BALL STATE UNIVERSITY

COLLEGE OF SCIENCES AND HUMANITIES
DEPARTMENT OF PHYSICS AND ASTRONOMY

Muncie, Indiana 47306-0505
Phone: 765-285-8860

MEMO

To: Bryan A. Parker
NRC, Region III Office
Lisle, IL 60532-4351

From: Mohammed S. Islam
RSO, Ball State University
Muncie, IN 47306

Date: 1/28/2013

Re: Ball State University's License Renewal Application (control number 578078)

This Memo is in response to questions arising during your review of Ball State University's NRC license renewal application, and our conversation over the telephone as well as email exchanges on 1/24/13. Our current license number is 13-06231-01.

**1) Materials listing (Page 1 of application)**

The table containing the list of isotopes has been modified to reflect our current use and inventory. This new table will replace one which was part of our original license application. The modified table is attached.

**2) The RSO Delegation of Authority**

A signed version of the RSO Delegation of Authority (page D-1) is attached and should replace the one without signature which was submitted with the original application.

**3) Neutron Generator Decommissioning Report**

A full version of the Neutron Generator Facility Decommissioning report is attached. Pages J-3 to J-29 of Appendix-J of our original application will be replaced by the content of this file.

I appreciate you assistance in the review of our renewal application. If you have additional questions, my phone number is (765) 285-8066 and e-mail is mislam@bsu.edu.

5. Radioactive Materials

| Byproduct, source, and/or special nuclear material | Chemical and/or physical form | Maximum amount that licensee may possess at any one time under this license | Proposed Use |
|---|---|---|---|
| Any byproduct material with atomic numbers 1 through 83 with half-lives less than 120 days | Any | 10 millicuries per radionuclide and 500 millicuries total | In vitro studies |
| C-14 | Any | 25 mCi | In vitro studies |
| H-3 | Any | 100 mCi | In vitro studies |
| Ca-45 | Any | 2 mCi | In vitro studies |
| I-125 | Bound/non-volatile | 2 mCi | RIA/In vitro studies |

BALL STATE UNIVERSITY

ACADEMIC AFFAIRS
ASSOCIATE PROVOST FOR RESEARCH
AND DEAN OF THE GRADUATE SCHOOL

Muncie, Indiana 47306-0155
Phone: 765-285-5002-1300
Fax: 765-285-1624-1328

MEMO

To: All Ball State University Employees

From: Robert J. Morris
Associate Provost for Research and Dean of the Graduate School

Subject: Delegation of Authority for Radiation Safety Officer

Mohammed Islam has been appointed Radiation Safety Officer and is responsible for ensuring the safe use of byproduct material. The Radiation Safety Officer is responsible for managing the radiation safety program; identifying radiation safety problems; initiating, recommending, or providing corrective actions; verifying implementation of corrective actions; and ensuring compliance with regulations for the use of byproduct material. The Radiation Safety Officer is hereby delegated the authority necessary to meet these responsibilities.

The Radiation Safety Officer has the authority to immediately stop any operations involving the use of byproduct material in which health and safety may be compromised or may result in non-compliance with Nuclear Regulatory Commission requirements.

I accept this appointment to be Radiation Safety Officer at Ball State University.

Islam

# Neutron Generator Facility Decommissioning Report

## Ball State University
2201 Riverside Ave.
Muncie, IN

Work Performed Under
Ball State University
US Nuclear Regulatory Commission
Radioactive Materials License No. 13-06231-01

February 2010

Prepared by:
Chase Environmental Group, Inc.
109 Flint Road
Oak Ridge, TN 37830
865-207-3664

CHASE
Environmental Group INC.

# Neutron Generator Facility Decommissioning Report

## Ball State University
## 2201 Riverside Ave.
## Muncie, IN 47303

## U.S. Nuclear Regulatory Commission Radioactive Materials License Number 13-06231-01

## 2/10/2010

Prepared: _____ Project Manager Date: 2/10/2010
Ken Gavlik

Approved: _____ Radiological Engineer Date: 2/10/2010
Dave Culp

**Prepared by:**
**Chase Environmental Group, Inc.**
**109 Flint Road**
**Oak Ridge, TN 37830**
**865-481-8801**

## TABLE OF CONTENTS

**1.0 EXECUTIVE SUMMARY** ..... 1
**2.0 FACILITY DESCRIPTION** ..... 1
**3.0 SITE HISTORY** ..... 1
3.1 Historical Operations ..... 1
3.2 Potential Contaminants ..... 1
3.3 License ..... 1
**4.0 RELEASE CRITERIA** ..... 2
**5.0 DERIVED CONCENTRATION GUIDELINE LEVELS (DCGL)** ..... 2
5.1 Volumetric DCGLs ..... 2
5.2 Summary of DCGLs ..... 2
**6.0 SURVEY INSTRUMENTATION** ..... 2
6.1 Functional Checks ..... 2
6.2 Instrumentation Used ..... 3
6.3 Determination of Counting Times and Minimum Detectable Concentrations ..... 4
6.3.1 Static Counting ..... 4
6.3.2 Surface Ratemeter Scanning ..... 4
6.3.3 Smear Counting ..... 5
6.3.4 Determination of Uncertainty ..... 5
**7.0 REMOVAL ACTIVITIES** ..... 5
7.1 Accelerator Equipment Removal ..... 5
**8.0 RADIOACTIVE MATERIALS MANAGEMENT** ..... 5
**9.0 SURVEYS** ..... 6
9.1 Data Quality Objectives ..... 6
9.2 Area Classifications ..... 6
9.2.1 Non-Impacted Area ..... 6
9.2.2 Impacted Areas ..... 7
9.3 Survey Units ..... 7
9.4 Surface Scans ..... 7
9.5 Total Surface Activity Measurements ..... 7
9.6 Dose Rate Measurements ..... 8
9.7 Determining the Number of Samples ..... 8
9.7.1 Determination of the Relative Shift ..... 8
9.7.2 Determination of Acceptable Decision Errors ..... 9
9.7.3 Determination of Number of Data Points (Sign Test) ..... 9
9.7.4 Determination of Number of Data Points (WRS Test) ..... 10
9.8 Determination of Sample Locations ..... 10
9.8.1 Determining Class 1 Sample Locations ..... 10
9.9 Removable Contamination Measurements ..... 10
9.10 Surveys of Building Mechanical System Internals ..... 11
9.11 Survey Investigation Levels ..... 11
9.12 Volumetric Scan Results ..... 11
9.13 Surface Scan Results ..... 11
9.14 Total Surface Activity Results ..... 11
9.15 Removable Contamination Results ..... 12
9.16 Dose Rate Measurement Results ..... 12
**10.0 DATA QUALITY ASSESSMENT AND INTERPRETATION OF SURVEY RESULTS** ..... 13
10.1 Data Validation ..... 14

10.2 Preliminary Data Review ..... 14
10.3 Determining Compliance for Building Surfaces and Structures ..... 15
10.4 Determining Compliance for Volumetric Activity ..... 15
10.5 Determining Compliance for Building Systems ..... 16
**11.0 REFERENCES ..... 16**

## TABLES

Table 5-1 Removable Activity Contribution to Total Dose ..... 2
Table 5-2 Summary of DCGLs ..... 2
Table 6-1 Instrumentation Specifications ..... 3
Table 6-2 Typical Instrument Operating Parameters and Sensitivities ..... 3
Table 9-1 MicroRem Measurements in Background Reference Area ..... 12
Table 9-2 MicroRem Measurements in Cyclotron Room ..... 13
Table 10-1 Structural Surfaces - Total Beta Surface Activity Summary ..... 14
Table 10-2 Structural Surfaces - Removable Surface Activity Summary ..... 14
Table 10-3 Systems - Total Surface Activity Summary ..... 15
Table 10-4 Systems - Removable Surface Activity Summary ..... 15
Table 10-5 Structural Surfaces - Total Beta Surface Activity Dose Calculations ..... 15
Table 10-6 Structural Surfaces - Volumetric Activity Dose Calculations ..... 15

## APPENDICES

Appendix A – Site Map
Appendix B – Final Status Survey Location Maps
Appendix C – Instrument Calibration Records
Appendix D – Structural Surfaces Survey Results
Appendix E – QA Survey Results
Appendix F – Systems Survey Results
Appendix G – Material Release Survey Results

## ACRONYM LIST

| | |
|---|---|
| ALARA | As Low As Reasonably Achievable |
| Chase | Chase Environmental Group, Inc. |
| CFR | Code of Federal Regulations |
| DAC | Derived Air Concentration |
| DAW | Dry Active Waste |
| DCGL | Derived Concentration Guideline Level |
| DQO | Data Quality Objective |
| DSV | Default Screening Value |
| DWP | Decommissioning Work Plan |
| GM | Geiger-Mueller |
| FSS | Final Status Survey |
| FSSR | Final Status Survey Report |
| $H_0$ | Null Hypothesis |
| $H_A$ | Alternate Hypothesis |
| HSA | Historical Site Assessment |
| MARSSIM | Multi-Agency Radiation Survey and Site Investigation Manual |
| MDC | Minimum Detectable Concentration |
| NRC | U.S. Nuclear Regulatory Commission |
| NIST | National Institute of Standards and Technology |
| RSO | Radiation Safety Officer |
| RWP | Radiation Work Permit |
| TEDE | Total Effective Dose Equivalent |
| TMMC | Toxco Materials Management Center |
| WRS | Wilcoxon Rank Sum Test |

# 1.0 EXECUTIVE SUMMARY

Ball State University (BSU) removed its neutron generator from service and decommissioned their vault facility located at the Cooper Science Complex, 22091 Riverside Ave., Muncie, Indiana, 47303. The accelerator was historically used to generate neutrons by bombarding tritium targets.

BSU retained Chase Environmental Group, Inc. (Chase) to perform accelerator removal, characterization, transportation, waste disposal, surveys, and reporting. No aggressive remediation was required. Decommissioning activities were performed under BSU's US Nuclear Regulatory Commission (NRC) Radioactive Materials License Number 13-06231-01. All activities were performed in accordance with a Decommissioning Work Plan (DWP). On-site decommissioning activities were performed from December 14 to December 17, 2009.

The DWP was developed using the guidance provided in NUREG-1757, "Consolidated NMSS Decommissioning Guidance" and NUREG-1575, "Multi-Agency Radiation Survey and Site Investigation Manual" (MARSSIM) and provided the approach, methods, and techniques for the radiological decommissioning of impacted areas of the facility. Final status surveys were designed using the guidance provided in MARSSIM to demonstrate compliance with the default screening values specified in NUREG-1757, Volume 1, Appendix B. These methods ensure technically defensible data are generated to aid in determining compliance with release criteria for unrestricted use specified in 10CFR20.1402 (25mrem/yr.).

This report presents sufficient data to support the conclusion that the facility meets the release criteria. Final status surveys demonstrate that building structural surfaces included in the scope of this report are below release criteria and are suitable for unrestricted release. Based on the building occupancy scenario, the Total Effective Dose Equivalent (TEDE) to an average member of the critical group is < 1.0 mrem/year (< 4% of the release criterion of 25 mrem/yr).

# 2.0 FACILITY DESCRIPTION

The Neutron Generator Facility, located in the basement of the Cooper Science Complex, has a footprint of approximately 140 square feet and consists of one room (a concrete vault) and a facility entrance and exit walkway. The vault is equipped with metal ventilation ducting, a sink, and a drain sump. A neutron generator resided in the room along with the associated electric supply, transformer and vacuum pumps. The ventilation system duct extended along the back (east) wall inside the vault to the courtyard where it exited horizontally through the wall. The general layout of the facility is depicted in Appendix A.

# 3.0 RELEASE CRITERIA

The radiological release criteria are that of 10CFR20.1402, "Radiological criteria for unrestricted use": "A site will be considered acceptable for unrestricted use if the residual radioactivity that is distinguishable from background radiation results in a Total Effective Dose Equivalent (TEDE) to an average member of the critical group that does not exceed 25 mrem (0.25mSv) per year, including that from groundwater sources of drinking water and the residual radioactivity has been reduced to levels that are as low as reasonable achievable (ALARA). Determination of the levels which are ALARA must take into account consideration of any detriments, such as deaths from transportation accidents, expected to potentially result from decontamination and waste disposal."

# 4.0 DERIVED CONCENTRATION GUIDELINE LEVELS (DCGL)

The Derived Concentration Guideline Level (DCGL) is the radionuclide-specific surface contamination or volumetric concentration that could result in a dose equal to the release criterion. $DCGL_W$ is the concentration limit if the residual activity is essentially evenly distributed over a large area. Gamma scans conducted during characterization indicated that there was no detectable activation of building structures. As such, the facility was classified as non-impacted by activation products. However, dose rate surveys were conducted to provide a statistically-based systematic protocol for verification of non-impacted status.

The release criteria for loose equipment and materials from the vault were per FC 83-23, "Guidelines for the Decontamination of Facilities and Equipment Prior to Release for Unrestricted Use or Termination of Byproduct, Source or Special Nuclear Material Licenses." These limits were also used as site DCGL's[3] for release of vault structures. These limits are:

- 5,000 dpm/100 $cm^2$ average total surface contamination over any 1 $m^2$
- 15,000 dpm/100 $cm^2$ maximum total surface contamination limited to 100 $cm^2$
- 1,000 dpm/100 $cm^2$ removable surface contamination

# 5.0 SURVEY INSTRUMENTATION

Laboratory and portable field instruments were calibrated within the previous year with National Institute of Standards and Technology (NIST) traceable sources. Portable instrument calibration records are included as Appendix C.

## 5.1 Functional Checks

Functional checks were performed at least daily when in use. The background, source check, and field measurement count times were determined to ensure measurements were

[3] H-3 is the only nuclide of concern for decommissioning. However, the survey design includes C-14 for conservatism. The NRC default screening values are 1.2E8 dpm/100$cm^2$ for H-3 and 3.7E6 dpm/100$cm^2$ for C-14.

statistically valid. Background readings were taken as part of the daily instrument check and compared with the acceptance range for instrument and site conditions.

### 5.2 Instrumentation Used

The instrumentation used for facility decommissioning surveys is summarized in Table 5-1 and Table 5-2.

**Table 5-1 Instrumentation Specifications**

| Detector Model | Detector Type | Detector Area | Meter Model | Window Thickness | Typical $4\pi$ Efficiency |
|---|---|---|---|---|---|
| Ludlum 43-68 | Gas Flow Proportional | 126 $cm^2$ | Ludlum 2221 | 0.8 $mg/cm^2$ | 13 % (C-14) |
| Ludlum 43-37 | Gas Flow Proportional | 582 $cm^2$ | Ludlum 2241 | 0.8 $mg/cm^2$ | 13 % (C-14) |
| Ludlum 44-10 | 2" x 2" Sodium Iodide | N/A | Ludlum 2241 | N/A | 900 cpm per μR/hr (Cs-137) |
| Bicron MicroRem | Organic Scintillator | N/A | N/A | N/A | N/A |
| Beckman | Liquid Scintillation | N/A | N/A | N/A | 60% (H-3) 80% (C-14) |
| Ludlum 43-10-1 | Dual Phosphor | N/A | Ludlum 2929 | 0.4 $mg/cm^2$ | 10% (C-14) |

**Table 5-2 Typical Instrument Operating Parameters and Sensitivities**

| Measurement Type | Detector Model | Max. Scan Rate | Count Time | Bkg. Count Time | Background (cpm) | MDC ($dpm/100cm^2$) |
|---|---|---|---|---|---|---|
| Surface Scans (Beta) | Ludlum 43-68 | 10 in./sec. | N/A | 60 sec. | 500 | 2,279 |
| Surface Scans (Beta) | Ludlum 43-37 | 10 in./sec. | N/A | 60 sec. | 1000 | 612 |
| Total Surface Activity (Beta) | Ludlum 43-68 | N/A | 6 sec. | 60 sec. | 500 | 1087 |
| Volumetric Scans (Gamma) | Ludlum 44-10 | 5 in./sec. | N/A | 60 sec. | 17,000 | 1.45 μR/hr |
| Removable Activity | Beckman | N/A | 60 sec. | 60 sec. | 30 | 28 |
| Removable Activity | 2929/ 43-10-1 | N/A | 180 sec. | 600 sec. | 60 | 185 |

## 5.3 Determination of Counting Times and Minimum Detectable Concentrations

Minimum counting times for background determinations and measurement of total and removable contamination were chosen to provide a Minimum Detectable Concentration (MDC) that met the criteria specified in the DWP. MARSSIM equations relative to building surfaces were modified to convert to units of dpm/100cm$^2$. Count times and scanning rates were determined using the following equations:

### 5.3.1 Static Counting

Static counting Minimum Detectable Concentration at a 95% confidence level is calculated using the following equation, which is an expansion of NUREG 1507, "Minimum Detectable Concentrations with Typical Radiation Survey Instruments for Various Contaminants and Field Conditions", Table 3.1 (Strom & Stansbury, 1992):

$$MDC_{static} = \frac{3 + 3.29\sqrt{B_r \cdot t_s \cdot (1 + \frac{t_s}{t_b})}}{t_s \cdot E_{tot} \cdot \frac{A}{100cm^2}}$$

Where:

$MDC_{static}$ = minimum detectable concentration (dpm/100cm$^2$)
$B_r$ = background count rate (counts per minute)
$t_b$ = background count time (minutes)
$t_s$ = sample count time (minutes)
$E_{tot}$ = total detector efficiency for radionuclide emission of interest (cpm/dpm)
$A$ = detector probe area (cm$^2$)

### 5.3.2 Surface Ratemeter Scanning

Scanning Minimum Detectable Concentration at a 95% confidence level is calculated using the following equation, which is a combination of MARSSIM equations 6-8, 6-9, and 6-10:

$$MDC_{scan} = \frac{d'\sqrt{b_i}\left(\frac{60}{i}\right)}{\sqrt{p} \cdot E_{tot} \cdot \frac{A}{100cm^2}}$$

Where:

$MDC_{scan}$ = minimum detectable concentration (dpm/100 $cm^2$)
$d'$ = desired performance variable (1.38)
$b_i$ = background counts during the residence interval (counts)
$i$ = residence interval (seconds)
$p$ = surveyor efficiency (0.5)
$E_{tot}$ = total detector efficiency for radionuclide emission of interest (cpm/dpm)
$A$ = detector probe area ($cm^2$)

### 5.3.3 Smear Counting

Smear counting Minimum Detectable Concentration at a 95% confidence level is calculated using the following equation, which is NUREG 1507, "Minimum Detectable Concentrations with Typical Radiation Survey Instruments for Various Contaminants and Field Conditions", Table 3.1 (Strom & Stansbury, 1992):

$$MDC_{smear} = \frac{3 + 3.29\sqrt{B_r \cdot t_s \cdot (1 + \frac{t_s}{t_b})}}{t_s \cdot E}$$

Where:

$MDC_{smear}$ = minimum detectable concentration level (dpm/smear)
$B_r$ = background count rate (counts per minute)
$t_b$ = background count time (minutes)
$t_s$ = sample count time (minutes)
$E$ = instrument efficiency for radionuclide emission of interest (cpm/dpm)

## 6.0 REMOVAL ACTIVITIES

### 6.1 Accelerator Equipment Removal

Chase personnel disassembled and removed the accelerator and ancillary equipment. All activities were performed under a Radiation Work Permit (RWP), authorized by the Radiation Safety Officer (RSO) and conducted to control the spread of contamination and to maintain personnel exposures ALARA. Monitoring for airborne particulate radioactivity was conducted during removal and disassembly and the highest sample result was below the MDC of 2.0E-12 µCi/ml.

## 7.0 RADIOACTIVE MATERIALS MANAGEMENT

All operational and disassembly wastes were moved to BSU's on-site waste storage facility pending milk-run transportation to the Toxco Material Management Center (TMMC) in Oak Ridge, TN for processing and disposal.

Waste consists of eight 2 $ft^3$ fiberboard boxes of activated metal and dry active waste (DAW) weighing 455 lbs., the diffusion pump weighing 110 lbs., and ½ gallon of vacuum pump oil.

# 8.0 SURVEYS

Surveys were performed using the Data Quality Objectives (DQO) process to demonstrate that residual radioactivity in the vault satisfied the predetermined criteria for release for unrestricted use. Vault interior surfaces were considered a single survey unit. Surveys were conducted by performing the appropriate combination of scan surveys, total activity measurements, dose rate measurements and removable activity measurements.

## 8.1 Data Quality Objectives

The following is a list of the major DQOs for the survey design:

- Static measurements will be taken to achieve an $MDC_{static}$ of less than 5,000 dpm/100$cm^2$.
- Scanning will be conducted at a rate to achieve an $MDC_{scan}$ of less than 5,000 dpm/100$cm^2$.
- Smear counting will be conducted to achieve an MDC of less than 200 dpm/100$cm^2$.
- Individual measurements will be made to a 95% confidence interval.
- Decision error probability rates will be set at 0.05 for both $\alpha$ and $\beta$.
- The null hypothesis ($H_0$) and alternate null hypothesis ($H_A$) are that of NUREG 1505 scenario A:
  $H_0$ is that the survey unit does not meet the release criteria
  $H_A$ is that the survey unit meets the release criteria
- Characterization and in-process waste packaging surveys will be conducted under the same quality assurance criteria as final status surveys such that the data may be used as final status survey data to the maximum extent possible.
- Quality Assurance Surveys will be conducted at a rate of 5%.

## 8.2 Area Classifications

Based on the facilities operational history and previous survey results, the facility areas were initially classified as impacted areas and non-impacted areas for the purposes of characterization.

### 8.2.1 Non-Impacted Area

Non-impacted areas were areas without residual radioactivity from licensed activities and were not surveyed during final status surveys. Surfaces outside the vault were classified as non-impacted. Thorough surveys of vault entrances/exits and ventilation exhausts were conducted to provide adequate assurance that any residual contamination was contained within the building structure.

### 8.2.2 Impacted Areas

Impacted areas were those areas that had potential residual radioactivity from licensed activities. Impacted areas were subdivided into Class 1, Class 2 or Class 3 areas. Class 1 areas have the greatest potential for contamination and therefore receive the highest degree of survey effort for the final status survey using a graded approach, followed by Class 2, and then by Class 3. Impacted sub-classifications are defined as follows:

- Class 1 Area: Areas with the highest potential for contamination, and meet the following criteria: (1) impacted; (2) potential for delivering a dose above the release criterion; (3) potential for small areas of elevated activity; and (4) insufficient evidence to support classification as Class 2 or Class 3.
- Class 2 Area: Areas that meet the following criteria: (1) impacted; (2) low potential for delivering a dose above the release criterion; and (3) little or no potential for small areas of elevated activity.
- Class 3 Area: Areas that meet the following criteria: (1) impacted; (2) little or no potential for delivering a dose above the release criterion; and (3) little or no potential for small areas of elevated activity.

## 8.3 Survey Units

A survey unit is a geographical area of specified size and shape for which a separate decision will be made whether or not that area meets the release criteria. A survey unit is normally a portion of a building or site that is surveyed, evaluated, and released as a single unit. Areas of similar construction and composition were grouped together as survey units and tested individually against the DCGLs and the null hypothesis to show compliance with the release criteria. Survey units are homogeneous in construction, contamination potential, and contamination distribution. Survey unit designations and classifications are as follows:

- Survey Unit 0101: Accelerator Vault Internal Surfaces – Class 1
- There were no Class 2 areas
- There were no Class 3 areas

## 8.4 Surface Scans

Scanning was used to identify locations within the survey unit that exceeded the investigation level. 100% of accessible building structural surfaces were scanned using a gas flow surface contamination detector. Additionally, surfaces in the vault were scanned for volumetric activation products using a 2" x 2" NaI detector.

## 8.5 Total Surface Activity Measurements

Direct surveys (static measurements) were taken on building surfaces and system internals to the extent practical in impacted areas utilizing instrumentation of the best geometry based on the surface at the survey location.

### 8.6 Dose Rate Measurements

Dose rate measurements were taken on building surfaces in the accelerator room and in a background reference area. The background reference area was selected outside the accelerator room near concrete surfaces, yet away from potentially activated portions of the vault. Dose rate measurements were taken at each accelerator room sample location and in the background reference area. At each location, a measurement was taken at 1 m from the surface to determine the dose rate at the midpoint of a receptor.

Dose rate measurements were performed with a tissue equivalent Bicron MicroRem meter. This instrument was selected due to its flat energy response. Additionally, a one-minute count was performed at each location using a 2" x 2" sodium iodide detector. Because the Bicron is a ratemeter, an average of ten instantaneous rates was determined at each location by covering the meter and recording the measurement observed when it is uncovered (this is a relatively unbiased method to obtain an average).

### 8.7 Determining the Number of Samples

A minimum number of samples are needed to obtain sufficient statistical confidence that the conclusions drawn from the samples are correct. The number of samples depends on the Relative Shift (the ratio of the concentration to be measured relative to the statistical variability of the contaminant concentration).

The minimum number of samples is obtained from MARSSIM tables or calculated using equations in Section 5 of MARSSIM.

#### 8.7.1 Determination of the Relative Shift

The number of required samples depends on the ratio involving the activity level to be measured relative to the variability in the concentration. The ratio to be used is called the Relative Shift, $\Delta/\sigma_S$ and is defined in MARSSIM as:

$$\Delta / \sigma_S = \frac{DCGL - LBGR}{\sigma_S}$$

Where:

DCGL = derived concentration guideline level
LBGR = concentration at the lower bound of the gray region. The LBGR is the average concentration to which the survey unit should be cleaned in order to have an acceptable probability of passing the test
$\sigma_S$ = an estimate of the standard deviation of the residual radioactivity in the survey unit

The actual calculations are provided below:

$$\Delta/\sigma_S = \frac{1.2E8 - 6.0E7}{25000} = 2400$$

Since MARRSIM Table 5.5 does not include relative shifts above 3 and the number of samples required decreases with an increasing relative shift, the relative shift for structural surface activity was conservatively set at 3.

**8.7.2 Determination of Acceptable Decision Errors**

A decision error is the probability of making an error in the decision on a survey unit by passing a unit that should fail (α decision error) or failing a unit that should pass (β decision error). MARSSIM uses the terminology α and β decision errors; this is the same as the more common terminology of Type I and Type II errors, respectively. The decision errors are 0.05 for Type I errors and 0.05 for Type II errors.

**8.7.3 Determination of Number of Data Points (Sign Test)**

The number of direct measurements for a particular survey unit, employing the Sign Test, is determined from MARSSIM Table 5.5, which is based on the following equation (MARSSIM equation 5-2):

$$N = \frac{\left(Z_{1-\alpha} + Z_{1-\beta}\right)^2}{4\left(SignP - 0.5\right)^2}$$

Where:

| | | |
|---|---|---|
| N | = | number of samples needed in the survey unit |
| $Z_{1-\alpha}$ | = | percentile represented by the decision error α |
| $Z_{1-\beta}$ | = | percentile represented by the decision error β |
| *SignP* | = | estimated probability that a random measurement will be less than the DCGL when the survey unit median is actually at the LBGR |

*Note: SignP* is determined from MARSSIM Table 5.4

MARSSIM recommends increasing the calculated number of measurements by 20% to ensure sufficient power of the statistical tests and to allow for possible data losses. MARSSIM Table 5.5 values include an increase of 20% of the calculated value. The following calculations were made to determine this number:

$$N = \frac{\left(1.645 + 1.645\right)^2}{4\left(0.998650 - 0.5\right)^2} = 11$$

$Z_{1-\alpha}$ and $Z_{1-\beta}$ are equal to 1.645 using the error rate of 0.05 from MARSSIM Table 5.2. SignP is equal to 0.998650 from MARSSIM Table 5.4. Adding an additional

20% to account for data losses resulted in a value of 14. Therefore, the determined number of samples per survey unit for planning purposes was **14.**

## 8.8 Determination of Sample Locations

Determination of Class 1 survey unit sample locations is accomplished by first determining sample spacing and then systematically plotting the sample locations from a randomly generated start location. The random starting point of the grid provides an unbiased method for obtaining measurement locations to be used in the statistical tests.

### 8.8.1 Determining Class 1 Sample Locations

In Class 1 survey units, the sampling locations are established in a unique pattern beginning with the random start location and the determined sample spacing. After determining the number of samples needed in the survey unit, sample spacing is determined from MARSSIM equation 5-8:

$$L = \sqrt{\frac{A}{N}} \text{ for a square grid}$$

Where:

L = sample spacing interval
A = the survey unit area
N = number of samples needed in the survey unit

A map was generated of the survey unit's permanent surfaces included in the statistical tests (floors, walls, ceilings, etc.) and folded out in a 2-dimensional view. A random starting point is determined using computer-generated random numbers coinciding with the x and y coordinates of the total survey unit. A grid was plotted across the survey unit surfaces based on the random start point and the determined sample spacing. A measurement location was plotted at each intersection of the grid plot. Survey unit map showing sample locations is presented in Appendix B.

## 8.9 Removable Contamination Measurements

Removable contamination measurements (smears) were collected on building structural surfaces at each sample location and internal surfaces of building systems. For each sample, an area of approximately 100cm$^2$ was wiped. Smears were collected and counted using a both a liquid scintillation counter (LSC) and a phoswich counter scaler (2929).

Both instruments were set up for one (1) minute count times. The LSC ran each smear three (3) times and provided a maximum and mean for the three (3) sample counts. For conservatism, the maximum value was used for the results provided in Appendices D,E, and F.

### 8.10 Surveys of Building Mechanical System Internals

Surveys of various building system components were performed. Survey design for these systems is out of the scope of MARSSIM. For the purposes of identifying potential residual contamination within these systems, scan surveys, total activity measurements, and removable contamination measurements of accessible ventilation exhaust points and the floor drain sump.

### 8.11 Survey Investigation Levels

Investigation levels are used to flag locations that require special attention and further investigation to ensure areas are properly classified and adequate surveys are performed. These locations are marked and receive additional investigations to determine the concentration, area, and extent of the contamination. The survey investigation levels for each type of measurement are listed by classification in Table 14.2.

**Table 14.2 Survey Investigation Levels**

| Survey Unit Classification | Flag Direct Measurement or Sample Result When: | Flag Scanning Measurement Result When: | Flag Removable Measurement Result When: |
|---|---|---|---|
| Class 1 | >75% of DCGL | >MDC | > 200 dpm/100cm$^2$ |

### 8.12 Volumetric Scan Results

Sodium iodide scans were performed to detect areas of elevated activity as a result of activation based on the audible response. No areas of elevated activity were detected.

### 8.13 Surface Scan Results

No areas of elevated activity were detected during the scans of building structural surfaces inside the vault.

### 8.14 Total Surface Activity Results

Direct surveys (static measurements) for total surface activity were taken on building surfaces inside the vault (survey unit 0101) using gas flow proportional detectors. Static measurements were taken in impacted areas at each identified sample location. Scaler count times were determined to achieve the detection sensitivities stated in the DQOs. Field measurements were converted to an activity concentration using the following equation:

**Equation 1**

$$\text{Activity}\,(\text{dpm}/100\text{cm}^2) = \frac{cpm_{sample} - cpm_{background}}{E_{total} \cdot \frac{A}{100cm^2}}$$

The results of total surface activity measurements are presented in Appendix D.

### 8.15 Removable Contamination Results

Removable contamination measurements were collected by wiping an area of approximately 100 $cm^2$ on structural surfaces for Liquid Scintillation and Counter-Scaler measurement. Samples were then counted for one minute on a Beckman Liquid Scintillation Counter and three minutes on Ludlum Model 2929 Counter-Scaler. Smear results were converted to an activity concentration using the following equation:

**Equation 2**

$$\text{Activity}(\text{dpm}/100\text{cm}^2) = \frac{cpm_{sample} - cpm_{background}}{E_{total}}$$

The results of removable surface activity measurements are presented in Appendix E

### 8.16 Dose Rate Measurement Results

Dose rate measurement results from the background reference area and the accelerator room are presented in Table 8-1 and
Table 8-2.

**Table 8-1 MicroRem Measurements in Background Reference Area**

| | Bicron Instantaneous Measurements (µRem/hr) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Loc.** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **SD** | **Mean** |
| **1** | 3 | 3 | 4 | 3 | 4 | 4 | 3 | 5 | 4 | 5 | 0.8 | 3.8 |
| **2** | 5 | 4 | 5 | 4 | 4 | 5 | 4 | 4 | 5 | 5 | 0.5 | 4.5 |
| **3** | 4 | 4 | 4 | 4 | 5 | 4 | 5 | 5 | 5 | 4 | 0.5 | 4.4 |
| **4** | 6 | 6 | 6 | 5 | 4 | 5 | 5 | 6 | 5 | 4 | 0.8 | 5.2 |
| **5** | 5 | 4 | 4 | 4 | 5 | 5 | 4 | 4 | 4 | 4 | 0.5 | 4.3 |
| **6** | 4 | 4 | 3 | 4 | 5 | 5 | 6 | 5 | 4 | 4 | 0.8 | 4.4 |
| **7** | 4 | 4 | 4 | 5 | 4 | 4 | 4 | 4 | 5 | 4 | 0.4 | 4.2 |
| **8** | 4 | 4 | 4 | 3 | 4 | 4 | 5 | 4 | 5 | 4 | 0.6 | 4.1 |
| **9** | 3 | 3 | 3 | 4 | 4 | 3 | 4 | 4 | 5 | 5 | 0.8 | 3.8 |
| **10** | 4 | 5 | 6 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 0.5 | 5 |
| **11** | 5 | 6 | 6 | 5 | 5 | 6 | 6 | 5 | 4 | 4 | 0.8 | 5.2 |
| **12** | 4 | 4 | 4 | 4 | 5 | 4 | 5 | 6 | 6 | 5 | 0.8 | 4.7 |
| **13** | 5 | 6 | 5 | 5 | 5 | 6 | 7 | 6 | 5 | 5 | 0.7 | 5.5 |
| **14** | 4 | 4 | 3 | 4 | 4 | 5 | 4 | 3 | 4 | 4 | 0.6 | 3.9 |
| **15** | 4 | 3 | 4 | 4 | . | 4 | 4 | 5 | 5 | 5 | 0.7 | 4.1 |
| **16** | 4 | 5 | 4 | 5 | 5 | 4 | 4 | 4 | 5 | 5 | 0.5 | 4.5 |
| **17** | 4 | 3 | 4 | 5 | 6 | 5 | 6 | 5 | 5 | 6 | 1.0 | 4.9 |
| **18** | 5 | 4 | 4 | 5 | 4 | 4 | 4 | 4 | 4 | 4 | 0.4 | 4.2 |
| **19** | 5 | 4 | 5 | 4 | 5 | 4 | 4 | 5 | 5 | 4 | 0.5 | 4.5 |
| **20** | 4 | 5 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 0.3 | 4.1 |
| **21** | 3 | 3 | 4 | 4 | 4 | 3 | 4 | 4 | 4 | 5 | 0.6 | 3.8 |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **22** | 4 | 4 | 5 | 5 | 6 | 5 | 5 | 4 | 5 | 5 | 0.6 | 4.8 |
| **23** | 5 | 5 | 6 | 6 | 6 | 5 | 5 | 4 | 4 | 4 | 0.8 | 5 |
| | | | | | | | | | | | **Mean** | **4.5** |
| | | | | | | | | | | | **SD** | **0.6** |

**Table 8-2 MicroRem Measurements in Accelerator Room**

| **Loc.** | **Bicron Instantaneous Measurements (μRem/hr)** | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **SD** | **Mean** |
| **1** | 4 | 4 | 4 | 5 | 5 | 4 | 5 | 4 | 4 | 5 | 0.5 | 4.4 |
| **2** | 5 | 5 | 6 | 5 | 6 | 6 | 5 | 5 | 6 | 5 | 0.5 | 5.4 |
| **3** | 5 | 5 | 6 | 7 | 7 | 6 | 7 | 6 | 5 | 6 | 0.8 | 6 |
| **4** | 5 | 5 | 4 | 5 | 5 | 6 | 5 | 5 | 5 | 6 | 0.6 | 5.1 |
| **5** | 4 | 4 | 4 | 4 | 5 | 4 | 4 | 4 | 4 | 4 | 0.3 | 4.1 |
| **6** | 4 | 4 | 3 | 4 | 4 | 3 | 4 | 4 | 4 | 4 | 0.4 | 3.8 |
| **7** | 6 | 6 | 5 | 7 | 6 | 5 | 5 | 6 | 5 | 5 | 0.7 | 5.6 |
| **8** | 5 | 6 | 6 | 5 | 6 | 5 | 5 | 4 | 5 | 5 | 0.6 | 5.2 |
| **9** | 6 | 6 | 5 | 6 | 5 | 6 | 5 | 5 | 5 | 5 | 0.5 | 5.4 |
| **10** | 4 | 5 | 4 | 4 | 3 | 4 | 3 | 4 | 4 | 4 | 0.6 | 3.9 |
| **11** | 4 | 4 | 4 | 5 | 5 | 5 | 4 | 5 | 5 | 4 | 0.5 | 4.5 |
| **12** | 4 | 4 | 4 | 5 | 4 | 4 | 4 | 5 | 4 | 5 | 0.5 | 4.3 |
| **13** | 7 | 6 | 5 | 6 | 7 | 6 | 6 | 5 | 6 | 5 | 0.7 | 5.9 |
| **14** | 5 | 4 | 5 | 5 | 4 | 4 | 5 | 5 | 6 | 5 | 0.6 | 4.8 |
| **15** | 4 | 5 | 4 | 4 | 4 | 4 | 5 | 4 | 4 | 4 | 0.4 | 4.2 |
| **16** | 5 | 5 | 4 | 5 | 5 | 6 | 5 | 4 | 5 | 5 | 0.6 | 4.9 |
| **17** | 4 | 5 | 6 | 5 | 6 | 4 | 5 | 6 | 6 | 5 | 0.8 | 5.2 |
| **18** | 4 | 4 | 5 | 4 | 4 | 4 | 4 | 5 | 5 | 4 | 0.5 | 4.3 |
| **19** | 5 | 5 | 4 | 4 | 5 | 5 | 5 | 4 | 4 | 4 | 0.5 | 4.5 |
| **20** | 6 | 6 | 5 | 7 | 5 | 5 | 4 | 5 | 5 | 6 | 0.8 | 5.4 |
| **21** | 5 | 6 | 5 | 5 | 5 | 6 | 5 | 5 | 4 | 5 | 0.6 | 5.1 |
| **22** | 5 | 5 | 4 | 4 | 4 | 5 | 4 | 4 | 5 | 4 | 0.5 | 4.4 |
| **23** | 6 | 6 | 5 | 6 | 5 | 5 | 5 | 6 | 5 | 5 | 0.5 | 5.4 |
| | | | | | | | | | | | **Mean** | **4.9** |
| | | | | | | | | | | | **SD** | **0.6** |

## 9.0 DATA QUALITY ASSESSMENT AND INTERPRETATION OF SURVEY RESULTS

The statistical guidance contained in Section 8 of MARSSIM was used to determine if areas are acceptable for unrestricted release and whether additional surveys or sample measurements were required.

### 9.1 Data Validation

Field data were reviewed by the Project Manager and validated to ensure:

- Completeness of forms
- Proper types of surveys were performed
- The MDCs for measurements met the established data quality objectives
- Independent calculations were performed on a representative sample of data sheets
- Satisfactory instrument calibrations and daily functionality checks were performed as required

### 9.2 Preliminary Data Review

A preliminary data review was performed for each survey unit to identify any patterns, relationships or anomalies. Additionally, measurement data were reviewed and compared with the DCGLs and ALARA goals to confirm the correct classification of survey units. All calculations of means, standard deviations, minimum and maximum values, and comparisons between survey data and ALARA goals and investigation levels are presented in the following tables. Structural surfaces final status survey results are presented in Appendix D.

**Table 9-1 Structural Surfaces - Total Beta Surface Activity Summary**

| Survey Unit | # of Sample Locations | Mean | MDC | Standard Deviation | Min. | Max. | Investigation Level | Any Result Exceeding Investigation Level? |
|---|---|---|---|---|---|---|---|---|
| | | (dpm/100 cm$^2$) | | | | | | |
| 0101 | 23 | 98 | 297 | 108 | -36 | 407 | 5000 | NO |

**Table 9-2 Structural Surfaces - Removable Surface Activity Summary**

| Survey Unit | # of Sample Locations | Mean | MDC | Standard Deviation | Min. | Max. | Investigation Level | Any Result Exceeding Investigation Level? |
|---|---|---|---|---|---|---|---|---|
| | | (dpm/100 cm$^2$) | | | | | | |
| 0101 (2929) | 23 | -13 | 171 | 31 | -93 | 53 | 200 | NO |
| 0101 (LSC) | 23 | 24 | 5 | 7 | 13 | 42 | 200 | NO |

**Table 9-3 Systems - Total Surface Activity Summary**

| Survey Unit | # of Sample Locations | Mean | MDC | Standard Deviation | Min. | Max. | Investigation Level | Any Result Exceeding Investigation Level? |
|---|---|---|---|---|---|---|---|---|
| | | (dpm/100 cm$^2$) | | | | | | |
| N/A | 2 | 198 | 297 | 288 | -5 | 402 | 5000 | NO |

**Table 9-4 Systems - Removable Surface Activity Summary**

| Survey Unit | # of Sample Locations | Mean | MDC | Standard Deviation | Min. | Max. | Investigation Level | Any Result Exceeding Investigation Level? |
|---|---|---|---|---|---|---|---|---|
| | | (dpm/100 cm$^2$) | | | | | | |
| 2929N/A | 2 | 7 | 171 | 40 | -21 | 36 | 200 | NO |
| LSCN/A | 2 | 142 | 5 | 177 | 17 | 267 | 200 | YES |

### 9.3 Determining Compliance for Building Surfaces and Structures

Survey results were initially compared to the investigation levels. No total activity results in survey unit 0101 were above the investigation level, and were well below the DCGL. Removable activity results in survey unit 0101 were above the investigation level, but were well below the DCGL. For surface activity, the Sign test is used to determine the minimum number of sample locations. Because all surface activity measurements are less than the DCGL, the survey unit passes the Sign Test. Therefore, the null hypothesis can be rejected and the survey unit meets the release criterion and is suitable for release for unrestricted use.

The results of the data quality assessment and calculations of the dose from each structural surface survey unit are presented in Table 10-5.

**Table 9-5 Structural Surfaces - Total Beta Surface Activity Dose Calculations**

| Survey Unit | Standard Deviation (dpm/100 cm$^2$) | # Samples Required | # of Samples | Adequate # of Samples? | Mean (dpm/100 cm$^2$) | Calculated Annual TEDE[4] (mrem/yr) |
|---|---|---|---|---|---|---|
| 0101 | 107 | 11 | 23 | YES | 98 | .0013 |

[4] The TEDE shown is calculated by multiplying 25 mrem/yr by the ratio of the mean total surface activity to the C-14 DCGL of 3.7E6 dpm/100cm$^2$ and then multiplying by 2 to account for the ISO 7503-1 surface efficiency.

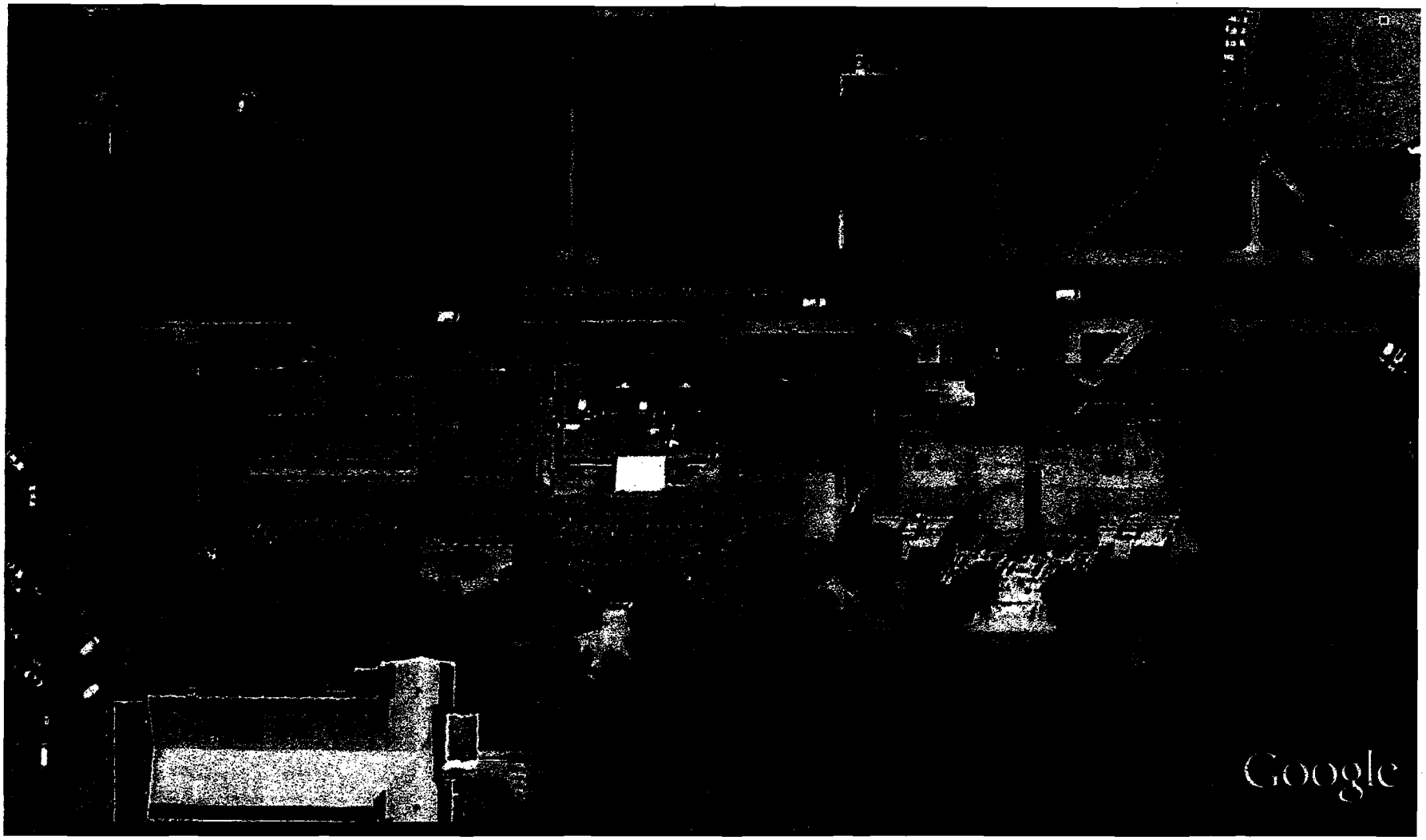
### 9.4 Determining Compliance for Building Systems

All total and removable surface activity measurements were compared directly to the investigation levels to determine if an area required further examination. All measurements were less than the investigation levels, therefore all systems meet the release criteria and are suitable for release for unrestricted release.

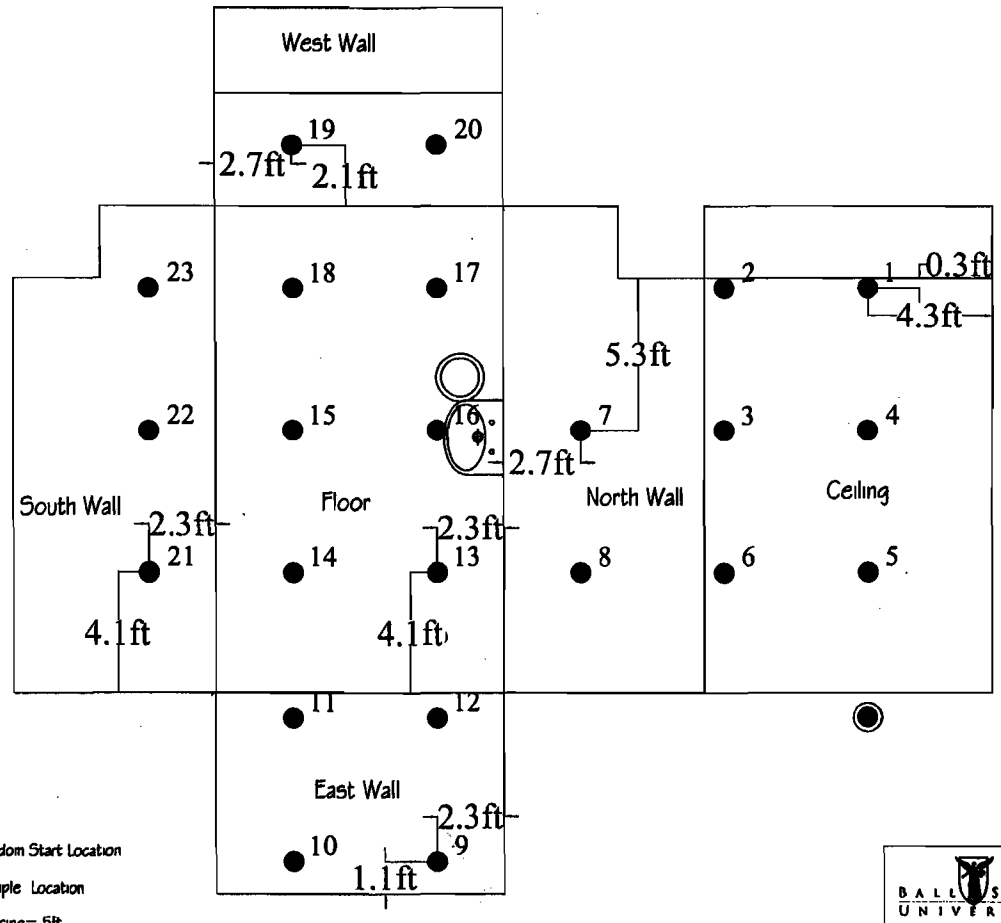
## 10.0 REFERENCES


- Ball State University US NRC Radioactive Materials License Number 13-06231-01
- NUREG-1575, "Multi-Agency Radiation Survey and Site Investigation Manual" (MARSSIM)
- NUREG-1505, "A Nonparametric Statistical Methodology for the Design and Analysis of Final Decommissioning Surveys"
- NUREG-1507, "Minimum Detectable Concentrations with Typical Radiation Survey Instruments for Various Contaminants and Field Conditions"
- NUREG-1757, Volume 1 "Consolidated NMSS Decommissioning Guidance," September, 2002
- NUREG-1757, Volume 2 "Consolidated NMSS Decommissioning Guidance," September, 2002
- USNRC Policy and Guidance Directive FC 83-23, "Guidelines for the Decontamination of Facilities and Equipment Prior to Release for Unrestricted Use or Termination of Byproduct, Source, or Special Nuclear Material Licenses."
- ISO-7503-1, "Evaluation of Surface Contamination – Part 1: Beta Emitters and Alpha Emitters." 1988
- Decommissioning Work Plan

**Appendix A**
**Site Map**


Google

**Appendix B**
**FSS Location Maps**




| | | |
|---|---|---|
| BALL STATE UNIVERSITY | Ball State University Neutron Generator Facility Decommissioning Report FSS | CHASE Environmental Group |
| Building: V01 | Survey Unit:0101 | Page: B.1 of B.1 |

**Appendix C**
**Inst Calibration Records**

# GRIFFIN INSTRUMENTS

## CALIBRATION CERTIFICATE FOR 2929 SERIAL# 149121

Owner: CHASE ENV.

DATE: 10/28/09 LOCATION: Griffin Inst

TECH: Joanne Glenn DATE LAST CAL EXPIRES: 12/18/09

Reason For Calibration: (•) Due For Calibration ( ) Repair (See Remarks)

CABLE LENGTH: 39" ( ) Other (See Remarks) ( ) Due and Repair (See Remarks)

### NIST TRACEABLE EQUIPMENT USED DURING CALIBRATION

MODEL: M-500 SERIAL #: 114512 CAL. DUE: 09/05/10

MODEL: SERIAL #: CAL DUE:

Condition: (•) Sat ( ) Unsat

AF Mechanical Zero: 0

AL Mechanical Zero: 0

| Set/Function/Check | Acceptance | Actual | | |
|---|---|---|---|---|
| Beta Channel Window (4-50 mV): | 4-48 | A.F. | | |
| Alpha Channel Window (175 mV, 120 for 3030): | 175 | A.F. | | |
| Alpha Counts w/Pulser @ 10,000 CPM: | 9,946 | A.F. | % Error: | 0.5% |
| Beta Counts w/Pulser @ 10,000 CPM: | 9,946 | A.F. | % Error: | 0.5% |
| HIGH VOLTAGE POWER UNIT CAL (2250volts) | | | | |
| 1 KV Reading (R-5 on HV Board): | 1 | A.F. | | |
| Max HV (1600 V +): | (•) Sat | ( ) Unsat | | |

REMARKS:

Does Instrument Meet Final Acceptance Criteria?: (•) Yes ( ) No

Calibration Sticker Attached?: (•) Yes ( ) No

Date Instrument is Due For Next Calibration: 10/28/10

INSTRUMENT MARRIED WITH 43-10-1 # PR150791

Performed/Reviewed by: Joanne Glenn Date: 10/28/2009 Entered by: _____ Initials



Calibrations performed to ANSI N323A-1997 standards.

GRIFFIN INSTRUMENTS

# CALIBRATION CERTIFICATE FOR 43-10-1 PROBE # PR150791

Owner: CHASE ENV

DATE: 10/26/09 LOCATION: Griffin Inst

TECH: Joanne Glenn DATE LAST CAL EXPIRES: 12/18/09

REASON FOR CALIBRATION:

(●) Due For Calibration ( ) Repair (See Remarks) ( ) Other (See Remarks) ( ) Due and Repair

CABLE LENGTH: 39" INPUT SENSITIVITY: dual

## NIST TRACEABLE EQUIPMENT AND STANDARDS USED DURING CALIBRATION

MODEL: 2929 SERIAL #: 146121 CAL. DUE: 10/26/10

## NIST TRACEABLE SOURCES USED

| Source Number | Isotope | 4 pi Activity | Assay Date | 2 pi Activity |
|---|---|---|---|---|
| 00TC470-0854 | Tc99 SS | 17,300 dpm | 06/15/09 | 10,800 cpm |
| 94TH470-1593 | Th230 | 16,700 dpm | 06/16/09 | 8,170 cpm |
| 2696-00 | Pu239 | 18,500 dpm | 07/18/06 | 9,380 cpm |
| 2697-00 | Sr90 | 12,200 dpm | 03/01/00 | 8,530 cpm |
| PX 728 | C14 | 46,780 dpm | 01/21/08 | 18,660 cpm |

Efficiencies from last cal.:

Condition: (●) Sat ( ) Unsat

| Pu: | | Th: | 36.29% | Sr: | |
|---|---|---|---|---|---|
| Tc ss: | 26.33% | C14: | | Tc Ni: | |

As Found (AF) Efficiencies:

| HV / Vernier: | Tc-99 Source Response Nickel (CPM): | | | Pu-239 Source Response (CPM): | | | Background (CPM): | | Tc-99 Source Response Stainless Steel (CPM): | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | A ch. | B ch. | Net Eff. | A ch. | B ch. | Net Eff. | A ch. | B ch. | A ch. | B ch. | Net Eff. |
| 800 / 3.16 | | | | 7290 | 263 | 39.41% | 0 | 84 | 1 | 4627 | 26.26% |

| Net A to B Xtalk: <10% | B to A Xtalk: <1% |
|---|---|
| 2.3% | <1% |

| | Pu239 | Tc99 Ni | Tc99 ss | Th-230 | Sr90 | C-14 |
|---|---|---|---|---|---|---|
| AF CPM: | 7290 | | 4627 | 6159 | 4042 | 6851 |
| AF 4 pi eff: | 39.41% | | 26.26% | 36.88% | 40.86% | 11.82% |
| *AF 2 pi eff:* | *77.64%* | | *42.06%* | *76.39%* | *58.44%* | *30.91%* |

Is as found efficiency within 20% of the efficiency from the last cal? (●) Yes ( ) No (See Remarks)

Note: If the as found data is within 10% of the last calibration and the B-A Xtalk is <1% and the A-B Xtalk is <10%, then the technician may N/A the plateau section and go directly to remarks.

**GRIFFIN INSTRUMENTS**

**PROBE #: PR150791**
**Date: 10/28/09**

# PLATEAU AND SET POINT DATA

| HV./ Vernier: | Tc-99 Source Response SS (CPM): | | | Pu-239 Source Response (CPM): | | | Background (CPM): | | Net A to B Xtalk: <10% | B to A Xtalk: <1% |
|---|---|---|---|---|---|---|---|---|---|---|
| | A ch. | B ch. | Net Eff. | A ch. | B ch. | Net Eff. | A ch. | B ch. | | |
| 700 / 2.72 | 0 | 3428 | 19.8% | 6515 | 222 | 35.2% | 0 | 44 | 2.7% | <1% |
| 750 / 2.90 | 0 | 3935 | 22.4% | 6946 | 253 | 37.5% | 0 | 66 | 2.6% | <1% |
| 775 / 3.00 | 1 | 4234 | 24.1% | 7058 | 221 | 38.2% | 0 | 66 | 2.1% | <1% |
| | | | | | | | | | | |
| | | | | | | | | | | |
| | | | | | | | | | | |

| Alpha / Beta Bkg (cpm) | | 0 | 66 | | | | |
|---|---|---|---|---|---|---|---|
| HV / Vernier | | Pu-239 | Tc-99 Ni | Tc-99 SS | Th-230 | C-14 | Sr-90 |
| 775 / 3.00 | CPM: | 7058 | | 4234 | 6009 | 4628 | 4203 |
| 4 pi AL Efficiencies: | | 38.15% | | 24.09% | 36.96% | 9.35% | 42.71% |
| *2 pi AL Efficiencies:* | | *75.17%* | | *38.59%* | *73.55%* | *24.45%* | *61.09%* |

REMARKS:

Does Instrument Meet Final Acceptance Criteria?: (●) Yes ( ) No

Calibration Sticker Attached?: (●) Yes ( ) No

Date Instrument is Due For Next Calibration: 10/28/10

INSTRUMENT MARRIED WITH 2929 # 149121

Performed/Reviewed by: James Harris Date: 10/28/2009 Entered by: _____ Initials

2 pi efficiencies denoted in italics. Calibrations performed to ANSI N323A-1997 standards.

GRIFFIN INSTRUMENTS

# CALIBRATION CERTIFICATE FOR 2929 SERIAL# 160013

Owner: CHASE ENV

DATE: 08/18/09 LOCATION: Griffin Inst

TECH: Joanne Glenn DATE LAST CAL EXPIRES: 09/05/09

Reason For Calibration: (●) Due For Calibration ( ) Repair (See Remarks)

CABLE LENGTH: 39" ( ) Other (See Remarks) ( ) Due and Repair (See Remarks)

## NIST TRACEABLE EQUIPMENT USED DURING CALIBRATION

MODEL: M-500 SERIAL #: 114612 CAL. DUE: 09/05/09

MODEL: SERIAL #: CAL DUE:

Condition: (●) Sat ( ) Unsat

AF Mechanical Zero: 0

AL Mechanical Zero: 0

| [redacted] | [redacted] | [redacted] | |
|---|---|---|---|
| Beta Channel Window (4-60 mV): | 4-60 | A.F. | |
| Alpha Channel Window (175 mV, 120 for 3030): | 175 | A.F. | |
| Alpha Counts w/Pulser @ 10,000 CPM: | 9,994 | A.F. | % Error: 0.2% |
| Beta Counts w/Pulser @ 10,000 CPM: | 9,994 | A.F. | % Error: 0.1% |
| [redacted] | | | |
| 1 KV Reading (R-5 on HV Board): | 1 | A.F. | |
| Max HV (1800 V +): | (●) Sat | ( ) Unsat | |

REMARKS:

Does Instrument Meet Final Acceptance Criteria?: (●) Yes ( ) No

Calibration Sticker Attached?: (●) Yes ( ) No

Date Instrument is Due For Next Calibration: 08/18/10

INSTRUMENT MARRIED WITH 43-10-1 # PR167231

Performed/Reviewed by: Joanne Glenn Date: 8/18/2009 Entered by: ____ Initials



Calibrations performed to ANSI N323A-1997 standards.

GRIFFIN INSTRUMENTS

# CALIBRATION CERTIFICATE FOR 43-10-1 PROBE # PR167231

Owner: CHASE ENV

DATE: 08/18/09 LOCATION: Griffin Inst
TECH: Joanne Glenn DATE LAST CAL EXPIRES: 09/05/09

REASON FOR CALIBRATION:

(●) Due For Calibration ( ) Repair (See Remarks) ( ) Other (See Remarks) ( ) Due and Repair

CABLE LENGTH: 39" INPUT SENSITIVITY: dual

## NIST TRACEABLE EQUIPMENT AND STANDARDS USED DURING CALIBRATION

MODEL: 2929 SERIAL #: 160013 CAL. DUE: 08/18/10

## NIST TRACEABLE SOURCES USED

| Source Number | Isotope | 4 pi Activity | Assay Date | 2 pi Activity |
|---|---|---|---|---|
| 94TH470-1593 | Th230 | 16,700 dpm | 06/18/09 | 8,170 cpm |
| 00TC470-0854 | Tc99 SS | 17,300 dpm | 08/15/09 | 10,800 cpm |
| 2697-00 | Sr90 | 12,200 dpm | 03/01/00 | 8,530 cpm |
| 2696-00 | Pu239 | 18,500 dpm | 07/18/06 | 9,390 cpm |
| PX 728 | C14 | 48,780 dpm | 01/21/08 | 18,880 cpm |

Condition: (●) Sat ( ) Unsat

Efficiencies from last cal.:

| Pu: | 37.77% | Th: | 33.64% | Sr: | 40.49% |
|---|---|---|---|---|---|
| Tc ss: | 22.31% | C14: | 10.84% | Tc Ni: | |

As Found (AF) Efficiencies:

| HV / Vernier: | Tc-99 Source Response Nickel (CPM): | | | Pu-239 Source Response (CPM): | | | Background (CPM): | | Tc-99 Source Response Stainless Steel (CPM): | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | A ch. | B ch. | Net Eff. | A ch. | B ch. | Net Eff. | A ch. | B ch. | A ch. | B ch. | Net Eff. |
| 850 / 3.50 | | | | 7067 | 337 | 38.18% | 3 | 81 | 2 | 4567 | 25.93% |

| Net A to B Xtalk: <10% | B to A Xtalk: <1% |
|---|---|
| 3.5% | <1% |

| | Pu239 | Tc99 Ni | Tc99 ss | Th-230 | Sr90 | C-14 |
|---|---|---|---|---|---|---|
| AF CPM: | 7067 | | 4567 | 5980 | 3864 | 6258 |
| AF 4 pi eff: | 38.18% | | 25.93% | 35.67% | 38.80% | 12.66% |
| *AF 2 pi eff:* | *75.23%* | | *41.54%* | *72.91%* | *55.49%* | *33.10%* |

Is as found efficiency within 20% of the efficiency from the last cal? (●) Yes ( ) No (See Remarks)

Note: If the as found data is within 10% of the last calibration and the B-A Xtalk is <1% and the A-B Xtalk is <10%, then the technician may N/A the plateau section and go directly to remarks.

# GRIFFIN INSTRUMENTS

PROBE #: PR167231
Date: 08/18/09

## PLATEAU AND SET POINT DATA

| HV / Vernier: | Tc-99 Source Response SS (CPM): | | | Pu-239 Source Response (CPM): | | | Background (CPM): | | Net A to B Xtalk: <10% | B to A Xtalk: <1% |
|---|---|---|---|---|---|---|---|---|---|---|
| | A ch. | B ch. | Net Eff. | A ch. | B ch. | Net Eff. | A ch. | B ch. | | |
| 700 / 2.90 | 0 | 2517 | 14.3% | 6369 | 317 | 34.4% | 1 | 47 | 4.1% | <1% |
| 750 / 3.10 | 2 | 3194 | 18.1% | 6684 | 308 | 36.1% | 0 | 59 | 3.8% | <1% |
| 800 / 3.32 | 1 | 4174 | 23.7% | 6870 | 328 | 37.1% | 1 | 68 | 3.7% | <1% |
| 850 / 3.50 | | | | | | | 1 | 103 | | |
| | | | | | | | | | | |
| | | | | | | | | | | |

Alpha / Beta Bkg (cpm) 2 73

| HV / Vernier | | Pu-239 | Tc-99 Ni | Tc-99 SS | Th-230 | C-14 | Sr-90 |
|---|---|---|---|---|---|---|---|
| 800 / 3.32 | CPM: | 6832 | | 4134 | 5868 | 4779 | 4098 |
| | 4 pi AL Efficiencies: | 38.92% | | 23.47% | 35.25% | 9.65% | 41.39% |
| | 2 pi AL Efficiencies: | 72.74% | | 37.60% | 72.04% | 25.22% | 59.20% |

REMARKS: Noticed erratic bkg - Reset mylar that slipped.

Does Instrument Meet Final Acceptance Criteria?: (●) Yes ( ) No

Calibration Sticker Attached?: (●) Yes ( ) No

Date Instrument is Due For Next Calibration: 08/18/10

INSTRUMENT MARRIED WITH 2929 # 160018

Performed/Reviewed by: [signature] Date: 8/18/2009 Entered by: DP Initials

2 pi efficiencies counted in tulips.

Calibrations performed to ANSI N323A-1997 standards.

**GRIFFIN INSTRUMENTS**

# CALIBRATION CERTIFICATE FOR 2241-3 SERIAL# 253346

Owner: CHASE ENV

DATE: 08/18/09 LOCATION: Griffin Inst

TECH: Joanne Glenn DATE LAST CAL EXPIRES: 08/13/09

Reason For Calibration: (●) Due For Calibration ( ) Repair (See Remarks)
( ) Other (See Remarks) ( ) Due and Repair (See Remarks)

## NIST TRACEABLE EQUIPMENT USED DURING CALIBRATION

MODEL: M-500 SERIAL #: 114612 CAL. DUE: 09/05/09

MODEL: SERIAL #: CAL DUE:

[x] Fast/Slow Switch working properly [x] Audio Response [ ] Geotropism CABLE LENGTH 10'

CONDITION: Sat

NEW BATTERIES: ( ) Yes (●) No BATTERY CHECK: Sat

HV TEST ( ) N/A (●) Sat ( ) Unsat

| | | | |
|---|---|---|---|
| AF INPUT SENSITIVITY (mV) #1: | 2.5 | AL INPUT SENSITIVITY (mV) #1: | 4 |
| AF INPUT SENSITIVITY (mV) #2: | 2.5 | AL INPUT SENSITIVITY (mV) #2: | 4 |
| AF INPUT SENSITIVITY (mV) #3: | 2.5 | AL INPUT SENSITIVITY (mV) #3: | 4 |
| AF INPUT SENSITIVITY (mV) #4: | 2.5 | AL INPUT SENSITIVITY (mV) #4: | 4 |

| RATE CPM | AS FOUND | | % ERROR | AS LEFT | % ERROR |
|---|---|---|---|---|---|
| 250 | 251 | | 0.4% | A.F. | |
| 2500 | 2498 | | 0.1% | A.F. | |
| 25K | 24.993 | K | 0.0% | A.F. | |
| 250K | 249.955 | K | 0.0% | A.F. | |

Is the As Found Data Within 2% of the Set Point?:
(●) Yes ( ) No

| DETECTOR 1: | | DETECTOR 2: | | DETECTOR 3: | | DETECTOR 4: | |
|---|---|---|---|---|---|---|---|
| AF 1-6 | AL 1-6 | AF 1-6 | AL 1-6 | AF 1-6 | AL 1-6 | AF 1-6 | AL 1-6 |
| 0000 S-6 | A.F. | 0000 S-6 | A.F. | 0000 S-6 | A.F. | 0000 s-6 | A.F. |
| 0100 -2 | A.F. | 0100 -2 | A.F. | 0100 -2 | A.F. | 0100 -2 | A.F. |
| c/ | A.F. | c/ | A.F. | c/ | A.F. | C/ | A.F. |
| m | A.F. | m | A.F. | m | A.F. | M | A.F. |
| 1 | A.F. | 1 | A.F. | 1 | A.F. | 1 | A.F. |
| 000s | A.F. | 000s | A.F. | 000s | A.F. | 000s | A.F. |

REMARKS: See side of instrument for HV settings and detectors.

Does Instrument Meet Final Acceptance Criteria?: (●) Yes ( ) No

Calibration Sticker Attached?: (●) Yes ( ) No

Date Instrument Is Due For Next Calibration: 08/18/10

INSTRUMENT MARRIED WITH #

Performed/Reviewed by: Joanne Glenn Date: 8/18/2009 Entered by: JG Initials



Calibrations performed to ANSI N323A-1997 standards.

GRIFFIN INSTRUMENTS

# CALIBRATION CERTIFICATE FOR 43-68 PROBE # PR216394

Owner: CHASE ENV

DATE: 08/18/09 LOCATION: Griffin Inst
TECH: Joanne Glenn DATE LAST CAL EXPIRES: 08/13/09

REASON FOR CALIBRATION:

(●) Due For Calibration ( ) Repair (See Remarks) ( ) Other (See Remarks) ( ) Due and Repair

CABLE LENGTH: 10' INPUT SENSITIVITY: 4 mV

## NIST TRACEABLE EQUIPMENT AND STANDARDS USED DURING CALIBRATION

MODEL: 2241-3 SERIAL #: 253346 CAL. DUE: 08/18/10

## NIST TRACEABLE SOURCES USED

| Source Number | Isotope | 4 pi Activity | Assay Date | 2 pi Activity |
|---|---|---|---|---|
| 94TH470-1593 | Th230 | 16,700 dpm | 06/16/09 | 8,170 cpm |
| 00TC470-0664 | Tc99 SS | 17,300 dpm | 06/15/09 | 10,800 cpm |
| 2696-00 | Pu239 | 18,600 dpm | 07/18/06 | 9,390 cpm |
| 2697-00 | Sr90 | 12,200 dpm | 03/01/00 | 6,530 cpm |
| PX 726 | C14 | 48,780 dpm | 01/21/06 | 18,660 cpm |

Efficiencies from last cal.:

Condition: (●) Sat ( ) Unsat Pu: Th: 20.31% Sr:

Tc ss: 25.60% C14: 15.38% Tc Ni:

As Found (AF) Efficiencies:

| HV / Vernier: | Tc-99 Source Response Nickel (CPM): | | | Pu-239 Source Response (CPM): | | | Background (CPM): | | Tc-99 Source Response Stainless Steel (CPM): | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | A ch. | B ch. | Net Eff. | A ch. | B ch. | Net Eff. | A ch. | B ch. | A ch. | B ch. | Net Eff. |
| 1250 / 1650 | | | | 4764 | | 25.75% | 1 | 149 | | 4642 | 25.97% |

| Net A to B Xtalk: <10% | B to A Xtalk: <1% |
|---|---|
| | |

| | Pu239 | Tc99 Ni | Tc99 ss | Th-230 | Sr90 | C-14 |
|---|---|---|---|---|---|---|
| AF CPM: | 4764 | | 4642 | 4139 | 3521 | 7682 |
| AF 4 pi eff: | 25.75% | | 25.97% | 24.75% | 34.67% | 15.40% |
| AF 2 pi eff: | 50.72% | | 41.80% | 50.65% | 49.59% | 40.26% |

Is as found efficiency within 20% of the efficiency from the last cal? (●) Yes ( ) No (See Remarks)

Note: If the as found data is within 10% of the last calibration and the B-A Xtalk is <1% and the A-B Xtalk is <10%, then the technician may N/A the plateau section and go directly to remarks.

## GRIFFIN INSTRUMENTS

PROBE #: PR216394
Date: 08/18/09

# PLATEAU AND SET POINT DATA

| HV / Vernier: | Tc-99 Source Response SS (CPM): | | | Pu-239 Source Response (CPM): | | | Background (CPM): | | Net A to B Xtalk: <10% | B to A Xtalk: <1% |
|---|---|---|---|---|---|---|---|---|---|---|
| | A ch: | B ch. | Net Eff. | A ch. | B ch. | Net Eff. | A ch. | B ch. | | |
| N/A | | | | | | | | | | |
| | | | | | | | | | | |
| | | | | | | | | | | |
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| | | | | | | | | | | |

Alpha / Beta Bkg (cpm) 1 149

| HV / Vernier | | Pu-239 | Tc-99 Ni | Tc-99 SS | Th-230 | C-14 | Sr-90 |
|---|---|---|---|---|---|---|---|
| 1250 /1650 | CPM: | 4764 | | 4642 | 4139 | 7662 | 3521 |
| | 4 pi AL Efficiencies: | 25.75% | | 25.97% | 24.78% | 15.40% | 34.67% |
| | *2 pi AL Efficiencies:* | *50.72%* | | *41.60%* | *50.65%* | *40.26%* | *49.59%* |

REMARKS:

Does Instrument Meet Final Acceptance Criteria?: (●) Yes ( ) No

Calibration Sticker Attached?: (●) Yes ( ) No

Date Instrument is Due For Next Calibration: 08/18/10

INSTRUMENT MARRIED WITH 2241-3 # 253348

Performed/Reviewed by: Eugene Glover Date: 8/18/2009 Entered by: ____ Initials

2 pi efficiencies denoted in italics. Calibrations performed to ANSI.N323A-1997 standards.

# GRIFFIN INSTRUMENTS

## CALIBRATION CERTIFICATE FOR 2241 SERIAL# 215484

Owner: CHASE ENV

DATE: 01/13/09 LOCATION: Griffin Inst

TECH: Joanne Glenn DATE LAST CAL EXPIRES: 04/02/09

Reason For Calibration: ○ Due For Calibration ○ Repair (See Remarks)
◉ Other (See Remarks) ○ Due and Repair (See Remarks)

NIST-TRACEABLE EQUIPMENT USED DURING CALIBRATION

MODEL: M-600 SERIAL #: 42386 CAL. DUE: 05/15/09

MODEL: SERIAL #: CAL DUE:

☐ Fast/Slow Switch working properly ☑ Audio Response ☐ Geotropism CABLE LENGTH 5'

CONDITION: Sat

NEW BATTERIES: ○ Yes ◉ No BATTERY CHECK: Sat

HV TEST ○ N/A ◉ Sat ○ Unsat

| | | | |
|---|---|---|---|
| AF INPUT SENSITIVITY (mV) #1: | 10 | AL INPUT SENSITIVITY (mV) #1: | A.F. |
| AF INPUT SENSITIVITY (mV) #2: | N/A | AL INPUT SENSITIVITY (mV) #2 : | N/A |
| AF INPUT SENSITIVITY (mV) #3: | N/A | AL INPUT SENSITIVITY (mV) #3: | N/A |
| AF INPUT SENSITIVITY (mV) #4: | N/A | AL INPUT SENSITIVITY (mV) #4: | N/A |

| RATE CPM | AS FOUND | % ERROR | AS LEFT | % ERROR |
|---|---|---|---|---|
| 250 | 251 | 0.4% | A.F. | |
| 2500 | 2492 | 0.3% | A.F. | |
| 25K | 24.885 K | 0.5% | A.F. | |
| 250K | 248.520 K | 0.5% | A.F. | |

Is the As Found Data Within 2% of the Set Point?:
◉ Yes ○ No

| DETECTOR 1: | | DETECTOR 2: | | DETECTOR 3: | | DETECTOR 4: | |
|---|---|---|---|---|---|---|---|
| AF 1-6 | AL 1-6 | AF 1-6 | AL 1-6 | AF 1-6 | AL 1-6 | AF 1-6 | AL 1-6 |
| 0000 S-6 | A.F. | N/A | N/A | N/A | N/A | N/A | N/A |
| 0100 -2 | A.F. | N/A | N/A | N/A | N/A | N/A | N/A |
| c/ | A.F. | N/A | N/A | N/A | N/A | N/A | N/A |
| m | A.F. | N/A | N/A | N/A | N/A | N/A | N/A |
| 100 | A.F. | N/A | N/A | N/A | N/A | N/A | N/A |
| 000 s | A.F. | N/A | N/A | N/A | N/A | N/A | N/A |

REMARKS: Client requested cal. Re-set up with new 44-10 #RN012930 on 4/28/09.

Does Instrument Meet Final Acceptance Criteria?: ◉ Yes ○ No

Calibration Sticker Attached?: ◉ Yes ○ No

Date Instrument is Due For Next Calibration: 01/13/10

INSTRUMENT MARRIED WITH 44-10 # RN012930

Performed/Reviewed by: Joanne Glenn Date: 1/13/2009 Entered by: ____ Initials



Calibrations performed to ANSI N323A-1997 standards.

# GRIFFIN INSTRUMENTS

## CALIBRATION CERTIFICATE FOR 44-10 PROBE # RN012930

Owner: CHASE ENV

DATE: 04/28/09 LOCATION: Griffin Inst
TECH: Joanne Glenn DATE LAST CAL EXPIRES: 08/19/09

○ Due For Calibration ◉ Other (See Remarks) Cable Length: 5'
○ Repair (See Remarks) ○ Due and Repair L.S.: 10 mV

NIST TRACEABLE EQUIPMENT AND STANDARDS USED DURING CALIBRATION

MODEL: 2241 SERIAL #: 215484 CAL. DUE: 01/13/10

SOURCE #: 99-1816 ISOTOPE: Cs137 ACTIVITY: 1.23 uCi ASSAY DATE: 08/12/99

GEOMETRY: Jig upside down with source underneath, activity side up.

Physical Condition: ◉ Sat ○ Unsat

Efficiency From Last Calibration: 5.4% Previous HV Set Point: 1050 V

| Counts (CPM) | Background (CPM) | Net CPM: |
|---|---|---|
| 128140 | 10180 | 117960 |

AF Efficiency: 5.40%

Is the AF efficiency within 20% of the efficiency from the last calibration? ◉ Yes ○ No

Reproducibility: 128140 129080 129850 Average: 129023.33

Are the individual counts within 10% of the average? ◉ Yes ○ No

| High Voltage: | Source Response (CPM): | Background (CPM): | Net CPM: |
|---|---|---|---|
| 900 | 107980 | 5890 | 102090 |
| 950 | 119110 | 7760 | 111350 |
| 1000 | 122350 | 9450 | 112900 |
| 1050 | 128140 | 10180 | 117960 |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |

| HV | RESPONSE | BACKGROUND | NET CPM | |
|---|---|---|---|---|
| 1000 V | 122350 | 9450 | 112900 | Efficiency: 5.17% |

REMARKS: Calibrated with new meter. Cal due 1/13/10 to match box.

Does Instrument Meet Final Acceptance Criteria?: ◉ Yes ○ No

Calibration Sticker Attached?: ◉ Yes ○ No

Date Instrument Is Due For Next Calibration: 01/13/10

INSTRUMENT MARRIED WITH 2241 # 215484

Performed/Reviewed by: Joanne Glenn Date: 4/28/2009 Entered by: ____ Initials



Calibrations performed to ANSI N323A-1997 standards

# GRIFFIN INSTRUMENTS

## CALIBRATION CERTIFICATE FOR MICRO REM SERIAL# B226L

Owner: CHASE ENV

DATE: 08/19/09 LOCATION: Griffin Inst

TECH: Joanne Glenn DATE LAST CAL EXPIRES: 09/11/09

REASON FOR CALIBRATION: Due for Calibration

NIST TRACEABLE EQUIPMENT AND SOURCES USED DURING CALIBRATION

PULSER MODEL: MP-2 PULSER SERIAL: 1000 PULSER CAL DUE: 07/13/10

SOURCE NUMBE 10250 ISOTOPE: Cs137 ASSAY DATE: 08/30/07

☑ Geotropism TEMP 71.6 F BARO PRESS: 30.08" HUMIDITY 42%

| | A.F.Data | A.F. % ERROR | A.L.Data | A.L. % ERROR | |
|---|---|---|---|---|---|
| uR/hr | | | | | |
| x0.1 Scale* | 4 | 0.0% | A.F. | | *Pulsed Scale |
| x0.1 Scale* | 16.5 | 3.1% | A.F. | | |
| x1 Scale* | 40 | 0.0% | A.F. | | |
| x1 Scale* | 160 | 0.0% | A.F. | | |
| mR/hr | | | | | |
| x10 Scale | 0.4 | 0.0% | A.F. | | |
| x10 Scale | 1.0 | 0.0% | A.F. | | |
| x10 Scale | 1.6 | 0.0% | A.F. | | |
| x100 Scale | 4 | 0.0% | A.F. | | |
| x100 Scale | 10 | 0.0% | A.F. | | |
| x100 Scale | 15.25 | 4.7% | A.F. | | |
| x1000 Scale | 40 | 0.0% | A.F. | | |
| x1000 Scale | 100 | 0.0% | A.F. | | |
| x1000 Scale | 150 | 6.3% | A.F. | | |

Is the As Found Data Within 20% of the Set Point?:

◉ Yes ○ No, See Remarks

REMARKS:

Does Instrument Meet Final Acceptance Criteria?: ◉ Yes ○ No

Calibration Sticker Attached?: ◉ Yes ○ No

Date Instrument is Due For Next Calibration: 08/19/10

Performed/Reviewed by: Joanne Glenn Date: 8/19/2009 Entered by:_____Initials

Calibrations performed to ANSI N323A-1997 standards.

# Appendix D
# Struct Surfaces Results

Radiological Survey Record

| Location: Ball State University | Area: Neutron Generator Vault | Survey: V01-0101 | Date: 12/16/2009 | Time: 4:00 PM |
|---|---|---|---|---|
| Surveyor: Ken Gavlik | Reviewed: Mike Culp | Notes: Final Status Survey | | |

| Instrument / Serial # Detector / Serial # | Source Check | Cal. Due | Alpha/ Beta | Total/ Removable | Bkgd (cpm) | Efficiency | Count Time (min) Sample | Count Time (min) Bkg. | Area ($cm^2$) | MDC ($dpm/100cm^2$) |
|---|---|---|---|---|---|---|---|---|---|---|
| Ludlum 2241-3 / 253346 43-68 / PR216394 | SAT | 8/18/2010 | Beta | Total | 138 | 15.40% | 1 | 1 | 126 | 297 |
| Ludlum 2929 / 149121 43-10-1 /PR150791 | SAT | 10/28/2010 | Beta | Removable | 48 | 9.35% | 3 | 10 | 100 | 171 |

| Location | Total Surface Activity: Gross Counts | Net CPM | Activity ($dpm/100cm^2$) | Notes | Removable Surface Activity: Gross Counts | Net CPM | Activity ($dpm/100cm^2$) | Notes | Description |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 136 | -2 | -10 | <MDC | 143 | 0 | -4 | <MDC | Ceiling |
| 2 | 165 | 27 | 139 | <MDC | 144 | 0 | 0 | <MDC | Ceiling |
| 3 | 145 | 7 | 36 | <MDC | 137 | -2 | -25 | <MDC | Ceiling |
| 4 | 142 | 4 | 21 | <MDC | 145 | 0 | 4 | <MDC | Ceiling |
| 5 | 176 | 38 | 196 | <MDC | 159 | 5 | 53 | <MDC | Ceiling |
| 6 | 134 | -4 | -21 | <MDC | 146 | 1 | 7 | <MDC | Ceiling |
| 7 | 170 | 32 | 165 | <MDC | 136 | -3 | -29 | <MDC | Wall |
| 8 | 171 | 33 | 170 | <MDC | 141 | -1 | -11 | <MDC | Wall |
| 9 | 192 | 54 | 278 | <MDC | 138 | -2 | -21 | <MDC | Wall |
| 10 | 132 | -6 | -31 | <MDC | 118 | -9 | -93 | <MDC | Wall |
| 11 | 146 | 8 | 41 | <MDC | 127 | -6 | -61 | <MDC | Wall |
| 12 | 146 | 8 | 41 | <MDC | 137 | -2 | -25 | <MDC | Wall |
| 13 | 174 | 36 | 186 | <MDC | 139 | -2 | -18 | <MDC | Floor |
| 14 | 156 | 18 | 93 | <MDC | 136 | -3 | -29 | <MDC | Floor |
| 15 | 131 | -7 | -36 | <MDC | 148 | 1 | 14 | <MDC | Floor |
| 16 | 151 | 13 | 67 | <MDC | 140 | -1 | -14 | <MDC | Floor |
| 17 | 217 | 79 | 407 | | 139 | -2 | -18 | <MDC | Floor |
| 18 | 152 | 14 | 72 | <MDC | 156 | 4 | 43 | <MDC | Floor |

| | | | |
|---|---|---|---|
| (1-23) min: | -36 | (1-23) min: | -93 |
| (1-23) max: | 407 | (1-23) max: | 53 |
| (1-23) average: | 98 | (1-23) average: | -13 |
| (1-23) SD: | 108 | (1-23) SD: | 31 |

Radiological Survey Record

| Location: Ball State University | Area: Neutron Generator Vault | Survey: V01-0101 | Date: 12/16/2009 | Time: 4:00 PM |
|---|---|---|---|---|
| Surveyor: Ken Gavlik | Reviewed: Mike Culp | Notes: Final Status Survey | | |

| Instrument / Serial # Detector / Serial # | Source Check | Cal. Due | Alpha/ Beta | Total/ Removable | Bkgd (cpm) | Efficiency | Count Time (min) Sample | Count Time (min) Bkg. | Area ($cm^2$) | MDC ($dpm/100cm^2$) |
|---|---|---|---|---|---|---|---|---|---|---|
| Ludlum 2241-3 / 253346 43-68 / PR216394 | SAT | 8/18/2010 | Beta | Total | 138 | 15.40% | 1 | 1 | 126 | 297 |
| Ludlum 2929 / 149121 43-10-1 /PR150791 | SAT | 10/28/2010 | Beta | Removable | 48 | 9.35% | 3 | 10 | 100 | 171 |

| Location | Total Surface Activity: Gross Counts | Net CPM | Activity ($dpm/100cm^2$) | Notes | Removable Surface Activity: Gross Counts | Net CPM | Activity ($dpm/100cm^2$) | Notes | Description |
|---|---|---|---|---|---|---|---|---|---|
| 19 | 157 | 19 | **98** | <MDC | 144 | 0 | **0** | <MDC | Wall |
| 20 | 133 | -5 | **-26** | <MDC | 137 | -2 | **-25** | <MDC | Wall |
| 21 | 156 | 18 | **93** | <MDC | 147 | 1 | **11** | <MDC | Wall |
| 22 | 160 | 22 | **113** | <MDC | 134 | -3 | **-36** | <MDC | Wall |
| 23 | 169 | 31 | **160** | <MDC | 132 | -4 | **-43** | <MDC | Wall |
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| | | | |
|---|---|---|---|
| (1-23) min: | -36 | (1-23) min: | -93 |
| (1-23) max: | 407 | (1-23) max: | 53 |
| (1-23) average: | 98 | (1-23) average: | -13 |
| (1-23) SD: | 108 | (1-23) SD: | 31 |

Radiological Survey Record

| **Location:** Ball State University | **Area:** Neutron Generator Vault | **Survey:** V01-0101 | **Date:** 12/16/2009 | **Time:** 4:00 PM |
|---|---|---|---|---|
| **Surveyor: Ken Gavlik** | **Reviewed:** Mike Culp | **Notes:** Final Status Survey | | |

| **Instrument / Serial # Detector / Serial #** | **Source Check** | **Cal. Due** | **Alpha/ Beta** | **Total/ Removable** | **Bkgd (cpm)** | **Efficiency** | **Count Time (min) Sample** | **Count Time (min) Bkg.** | **Area ($cm^2$)** | **MDC ($dpm/100cm^2$)** |
|---|---|---|---|---|---|---|---|---|---|---|
| Ludlum 2241-3 / 253346 43-68 / PR216394 | SAT | 8/18/2010 | Beta | Total | 138 | 15.40% | 1 | 1 | 126 | 297 |
| LSC Beckman 6500 | SAT | N/A | Beta | Removable | 0 | 60.00% | 1 | 1 | 100 | 5 |

| **Location** | **Total Surface Activity** | | | | **Removable H-3 Surface Activity** | | | | **Description** |
|---|---|---|---|---|---|---|---|---|---|
| | **Gross Counts** | **Net CPM** | **Activity ($dpm/100cm^2$)** | **Notes** | **Gross Counts** | **Net CPM** | **Activity ($dpm/100cm^2$)** | **Notes** | |
| 1 | N/A | N/A | N/A | | 15 | 15 | **25** | | Ceiling |
| 2 | N/A | N/A | N/A | | 10 | 10 | **17** | | Ceiling |
| 3 | N/A | N/A | N/A | | 20 | 20 | **33** | | Ceiling |
| 4 | N/A | N/A | N/A | | 25 | 25 | **42** | | Ceiling |
| 5 | N/A | N/A | N/A | | 22 | 22 | **37** | | Ceiling |
| 6 | N/A | N/A | N/A | | 19 | 19 | **32** | | Ceiling |
| 7 | N/A | N/A | N/A | | 14 | 14 | **23** | | Wall |
| 8 | N/A | N/A | N/A | | 13 | 13 | **22** | | Wall |
| 9 | N/A | N/A | N/A | | 15 | 15 | **25** | | Wall |
| 10 | N/A | N/A | N/A | | 12 | 12 | **20** | | Wall |
| 11 | N/A | N/A | N/A | | 12 | 12 | **20** | | Wall |
| 12 | N/A | N/A | N/A | | 12 | 12 | **20** | | Wall |
| 13 | N/A | N/A | N/A | | 20 | 20 | **33** | | Floor |
| 14 | N/A | N/A | N/A | | 14 | 14 | **23** | | Floor |
| 15 | N/A | N/A | N/A | | 13 | 13 | **22** | | Floor |
| 16 | N/A | N/A | N/A | | 12 | 12 | **20** | | Floor |
| 17 | N/A | N/A | N/A | | 13 | 13 | **22** | | Floor |
| 18 | N/A | N/A | N/A | | 12 | 12 | **20** | | Floor |

(1-23) min: 13
(1-23) max: 42
(1-23) average: 24
(1-23) SD: 7

Radiological Survey Record

| **Location:** Ball State University | **Area:** Neutron Generator Vault | **Survey:** V01-0101 | **Date:** 12/16/2009 | **Time:** 4:00 PM |
|---|---|---|---|---|
| **Surveyor:** Ken Gavlik | **Reviewed:** Mike Culp | **Notes:** Final Status Survey | | |

| **Instrument / Serial # Detector / Serial #** | **Source Check** | **Cal. Due** | **Alpha/ Beta** | **Total/ Removable** | **Bkgd (cpm)** | **Efficiency** | **Count Time (min) Sample** | **Count Time (min) Bkg.** | **Area ($cm^2$)** | **MDC ($dpm/100cm^2$)** |
|---|---|---|---|---|---|---|---|---|---|---|
| Ludlum 2241-3 / 253346 43-68 / PR216394 | SAT | 8/18/2010 | Beta | Total | 138 | 15.40% | 1 | 1 | 126 | 297 |
| LSC Beckman 6500 | SAT | N/A | Beta | Removable | 0 | 60.00% | 1 | 1 | 100 | 5 |

| **Location** | **Total Surface Activity** | | | | **Removable H-3 Surface Activity** | | | | **Description** |
|---|---|---|---|---|---|---|---|---|---|
| | **Gross Counts** | **Net CPM** | **Activity ($dpm/100cm^2$)** | **Notes** | **Gross Counts** | **Net CPM** | **Activity ($dpm/100cm^2$)** | **Notes** | |
| 19 | N/A | N/A | N/A | | 12 | 12 | **20** | | Wall |
| 20 | N/A | N/A | N/A | | 14 | 14 | **23** | | Wall |
| 21 | N/A | N/A | N/A | | 8 | 8 | **13** | | Wall |
| 22 | N/A | N/A | N/A | | 11 | 11 | **18** | | Wall |
| 23 | N/A | N/A | N/A | | 13 | 13 | **22** | | Wall |

(1-23) min: 13
(1-23) max: 42
(1-23) average: 24
(1-23) SD: 7

Radiological Survey Record

| Location: Ball State University | Area: Neutron Generator Vault | Survey:QA-V01-0101 | Date: 12/17/2009 | Time: 9:00 AM |
|---|---|---|---|---|
| Surveyor: Mike Culp | Reviewed: Ken Gavlik | Notes: Final Status Survey 5% QA | | |

| Instrument / Serial # Detector / Serial # | Source Check | Cal. Due | Alpha/ Beta | Total/ Removable | Bkgd (cpm) | Efficiency | Count Time (min) Sample | Count Time (min) Bkg. | Area ($cm^2$) | MDC ($dpm/100cm^2$) |
|---|---|---|---|---|---|---|---|---|---|---|
| Ludlum 2241-3 / 253346 43-68 / PR216394 | SAT | 8/18/2010 | Beta | Total | 134 | 15.40% | 1 | 1 | 126 | 293 |
| Ludlum 2929 / 149121 43-10-1 /PR150791 | SAT | 10/28/2010 | Beta | Removable | 43 | 9.35% | 3 | 10 | 100 | 163 |

| Location | Total Surface Activity: Gross Counts | Net CPM | Activity ($dpm/100cm^2$) | Notes | Removable Surface Activity: Gross Counts | Net CPM | Activity ($dpm/100cm^2$) | Notes | Description |
|---|---|---|---|---|---|---|---|---|---|
| 2 | 162 | 28 | 144 | <MDC | 136 | 2 | 25 | <MDC | Ceiling |
| 15 | 208 | 74 | 381 | | 113 | -5 | -57 | <MDC | Floor |
| 19 | 133 | -1 | -5 | <MDC | 112 | -6 | -61 | <MDC | Wall |
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|---|---|---|---|
| min: | -5 | min: | -61 |
| max: | 381 | max: | 25 |
| average: | 174 | average: | -31 |
| SD: | 195 | SD: | 48 |

Radiological Survey Record

| Location: Ball State University | Area: Neutron Generator Vault | Survey:QA-V01-0101 | Date: 12/17/2009 | Time: 9:00 AM |
|---|---|---|---|---|
| Surveyor: Mike Culp | Reviewed: Ken Gavlik | Notes: Final Status Survey 5% QA | | |

| Instrument / Serial # Detector / Serial # | Source Check | Cal. Due | Alpha/ Beta | Total/ Removable | Bkgd (cpm) | Efficiency | Count Time (min) Sample | Count Time (min) Bkg. | Area ($cm^2$) | MDC ($dpm/100cm^2$) |
|---|---|---|---|---|---|---|---|---|---|---|
| Ludlum 2241-3 / 253346 43-68 / PR216394 | SAT | 8/18/2010 | Beta | Total | 134 | 15.40% | 1 | 1 | 126 | 293 |
| LSC Beckman 6500 | SAT | N/A | Beta | Removable | 0 | 60.00% | 1 | 1 | 100 | 5 |

| Location | Total Surface Activity Gross Counts | Net CPM | Activity ($dpm/100cm^2$) | Notes | Removable H-3 Surface Activity Gross Counts | Net CPM | Activity ($dpm/100cm^2$) | Notes | Description |
|---|---|---|---|---|---|---|---|---|---|
| 2 | N/A | N/A | N/A | | 21 | 21 | 35 | | Ceiling |
| 15 | N/A | N/A | N/A | | 21 | 21 | 35 | | Floor |
| 19 | N/A | N/A | N/A | | 13 | 13 | 22 | | Wall |
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|---|---|---|---|
| min: | 0 | min: | 22 |
| max: | 0 | max: | 35 |
| average: | #DIV/0! | average: | 31 |
| SD: | #DIV/0! | SD: | 8 |

**Appendix F**
**Systems Results**

Radiological Survey Record

| **Location:** Ball State University | **Area:** Neutron Generator Vault | **Survey:Systems** | **Date:** 12/16/2009 | **Time:** 3:00 PM |
|---|---|---|---|---|
| **Surveyor: Mike Culp** | **Reviewed:** Ken Gavlik | **Notes:** | | |

| **Instrument / Serial # Detector / Serial #** | **Source Check** | **Cal. Due** | **Alpha/ Beta** | **Total/ Removable** | **Bkgd (cpm)** | **Efficiency** | **Count Time (min) Sample** | **Bkg.** | **Area ($cm^2$)** | **MDC ($dpm/100cm^2$)** |
|---|---|---|---|---|---|---|---|---|---|---|
| Ludlum 2241-3 / 253346 43-68 / PR216394 | SAT | 8/18/2010 | Beta | Total | 138 | 15.40% | 1 | 1 | 126 | 297 |
| Ludlum 2929 / 149121 43-10-1 /PR150791 | SAT | 10/28/2010 | Beta | Removable | 48 | 9.35% | 3 | 10 | 100 | 171 |

| **Location** | **Total Surface Activity** | | | | **Removable Surface Activity** | | | | **Description** |
|---|---|---|---|---|---|---|---|---|---|
| | **Gross Counts** | **Net CPM** | **Activity ($dpm/100cm^2$)** | **Notes** | **Gross Counts** | **Net CPM** | **Activity ($dpm/100cm^2$)** | **Notes** | |
| 48 | 137 | -1 | -5 | <MDC | 138 | -2 | -21 | <MDC | Ventilation |
| 51 | 216 | 78 | 402 | | 154 | 3 | 36 | <MDC | Drain Sump |
| | | | | | | | | | |
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|---|---|---|---|
| min: | -5 | min: | -21 |
| max: | 402 | max: | 36 |
| average: | 198 | average: | 7 |
| SD: | 288 | SD: | 40 |

Radiological Survey Record

| **Location:** Ball State University | **Area:** Neutron Generator Vault | **Survey:Systems** | **Date:** 12/16/2009 | **Time:** 3:00 PM |
|---|---|---|---|---|
| **Surveyor: Mike Culp** | **Reviewed:** Ken Gavlik | **Notes:** | | |

| **Instrument / Serial # Detector / Serial #** | **Source Check** | **Cal. Due** | **Alpha/ Beta** | **Total/ Removable** | **Bkgd (cpm)** | **Efficiency** | **Count Time (min) Sample** | **Count Time (min) Bkg.** | **Area ($cm^2$)** | **MDC ($dpm/100cm^2$)** |
|---|---|---|---|---|---|---|---|---|---|---|
| Ludlum 2241-3 / 253346 43-68 / PR216394 | SAT | 8/18/2010 | Beta | Total | 138 | 15.40% | 1 | 1 | 126 | 297 |
| LSC Beckman 6500 | SAT | N/A | Beta | Removable | 0 | 60.00% | 1 | 1 | 100 | 5 |

| **Location** | **Total Surface Activity** | | | | **Removable H-3 Surface Activity** | | | | **Description** |
|---|---|---|---|---|---|---|---|---|---|
| | **Gross Counts** | **Net CPM** | **Activity ($dpm/100cm^2$)** | **Notes** | **Gross Counts** | **Net CPM** | **Activity ($dpm/100cm^2$)** | **Notes** | |
| 48 | N/A | N/A | N/A | | 10 | 10 | **17** | | Ventilation |
| 51 | N/A | N/A | N/A | | 160 | 160 | **267** | | Drain Sump |
| | | | | | | | | | |
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|---|---|---|---|
| min: | 0 | min: | 17 |
| max: | 0 | max: | 267 |
| average: | #DIV/0! | average: | 142 |
| SD: | #DIV/0! | SD: | 177 |

**Appendix G**
**Mat'l Release Results**

Radiological Survey Record

| Location: Ball State University | | Area: Neutron Generator Vault | | Survey: Release of Materials | | | Date: 12/15/2009 | | Time: 3:00 PM | |
|---|---|---|---|---|---|---|---|---|---|---|
| Surveyor: Ken Gavlik | | Reviewed: Mike Culp | | Notes: Free release surveys of materials and equipment from vault | | | | | | |
| Instrument / Serial # Detector / Serial # | Source Check | Cal. Due | Alpha/ Beta | Total/ Removable | Bkgd (cpm) | Efficiency | Count Time (min) Sample | Count Time (min) Bkg. | Area ($cm^2$) | MDC ($dpm/100cm^2$) |
| Ludlum 2241-3 / 253346 43-68 / PR216394 | SAT | 8/18/2010 | Beta | Total | 137 | 15.40% | 1 | 1 | 126 | 296 |
| Ludlum 2929 / 149121 43-10-1 /PR150791 | SAT | 10/28/2010 | Beta | Removable | 45 | 9.35% | 3 | 10 | 100 | 166 |

| Location | Total Surface Activity | | | | Removable Surface Activity | | | | Description |
|---|---|---|---|---|---|---|---|---|---|
| | Gross Counts | Net CPM | Activity ($dpm/100cm^2$) | Notes | Gross Counts | Net CPM | Activity ($dpm/100cm^2$) | Notes | |
| 1 | 125 | -12 | **-62** | <MDC | 134 | 0 | **-4** | <MDC | Ionization Vacuum Gauge |
| 2 | 142 | 5 | **26** | <MDC | 132 | -1 | **-11** | <MDC | Ionization Vacuum Gauge |
| 3 | 135 | -2 | **-10** | <MDC | 145 | 3 | **36** | <MDC | Power Guard |
| 4 | 128 | -9 | **-46** | <MDC | 147 | 4 | **43** | <MDC | Harrison 6516A DC Power Supply |
| 5 | 141 | 4 | **21** | <MDC | 137 | 1 | **7** | <MDC | Harrison 6516A DC Power Supply |
| 6 | 112 | -25 | **-129** | <MDC | 132 | -1 | **-11** | <MDC | Thermocouple Ionization Control |
| 7 | 138 | 1 | **5** | <MDC | 140 | 2 | **18** | <MDC | Powercord |
| 8 | 123 | -14 | **-72** | <MDC | 132 | -1 | **-11** | <MDC | Powercord |
| 9 | 140 | 3 | **15** | <MDC | 168 | 11 | **118** | <MDC | Ortec Highvoltage Power Supply |
| 10 | 127 | -10 | **-52** | <MDC | 156 | 7 | **75** | <MDC | Ortec Highvoltage Power Supply |
| 11 | 120 | -17 | **-88** | <MDC | 141 | 2 | **21** | <MDC | Harrison 6516A DC Power Supply |
| 12 | 139 | 2 | **10** | <MDC | 151 | 5 | **57** | <MDC | Harrison 6516A DC Power Supply |
| 13 | 139 | 2 | **10** | <MDC | 126 | -3 | **-32** | <MDC | Vacuum Pump |
| 14 | 132 | -5 | **-26** | <MDC | 145 | 3 | **36** | <MDC | Kinney Vacuum |
| 15 | 119 | -18 | **-93** | <MDC | 155 | 7 | **71** | <MDC | Poly Source Storage |
| 16 | 135 | -2 | **-10** | <MDC | 146 | 4 | **39** | <MDC | Poly Source Storage |
| 17 | 121 | -16 | **-82** | <MDC | 174 | 13 | **139** | <MDC | Light |
| 18 | 161 | -440 | **-2268** | <MDC | 161 | 9 | **93** | <MDC | Light |

| | |
|---|---|
| min: | -2268 |
| max: | 26 |
| average: | -158 |
| SD: | 528 |

| | |
|---|---|
| min: | -32 |
| max: | 139 |
| average: | 38 |
| SD: | 47 |

Radiological Survey Record

| Location: Ball State University | Area: Neutron Generator Vault | Survey: Release of Materials | Date: 12/15/2009 | Time: 3:00 PM |
|---|---|---|---|---|
| Surveyor: Ken Gavlik | Reviewed: Mike Culp | Notes: Free release surveys of materials and equipment from vault | | |

| Instrument / Serial # Detector / Serial # | Source Check | Cal. Due | Alpha/ Beta | Total/ Removable | Bkgd (cpm) | Efficiency | Count Time (min) Sample | Count Time (min) Bkg. | Area ($cm^2$) | MDC ($dpm/100cm^2$) |
|---|---|---|---|---|---|---|---|---|---|---|
| Ludlum 2241-3 / 253346 43-68 / PR216394 | SAT | 8/18/2010 | Beta | Total | 137 | 15.40% | 1 | 1 | 126 | 296 |
| Ludlum 2929 / 149121 43-10-1 /PR150791 | SAT | 10/28/2010 | Beta | Removable | 45 | 9.35% | 3 | 10 | 100 | 166 |

| Location | Total Surface Activity: Gross Counts | Net CPM | Activity ($dpm/100cm^2$) | Notes | Removable Surface Activity: Gross Counts | Net CPM | Activity ($dpm/100cm^2$) | Notes | Description |
|---|---|---|---|---|---|---|---|---|---|
| 19 | 164 | 27 | **139** | <MDC | 155 | 7 | **71** | <MDC | Light |
| 20 | 135 | -2 | **-10** | <MDC | 129 | -2 | **-21** | <MDC | Lamp |
| 21 | 125 | -12 | **-62** | <MDC | 144 | 3 | **32** | <MDC | Intercomm |
| 22 | 149 | 12 | **62** | <MDC | 153 | 6 | **64** | <MDC | Powercords |
| 23 | 125 | -12 | **-62** | <MDC | 143 | 3 | **29** | <MDC | Flask Stand |
| 24 | 156 | 19 | **98** | <MDC | 143 | 3 | **29** | <MDC | Hastings Vacuum Pump |
| 25 | 140 | 3 | **15** | <MDC | 131 | -1 | **-14** | <MDC | Vacuum Pump |
| 26 | 132 | -5 | **-26** | <MDC | 162 | 9 | **96** | <MDC | Box Powercords |
| 27 | **54943** | **54806** | **282447** | | 157 | 7 | **78** | <MDC | Target Holder **(Disposed of as Rad Waste)** |
| 28 | **82717** | **82580** | **425582** | | 137 | 1 | **7** | <MDC | Beam Tube Internal **(Diposed of as Rad Waste)** |
| 29 | 152 | 15 | **77** | <MDC | 161 | 9 | **93** | <MDC | RAD Box DAW |
| 30 | 142 | 5 | **26** | <MDC | 137 | 1 | **7** | <MDC | RAD Box Beam Tubes |
| 31 | 143 | 6 | **31** | <MDC | 150 | 5 | **53** | <MDC | RAD Box Beam Stop, Diff Pump Tube |
| 32 | 141 | 4 | **21** | <MDC | 147 | 4 | **43** | <MDC | Stool |
| 33 | 121 | -16 | **-82** | <MDC | 149 | 5 | **50** | <MDC | Powercords |
| 34 | 134 | -3 | **-15** | <MDC | 166 | 10 | **111** | <MDC | Chair |
| 35 | 125 | -12 | **-62** | <MDC | 149 | 5 | **50** | <MDC | RAD Box Diff Pump Gate Valve |
| 36 | 121 | -12 | **-62** | <MDC | 139 | 1 | **14** | <MDC | RAD Box DAW (Tubing) |

| | |
|---|---|
| min: | -82 |
| max: | 425582 |
| average: | 39340 |
| SD: | 117082 |

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|---|---|
| min: | -21 |
| max: | 111 |
| average: | 44 |
| SD: | 38 |

Radiological Survey Record

| Location: Ball State University | Area: Neutron Generator Vault | Survey: Release of Materials | Date: 12/16/2009 | Time: 3:00 PM |
|---|---|---|---|---|
| Surveyor: Ken Gavlik | Reviewed: Mike Culp | Notes: Free release surveys of materials and equipment from vault | | |

| Instrument / Serial # Detector / Serial # | Source Check | Cal. Due | Alpha/ Beta | Total/ Removable | Bkgd (cpm) | Efficiency | Count Time (min) Sample | Count Time (min) Bkg. | Area ($cm^2$) | MDC ($dpm/100cm^2$) |
|---|---|---|---|---|---|---|---|---|---|---|
| Ludlum 2241-3 / 253346 43-68 / PR216394 | SAT | 8/18/2010 | Beta | Total | 138 | 15.40% | 1 | 1 | 126 | 297 |
| Ludlum 2929 / 149121 43-10-1 /PR150791 | SAT | 10/28/2010 | Beta | Removable | 48 | 9.35% | 3 | 10 | 100 | 171 |

| Location | Total Surface Activity: Gross Counts | Net CPM | Activity ($dpm/100cm^2$) | Notes | Removable Surface Activity: Gross Counts | Net CPM | Activity ($dpm/100cm^2$) | Notes | Description |
|---|---|---|---|---|---|---|---|---|---|
| 37 | 135 | -3 | **-15** | <MDC | 141 | -1 | **-11** | <MDC | Neutron Generator Stand |
| 38 | 139 | 1 | **5** | <MDC | 149 | 2 | **18** | <MDC | Neutron Generator Stand |
| 39 | 126 | -12 | **-62** | <MDC | 133 | -4 | **-39** | <MDC | Neutron Generator Stand |
| 40 | 136 | -2 | **-10** | <MDC | 148 | 1 | **14** | <MDC | Neutron Generator Stand |
| 41 | 135 | -3 | **-15** | <MDC | 121 | -8 | **-82** | <MDC | Neutron Generator Stand (Disposed of as Rad Waste) |
| 42 | 147 | 9 | **46** | <MDC | 139 | -2 | **-18** | <MDC | Neutron Generator Stand (Disposed of as Rad Waste) |
| 43 | 168 | 30 | **155** | <MDC | 152 | 3 | **29** | <MDC | Neutron Generator Stand (Disposed of as Rad Waste) |
| 44 | 137 | -1 | **-5** | <MDC | 148 | 1 | **14** | <MDC | Neutron Generator Stand |
| 45 | 141 | 3 | 15 | <MDC | 143 | 0 | **-4** | <MDC | Transformer |
| 46 | 105 | -33 | -170 | <MDC | 162 | 6 | **64** | <MDC | Transformer |
| 47 | 97 | -41 | **-211** | <MDC | 149 | 2 | **18** | <MDC | Steel Ramp |
| 48 | 137 | -1 | **-5** | <MDC | 138 | -2 | **-21** | <MDC | Ventilation |
| 49 | 144 | 6 | **31** | <MDC | 142 | -1 | **-7** | <MDC | Metal Container |
| 50 | 121 | -17 | **-88** | <MDC | 149 | 2 | **18** | <MDC | Metal Container |
| 51 | 216 | 78 | **402** | | 154 | 3 | **36** | <MDC | Drain Sump |
| 52 | 136 | -2 | **-10** | <MDC | 141 | -1 | **-11** | <MDC | Metal Can |
| 53 | 139 | 1 | **5** | <MDC | 155 | 4 | **39** | <MDC | Metal Can |
| 54 | 141 | 3 | **15** | <MDC | 135 | -3 | **-32** | <MDC | Metal Can |

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|---|---|
| min: | -211 |
| max: | 402 |
| average: | 5 |
| SD: | 127 |

| | |
|---|---|
| min: | -82 |
| max: | 64 |
| average: | 1 |
| SD: | 34 |

Radiological Survey Record

| Location: Ball State University | Area: Neutron Generator Vault | Survey: Release of Materials | Date: 12/16/2009 | Time: 3:00 PM |
|---|---|---|---|---|
| Surveyor: Ken Gavlik | Reviewed: Mike Culp | Notes: Free release surveys of materials and equipment from vault | | |

| Instrument / Serial # Detector / Serial # | Source Check | Cal. Due | Alpha/ Beta | Total/ Removable | Bkgd (cpm) | Efficiency | Count Time (min) Sample | Count Time (min) Bkg. | Area ($cm^2$) | MDC ($dpm/100cm^2$) |
|---|---|---|---|---|---|---|---|---|---|---|
| Ludlum 2241-3 / 253346 43-68 / PR216394 | SAT | 8/18/2010 | Beta | Total | 137 | 15.40% | 1 | 1 | 126 | 296 |
| Ludlum 2929 / 149121 43-10-1 /PR150791 | SAT | 10/28/2010 | Beta | Removable | 48 | 9.35% | 3 | 10 | 100 | 171 |

| Location | Total Surface Activity: Gross Counts | Net CPM | Activity ($dpm/100cm^2$) | Notes | Removable Surface Activity: Gross Counts | Net CPM | Activity ($dpm/100cm^2$) | Notes | Description |
|---|---|---|---|---|---|---|---|---|---|
| 55 | 156 | 19 | 98 | <MDC | 151 | 2 | 25 | <MDC | Metal Can |
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|---|---|---|---|
| min: | 98 | min: | 25 |
| max: | 98 | max: | 25 |
| average: | 98 | average: | 25 |
| SD: | #DIV/0! | SD: | #DIV/0! |

Radiological Survey Record

| Location: Ball State University | Area: Neutron Generator Vault | Survey: Release of Materials | Date: 12/15/2009 | Time: 3:00 PM |
|---|---|---|---|---|
| Surveyor: Ken Gavlik | Reviewed: Mike Culp | Notes: Free release surveys of materials and equipment from vault | | |

| Instrument / Serial # Detector / Serial # | Source Check | Cal. Due | Alpha/ Beta | Total/ Removable | Bkgd (cpm) | Efficiency | Count Time (min) Sample | Count Time (min) Bkg. | Area ($cm^2$) | MDC ($dpm/100cm^2$) |
|---|---|---|---|---|---|---|---|---|---|---|
| Ludlum 2241-3 / 253346 43-68 / PR216394 | SAT | 8/18/2010 | Beta | Total | 137 | 15.40% | 1 | 1 | 126 | 296 |
| LSC Beckman 6500 | SAT | N/A | Beta | Removable | 0 | 60.00% | 1 | 1 | 100 | 5 |

| Location | Total Surface Activity Gross Counts | Net CPM | Activity ($dpm/100cm^2$) | Notes | Removable Surface Activity Gross Counts | Net CPM | Activity ($dpm/100cm^2$) | Notes | Description |
|---|---|---|---|---|---|---|---|---|---|
| 1 | N/A | N/A | N/A | | 17 | 17 | 28 | | Ionization Vacuum Gauge |
| 2 | N/A | N/A | N/A | | 18 | 18 | 30 | | Ionization Vacuum Gauge |
| 3 | N/A | N/A | N/A | | 22 | 22 | 37 | | Power Guard |
| 4 | N/A | N/A | N/A | | 10 | 10 | 17 | | Harrison 6516A DC Power Supply |
| 5 | N/A | N/A | N/A | | 11 | 11 | 18 | | Harrison 6516A DC Power Supply |
| 6 | N/A | N/A | N/A | | 13 | 13 | 22 | | Thermocouple Ionization Control |
| 7 | N/A | N/A | N/A | | 12 | 12 | 20 | | Powercord |
| 8 | N/A | N/A | N/A | | 11 | 11 | 18 | | Powercord |
| 9 | N/A | N/A | N/A | | 17 | 17 | 28 | | Ortec Highvoltage Power Supply |
| 10 | N/A | N/A | N/A | | 13 | 13 | 22 | | Ortec Highvoltage Power Supply |
| 11 | N/A | N/A | N/A | | 9 | 9 | 15 | | Harrison 6516A DC Power Supply |
| 12 | N/A | N/A | N/A | | 12 | 12 | 20 | | Harrison 6516A DC Power Supply |
| 13 | N/A | N/A | N/A | | 51 | 51 | 85 | | Vacuum Pump |
| 14 | N/A | N/A | N/A | | 9 | 9 | 15 | | Kinney Vacuum |
| 15 | N/A | N/A | N/A | | 83 | 83 | 138 | | Poly Source Storage |
| 16 | N/A | N/A | N/A | | 29 | 29 | 48 | | Poly Source Storage |
| 17 | N/A | N/A | N/A | | 8 | 8 | 13 | | Light |
| 18 | N/A | N/A | N/A | | 14 | 14 | 23 | | Light |

| | | | |
|---|---|---|---|
| min: | 0 | min: | 13 |
| max: | 0 | max: | 138 |
| average: | #DIV/0! | average: | 33 |
| SD: | #DIV/0! | SD: | 31 |

Radiological Survey Record

| Location: Ball State University | Area: Neutron Generator Vault | Survey: Release of Materials | Date: 12/15/2009 | Time: 3:00 PM |
|---|---|---|---|---|
| Surveyor: Ken Gavlik | Reviewed: Mike Culp | Notes: Free release surveys of materials and equipment from vault | | |

| Instrument / Serial # Detector / Serial # | Source Check | Cal. Due | Alpha/ Beta | Total/ Removable | Bkgd (cpm) | Efficiency | Count Time (min) Sample | Count Time (min) Bkg. | Area ($cm^2$) | MDC ($dpm/100cm^2$) |
|---|---|---|---|---|---|---|---|---|---|---|
| Ludlum 2241-3 / 253346 43-68 / PR216394 | SAT | 8/18/2010 | Beta | Total | 137 | 15.40% | 1 | 1 | 126 | 296 |
| LSC Beckman 6500 | SAT | N/A | Beta | Removable | 0 | 60.00% | 1 | 1 | 100 | 5 |

| Location | Total Surface Activity Gross Counts | Net CPM | Activity ($dpm/100cm^2$) | Notes | Removable Surface Activity Gross Counts | Net CPM | Activity ($dpm/100cm^2$) | Notes | Description |
|---|---|---|---|---|---|---|---|---|---|
| 19 | | | | | 13 | 13 | **22** | | Light |
| 20 | N/A | N/A | N/A | | 16 | 16 | **27** | | Lamp |
| 21 | N/A | N/A | N/A | | 18 | 18 | **30** | | Intercomm |
| 22 | N/A | N/A | N/A | | 16 | 16 | **27** | | Powercords |
| 23 | N/A | N/A | N/A | | 16 | 16 | **27** | | Flask Stand |
| 24 | N/A | N/A | N/A | | 19 | 19 | **32** | | Hastings Vacuum Pump |
| 25 | N/A | N/A | N/A | | 29 | 29 | **48** | | Vacuum Pump |
| 26 | N/A | N/A | N/A | | 18 | 18 | **30** | | Box Powercords |
| 27 | N/A | N/A | N/A | | **446016** | **446016** | **743360** | | **Target Holder (Disposed of as Rad Waste)** |
| 28 | N/A | N/A | N/A | | **918306** | **918306** | **1530510** | | **Beam Tube Internal (Diposed of as Rad Waste)** |
| 29 | N/A | N/A | N/A | | 26 | 26 | **43** | | RAD Box DAW |
| 30 | N/A | N/A | N/A | | 144 | 144 | **240** | | RAD Box Beam Tubes |
| 31 | N/A | N/A | N/A | | 26 | 26 | **43** | | RAD Box Beam Stop, Diff Pump Tube |
| 32 | N/A | N/A | N/A | | 43 | 43 | **72** | | Stool |
| 33 | N/A | N/A | N/A | | 35 | 35 | **58** | | Powercords |
| 34 | N/A | N/A | N/A | | 202 | 202 | **337** | | Chair |
| 35 | N/A | N/A | N/A | | 31 | 31 | **52** | | RAD Box Diff Pump Gate Valve |
| 36 | N/A | N/A | N/A | | 21 | 21 | **35** | | RAD Box DAW (Tubing) |

| | | | |
|---|---|---|---|
| min: | 0 | min: | 22 |
| max: | 0 | max: | 1530510 |
| average: | #DIV/0! | average: | 126388 |
| SD: | #DIV/0! | SD: | 391642 |

Radiological Survey Record

| Location: Ball State University | Area: Neutron Generator Vault | Survey: Release of Materials | Date: 12/16/2009 | Time: 3:00 PM |
|---|---|---|---|---|
| Surveyor: Ken Gavlik | Reviewed: Mike Culp | Notes: Free release surveys of materials and equipment from vault | | |

| Instrument / Serial # Detector / Serial # | Source Check | Cal. Due | Alpha/ Beta | Total/ Removable | Bkgd (cpm) | Efficiency | Count Time (min) Sample | Count Time (min) Bkg. | Area ($cm^2$) | MDC ($dpm/100cm^2$) |
|---|---|---|---|---|---|---|---|---|---|---|
| Ludlum 2241-3 / 253346 43-68 / PR216394 | SAT | 8/18/2010 | Beta | Total | 138 | 15.40% | 1 | 1 | 126 | 297 |
| LSC Beckman 6500 | SAT | N/A | Beta | Removable | 0 | 60.00% | 1 | 1 | 100 | 5 |

| Location | Total Surface Activity Gross Counts | Net CPM | Activity ($dpm/100cm^2$) | Notes | Removable Surface Activity Gross Counts | Net CPM | Activity ($dpm/100cm^2$) | Notes | Description |
|---|---|---|---|---|---|---|---|---|---|
| 37 | N/A | N/A | N/A | | 17 | 17 | **28** | | Neutron Generator Stand |
| 38 | N/A | N/A | N/A | | 46 | 46 | **77** | | Neutron Generator Stand |
| 39 | N/A | N/A | N/A | | 42 | 42 | **70** | | Neutron Generator Stand |
| 40 | N/A | N/A | N/A | | 26 | 26 | **43** | | Neutron Generator Stand |
| 41 | N/A | N/A | N/A | | 525 | 525 | **875** | | Neutron Generator Stand **(Disposed of as Rad Waste)** |
| 42 | N/A | N/A | N/A | | 158 | 158 | **263** | | Neutron Generator Stand **(Disposed of as Rad Waste)** |
| 43 | N/A | N/A | N/A | | 419 | 419 | **698** | | Neutron Generator Stand **(Disposed of as Rad Waste)** |
| 44 | N/A | N/A | N/A | | 13 | 13 | **22** | | Neutron Generator Stand |
| 45 | N/A | N/A | N/A | | 10 | 10 | **17** | | Transformer |
| 46 | N/A | N/A | N/A | | 17 | 17 | **28** | | Transformer |
| 47 | N/A | N/A | N/A | | 16 | 16 | **27** | | Steel Ramp |
| 48 | N/A | N/A | N/A | | 10 | 10 | **17** | | Ventilation |
| 49 | N/A | N/A | N/A | | 14 | 14 | **23** | | Metal Container |
| 50 | N/A | N/A | N/A | | 12 | 12 | **20** | | Metal Container |
| 51 | N/A | N/A | N/A | | 160 | 160 | **267** | | Drain Sump |
| 52 | N/A | N/A | N/A | | 13 | 13 | **22** | | Metal Can |
| 53 | N/A | N/A | N/A | | 13 | 13 | **22** | | Metal Can |
| 54 | N/A | N/A | N/A | | 22 | 22 | **37** | | Metal Can |

| | | | |
|---|---|---|---|
| min: | 0 | min: | 17 |
| max: | 0 | max: | 875 |
| average: | #DIV/0! | average: | 142 |
| SD: | #DIV/0! | SD: | 249 |

Radiological Survey Record

| Location: Ball State University | Area: Neutron Generator Vault | Survey: Release of Materials | Date: 12/16/2009 | Time: 3:00 PM |
|---|---|---|---|---|
| Surveyor: Ken Gavlik | Reviewed: Mike Culp | Notes: Free release surveys of materials and equipment from vault | | |

| Instrument / Serial # Detector / Serial # | Source Check | Cal. Due | Alpha/ Beta | Total/ Removable | Bkgd (cpm) | Efficiency | Count Time (min) Sample | Count Time (min) Bkg. | Area ($cm^2$) | MDC ($dpm/100cm^2$) |
|---|---|---|---|---|---|---|---|---|---|---|
| Ludlum 2241-3 / 253346 43-68 / PR216394 | SAT | 8/18/2010 | Beta | Total | 137 | 15.40% | 1 | 1 | 126 | 296 |
| LSC Beckman 6500 | SAT | N/A | Beta | Removable | 0 | 60.00% | 1 | 1 | 100 | 5 |

| Location | Total Surface Activity: Gross Counts | Net CPM | Activity ($dpm/100cm^2$) | Notes | Removable Surface Activity: Gross Counts | Net CPM | Activity ($dpm/100cm^2$) | Notes | Description |
|---|---|---|---|---|---|---|---|---|---|
| 55 | N/A | N/A | N/A | | 15 | 15 | 25 | | Metal Can |
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|---|---|---|---|
| min: | 0 | min: | 25 |
| max: | 0 | max: | 25 |
| average: | #DIV/0! | average: | 25 |
| SD: | #DIV/0! | SD: | #DIV/0! |