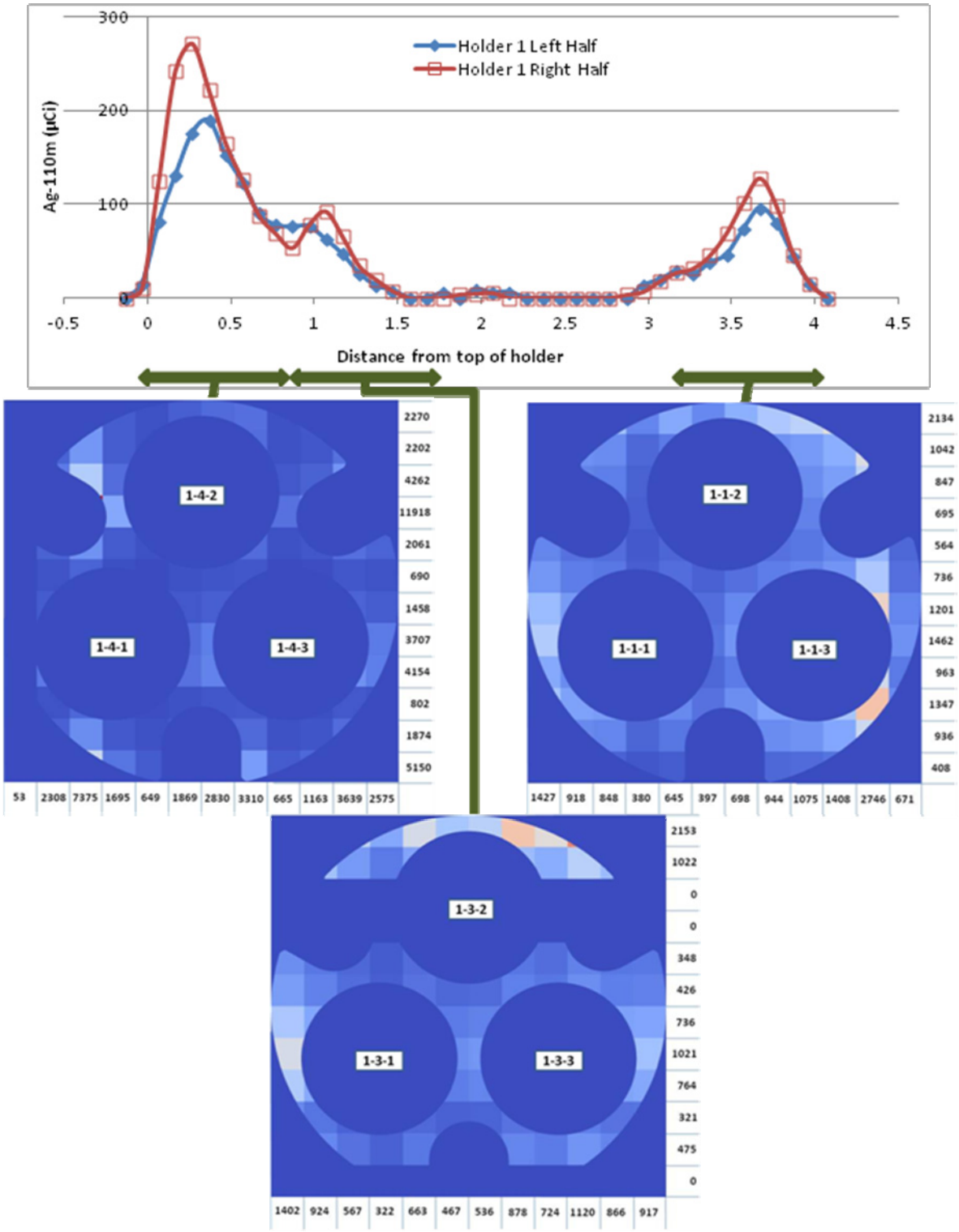

Fig. 8. Measured Ag-110m activity per slice (in µCi per cubic inch) derived from axial PGS scans and enhanced cross-sectional distributions of Ag-110m in the Capsule 1 graphite holder

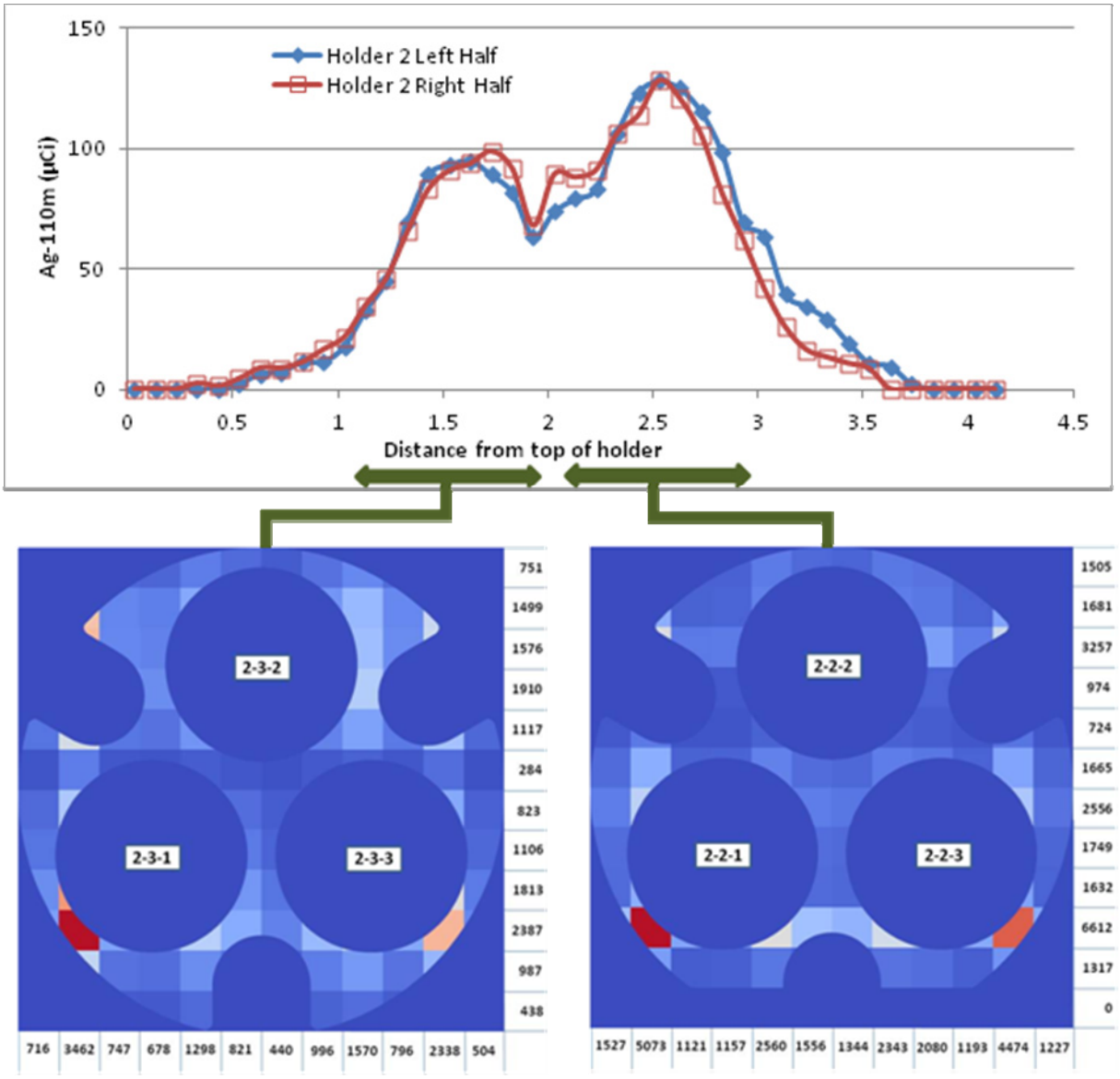

Fig. 9. Measured Ag-110m activity per slice (in µCi per cubic inch) derived from axial PGS scans and enhanced cross-sectional distributions of Ag-110m in the Capsule 2 graphite holder

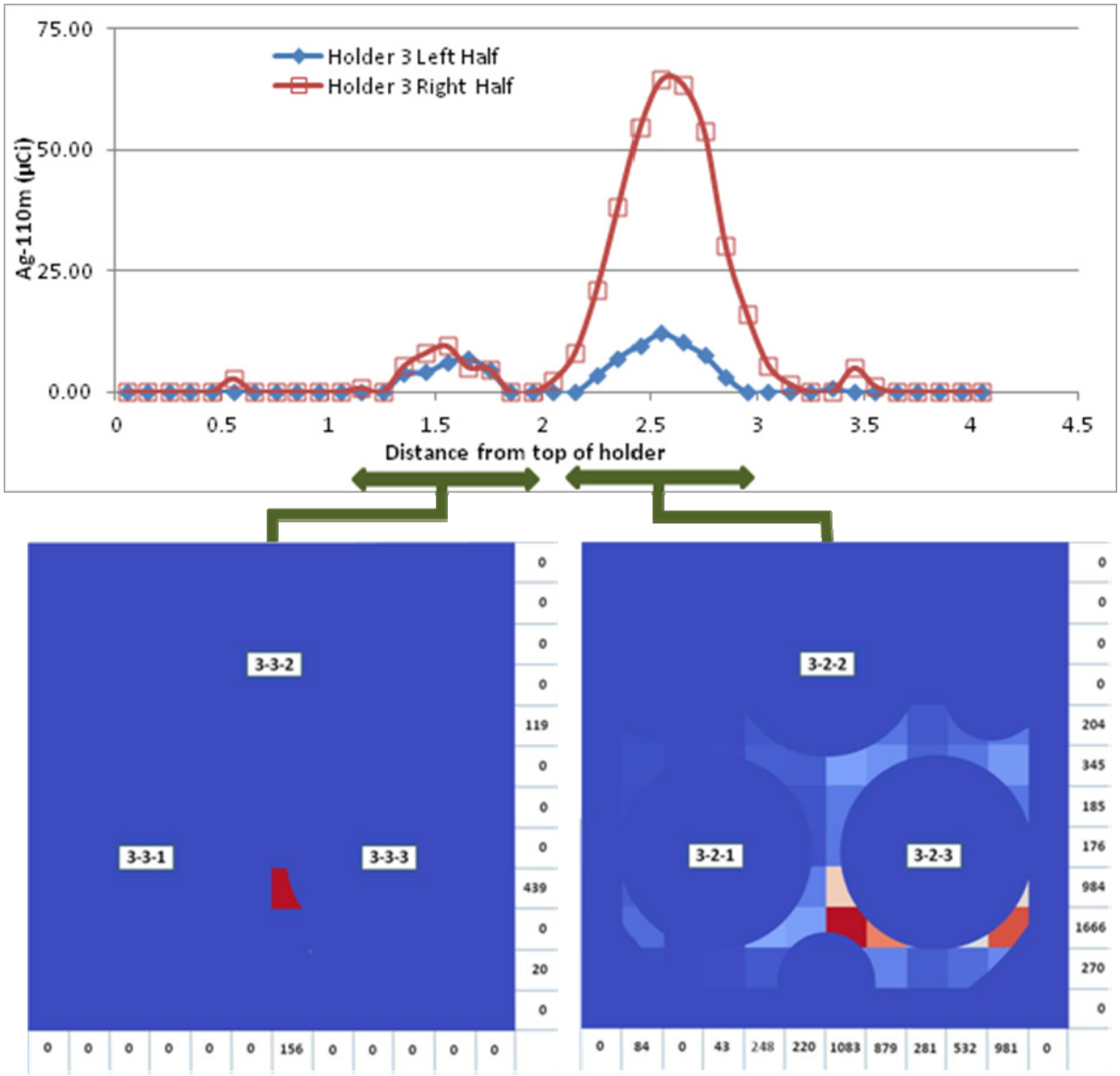

Fig. 10. Measured Ag-110m activity per slice (in µCi per cubic inch) derived from axial PGS scans and enhanced cross-sectional distributions of Ag-110m in the Capsule 3 graphite holder

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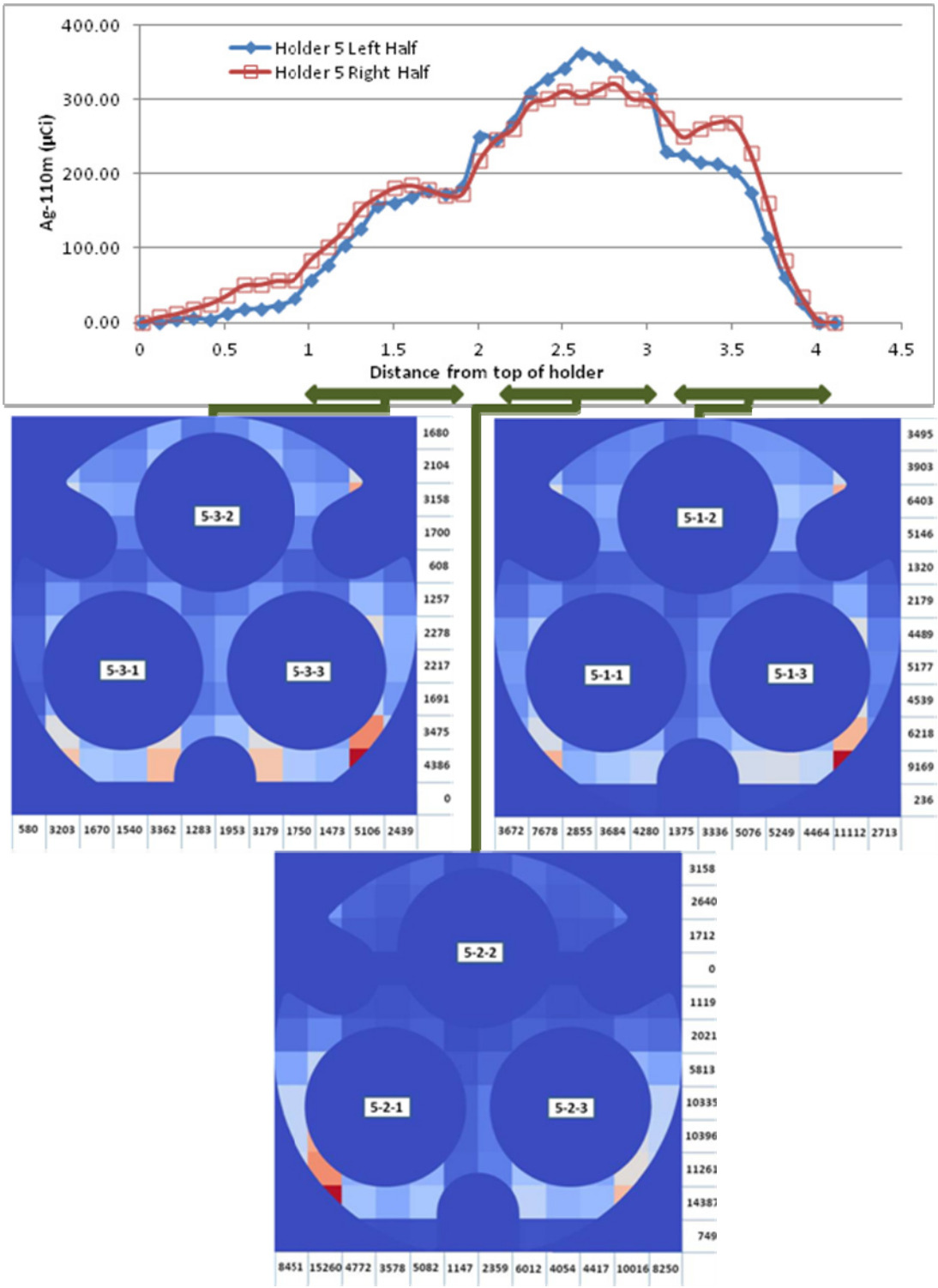

Fig. 11. Measured Ag-110m activity per slice (in µCi per cubic inch) derived from axial PGS scans and enhanced cross-section distributions of Ag-110m in the Capsule 5 graphite holder

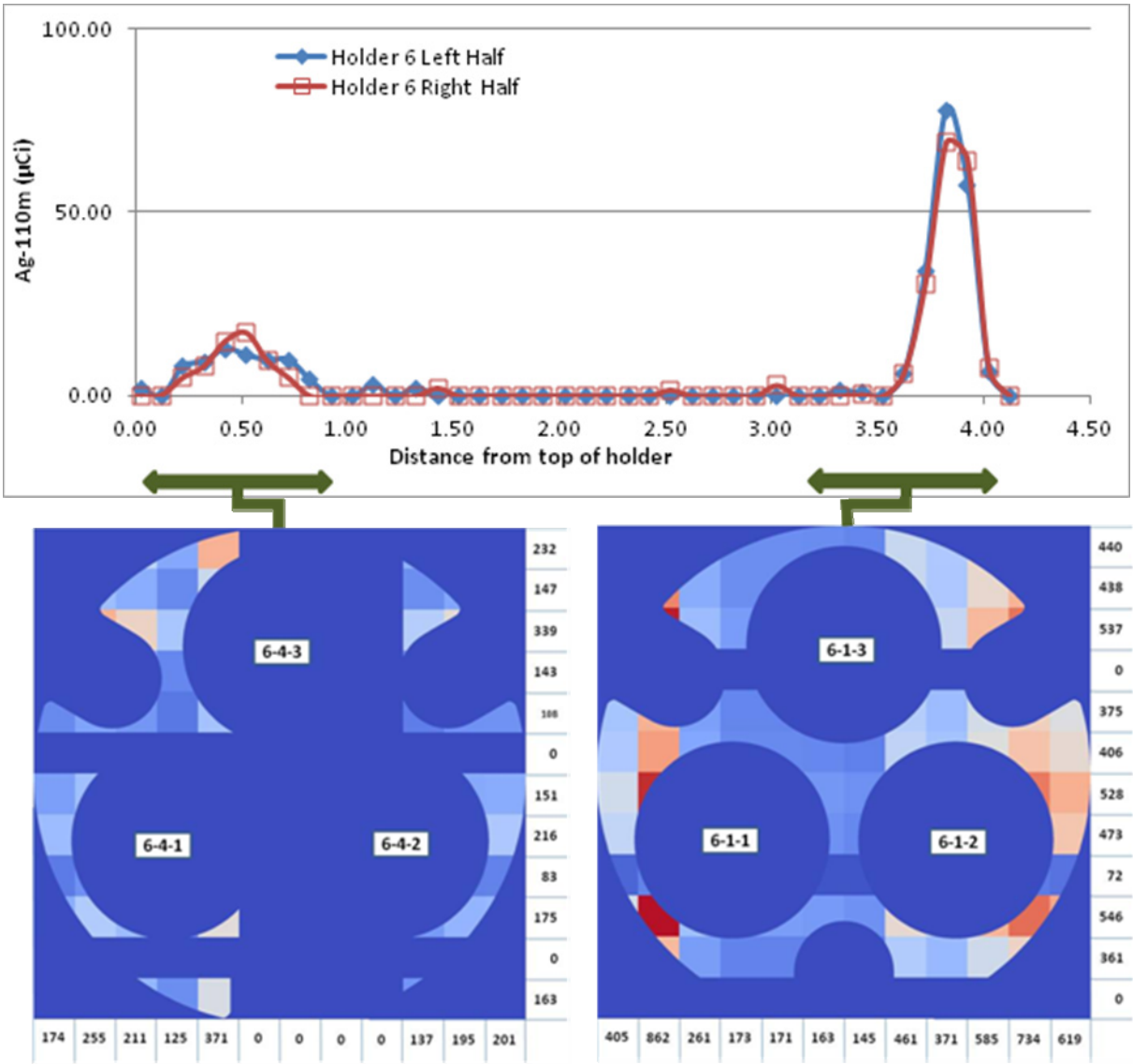

Fig. 12. Measured Ag-110m activity per slice (in µCi per cubic inch) derived from axial PGS scans of the graphite holder from Capsule 6, along with enhanced cross-sectional distributions of Ag-110m. Note that the Stack 3 hole is on top for Holder 6 whereas Hole 2 was on top in lateral scans of the other holders.

Other material was also present in the holders. Flux wires containing cobalt were found in the holders for Capsules 2 and 6. Iron flux wires containing Mn-54 were also found in the collected spectra. Identifying the location of the very small and sometimes hard to find flux wires proved to be a useful side benefit of the holder gamma scanning, and helped in subsequent removal of the flux wires from the graphite holders. The activation products of niobium (Nb-94, Nb-95) are also present in some PGS spectra. Niobium in the holder is due to two sources. The first source is niobium gas lines lodged in the holder. The other source is the thermocouples and thermocouple sleeves that are only present in the holder for Capsule 6. Hafnium activation products were also found in Holder 6 and are the result of HfO_2 that was used as insulation for the TC leads. Holder 6 also contains tantalum activation products. The tantalum appears to be located in the junction of an INL thermocouple (TC) that is still present in Holder 6. Additional tantalum appears to be present as an impurity in niobium TC sleeves. Tantalum is a common impurity in some minerals from which niobium metal is mined, but not all niobium metal is derived from minerals that contain tantalum. The distributions of niobium, hafnium and tantalum are shown in Fig. 13. The niobium seen on the left half near the top of the holder is due to a niobium tube lodged in the holder. The niobium activity peaks are due to an INL TC and the TC sleeve. For most spectra, the tantalum activity follows the niobium peaks, but there are spikes in the tantalum activity. The spikes in the tantalum activity probably indicate the TC junctions.

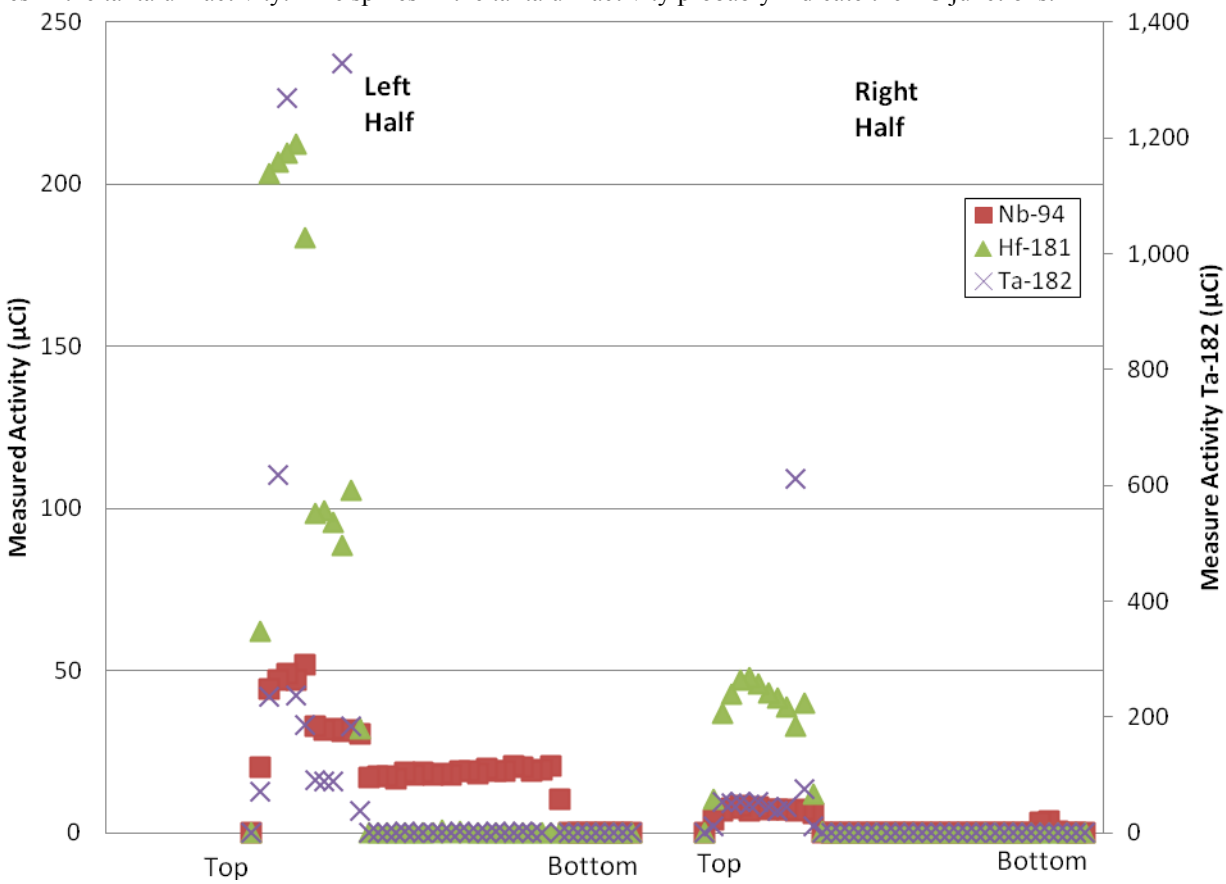

Fig. 13. Distribution of Nb, Hf, and Ta Activation products in Holder 6

In separate PIE activities, Compact AGR-1 6-3-2 was deconsolidated and a leach-burn-leach procedure was performed. The burn-leach solution contained about one particle equivalent of uranium indicating a particle with a defective SiC layer was present in that particular compact. The spectra collected for the graphite holders were closely inspected to see if any Cesium fission products could be found in the PGS scans that could help identify other particles with defective SiC layers. The spectra from Holder 6 revealed a consistent region of detectable quantities of Cs-137 and Cs-134 in the PGS scans. Cs-

137 by itself is a poor indicator of fission product release given its long half life and prevalence as contamination in the HFEF hot cell due to other activities. One issue in identifying very small quantities (~1 μCi) of Cs-134 is interference from natural background peaks that are close in energy to the primary Cs-134 peak. This makes Cs-134 detection by itself also a poor indication of fission product release from a single TRISO particle with a defective SiC layer. Detecting Cs-134 and Cs-137 together in a single spectrum is a good indication of true fission product release. The decay corrected activity ratio of Cs-134 to Cs-137 for the axial PGS scans of Holder 6 is shown in Fig. 14. There are 8 slices in a row in the right half scan that produced detectable activities of Cs-134 and Cs-137. These 8 scans correspond with the location of Compact 6-3-2 during the irradiation. The average ratio over this area also roughly corresponds with the Cs-134 to Cs-137 activity ratio of 0.626 detected by the PGS scans of Compact 6-3-2. Both cesium isotopes occur in coincidence in other axial scans, but both isotopes never occur consistently across a region that corresponds to a different compact.

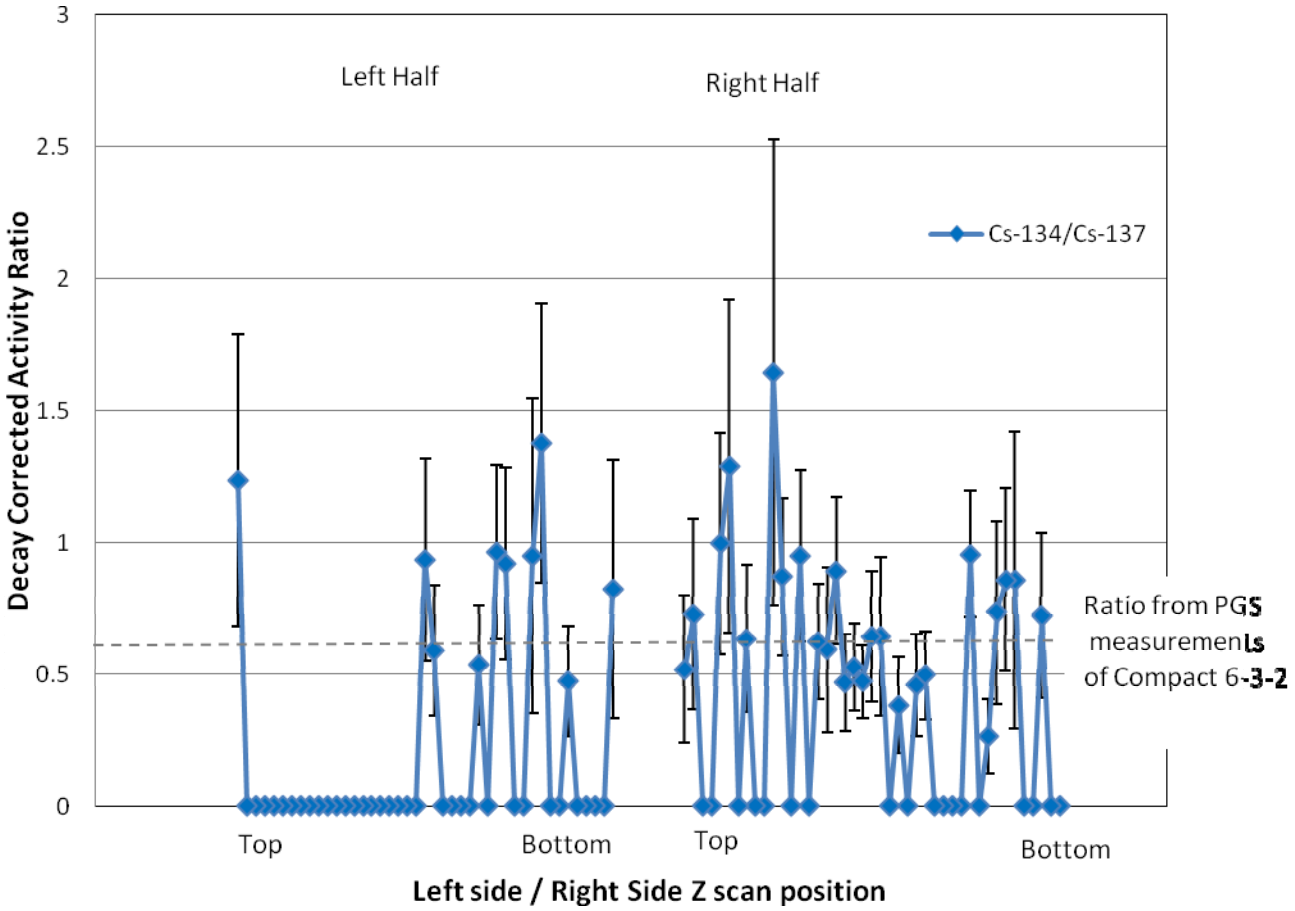

Fig. 14. Activity ratio of Cs-134 to Cs-137* for graphite Holder 6 axial PGS scans.
*Note this value is represented as 0 if either Cs-134 or Cs-137 is below the detection limit.

This investigation was applied to the other holders to detect other compacts that potentially have particles with defective SiC layers. Holder 5 was the only other holder to have a consistent detectable signal from Cs-134 and Cs-137 indicating the possible presence of a particle with a defective SiC layer. Holders 1, 2, and 3 all had some detectable Cs-134 and Cs-137 collocated in individual spectra, but they never had more than 2 consecutive axial scans that contained both cesium isotopes. The decay corrected activity of Cs-134 and Cs-137 is shown in Fig. 15. This plot illustrates the activity spike in cesium isotopes present in the axial scans that correspond to Level 2 of Holder 5 where the activities are several times greater than

the minimum detectable activity. Additionally, the decay corrected activity ratios of Cs-134 to Cs-137 for the two axial scans of Holder 5 are shown in Fig. 16. In this plot there is an area of 9 scans on the left side and 11 scans on the right side where Cs-134 and Cs-137 were concurrently detected, again corresponding to Level 2. When looking at the absolute activity detected in this area, the Cs isotopes are also present at a much higher activity than other locations in the Holder 5 scans. The activity is fairly evenly distributed between the two axial scans making it difficult to discern which compacts at Level 2 were responsible. Accordingly, a Cs-134 intensity map was prepared from lateral scans as described above for Ag-110m maps, and it is presented in Fig. 17. As shown, Compacts 5-2-1 and 5-2-3 both appear to have released Cs-134. As with Ag-110m, Cs-134 evidently migrated toward the relatively cool capsule shell as well as toward the bottom through-tube. Compacts 5-2-1 and 5-2-3 will be deconsolidated and the individual particles gamma counted in an attempt to locate any particles that were less retentive of cesium.

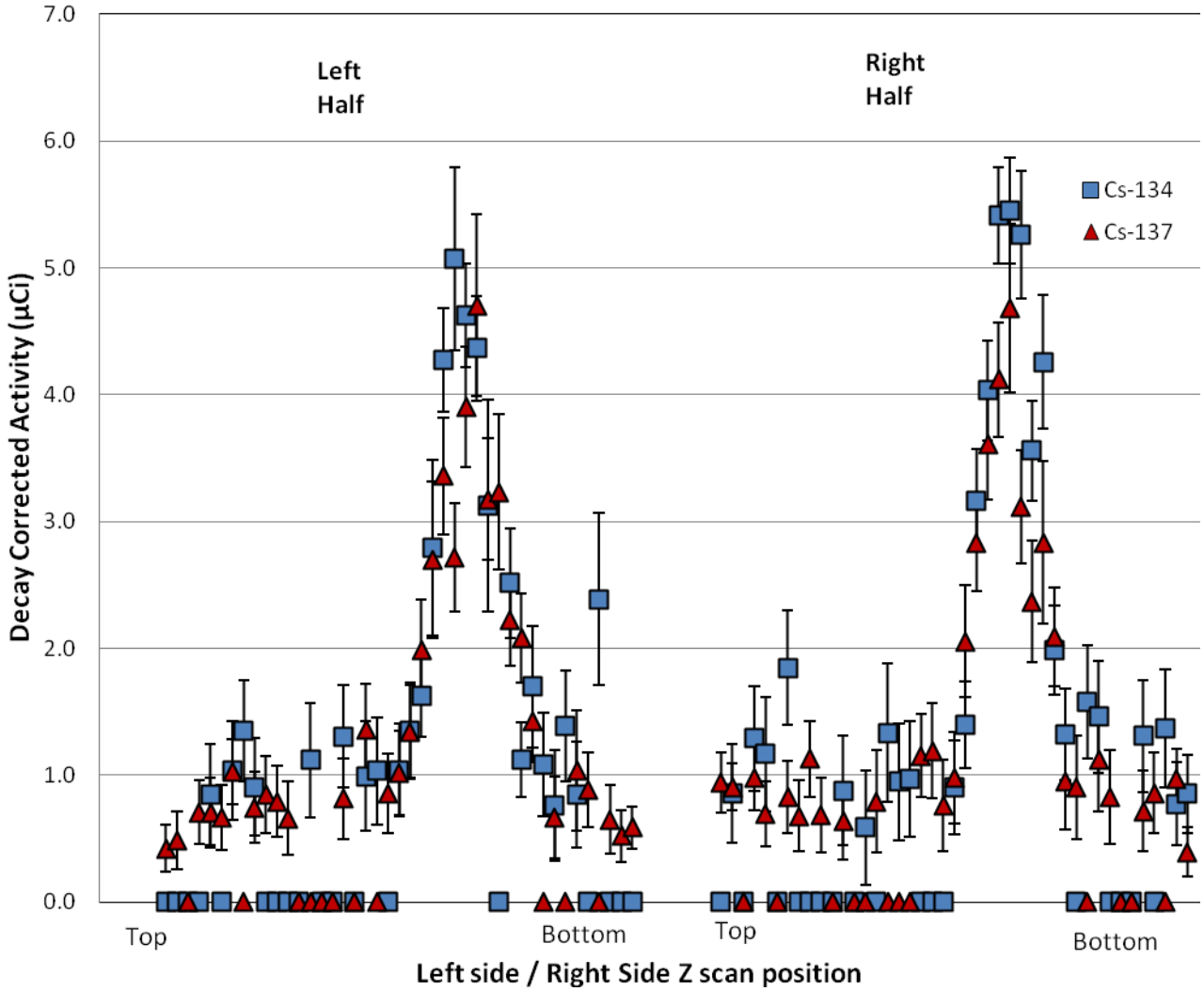

Fig. 15. Decay Corrected Activities of Cs-134 and Cs-137 derived from the axial scans of Holder 5

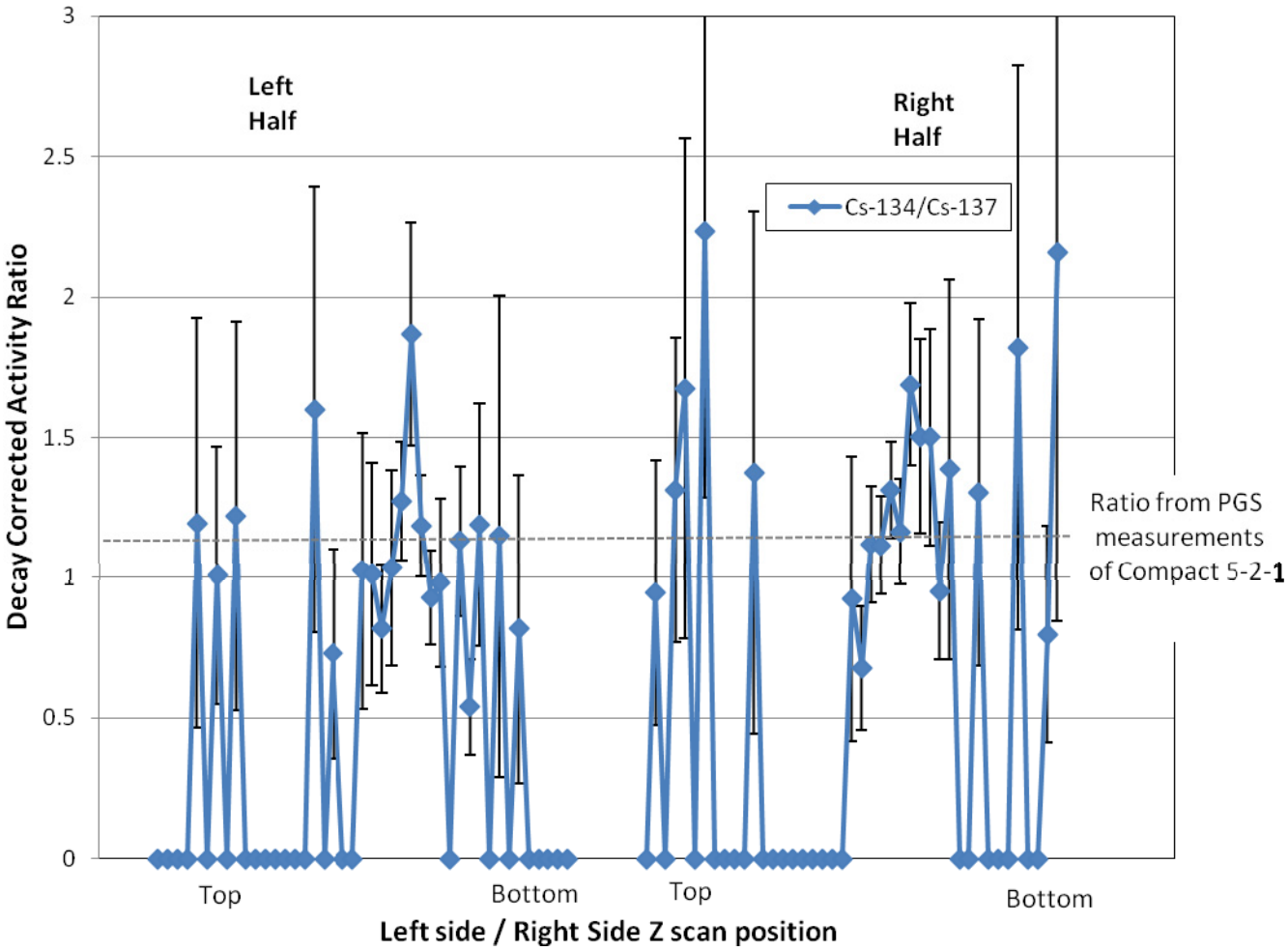

Fig. 16. Activity ratio of Cs-134 to Cs-137* for graphite Holder 5 axial PGS scans
*Note this value is represented as 0 if either Cs-134 or Cs-137 is below the detection limit.

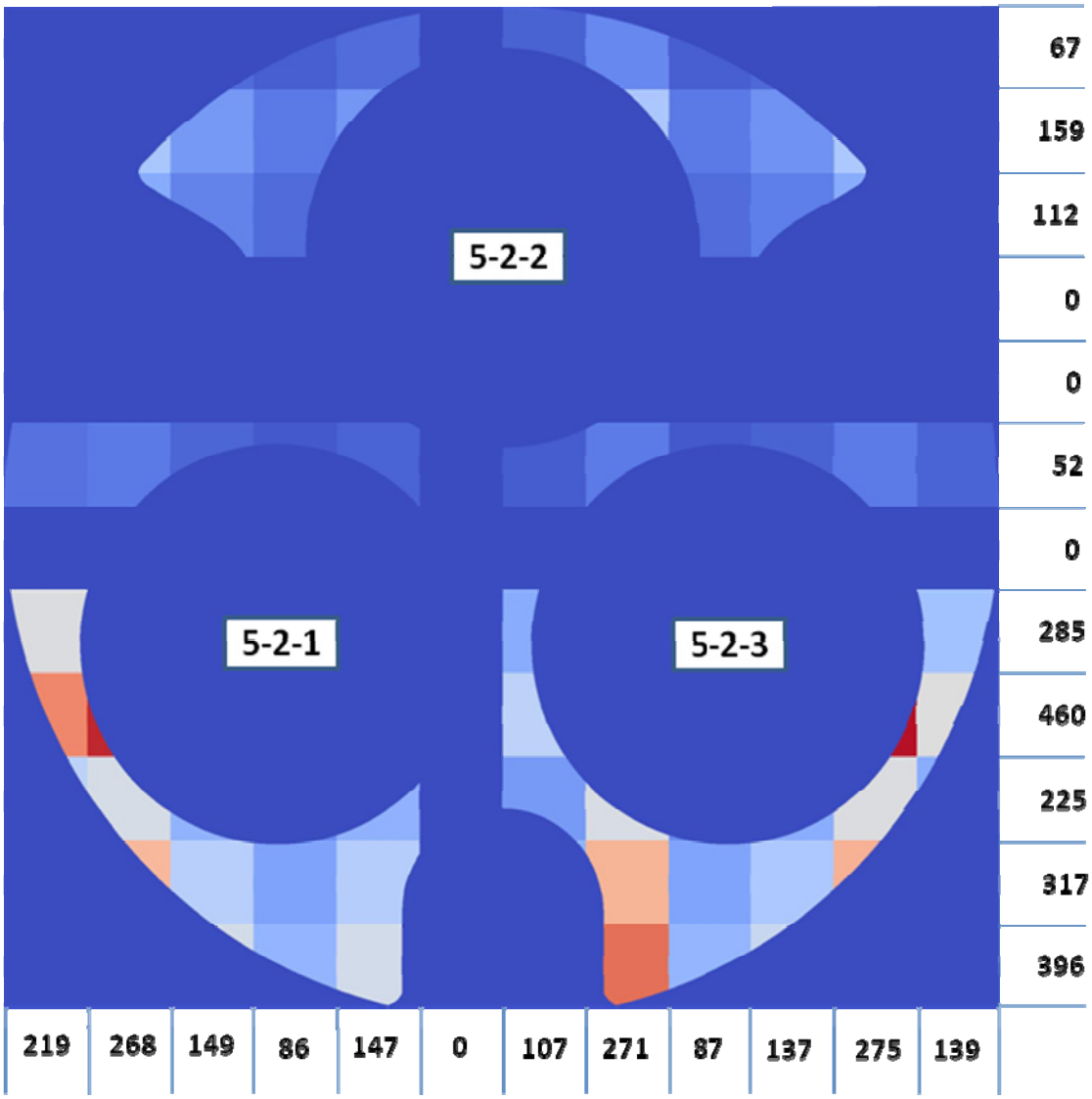

Fig. 17. Enhanced cross-section distribution of Cs-134 in Level 2 of the Capsule 5 graphite holder

Fission Product Inventory of Holders by Gamma Spectrometry in Analytical Lab

In addition to the PGS scans of the intact compact holders, the gamma-ray producing fission product inventory of all 6 compact holders was quantitatively evaluated using a detector in the Analytical Lab (AL). The fission product inventory found using the PGS system was viewed as a more qualitative evaluation of the spatial distribution of the fission products. By scanning the holders in the AL the geometry was better established and the minimum detectable activity was lower than in scans conducted with the PGS system. The compact holders were broken into pieces and loaded into containers that were transferred from HFEF to AL. Each holder was broken into 2 bottles in which the holder materials were not necessarily evenly distributed. This included Holder 4 which was broken in disassembly.

Table 3 contains the total, decay-corrected measured activity inventory for all holders.[8] Several isotopes had measureable activities in at least one of the holders including Ag-110m, Ce-144 (Pr-144), Co-60, Cs-134, Cs-137, Eu-154, Eu-155, and Mn-54. Some of these measured isotopes were not expected such as Mn-54 and Ce-144. Mn-54 is an activation product and is most likely due to Mn or Fe impurities in the graphite of the holders. The decay corrected activities for Mn-54

are roughly 2 to 2.5 times higher between Capsule 6 and Capsules 3 and 4, which is consistent with the fluence differences between those capsules. A detectable amount of Ce-144 appeared in Holders 1, 2, 4, 5, and 6. However the detected activities in Holders 1, 2, 4, and 5 were very near the detection limit and had very large relative uncertainties. Additionally, Ce-144 was only detected in both bottles that held pieces of Holder 6. The other four holders had detectable Ce-144 in only one of the two counted bottles which complicates defining the total detected amount. The following procedure was used in Table 3 in order to calculate a maximum detected limit for all cases where a minimum detectable activity was determined in at least one bottle that contained holder graphite. The calculated detection limit for a bottle was treated as a detected activity and summed with the detected activity from the other bottle that contained graphite from the same holder. The activity sum was then decay corrected and presented as a limit in Table 3.

Table 4 contains the fraction of total capsule inventory represented by the decay corrected activities in Table 3. The total capsule inventory is based on the predicted total fission product inventory for an entire Capsule from Reference 9. Silver by far has the most significant release to the holders. It also has a very large spread in the release fraction covering over 2 orders of magnitude from the inventory of Holder 3 to the inventory of Holder 5.

Table 3. Decay-corrected measured activity inventories for AGR-1 graphite compact holders.

	Activity (μCi)							
	Ag-110m	Ce/Pr-144	Co-60	Cs-134	Cs-137	Eu-154	Eu-155	Mn-54
Holder 1	3929.0	<19	3612.7	2.8	48.9	13.2	11.4	159.9
Holder 2	3718.2	<39	7909.3	<3	35.6	17.7	17.6	264.5
Holder 3	460.6	<24	7301.0	<3	12.9	19.6	17.3	281.3
Holder 4*	9513.5	<64	8367.3	<3	<8	16.6	<8	245.8
Holder 5	13116.8	<57	7480.1	61.7	91.4	21.6	14.9	222.4
Holder 6	501.5	245.9	2124.7	11.3	40.0	49.1	27.6	104.8

*Substantial graphite was lost from Holder 4 during disassembly; calculations estimate as much as 15%.

Table 4. The detected fission product activity from Table 3 is equivalent to the fraction of the total predicted capsule inventory indicated in this table

	Activity (μCi)							
	Ag-110m	Ce/Pr-144	Co-60	Cs-134	Cs-137	Eu-154	Eu-155	Mn-54
Holder 1	8.64E-02	<3E-7	N/A	5.24E-07	9.51E-06	7.42E-05	8.78E-05	N/A
Holder 2	4.94E-02	<5E-7	N/A	<4E-7	6.06E-06	7.53E-05	1.04E-04	N/A
Holder 3	5.13E-03	<3E-7	N/A	<4E-7	2.09E-06	7.58E-05	9.35E-05	N/A
Holder 4*	1.16E-01	<9E-7	N/A	<4E-7	<1E-6	6.74E-05	<5E-5	N/A
Holder 5	2.17E-01	<8E-7	N/A	9.90E-06	1.67E-05	1.06E-04	1.02E-04	N/A
Holder 6	1.64E-02	4.08E-06	N/A	2.99E-06	8.95E-06	3.71E-04	2.77E-04	N/A

The measured Ag-110m activities are similar to the activities measured with the PGS system (presented in Table 2). The maximum difference between the two sets of measurements was 5.7%. The Co-60 measurements are also similar, but not as close as the Ag-110m inventories. The maximum difference between the two sets of measurements was 23% for Holder 6 and less than 6% for all other holders. Measureable quantities of Cs-134 and Cs-137 were detected in Holders 1, 5, and 6, although the amount in Holder 1 was very close to the detection limit. The presence of Cs-134 is a good indicator of a defective SiC layer, as cesium is known to diffuse readily through intact pyrocarbon but be effectively retained by intact SiC. The presence of both cesium isotopes in Holder 6 corresponds to evidence of a particle with a defective SiC layer based on the leach-burn-leach analysis of Compact 6-3-2. There was also some evidence from the PGS gamma scans of Holder 6 that both Cs-137 and Cs-134 were possibly collocated in a section of the holder that corresponded to the location of Compact 6-3-2 (as discussed in the previous section). The measurements in Table 3 and the axial scans of Holder 5 discussed in the previous section suggest that one or more particles with a defective SiC layer can likely be found in Compact 5-2-3 and/or 5-2-1. The Europium isotopes Eu-154 and Eu-155 were also present in the holders. The activity of the Eu-154 in the holders is

low and appears to be below the minimum detectable activity for the PGS scans. More investigation is needed to understand the implication of Eu-154 being released to the holder. However it apparently was released through intact TRISO particles in a similar way to Ag-110m but to a much lesser extent. The release of fission products such as Ag-110m through intact TRISO is a complex process that may be influenced by neutron fluence, temperature history, and fuel variant type. The inventory and distribution of fission products in the holders is one component in determining the mass balance and distribution of Ag-110m in each AGR-1 Capsule. Careful analysis of all PIE data will need to be completed before the mechanisms of fission product release from intact TRISO fuel is fully understood.

Conclusions

Gamma-ray spectrometry scans of the graphite compact holders from the AGR-1 experiment have been completed using the Precision Gamma Scanning system located at the HFEF facility of the INL MFC. These scans investigated the distribution of fission and activation products in the graphite holders. Cobalt-60 and Mn-54 were present in all holders as activation products resulting from contamination in the graphite prior to irradiation. Other activation products detected in the holders appear to be from gas lines or thermocouples that remained in the holders after disassembly. The major fission product present in the holders was Ag-110m. The distribution of Ag-110m was closely examined in axial scans of the holders and further examined level by level with horizontal scans across the holder. The resulting Ag-110m activity intensity maps show Ag-110m tending to concentrate in lower temperature regions of the holders. The relative concentrations of Ag-110m among the holders is highly variable and may be related to a number of factors including neutron fluence, irradiation history, temperature history, and fuel variant type. There is evidence of Cs-134 and Cs-137 release in Holder 5 and 6. A single particle with a defective SiC layer was discovered during deconsolidation-leach-burn-leach of Compact 6-3-2. Either Compact 5-2-1 and/or Compact 5-2-3 is also suspected to also contain one or more particles with a defective SiC layer based on detailed gamma scanning data for Holder 5. Looking for consistent, concurrent Cs-134 and Cs-137 signals in the holder PGS scans should be useful tool in identifying compacts with defective TRISO particles during PIE of future AGR compacts. Additional gamma ray spectrometry measurements conducted in the Analytical Lab support the Ag-110m holder inventory measurements derived from the PGS scans and the detection of significant amounts of Cs-134 and Cs-137 in Holders 5 and 6.

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2. M.A. Pope “AGR-1 Irradiation Test Final As-Run Report,” INL/EXT-10-18097, Idaho National Laboratory, (2010)
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5. INL Drawing 760295, “MFC 785 AGR - 1 GRAPHITE HOLDER CONTAINER ASSEMBLY,” (2010)
6. INL Drawing 771937, “MFC 785 AGR – 1 GRAPHITE HOLDER STORAGE CONTAINER ASSEMBLY, (2010)
7. J.M. Harp “Analysis of Individual Compact Fission Product Inventory and Burnup for the AGR-1 TRISO Experiment using Gamma Spectrometry,” ECAR-1682, Idaho National Laboratory, (2011)
8. INL MFC Analytical Laboratory Interim Reports, AL Log#: 93654, 93655, 93656, 93657, 93658, 93659, 93858, 93859, 93860, 93861, 93862, 93863
9. J.W. Sterbentz, “JMOCUP As-Run Daily Depletion Calculations for the AGR-1 Experiment in ATR B-10 Position,” ECAR-958 Rev 1, Idaho National Laboratory, (2010)

APPENDIX A

Example PC-GAP Listing (.LIS) File

PC-GAP analyzes spectrum files and produces a Listing file (.LIS) that contains the activity of all identified nuclides in the analyzed spectrum as well as all the identified peaks and peak areas. To identify peaks and calculate accurate activities, PC-GAP must be supplied with the appropriate energy calibration and efficiency curve. Below is a sample from an example .LIS file from a scan of the left side of Holder 5. The collected spectrum was 20110304-140827-holder5_leftside_0004.chn or HOLDER5_LEFTSIDE_0004.CHN.

```
ccccccccccccccccccccccccccccccccccccPCGAP copyright (C) E.W.Killian 1995. All rights reserved cccccccccccccccccccccccccccccccccc

 06-SEP-11  13:45  ************************************ PULSE-HEIGHT SPECTRAL ANALYSIS ******************************************
*                                                                                                                                *
*                                                                                                                                *
*   SAMPLE NAME: ORTEC SPECTRUM C:\RESEARCH\AGR-PIE-GAMMASCAN\SPECTRA\CAP5HOLDERSCANS\HOLDER5_LEFT                               *
*                                                                                                                                *
*   SAMPLE ID:          HOLDER5_LEF                           SAMPLE NUMBER:     1                                              *
*                                                                                                                                *
*   SAMPLE COLLECTION (DATE/TIME):  30411/2009                SOURCE-TO-DETECTOR DISTANCE(CM):         0.0                   *
*                                                                                                                                *
*   SAMPLE COUNTED (DATE/TIME):     30411/2009                                                                                   *
*                                                                                                                                *
*   DECAY TIME (HRS):                 0.00                    DET. DEAD TIME(%):              0.21                             *
*                                                                                                                                *
*   COUNTING TIMES (REAL/LIVE SEC.): 7215/7200                                                                                   *
*                                                                                                                                *
*   SAMPLE QUANITY:              1.000E+00                    RANDOM SUM CORRECTION/COUNT RATE: 1.000/183.5                    *
*                                                                                                                                *
*   DETECTOR SYSTEM:                 HO                                                                                          *
*                                                                                                                                *
*   EFFICIENCY TABLE: HO00006246 .... Half Holder PGS Scan slice efficiency                                                      *
*                                                                                                                                *
*   LIBRARIES USED:     MASTER/Test/NOINTLIB                  PARENT-DAUGHTER CORRECTION DONE:  NO                             *
*                                                                                                                                *
*                                                  --BACKGROUNDS AVERAGED--                                                      *
*                                                                                                                                *
**********************************************************************************************************************************
Widths marked with ** deviate from the width equation by more than 20%
```

Title: Examination of Graphite Fuel Compact Holders for the AGR-1 TRISO Experiment using Gamma Spectrometry

ECAR No.: 1709 ECAR Rev. No.: 0 Project File No.: 23843 Date: 11/20/2011

CENTROID	WIDTH	ENERGY	AREA	%ERR	CHI	EFFICIENCY	PEAK CPS	COR CPS	COR GAM/SEC
389.22	8.5**	73.872	7371.	1.95	1.0	3.916E-07	1.02E+00	1.02E+00	2.61E+06

TAG	FIT FLAG	BR(%)	T(1/2)HR	DECAY CORR.	INTENSITY CODE
90 THPB 232	2	10.55	1.23E+14	1.000E+00	8

CENTROID	WIDTH	ENERGY	AREA	%ERR	CHI	EFFICIENCY	PEAK CPS	COR CPS	COR GAM/SEC
400.49	8.6**	76.048	12703.	1.39	1.0	3.973E-07	1.76E+00	1.76E+00	4.44E+06

TAG	FIT FLAG	BR(%)	T(1/2)HR	DECAY CORR.	INTENSITY CODE
91 PA 233	2	1.32	6.48E+02	1.001E+00	3

CENTROID	WIDTH	ENERGY	AREA	%ERR	CHI	EFFICIENCY	PEAK CPS	COR CPS	COR GAM/SEC
450.97	9.3**	85.799	6841.	2.93	1.1	4.210E-07	9.50E-01	9.50E-01	2.26E+06

TAG	FIT FLAG	BR(%)	T(1/2)HR	DECAY CORR.	INTENSITY CODE
55 CS 136	2	6.31	3.16E+02	1.002E+00	2
93 NP 237	2	0.12	1.88E+10	1.000E+00	2
63 EU 155	2	32.60	4.25E+04	1.000E+00	2
65 TB 160	2	13.16	1.74E+03	1.000E+00	2
91 PA 233	2	1.97	6.48E+02	1.001E+00	3

CENTROID	WIDTH	ENERGY	AREA	%ERR	CHI	EFFICIENCY	PEAK CPS	COR CPS	COR GAM/SEC
464.07	9.3**	88.330	2205.	6.76	1.1	4.268E-07	3.06E-01	3.06E-01	7.17E+05

TAG	FIT FLAG	BR(%)	T(1/2)HR	DECAY CORR.	INTENSITY CODE
48 CD 109	2	3.65	1.11E+04	1.000E+00	1
46 PD 109	2	3.61	1.37E+01	1.052E+00	1
63 EU 156	2	8.87	3.65E+02	1.002E+00	2

CENTROID	WIDTH	ENERGY	AREA	%ERR	CHI	EFFICIENCY	PEAK CPS	COR CPS	COR GAM/SEC
697.98	7.1	133.510	205.	84.14	1.1	5.018E-07	2.84E-02	2.84E-02	5.66E+04

TAG	FIT FLAG	BR(%)	T(1/2)HR	DECAY CORR.	INTENSITY CODE
58 CE 144	1	11.20	6.84E+03	1.000E+00	1
72 HF 181	1	43.30	1.02E+03	1.001E+00	2
74 W 187	1	8.56	2.39E+01	1.029E+00	2
56 BA 131	1	2.19	2.83E+02	1.002E+00	3

CENTROID	WIDTH	ENERGY	AREA	%ERR	CHI	EFFICIENCY	PEAK CPS	COR CPS	COR GAM/SEC
759.74	7.2	145.440	203.	78.08	1.1	5.137E-07	2.82E-02	2.82E-02	5.49E+04

TAG	FIT FLAG	BR(%)	T(1/2)HR	DECAY CORR.	INTENSITY CODE
58 CE 141	1	48.50	7.80E+02	1.001E+00	1

Title: Examination of Graphite Fuel Compact Holders for the AGR-1 TRISO Experiment using Gamma Spectrometry

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CENTROID	WIDTH	ENERGY	AREA	%ERR	CHI	EFFICIENCY	PEAK CPS	COR CPS	COR GAM/SEC
1245.24	8.4	239.235	951.	13.51	1.2	5.219E-07	1.32E-01	1.32E-01	2.53E+05

TAG	FIT FLAG	BR(%)	T(1/2)HR	DECAY CORR.	INTENSITY CODE
90 THPB 232	0	43.50	1.23E+14	1.000E+00	1
82 PB 212	0	43.50	1.06E+01	1.067E+00	1
56 BA 131	0	2.41	2.83E+02	1.002E+00	3

1536.29	5.9**	295.474	287.	17.96	1.0	4.803E-07	3.98E-02	3.98E-02	8.29E+04

TAG	FIT FLAG	BR(%)	T(1/2)HR	DECAY CORR.	INTENSITY CODE
88 RAPB 226	0	18.70	1.40E+07	1.000E+00	2
82 PB 214	0	18.70	4.47E-01	3.255E+00	2
68 ER 171	0	28.90	7.52E+00	1.095E+00	2
77 IR 192	0	28.70	1.77E+03	1.000E+00	2

1760.16	15.0**	338.737	255.	45.94	1.0	4.406E-07	3.55E-02	3.55E-02	8.05E+04

TAG	FIT FLAG	BR(%)	T(1/2)HR	DECAY CORR.	INTENSITY CODE
90 THAC 232	0	12.44	1.23E+14	1.000E+00	2
89 AC 228	0	12.44	6.13E+00	1.118E+00	2

1829.48	10.3	352.135	676.	11.12	1.2	4.287E-07	9.39E-02	9.39E-02	2.19E+05

TAG	FIT FLAG	BR(%)	T(1/2)HR	DECAY CORR.	INTENSITY CODE
88 RAPB 226	0	35.80	1.40E+07	1.000E+00	1
82 PB 214	0	35.80	4.47E-01	3.255E+00	1

2221.31	9.9	427.870	-48.	79.00	1.1	3.760E-07	-6.67E-03	-6.67E-03	-1.77E+04

TAG	FIT FLAG	BR(%)	T(1/2)HR	DECAY CORR.	INTENSITY CODE
51 SB 125	1	29.40	2.42E+04	1.000E+00	1

2353.93	10.1	453.506	55.	68.37	1.0	3.603E-07	7.62E-03	7.62E-03	2.11E+04

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ECAR No.: 1709 ECAR Rev. No.: 0 Project File No.: 23843 Date: 11/20/2011

CENTROID	WIDTH	ENERGY	AREA	%ERR	CHI	EFFICIENCY	PEAK CPS	COR CPS	COR GAM/SEC
2579.33	10.5	497.080	3.	976.45	1.0	3.383E-07	4.67E-04	4.67E-04	1.38E+03

TAG	FIT FLAG	BR(%)	T(1/2)HR	DECAY CORR.	INTENSITY CODE
56 BA 131	1	43.78	2.83E+02	1.002E+00	1
44 RU 103	1	89.50	9.42E+02	1.001E+00	1
36 KR 89	1	7.74	5.27E-02	2.638E+01	2

2650.43	14.0**	510.826	748.	8.27	1.0	3.324E-07	1.04E-01	1.04E-01	3.12E+05
2928.17	11.2	564.528	35.	106.60	1.2	3.129E-07	4.92E-03	4.92E-03	1.57E+04

TAG	FIT FLAG	BR(%)	T(1/2)HR	DECAY CORR.	INTENSITY CODE
51 SB 122	1	70.55	6.48E+01	1.011E+00	1

2953.00	11.2	569.330	48.	73.03	1.2	3.114E-07	6.65E-03	6.65E-03	2.14E+04

TAG	FIT FLAG	BR(%)	T(1/2)HR	DECAY CORR.	INTENSITY CODE
55 CS 134	1	15.39	1.81E+04	1.000E+00	2

3024.33	14.8**	583.124	522.	10.27	1.1	3.071E-07	7.26E-02	7.26E-02	2.36E+05

TAG	FIT FLAG	BR(%)	T(1/2)HR	DECAY CORR.	INTENSITY CODE
81 TL 208	0	85.10	5.09E-02	2.730E+01	2
90 THTL 232	0	30.58	1.23E+14	1.000E+00	2

3114.70	11.5	600.600	50.	58.49	1.0	3.020E-07	6.91E-03	6.91E-03	2.29E+04

TAG	FIT FLAG	BR(%)	T(1/2)HR	DECAY CORR.	INTENSITY CODE
51 SB 125	1	17.80	2.42E+04	1.000E+00	2

3136.01	11.5	604.720	-13.	218.20	1.0	3.009E-07	-1.84E-03	-1.84E-03	-6.12E+03

TAG	FIT FLAG	BR(%)	T(1/2)HR	DECAY CORR.	INTENSITY CODE
55 CS 134	1	97.63	1.81E+04	1.000E+00	2
35 BR 84	1	1.72	5.30E-01	2.827E+00	2
51 SB 127	1	4.27	9.24E+01	1.008E+00	2
77 IR 192	1	8.09	1.77E+03	1.000E+00	3

Title: Examination of Graphite Fuel Compact Holders for the AGR-1 TRISO Experiment using Gamma Spectrometry

ECAR No.: 1709 ECAR Rev. No.: 0 Project File No.: 23843 Date: 11/20/2011

CENTROID	WIDTH	ENERGY	AREA	%ERR	CHI	EFFICIENCY	PEAK CPS	COR CPS	COR GAM/SEC
3159.66	14.9**	609.293	909.	6.35	1.1	2.996E-07	1.26E-01	1.26E-01	4.21E+05

	TAG	FIT FLAG	BR(%)	T(1/2)HR	DECAY CORR.	INTENSITY CODE
83	BI 214	0	46.09	3.32E-01	4.253E+00	1
88	RABI 226	0	46.09	1.40E+07	1.000E+00	1
68	ER 172	0	44.20	4.93E+01	1.014E+00	1
22	TI 51	0	1.18	9.60E-02	1.447E+01	3

3165.02	11.6	610.330	-42.	97.72	1.1	2.993E-07	-5.83E-03	-5.83E-03	-1.95E+04

	TAG	FIT FLAG	BR(%)	T(1/2)HR	DECAY CORR.	INTENSITY CODE
44	RU 103	1	5.64	9.42E+02	1.001E+00	3

3225.00	11.7	621.930	11.	242.21	1.0	2.961E-07	1.59E-03	1.59E-03	5.38E+03

	TAG	FIT FLAG	BR(%)	T(1/2)HR	DECAY CORR.	INTENSITY CODE
45	RURH 106	1	9.81	8.94E+03	9.999E-01	1
53	I 134	1	10.59	8.77E-01	1.993E+00	2
53	I 132	1	1.58	2.28E+00	1.335E+00	3

3265.30	11.8	629.723	34.	81.97	1.0	2.939E-07	4.77E-03	4.77E-03	1.62E+04

	TAG	FIT FLAG	BR(%)	T(1/2)HR	DECAY CORR.	INTENSITY CODE
53	I 132	1	13.80	2.28E+00	1.335E+00	2

3297.50	11.8	635.950	0.	9999.00	1.0	2.922E-07	2.44E-05	2.44E-05	8.35E+01

	TAG	FIT FLAG	BR(%)	T(1/2)HR	DECAY CORR.	INTENSITY CODE
51	SB 125	1	11.30	2.42E+04	1.000E+00	2

3412.38	16.8**	658.169	169.	33.16	1.1	2.861E-07	2.35E-02	2.35E-02	8.20E+04

	TAG	FIT FLAG	BR(%)	T(1/2)HR	DECAY CORR.	INTENSITY CODE
41	NB 97	0	98.34	1.20E+00	1.687E+00	1
47	AGM 110	0	94.64	5.99E+03	1.000E+00	1
37	RB 89	0	9.98	2.53E-01	5.507E+00	2
52	TEM 127	0	0.01	2.62E+03	1.000E+00	3

Title: Examination of Graphite Fuel Compact Holders for the AGR-1 TRISO Experiment using Gamma Spectrometry

ECAR No.: 1709 ECAR Rev. No.: 0 Project File No.: 23843 Date: 11/20/2011

CENTROID	WIDTH	ENERGY	AREA	%ERR	CHI	EFFICIENCY	PEAK CPS	COR CPS	COR GAM/SEC
3430.22	12.1	661.620	89.	35.20	1.0	2.851E-07	1.24E-02	1.24E-02	4.33E+04

TAG	FIT FLAG	BR(%)	T(1/2)HR	DECAY CORR.	INTENSITY CODE
55 CS 137	1	85.20	2.65E+05	1.000E+00	1

CENTROID	WIDTH	ENERGY	AREA	%ERR	CHI	EFFICIENCY	PEAK CPS	COR CPS	COR GAM/SEC
3643.25	13.6	702.824	3783.	2.54	1.3	2.730E-07	5.25E-01	5.25E-01	1.92E+06

TAG	FIT FLAG	BR(%)	T(1/2)HR	DECAY CORR.	INTENSITY CODE
41 NB 94	0	99.79	1.75E+08	1.000E+00	2
40 ZR 97	0	0.93	1.69E+01	1.042E+00	3

CENTROID	WIDTH	ENERGY	AREA	%ERR	CHI	EFFICIENCY	PEAK CPS	COR CPS	COR GAM/SEC
3753.71	12.7	724.190	45.	69.49	1.2	2.665E-07	6.22E-03	6.22E-03	2.33E+04

TAG	FIT FLAG	BR(%)	T(1/2)HR	DECAY CORR.	INTENSITY CODE
44 RU 105	1	46.70	4.44E+00	1.165E+00	1
63 EU 156	1	5.91	3.65E+02	1.002E+00	2
40 ZR 95	1	44.15	1.54E+03	1.000E+00	2
63 EU 154	1	19.69	7.53E+04	1.000E+00	2
54 XE 139	1	1.67	1.10E-02	1.260E+02	3

CENTROID	WIDTH	ENERGY	AREA	%ERR	CHI	EFFICIENCY	PEAK CPS	COR CPS	COR GAM/SEC
3831.00	12.8	739.142	21.	123.67	1.0	2.620E-07	2.90E-03	2.90E-03	1.11E+04

TAG	FIT FLAG	BR(%)	T(1/2)HR	DECAY CORR.	INTENSITY CODE
36 KR 89	1	4.18	5.27E-02	2.638E+01	2
53 I 130	1	82.27	1.24E+01	1.057E+00	2
42 MO 99	1	12.28	6.59E+01	1.011E+00	2
56 BA 141	1	4.28	3.05E-01	4.611E+00	3

CENTROID	WIDTH	ENERGY	AREA	%ERR	CHI	EFFICIENCY	PEAK CPS	COR CPS	COR GAM/SEC
3921.87	13.0	756.720	22.	114.23	1.0	2.572E-07	3.12E-03	3.12E-03	1.21E+04

TAG	FIT FLAG	BR(%)	T(1/2)HR	DECAY CORR.	INTENSITY CODE
40 ZR 95	1	54.50	1.54E+03	1.000E+00	1
63 EU 154	1	4.34	7.53E+04	1.000E+00	2

Title: Examination of Graphite Fuel Compact Holders for the AGR-1 TRISO Experiment using Gamma Spectrometry

ECAR No.: 1709 ECAR Rev. No.: 0 Project File No.: 23843 Date: 11/20/2011

CENTROID	WIDTH	ENERGY	AREA	%ERR	CHI	EFFICIENCY	PEAK CPS	COR CPS	COR GAM/SEC
3970.91	16.4**	766.208	435.	9.93	1.0	2.549E-07	6.04E-02	6.04E-02	2.37E+05

TAG	FIT FLAG	BR(%)	T(1/2)HR	DECAY CORR.	INTENSITY CODE
41 NB 95	0	99.81	8.39E+02	1.001E+00	1
65 TB 160	0	2.00	1.74E+03	1.000E+00	2
53 I 134	0	4.10	8.77E-01	1.993E+00	2
91 PAM 234	0	0.30	3.92E+13	1.000E+00	2

CENTROID	WIDTH	ENERGY	AREA	%ERR	CHI	EFFICIENCY	PEAK CPS	COR CPS	COR GAM/SEC
4075.10	13.2	786.365	67.	40.32	1.0	2.507E-07	9.37E-03	9.37E-03	3.74E+04

TAG	FIT FLAG	BR(%)	T(1/2)HR	DECAY CORR.	INTENSITY CODE
41 NBM 98	1	93.00	8.55E-01	2.023E+00	1
90 THBI 232	1	1.10	1.23E+14	1.000E+00	2
83 BI 212	1	1.10	1.01E+00	1.841E+00	2
88 RAPB 226	1	1.05	1.40E+07	1.000E+00	3
82 PB 214	1	1.05	4.47E-01	3.255E+00	3

CENTROID	WIDTH	ENERGY	AREA	%ERR	CHI	EFFICIENCY	PEAK CPS	COR CPS	COR GAM/SEC
4124.18	13.3	795.860	39.	80.24	1.2	2.491E-07	5.46E-03	5.46E-03	2.19E+04

TAG	FIT FLAG	BR(%)	T(1/2)HR	DECAY CORR.	INTENSITY CODE
55 CS 134	1	85.52	1.81E+04	1.000E+00	1

CENTROID	WIDTH	ENERGY	AREA	%ERR	CHI	EFFICIENCY	PEAK CPS	COR CPS	COR GAM/SEC
4456.12	13.9	860.086	36.	74.03	1.0	2.403E-07	5.03E-03	5.03E-03	2.10E+04

TAG	FIT FLAG	BR(%)	T(1/2)HR	DECAY CORR.	INTENSITY CODE
81 TL 208	1	12.52	5.09E-02	2.730E+01	2
90 THTL 232	1	4.50	1.23E+14	1.000E+00	2

CENTROID	WIDTH	ENERGY	AREA	%ERR	CHI	EFFICIENCY	PEAK CPS	COR CPS	COR GAM/SEC
4513.38	15.6	871.167	3192.	2.48	1.1	2.383E-07	4.43E-01	4.43E-01	1.86E+06

TAG	FIT FLAG	BR(%)	T(1/2)HR	DECAY CORR.	INTENSITY CODE
41 NB 94	0	99.86	1.75E+08	1.000E+00	1
55 CS 138	0	5.12	5.37E-01	2.799E+00	2

CENTROID	WIDTH	ENERGY	AREA	%ERR	CHI	EFFICIENCY	PEAK CPS	COR CPS	COR GAM/SEC
4572.09	14.1	882.527	57.	57.60	1.2	2.360E-07	7.87E-03	7.87E-03	3.33E+04

TAG	FIT FLAG	BR(%)	T(1/2)HR	DECAY CORR.	INTENSITY CODE
35 BR 84	1	41.00	5.30E-01	2.827E+00	2

Title: Examination of Graphite Fuel Compact Holders for the AGR-1 TRISO Experiment using Gamma Spectrometry

ECAR No.: 1709 ECAR Rev. No.: 0 Project File No.: 23843 Date: 11/20/2011

CENTROID	WIDTH	ENERGY	AREA	%ERR	CHI	EFFICIENCY	PEAK CPS	COR CPS	COR GAM/SEC
4583.21	14.2	884.680	81.	37.20	1.1	2.356E-07	1.12E-02	1.12E-02	4.75E+04

	TAG	FIT FLAG	BR(%)	T(1/2)HR	DECAY CORR.	INTENSITY CODE
53	I 134	1	64.87	8.77E-01	1.993E+00	1
47	AGM 110	1	72.68	5.99E+03	1.000E+00	2

4718.25	16.7	910.812	486.	8.40	1.0	2.295E-07	6.75E-02	6.75E-02	2.94E+05

	TAG	FIT FLAG	BR(%)	T(1/2)HR	DECAY CORR.	INTENSITY CODE
90	THAC 232	0	28.73	1.23E+14	1.000E+00	1
89	AC 228	0	28.73	6.13E+00	1.118E+00	1
52	TEM 131	0	3.29	3.00E+01	1.023E+00	3
0	SGL_ESCAPE 1421	0	100.00	2.78E-04	1.000E+00	30

4856.04	14.7	937.480	-9.	322.59	1.0	2.229E-07	-1.21E-03	-1.21E-03	-5.42E+03

	TAG	FIT FLAG	BR(%)	T(1/2)HR	DECAY CORR.	INTENSITY CODE
47	AGM 110	1	34.36	5.99E+03	1.000E+00	2

5017.11	19.6**	968.654	200.	27.47	1.1	2.163E-07	2.78E-02	2.78E-02	1.28E+05

	TAG	FIT FLAG	BR(%)	T(1/2)HR	DECAY CORR.	INTENSITY CODE
90	THAC 232	0	17.42	1.23E+14	1.000E+00	2
89	AC 228	0	17.42	6.13E+00	1.118E+00	2
44	RU 105	0	2.08	4.44E+00	1.165E+00	2
51	SB 124	0	1.87	1.44E+03	1.000E+00	3

5159.73	15.2	996.260	-15.	178.47	1.1	2.120E-07	-2.06E-03	-2.06E-03	-9.72E+03

	TAG	FIT FLAG	BR(%)	T(1/2)HR	DECAY CORR.	INTENSITY CODE
63	EU 154	1	10.29	7.53E+04	1.000E+00	2
41	NBM 98	1	2.05	8.55E-01	2.023E+00	3
52	TE 131	1	3.34	4.17E-01	3.457E+00	3

5203.34	15.3	1004.700	-22.	118.52	1.1	2.110E-07	-3.05E-03	-3.05E-03	-1.45E+04

	TAG	FIT FLAG	BR(%)	T(1/2)HR	DECAY CORR.	INTENSITY CODE
63	EU 154	1	17.88	7.53E+04	1.000E+00	2

Title: Examination of Graphite Fuel Compact Holders for the AGR-1 TRISO Experiment using Gamma Spectrometry

ECAR No.: 1709 ECAR Rev. No.: 0 Project File No.: 23843 Date: 11/20/2011

CENTROID	WIDTH	ENERGY	AREA	%ERR	CHI	EFFICIENCY	PEAK CPS	COR CPS	COR GAM/SEC
5439.41	15.7	1050.400	-13.	188.34	1.0	2.068E-07	-1.81E-03	-1.81E-03	-8.75E+03

TAG	FIT FLAG	BR(%)	T(1/2)HR	DECAY CORR.	INTENSITY CODE
45 RURH 106	1	1.53	8.94E+03	9.999E-01	2

5800.55	23.8**	1120.318	449.	16.42	1.2	2.009E-07	6.23E-02	6.23E-02	3.10E+05

TAG	FIT FLAG	BR(%)	T(1/2)HR	DECAY CORR.	INTENSITY CODE
83 BI 214	0	15.04	3.32E-01	4.253E+00	2
88 RABI 226	0	15.04	1.40E+07	1.000E+00	2
21 SC 46	0	99.99	2.01E+03	1.000E+00	2
73 TA 182	0	34.75	2.76E+03	1.000E+00	2

5868.25	16.5	1133.427	65.	40.75	1.1	1.994E-07	9.08E-03	9.08E-03	4.55E+04
6072.20	19.6	1172.919	6329.	3.03	2.0	1.944E-07	8.79E-01	8.79E-01	4.52E+06

TAG	FIT FLAG	BR(%)	T(1/2)HR	DECAY CORR.	INTENSITY CODE
27 CO 60	0	99.89	4.62E+04	1.000E+00	2
53 I 132	0	1.09	2.28E+00	1.335E+00	3

6236.83	17.1	1204.800	15.	138.61	1.0	1.905E-07	2.09E-03	2.09E-03	1.10E+04

TAG	FIT FLAG	BR(%)	T(1/2)HR	DECAY CORR.	INTENSITY CODE
39 Y 91	1	0.30	1.40E+03	1.001E+00	1
56 BA 142	1	15.78	1.77E-01	7.867E+00	2

6323.16	19.4	1221.520	152.	16.91	1.0	1.887E-07	2.11E-02	2.11E-02	1.12E+05

TAG	FIT FLAG	BR(%)	T(1/2)HR	DECAY CORR.	INTENSITY CODE
73 TA 182	0	27.33	2.76E+03	1.000E+00	1

6402.30	17.4	1236.847	91.	24.55	1.0	1.873E-07	1.27E-02	1.27E-02	6.77E+04

TAG	FIT FLAG	BR(%)	T(1/2)HR	DECAY CORR.	INTENSITY CODE
53 I 133	1	1.49	2.08E+01	1.034E+00	3
0 SUM_SB 125	1	11.30	2.42E+04	1.000E+00	20

6451.68	17.5	1246.411	50.	39.46	1.0	1.865E-07	6.88E-03	6.88E-03	3.69E+04

Title: Examination of Graphite Fuel Compact Holders for the AGR-1 TRISO Experiment using Gamma Spectrometry

ECAR No.: 1709 ECAR Rev. No.: 0 Project File No.: 23843 Date: 11/20/2011

CENTROID	WIDTH	ENERGY	AREA	%ERR	CHI	EFFICIENCY	PEAK CPS	COR CPS	COR GAM/SEC
6596.18	17.8	1274.400	-4.	425.93	1.0	1.844E-07	-5.50E-04	-5.50E-04	-2.99E+03

TAG	FIT FLAG	BR(%)	T(1/2)HR	DECAY CORR.	INTENSITY CODE
63 EU 154	1	35.49	7.53E+04	1.000E+00	1
11 NA 22	1	99.93	2.28E+04	1.000E+00	1
36 KR 89	1	1.35	5.27E-02	2.638E+01	3

6733.50	18.0	1300.998	27.	59.43	1.1	1.825E-07	3.80E-03	3.80E-03	2.08E+04
6830.25	18.2	1319.740	24.	66.13	1.0	1.811E-07	3.38E-03	3.38E-03	1.86E+04
6894.34	20.6	1332.156	5544.	2.48	1.6	1.800E-07	7.70E-01	7.70E-01	4.28E+06

TAG	FIT FLAG	BR(%)	T(1/2)HR	DECAY CORR.	INTENSITY CODE
27 CO 60	0	99.98	4.62E+04	1.000E+00	1

7117.00	18.7	1375.291	41.	35.96	1.0	1.754E-07	5.69E-03	5.69E-03	3.24E+04
7163.50	18.8	1384.300	8.	160.95	1.0	1.742E-07	1.08E-03	1.08E-03	6.18E+03

TAG	FIT FLAG	BR(%)	T(1/2)HR	DECAY CORR.	INTENSITY CODE
38 SR 92	1	90.00	2.71E+00	1.278E+00	1
47 AGM 110	1	24.29	5.99E+03	1.000E+00	2

7282.86	19.5	1407.426	57.	28.46	1.1	1.704E-07	7.89E-03	7.89E-03	4.63E+04

TAG	FIT FLAG	BR(%)	T(1/2)HR	DECAY CORR.	INTENSITY CODE
83 BI 214	0	2.48	3.32E-01	4.253E+00	2
63 EU 152	0	20.85	1.18E+05	1.000E+00	2
88 RABI 226	0	2.48	1.40E+07	1.000E+00	3

7357.70	19.2	1421.928	5.	236.00	1.0	1.676E-07	6.43E-04	6.43E-04	3.84E+03
7554.25	23.5**	1460.014	2690.	2.65	1.1	1.581E-07	3.74E-01	3.74E-01	2.36E+06

TAG	FIT FLAG	BR(%)	T(1/2)HR	DECAY CORR.	INTENSITY CODE
19 K 40	0	10.67	1.10E+13	1.000E+00	1
89 AC 228	0	1.06	6.13E+00	1.118E+00	2
90 THAC 232	0	1.06	1.23E+14	1.000E+00	3

Title: Examination of Graphite Fuel Compact Holders for the AGR-1 TRISO Experiment using Gamma Spectrometry

ECAR No.: 1709 ECAR Rev. No.: 0 Project File No.: 23843 Date: 11/20/2011

CENTROID	WIDTH	ENERGY	AREA	%ERR	CHI	EFFICIENCY	PEAK CPS	COR CPS	COR GAM/SEC
7613.18	19.6	1471.433	25.	46.47	1.2	1.546E-07	3.45E-03	3.45E-03	2.23E+04
7801.00	20.0	1507.831	33.	36.17	1.0	1.415E-07	4.57E-03	4.57E-03	3.23E+04

TAG	FIT FLAG	BR(%)	T(1/2)HR	DECAY CORR.	INTENSITY CODE
49 INM 116	1	9.96	9.02E-01	1.960E+00	2

****

9 LINES NOT TAGGED
38 TAGS REMOVED--NO ICODE 1 LINE

ISOTOPE SUMMARY

ISOTOPE	LIB ENG	LINE ENG	I-C	FLAGS	OTHER TAGS	MICRO-CI/UNIT	%ERROR	NET MICRO-CI/UNIT	NET %ERROR(1-SIGMA)
11 NA 22	1274.54	1274.40	1	1	63 EU 154	-8.074E-02	425.93		
								-8.074E-02	425.93
								**********	
								MDL= 1.457E+00	
								**********	
19 K 40	1460.83	1460.01	1	0	89 AC 228	5.993E+02+	2.65		
					90 THAC 232				
								5.993E+02	2.65
27 CO 60	1173.24	1172.92	2	0		1.224E+02+	3.03		
	1332.50	1332.16	1	0		1.156E+02+	2.48		
								1.172E+02	2.41
38 SR 92	1384.06	1384.30	1	1	47 AGM 110	2.370E-01	160.95		
								2.370E-01	160.95
								**********	
								MDL= 1.648E+00	
								**********	
39 Y 91	1204.96	1204.80	1	1		9.883E+01	138.61		
								9.883E+01	138.61
								**********	
								MDL= 5.742E+02	

Title: Examination of Graphite Fuel Compact Holders for the AGR-1 TRISO Experiment using Gamma Spectrometry

ECAR No.: 1709 ECAR Rev. No.: 0 Project File No.: 23843 Date: 11/20/2011

ISOTOPE	LIB ENG	LINE ENG	I-C	FLAGS	OTHER TAGS	MICRO-CI/UNIT	%ERROR	NET MICRO-CI/UNIT	NET %ERROR(1-SIGMA)
								**********	
40 ZR 95	724.20	724.19	2	513	44 RU 105	1.429E+00	69.49		
					63 EU 154				
	756.73	756.72	1	1	63 EU 154	6.010E-01	114.23		
								6.010E-01	114.23
								**********	
								MDL= 2.853E+00	
								**********	
41 NB 94	702.65	702.82	2	0		5.212E+01+	2.54		
	871.12	871.17	1	0		5.034E+01+	2.48		
								5.089E+01	2.04
41 NB 95	765.81	766.21	1	0	53 I 134	6.419E+00+	9.93		
								6.419E+00	9.93
41 NB 97	658.22	658.17	1	0	47 AGM 110	3.802E+00+	33.16		
								3.802E+00	33.16
41 NBM 98	787.32	786.36	1	1	82 PB 214	2.198E+00+	40.32		
					88 RAPB 226				
	996.40	996.26	3	513	63 EU 154	-2.597E+01	178.47		
								2.198E+00	40.32
44 RU 103	497.05	497.08	1	1	56 BA 131	4.172E-02	976.45		
	610.30	610.33	3	513		-9.344E+00	97.72		
								4.172E-02	976.45
								**********	
								MDL= 1.679E+00	
								**********	
44 RU 105	724.27	724.19	1	1	40 ZR 95	1.573E+00	69.49		
					63 EU 154				
	969.46	968.65	2	512	89 AC 228	1.947E+02+	27.47		
					90 THAC 232				
								1.573E+00	69.49
								**********	
								MDL= 4.512E+00	
								**********	
45 RURH 106	621.92	621.93	1	1	53 I 134	1.483E+00	242.21		
	1050.36	1050.40	2	513		-1.550E+01	188.34		
								**********	
								MDL= 1.488E+01	
								**********	
46 PD 109	88.03	88.33	1	2	48 CD 109	5.656E+02+	6.76		
								5.656E+02	6.76

Title: Examination of Graphite Fuel Compact Holders for the AGR-1 TRISO Experiment using Gamma Spectrometry

ECAR No.: 1709 ECAR Rev. No.: 0 Project File No.: 23843 Date: 11/20/2011

ISOTOPE	LIB ENG	LINE ENG	I-C	FLAGS	OTHER TAGS	MICRO-CI/UNIT	%ERROR	NET MICRO-CI/UNIT	NET %ERROR(1-SIGMA)
47 AGM 110	657.76	658.17	1	0	41 NB 97	2.341E+00+	33.16		
	884.68	884.68	2	1	53 I 134	1.767E+00+	37.20		
	937.49	937.48	2	1		-4.263E-01	322.59		
	1384.30	1384.30	2	1	38 SR 92	6.872E-01	160.95		
								2.105E+00	28.31
48 CD 109	88.03	88.33	1	2	46 PD 109	5.322E+02+	6.76		
								5.322E+02	6.76
51 SB 122	564.09	564.53	1	1		6.085E-01	106.60		
								6.085E-01	106.60
								**********	
								MDL= 2.663E+00	
								**********	
51 SB 125	427.88	427.87	1	1		-1.631E+00	79.00		
	600.50	600.60	2	513		3.475E+00	58.49		
	635.89	635.95	2	513		1.996E-02	15760.67		
								-1.631E+00	79.00
								**********	
								MDL= 5.290E+00	
								**********	
53 I 134	621.82	621.93	2	513	45 RURH 106	2.738E+00	242.21		
	766.73	766.21	2	512	41 NB 95	3.113E+02+	9.93		
	884.13	884.68	1	1	47 AGM 110	3.944E+00+	37.20		
								3.944E+00	37.20
55 CS 134	569.32	569.33	2	513		3.752E+00	73.03		
	604.71	604.72	2	513		-1.693E-01	218.20		
	795.87	795.86	1	1		6.931E-01	80.24		
								6.931E-01	80.24
								**********	
								MDL= 2.295E+00	
								**********	
55 CS 137	661.66	661.62	1	1		1.375E+00+	35.20		
								1.375E+00	35.20
56 BA 131	133.58	133.51	3	513	58 CE 144	7.010E+01	84.14		
	239.61	239.23	3	512	82 PB 212	2.850E+02+	13.51		
					90 THPB 232				
	496.26	497.08	1	1	44 RU 103	8.534E-02	976.45		
								8.534E-02	976.45
								**********	
								MDL= 3.435E+00	
								**********	

Title: Examination of Graphite Fuel Compact Holders for the AGR-1 TRISO Experiment using Gamma Spectrometry

ECAR No.: 1709 ECAR Rev. No.: 0 Project File No.: 23843 Date: 11/20/2011

ISOTOPE	LIB ENG	LINE ENG	I-C	FLAGS	OTHER TAGS	MICRO-CI/UNIT	%ERROR	NET MICRO-CI/UNIT	NET %ERROR(1-SIGMA)
58 CE 141	145.44	145.44	1	1		3.063E+00	78.08		
								3.063E+00	78.08
								**********	
								MDL= 9.628E+00	
								**********	
58 CE 144	133.54	133.51	1	1	56 BA 131	1.367E+01	84.14		
								1.367E+01	84.14
								**********	
								MDL= 4.628E+01	
								**********	
63 EU 154	723.36	724.19	2	513	40 ZR 95	3.200E+00	69.49		
					44 RU 105				
	756.81	756.72	2	513	40 ZR 95	7.541E+00	114.23		
	996.33	996.26	2	513	41 NBM 98	-2.552E+00	178.47		
	1004.77	1004.70	2	513		-2.185E+00	118.52		
	1274.54	1274.40	1	1	11 NA 22	-2.273E-01	425.93		
								-2.273E-01	425.93
								**********	
								MDL= 4.103E+00	
								**********	
68 ER 172	610.06	609.29	1	0	83 BI 214	2.614E+01+	6.35		
					88 RABI 226				
								2.614E+01	6.35
73 TA 182	1121.30	1120.32	2	512	83 BI 214	2.415E+01+	16.42		
					88 RABI 226				
	1221.41	1221.52	1	0		1.104E+01+	16.91		
								1.104E+01	16.91
82 PB 212	238.63	239.23	1	0	56 BA 131	1.677E+01+	13.51		
					90 THPB 232				
								1.677E+01	13.51
82 PB 214	295.09	295.47	2	0	88 RAPB 226	3.896E+01+	17.96		
	351.87	352.14	1	0	88 RAPB 226	5.382E+01+	11.12		
	785.83	786.36	3	1	41 NBM 98	3.130E+02+	40.32		
					88 RAPB 226				
								4.999E+01	12.75
83 BI 214	609.31	609.29	1	0	68 ER 172	1.051E+02+	6.35		
					88 RABI 226				
	1120.27	1120.32	2	512	73 TA 182	2.371E+02+	16.42		
					88 RABI 226				
	1407.97	1407.43	2	0	88 RABI 226	2.149E+02+	28.46		

Title: Examination of Graphite Fuel Compact Holders for the AGR-1 TRISO Experiment using Gamma Spectrometry

ECAR No.: 1709 ECAR Rev. No.: 0 Project File No.: 23843 Date: 11/20/2011

ISOTOPE	LIB ENG	LINE ENG	I-C	FLAGS	OTHER TAGS	MICRO-CI/UNIT	%ERROR	NET MICRO-CI/UNIT	NET %ERROR(1-SIGMA)
	1407.97	1407.43	2	0	88 RABI 226	2.149E+02+	28.46		
								1.057E+02	7.97
88 RAPB 226	295.09	295.47	2	0	82 PB 214	1.197E+01+	17.96		
	351.87	352.14	1	0	82 PB 214	1.653E+01+	11.12		
	785.83	786.36	3	1	41 NBM 98	9.613E+01+	40.32		
					82 PB 214				
								1.536E+01	12.75
88 RABI 226	609.31	609.29	1	0	68 ER 172	2.470E+01+	6.35		
					83 BI 214				
	1120.27	1120.32	2	512	73 TA 182	5.574E+01+	16.42		
					83 BI 214				
	1407.97	1407.43	3	0	83 BI 214	5.053E+01+	28.46		
								2.481E+01	6.53
89 AC 228	338.42	338.74	2	0	90 THAC 232	1.954E+01+	45.94		
	911.16	910.81	1	0	90 THAC 232	3.094E+01+	8.40		
	968.97	968.65	2	0	44 RU 105	2.228E+01+	27.47		
					90 THAC 232				
	1459.19	1460.01	2	512	19 K 40	6.728E+03+	2.65		
					90 THAC 232				
								2.983E+01	8.19
90 THPB 232	74.81	73.87	8	514		6.655E+02+	1.95		
	238.63	239.23	1	0	56 BA 131	1.572E+01+	13.51		
					82 PB 212				
								1.572E+01	13.51
90 THAC 232	338.42	338.74	2	0	89 AC 228	1.748E+01+	45.94		
	911.16	910.81	1	0	89 AC 228	2.769E+01+	8.40		
	968.97	968.65	2	0	44 RU 105	1.994E+01+	27.47		
					89 AC 228				
	1459.19	1460.01	3	512	19 K 40	6.020E+03+	2.65		
					89 AC 228				
								2.669E+01	8.19

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PULSE-HEIGHT SPECTRAL ANALYSIS SUMMARY REPORT--06-SEP-11

SAMPLE NAME: ORTEC SPECTRUM C:\RESEARCH\AGR-PIE-GAMMASCAN\SPECTRA\CAP5HOLDERSCANS\HOLDER5_LEFTSIDE\HOLDER5_LEFTSI

SAMPLE ID: HOLDER5_LEFTSIDE_0004

SAMPLE COLLECTION (DATE/TIME): 30411/2009

SAMPLE COUNTED (DATE/TIME): 30411/2009

SAMPLE QUANTITY: 1.00000E+00 QUANTITY UNITS: SMPL

RADIONUCLIDE	SAMPLE ACTIVITY (uCi/SMPL)	% ERROR (1-SIGMA)	SAMPLE ACTIVITY +- STD DEV (uCi/SMPL)
11NA 22	-8.074E-02	425.93	(-8. +/- 30.)E-02
19 K 40	5.993E+02	2.65	(5.99 +/- 0.16)E+02
27CO 60	1.172E+02	2.41	(1.17 +/- 0.03)E+02
38SR 92	2.370E-01	160.95	(2. +/- 4.)E-01
39 Y 91	9.883E+01	138.61	(10. +/- 14.)E+01
40ZR 95	6.010E-01	114.23	(6. +/- 7.)E-01
41NB 94	5.089E+01	2.04	(5.09 +/- 0.10)E+01
41NB 95	6.419E+00	9.93	(6.4 +/- 0.6)E+00
41NB 97	3.802E+00	33.16	(3.8 +/- 1.3)E+00
41NBM 98	2.198E+00	40.32	(2.2 +/- 0.9)E+00
44RU 103	4.172E-02	976.45	(4. +/- 40.)E-02
44RU 105	1.573E+00	69.49	(1.6 +/- 1.1)E+00
45RURH106	1.483E+00	242.21	(2. +/- 4.)E+00
46PD 109	5.656E+02	6.76	(5.7 +/- 0.4)E+02
47AGM 110	2.105E+00	28.31	(2.1 +/- 0.6)E+00
48CD 109	5.322E+02	6.76	(5.3 +/- 0.4)E+02
51SB 122	6.085E-01	106.60	(6. +/- 7.)E-01
51SB 125	-1.631E+00	79.00	(-1.6 +/- 1.3)E+00
53 I 134	3.944E+00	37.20	(3.9 +/- 1.5)E+00

55CS 134	6.931E-01	80.24	(7. +/- 6.)E-01
55CS 137	1.375E+00	35.20	(1.4 +/- 0.5)E+00
56BA 131	8.534E-02	976.45	(8. +/- 80.)E-02
58CE 141	3.063E+00	78.08	(3. +/- 2.)E+00
58CE 144	1.367E+01	84.14	(1.4 +/- 1.2)E+01
63EU 154	-2.273E-01	425.93	(-2. +/- 10.)E-01
68ER 172	2.614E+01	6.35	(2.61 +/- 0.17)E+01
73TA 182	1.104E+01	16.91	(1.10 +/- 0.19)E+01
82PB 212	1.677E+01	13.51	(1.7 +/- 0.2)E+01
82PB 214	4.999E+01	12.75	(5.0 +/- 0.6)E+01
83BI 214	1.057E+02	7.97	(1.06 +/- 0.08)E+02
88RAPB226	1.536E+01	12.75	(1.5 +/- 0.2)E+01
88RABI226	2.481E+01	6.53	(2.48 +/- 0.16)E+01
89AC 228	2.983E+01	8.19	(3.0 +/- 0.2)E+01
90THPB232	1.572E+01	13.51	(1.6 +/- 0.2)E+01
90THAC232	2.669E+01	8.19	(2.7 +/- 0.2)E+01