

Radiological Sampling and Gamma Scans Aboard the N.S. Savannah Conducted for the U.S. Maritime Administration April, 2005

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Background

Thomas Jefferson National Accelerator Facility (Jefferson Lab) has entered into an agreement with the U.S. Maritime Administration (MARAD) to provide support for the Savannah Emergency Response Assessment Team (SERAT) efforts related to N.S. Savannah in the event of an incident that might have radiological implications (Reimbursable Agreement #MA-5-A04, to fund Work for Others Project SURA 2004W007). The lab's role is advisory, related to the health physics concerns associated with initial response activities in the event of an emergency.

Commensurate with its role of health physics support for SERAT efforts, Jefferson Lab conducted a series of measurements to confirm the primary nuclides of concern remaining in the reactor systems of the Savannah. This report details the findings of the measurements.

Acknowledgements

Jefferson Lab was afforded access to the primary plant areas of Savannah in conjunction with work being conducted by WPISM (WPI). WPI performed radiological and environmental assessments aboard Savannah which required opening all reactor-related spaces. The assessment included a breach of the primary reactor cooling water system in which samples were taken by WPI. WPI provided various samples to Jefferson Lab for analysis. Jefferson Lab acknowledges the kind assistance of WPI in obtaining data for this report.

Introduction

The purpose of conducting the measurements described in this report is to obtain a measurement-based estimate of the quantity and distribution of radionuclides in reactor primary systems aboard Savannah. The specific focus of this assessment is radioactivity in residual liquids and transferable contamination that may be subject to a spill or spread in the event of damage to the ship or flooding of compartments containing reactor systems. In the event of an emergency, knowledge of the reactor plant nuclide inventory is important in facilitating emergency response efforts in which Jefferson Lab may be involved. Previous calculations have been conducted to estimate volumetric nuclide content in the reactor vessel⁽¹⁾. This report does not address volumetric activation, but rather the distribution of internal surface contamination and contaminated liquids within piping and components of the primary system. The quantity of radioactivity deposited in the system as contamination is very small compared to the total activity in reactor vessel components.

Internal surface contamination content has been estimated previously, but the present assessment effort provided a rare opportunity to re-evaluate radioactivity estimates based on a combination of measurement methods.

General Approach

Two methods were used to assess the residual radioactivity in the reactor systems. One method was to analyze samples from within the primary system. The second method was by direct scans with portable gamma spectroscopy equipment.

Samples (smears and liquid) taken from the primary system and within the reactor containment were quantitatively analyzed by high-resolution gamma spectroscopy at the Jefferson Lab Radiation Control Group (RCG) radioanalytical lab for presence and amounts of gamma-emitting radionuclides.

The direct gamma scan survey is qualitative in nature – its goal being to gather “snapshots” of the radiation field around various system components to further enhance the understanding of primary system nuclide content.

Equipment and Measurement Techniques

Measurements of sample media were made with a Canberra Industries ultra-high purity, coaxial germanium detector (relative efficiency, ~20%) with associated NIM electronics, operated via the Canberra Genie[®] software package. The system is energy and efficiency calibrated for a number of sample geometries annually and receives daily quality assurance checks according to Jefferson Lab RCG procedures. Jefferson Lab also participates in the Department Of Energy (DOE) Mixed Analyte Performance Evaluation Program (MAPEP) for measurement quality assurance.

Onboard gamma spectra were collected primarily with a Berkeley Nucleonics Corporation model SAM-935[®] portable surveillance and measurement system, consisting of a 3x3 NaI(Tl) detector coupled to the base unit electronics. The collected spectra can be analyzed with built-in software or uploaded to a PC for analysis using third-party software. A few spectra were also collected with a portable high-resolution germanium detector coupled to a Canberra Inspector[®] electronics package and analyzed using the Genie[®] software. This system proved to be difficult to manage in the shipboard environment due to its bulkiness and required a lengthy stabilization period each time the detector was shut down for movement and subsequently restarted.

Energy calibration of the SAM-935 is initially conducted by the factory using a multi-nuclide source. The calibration coefficients are stored in the firmware of the instrument. Field adjustment/drift-correction of the energy calibration is done with an automated calibration routine using a small Cs-137 check source. This routine can be conducted repeatedly at the user's discretion. In addition, to enhance the accuracy the field measurements, some spectra were collected with reference sources present. The reference sources provided gamma rays of known energy, which can be used for a posteriori energy calibration corrections.

Nuclide identification from the SAM spectra was conducted using on-board analysis routines. Some of the spectra were also analyzed using a third-party program, PGT Quantum[®] gamma analysis software. This was done to conduct manual energy calibration corrections that allowed better photopeak identification when a peak could not be confidently identified by the SAM. Quantum also contains a superior nuclide library.

Energy calibration of the portable high resolution system was initially conducted at Jefferson Lab, with manual fine adjustments made in the field using reference peaks from small sources and known nuclides in the sampled spectrum.

Scope and Limitations

The direct survey is limited to those nuclides which decay with gamma emissions between approximately 30 keV and 3 MeV. Locations for measurement were chosen with the intent to monitor a reasonable cross-section of systems that contain radioactivity. Consideration had to be given to ambient radiation intensity such that the monitoring system could acquire spectra without encountering detector saturation problems (ambient radiation fields above about 1 mR/h cause significant detector dead-time), as well as the physical constraints of manipulating the detector and associated equipment within the spaces aboard the ship and protecting the equipment from potential radioactive contamination. Several locations within and outside the primary containment were monitored. Since these measurements were made in a “general area” radiation field involving complex source geometries, quantitative results regarding the concentration of radioactive material are not possible. However, gamma energy peaks provide qualitative verification of the presence and distribution of the most predominant gamma-emitting nuclides.

A limitation inherent in all the area scans is that the spectra include contributions from all sources in the vicinity of the item being monitored. One cannot determine conclusively that the activity indicated is attributable exclusively to the item of interest. Another limitation in assessing the contents of components is the self-shielding of the radiation by the components themselves.

Analysis of samples from the primary system provides the best opportunity to determine what nuclides might be present in the event of a spill from the system. The gamma analysis system used for sample counting has a functional energy range of about 5 – 2000 keV. Detector response extends below 5 keV (making detection of Fe55 possible in principle), but sample configuration and self-shielding probably prevent detection of photons below about 5 – 7 keV.

One goal of the WPI assessment team was to investigate the existence and quantity of water in the primary system beyond the reactor vessel. Steam generator hot-leg access was performed for this purpose. It was discovered that a significant quantity of water was present in the generators and lower hot-leg piping. Smear and water samples were obtained from inside the steam generators. An estimate of the total contamination inventory is made based on samples from the starboard steam generator. Also analyzed were smear samples from the primary containment enclosure that showed positive results during gross alpha/beta counting.

General Findings

Co60 was expected to be the most widespread nuclide in the primary system. This expectation was confirmed in the measurements taken. All the area monitoring spectra taken around primary systems indicated Co60 activity. Most monitored locations also indicated the presence of Cs137 (this may have some practical implications, as is discussed below). A photopeak present in some of the spectra at approximately 75 keV is attributed to lead fluorescence X-rays (K_{α} - 72.8 keV, K_{β} - 74.9 keV), as significant quantities of lead shielding are present around the reactor vessel and in other monitored areas.

The WPI assessment team found very little surface contamination external to primary system piping and components. A few smear samples from reactor spaces showed a combination of Co60 and Cs137. In one case, only Cs137 was present. This is reasonable given the low activity in that area and the ratio of Cs137 to Co60 on the other smears (see detailed findings). It might also be surmised that the presence of the contamination is due to past spills of system coolant or ion-exchange media, rather than the dry release of crud from piping internals. This deduction is discussed further below.

Detailed Findings

Samples from inside the primary system showed the following characteristics. The steam generator water sample contained Cs137 almost exclusively (Cs137 concentration was about 1000 times greater than Co60), but contamination on interior surfaces of the steam generator was found to contain only Co60. This is undoubtedly a result of the chemical form of the contaminants. Co60 is usually found as an insoluble oxide, and tends to deposit on surfaces of reactor systems (forming the common “crud” deposits found in all reactors), whereas Cs137 is present as a very soluble oxide or hydroxide.

A spill of the coolant would be likely to spread both Co60 and Cs137, as the Co60 is easily removable and would be flushed from surfaces by any significant movement of the water (hence the speculation above that contamination on surfaces in the reactor compartment may be the result of past liquid (or ion-exchange media) spills). A spill to the environment (i.e. into the James River) would probably behave similarly with respect to the distribution of these nuclides. The Cs137 would likely remain dissolved in the river water, whereas insoluble components would eventually find their way into sediment.

The tables below summarize the area monitoring and sample analysis results. The area scans performed with the SAM 935 contain exposure rate estimates associated with the identified nuclides. This is a calculation made by the SAM using an algorithm that converts counts in a photopeak to an energy-corrected exposure rate. The exposure rate indication provides a reasonably accurate relative intensity measurement.

Area Monitoring Results

| Scan Ref # | Location | Component or System | Nuclides and Exposure Rate (uR/h) | | Cs137/Co60 Exp. Rate Ratio | Notes |
|------------|---|--|-----------------------------------|-------|----------------------------|-------|
| | | | Cs137 | Co60 | | |
| M1 | Hold Deck, Port passageway | 4" Piping below deck level | Cs137 | 0.95 | 0.03 | |
| | | | Co60 | 30 | | |
| M2 | Hold Deck Port passageway | Aft end of passage, effluent piping under deck | Cs137 | 0.08 | 0.05 | |
| | | | Co60 | 1.6 | | |
| M3 | Hold Deck Port passageway | Small diameter pipe behind cage chg. pmp. buffer seal system | Cs137 | 1.4 | 0.24 | |
| | | | Co60 | 5.9 | | |
| M4 | Port Stabilizer Room | 6" piping from charging pump buffer seal system | Cs137 | 12.1 | 0.56 | 1 |
| | | | Co60 | 21.6 | | |
| M5 | Prim. Containment Upper level | Primary coolant line interface to reactor vessel Fwd | Co60 | 581 | N/A | |
| M6 | Prim. Containment Upper Level | Primary coolant line interface to reactor vessel Aft | Co60 | 564 | N/A | |
| M7 | Prim. Containment Upper Level | Upper pressurizer head, Port | Co60 | 183 | N/A | |
| M8 | Prim. Containment Upper Level | Fwd upper Regen/non-regen heat exchanger | Cs137 | 6 | 0.025 | |
| | | | Co60 | 242 | | |
| M9 | Prim. Containment 2 nd Level | Crossover line from upper to lower Regen/non-regen HtXchr | Cs137 | 8.5 | 0.062 | |
| | | | Co60 | 137 | | |
| M10 | Prim. Containment 3 rd Level | Main pressurizer leg to prim. coolant line, just under preszr. | Cs137 | 6.8 | 0.044 | |
| | | | Co60 | 156 | | |
| M11 | Prim. Containment 4 th Level | Check valve adjacent to Fwd primary coolant line near vessel | Cs137 | 19 | 0.053 | |
| | | | Co60 | 360 | | |
| M12 | Prim. Containment 4 th Level | Reactor vessel (shield tank wall) Fwd, just Stb. of center | Cs137 | 11 | 0.023 | |
| | | | Co60 | 479 | | |
| M13 | Prim. Containment 1 st Level | Rx ventilation plenum duct, Stbd | Cs137 | 18 | 0.21 | 2 |
| | | | Co60 | 84.5 | | |
| M14 | Cold Chem lab Upper Level | Rx ventilation duct | Cs137 | 0.043 | 0.17 | 2 |
| | | | Co60 | 0.25 | | |
| M15 | Cold Chem lab Lower Level | Primary sample sink, sample bulb inside sink hood | Cs137 | 3.6 | 0.015 | |
| | | | Co60 | 242 | | |
| M16 | Port Charge Pump Room | Between pumps at Aft bulkhead | Cs137 | -- | 0.096 | 3 |
| | | | Co60 | -- | | |

Table 1: Area monitor scan results

1 – Exposure rates estimated

2 – Measurement on ventilation ducts

3 – Measured with high resolution Ge detector. Ratio taken from peak area data.

Sample Analysis Results

| Ref # | Location/Component | Sample Type | Nuclides | Activity |
|-------|---|--------------|----------|--------------------------------|
| S1 | Stbd. Steam generator tube sheet | Smear | Co60 | 144,300 dpm/100cm ² |
| S2 | Stbd. Steam generator interior (average) ¹ | Smear | Co60 | 22,000 dpm/100cm ² |
| W1 | Stdb. Steam generator water | 100 ml water | Cs137 | 1.04E-3 μ Ci/ml |
| | | | Co60 | 1.45E-6 μ Ci/ml |
| S3 | Reactor 3 rd Level Fwd at Przr. (highest) ² | Smear | Cs137 | 1200 dpm/100cm ² |
| | | | Co60 | 250 dpm/100cm ² |
| S4 | Reactor 1 st Level Fwd Rx head (average) ³ | Smear | Cs137 | 350 dpm/100cm ² |

Table 2 – Laboratory gamma analysis of samples

¹ Average of 4 smears, excludes tube sheet² Composite count of 6 smears, all activity attributed to one smear³ Composite count of 5 smears, activity averaged over the totalCalculation of Total Contamination Inventory

The total contamination inventory for the primary system was estimated based on the sample data. The contamination inventory is broken into two parts; (1) internal surface contamination, and (2) contamination entrained in residual coolant.

Surface Contamination

The surface contamination estimate begins with an assessment of the steam generator contamination content. Published industry data⁽²⁾ indicate that in PWRs, the majority of coolant-borne corrosion/fission products that are not removed by the chemical volume and control system (CVCS) are deposited in the steam generators. For a *reference PWR**, the generators contain about 85% of the total deposited activation product inventory. The balance of the activity is distributed in various other components based on relative surface area and deposition characteristics of the system/component.

Steam generator activity content was estimated based on the highest contamination level found in the starboard generator. Assumptions for the calculation are as follows.

- The only nuclide of concern for surface contamination is Co60
- Smears were taken over a 100cm² area
- The removal factor for smears is assumed to be 0.1

Steam Generator Dimensional Estimates

- Tube diameter: 0.5" (1.27 cm)
- Average tube length: 30' (900 cm)
- Number of tubes: 2000
- Shell ID: 100 cm
- Total plenum length: 100 cm

* The *Reference PWR* in the literature was the Trojan Nuclear Plant. Distribution of radioactivity in three other PWRs was evaluated and reported in Ref. 2. The percentage of radioactivity deposited in steam generators was similar in each case.

$$\text{Tube surface area: } 2\pi(0.635)(900)(2000) = 7.18\text{E}6 \text{ cm}^2$$

$$\text{Total tube sheet area: } 2[\pi(50)^2 - \pi(0.635)^2(2000)] = 1.06\text{E}4 \text{ cm}^2$$

$$\text{Plenum area: } 2\pi(50)(100) = 3.14\text{E}4 \text{ cm}^2$$

$$\text{Internal surface area of one steam generator: } 7.18\text{E}6 + 1.06\text{E}4 + 3.14\text{E}4 = 7.2\text{E}6 \text{ cm}^2$$

Total activity in one generator in curies is calculated as follows:

$$\frac{144,300 \text{ dpm} \times 7.2\text{E}6 \text{ cm}^2}{0.1 \times 100 \text{ cm}^2 \times 2.22\text{E}12} = 0.0468 \text{ Ci} \quad \text{or, } 93.6 \text{ mCi} \text{ for both steam generators}$$

Adjusting for reactor/steam generator surface area ratios and unit layout (2-loop vs. 4-loop), activity distribution assignments were made based on the reference PWR. Associated activity levels were calculated and are summarized in Table 3.

| System | Activity Distribution (%) | Total Activity (Ci) |
|------------------------------|---------------------------|---------------------|
| Reactor Vessel and Internals | 5 | 0.0054* |
| Steam Generators | 87 | 0.0936 |
| RCS ¹ Piping | 3 | 0.0032 |
| Non-RCS Piping | 2.3 | 0.0025 |
| Pressurizer | 0.2 | 0.0002 |
| Other | 2.5 | 0.0027 |
| Totals | 100 | 0.108 |

Table 3 – Total Surface Contamination Inventory

*Excludes volumetrically distributed activation products in the reactor vessel

¹RCS = Reactor Cooling System (main cooling loops)

Contamination in Residual Coolant

Using visual indications from the steam generator coolant content, the estimated volume of water in the primary system is calculated below, with the associated total radioactivity.

$$\text{Volume of generator primary side: } \pi(0.635)^2(900)(2000) + \pi(50)^2(100) = 3.1\text{E}6 \text{ cc (ml)}$$

In addition, a portion of the RCS hot and cold legs run horizontally into and out of the generator. The total length of this piping is estimated to be about 26 feet (780 cm) for each loop. The piping diameter is estimated at 18" (45cm).

$$\text{Volume of horizontal piping: } \pi(22.5)^2(780) = 1.2\text{E}6 \text{ ml}$$

$$\text{Total volume of contiguous horizontal coolant envelope (1 loop): } 1.2\text{E}6 + 3.1\text{E}6 = 4.6\text{E}6 \text{ ml}$$

The water level in the starboard generator was observed to be about halfway up the generator tube sheet, the port generator was reported to be about one third full. For this estimate, both will be considered half full.

Total water volume in horizontal legs: $\frac{4.6E6}{2}(2) = 4.6E6$ ml (~1200 gal)

It has been estimated by others that about 1100 gallons of water reside in the lower reactor head. We estimate another 200 gallons is distributed around the balance of the reactor systems (this is based partly on the observation discussed below regarding location of liquid via the presence of Cs137). This brings the total volume to 2500 gallons ($9.5E^6$ ml). Assuming the activity in the water is uniform through the plant, and represented by the activity in the steam generator, the total activity is:

$$\text{Cs137} - (1.04E-3 \mu\text{Ci/ml})(9.5E6 \text{ ml}) = 9840 \mu\text{Ci}$$

$$\text{Co60} - (1.45E-6 \mu\text{Ci/ml})(9.5E6 \text{ ml}) = 14 \mu\text{Ci}$$

Additional Observations and Some Speculation

The observed distribution of Co60 and Cs137 might serve as an indicator of the presence of liquid within various systems and components. If the same physical separation of nuclides found in the steam generator is assumed to exist throughout the system, one could use the presence of Cs137 in an area scan of primary piping as an indicator of liquid in the component in question. If only Co60 is present, it may be an indication that the piping or component is internally dry or contains little liquid.

The results of the area scans taken qualitatively support this idea. For instance, no Cs137 was seen in scans of the upper main coolant lines at their interface to the reactor vessel. By comparison, all the scans of the lower level reactor compartment (containing the primary side of the steam generators and other low-point piping) show Cs137. Although not conclusive, this is consistent with the hypothesis that dry piping contains little or no Cs137 contamination. The ratio of Cs137 to Co60 activity was found to be highest near piping outside the primary containment in the lowest levels of the ship (eg. piping in the Hold level, Stabilizer Room lower level and Charge Pump Room). Table 1 includes these ratios for information purposes.

Several gamma scans were taken on reactor ventilation ductwork, both inside and outside the primary containment. In these scans, the ratio of Cs137 to Co60 is considerably higher than in primary piping (it is difficult to state this conclusively since the source of the radiation in any given scan cannot be isolated to a particular component, but this limitation is inherent to all the scans). Based on the characteristics of the contaminants we surmise the following process. Soluble Cs137 was preferentially released to the atmosphere (compared to Co60) during plant operations via “weeping” of small primary system leaks. The dissolved cesium contamination was released as an aqueous vapor and distributed through the ventilation system, some of it being deposited within the system. No samples from within the ventilation system were analyzed to confirm the nuclide ratio.

Conclusions

Scans and samples confirmed that the primary nuclide deposited on surfaces in reactor systems aboard Savannah is Co60. It is estimated that the total inventory of Co60 in surface deposits is approximately 100 mCi. This is in reasonable agreement with previous estimates⁽¹⁾. Cs137 is the predominant nuclide present in residual water within the primary system. We estimate the presence of about 2500 gallons of water total within the primary system. The total waterborne Cs137 content in the reactor system is estimated at about 10 mCi.

We believe that this represents the bulk of the potentially mobile nuclide inventory. This result supports the conclusion that even a worst-case incident aboard Savannah, resulting in the loss of all the transferable contamination to the environment, would have no significant impact on the environment or on dose to the public.

References

1. "Nuclear Ship Savannah Reactor Vessel, Internals and Neutron Shield Tank Characterization and Classification Assessment", April, 2004, prepared by R. J. Stouky, J. W. Bowen, R. Ranellone, for U.S. DOT (attached as Appendix 4)
2. "Potential Recycling of Scrap Metal From Nuclear Facilities", Appendix A, September, 2001, R. Anigstein, et.al., for U.S. EPA. Available at: http://www.epa.gov/radiation/docs/cleanmetals/tsd/scrap_tsd_041802_apal.pdf
3. Materials from meeting presentation "NS Savannah Decommissioning Plans" for NRC, September 24, 200. Available at: voa.marad.dot.gov/programs/ns_savannah/docs/Final%20NRC%20Meeting%20Presentation%20Rev%206%20dated%209-23-03.ppt

Appendices

Appendix 1: Area scan monitoring data

Appendix 2: Sample analysis data

Appendix 3: Plan layout of reactor containment, taken from Reference 3

Appendix 4: Reference 1

Appendix 1
Area Scan Monitoring Data

JLAB-TN-05-048

MONITORING REPORT M1

Hold Deck passageway Port side under deckplate on 4" pipe

SAM Area Monitor Report

Alarm # 1 at 06-Apr-2005 09:23:28 for 182 sec (captured)
 Nuclide(s) Peak Conf Total Conf Peak Dose Avg Dose
 Full 2055.03 1087.84 38.11 uR/hr 35.73 uR/hr
 Co60 543.33 331.94 31.95 uR/hr 30.23 uR/hr
 Cs137 101.66 44.23 1.39 uR/hr 947.68 nR/hr
 Peak 11.41 0 219.19 nR/hr 0.00 nR/hr

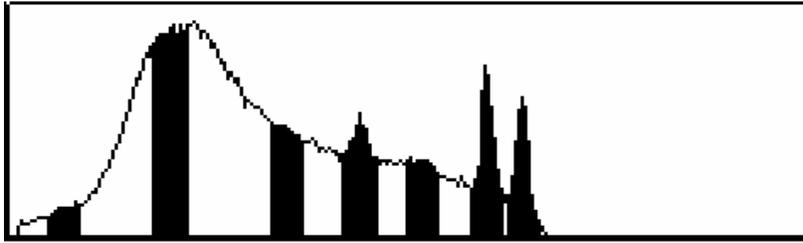
The following monitors had no measured activity:
 Co57 Cr51 Mn54 Na22 Sb124 Sc46 Ta182 Zn65

MCA REPORT

Alarm #1 Port Hold Deck walkway under deck on upper 4"pipe (~38 ur/hr total)

| | | | |
|-----------------|-------------------|------------------------|---------|
| DATE: | 06-Apr-2005 09:23 | SAVED AS: Spectrum # 1 | |
| EN CAL DATE: | 06-Apr-2005 07:59 | BIAS: | 826 |
| | | COARSE GAIN: | 1 |
| BKG DATE: | 06-Apr-2005 08:14 | FINE GAIN: | 1.24 |
| GROSS CPM: | 94075 | LOW DISC: | 0.41% |
| NET CPM: | 88511 | HIGH DISC: | 100.05% |
| GROSS INTEGRAL: | 282163 | ELAPSED LT: | 179.96 |
| NET INTEGRAL: | 265474 | ELAPSED RT: | 182.42 |
| | | DEAD TIME: | 1.35% |

FULL SCALE: 3594



| CHN | ENERGY (keV) | GROSS CPM | AMBIENT CPM | CONTINUUM CPM | NET CPM | UNC % | |
|-----|--------------|-----------|-------------|---------------|-------------|-------|-------|
| 18 | 38.9 | 1856 | 176 | 1485 | 194 ± 13.4 | | |
| 50 | 168.2 | 12913 | 972 | 11697 | 243 ± 27.9 | | |
| 88 | 430.3 | 6514 | 276 | 6146 | 91 ± 52.1 | | |
| 112 | 660.7 | 5853 | 178 | 4589 | 1085 ± 4.13 | | Cs137 |
| 132 | 896.8 | 4427 | 110 | 3913 | 404 ± 9.63 | | |
| 152 | 1173.1 | 5961 | 94 | 2545 | 3322 ± 1.35 | | Co60 |
| 163 | 1339.4 | 4498 | 64 | 1310 | 3124 ± 1.25 | | Co60 |

2 OF 2 LIBRARY LINES FOR Co60 FOUND Correlation = 1.00
 LINE PEAK INTENSITY NET CPM
 1173.2 1168.7 99.90 3322
 1332.5 1342.9 99.98 3124

1 OF 1 LIBRARY LINES FOR Cs137 FOUND Correlation = 0.80
 LINE PEAK INTENSITY NET CPM
 661.7 661.2 85.21 1085

LINES NOT ASSOCIATED WITH ANY NUCLIDE:

| Energy | Net CPM | Eff Corrected |
|--------|---------|---------------|
| 37.4 | 194.4 | 1007.4 C |
| 172.0 | 243.7 | 1068.4 C |
| 438.8 | 91.4 | 707.8 C |
| 894.2 | 404.1 | 6863.5 C |

Appendix 1
Area Scan Monitoring Data

JLAB-TN-05-048

MONITORING REPORT M2

Port Hold Deck aft under deck "backwash to Eff Filter" piping

Area Monitor Report

Alarm # 34 at 19-Apr-2005 11:56:43 for 60 sec (captured)

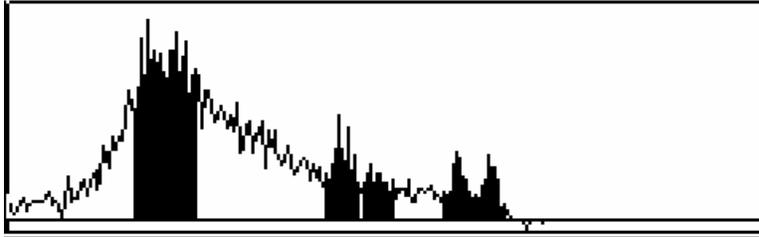
| Nuclide(s) | Peak Conf | Total Conf | Peak Dose | Avg Dose |
|------------|-----------|------------|-------------|-------------|
| Full | 173.84 | 173.84 | 7.73 uR/hr | 7.73 uR/hr |
| Co60 | 14.98 | 14.98 | 1.59 uR/hr | 1.59 uR/hr |
| Zn65 | 14.98 | 14.98 | 0.00 nR/hr | 0.00 nR/hr |
| Cs137 | 3.59 | 3.59 | 78.99 nR/hr | 78.99 nR/hr |
| Mn54 | 2.14 | 2.14 | 50.49 nR/hr | 50.49 nR/hr |

The following monitors had no measured activity:
Peak Co57 Cr51 Na22 Sb124 Sc46 Ta182

MCA REPORT

| | | | |
|-----------------|-------------------|--------------|---------|
| DATE: | 19-Apr-2005 11:56 | BIAS: | 826 |
| EN CAL DATE: | 19-Apr-2005 11:38 | COARSE GAIN: | 1 |
| | | FINE GAIN: | 1.28 |
| BKG DATE: | 18-Apr-2005 12:34 | LOW DISC: | 0.00% |
| GROSS CPM: | 14748 | HIGH DISC: | 100.05% |
| NET CPM: | 10854 | ELAPSED LT: | 59.91 |
| GROSS INTEGRAL: | 14726 | ELAPSED RT: | 60.05 |
| NET INTEGRAL: | 10838 | DEAD TIME: | 0.23% |

FULL SCALE: 212



| PEAKS FOUND | | | | | | |
|-------------|--------------|-----------|-------------|---------------|------------|-------|
| CHN | ENERGY (keV) | GROSS CPM | AMBIENT CPM | CONTINUUM CPM | NET CPM | UNC % |
| 48 | 158.7 | 2365 | 662 | 1304 | 397 ± 13.8 | |
| 59 | 219.0 | 2371 | 612 | 1597 | 161 ± 33.9 | |
| 113 | 675.6 | 841 | 144 | 401 | 295 ± 10.6 | Cs137 |
| 124 | 803.7 | 536 | 83 | 319 | 134 ± 18.6 | Mn54 |
| 152 | 1158.5 | 512 | 75 | 253 | 184 ± 13.2 | Co60 |
| 163 | 1316.9 | 431 | 42 | 192 | 197 ± 11.0 | Co60 |

| | | | | |
|--|--------|-----------|---------|--|
| 2 OF 2 LIBRARY LINES FOR Co60 FOUND Correlation = 0.99 | | | | |
| LINE | PEAK | INTENSITY | NET CPM | |
| 1173.2 | 1156.4 | 99.90 | 184 | |
| 1332.5 | 1319.8 | 99.98 | 197 | |

| | | | | |
|---|-------|-----------|---------|--|
| 1 OF 1 LIBRARY LINES FOR Cs137 FOUND Correlation = 0.80 | | | | |
| LINE | PEAK | INTENSITY | NET CPM | |
| 661.7 | 674.2 | 85.21 | 295 | |

| | | | | |
|--|-------|-----------|---------|--|
| 1 OF 1 LIBRARY LINES FOR Mn54 FOUND Correlation = 0.80 | | | | |
| LINE | PEAK | INTENSITY | NET CPM | |
| 834.8 | 809.0 | 99.98 | 134 | |

[NOTE: This nuclide is not likely present. Longer counts did not identify it.]

Lines NOT ASSOCIATED WITH ANY NUCLIDE:

| Energy | Net CPM | Eff Corrected |
|--------|---------|---------------|
| 155.0 | 397.6 | 1709.9 C |
| 220.9 | 161.2 | 786.0 C |

Appendix 1
Area Scan Monitoring Data

JLAB-TN-05-048

MONITORING REPORT M3

Small dia piping behind cage, Hold Deck Port passage

Area Monitor Report

Alarm # 32 at 19-Apr-2005 11:44:44 for 60 sec (captured)

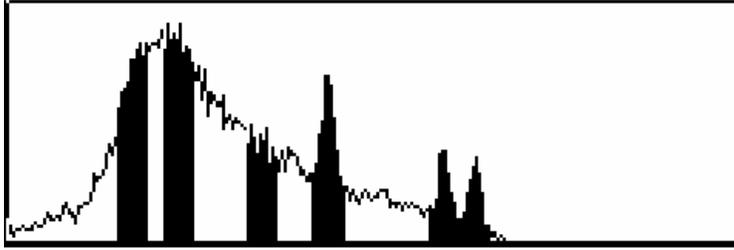
| Nuclide(s) | Peak Conf | Total Conf | Peak Dose | Avg Dose |
|------------|-----------|------------|-------------|-------------|
| Full | 453.76 | 453.76 | 13.32 uR/hr | 13.32 uR/hr |
| Co60 | 68.08 | 68.08 | 5.90 uR/hr | 5.90 uR/hr |
| Zn65 | 68.08 | 68.08 | 0.00 nR/hr | 0.00 nR/hr |
| Cs137 | 60.64 | 60.64 | 1.36 uR/hr | 1.36 uR/hr |
| Peak | 1.73 | 1.73 | 51.29 nR/hr | 51.29 nR/hr |

The following monitors had no measured activity:
Co57 Cr51 Mn54 Na22 Sb124 Sc46 Ta182

MCA REPORT

| | | | |
|-----------------|-------------------|--------------|---------|
| DATE: | 19-Apr-2005 11:44 | BIAS: | 826 |
| EN CAL DATE: | 19-Apr-2005 11:38 | COARSE GAIN: | 1 |
| | | FINE GAIN: | 1.28 |
| BKG DATE: | 18-Apr-2005 12:34 | LOW DISC: | 0.00% |
| GROSS CPM: | 32208 | HIGH DISC: | 100.05% |
| NET CPM: | 28315 | ELAPSED LT: | 59.99 |
| GROSS INTEGRAL: | 32203 | ELAPSED RT: | 60.27 |
| NET INTEGRAL: | 28310 | DEAD TIME: | 0.46% |

FULL SCALE: 444



PEAKS FOUND

| CHN | ENERGY (keV) | GROSS CPM | AMBIENT CPM | CONTINUUM CPM | NET CPM | UNC % | |
|-----|--------------|-----------|-------------|---------------|------------|-------|-------|
| 43 | 134.1 | 4328 | 611 | 3129 | 588 ± 12.0 | | |
| 60 | 226.4 | 4875 | 620 | 3954 | 301 ± 24.6 | | |
| 90 | 448.8 | 2309 | 203 | 1980 | 126 ± 39.8 | | |
| 111 | 660.1 | 2488 | 164 | 1331 | 993 ± 5.19 | | Cs137 |
| 152 | 1155.1 | 1305 | 76 | 610 | 619 ± 6.00 | | Co60 |
| 163 | 1314.0 | 1052 | 43 | 352 | 657 ± 5.04 | | Co60 |

2 OF 2 LIBRARY LINES FOR Co60 FOUND Correlation = 0.99
 LINE PEAK INTENSITY NET CPM
 1173.2 1150.9 99.90 619
 1332.5 1318.4 99.98 657

1 OF 1 LIBRARY LINES FOR Cs137 FOUND Correlation = 0.80
 LINE PEAK INTENSITY NET CPM
 661.7 660.4 85.21 993

1 OF 1 LIBRARY LINES FOR Zn65 FOUND Correlation = 0.80
 LINE PEAK INTENSITY NET CPM
 1115.5 1150.9 50.70 619 [NOTE: nuclide misidentified based on the Co-60 peak]

LINES NOT ASSOCIATED WITH ANY NUCLIDE:

| Energy | Net CPM | Eff Corrected |
|--------|---------|---------------|
| 136.9 | 588.1 | 2413.9 C |
| 224.5 | 301.1 | 1491.2 C |
| 439.8 | 126.0 | 1015.4 C |

Appendix 1
Area Scan Monitoring Data

JLAB-TN-05-048

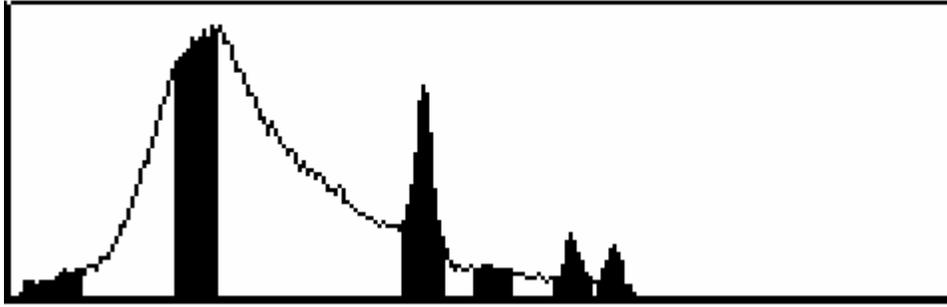
MONITORING REPORT M4

MCA REPORT

Alarm 25 Port stabilizer room gen area

| | | | |
|-----------------|-------------------|-------------------------|---------|
| DATE: | 05-Apr-2005 09:59 | SAVED AS: Spectrum # 31 | |
| EN CAL DATE: | 05-Apr-2005 09:42 | BIAS: | 826 |
| | | COARSE GAIN: | 1 |
| BKG DATE: | 05-Apr-2005 06:12 | FINE GAIN: | 1.24 |
| GROSS CPM: | 154629 | LOW DISC: | 0.41% |
| NET CPM: | 150311 | HIGH DISC: | 100.05% |
| GROSS INTEGRAL: | 154552 | ELAPSED LT: | 59.97 |
| NET INTEGRAL: | 150236 | ELAPSED RT: | 61.31 |
| | | DEAD TIME: | 2.19% |

FULL SCALE: 2698



PEAKS FOUND

| CHN | ENERGY (keV) | GROSS CPM | AMBIENT CPM | CONTINUUM CPM | NET CPM | UNC % | |
|-----|--------------|-----------|-------------|---------------|-------------|-------|-------|
| 6 | 13.4 | 1471 | 61 | 1160 | 250 ± 15.4 | | |
| 13 | 27.2 | 2721 | 151 | 2487 | 83 ± 63.4 | | Cs137 |
| 51 | 168.9 | 27235 | 712 | 25730 | 792 ± 20.9 | | |
| 112 | 661.9 | 13796 | 124 | 5876 | 7795 ± 1.51 | | Cs137 |
| 131 | 882.1 | 3245 | 45 | 3081 | 119 ± 48.0 | | |
| 152 | 1169.7 | 4100 | 37 | 1870 | 2192 ± 2.93 | | Co60 |
| 163 | 1338.7 | 3097 | 30 | 979 | 2088 ± 2.67 | | Co60 |

2 OF 2 LIBRARY LINES FOR Co60 FOUND Correlation = 1.00

| LINE | PEAK | INTENSITY | NET CPM |
|--------|--------|-----------|---------|
| 1173.2 | 1165.7 | 99.90 | 2192 |
| 1332.5 | 1342.0 | 99.98 | 2088 |

2 OF 2 LIBRARY LINES FOR Cs137 FOUND Correlation = 0.99

| LINE | PEAK | INTENSITY | NET CPM |
|-------|-------|-----------|---------|
| 32.9 | 30.7 | 7.12 | 83 |
| 661.7 | 661.7 | 85.21 | 7795 |

LINES NOT ASSOCIATED WITH ANY NUCLIDE:

| Energy | Net CPM | Eff Corrected | |
|--------|---------|---------------|---|
| 14.9 | 250.1 | 250125.1 | C |
| 171.2 | 792.4 | 3478.7 | C |
| 884.1 | 119.1 | 1986.2 | C |

Appendix 1
Area Scan Monitoring Data

JLAB-TN-05-048

MONITORING REPORT M5

Forward upper main coolant nozzle

Area Monitor Report

Alarm # 7 at 18-Apr-2005 13:27:17 for 139 sec (captured)

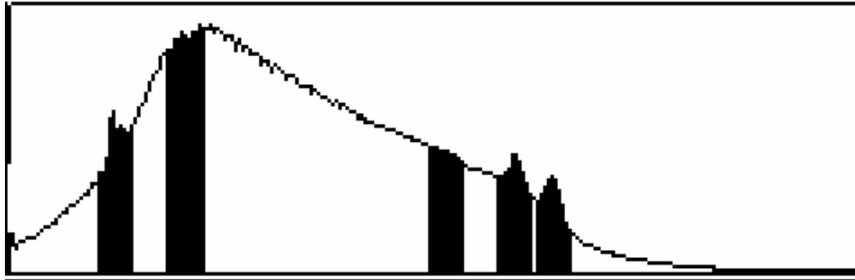
| Nuclide(s) | Peak Conf | Total Conf | Peak Dose | Avg Dose |
|------------|-----------|------------|--------------|--------------|
| Full | 124591.5 | 124591.5 | 595.81 uR/hr | 595.81 uR/hr |
| Co60 | 5905.16 | 5905.16 | 580.70 uR/hr | 580.70 uR/hr |
| Zn65 | 5905.16 | 5905.16 | 0.00 nR/hr | 0.00 nR/hr |
| Peak | 3372.26 | 3372.26 | 10.36 uR/hr | 10.36 uR/hr |

The following monitors had no measured activity:
Co57 Cr51 Cs137 Mn54 Na22 Sb124 Sc46 Ta182

MCA REPORT

| | | | |
|-----------------|-------------------|--------------|---------|
| DATE: | 18-Apr-2005 13:27 | BIAS: | 826 |
| EN CAL DATE: | 18-Apr-2005 12:41 | COARSE GAIN: | 1 |
| | | FINE GAIN: | 1.22 |
| BKG DATE: | 18-Apr-2005 12:34 | LOW DISC: | 0.00% |
| GROSS CPM: | 7779240 | HIGH DISC: | 100.05% |
| NET CPM: | 7775346 | ELAPSED LT: | 59.98 |
| GROSS INTEGRAL: | 7776647 | ELAPSED RT: | 139.17 |
| NET INTEGRAL: | 7772755 | DEAD TIME: | 56.90% |

FULL SCALE: 82509



| CHN | ENERGY (keV) | GROSS CPM | AMBIENT CPM | CONTINUUM CPM | NET CPM | UNC % | |
|-----|--------------|-----------|-------------|---------------|--------------|-------|-------|
| 31 | 82.5 | 469997 | 323 | 410084 | 59589 ± 1.15 | | Cd109 |
| 52 | 178.8 | 823156 | 640 | 806639 | 15876 ± 5.72 | | |
| 131 | 885.0 | 414173 | 102 | 409319 | 4751 ± 13.5 | | |
| 151 | 1148.8 | 353942 | 75 | 296641 | 57226 ± 1.04 | | Co60 |
| 162 | 1306.7 | 256300 | 43 | 194357 | 61899 ± 0.82 | | Co60 |

2 OF 2 LIBRARY LINES FOR Co60 FOUND Correlation = 0.99

| LINE | PEAK | INTENSITY | NET CPM |
|--------|--------|-----------|---------|
| 1173.2 | 1145.0 | 99.90 | 57226 |
| 1332.5 | 1310.0 | 99.98 | 61899 |

1 OF 1 LIBRARY LINES FOR Cd109 FOUND Correlation = 0.80

| LINE | PEAK | INTENSITY | NET CPM |
|------|------|-----------|---------|
| 88.0 | 82.6 | 3.61 | 59589 |

1 OF 1 LIBRARY LINES FOR Zn65 FOUND Correlation = 0.80

| LINE | PEAK | INTENSITY | NET CPM |
|--------|--------|-----------|---------|
| 1115.5 | 1145.0 | 50.70 | 57226 |

NOTE: nuclide misidentified based on the Co-60 peak]

Lines not associated with any nuclide:

| Energy | Net CPM | Eff Corrected |
|--------|---------|---------------|
| 182.2 | 15876.3 | 71116.4 C |
| 881.4 | 4751.6 | 79550.3 C |

Appendix 1
Area Scan Monitoring Data

JLAB-TN-05-048

MONITORING REPORT M6

Aft upper main coolant nozzle

Area Monitor Report

Alarm # 3 at 18-Apr-2005 13:06:43 for 142 sec (captured)

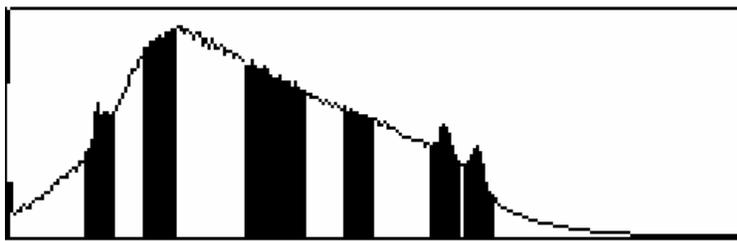
| Nuclide(s) | Peak Conf | Total Conf | Peak Dose | Avg Dose |
|------------|-----------|------------|--------------|--------------|
| Full | 128503.3 | 128503.3 | 575.50 uR/hr | 575.50 uR/hr |
| Co60 | 5762.72 | 5762.72 | 563.81 uR/hr | 563.81 uR/hr |
| Zn65 | 5762.72 | 5762.72 | 0.00 nR/hr | 0.00 nR/hr |
| Peak | 2737.39 | 2737.39 | 6.93 uR/hr | 6.93 uR/hr |

The following monitors had no measured activity:
Co57 Cr51 Cs137 Mn54 Na22 Sb124 Sc46 Ta182

MCA REPORT

| | | | |
|-----------------|-------------------|--------------|---------|
| DATE: | 18-Apr-2005 13:06 | BIAS: | 826 |
| EN CAL DATE: | 18-Apr-2005 12:41 | COARSE GAIN: | 1 |
| | | FINE GAIN: | 1.22 |
| BKG DATE: | 18-Apr-2005 12:34 | LOW DISC: | 0.00% |
| GROSS CPM: | 8025364 | HIGH DISC: | 100.05% |
| NET CPM: | 8021469 | ELAPSED LT: | 59.95 |
| GROSS INTEGRAL: | 8018676 | ELAPSED RT: | 141.88 |
| NET INTEGRAL: | 8014784 | DEAD TIME: | 57.75% |

FULL SCALE: 80337



| PEAKS FOUND | | | | | | |
|-------------|--------------|-----------|-------------|---------------|--------------|-------|
| CHN | ENERGY (keV) | GROSS CPM | AMBIENT CPM | CONTINUUM CPM | NET CPM | UNC % |
| 31 | 83.3 | 454604 | 322 | 402726 | 51555 ± 1.31 | Cd109 |
| 51 | 175.5 | 794562 | 639 | 781001 | 12920 ± 6.90 | |
| 88 | 438.0 | 670028 | 199 | 665152 | 4676 ± 17.5 | |
| 98 | 527.7 | 613958 | 181 | 608367 | 5410 ± 14.5 | |
| 121 | 769.2 | 491645 | 96 | 487568 | 3981 ± 17.6 | |
| 152 | 1159.2 | 384306 | 75 | 328425 | 55805 ± 1.11 | Co60 |
| 163 | 1320.3 | 279065 | 44 | 211645 | 67376 ± 0.78 | Co60 |

2 OF 2 LIBRARY LINES FOR Co60 FOUND Correlation = 0.98

| LINE | PEAK | INTENSITY | NET CPM |
|--------|--------|-----------|---------|
| 1173.2 | 1154.0 | 99.90 | 55805 |
| 1332.5 | 1322.0 | 99.98 | 67376 |

1 OF 1 LIBRARY LINES FOR Cd109 FOUND Correlation = 0.80

| LINE | PEAK | INTENSITY | NET CPM |
|------|------|-----------|---------|
| 88.0 | 83.3 | 3.61 | 51555 |

1 OF 1 LIBRARY LINES FOR Zn65 FOUND Correlation = 0.80

| LINE | PEAK | INTENSITY | NET CPM |
|--------|--------|-----------|---------|
| 1115.5 | 1154.0 | 50.70 | 55805 |

NOTE: nuclide misidentified based on the Co-60 peak]

LINES NOT ASSOCIATED WITH ANY NUCLIDE:

| Energy | Net CPM | Eff Corrected |
|--------|---------|---------------|
| 184.0 | 12920.8 | 57490.2 C |
| 429.6 | 4676.9 | 36832.5 C |
| 524.0 | 5410.5 | 51179.9 C |
| 777.1 | 3981.3 | 56983.9 C |

Appendix 1
Area Scan Monitoring Data

JLAB-TN-05-048

MONITORING REPORT M7

Top of pressurizer head port side

Area Monitor Report

Alarm # 4 at 18-Apr-2005 13:15:31 for 69 sec (captured)

| Nuclide(s) | Peak Conf | Total Conf | Peak Dose | Avg Dose |
|------------|-----------|------------|--------------|--------------|
| Full | 16499.05 | 16499.05 | 192.64 uR/hr | 192.64 uR/hr |
| Co60 | 2014.36 | 2014.36 | 182.69 uR/hr | 182.69 uR/hr |
| Zn65 | 2014.36 | 2014.36 | 0.00 nR/hr | 0.00 nR/hr |
| Peak | 165.53 | 165.53 | 5.20 uR/hr | 5.20 uR/hr |

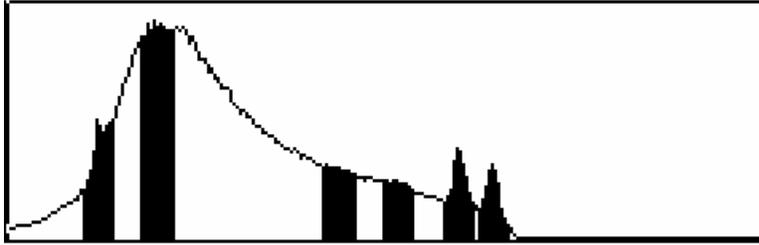
The following monitors had no measured activity:

Co57 Cr51 Cs137 Mn54 Na22 Sb124 Sc46 Ta182

MCA REPORT

| | | | |
|-----------------|-------------------|--------------|---------|
| DATE: | 18-Apr-2005 13:15 | BIAS: | 826 |
| EN CAL DATE: | 18-Apr-2005 12:41 | COARSE GAIN: | 1 |
| | | FINE GAIN: | 1.22 |
| BKG DATE: | 18-Apr-2005 12:34 | LOW DISC: | 0.00% |
| GROSS CPM: | 1033716 | HIGH DISC: | 100.05% |
| NET CPM: | 1029822 | ELAPSED LT: | 59.96 |
| GROSS INTEGRAL: | 1033027 | ELAPSED RT: | 69.26 |
| NET INTEGRAL: | 1029136 | DEAD TIME: | 13.43% |

FULL SCALE: 15103



PEAKS FOUND

| CHN | ENERGY (keV) | GROSS CPM | AMBIENT CPM | CONTINUUM CPM | NET CPM | UNC % | |
|-----|--------------|-----------|-------------|---------------|--------------|-------|---------------------|
| 30 | 80.0 | 70290 | 288 | 63930 | 6072 ± 4.38 | | Cd109 -- LEAD X-RAY |
| 49 | 166.2 | 153194 | 624 | 149083 | 3486 ± 11.3 | | |
| 112 | 665.3 | 50828 | 163 | 49538 | 1127 ± 20.0 | | Cs137 |
| 131 | 887.7 | 40398 | 102 | 38552 | 1744 ± 11.5 | | |
| 152 | 1162.0 | 44108 | 75 | 25614 | 18419 ± 1.14 | | Co60 |
| 163 | 1322.8 | 32652 | 44 | 14001 | 18607 ± 0.97 | | Co60 |

2 OF 2 LIBRARY LINES FOR Co60 FOUND Correlation = 1.00

| LINE | PEAK | INTENSITY | NET CPM |
|--------|--------|-----------|---------|
| 1173.2 | 1158.2 | 99.90 | 18419 |
| 1332.5 | 1325.9 | 99.98 | 18607 |

1 OF 1 LIBRARY LINES FOR Cd109 FOUND Correlation = 0.80 [Lead x-ray]

| LINE | PEAK | INTENSITY | NET CPM |
|------|------|-----------|---------|
| 88.0 | 80.0 | 3.61 | 6072 |

1 OF 1 LIBRARY LINES FOR Cs137 FOUND Correlation = 0.80

| LINE | PEAK | INTENSITY | NET CPM |
|-------|-------|-----------|---------|
| 661.7 | 664.6 | 85.21 | 1127 |

LINEs NOT ASSOCIATED WITH ANY NUCLIDE:

| Energy | Net CPM | Eff Corrected |
|--------|---------|---------------|
| 169.5 | 3486.3 | 15221.7 C |
| 886.3 | 1744.2 | 29297.5 C |

Appendix 1
Area Scan Monitoring Data

JLAB-TN-05-048

MONITORING REPORT M8

Upper forward Heat Exchanger

Area Monitor Report

Alarm # 2 at 18-Apr-2005 13:00:42 for 84 sec (captured)

| Nuclide(s) | Peak Conf | Total Conf | Peak Dose | Avg Dose |
|------------|-----------|------------|--------------|--------------|
| Full | 40938.80 | 40938.80 | 258.57 uR/hr | 258.57 uR/hr |
| Co60 | 2567.92 | 2567.92 | 242.04 uR/hr | 242.04 uR/hr |
| Zn65 | 2567.92 | 2567.92 | 0.00 nR/hr | 0.00 nR/hr |
| Peak | 1881.39 | 1881.39 | 5.78 uR/hr | 5.78 uR/hr |
| Cs137 | 270.52 | 270.52 | 6.00 uR/hr | 6.00 uR/hr |

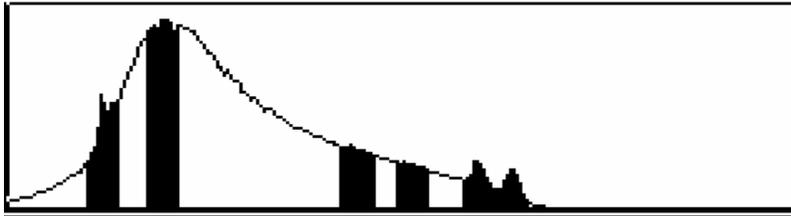
The following monitors had no measured activity:

Co57 Cr51 Mn54 Na22 Sb124 Sc46 Ta182

MCA REPORT

| | | | |
|-----------------|-------------------|--------------|---------|
| DATE: | 18-Apr-2005 13:00 | BIAS: | 826 |
| EN CAL DATE: | 18-Apr-2005 12:41 | COARSE GAIN: | 1 |
| | | FINE GAIN: | 1.22 |
| BKG DATE: | 18-Apr-2005 12:34 | LOW DISC: | 0.00% |
| GROSS CPM: | 2558961 | HIGH DISC: | 100.05% |
| NET CPM: | 2555068 | ELAPSED LT: | 59.97 |
| GROSS INTEGRAL: | 2557682 | ELAPSED RT: | 83.70 |
| NET INTEGRAL: | 2553790 | DEAD TIME: | 28.35% |

FULL SCALE: 38426



PEAKS FOUND

| CHN | ENERGY (keV) | GROSS CPM | AMBIENT CPM | CONTINUUM CPM | NET CPM | UNC % | |
|-----|--------------|-----------|-------------|---------------|--------------|-------|---------------------|
| 30 | 80.4 | 192156 | 288 | 171927 | 19939 ± 2.20 | | Cd109 -- LEAD X-RAY |
| 49 | 165.9 | 389775 | 638 | 376278 | 12859 ± 4.86 | | |
| 113 | 674.6 | 127080 | 144 | 124142 | 2794 ± 12.8 | | Cs137 |
| 131 | 880.0 | 93962 | 101 | 90987 | 2874 ± 10.7 | | |
| 151 | 1153.5 | 77098 | 75 | 54185 | 22838 ± 1.22 | | Co60 |
| 162 | 1312.8 | 55236 | 42 | 29923 | 25270 ± 0.93 | | Co60 |

2 OF 2 LIBRARY LINES FOR Co60 FOUND Correlation = 0.99

| LINE | PEAK | INTENSITY | NET CPM |
|--------|--------|-----------|---------|
| 1173.2 | 1148.8 | 99.90 | 22838 |
| 1332.5 | 1317.2 | 99.98 | 25270 |

1 OF 1 LIBRARY LINES FOR Cd109 FOUND Correlation = 0.80

| LINE | PEAK | INTENSITY | NET CPM |
|------|------|-----------|---------|
| 88.0 | 80.1 | 3.61 | 19939 |

1 OF 1 LIBRARY LINES FOR Cs137 FOUND Correlation = 0.80

| LINE | PEAK | INTENSITY | NET CPM |
|-------|-------|-----------|---------|
| 661.7 | 668.9 | 85.21 | 2794 |

1 OF 1 LIBRARY LINES FOR Zn65 FOUND Correlation = 0.80

| LINE | PEAK | INTENSITY | NET CPM |
|--------|--------|-----------|---------|
| 1115.5 | 1148.8 | 50.70 | 22838 |

[NOTE: nuclide misidentified based on the Co-60 peak]

LINES NOT ASSOCIATED WITH ANY NUCLIDE:

| Energy | Net CPM | Eff Corrected |
|--------|---------|---------------|
| 168.2 | 12859.4 | 56106.0 C |
| 881.9 | 2874.4 | 47826.2 C |

Appendix 1 Area Scan Monitoring Data

JLAB-TN-05-048

MONITORING REPORT M9

Regen/Nonregen crossover line

Area Monitor Report

Alarm # 19 at 19-Apr-2005 08:58:00 for 143 sec (captured)

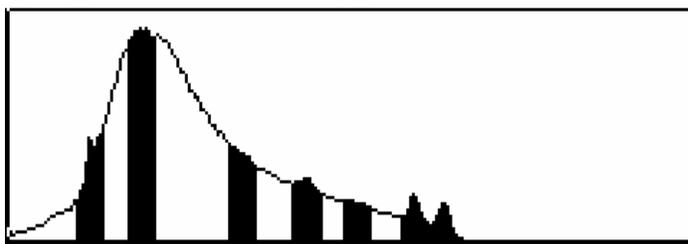
| Nuclide(s) | Peak Conf | Total Conf | Peak Dose | Avg Dose |
|------------|-----------|------------|--------------|--------------|
| Full | 29162.19 | 29162.19 | 146.83 uR/hr | 146.83 uR/hr |
| Co60 | 2049.96 | 2049.96 | 136.56 uR/hr | 136.56 uR/hr |
| Zn65 | 2049.96 | 2049.96 | 0.00 nR/hr | 0.00 nR/hr |
| Cs137 | 536.32 | 536.32 | 8.48 uR/hr | 8.48 uR/hr |
| Peak | 303.93 | 303.93 | 1.78 uR/hr | 1.78 uR/hr |

The following monitors had no measured activity:
Co57 Cr51 Mn54 Na22 Sb124 Sc46 Ta182

MCA REPORT

| | | | |
|-----------------|-------------------|--------------|---------|
| DATE: | 19-Apr-2005 08:58 | BIAS: | 826 |
| EN CAL DATE: | 19-Apr-2005 08:54 | COARSE GAIN: | 1 |
| | | FINE GAIN: | 1.27 |
| BKG DATE: | 18-Apr-2005 12:34 | LOW DISC: | 0.00% |
| GROSS CPM: | 1291036 | HIGH DISC: | 100.05% |
| NET CPM: | 1287142 | ELAPSED LT: | 119.91 |
| GROSS INTEGRAL: | 2580136 | ELAPSED RT: | 143.13 |
| NET INTEGRAL: | 2572353 | DEAD TIME: | 16.22% |

FULL SCALE: 43034



PEAKS FOUND

| CHN | ENERGY (keV) | GROSS CPM | AMBIENT CPM | CONTINUUM CPM | NET CPM | UNC % | |
|-----|--------------|-----------|-------------|---------------|--------------|-------|---------------------|
| 30 | 79.4 | 91929 | 288 | 86868 | 4772 ± 4.51 | | Cd109 -- LEAD X-RAY |
| 49 | 165.6 | 218658 | 638 | 209335 | 8684 ± 3.82 | | |
| 86 | 420.7 | 92810 | 199 | 92185 | 425 ± 50.8 | | |
| 111 | 659.3 | 62112 | 163 | 56480 | 5468 ± 3.23 | | Cs137 |
| 130 | 875.8 | 41006 | 101 | 39544 | 1361 ± 10.6 | | |
| 152 | 1155.1 | 36195 | 75 | 22475 | 13643 ± 0.99 | | Co60 |
| 163 | 1314.7 | 26816 | 42 | 13055 | 13718 ± 0.85 | | Co60 |

2 OF 2 LIBRARY LINES FOR Co60 FOUND Correlation = 1.00

| LINE | PEAK | INTENSITY | NET CPM |
|--------|--------|-----------|---------|
| 1173.2 | 1150.7 | 99.90 | 13643 |
| 1332.5 | 1318.7 | 99.98 | 13718 |

1 OF 1 LIBRARY LINES FOR Cd109 FOUND Correlation = 0.80

| LINE | PEAK | INTENSITY | NET CPM |
|------|------|-----------|---------|
| 88.0 | 80.1 | 3.61 | 4772 |

1 OF 1 LIBRARY LINES FOR Cs137 FOUND Correlation = 0.80

| LINE | PEAK | INTENSITY | NET CPM |
|-------|-------|-----------|---------|
| 661.7 | 659.0 | 85.21 | 5468 |

LINE NOT ASSOCIATED WITH ANY NUCLIDE:

| Energy | Net CPM | Eff Corrected |
|--------|---------|---------------|
| 168.6 | 8684.0 | 37866.5 C |
| 430.9 | 425.3 | 3228.3 C |
| 877.0 | 1361.0 | 22526.6 C |

Appendix 1
Area Scan Monitoring Data

JLAB-TN-05-048

MONITORING REPORT M10

Base of pressurizer, on port side main press line

Area Monitor Report

Alarm # 10 at 18-Apr-2005 13:38:18 for 73 sec (captured)

| Nuclide(s) | Peak Conf | Total Conf | Peak Dose | Avg Dose |
|------------|-----------|------------|--------------|--------------|
| Full | 22132.06 | 22132.06 | 169.62 uR/hr | 169.62 uR/hr |
| Co60 | 1678.39 | 1678.39 | 156.27 uR/hr | 156.27 uR/hr |
| Zn65 | 1678.39 | 1678.39 | 0.00 nR/hr | 0.00 nR/hr |
| Cs137 | 305.90 | 305.90 | 6.78 uR/hr | 6.78 uR/hr |
| Peak | 258.29 | 258.29 | 1.81 uR/hr | 1.81 uR/hr |

The following monitors had no measured activity:
Co57 Cr51 Mn54 Na22 Sb124 Sc46 Ta182

MCA REPORT

| | | | |
|-----------------|-------------------|--------------|---------|
| DATE: | 18-Apr-2005 13:38 | BIAS: | 826 |
| EN CAL DATE: | 18-Apr-2005 12:41 | COARSE GAIN: | 1 |
| | | FINE GAIN: | 1.22 |
| BKG DATE: | 18-Apr-2005 12:34 | LOW DISC: | 0.00% |
| GROSS CPM: | 1384852 | HIGH DISC: | 100.05% |
| NET CPM: | 1380959 | ELAPSED LT: | 60.00 |
| GROSS INTEGRAL: | 1384852 | ELAPSED RT: | 72.53 |
| NET INTEGRAL: | 1380959 | DEAD TIME: | 17.28% |

FULL SCALE: 22766



PEAKS FOUND

| CHN | ENERGY (keV) | GROSS CPM | AMBIENT CPM | CONTINUUM CPM | NET CPM | UNC % | |
|-----|--------------|-----------|-------------|---------------|--------------|-------|---------------|
| 30 | 79.7 | 118521 | 289 | 95964 | 22268 ± 1.55 | | -- LEAD X-RAY |
| 50 | 166.9 | 231388 | 639 | 217019 | 13730 ± 3.51 | | |
| 111 | 657.9 | 60719 | 164 | 57832 | 2723 ± 9.06 | | Cs137 |
| 130 | 874.5 | 43218 | 98 | 41959 | 1161 ± 17.9 | | |
| 151 | 1144.1 | 39936 | 75 | 24733 | 15128 ± 1.32 | | Co60 |
| 162 | 1301.7 | 29757 | 47 | 14652 | 15058 ± 1.15 | | Co60 |

2 OF 2 LIBRARY LINES FOR Co60 FOUND Correlation = 1.00

| LINE | PEAK | INTENSITY | NET CPM |
|--------|--------|-----------|---------|
| 1173.2 | 1139.5 | 99.90 | 15128 |
| 1332.5 | 1305.3 | 99.98 | 15058 |

1 OF 1 LIBRARY LINES FOR Cd109 FOUND Correlation = 0.80

| LINE | PEAK | INTENSITY | NET CPM |
|------|------|-----------|---------|
| 88.0 | 79.4 | 3.61 | 22268 |

1 OF 1 LIBRARY LINES FOR Cs137 FOUND Correlation = 0.80

| LINE | PEAK | INTENSITY | NET CPM |
|-------|-------|-----------|---------|
| 661.7 | 660.2 | 85.21 | 2723 |

Lines NOT ASSOCIATED WITH ANY NUCLIDE:

| Energy | Net CPM | Eff Corrected |
|--------|---------|---------------|
| 169.0 | 13730.0 | 60032.3 C |
| 872.0 | 1161.0 | 19184.2 C |

Appendix 1
Area Scan Monitoring Data

JLAB-TN-05-048

MONITORING REPORT M11

Check Valve adjacent to lower RCS RX inlet

Area Monitor Report

Alarm # 14 at 18-Apr-2005 13:56:24 for 87 sec (captured)

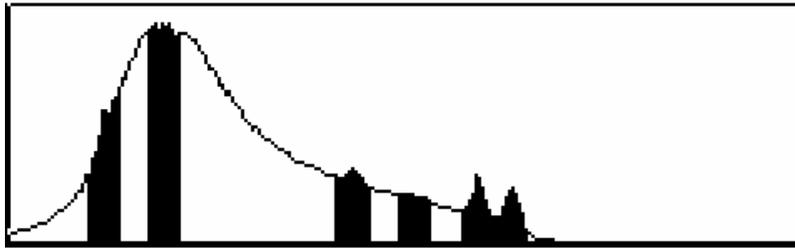
| Nuclide(s) | Peak Conf | Total Conf | Peak Dose | Avg Dose |
|------------|-----------|------------|--------------|--------------|
| Full | 46449.77 | 46449.77 | 387.81 uR/hr | 387.81 uR/hr |
| Co60 | 3995.95 | 3995.95 | 360.35 uR/hr | 360.35 uR/hr |
| Zn65 | 3995.95 | 3995.95 | 0.00 nR/hr | 0.00 nR/hr |
| Cs137 | 852.04 | 852.04 | 19.06 uR/hr | 19.06 uR/hr |
| Peak | 445.93 | 445.93 | 3.65 uR/hr | 3.65 uR/hr |

The following monitors had no measured activity:
Co57 Cr51 Mn54 Na22 Sb124 Sc46 Ta182

MCA REPORT

| | | | |
|-----------------|-------------------|--------------|---------|
| DATE: | 18-Apr-2005 13:56 | BIAS: | 826 |
| EN CAL DATE: | 18-Apr-2005 12:41 | COARSE GAIN: | 1 |
| | | FINE GAIN: | 1.22 |
| BKG DATE: | 18-Apr-2005 12:34 | LOW DISC: | 0.00% |
| GROSS CPM: | 2902187 | HIGH DISC: | 100.05% |
| NET CPM: | 2898294 | ELAPSED LT: | 60.00 |
| GROSS INTEGRAL: | 2902187 | ELAPSED RT: | 87.09 |
| NET INTEGRAL: | 2898294 | DEAD TIME: | 31.11% |

FULL SCALE: 43975



PEAKS FOUND

| CHN | ENERGY (keV) | GROSS CPM | AMBIENT CPM | CONTINUUM CPM | NET CPM | UNC % | |
|-----|--------------|-----------|-------------|---------------|--------------|-------|---------------------|
| 30 | 79.9 | 251082 | 289 | 242181 | 8612 ± 5.82 | | Cd109 -- LEAD X-RAY |
| 49 | 165.0 | 449468 | 639 | 438454 | 10375 ± 6.47 | | |
| 111 | 653.8 | 141051 | 175 | 129838 | 11038 ± 3.40 | | Cs137 |
| 131 | 879.4 | 98690 | 102 | 95562 | 3026 ± 10.4 | | |
| 151 | 1142.7 | 98351 | 75 | 61484 | 36792 ± 0.85 | | Co60 |
| 162 | 1301.0 | 76171 | 47 | 40782 | 35342 ± 0.78 | | Co60 |
| 224 | 2395.8 | 303 | 8 | 203 | 92 ± 19.2 | | |

2 OF 2 LIBRARY LINES FOR Co60 FOUND Correlation = 1.00

| LINE | PEAK | INTENSITY | NET CPM |
|--------|--------|-----------|---------|
| 1173.2 | 1138.4 | 99.90 | 36792 |
| 1332.5 | 1304.9 | 99.98 | 35342 |

1 OF 1 LIBRARY LINES FOR Cd109 FOUND Correlation = 0.80

| LINE | PEAK | INTENSITY | NET CPM |
|------|------|-----------|---------|
| 88.0 | 80.4 | 3.61 | 8612 |

1 OF 1 LIBRARY LINES FOR Cs137 FOUND Correlation = 0.80

| LINE | PEAK | INTENSITY | NET CPM |
|-------|-------|-----------|---------|
| 661.7 | 653.8 | 85.21 | 11038 |

LINES NOT ASSOCIATED WITH ANY NUCLIDE:

| Energy | Net CPM | Eff Corrected |
|--------|---------|---------------|
| 167.3 | 10375.0 | 45187.1 C |
| 872.3 | 3026.0 | 50310.1 C |
| 2403.7 | 92.0 | 1970.8 C |

Appendix 1
Area Scan Monitoring Data

JLAB-TN-05-048

MONITORING REPORT M12

Base of RX vessel outside shield FWD Stbd

Area Monitor Report

Alarm # 12 at 18-Apr-2005 13:52:38 for 83 sec (captured)

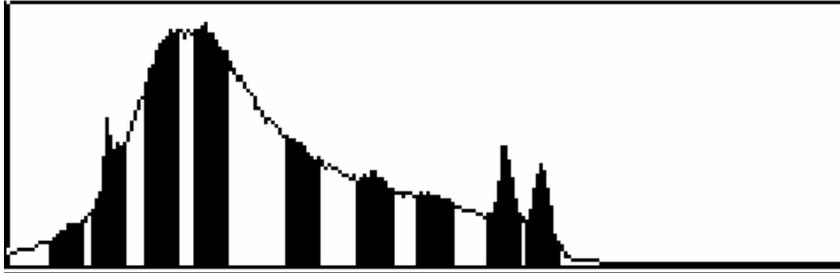
| Nuclide(s) | Peak Conf | Total Conf | Peak Dose | Avg Dose |
|------------|-----------|------------|--------------|--------------|
| Full | 39336.61 | 39336.61 | 505.28 uR/hr | 505.28 uR/hr |
| Co60 | 5467.72 | 5467.72 | 478.74 uR/hr | 478.74 uR/hr |
| Zn65 | 5467.72 | 5467.72 | 0.00 nR/hr | 0.00 nR/hr |
| Cs137 | 494.31 | 494.31 | 10.97 uR/hr | 10.97 uR/hr |
| Peak | 360.47 | 360.47 | 3.71 uR/hr | 3.71 uR/hr |
| Mn54 | 245.56 | 245.56 | 7.10 uR/hr | 7.10 uR/hr |

The following monitors had no measured activity:
Co57 Cr51 Na22 Sb124 Sc46 Ta182

MCA REPORT

| | | | |
|-----------------|-------------------|--------------|---------|
| DATE: | 18-Apr-2005 13:52 | BIAS: | 826 |
| EN CAL DATE: | 18-Apr-2005 12:41 | COARSE GAIN: | 1 |
| | | FINE GAIN: | 1.22 |
| BKG DATE: | 18-Apr-2005 12:34 | LOW DISC: | 0.00% |
| GROSS CPM: | 2459784 | HIGH DISC: | 100.05% |
| NET CPM: | 2455890 | ELAPSED LT: | 59.93 |
| GROSS INTEGRAL: | 2456915 | ELAPSED RT: | 82.72 |
| NET INTEGRAL: | 2453025 | DEAD TIME: | 27.55% |

FULL SCALE: 34605



| CHN | ENERGY (keV) | GROSS CPM | AMBIENT CPM | CONTINUUM CPM | NET CPM | UNC % | |
|-----|--------------|-----------|-------------|---------------|--------------|-------|---------------|
| 19 | 43.6 | 52607 | 132 | 49469 | 3005 ± 7.65 | | Pb210 |
| 30 | 80.4 | 162233 | 288 | 135590 | 26354 ± 1.53 | | Th232 |
| 47 | 151.2 | 323336 | 650 | 300072 | 22613 ± 2.52 | | -- LEAD X-RAY |
| 62 | 236.8 | 343903 | 627 | 321514 | 21761 ± 2.70 | | Th232 |
| 88 | 436.8 | 174662 | 203 | 172318 | 2141 ± 19.5 | | |
| 112 | 662.8 | 128637 | 163 | 121449 | 7024 ± 5.11 | | Cs137 |
| 130 | 866.2 | 102811 | 97 | 99864 | 2850 ± 11.3 | | |
| 151 | 1148.5 | 122084 | 74 | 69242 | 52767 ± 0.66 | | Co60 |
| 162 | 1308.2 | 94449 | 42 | 43963 | 50443 ± 0.61 | | Co60 |

2 OF 2 LIBRARY LINES FOR Co60 FOUND Correlation = 1.00

| LINE | PEAK | INTENSITY | NET CPM |
|--------|--------|-----------|---------|
| 1173.2 | 1145.3 | 99.90 | 52767 |
| 1332.5 | 1311.8 | 99.98 | 50443 |

1 OF 1 LIBRARY LINES FOR Cs137 FOUND Correlation = 0.80

| LINE | PEAK | INTENSITY | NET CPM |
|-------|-------|-----------|---------|
| 661.7 | 660.8 | 85.21 | 7024 |

1 OF 1 LIBRARY LINES FOR Pb210 FOUND Correlation = 0.80

| LINE | PEAK | INTENSITY | NET CPM |
|------|------|-----------|---------|
| 46.5 | 38.9 | 4.25 | 3005 |

LINES NOT ASSOCIATED WITH ANY NUCLIDE:

| Energy | Net CPM | Eff Corrected |
|--------|---------|---------------|
| 151.5 | 22613.4 | 95817.7 C |
| 447.2 | 2141.5 | 16824.7 C |
| 871.2 | 2850.3 | 46607.4 C |

Appendix 1
Area Scan Monitoring Data

JLAB-TN-05-048

MONITORING REPORT M13

RX vent plenum 1st level RC

Area Monitor Report

Alarm # 21 at 19-Apr-2005 09:06:09 for 70 sec (captured)

| Nuclide(s) | Peak Conf | Total Conf | Peak Dose | Avg Dose |
|------------|-----------|------------|--------------|--------------|
| Full | 18226.33 | 18226.33 | 103.48 uR/hr | 103.48 uR/hr |
| Co60 | 845.39 | 845.39 | 84.52 uR/hr | 84.52 uR/hr |
| Zn65 | 845.39 | 845.39 | 0.00 nR/hr | 0.00 nR/hr |
| Cs137 | 812.00 | 812.00 | 18.01 uR/hr | 18.01 uR/hr |
| Peak | 202.82 | 202.82 | 946.46 nR/hr | 946.46 nR/hr |

The following monitors had no measured activity:
Co57 Cr51 Mn54 Na22 Sb124 Sc46 Ta182

MCA REPORT

| | | | |
|-----------------|-------------------|--------------|---------|
| DATE: | 19-Apr-2005 09:06 | BIAS: | 826 |
| EN CAL DATE: | 19-Apr-2005 08:54 | COARSE GAIN: | 1 |
| | | FINE GAIN: | 1.27 |
| BKG DATE: | 18-Apr-2005 12:34 | LOW DISC: | 0.00% |
| GROSS CPM: | 1141338 | HIGH DISC: | 100.05% |
| NET CPM: | 1137445 | ELAPSED LT: | 59.98 |
| GROSS INTEGRAL: | 1140958 | ELAPSED RT: | 70.22 |
| NET INTEGRAL: | 1137066 | DEAD TIME: | 14.58% |

FULL SCALE: 19884



PEAKS FOUND

| CHN | ENERGY (keV) | GROSS CPM | AMBIENT CPM | CONTINUUM CPM | NET CPM | UNC % | |
|-----|--------------|-----------|-------------|---------------|--------------|-------|-------|
| 50 | 167.3 | 200542 | 639 | 189257 | 10646 ± 4.21 | | |
| 112 | 665.0 | 60017 | 164 | 48135 | 11717 ± 2.09 | | Cs137 |
| 130 | 876.6 | 33808 | 98 | 32790 | 919 ± 20.0 | | Mn54 |
| 152 | 1157.9 | 25863 | 76 | 17990 | 7796 ± 2.07 | | Co60 |
| 163 | 1318.6 | 17631 | 45 | 7927 | 9659 ± 1.38 | | Co60 |

2 OF 2 LIBRARY LINES FOR Co60 FOUND Correlation = 0.98
 LINE PEAK INTENSITY NET CPM
 1173.2 1152.1 99.90 7796
 1332.5 1320.9 99.98 9659

1 OF 1 LIBRARY LINES FOR Cs137 FOUND Correlation = 0.80
 LINE PEAK INTENSITY NET CPM
 661.7 665.3 85.21 11717

1 OF 1 LIBRARY LINES FOR Mn54 FOUND Correlation = 0.80
 LINE PEAK INTENSITY NET CPM
 834.8 861.2 99.98 919

0 OF 2 LIBRARY LINES FOR U238 FOUND Correlation = 0.00

LINE NOT ASSOCIATED WITH ANY NUCLIDE:

| Energy | Net CPM | Eff Corrected |
|--------|---------|---------------|
| 166.1 | 10646.5 | 46586.8 C |

Appendix 1
Area Scan Monitoring Data

JLAB-TN-05-048

MONITORING REPORT M14

Upper Cold Chem RX ventilation "emergency"

Area Monitor Report

Alarm # 28 at 19-Apr-2005 11:19:57 for 180 sec (captured)

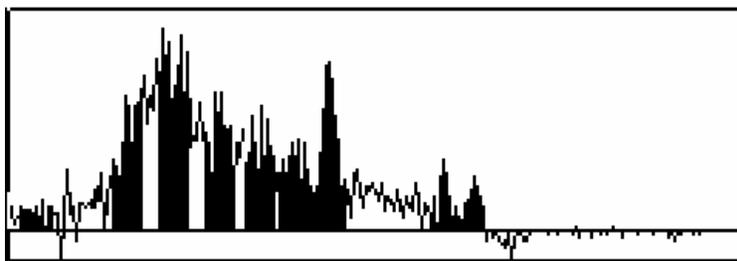
| Nuclide(s) | Peak Conf | Total Conf | Peak Dose | Avg Dose |
|------------|-----------|------------|--------------|--------------|
| Full | 107.72 | 107.72 | 5.09 uR/hr | 5.09 uR/hr |
| Co60 | 4.56 | 4.56 | 253.01 nR/hr | 253.01 nR/hr |
| Zn65 | 4.56 | 4.56 | 0.00 nR/hr | 0.00 nR/hr |
| Cs137 | 3.32 | 3.32 | 42.82 nR/hr | 42.82 nR/hr |

The following monitors had no measured activity:
Peak Co57 Cr51 Mn54 Na22 Sb124 Sc46 Ta182

MCA REPORT

| | | | |
|-----------------|-------------------|--------------|---------|
| DATE: | 19-Apr-2005 11:19 | BIAS: | 826 |
| EN CAL DATE: | 19-Apr-2005 11:14 | COARSE GAIN: | 1 |
| | | FINE GAIN: | 1.27 |
| BKG DATE: | 18-Apr-2005 12:34 | LOW DISC: | 0.00% |
| GROSS CPM: | 7774 | HIGH DISC: | 100.05% |
| NET CPM: | 3881 | ELAPSED LT: | 179.94 |
| GROSS INTEGRAL: | 23316 | ELAPSED RT: | 180.15 |
| NET INTEGRAL: | 11640 | DEAD TIME: | 0.12% |

FULL SCALE: 233



PEAKS FOUND

| CHN | ENERGY (keV) | GROSS CPM | AMBIENT CPM | CONTINUUM CPM | NET CPM | UNC % | |
|-----|--------------|-----------|-------------|---------------|------------|-------|-------|
| 9 | 19.9 | 136 | 52 | 47 | 36 ± 26.9 | | |
| 41 | 122.4 | 977 | 572 | 348 | 57 ± 52.6 | | |
| 58 | 217.3 | 1282 | 601 | 579 | 102 ± 31.4 | | |
| 72 | 311.1 | 830 | 435 | 339 | 56 ± 47.4 | | |
| 88 | 434.6 | 551 | 200 | 287 | 63 ± 30.8 | | |
| 100 | 544.5 | 449 | 169 | 221 | 58 ± 30.6 | | |
| 112 | 662.8 | 556 | 164 | 159 | 233 ± 8.01 | | Cs137 |
| 152 | 1163.1 | 207 | 76 | 75 | 56 ± 21.3 | | Co60 |
| 162 | 1306.8 | 143 | 43 | 36 | 63 ± 15.0 | | Co60 |

2 OF 2 LIBRARY LINES FOR Co60 FOUND Correlation = 0.99

| LINE | PEAK | INTENSITY | NET CPM |
|--------|--------|-----------|---------|
| 1173.2 | 1152.8 | 99.90 | 56 |
| 1332.5 | 1307.7 | 99.98 | 63 |

1 OF 1 LIBRARY LINES FOR Cs137 FOUND Correlation = 0.80

| LINE | PEAK | INTENSITY | NET CPM |
|-------|-------|-----------|---------|
| 661.7 | 662.7 | 85.21 | 233 |

NUCLIDES NOT PRESENT:

LINES NOT ASSOCIATED WITH ANY NUCLIDE:

| Energy | Net CPM | Eff Corrected |
|--------|---------|---------------|
| 21.7 | 36.7 | 1187.9 C |
| 126.4 | 57.0 | 229.5 C |
| 209.3 | 102.0 | 495.6 C |
| 319.1 | 56.4 | 335.9 C |
| 432.8 | 63.7 | 498.0 C |
| 542.6 | 58.4 | 570.2 C |

Appendix 1
Area Scan Monitoring Data

JLAB-TN-05-048

MONITORING REPORT M15

Coldchem lab lower level sample sink on installed sample bulb

Area Monitor Report

Alarm # 24 at 19-Apr-2005 10:36:18 for 132 sec (captured)

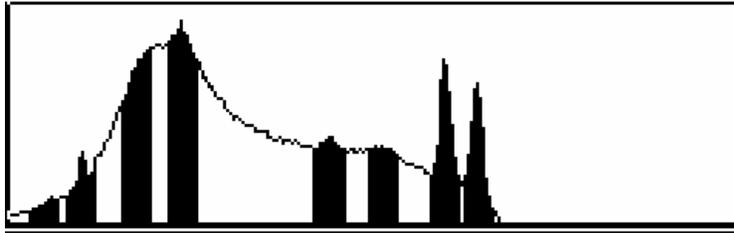
| Nuclide(s) | Peak Conf | Total Conf | Peak Dose | Avg Dose |
|------------|-----------|------------|--------------|--------------|
| Full | 14497.27 | 14497.27 | 250.14 uR/hr | 250.14 uR/hr |
| Co60 | 3800.43 | 3800.43 | 242.12 uR/hr | 242.12 uR/hr |
| Zn65 | 3800.43 | 3800.43 | 0.00 nR/hr | 0.00 nR/hr |
| Peak | 263.18 | 263.18 | 4.38 uR/hr | 4.38 uR/hr |
| Cs137 | 231.89 | 231.89 | 3.64 uR/hr | 3.64 uR/hr |

The following monitors had no measured activity:
Co57 Cr51 Mn54 Na22 Sb124 Sc46 Ta182

MCA REPORT

| | | | |
|-----------------|-------------------|--------------|---------|
| DATE: | 19-Apr-2005 10:36 | BIAS: | 826 |
| EN CAL DATE: | 19-Apr-2005 10:31 | COARSE GAIN: | 1 |
| | | FINE GAIN: | 1.27 |
| BKG DATE: | 18-Apr-2005 12:34 | LOW DISC: | 0.00% |
| GROSS CPM: | 643525 | HIGH DISC: | 100.05% |
| NET CPM: | 639632 | ELAPSED LT: | 120.00 |
| GROSS INTEGRAL: | 1287050 | ELAPSED RT: | 131.50 |
| NET INTEGRAL: | 1279264 | DEAD TIME: | 8.75% |

FULL SCALE: 17736



| CHN | ENERGY (keV) | GROSS CPM | AMBIENT CPM | CONTINUUM CPM | NET CPM | UNC % | |
|-----|--------------|-----------|-------------|---------------|--------------|-------|-------|
| 13 | 29.5 | 9913 | 72 | 9721 | 120 ± 58.8 | | Am241 |
| 25 | 61.4 | 23968 | 187 | 22060 | 1720 ± 6.41 | | Am241 |
| 45 | 141.3 | 71854 | 621 | 66858 | 4375 ± 4.37 | | |
| 60 | 230.3 | 85837 | 627 | 77783 | 7426 ± 2.81 | | |
| 112 | 667.4 | 36801 | 164 | 35158 | 1478 ± 9.22 | | Cs137 |
| 131 | 878.5 | 34338 | 102 | 32021 | 2215 ± 5.93 | | |
| 152 | 1159.0 | 46308 | 76 | 21521 | 24710 ± 0.62 | | Co60 |
| 163 | 1318.4 | 36518 | 45 | 11800 | 24673 ± 0.55 | | Co60 |
| 228 | 2472.9 | 92 | 15 | 44 | 33 ± 23.4 | | |

2 OF 2 LIBRARY LINES FOR Co60 FOUND Correlation = 1.00

| LINE | PEAK | INTENSITY | NET CPM |
|--------|--------|-----------|---------|
| 1173.2 | 1154.7 | 99.90 | 24710 |
| 1332.5 | 1321.6 | 99.98 | 24673 |

1 OF 1 LIBRARY LINES FOR Cs137 FOUND Correlation = 0.80

| LINE | PEAK | INTENSITY | NET CPM |
|-------|-------|-----------|---------|
| 661.7 | 665.0 | 85.21 | 1478 |

2 OF 2 LIBRARY LINES FOR Am241 FOUND Correlation = 0.72 **CHECK SOURCE REFERENCE PEAKS**

| LINE | PEAK | INTENSITY | NET CPM |
|------|------|-----------|---------|
| 26.3 | 28.5 | 30.00 | 120 |
| 59.5 | 62.0 | 35.90 | 1720 |

Lines NOT ASSOCIATED WITH ANY NUCLIDE:

| Energy | Net CPM | Eff Corrected |
|--------|---------|---------------|
| 142.9 | 4375.0 | 18193.9 C |
| 230.8 | 7426.5 | 37087.8 C |
| 879.9 | 2215.5 | 36793.7 C |
| 2469.8 | 33.5 | 700.0 C |

Appendix 1
Area Scan Monitoring Data

JLAB-TN-05-048

MONITORING REPORT M16

***** G A M M A S P E C T R U M A N A L Y S I S *****

Report Generated On : 5/4/05 3:14:33 PM

Sample Title : PrtChgPmp

Peak Locate Threshold : 5.00
Peak Locate Range (in channels) : 1 - 65535
Peak Area Range (in channels) : 1 - 65535
Identification Energy Tolerance : 1.000 keV

Sample Size : 1.000E+000 Unit
Acquisition Started : 4/15/05 10:49:01 AM

Live Time : 600.0 seconds
Real Time : 626.3 seconds

Energy Calibration Used Done On :
Efficiency Calibration Used Done On : 3/22/05

Peak Analysis Report 5/4/05 3:14:34 PM Page 2

Peak Analysis Performed on: 5/4/05 3:14:34 PM
Peak Analysis From Channel: 1
Peak Analysis To Channel: 8192

| Peak No. | ROI start | ROI end | Peak centroid | Energy (keV) | Net Peak Area | Net Area Uncert. | Continuum Counts |
|----------|-----------|---------|---------------|--------------|---------------|------------------|------------------|
| 1 | 47- | 64 | 53.53 | 13.38 | 1.87E+003 | 91.28 | 1.85E+003 |
| 2 | 2635- | 2660 | 2646.79 | 661.70 | 9.57E+002 | 72.50 | 1.01E+003 |
| 3 | 4675- | 4709 | 4691.86 | 1172.96 | 1.03E+004 | 112.79 | 4.59E+002 |
| 4 | 5308- | 5349 | 5328.52 | 1332.13 | 9.62E+003 | 99.67 | 5.11E+001 |

Errors quoted at 1.000 sigma

Interference Corrected Activity Report 5/4/05 3:14:34 PM Page 3

Nuclide Library Used: C:\GENIE2K\CAMFILES\STDLIB.NLB

..... IDENTIFIED NUCLIDES

| Nuclide Name | Id Confidence | Energy (keV) | Yield (%) | Activity (uCi/Unit) | Activity Uncertainty |
|--------------|---------------|--------------|-----------|---------------------|----------------------|
| CO-60 | 0.985 | 1173.22* | 100.00 | 1.86816E+001 | 5.95934E-001 |
| | | 1332.49* | 100.00 | 1.90296E+001 | 6.22454E-001 |
| CS-137 | 1.000 | 661.65* | 85.12 | 1.39403E+000 | 1.16693E-001 |

* = Energy line found in the spectrum.
@ = Energy line not used for Weighted Mean Activity
Energy Tolerance : 1.000 keV
Nuclide confidence index threshold = 0.30
Errors quoted at 1.000 sigma

Appendix 1
Area Scan Monitoring Data

JLAB-TN-05-048

MONITORING REPORT M16 (cont'd)

Interference Corrected Activity Report 5/4/05 3:14:34 PM Page 4

| Nuclide Name | Nuclide Id Confidence | Wt mean Activity (uCi/Unit) | Wt mean Activity Uncertainty |
|--------------|--------------------------|--------------------------------|---------------------------------|
| CO-60 | 0.985 | 1.884806E+001 | 4.304592E-001 |
| CS-137 | 1.000 | 1.394030E+000 | 1.166933E-001 |

? = nuclide is part of an undetermined solution
 X = nuclide rejected by the interference analysis
 @ = nuclide contains energy lines not used in Weighted Mean Activity

Errors quoted at 1.000 sigma

***** U N I D E N T I F I E D P E A K S *****

Peak Locate Performed on: 5/4/05 3:14:34 PM
 Peak Locate From Channel: 1
 Peak Locate To Channel: 8192

| Peak No. | Energy (keV) | Peak Size in Counts per Second | Peak CPS % Uncertainty |
|----------|--------------|-----------------------------------|---------------------------|
| 1 | 13.38 | 3.1145E+000 | 4.88 |

M = First peak in a multiplet region
 m = Other peak in a multiplet region
 F = Fitted singlet

Errors quoted at 1.000 sigma

Gamma Analysis Report S1

***** G A M M A S P E C T R U M A N A L Y S I S *****

Filename: C:\PCNT2K\CAMFILES\WIPE\WIP02667.CNF

Report Generated On : 4/20/2005 5:15:41 PM

Sample Title : Wipes
Sample Description :
Sample Identification : SG WIPE 4B
Sample Type : WIP
Sample Geometry : FILTER

Peak Locate Threshold : 2.75
Peak Locate Range (in channels) : 1 - 4096
Peak Area Range (in channels) : 1 - 4096
Identification Energy Tolerance : 1.250 keV

Sample Size : 1.000E+000 WIPE

Sample Taken On : 4/20/2005 5:12:37 PM
Acquisition Started : 4/20/2005 5:12:37 PM

Live Time : 180.0 seconds
Real Time : 182.1 seconds

Dead Time : 1.17 %

Energy Calibration Used Done On : 4/7/2005
Efficiency Calibration Used Done On : 11/19/2004
Efficiency ID : FILTER

Peak Locate Analysis Report 4/20/2005 5:15:41 PM Page 2

Detector Name: DET01
Sample Title: Wipes
Peak Locate Performed on: 4/20/2005 5:15:41 PM
Peak Locate From Channel: 1
Peak Locate To Channel: 4096
Peak Search Sensitivity: 2.75

| Peak No. | Centroid Channel | Centroid Uncertainty | Energy (keV) | Peak Significance |
|----------|------------------|----------------------|--------------|-------------------|
| 1 | 729.64 | 0.4747 | 364.44 | 2.85 |
| 2 | 1052.74 | 0.4662 | 525.97 | 2.93 |
| 3 | 1758.84 | 0.3951 | 878.97 | 3.08 |
| 4 | 2346.71 | 0.0966 | 1172.87 | 39.03 |
| 5 | 2665.46 | 0.0986 | 1332.22 | 33.94 |

? = Adjacent peak noted
Errors quoted at 1.000 sigma

Gamma Analysis Report S1 (cont'd)

Peak Analysis Report 4/20/2005 5:15:41 PM Page 3

Detector Name: DET01
Sample Title: Wipes
Peak Analysis Performed on: 4/20/2005 5:15:41 PM
 Peak Analysis From Channel: 1
 Peak Analysis To Channel: 4095

| Peak No. | ROI start | ROI end | Peak centroid | Energy (keV) | FWHM (keV) | Net Peak Area | Net Area Uncert. | Continuum Counts |
|----------|-----------|---------|---------------|--------------|------------|---------------|------------------|------------------|
| 1 | 727- | 732 | 729.64 | 364.44 | 0.50 | 1.00E+000 | 16.39 | 1.53E+002 |
| 2 | 1046- | 1055 | 1052.74 | 525.97 | 0.84 | 1.68E+001 | 22.43 | 2.16E+002 |
| 3 | 1756- | 1762 | 1758.84 | 878.97 | 1.05 | 3.34E+001 | 21.41 | 2.27E+002 |
| 4 | 2334- | 2358 | 2346.71 | 1172.87 | 1.91 | 7.00E+003 | 91.55 | 3.34E+002 |
| 5 | 2656- | 2675 | 2665.46 | 1332.22 | 2.08 | 6.32E+003 | 80.89 | 6.50E+001 |

M = First peak in a multiplet region
m = Other peak in a multiplet region
F = Fitted singlet

Errors quoted at 1.000 sigma

Interference Corrected Activity Report 4/20/2005 5:15:41 PM Page 4

Sample Title: Wipes
Nuclide Library Used: C:\GENIE2K\CAMFILES\SURFH20.NLB

..... IDENTIFIED NUCLIDES

| Nuclide Name | Id Confidence | Energy (keV) | Yield (%) | Activity (uCi/WIPE) | Activity Uncertainty |
|--------------|---------------|--------------|-----------|---------------------|----------------------|
| CO-60 | 0.990 | 1173.22* | 100.00 | 6.42200E-002 | 1.50810E-003 |
| | | 1332.49* | 100.00 | 6.67960E-002 | 1.52628E-003 |

* = Energy line found in the spectrum.
@ = Energy line not used for Weighted Mean Activity
Energy Tolerance : 1.250 keV
Nuclide confidence index threshold = 0.30
Errors quoted at 1.000 sigma

Gamma Analysis Report S1 (cont'd)

Interference Corrected Activity Report 4/20/2005 5:15:41 PM Page 5

| Nuclide Name | Nuclide Id Confidence | Wt mean Activity (uCi/WIPE) | Wt mean Activity Uncertainty |
|--------------|-----------------------|-----------------------------|------------------------------|
| CO-60 | 0.990 | 6.549252E-002 | 1.072761E-003 |

? = nuclide is part of an undetermined solution
X = nuclide rejected by the interference analysis
@ = nuclide contains energy lines not used in Weighted Mean Activity

Errors quoted at 1.000 sigma

***** UNIDENTIFIED PEAKS *****

Peak Locate Performed on: 4/20/2005 5:15:41 PM
Peak Locate From Channel: 1
Peak Locate To Channel: 4096

| Peak No. | Energy (keV) | Peak Size in Counts per Second | Peak CPS % Uncertainty |
|----------|--------------|--------------------------------|------------------------|
| 1 | 364.44 | 5.5556E-003 | 1639.36 |
| 2 | 525.97 | 9.3056E-002 | 133.94 |
| 3 | 878.97 | 1.8542E-001 | 64.14 |

M = First peak in a multiplet region
m = Other peak in a multiplet region
F = Fitted singlet

Errors quoted at 1.000 sigma

Gamma Analysis Report S2

***** G A M M A S P E C T R U M A N A L Y S I S *****

Filename: C:\PCNT2K\CAMFILES\WIPE\WIP02670.CNF

Report Generated On : 4/20/2005 5:32:57 PM
Sample Title : Wipes
Sample Description :
Sample Identification : SG WIPE 1B
Sample Type : WIP
Sample Geometry : FILTER
Peak Locate Threshold : 2.75
Peak Locate Range (in channels) : 1 - 4096
Peak Area Range (in channels) : 1 - 4096
Identification Energy Tolerance : 1.250 keV
Sample Size : 1.000E+000 WIPE
Sample Taken On : 4/20/2005 5:29:56 PM
Acquisition Started : 4/20/2005 5:29:56 PM
Live Time : 180.0 seconds
Real Time : 180.2 seconds
Dead Time : 0.08 %

Energy Calibration Used Done On : 4/7/2005
Efficiency Calibration Used Done On : 11/19/2004
Efficiency ID : FILTER

Peak Locate Analysis Report 4/20/2005 5:32:57 PM Page 2

Detector Name: DET01
Sample Title: Wipes
Peak Locate Performed on: 4/20/2005 5:32:57 PM
Peak Locate From Channel: 1
Peak Locate To Channel: 4096
Peak Search Sensitivity: 2.75

| Peak No. | Centroid Channel | Centroid Uncertainty | Energy (keV) | Peak Significance |
|----------|------------------|----------------------|--------------|-------------------|
| 1 | 2347.18 | 0.1823 | 1173.10 | 11.72 |
| 2 | 2665.71 | 0.1906 | 1332.35 | 9.71 |

? = Adjacent peak noted

Errors quoted at 1.000 sigma

Appendix 2
Sample Analysis Data

JLAB-TN-05-048

Gamma Analysis Report S2 (cont't)

Peak Analysis Report 4/20/2005 5:32:57 PM Page 3

Detector Name: DET01
Sample Title: Wipes
Peak Analysis Performed on: 4/20/2005 5:32:57 PM
 Peak Analysis From Channel: 1
 Peak Analysis To Channel: 4095

| Peak No. | ROI start | ROI end | Peak centroid | Energy (keV) | FWHM (keV) | Net Peak Area | Net Area Uncert. | Continuum Counts |
|----------|-----------|---------|---------------|--------------|------------|---------------|------------------|------------------|
| 1 | 2339- | 2354 | 2347.18 | 1173.10 | 1.70 | 4.35E+002 | 21.84 | 1.40E+001 |
| 2 | 2657- | 2673 | 2665.71 | 1332.35 | 1.93 | 4.04E+002 | 20.58 | 6.38E+000 |

M = First peak in a multiplet region
m = Other peak in a multiplet region
F = Fitted singlet

Errors quoted at 1.000 sigma

Interference Corrected Activity Report 4/20/2005 5:32:57 PM Page 4

Sample Title: Wipes
Nuclide Library Used: C:\GENIE2K\CAMFILES\SURFH20.NLB

..... IDENTIFIED NUCLIDES

| Nuclide Name | Id Confidence | Energy (keV) | Yield (%) | Activity (uCi/WIPE) | Activity Uncertainty |
|--------------|---------------|--------------|-----------|---------------------|----------------------|
| CO-60 | 0.998 | 1173.22* | 100.00 | 3.99026E-003 | 2.14932E-004 |
| | | 1332.49* | 100.00 | 4.26969E-003 | 2.32212E-004 |

* = Energy line found in the spectrum.
@ = Energy line not used for Weighted Mean Activity
Energy Tolerance : 1.250 keV
Nuclide confidence index threshold = 0.30
Errors quoted at 1.000 sigma

Gamma Analysis Report S2 (cont't)

Interference Corrected Activity Report 4/20/2005 5:32:57 PM Page 5

| Nuclide Name | Nuclide Id Confidence | Wt mean Activity (uCi/WIPE) | Wt mean Activity Uncertainty |
|--------------|--------------------------|--------------------------------|---------------------------------|
| CO-60 | 0.998 | 4.119192E-003 | 1.577354E-004 |

? = nuclide is part of an undetermined solution

X = nuclide rejected by the interference analysis

@ = nuclide contains energy lines not used in Weighted Mean Activity

Errors quoted at 1.000 sigma

***** U N I D E N T I F I E D P E A K S *****

Peak Locate Performed on: 4/20/2005 5:32:57 PM
Peak Locate From Channel: 1
Peak Locate To Channel: 4096

| Peak No. | Energy (keV) | Peak Size in Counts per Second | Peak CPS % Uncertainty |
|----------|--------------|--------------------------------|------------------------|
|----------|--------------|--------------------------------|------------------------|

All peaks were identified.

Gamma Analysis Report S2 (cont't)

***** G A M M A S P E C T R U M A N A L Y S I S *****

Filename: C:\PCNT2K\CAMFILES\WIPE\WIP02669.CNF

Report Generated On : 4/20/2005 5:28:30 PM

Sample Title : Wipes
Sample Description :
Sample Identification : SG WIPE 2B
Sample Type : WIP
Sample Geometry : FILTER

Peak Locate Threshold : 2.75
Peak Locate Range (in channels) : 1 - 4096
Peak Area Range (in channels) : 1 - 4096
Identification Energy Tolerance : 1.250 keV

Sample Size : 1.000E+000 WIPE

Sample Taken On : 4/20/2005 5:25:28 PM
Acquisition Started : 4/20/2005 5:25:28 PM

Live Time : 180.0 seconds
Real Time : 180.2 seconds

Dead Time : 0.11 %

Energy Calibration Used Done On : 4/7/2005
Efficiency Calibration Used Done On : 11/19/2004
Efficiency ID : FILTER

Peak Locate Analysis Report 4/20/2005 5:28:30 PM Page 2

Detector Name: DET01
Sample Title: Wipes
Peak Locate Performed on: 4/20/2005 5:28:30 PM
Peak Locate From Channel: 1
Peak Locate To Channel: 4096
Peak Search Sensitivity: 2.75

| Peak No. | Centroid Channel | Centroid Uncertainty | Energy (keV) | Peak Significance |
|----------|------------------|----------------------|--------------|-------------------|
| 1 | 2346.69 | 0.1918 | 1172.86 | 10.13 |
| 2 | 2665.44 | 0.1923 | 1332.21 | 9.43 |

? = Adjacent peak noted

Errors quoted at 1.000 sigma

Gamma Analysis Report S2 (cont't)

Peak Analysis Report 4/20/2005 5:28:30 PM Page 3

Detector Name: DET01
Sample Title: Wipes
Peak Analysis Performed on: 4/20/2005 5:28:30 PM
 Peak Analysis From Channel: 1
 Peak Analysis To Channel: 4095

| Peak No. | ROI start | ROI end | Peak centroid | Energy (keV) | FWHM (keV) | Net Peak Area | Net Area Uncert. | Continuum Counts |
|----------|-----------|---------|---------------|--------------|------------|---------------|------------------|------------------|
| 1 | 2337- | 2355 | 2346.69 | 1172.86 | 1.84 | 6.10E+002 | 25.96 | 1.90E+001 |
| 2 | 2654- | 2673 | 2665.44 | 1332.21 | 1.88 | 4.83E+002 | 22.37 | 5.00E+000 |

M = First peak in a multiplet region
m = Other peak in a multiplet region
F = Fitted singlet

Errors quoted at 1.000 sigma

Interference Corrected Activity Report 4/20/2005 5:28:30 PM Page 4

Sample Title: Wipes
Nuclide Library Used: C:\GENIE2K\CAMFILES\SURFH20.NLB

..... IDENTIFIED NUCLIDES

| Nuclide Name | Id Confidence | Energy (keV) | Yield (%) | Activity (uCi/WIPE) | Activity Uncertainty |
|--------------|---------------|--------------|-----------|---------------------|----------------------|
| CO-60 | 0.990 | 1173.22* | 100.00 | 5.59414E-003 | 2.61924E-004 |
| | | 1332.49* | 100.00 | 5.10874E-003 | 2.55614E-004 |

* = Energy line found in the spectrum.
@ = Energy line not used for Weighted Mean Activity
Energy Tolerance : 1.250 keV
Nuclide confidence index threshold = 0.30
Errors quoted at 1.000 sigma

Gamma Analysis Report S2 (cont't)

Interference Corrected Activity Report 4/20/2005 5:28:30 PM Page 5

| Nuclide Name | Nuclide Id Confidence | Wt mean Activity (uCi/WIPE) | Wt mean Activity Uncertainty |
|--------------|--------------------------|-----------------------------------|------------------------------------|
| CO-60 | 0.990 | 5.345520E-003 | 1.829365E-004 |

? = nuclide is part of an undetermined solution
X = nuclide rejected by the interference analysis
@ = nuclide contains energy lines not used in Weighted Mean Activity

Errors quoted at 1.000 sigma

***** U N I D E N T I F I E D P E A K S *****

Peak Locate Performed on: 4/20/2005 5:28:30 PM
Peak Locate From Channel: 1
Peak Locate To Channel: 4096

| Peak No. | Energy (keV) | Peak Size in Counts per Second | Peak CPS % Uncertainty |
|----------|--------------|-----------------------------------|---------------------------|
|----------|--------------|-----------------------------------|---------------------------|

All peaks were identified.

Gamma Analysis Report S2 (cont't)

***** G A M M A S P E C T R U M A N A L Y S I S *****

Filename: C:\PCNT2K\CAMFILES\WIPE\WIP02668.CNF

Report Generated On : 4/20/2005 5:23:23 PM

Sample Title : Wipes
Sample Description :
Sample Identification : SG WIPE 3B
Sample Type : WIP
Sample Geometry : FILTER

Peak Locate Threshold : 2.75
Peak Locate Range (in channels) : 1 - 4096
Peak Area Range (in channels) : 1 - 4096
Identification Energy Tolerance : 1.250 keV

Sample Size : 1.000E+000 WIPE

Sample Taken On : 4/20/2005 5:18:21 PM
Acquisition Started : 4/20/2005 5:18:21 PM

Live Time : 300.0 seconds
Real Time : 300.3 seconds

Dead Time : 0.10 %

Energy Calibration Used Done On : 4/7/2005
Efficiency Calibration Used Done On : 11/19/2004
Efficiency ID : FILTER

Peak Locate Analysis Report 4/20/2005 5:23:23 PM Page 2

Detector Name: DET01
Sample Title: Wipes
Peak Locate Performed on: 4/20/2005 5:23:23 PM
Peak Locate From Channel: 1
Peak Locate To Channel: 4096
Peak Search Sensitivity: 2.75

| Peak No. | Centroid Channel | Centroid Uncertainty | Energy (keV) | Peak Significance |
|----------|------------------|----------------------|--------------|-------------------|
| 1 | 2346.87 | 0.1528 | 1172.95 | 16.69 |
| 2 | 2665.34 | 0.1534 | 1332.16 | 15.18 |

? = Adjacent peak noted

Errors quoted at 1.000 sigma

Gamma Analysis Report S2 (cont't)

Interference Corrected Activity Report 4/20/2005 5:23:23 PM Page 5

| Nuclide Name | Nuclide Id Confidence | Wt mean Activity (uCi/WIPE) | Wt mean Activity Uncertainty |
|--------------|--------------------------|-----------------------------------|------------------------------------|
| CO-60 | 0.991 | 5.319765E-003 | 1.473768E-004 |

? = nuclide is part of an undetermined solution

X = nuclide rejected by the interference analysis

@ = nuclide contains energy lines not used in Weighted Mean Activity

Errors quoted at 1.000 sigma

***** U N I D E N T I F I E D P E A K S *****

Peak Locate Performed on: 4/20/2005 5:23:23 PM
Peak Locate From Channel: 1
Peak Locate To Channel: 4096

| Peak No. | Energy (keV) | Peak Size in Counts per Second | Peak CPS % Uncertainty |
|----------|--------------|-----------------------------------|---------------------------|
|----------|--------------|-----------------------------------|---------------------------|

All peaks were identified.

Gamma Analysis Report S2 (cont't)

***** G A M M A S P E C T R U M A N A L Y S I S *****

Filename: C:\PCNT2K\CAMFILES\WIPE\WIP02666.CNF

Report Generated On : 4/20/2005 5:10:10 PM

Sample Title : Wipes
Sample Description :
Sample Identification : SG WIPE 5B
Sample Type : WIP
Sample Geometry : FILTER

Peak Locate Threshold : 2.75
Peak Locate Range (in channels) : 1 - 4096
Peak Area Range (in channels) : 1 - 4096
Identification Energy Tolerance : 1.250 keV

Sample Size : 1.000E+000 WIPE

Sample Taken On : 4/20/2005 5:07:08 PM
Acquisition Started : 4/20/2005 5:07:08 PM

Live Time : 180.0 seconds
Real Time : 180.9 seconds

Dead Time : 0.48 %

Energy Calibration Used Done On : 4/7/2005
Efficiency Calibration Used Done On : 11/19/2004
Efficiency ID : FILTER

Peak Locate Analysis Report 4/20/2005 5:10:10 PM Page 2

Detector Name: DET01
Sample Title: Wipes
Peak Locate Performed on: 4/20/2005 5:10:10 PM
Peak Locate From Channel: 1
Peak Locate To Channel: 4096
Peak Search Sensitivity: 2.75

| Peak No. | Centroid Channel | Centroid Uncertainty | Energy (keV) | Peak Significance |
|----------|------------------|----------------------|--------------|-------------------|
| 1 | 2345.94 | 0.1373 | 1172.48 | 13.62 |
| 2 | 2664.47 | 0.1407 | 1331.72 | 11.62 |

? = Adjacent peak noted

Errors quoted at 1.000 sigma

Gamma Analysis Report S2 (cont't)

Interference Corrected Activity Report 4/20/2005 5:10:10 PM Page 5

| Nuclide Name | Nuclide Id Confidence | Wt mean Activity (uCi/WIPE) | Wt mean Activity Uncertainty |
|--------------|--------------------------|--------------------------------|---------------------------------|
| CO-60 | 0.944 | 2.489426E-002 | 4.948702E-004 |

? = nuclide is part of an undetermined solution
X = nuclide rejected by the interference analysis
@ = nuclide contains energy lines not used in Weighted Mean Activity
Errors quoted at 1.000 sigma

***** U N I D E N T I F I E D P E A K S *****

Peak Locate Performed on: 4/20/2005 5:10:10 PM
Peak Locate From Channel: 1
Peak Locate To Channel: 4096

| Peak No. | Energy (keV) | Peak Size in Counts per Second | Peak CPS % Uncertainty |
|----------|--------------|--------------------------------|------------------------|
|----------|--------------|--------------------------------|------------------------|

All peaks were identified.

Gamma Analysis Report S3

***** G A M M A S P E C T R U M A N A L Y S I S *****

Filename: C:\PCNT2K\CAMFILES\WIPE\WIP02660.CNF

Report Generated On : 4/19/2005 6:23:12 PM

Sample Title : Wipes
Sample Description :
Sample Identification : NNS-089
Sample Type : WIP
Sample Geometry : FILTER

Peak Locate Threshold : 2.75
Peak Locate Range (in channels) : 1 - 4096
Peak Area Range (in channels) : 1 - 4096
Identification Energy Tolerance : 1.250 keV

Sample Size : 6.000E+000 WIPE

Sample Taken On : 4/19/2005 5:53:11 PM
Acquisition Started : 4/19/2005 5:53:11 PM

Live Time : 1800.0 seconds
Real Time : 1800.4 seconds

Dead Time : 0.02 %

Energy Calibration Used Done On : 4/7/2005
Efficiency Calibration Used Done On : 11/19/2004
Efficiency ID : FILTER

Peak Locate Analysis Report 4/19/2005 6:23:12 PM Page 2

Detector Name: DET01
Sample Title: Wipes
Peak Locate Performed on: 4/19/2005 6:23:12 PM
Peak Locate From Channel: 1
Peak Locate To Channel: 4096
Peak Search Sensitivity: 2.75

| Peak No. | Centroid Channel | Centroid Uncertainty | Energy (keV) | Peak Significance |
|----------|------------------|----------------------|--------------|-------------------|
| 1 | 5.00 | 0.2755 | 2.17 | 13.18 |
| 2 | 63.70 | 0.3603 | 31.51 | 5.42 |
| 3 | 127.00 | 0.5177 | 63.16 | 3.73 |
| 4 | 185.80 | 0.4916 | 92.55 | 3.30 |
| 5 | 1324.15 | 0.1827 | 661.65 | 13.01 |
| 6 | 2347.68 | 0.2539 | 1173.35 | 6.00 |
| 7 | 2666.36 | 0.2645 | 1332.67 | 5.12 |

? = Adjacent peak noted
Errors quoted at 1.000 sigma

Gamma Analysis Report S3 (cont'd)

Interference Corrected Activity Report 4/19/2005 6:23:12 PM Page 5

| Nuclide Name | Nuclide Id Confidence | Wt mean Activity (uCi/WIPE) | Wt mean Activity Uncertainty |
|--------------|--------------------------|--------------------------------|---------------------------------|
| CO-60 | 0.997 | 1.845500E-005 | 1.535243E-006 |
| CS-137 | 1.000 | 9.243435E-005 | 3.679413E-006 |

? = nuclide is part of an undetermined solution
X = nuclide rejected by the interference analysis
@ = nuclide contains energy lines not used in Weighted Mean Activity

Errors quoted at 1.000 sigma

***** U N I D E N T I F I E D P E A K S *****

Peak Locate Performed on: 4/19/2005 6:23:12 PM
Peak Locate From Channel: 1
Peak Locate To Channel: 4096

| Peak No. | Energy (keV) | Peak Size in Counts per Second | Peak CPS % Uncertainty |
|----------|--------------|-----------------------------------|---------------------------|
| 1 | 2.17 | 9.7500E-002 | 8.91 |
| 2 | 31.51 | 1.8444E-001 | 8.38 |
| 3 | 63.16 | 1.2639E-002 | 62.11 |
| 4 | 92.55 | 2.6806E-002 | 40.45 |

M = First peak in a multiplet region
m = Other peak in a multiplet region
F = Fitted singlet

Errors quoted at 1.000 sigma

Gamma Analysis Report S4

***** G A M M A S P E C T R U M A N A L Y S I S *****

Filename: C:\PCNT2K\CAMFILES\WIPE\WIP02659.CNF

Report Generated On : 4/19/2005 5:48:53 PM

Sample Title : Wipes
Sample Description :
Sample Identification : NSS-078-079
Sample Type : WIP
Sample Geometry : FILTER

Peak Locate Threshold : 2.75
Peak Locate Range (in channels) : 1 - 4096
Peak Area Range (in channels) : 1 - 4096
Identification Energy Tolerance : 1.250 keV

Sample Size : 5.000E+000 WIPE

Sample Taken On : 4/19/2005 5:08:51 PM
Acquisition Started : 4/19/2005 5:08:51 PM

Live Time : 2400.0 seconds
Real Time : 2400.5 seconds

Dead Time : 0.02 %

Energy Calibration Used Done On : 4/7/2005
Efficiency Calibration Used Done On : 11/19/2004
Efficiency ID : FILTER

Peak Locate Analysis Report 4/19/2005 5:48:53 PM Page 2

Detector Name: DET01
Sample Title: Wipes
Peak Locate Performed on: 4/19/2005 5:48:53 PM
Peak Locate From Channel: 1
Peak Locate To Channel: 4096
Peak Search Sensitivity: 2.75

| Peak No. | Centroid Channel | Centroid Uncertainty | Energy (keV) | Peak Significance |
|----------|------------------|----------------------|--------------|-------------------|
| 1 | 5.00 | 0.2378 | 2.17 | 17.69 |
| 2 | 63.77 | 0.3051 | 31.55 | 8.31 |
| 3 | 72.22 | 0.4949 | 35.77 | 3.20 |
| 4 | 93.00 | 0.5608 | 46.16 | 3.18 |
| 5 | 185.62 | 0.4694 | 92.46 | 2.80 |
| 6 | 1324.16 | 0.1553 | 661.66 | 18.00 |
| 7 | 2923.03 | 0.3852 | 1460.99 | 2.94 |

? = Adjacent peak noted
Errors quoted at 1.000 sigma

Appendix 2
Sample Analysis Data

JLAB-TN-05-048

Gamma Analysis Report S4 (cont'd)

Peak Analysis Report 4/19/2005 5:48:53 PM Page 3

Detector Name: DET01
 Sample Title: Wipes
 Peak Analysis Performed on: 4/19/2005 5:48:53 PM
 Peak Analysis From Channel: 1
 Peak Analysis To Channel: 4095

| Peak No. | ROI start | ROI end | Peak centroid | Energy (keV) | FWHM (keV) | Net Peak Area | Net Area Uncert. | Continuum Counts |
|----------|-----------|---------|---------------|--------------|------------|---------------|------------------|------------------|
| 1 | 4- | 9 | 5.00 | 2.17 | 0.50 | 3.14E+002 | 20.65 | 6.94E+001 |
| 2 | 57- | 68 | 63.77 | 31.55 | 1.03 | 6.10E+002 | 37.08 | 3.06E+002 |
| 3 | 69- | 78 | 72.22 | 35.77 | 1.05 | 2.43E+001 | 24.85 | 2.64E+002 |
| 4 | 89- | 97 | 93.00 | 46.16 | 0.52 | 2.20E+001 | 14.60 | 9.00E+001 |
| 5 | 178- | 192 | 185.62 | 92.46 | 1.15 | 1.50E+002 | 26.15 | 1.86E+002 |
| 6 | 1317- | 1331 | 1324.16 | 661.66 | 1.69 | 1.81E+003 | 43.02 | 1.31E+001 |
| 7 | 2919- | 2926 | 2923.03 | 1460.99 | 1.31 | 1.00E+001 | 4.47 | 5.00E+000 |

M = First peak in a multiplet region
 m = Other peak in a multiplet region
 F = Fitted singlet

Errors quoted at 1.000 sigma

Interference Corrected Activity Report 4/19/2005 5:48:53 PM Page 4

Sample Title: Wipes
 Nuclide Library Used: C:\GENIE2K\CAMFILES\SURFH20.NLB

..... IDENTIFIED NUCLIDES

| Nuclide Name | Id Confidence | Energy (keV) | Yield (%) | Activity (uCi/WIPE) | Activity Uncertainty |
|--------------|---------------|--------------|-----------|---------------------|----------------------|
| K-40 | 0.997 | 1460.81* | 10.67 | 1.64921E-005 | 7.38355E-006 |
| CS-137 | 1.000 | 661.65* | 85.12 | 1.56407E-004 | 5.00501E-006 |
| PB-210 | 0.988 | 46.50* | 4.00 | 6.88734E-006 | 4.57634E-006 |

* = Energy line found in the spectrum.
 @ = Energy line not used for Weighted Mean Activity
 Energy Tolerance : 1.250 keV
 Nuclide confidence index threshold = 0.30
 Errors quoted at 1.000 sigma

Gamma Analysis Report S4 (cont'd)

Interference Corrected Activity Report 4/19/2005 5:48:53 PM Page 5

| Nuclide Name | Nuclide Id Confidence | Wt mean Activity (uCi/WIPE) | Wt mean Activity Uncertainty |
|--------------|--------------------------|--------------------------------|---------------------------------|
| K-40 | 0.997 | 1.649214E-005 | 7.383555E-006 |
| CS-137 | 1.000 | 1.564067E-004 | 5.005005E-006 |
| PB-210 | 0.988 | 6.887340E-006 | 4.576336E-006 |

? = nuclide is part of an undetermined solution
 X = nuclide rejected by the interference analysis
 @ = nuclide contains energy lines not used in Weighted Mean Activity

Errors quoted at 1.000 sigma

***** U N I D E N T I F I E D P E A K S *****

Peak Locate Performed on: 4/19/2005 5:48:53 PM
 Peak Locate From Channel: 1
 Peak Locate To Channel: 4096

| Peak No. | Energy (keV) | Peak Size in Counts per Second | Peak CPS % Uncertainty |
|----------|--------------|--------------------------------|------------------------|
| 1 | 2.17 | 1.3068E-001 | 6.58 |
| 2 | 31.55 | 2.5417E-001 | 6.08 |
| 3 | 35.77 | 1.0104E-002 | 102.49 |
| 5 | 92.46 | 6.2656E-002 | 17.39 |

M = First peak in a multiplet region
 m = Other peak in a multiplet region
 F = Fitted singlet

Errors quoted at 1.000 sigma

Gamma Analysis Report W1

***** G A M M A S P E C T R U M A N A L Y S I S *****

Filename: C:\PCNT2K\CAMFILES\100CCCUP\CUP00497.CNF

Report Generated On : 4/20/2005 6:05:58 PM

Sample Title : 100CC CUP
Sample Description :
Sample Identification : SAVANNAH SG H2O
Sample Type : CUP
Sample Geometry : 100CC CUP

Peak Locate Threshold : 2.75
Peak Locate Range (in channels) : 1 - 4096
Peak Area Range (in channels) : 1 - 4096
Identification Energy Tolerance : 1.250 keV

Sample Size : 1.000E+002 ml

Sample Taken On : 4/20/2005 5:35:49 PM
Acquisition Started : 4/20/2005 5:35:49 PM

Live Time : 1800.0 seconds
Real Time : 1807.9 seconds

Dead Time : 0.44 %

Energy Calibration Used Done On : 4/7/2005
Efficiency Calibration Used Done On : 11/19/2004
Efficiency ID : 100CC CUP

Peak Locate Analysis Report 4/20/2005 6:05:58 PM Page 2

Detector Name: DET01
Sample Title: 100CC CUP
Peak Locate Performed on: 4/20/2005 6:05:58 PM
Peak Locate From Channel: 1
Peak Locate To Channel: 4096
Peak Search Sensitivity: 2.75

| Peak No. | Centroid Channel | Centroid Uncertainty | Energy (keV) | Peak Significance |
|----------|------------------|----------------------|--------------|-------------------|
| 1 | 5.00 | 0.4187 | 2.17 | 5.71 |
| 2 | 43.70 | 0.4505 | 21.51 | 3.43 |
| 3 | 63.68 | 0.1387 | 31.50 | 35.54 |
| 4 | 72.35 | 0.2079 | 35.84 | 14.96 |
| 5 | 1126.95 | 0.4654 | 563.06 | 2.92 |
| 6 | 1323.99 | 0.0573 | 661.58 | 137.19 |
| 7 | 2346.62 | 0.2979 | 1172.82 | 4.03 |
| 8 | 2665.35 | 0.3252 | 1332.16 | 3.86 |

? = Adjacent peak noted
Errors quoted at 1.000 sigma

Appendix 2
Sample Analysis Data

JLAB-TN-05-048

Gamma Analysis Report W1 (cont'd)

Peak Analysis Report 4/20/2005 6:05:58 PM Page 3

Detector Name: DET01
 Sample Title: 100CC CUP
 Peak Analysis Performed on: 4/20/2005 6:05:58 PM
 Peak Analysis From Channel: 1
 Peak Analysis To Channel: 4095

| Peak No. | ROI start | ROI end | Peak centroid | Energy (keV) | FWHM (keV) | Net Peak Area | Net Area Uncert. | Continuum Counts |
|----------|-----------|---------|---------------|--------------|------------|---------------|------------------|------------------|
| 1 | 37- | 46 | 43.70 | 21.51 | 1.30 | 4.23E+002 | 76.81 | 2.43E+003 |
| 2 | 57- | 67 | 63.68 | 31.50 | 1.11 | 1.71E+004 | 170.18 | 4.98E+003 |
| 3 | 1123- | 1130 | 1126.95 | 563.06 | 0.95 | 3.70E+001 | 26.59 | 3.35E+002 |
| 4 | 1316- | 1334 | 1323.99 | 661.58 | 1.44 | 5.92E+004 | 245.61 | 3.30E+002 |
| 5 | 2342- | 2353 | 2346.62 | 1172.82 | 1.00 | 6.20E+001 | 8.34 | 3.00E+000 |
| 6 | 2659- | 2670 | 2665.35 | 1332.16 | 1.55 | 4.70E+001 | 7.87 | 6.00E+000 |

M = First peak in a multiplet region
 m = Other peak in a multiplet region
 F = Fitted singlet

Errors quoted at 1.000 sigma

Interference Corrected Activity Report 4/20/2005 6:05:58 PM Page 4

Sample Title: 100CC CUP
 Nuclide Library Used: C:\GENIE2K\CAMFILES\SURFH20.NLB

..... IDENTIFIED NUCLIDES

| Nuclide Name | Id Confidence | Energy (keV) | Yield (%) | Activity (uCi/ml) | Activity Uncertainty |
|--------------|---------------|--------------|-----------|--------------------|----------------------|
| CO-60 | 0.987 | 1173.22* | 100.00 | 1.56294E-006 | 2.11861E-007 |
| | | 1332.49* | 100.00 | 1.32373E-006 | 2.22996E-007 |
| CS-137 | 0.999 | 661.65* | 85.12 | 1.04206E-003 | 2.01192E-005 |

* = Energy line found in the spectrum.
 @ = Energy line not used for Weighted Mean Activity
 Energy Tolerance : 1.250 keV
 Nuclide confidence index threshold = 0.30
 Errors quoted at 1.000 sigma

Gamma Analysis Report W1 (cont'd)

Interference Corrected Activity Report 4/20/2005 6:05:58 PM Page 5

| Nuclide Name | Nuclide Id Confidence | Wt mean Activity (uCi/ml) | Wt mean Activity Uncertainty |
|--------------|--------------------------|-------------------------------|---------------------------------|
| CO-60 | 0.987 | 1.449456E-006 | 1.535940E-007 |
| CS-137 | 0.999 | 1.042058E-003 | 2.011923E-005 |

? = nuclide is part of an undetermined solution
X = nuclide rejected by the interference analysis
@ = nuclide contains energy lines not used in Weighted Mean Activity

Errors quoted at 1.000 sigma

***** U N I D E N T I F I E D P E A K S *****

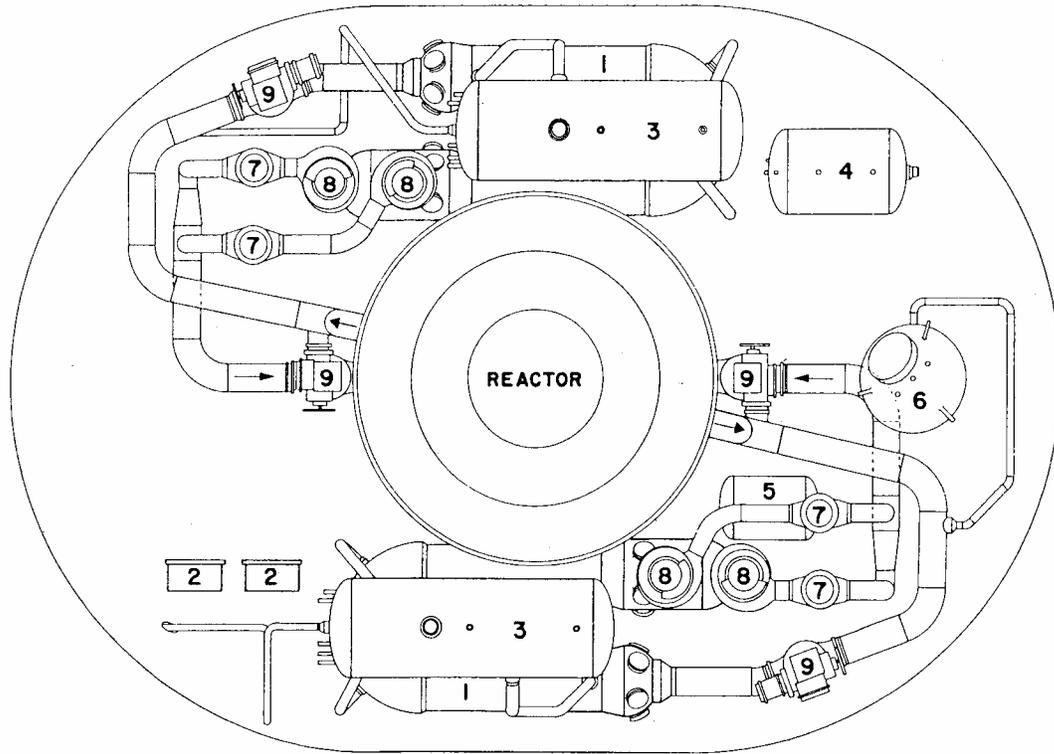
Peak Locate Performed on: 4/20/2005 6:05:58 PM
Peak Locate From Channel: 1
Peak Locate To Channel: 4096

| Peak No. | Energy (keV) | Peak Size in Counts per Second | Peak CPS % Uncertainty |
|----------|--------------|-----------------------------------|---------------------------|
| 1 | 21.51 | 2.3514E-001 | 18.15 |
| 2 | 31.50 | 9.5137E+000 | 0.99 |
| 3 | 563.06 | 2.0556E-002 | 71.86 |

M = First peak in a multiplet region
m = Other peak in a multiplet region
F = Fitted singlet

Errors quoted at 1.000 sigma

Appendix 3
Plan Layout of Reactor Containment



- | | |
|--------------------|--------------------|
| ① HEAT EXCHANGER | ② LET DOWN COOLERS |
| ③ STEAM DRUM | ④ CONDENSING TANK |
| ⑤ CONT. DRAIN TANK | ⑥ PRESSURIZER |
| ⑦ CHECK VALVE | ⑧ PUMP |
| ⑨ GATE VALVE | |

Nuclear Ship SAVANNAH Reactor Vessel, Internals and Neutron Shield Tank Characterization and Classification Assessment

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EXECUTIVE SUMMARY

The objective of this assessment is the analytical determination of nuclide activation levels in the NS SAVANNAH (NSS) reactor pressure vessel (RPV), reactor internals and neutron shield tank. This effort involved a dual approach – manual calculations using a simplified reactor model for isotopic irradiation/decay, and a detailed irradiation analysis using the ORIGEN-ARP 2.00 computer code. Oak Ridge National Laboratory developed the code for the Nuclear Regulatory Commission and Department of Energy to satisfy a need for an “easy-to-use” standardized method of isotope activation and depletion/decay analysis for radioactive material.

Currently, the principal isotopes contributing to activity levels include Fe-55, Co-60, Ni-63, Nb-94, C-14 and Ni-59. Other activation products present at shutdown (1970) either have half-lives less than a year and have now decayed to insignificant Curie levels, or are present in insignificant quantities resulting in negligible contributions to the current Curie inventory. The decay time used for this evaluation is 37 years, which assumes that the RPV, reactor internals and neutron shield tank would be packaged and shipped in November 2007. This assumption provides additional conservatism to this assessment since the more realistic timetable for the packaging and shipment of the RPV, reactor internals and subcomponents is 2008 or 2009.

Activity levels were determined analytically and then averaged over the waste volume in the RPV, reactor internals and neutron shield tank to obtain Curie concentrations for each nuclide in accordance with calculation techniques acceptable to Barnwell and in accordance with 10 CFR Part 61. The averaged Curie concentration levels of each nuclide were compared with Barnwell's waste acceptance criteria per Exhibit ES-1.

Exhibit ES-1 Barnwell Waste Acceptance Classification Determination for the RPV

| Radionuclide | NSS Total Curies (November 2007) in RPV, and internals (Curies) | NSS Concentration in RPV, and internals (Curies/m ³) | | Barnwell Waste Acceptance Criteria | NSS Concentration Relative to the Waste Acceptance Classification Limit |
|---------------------------------------|---|--|--------|------------------------------------|---|
| | Concentration (Curies/m ³) | | | Classification | |
| Fe-55 | 17.8 | 1.39 | < 700 | A | 0.002 |
| Co-60 | 1108 | 86.74 | < 700 | A | 0.124 |
| Ni-59 | 30.6 | 2.40 | < 22 | A | 0.109 |
| C-14 in metal | 7.32 | 0.57 | < 8 | A | 0.072 |
| Nb-94 | 0.100 | 0.0078 | < 0.02 | A | 0.391 |
| Sum of the Fractions – Class A Waste: | | | | 0.698 | |
| Ni-63 in metal | 2902 | 227.2 | < 700 | B | 0.324 |

Based on these analyses, it is concluded that the NSS RPV, reactor internals and neutron shield tank can be transported to Barnwell for ultimate disposal without removal of any components. The highest waste classification for the NSS RPV, internals and neutron shield tank is Class B due to Ni-63.

1.0 BACKGROUND

One approach for disposal of the NS SAVANNAH (NSS) reactor pressure vessel (RPV), reactor internals and neutron shield tank is to sever all piping connections, seal all openings/accesses, package for transportation and ship the RPV, reactor internals and applicable portions of the neutron shield tank intact to Barnwell. At present, Barnwell can accept Class A, B and C waste.

2.0 ASSESSMENT DESCRIPTION

Determine the current activation levels of residual nuclides in the NSS RPV, reactor internals and neutron shield tank. This assessment ensures that the proper Curie inventory is used in determining the optimum disposal methods and packaging (if required), and that class A, B and C waste will be packaged in accordance with the proper Waste Acceptance Criteria (WAC) for the selected disposal site.

3.0 TECHNICAL APPROACH

A dual approach was used in determining the Curie content of the NSS RPV, reactor internals and applicable portions of the neutron shield tank. The ORIGEN-ARP 2.00 computer code, developed by Oak Ridge National Laboratory, was used for detailed analysis. A simplified model suitable for manual calculations was developed to benchmark the problem and validate the ORIGEN-ARP code.

The decay time assumed for this evaluation is 37 years based on a November 2007 packaging/shipping date. Based on this decay time, any radionuclide with a half-life of less than 1 year is not considered in the evaluation due to the minimal amounts remaining in the RPV, reactor internals and neutron shield tank. Additionally, the NSS power history from 1962 through 1970 was modeled in ORIGEN-ARP.

3.1 Manual Calculation Model

A simplified homogeneous reactor was used to approximate the core and internals of the RPV. The core and major internals were modeled as a homogeneous composition in cylindrical geometry with a single group of neutrons at core average thermal energy. Average thermal neutron fluxes within the active core volume and external to it were determined from axial and radial neutron flux curves provided in the Primary Shield Report (Reference 1). An incident thermal neutron flux was assigned to the RPV and each internal/component. Atomic densities of target isotopes (precursors) and thermal neutron cross sections at core average temperature were calculated. Material composition data for stainless steel and carbon steel are shown in Table 1. The data for Table 1 was obtained from Reference 2.

Currently, the principal isotopes contributing to activity levels include Fe-55, Co-60, Ni-63, Nb-94, C-14 and Ni-59. Other activation products present at shutdown (1970) either have half-lives less than a year and have now decayed to insignificant Curie levels, or are present in insignificant quantities resulting in negligible contributions to the current Curie inventory.

With only 2.423 effective full power years of irradiation time, none of the nuclides of interest reached saturation (highest activity that can be produced in a target with a given neutron flux, i.e., rate of production equals rate of decay). Fe-55, with the shortest half-life of the nuclides analyzed, reached 46% of saturation; Co-60 reached 27%. Ni-59, with a half-life of 7.5×10^4 years attained less than 0.003% of saturation while Ni-63 reach 1.7% (See Table 2).

For the nuclides of interest, the production rate was calculated based on atomic density of target atoms, absorption cross-sections and core average thermal neutron flux. The reactor operated from 1962 to 1970 at an average plant thermal power of 30% resulting in 2.423 effective full power years of irradiation (Reference 6).

Isotopic production rates and decay rates were inserted into the standard activity equation (Table 2) to obtain activity levels projected to November 2007. The activity levels calculated manually are presented in Table 3.

3.2 ORIGEN-ARP Code

ORIGEN-ARP (automatic rapid processing) performs isotopic activation and depletion/decay calculations for light water reactors. Oak Ridge National Laboratory developed ORIGEN-ARP (and its predecessors) for the Nuclear Regulatory Commission and the Department of Energy to satisfy the need for a standardized method of isotope depletion/decay analysis of spent fuel, fissile material and radioactive material. It can be used for spent fuel characterization, isotopic inventory, radiation source terms and decay heat. The code automatically interpolates cross sections for depletion/decay analysis using enrichments (1.5 to 5wt% U-235) and burnups (0 to 60,000 MWD/MTU) generated from a set of libraries for light water reactor designs. Interpolated cross sections from ARP are passed to ORIGEN-S to perform the depletion/decay calculations.

The ORIGEN-ARP sequence includes the post-processing module OPUS to generate ASCII plot data files and the PlotOPUS Windows graphical user interface to plot the data. The ORIGEN-ARP 2.00 computer code includes the use of a streamlined version of the SAS2H sequence of the SCALE code system that has been used worldwide for treating problems related to the characterization of spent nuclear fuel from light-water reactors and other types of reactors for disposal, storage and shipment.

ORIGEN-ARP develops its own neutron flux curves based on input data (initial enrichment, burnup and average power days per fuel cycle) and fuel type. ORIGEN-ARP produces problem-dependent ORIGEN-S cross-section libraries by reading a set of standard libraries for a fuel assembly type and interpolating on enrichment and burnup. The standard PWR fuel assembly in the ORIGEN-ARP library is an 14 x 14 array. An NSS fuel element was composed of four subassemblies, which were six-by-seven arrays of fuel rods in a square matrix (164 fuel rods per element – effectively a 12 x 14 fuel assembly). The effect of using an 14 x 14 library is minimal for this evaluation. In addition and as stated later in Section 4.0, the average thermal neutron flux calculated and used by ORIGEN-ARP yielded almost identical results when compared with the thermal neutron fluxes calculated during the NSS initial design efforts by Babcock & Wilcox.

ORIGEN-ARP used 27 groups of neutrons and spectrum-weighted cross sections in calculating activity levels of the RPV, reactor internals and neutron shield tank at 37 years (November 2007) after the shutdown of NSS. The ORIGEN-ARP results are presented in Table 4.

To determine the material activation outside the active core region, the volumes (or weights) of natural elements were reduced by the ratio of incident flux to core average thermal flux. This is appropriate since activation is directly proportional to quantity of material and neutron flux (Table 5).

3.3 Surface Coating Analysis

The exposure of the RPV and reactor internals to reactor coolant may result in surface coatings of trace transuranics and fission product radionuclides such as Sr-90 and Cs-137. The presence of these radionuclides can have a significant effect on the classification of irradiated hardware, especially if failed fuel occurred in the reactor core.

The failure-free performance of the NSS fuel precluded the deposition of fission products (e.g., Sr-90 and Cs-137), uranium and transuranic isotopes in the reactor vessel, internals, primary piping, heat exchanger and pressurizer. The crud content is essentially all Co-60. Measurements taken at the primary inlet piping in 1971 found the crud activity to be 1.485 millicuries per square foot. Assuming the crud to be equally distributed over the total surface area of the primary system results in an activity level in November 2007 of less than 0.3 Curies of Co-60.

4.0 VERIFICATION OF ORIGEN-ARP

Manual calculations provided upper bound activity levels for the RPV, internals and subcomponents. ORIGEN-ARP 2.00 was expected to compute lower though more accurate activation levels.

Activity levels computed by ORIGEN-ARP were about 50% lower than those calculated manually. Much of this difference is attributable to the difference in thermal neutron flux values. The average thermal neutron flux used in the manual calculations was 1.45×10^{13} neutrons/cm²-sec as provided in the NMSR Primary Shield Report (Reference 1). Thermal neutron fluxes calculated by ORIGEN-ARP ranged from 0.91×10^{13} neutrons/cm²-sec. This difference in neutron fluxes contributes about 37% to the difference between the manual calculation and the ORIGEN-ARP results.

Another factor contributing to the difference in estimates is the calculation of effective thermal cross sections by scaling room temperature (0.0253eV) cross sections to core average temperature cross sections. This methodology assumes a well-moderated medium where neutrons follow a Maxwellian energy distribution. In fact, the low moderator density in the core region of the pressurized water reactor results in a harder (less thermalized) neutron energy spectrum, and consequently lower effective cross sections than calculated by hand.

In the case of Nb-94, ORIGEN-ARP yielded a higher Curie content than manual calculations due to the large resonance capture cross-sections at epithermal energy levels. This complex phenomenon is not easily accounted for in manual calculations.

The high thermal neutron flux coupled with large thermal cross sections will over-predict activation of internals and components, particularly in the active core volume. For components further from the fuel, the flux will likely be more thermalized and yield more activation per unit of thermal flux. However, flux levels (and therefore activation rates) decrease rapidly outside the active fuel region.

In addition to the comparison between the manual calculation and the ORIGEN-ARP results, the ORIGEN-ARP code was also verified or benchmarked against a PWR test case provided by the Oak Ridge National Laboratory. The results from both comparisons verified that the ORIGEN-ARP computer code was installed and functioning properly.

5.0 COMPARISON WITH BARNWELL WASTE ACCEPTANCE CRITERIA

Activity levels (Curies) for each nuclide were averaged over the waste volume that included the RPV wall, reactor internals and neutron shield tank. The volume was estimated to be 12.774 cubic meters (Table 6). This approach is in accordance with calculation techniques specified by Barnwell (Reference 7) and 10 CFR Part 61 (Reference 8).

As identified earlier in this report, the decay time assumed for this evaluation is 37 years. Based on this decay time, any radionuclide with a half-life of less than 1 year is not considered in the evaluation due to the minimal amounts remaining in the RPV, reactor internals and neutron shield tank.

The averaged Curie concentration levels of each nuclide were compared with Barnwell's Waste Acceptance Criteria (WAC) limits for Class A, B and C waste (Table 7).

6.0 CONCLUSIONS

Based on these analyses, it is concluded that the NSS RPV, reactor internals and neutron shield tank can be transported intact to Barnwell for ultimate disposal without accessing the vessel interior for activity assessments and/or removal of high Curie content components.

As the calculations have demonstrated, the highest waste classification for the NSS RPV, reactor internals and neutron shield tank is Class B due to Ni-63.

TABLE 1 MATERIAL COMPOSITION (WEIGHT %)

| Material Element | 304 Stainless Steel* | Carbon Steel* |
|---------------------|----------------------|---------------|
| Nitrogen | 0.045 | 0.008 |
| Chromium | 18.400 | 0.000 |
| Manganese | 1.530 | 1.350 |
| Iron | 70.600 | 97.570 |
| Nickel | 10.000 | 0.610 |
| Molybdenum | 0.260 | 0.580 |
| Niobium | 0.009 | 0.002 |
| Cobalt | 0.141 | 0.012 |

* - Data taken from NUREG/CR-3474 (Reference 2)

TABLE 2 MANUAL CALCULATION DATA AS OF NOVEMBER 2007

| Isotope Activity $\bar{N}\sigma\phi(1 - e^{-\lambda t_i}) e^{-\lambda t_d}$ (dis/sec-cm ³) | Half-Life (years) | N (atoms/cc) | σ 1×10^{-24} cm ² (temperature corrected) | $(1 - e^{-\lambda t_i})$ | $e^{-\lambda t_d}$ |
|--|---------------------------|----------------------------|--|--------------------------|-------------------------|
| Fe-55 2.6 x 10 ⁶ (304 SS) | 2.7 | 3.48 x 10 ²¹ | 1.5 | 0.46 | 7.42 x 10 ⁻⁵ |
| Co-60 8.4 x 10 ⁷ (304 SS) | 5.27 | 1.14 x 10 ²⁰ | 24.4 | 0.27 | 7.71 x 10 ⁻³ |
| Ni-59 5.3 x 10 ⁶ (304 SS) | 7.5 x 10 ⁴ | 5.50 x 10 ²¹ | 3.0 | 2.2 x 10 ⁻⁵ | 1 |
| Ni-63 5.2 x 10 ⁸ (304 SS) | 100.1 | 2.97 x 10 ²⁰ | 9.3 | 0.017 | 0.77 |
| Nb-94 4.2 x 10 ³ (304 SS) | 2 x 10 ⁴ | 4.56 x 10 ¹⁸ | 0.75 | 8.4 x 10 ⁻⁵ | 1 |
| C-14 9.2 x 10 ⁵ (304 SS) | 5.73 x 10 ³ | 1.52 x 10 ²⁰ | 1.2 | 2.9 x 10 ⁻⁴ | 1 |

ϕ = flux = 1.45×10^{13} neutrons/ cm²-sec

t_i = $t_{(\text{irradiation})}$ = 2.423 years

t_d = $t_{(\text{decay})}$ = 37 years

TABLE 3 MANUAL CALCULATION RESULTS AS OF NOVEMBER 2007

| Reactor Components | Activity in Curies | | | | | | Totals |
|--|--------------------|--------|-------|--------|-------|-----------|--------|
| | Fe-55 | Co-60 | Ni-59 | Ni-63 | Nb-94 | C-14 | |
| Core Basket | 13.1 | 422 | 26.6 | 2641 | 0.021 | 4.6 | 3107.3 |
| Core Barrel | 4.7 | 153 | 9.6 | 954 | 0.008 | 1.7 | 1123 |
| Upper Transition Nozzles (32) | 6.6 | 213 | 13.4 | 1335 | 0.011 | 2.3 | 1570.3 |
| Lower Transition Nozzles (32) | 6.6 | 213 | 13.4 | 1335 | 0.011 | 2.3 | 1570.3 |
| Control Rods (22) | 0.2 | 6.3 | 0.4 | 39 | ** | 0.07 | 159.9 |
| Inner Thermal Shield | 0.6 | 21.0 | 1.3 | 131 | 0.001 | 0.20 | 154.1 |
| Outer Thermal Shield | 0.2 | 5.0 | 0.3 | 31.2 | ** | 0.05 | 36.7 |
| Lower Grid Plate and Flow Baffle Plate | 0.1 | 4.3 | 0.3 | 26.8 | ** | 0.05 | 31.5 |
| Upper Grid Plate (Bottom Plate) | * | 1.7 | 0.1 | 10.4 | ** | 0.02 | 12.2 |
| Upper Grid Plate Shrouds | 0.2 | 8.0 | 0.5 | 49.7 | ** | 0.09 | 58.5 |
| Lower Flow Baffle Shrouds | * | 0.2 | * | 1.1 | ** | 0.00 2 | 1.3 |
| Upper Flow Baffle Shrouds | * | * | * | 0.1 | ** | ** | 0.1 |
| Upper Flow Baffle Shrouds | * | * | * | * | * | ** | ** |
| Pressure Vessel (Middle Cylinder) | * | 0.4 | * | 2.4 | ** | ** | 2.8 |
| Neutron Shield Tank Inner Wall | * | * | * | 0.2 | ** | ** | 0.2 |
| Totals: | 32.3 | 1047.9 | 65.9 | 6556.9 | 0.052 | 11.3 8 | 7828 |

(*) – less than 0.1 Curies; (**) – less than 0.001 Curies

TABLE 4 ORIGEN-ARP RESULTS AS OF NOVEMBER 2007

| Reactor Components | Activity in Curies | | | | | | Totals |
|--|--------------------|-------|-------|-------|-------|-------|--------|
| | Fe-55 | Co-60 | Ni-59 | Ni-63 | Nb-94 | C-14 | |
| Core Basket | 6.9 | 446 | 12.3 | 1174 | 0.041 | 2.95 | 1642 |
| Core Barrel | 2.5 | 161 | 4.5 | 426 | 0.015 | 1.07 | 595 |
| Upper Transition Nozzles (32) | 3.5 | 226 | 6.2 | 594 | 0.021 | 1.49 | 831 |
| Lower Transition Nozzles (32) | 3.5 | 226 | 6.2 | 594 | 0.021 | 1.49 | 831 |
| Control Rods (22) | 0.1 | 6.6 | 0.2 | 1.7 | ** | 0.04 | 9 |
| Inner Thermal Shield | 0.3 | 22.2 | 0.6 | 58.6 | 0.002 | 0.15 | 82 |
| Outer Thermal Shield | 0.8 | 5.2 | 0.1 | 13.9 | ** | 0.03 | 20 |
| Lower Grid Plate and Flow Baffle Plate | * | 4.6 | 0.1 | 12.0 | ** | 0.03 | 17 |
| Upper Grid Plate (Bottom Plate) | * | 1.8 | * | 4.6 | ** | 0.01 | 6 |
| Upper Grid Plate Shrouds | 0.2 | 8.4 | 0.2 | 22.1 | ** | 0.06 | 31 |
| Lower Flow Baffle Shrouds | * | 0.2 | * | 0.5 | ** | 0.001 | 0.7 |
| Upper Flow Baffle Shrouds | * | * | * | * | ** | ** | - |
| Upper Flow Baffle Shrouds | * | * | * | * | ** | ** | - |
| Pressure Vessel (Middle Cylinder) | * | 0.4 | * | 1.0 | ** | 0.003 | 1.4 |
| Neutron Shield Tank Inner Wall | * | * | * | * | ** | ** | - |
| Totals: | 17.8 | 1108 | 30.6 | 2902 | 0.100 | 7.32 | 4066 |

(*) – less than 0.1 Curies; (**) – less than 0.001 Curies

TABLE 5 NSS VOLUME AND FLUX ESTIMATES FOR ACTIVATION

| Reactor Component | Activated Material Volume (cm ³) | Applicable neutron flux (n/cm ² -sec) |
|--|--|--|
| Core Basket | 1.86 x 10 ⁵ | 1.45 x 10 ¹³ |
| Core Barrel | 6.72 x 10 ⁴ | 2.90 x 10 ¹² |
| Upper Transition Nozzles (32) | 9.40 x 10 ⁴ | 1.45 x 10 ¹³ |
| Lower Transition Nozzles (32) | 9.40 x 10 ⁴ | 1.45 x 10 ¹³ |
| Control Rods (22) | 2.76 x 10 ³ | 5.00 x 10 ¹² |
| Inner Thermal Shield | 9.24 x 10 ³ | 1.45 x 10 ¹¹ |
| Outer Thermal Shield | 2.20 x 10 ³ | 7.25 x 10 ¹⁰ |
| Lower Grid Plate and Flow Baffle Plate | 1.89 x 10 ³ | 1.45 x 10 ¹¹ |
| Upper Grid Plate (Bottom Plate) | 7.30 x 10 ² | 1.45 x 10 ¹¹ |
| Upper Grid Plate Shrouds | 3.50 x 10 ³ | 2.90 x 10 ¹¹ |
| Lower Flow Baffle Shrouds | 74.5 | 7.25 x 10 ⁹ |
| Upper Flow Baffle Shrouds | 10.6 | 7.25 x 10 ⁹ |
| Upper Flow Baffle Shrouds | 4.9 | 2.9 x 10 ⁸ |
| Pressure Vessel (Middle Cylinder) | 1.67 x 10 ² | 7.25 x 10 ⁸ |
| Neutron Shield Tank Inner Wall | 14.3 | 7.25 x 10 ⁸ |

Volumes of RPV, internals and subcomponents were reduced by the ratio of incident flux to core average thermal flux to calculate irradiated quantities.

TABLE 6 NSS VOLUME ESTIMATES FOR AVERAGING WASTE

| Component Description | Volume (m ³) |
|--|--------------------------|
| Core Basket | 0.186 |
| Core Barrel | 0.336 |
| Upper Transition Nozzles (32) | 0.094 |
| Lower Transition Nozzles (32) | 0.094 |
| Control Rods (22) | 0.008 |
| Inner Thermal Shield | 0.924 |
| Outer Thermal Shield | 0.439 |
| Lower Grid Plate and Flow Baffle Plate | 0.189 |
| Upper Grid Plate (Bottom Plate) | 0.073 |
| Upper Grid Plate Shrouds | 0.175 |
| Lower Flow Baffle Shrouds | 0.149 |
| Upper Flow Baffle Shrouds | 0.212 |
| Upper Flow Baffle Shrouds | 0.245 |
| Pressure Vessel (Middle Cylinder) | 3.349 |
| Neutron Shield Tank Inner Wall | 0.286 |
| Vessel Head and Lower Flange | 6.015 |
| Total: | 12.774 |

TABLE 7 BARNWELL WASTE CLASSIFICATION DETERMINATION

| Radionuclide | NSS Total Curies (November 2007) in RPV, and internals (Curies) | NSS Concentration in RPV, and internals (Curies/m ³) | | Barnwell Waste Acceptance Criteria | NSS Concentration Relative to the Waste Acceptance Classification Limit |
|---------------------------------------|---|--|--------|------------------------------------|---|
| | Concentration (Curies/m ³) | | | Classification | |
| Fe-55 | 17.8 | 1.39 | < 700 | A | 0.002 |
| Co-60 | 1108 | 86.74 | < 700 | A | 0.124 |
| Ni-59 | 30.6 | 2.40 | < 22 | A | 0.109 |
| C-14 in metal | 7.32 | 0.57 | < 8 | A | 0.072 |
| Nb-94 | 0.100 | 0.0078 | < 0.02 | A | 0.391 |
| Sum of the Fractions – Class A Waste: | | | | 0.698 | |
| Ni-63 in metal | 2902 | 227.2 | < 700 | B | 0.324 |

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