ENGINEERING CHANGE NOTICE

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1. ECN 655138

Proj. ECN N/A

2. ECN Category (mark one) Supplemental ☐ Direct Revision ☒ Change ECN ☐ Temporary ☐ Standby ☐ Supersedeure ☐ Cancel/Void ☐		3. Originator's Name, Organization, MSIN, and Telephone No. CE Wills, WRAP Engineering, T4-52, 373-9844		4. USQ Required? ☒ Yes ☐ No		5. Date 02/14/00	
		6. Project Title/No./Work Order No. TRU Waste/101692/AJ70		7. Bldg./Sys./Fac. No. 2336-W		8. Approval Designator Q	
		9. Document Numbers Changed by this ECN (includes sheet no. and rev.) HNF-5148, Rev. 0-A		10. Related ECN No(s). N/A		11. Related PO No. N/A	
12a. Modification Work ☐ Yes (fill out Blk. 12b) ☒ No (NA Blks. 12b, 12c, 12d)		12b. Work Package No. N/A		12c. Modification Work Completed N/A Design Authority/Cog. Engineer Signature & Date		12d. Restored to Original Condition (Temp. or Standby ECNs only) N/A Design Authority/Cog. Engineer Signature & Date	
13a. Description of Change This document is being revised in it's entirety to satisfy a WIPP audit recommendation and to incorporate GEA-A Multi Gamma Analysis (MGA) data.							
13b. Design Baseline Document? ☐ Yes ☒ No							
14a. Justification (mark one) Criteria Change ☐ Design Improvement ☐ Environmental ☐ Facility Deactivation ☐ As-Found ☒ Facilitate Const. ☐ Const. Error/Omission ☐ Design Error/Omission ☐							
14b. Justification Details Design verification not required USQ WRP-038							
15. Distribution (include name, MSIN, and no. of copies) See attached distribution sheet							

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DATE:	STA: 5		
		ID:	

ENGINEERING CHANGE NOTICE

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1. ECN (use no. from pg. 1)

ECN-655138

16. Design Verification Required

☐ Yes
☒ No

17. Cost Impact

ENGINEERING

Additional ☐ \$ N/A
Savings ☐ \$ N/A

CONSTRUCTION

Additional ☐ \$ N/A
Savings ☐ \$ N/A

18. Schedule Impact (days)

Improvement ☐ N/A
Delay ☐ N/A

19. Change Impact Review: Indicate the related documents (other than the engineering documents identified on Side 1) that will be affected by the change described in Block 13. Enter the affected document number in Block 20.

SDD/DD	☐	Seismic/Stress Analysis	☐	Tank Calibration Manual	☐
Functional Design Criteria	☐	Stress/Design Report	☐	Health Physics Procedure	☐
Operating Specification	☐	Interface Control Drawing	☐	Spares Multiple Unit Listing	☐
Criticality Specification	☐	Calibration Procedure	☐	Test Procedures/Specification	☐
Conceptual Design Report	☐	Installation Procedure	☐	Component Index	☐
Equipment Spec.	☐	Maintenance Procedure	☐	ASME Coded Item	☐
Const. Spec.	☐	Engineering Procedure	☐	Human Factor Consideration	☐
Procurement Spec.	☐	Operating Instruction	☐	Computer Software	☐
Vendor Information	☐	Operating Procedure	☐	Electric Circuit Schedule	☐
OM Manual	☐	Operational Safety Requirement	☐	ICRS Procedure	☐
FSAR/SAR	☐	IEFD Drawing	☐	Process Control Manual/Plan	☐
Safety Equipment List	☐	Cell Arrangement Drawing	☐	Process Flow Chart	☐
Radiation Work Permit	☐	Essential Material Specification	☐	Purchase Requisition	☐
Environmental Impact Statement	☐	Fac. Proc. Samp. Schedule	☐	Tickler File	☐
Environmental Report	☐	Inspection Plan	☐	<u>None</u>	☒
Environmental Permit	☐	Inventory Adjustment Request	☐		☐

20. Other Affected Documents: (NOTE: Documents listed below will not be revised by this ECN.) Signatures below indicate that the signing organization has been notified of other affected documents listed below.

Document Number/Revision

Document Number/Revision

Document Number/Revision

None

21. Approvals

Signature

Date

Signature

Date

Design Authority

Cog. Eng. CE Wills

Cog. Mgr. JR Weidert

QA WR Thackaberry

Safety

Environ.

Other

SPO QA. JL Maupin

Design Agent

PE

QA

Safety

Design

Environ.

Other

DEPARTMENT OF ENERGY

Signature or a Control Number that tracks the Approval Signature

ADDITIONAL

[illegible]

CALIBRATION REPORT FOR THE WRAP FACILITY GAMMA ENERGY ANALYSIS SYSTEM

CE Wills
Fluor Hanford, Inc., Richland, WA 99352
U.S. Department of Energy Contract DE-AC06-96RL13200

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Abstract: This calibration report outlines the specific items included in the TRU Control of Measuring, Testing and Data Collection Equipment. This report also shows the development of the calibration errors which are to be folded into the Total Measurement Uncertainty (TMU) document.

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** MGA Software is a registered trademark of Mitchell & Gauthier
Associates, Inc., Concord, M.A.

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Release Approval

2/15/00

Date

Approved for Public Release

CALIBRATION REPORT
FOR
GAMMA ENERGY ANALYSIS SYSTEM
104-ND-06-102 A
REVISION 1

Prepared for
Waste Receiving and Processing Facility Engineering

Prepared by
Albert I. Davis
Waste Management Technical Services

February, 2000

Certificate of Calibration

This calibration report outlines the specific items included in the TRU Control of Measuring, Testing and Data Collection Equipment⁽¹⁾.

Equipment Identifier: 104-ND-06-102 A, GEA-A

Calibration Interval: Calibration upon installation, then calibration verification annually thereafter.

Date of Calibration: 20 January, 2000

Calibration Verification
Due date: 20 January, 2000

Limitations: 55 gallon drums.

Calibration applies to
Listed equipment: 104-ND-06-102 A

Calibration Method WMH 350 Section 2.5.

Calibration range and
Tolerance: Gamma energy range from 35 keV to 2.0 MeV. Tolerance error is developed within the proprietary Canberra⁽²⁾ calibration software. Analytical span, 0 to 160 grams ²³⁹Pu defined in HNF-4051⁽³⁾.

Calibration Acceptability: Calibration has been deemed acceptable with no non-conformance items.

Standards Standards are listed in Appendix B of this document.

Performers of Calibration: The system Cognizant Engineer: Craig Wills.
Signature: , Date: 2/15/00

Reference to Out-of-Cal.,
or non-conformance issues: None

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1.0 Introduction

The Waste Receiving And Processing facility (WRAP) adheres to providing gamma-ray spectroscopy instrument calibrations traceable to the National Institute for Standards and Technology (NIST) standards⁽⁴⁾. The detectors are used to produce quantitative results for the Waste Isolation Pilot Plant (WIPP) and must meet calibration programmatic calibration goals. Instruments must meet portions of ANSI N42.14, 1978 guide for Germanium detectors. The Non-Destructive Assay (NDA) Gamma Energy Analysis (GEA) utilizes NIST traceable line source standards for the detector system calibrations. The counting configuration is a series of drums containing the line sources and different density filler matrices. The drums are used to develop system efficiencies with respect to density. The efficiency and density correction factors are required for the processing of drummed waste materials of similar densities. The calibration verification is carried out after the calibration is deemed final, by counting a second drum of NIST traceable sources. Three in-depth calibrations have been completed on one of the two systems to date, the first being the system acceptance plan.

This report has a secondary function; that being the development of the instrument calibration errors which are to be folded into the Total Instrument Uncertainty document, HNF-4050.

2.0 Calibration Configuration

The two gamma systems, GEA-A and GEA-B, are calibrated utilizing a vendor supplied drum with six full length line sources distributed in a radial related pattern and differing density fillers. A study by the vendor was cited to develop the source placement. The recommended source placement pattern is considered the best representation of a homogeneous distribution of activity in the drum; see Appendix A. This drum source is the sole calibration source geometry for the Gamma Waste Analysis System, GWAS, for the development of efficiency curves. The source certifications are in Appendix B. The uncertainties listed on the certificates are at 3σ (2.576), per telecom from the supplier.

3.0 GWAS detectors

The Gamma Energy Analysis (GEA) system utilizes six detectors; four are the Segmented Energy Germanium gamma detectors (SEGe-#) used for quantitative analysis, and two Low Energy Germanium detectors (LEGe-#) which are used for peak ratios analysis of low energy gamma-rays from the 45 to 300 keV region. The segmented detectors are 22% to 25% efficient HPGe detectors (High Purity Germanium) relative to a 3x3 NaI(Tl) detector. The detector specifications are in Appendix C; they are not identified with a particular system, but, are the system detectors. The SEGe detectors have gamma attenuators that can be activated to reduce the drum gamma-ray activity to levels that the detector and their electronics can handle without signal distortion. The system drawings state the attenuators are 0.5 inch (1.25 cm) thick, and are machined Iron plate.

4.0 GWAS Configuration

The GWAS counting system⁽⁵⁾, detectors, shield and the drum elevation platform will adequately analyze 55 and 85 gallon drums (208 and 321.5 liters), see Figure 1 bottom. The drum platform elevates in two steps, 8.9 cm each, and the platform continually rotates at 10 rpm during analysis and calibrations. The middle diagram shows the SEGe gamma detector's angle of coverage for the drums. These zones of sensitivity overlap and ensure the entire drum is scanned. The lowest segment in the analysis group views only the rotational portion of the platform and is not included in the calibration. The highest segment in the group views the drum lid and "air" space, it also is not included in the calibration for 55 gallon drums.

Figure 1. NDA detector layout and zone of sensitivities.

5.0 Vertical Activity Response

A series of counts were made with the daily source check drum, following calibration, to evaluate system parameters. The system's response to the standards is shown in the next two figures. Figure 2 is a plot of the counts for selected calibration peaks versus SEGe and position. Note that analytical segment 11 is the top of the drum. The segment's count along the vertical axis is reduced for the drum extremities; the bottom two analysis groups are lower as well as the upper two analysis groups. This count distribution will reflect the efficiency curve's as well.

Figure 2.

6.0 Comparative Analysis

The daily control drum, using a separate set of six NIST traceable line sources, was analyzed a multiple of times to evaluate the response to the calibration. One feature was to view the activity per segment; Figure 3 portrays a plot of that activity versus segment. This plot demonstrates the system's ability to reproduce the drum's vertical isotopic activity. The plot does not indicate losses at the drum extremes. The spreadsheet for Figures 2 and 3 are in Appendix F.

Figure 3.

The following table, Table 1, displays the calibration on a second separate NIST traceable source drum. This drum is configured in the exact same geometry, but, with another second set of rod (line) sources; certificates are shown in Appendix B, E838 to E843. This particular evaluation could be considered the calibration verification.

Seg #	Seg	59 keV		81 keV		356 keV		661 keV		1332.5 keV	
		AVG	% err	AVG	% err	AVG	% err	AVG	% err	AVG	% err
11	S12	4.02	2.46	4.46	3.90	3.13	1.61	0.577	1.89	0.408	1.61
10	S13	3.73	1.44	3.58	1.04	3.08	1.61	0.547	2.08	0.373	1.61
9	S21	3.77	2.49	3.02	7.61	3.15	1.37	0.563	1.20	0.395	1.37
8	S22	3.90	1.82	3.54	6.28	3.12	1.93	0.579	1.81	0.394	1.93
7	S23	3.50	1.58	3.33	3.68	3.13	0.580	0.569	1.06	0.408	0.580
6	S31	3.61	1.67	3.45	1.43	3.14	1.39	0.601	0.688	0.384	1.39
5	S32	3.82	2.10	3.52	1.55	3.18	1.49	0.588	1.28	0.411	1.49
4	S33	3.80	2.95	3.30	1.95	3.11	1.79	0.557	1.57	0.388	1.79
3	S41	3.45	3.00	3.13	16.06	3.16	1.66	0.562	0.701	0.400	1.66
2	S42	3.54	2.70	3.59	10.82	3.22	2.64	0.566	1.56	0.366	2.64
A04		37.27	1.05	34.28	0.496	32.11	0.455	5.93	0.186	4.04	0.455
Sum	% Diff	37.14	0.35	34.91	-1.85	31.44	2.10	5.71	3.79	3.93	2.76
Src Act		35.97	2.77	31.62	2.91	31.62	2.91	5.57	3.42	3.94	3.05
Ratio	A04/Std	1.036		1.08		1.02		1.07		1.03	
	Sum/Std	1.032		1.10		0.994		1.03		0.997	

Table 1. Daily QC-57 drum response.

The total activity is calculated in Table 1, note specifically the rows for the activity ratios to the standard, per isotope. The summed spectrum analysis is contained in the A04 module and its ratio to the actual standard is A04/Std. The summation of each of the segment's activity into a summed activity is ratioed to the standard; Sum/Std. The agreement in both cases is quite good, better than 4%. The 81 keV peak of ^{133}Ba has less agreement due to the interference produced by lead X-rays from unshielded lead next to the detectors.

7.0 SEGe Detectors

The Segmented detectors are set to view energy from 35 keV to 2.0 MeV within a 4096 channel memory block. The gain and zero are carefully adjusted to ensure the resolution is not lost during the summation of the spectra of the individual segmented counts. The Canberra program also contains a built in function to aid in the zero and gain normalization for this summation. The effectiveness of this summation is demonstrated in Table 2 and its associated graph, Figure 4.

The energy equations are of the form:

$$\text{Energy (keV)} = a + b \cdot \text{chn} + c \cdot \text{chn}^2$$

Detector	Intercept Multiplier (a)	Linear Multiplier (b)	Quadratic Multiplier ©
SEGe-1	-0.983	0.500	-1.68E-07
SEGe-2	-0.757	0.500	-1.72E-07
SEGe-3	-0.693	0.500	-1.64E-07
SEGe-4	-1.687	0.501	-1.51E-07
Summed	-1.691	0.501	1.54E-07

Table 2.

Figure 4

The Energy versus Channel plot demonstrated the good fit of the equations to the summed spectrum plot. The individual SEGe detectors are adjusted to as close as practical to the ideal setting, thus the low error values.

The equations for energy and FWHM also demonstrate this normalization effect in the consistency of the equation's coefficients as follows:

FWHM vs Energy

$$\text{FWHM(keV)} = a + b \cdot E^{0.5}$$

	a	b
SEGe-1	0.543	0.030
SEGe-2	0.378	0.039
SEGe-3	0.543	0.032
SEGe-4	0.529	0.029
Summed	0.605	0.033

Table 3.

Figure 5.

The FWHM plot does demonstrate that broadening occurs in the spectrum summation; one of the SEGe detectors (2), is wider than the others and causes the error to increase at the higher energies. The combination of these two plots suggest peak identification should be within the

acceptable parameters for the gamma analysis program. The individual curves for the detectors are with the parameter printouts in Appendix D.

8.0 Low Energy Detectors

The two LEGe HPGe detectors are 10 % efficient relative to a 3x3 NaI(Tl) detector. The detector crystal has less depth to enhance the efficiency of the lower energy gamma-rays. These detectors are shielded with 31 mil Sn. These detectors are calibrated only for energy and FWHM (Full Width at Half Maximum) parameters. The detectors need to have good resolution and have little degradation with respect to high gamma-ray throughput rates. Figure 1 shows the placement of these detectors.

The LEGe detectors, used for the MGA⁽⁶⁾ and MGAU analysis are looked upon as separate entities, that is no spectrum summing is done. The energy range for these detectors is from 35 to 300 keV stored into a 4096 channel buffer. Calibration for energy is linear and has only two terms, a requirement of the MGA/MGAU software. The equations are as follows:

$$\text{Energy (keV)} = a + b \cdot \text{Chn} \quad \text{FWHM (keV)} = a + b \cdot \text{Eng}^{0.5}$$

Detector	Energy equation		FWHM Equation	
	Intercept	Linear Multiplier	Intercept	Linear Multiplier
LEGe-5 (Upper)	0.159	0.076	0.273	0.039
LEGe-6 (Lower)	0.150	0.076	0.223	0.040

Table 4.

The FWHM for the LEGe detectors is 0.575 and 0.533 keV respectively at 60 keV and increases to 0.663 and 0.623 keV at 100 KeV, then 0.825 and 0.789 keV respectively at 200 keV. The FWHM is within the 0.85 keV resolution needed for the MGA and MGAU analysis software. The MGA and MGAU program is designed to analyze for both gamma and X-ray peak areas below 300 keV. The LEGe detectors are not calibrated for efficiency, as the Canberra program doesn't calculate activities from these spectra, only compares relative peak areas. The energy and FWHM data is included in Appendix D for the LEGe detectors.

9.0 SEGe Efficiency

The efficiency calibration output for the segmented detectors is contained in Appendix E. The efficiency curve formulas are the "best fit" selected from the regression analysis contained in the Canberra⁽⁷⁾ software. The equation's coefficients listed below are in two groups; one without the collimators (shields) activated, and the second with the collimators activated. Each equation takes the basic form:

$$\text{Ln}(\text{Eff}) = a + b \cdot \text{Ln}(E) + c \cdot \text{Ln}(E)^2 + d \cdot \text{Ln}(E)^3 + \dots$$

The spreadsheet containing the equation's coefficients are in Appendix F, F8 and F9. The efficiency parameters can regenerate portions of the Canberra's software curve, but lack the inflection point input to completely draw the efficiency curve. The error associated with each efficiency point also includes the error developed in the regression analysis matrix. The error listing or report is not readily available for printout as an equation or plot. Uncertainty for selected efficiencies is discussed below.

Figures 5 and 6 displays the efficiency curve variations with respect to density, Figure 5 has the curves for a non-shielded count, No Collimator, while Figure 6 is the efficiency curves with the shield (Collimator).

Figure 5: No Collimator

Figure 6: With Collimator

The uncertainty plots for the summed curves are seen in the following two figures, 7 and 8. Figure 7 is the plot with no shield in front of the detector, while Figure 8 has the iron shield in the analytical path.

Error versus Energy
No Shield (collimator)

Figure 7

Figure 8

The uncertainty for the calibration never gets less than 6.5% for the efficiency calibration error. The slight deviations from the curve in the 385 keV region is due to the low gamma yield of the upper Ba133 gamma line, longer counting would bring the efficiency error back to the base curve.

REFERENCES

1. TRU Control of Measuring, Testing and Data collection Equipment, WMH-400, Waste Isolation Pilot Plant (WIPP) Procedures, Section 2.2.4, Rev 1, Sub Section 2.1.2.
2. Canberra Model S431 Genie-PC Gamma Waste Assay Software, Technical Reference Manual S431-TEC, V 2.3, May 1998.
3. Quality Assurance Objectives for Nondestructive Assay at the Waste Receiving and Processing facility, HNF-4051, Rev 2 (to be issued).
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5. WRAP Gamma Energy Assay System, KEH 5369, Installation and Maintenance Manual, 2/23/96, Document # 96048.
6. MGA: A Gamma-ray Spectrum Analysis Code for determining Plutonium isotopic abundances. Vol 1, Methods and Algorithms. NTIS-DE90013529, Lawrence Livermore National Laboratory, Livermore, Ca. April 1990.
7. Canberra Genie-PC, V2 – Advanced Topics, S400-usr, V 2.4, February 1997.

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APPENDIX A

Calibration Configuration

Drum Source Distribution

Q2 SYSTEM CALIBRATION AND SOURCE DISTRIBUTION

Calibration Drum Description:

A set of four calibration matrix drums was used to determine the Q2 (Canberra GWAS) system efficiencies as a function of photon energy and source matrix density. Four 208 Liter (55 gallon) drums were homogeneously loaded with the following materials and approximate densities:

- 1) Polyurethane foam (0.14 gm/cc)
- 2) Soft Board (Homosote) (0.470 gm/cc)
- 3) Particle board (0.76 gm/cc)
- 4) Sand (1.67 g/cc)

Each calibration matrix is divided into 6 cylindrical shells, designed to simulate a homogeneous source distribution. A set of hollow tubes was mounted in each of these shells. The source tubes extended the full height of the matrix, and were mounted parallel to the center of the axis of the drum at the positions shown in the following top view diagram.

In order to simulate routine sample counting conditions during the calibration process, the drums were placed on the turntable platform and rotated at a constant speed during all the counts. The axis of rotation was perpendicular to the axis of the Q2 system detectors. In this case a line geometry source (with equal activity per unit length) positioned in a source tube provides counting results equivalent to a cylindrical shell-geometry source with the same radial distance from the center axis of the drum. Taken together, the six shells simulate a homogeneous source distribution throughout the matrix.

Each calibration drum is divided into six shells of equal volume, and labeled A, B, C, D, E, and F. The individual source tubes are numbered 1 – 9. The radial distance from the drum to the center of each of these hollow source tubes is provided in the following table.

Source Tube Location	Radius from Drum Center (inches)
1	0
2	2.3
3	5.6
4	7.3
5	8.6
6	9.8
7	10.2
8	10.5
9	10.8

Efficiency Calibration Theory

Since the cylindrical shells used in this calibration have equal volumes, count rate data obtained for calibration counts with the line sources in tubes 2, 3, 4, 5, 6, and 9 should be weighted equally for reference counting geometry efficiency determinations. Efficiency values may be calculated using the following equation:

$$\text{Efficiency} = (A2 + B3 + C4 + D5 + E6 + F9)/(\text{activity} * \text{abundance})$$

Where

Efficiency is given in the units of counts per gamma emitted from a uniform matrix, and

A2 = measured counts per second (cps) with the line source in tube 2 (shell A)

B3 = measured cps with the line source in tube 3 (shell B)

C4 = measured cps with the line source in tube 4 (shell C)

D5 = measured cps with the line source in tube 5 (shell D)

E6 = measured cps with the line source in tube 6 (shell E)

F9 = measured cps with the line source in tube 9 (shell F)

Activity = decay corrected activity of the calibration source.

APPENDIX B

Source Certificates

Calibration Certificates

The following certificates have been scanned from the originals, only one source leak page will be evident as it is a copy on the backs of each certificate. The certificates will be in two groups, one being the calibration sources and the second being the verification and daily check sources. In each set the stated uncertainty is at the 3σ level.

GWAS Calibration Source Set

A matched set of six calibrated line sources is used to perform the energy, full-width-at-half-maximum (FWHM), and the four efficiency calibrations.

Calibration Source Certificate File

The GWAS efficiency calibration requires the generation of a certificate file containing the total activity of the line sources, expressed as the number of gammas per second for each gamma line used. This is just the sum of the isotopic activities, multiplied by the abundance (branching ratio) for each of the gamma lines.

The current gamma rates are calculated from the current date and time and the reference date and time.

The total uncertainty for the line sources is calculated from the square root of the sum of the squares of the individual line source uncertainties (RMS).

CERTIFICATE OF CALIBRATION

MODEL ENV4057 LINE SOURCE

SERIAL NUMBER D846

Reference Date March 1, 1996

Radionuclide	Activity	Total Uncertainty (%)	Half Life ⁽¹⁾
Am-241	147.7 kBq (3.991 μ Ci)	3.27%	432.7 $\pm$ 0.5 years
Ba-133	206.7 kBq (5.587 μ Ci)	3.22%	10.54 $\pm$ 0.03 years
Cs-137	38.54 kBq (1.042 μ Ci)	3.07%	30.0 $\pm$ 0.2 years
Co-60	38.86 kBq (1.045 μ Ci)	2.80%	5.271 $\pm$ 0.001 years

PRINCIPLE EMISSIONS⁽¹⁾

	Type	Energy (keV)	Intensity (%)
Am-241	gamma	59.5364	35.7
Ba-133	gamma	80.989	34.2
		278.388	7.08
		302.851	18.4
		355.998	62.2
		382.841	8.92
Cs-137	gamma	661.660	85.21
Co-60	gamma	1173.237	99.90
		1332.501	99.9824

SOURCE DESCRIPTION

The activity is uniformly distributed in an epoxy matrix with a density of 1.07 g/cc and cast in a 9.53 mm (0.375") O.D. by 813 mm (32.0") long Aluminum tube with 0.89 mm (0.035") thick walls. 2 mm (0.080") end plugs are placed at both ends of the tube to give an active length of 808 mm (31.84").

METHOD OF CALIBRATION

The source was calibrated on a high purity Germanium detector against an NIST traceable standard in a similar geometry. The activity of the standard was determined using an energy vs. efficiency curve established through ongoing intercomparisons with the National Institute of Standards and Technology. This standard is indirectly (implicitly) traceable to the National Institute of Standards and Technology.

North American Scientific, Inc. actively participates in the Radioactivity Measurements Assurance Program conducted by the National Institute of Standards and Technology in cooperation with the Nuclear Energy Institute.

Jay Fan, Ph.D.
Calibration Laboratory Manager

March 19, 1996

Date

REFERENCES

- (1) Table of Radioactive Isotopes, 7th edition, 1986.

• LEAK TEST CERTIFICATION ON REVERSE •

North American Scientific, Inc. 7435 Greenbush Ave., North Hollywood, CA 91605 (818) 503-9201 Fax (818) 503-0764

CERTIFICATE OF CALIBRATION

MODEL ENV4057 LINE SOURCE

SERIAL NUMBER D847

Reference Date March 1, 1996

Radionuclide	Activity	Total Uncertainty (±)	Half Life ⁽¹⁾
Am-241	148.5 kBq (4.013 µCi)	3.25%	432.7 ± 0.6 years
Ba-133	204.9 kBq (5.538 µCi)	3.19%	10.54 ± 0.03 years
Cs-137	38.10 kBq (1.030 µCi)	2.88%	30.0 ± 0.2 years
Co-60	38.85 kBq (1.045 µCi)	2.63%	5.271 ± 0.001 years

PRINCIPLE EMISSIONS⁽¹⁾

	Type	Energy (keV)	Intensity (%)
Am-241	gamma	59.5364	35.7
Ba-133	gamma	80.989	34.2
		276.388	7.09
		302.851	18.4
		355.999	62.2
Cs-137	gamma	383.841	8.82
		661.660	85.21
Co-60	gamma	1173.237	99.90
		1332.501	99.9824

SOURCE DESCRIPTION

The activity is uniformly distributed in an epoxy matrix with a density of 1.07 g/cc and cast in a 9.53 mm (0.375") O.D. by 813 mm (32.0") long Aluminum tube with 0.89 mm (0.035") thick walls. 2 mm (0.080") end plugs are placed at both ends of the tube to give an active length of 809 mm (31.84").

METHOD OF CALIBRATION

The source was calibrated on a high purity Germanium detector against an NIST traceable standard in a similar geometry. The activity of the standard was determined using an energy vs. efficiency curve established through ongoing intercomparisons with the National Institute of Standards and Technology. This standard is indirectly (implicitly) traceable to the National Institute of Standards and Technology.

North American Scientific, Inc. actively participates in the Radioactivity Measurements Assurance Program conducted by the National Institute of Standards and Technology in cooperation with the Nuclear Energy Institute.

Jay Fan, Ph.D.
Calibration Laboratory Manager

March 19, 1996

Date

REFERENCES

- (1) Table of Radioactive Isotopes, 7th edition, 1986.

• LEAK TEST CERTIFICATION ON REVERSE •

North American Scientific, Inc. 7435 Greenbush Ave., North Hollywood, CA 91605 (818) 503-9201 Fax (818) 503-0764

CERTIFICATE OF CALIBRATION

MODEL ENV4057 LINE SOURCE

SERIAL NUMBER D848

Reference Date March 1, 1996

<u>Radionuclide</u>	<u>Activity</u>	<u>Total Uncertainty (%)</u>	<u>Half Life⁽¹⁾</u>
Am-241	150.4 kBq (4.085 μ Ci)	3.25%	432.7 $\pm$ 0.5 years
Ba-133	205.4 kBq (5.552 μ Ci)	3.20%	10.54 $\pm$ 0.03 years
Cs-137	38.27 kBq (1.034 μ Ci)	2.89%	30.0 $\pm$ 0.2 years
Co-60	38.35 kBq (1.038 μ Ci)	2.68%	5.271 $\pm$ 0.001 years

PRINCIPLE EMISSIONS⁽¹⁾

	<u>Type</u>	<u>Energy (keV)</u>	<u>Intensity (%)</u>
Am-241	gamma	59.5364	35.7
Ba-133	gamma	80.989	34.2
		276.388	7.09
		302.851	18.4
		355.999	62.2
		383.841	8.92
Cs-137	gamma	661.660	85.21
Co-60	gamma	1173.237	99.90
		1332.501	99.9824

SOURCE DESCRIPTION

The activity is uniformly distributed in an epoxy matrix with a density of 1.07 g/cc and cast in a 9.53 mm (0.375") O.D. by 813 mm (32.0") long Aluminum tube with 0.89 mm (0.035") thick walls. 2 mm (0.080") end plugs are placed at both ends of the tube to give an active length of 809 mm (31.84").

METHOD OF CALIBRATION

The source was calibrated on a high purity Germanium detector against an NIST traceable standard in a similar geometry. The activity of the standard was determined using an energy vs. efficiency curve established through ongoing intercomparisons with the National Institute of Standards and Technology. This standard is indirectly (implicitly) traceable to the National Institute of Standards and Technology.

North American Scientific, Inc. actively participates in the Radioactivity Measurements Assurance Program conducted by the National Institute of Standards and Technology in cooperation with the Nuclear Energy Institute.

Jay Fan, Ph.D.
Calibration Laboratory Manager

March 19, 1996

Date

REFERENCES

- (1) Table of Radioactive Isotopes, 7th edition, 1985.

• LEAK TEST CERTIFICATION ON REVERSE •

North American Scientific, Inc. 7435 Greenbush Ave., North Hollywood, CA 91605 (818) 503-9201 Fax (818) 503-0764

CERTIFICATE OF CALIBRATION

MODEL ENV4057 LINE SOURCE

SERIAL NUMBER D849

Reference Date March 1, 1996

<u>Radionuclide</u>	<u>Activity</u>	<u>Total Uncertainty (%)</u>	<u>Half Life⁽¹⁾</u>
Am-241	145.1 kBq (3.920 μ Cl)	3.24%	432.7 $\pm$ 0.5 years
Ba-133	208.3 kBq (5.575 μ Cl)	3.19%	10.64 $\pm$ 0.03 years
Cs-137	37.44 kBq (1.012 μ Cl)	2.83%	30.0 $\pm$ 0.2 years
Co-60	38.30 kBq (1.035 μ Cl)	2.60%	5.271 $\pm$ 0.001 years

PRINCIPLE EMISSIONS⁽¹⁾

	<u>Type</u>	<u>Energy (keV)</u>	<u>Intensity (%)</u>
Am-241	gamma	59.5364	35.7
Ba-133	gamma	80.889	34.2
		276.388	7.09
		302.851	18.4
		355.999	62.2
		383.841	8.92
Cs-137	gamma	661.660	85.21
Co-60	gamma	1173.237	99.90
		1332.501	99.9824

SOURCE DESCRIPTION

The activity is uniformly distributed in an epoxy matrix with a density of 1.07 g/cc and cast in a 9.53 mm (0.375") O.D. by 813 mm (32.0") long Aluminum tube with 0.89 mm (0.035") thick walls. 2 mm (0.080") end plugs are placed at both ends of the tube to give an active length of 808 mm (31.84").

METHOD OF CALIBRATION

The source was calibrated on a high purity Germanium detector against an NIST traceable standard in a similar geometry. The activity of the standard was determined using an energy vs. efficiency curve established through ongoing intercomparisons with the National Institute of Standards and Technology. This standard is indirectly (implicitly) traceable to the National Institute of Standards and Technology.

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Jay Fan, Ph.D.
Calibration Laboratory Manager

March 19, 1996

Date

REFERENCES

- (1) Table of Radioactive Isotopes, 7th edition, 1986.

• LEAK TEST CERTIFICATION ON REVERSE •

North American Scientific, Inc. 7435 Greenbush Ave., North Hollywood, CA 91605 (818) 503-9201 Fax (818) 503-0784

CERTIFICATE OF CALIBRATION

MODEL ENV4057 LINE SOURCE

SERIAL NUMBER D850

Reference Date March 1, 1996

<u>Radionuclide</u>	<u>Activity</u>	<u>Total Uncertainty ($\pm$)</u>	<u>Half Life⁽¹⁾</u>
Am-241	148.4 kBq (3.956 μ CI)	3.26%	432.7 $\pm$ 0.5 years
Ba-133	205.6 kBq (5.553 μ CI)	3.21%	10.54 $\pm$ 0.03 years
Cs-137	37.39 kBq (1.010 μ CI)	3.01%	30.0 $\pm$ 0.2 years
Co-60	38.52 kBq (1.041 μ CI)	2.74%	5.271 $\pm$ 0.001 years

PRINCIPLE EMISSIONS⁽¹⁾

	<u>Type</u>	<u>Energy (keV)</u>	<u>Intensity (%)</u>
Am-241	gamma	59.5364	35.7
Ba-133	gamma	80.989	34.2
		276.388	7.06
		302.851	18.4
		355.999	62.2
		383.841	8.92
Cs-137	gamma	661.660	85.21
Co-60	gamma	1173.237	99.90
		1332.601	99.8824

SOURCE DESCRIPTION

The activity is uniformly distributed in an epoxy matrix with a density of 1.07 g/cc and cast in a 9.53 mm (0.375") O.D. by 813 mm (32.0") long Aluminum tube with 0.89 mm (0.035") thick walls. 2 mm (0.080") end plugs are placed at both ends of the tube to give an active length of 808 mm (31.84").

METHOD OF CALIBRATION

The source was calibrated on a high purity Germanium detector against an NIST traceable standard in a similar geometry. The activity of the standard was determined using an energy vs. efficiency curve established through ongoing intercomparisons with the National Institute of Standards and Technology. This standard is indirectly (implicitly) traceable to the National Institute of Standards and Technology.

North American Scientific, Inc. actively participates in the Radioactivity Measurements Assurance Program conducted by the National Institute of Standards and Technology in cooperation with the Nuclear Energy Institute.

Jay Fan, Ph.D.

Calibration Laboratory Manager

March 18, 1996

Date

REFERENCES

- (1) Table of Radioactive Isotopes, 7th edition, 1986.

• LEAK TEST CERTIFICATION ON REVERSE •

North American Scientific, Inc. 7435 Greenbush Ave., North Hollywood, CA 91605 (818) 503-9201 Fax (818) 503-0764

CERTIFICATE OF CALIBRATION

MODEL ENV4057 LINE SOURCE

SERIAL NUMBER D851

Reference Date March 1, 1996

<u>Radionuclide</u>	<u>Activity</u>	<u>Total Uncertainty (%)</u>	<u>Half Life^m</u>
Am-241	147.2 kBq (3.977 μ Ci)	2.25%	432.7 $\pm$ 0.5 years
Ba-133	205.4 kBq (5.553 μ Ci)	3.19%	10.54 $\pm$ 0.03 years
Cs-137	38.01 kBq (1.027 μ Ci)	2.86%	30.0 $\pm$ 0.2 years
Co-60	38.50 kBq (1.041 μ Ci)	2.63%	5.271 $\pm$ 0.001 years

PRINCIPLE EMISSIONS^m

	<u>Type</u>	<u>Energy (keV)</u>	<u>Intensity (%)</u>
Am-241	gamma	59.5364	35.7
Ba-133	gamma	80.989	34.2
		276.388	7.09
		302.851	18.4
		355.999	62.2
		383.841	8.92
Cs-137	gamma	661.660	85.21
Co-60	gamma	1173.237	99.90
		1332.501	99.9824

SOURCE DESCRIPTION

The activity is uniformly distributed in an epoxy matrix with a density of 1.07 g/cc and cast in a 9.53 mm (0.375") O.D. by 813 mm (32.0") long Aluminum tube with 0.89 mm (0.035") thick walls. 2 mm (0.080") end plugs are placed at both ends of the tube to give an active length of 809 mm (31.84").

METHOD OF CALIBRATION

The source was calibrated on a high purity Germanium detector against an NIST traceable standard in a similar geometry. The activity of the standard was determined using an energy vs. efficiency curve established through ongoing intercomparisons with the National Institute of Standards and Technology. This standard is indirectly (implicitly) traceable to the National Institute of Standards and Technology.

North American Scientific, Inc. actively participates in the Radioactivity Measurements Assurance Program conducted by the National Institute of Standards and Technology in cooperation with the Nuclear Energy Institute.

Jay Fan, Ph.D.
Calibration Laboratory Manager

March 19, 1996

Date

REFERENCES

- (1) Table of Radioactive Isotopes, 7th edition, 1986.

• LEAK TEST CERTIFICATION ON REVERSE •

North American Scientific, Inc. 7435 Greenbush Ave., North Hollywood, CA 91605 (818) 503-9201 Fax (818) 503-0764

LEAK TEST METHODS

1. **Soak (Immersion) Test** (ISO/TR 4826-1979 (E) section 2.1.3)

The source is immersed in water or other suitable liquid at 50°C for at least 4 hours and the activity in the liquid measured. Acceptance limit: 0.0001 μCi alpha, 0.001 μCi beta-gamma.

2. **Immersion Test** (ANSI N542-1977, Appendix A2.1.3)

The source is immersed in water at 100°C for 10 minutes. The water is removed and the source cooled and rinsed using fresh water. These operations are repeated twice, boiling in the water from the previous rinsing operation. Acceptance limit: 0.0001 μCi alpha, 0.005 μCi beta-gamma for all the water collected.

3. **Wipe (Smear) Test** (ANSI N542-1977, Appendix A2.1.1)

All external surfaces of the source are wiped with a piece of filter paper or other absorbent material which has been moistened with an appropriate solvent and the activity removed is measured. Acceptance limit: 0.0001 μCi alpha, 0.001 μCi beta-gamma.

4. **Leak Test Not Applicable**

For sources with no covering or a delicate covering over the radioactive portion or gas standards and sources, the inactive portions or containment vessel are wipe tested as in Method 3 above. Acceptance limit: 0.0001 μCi alpha, 0.001 μCi beta-gamma.

5. **Other**

LEAK TEST CERTIFICATION

The standard was leak tested in accordance with Leak Test Method 3 as described above. The removable activity was determined to be less than 0.001 beta-gamma and 0.0001 μCi alpha. This leak test should be performed every six months or as required by a specific NRC or Agreement State License.

B. H. H. H. H.

Health Physics

March 19, 1996

Date

Calibration check and daily control drum sources.

CERTIFICATE OF CALIBRATION**MODEL ENV4057 LINE SOURCE****SERIAL NUMBER E838****Reference Date October 1, 1996**

<u>Radionuclide</u>	<u>Activity</u>	<u>Total Uncertainty (%)</u>	<u>Half Life⁽¹⁾</u>
Am-241	221.5 kBq (5.987 μ Ci)	3.18%	432.7 $\pm$ 0.5 years
Ba-133	239.4 kBq (6.470 μ Ci)	3.34%	10.54 $\pm$ 0.03 years
Cs-137	37.20 kBq (1.005 μ Ci)	3.94%	30.0 $\pm$ 0.2 years
Co-60	37.77 kBq (1.021 μ Ci)	3.51%	5.271 $\pm$ 0.001 years

PRINCIPLE EMISSIONS⁽¹⁾

	<u>Type</u>	<u>Energy (keV)</u>	<u>Intensity (%)</u>
Am-241	gamma	59.5364	35.7
Ba-133	gamma	80.989	34.2
		276.388	7.09
		302.851	18.4
		355.999	62.2
Cs-137	gamma	383.841	8.92
		661.660	85.21
Co-60	gamma	1173.237	99.90
		1332.501	99.9824

SOURCE DESCRIPTION

The activity is uniformly distributed in an epoxy matrix with a density of 1.07 g/cc and cast in a 9.53 mm (0.375") O.D. by 813 mm (32.0") long Aluminum tube with 0.89 mm (0.035") thick walls. 2 mm (0.080") end plugs are placed at both ends of the tube to give an active length of 809 mm (31.84").

METHOD OF CALIBRATION

The source was calibrated on a high purity Germanium detector against an NIST traceable standard in a similar geometry. The activity of the standard was determined using an energy vs. efficiency curve established through ongoing intercomparisons with the National Institute of Standards and Technology. This standard is indirectly (implicitly) traceable to the National Institute of Standards and Technology.

North American Scientific, Inc. actively participates in the Radioactivity Measurements Assurance Program conducted by the National Institute of Standards and Technology in cooperation with the Nuclear Energy Institute.

Jay Fan, Ph.D.

Calibration Laboratory Manager

October 8, 1996

Date

REFERENCES

- (1) Table of Radioactive Isotopes, 7th edition, 1968.

• LEAK TEST CERTIFICATION ON REVERSE •

North American Scientific, Inc. 7435 Greenbush Ave., North Hollywood, CA 91605 (818) 503-9201 Fax (818) 503-0764

CERTIFICATE OF CALIBRATION

MODEL ENV4057 LINE SOURCE

SERIAL NUMBER E839

Reference Date October 1, 1996

<u>Radionuclide</u>	<u>Activity</u>	<u>Total Uncertainty (%)</u>	<u>Half Life¹⁾</u>
Am-241	220.3 kBq (5.953 μ Ci)	3.20%	432.7 $\pm$ 0.5 years
Ba-133	242.9 kBq (6.564 μ Ci)	3.35%	10.54 $\pm$ 0.03 years
Cs-137	36.95 kBq (998.7 nCi)	4.04%	30.0 $\pm$ 0.2 years
Co-60	37.40 kBq (1.012 μ Ci)	3.60%	5.271 $\pm$ 0.001 years

PRINCIPLE EMISSIONS¹⁾

	<u>Type</u>	<u>Energy (keV)</u>	<u>Intensity (%)</u>
Am-241	gamma	59.5364	35.7
Ba-133	gamma	80.989	34.2
		278.388	7.09
		302.851	18.4
		355.999	62.2
		383.841	8.92
Cs-137	gamma	661.660	85.21
Co-60	gamma	1173.237	99.90
		1332.501	99.9624

SOURCE DESCRIPTION

The activity is uniformly distributed in an epoxy matrix with a density of 1.07 g/cc and cast in a 9.53 mm (0.375") O.D. by 813 mm (32.0") long Aluminum tube with 0.89 mm (0.035") thick walls. 2 mm (0.080") end plugs are placed at both ends of the tube to give an active length of 809 mm (31.84").

METHOD OF CALIBRATION

The source was calibrated on a high purity Germanium detector against an NIST traceable standard in a similar geometry. The activity of the standard was determined using an energy vs. efficiency curve established through ongoing intercomparisons with the National Institute of Standards and Technology. This standard is indirectly (implicitly) traceable to the National Institute of Standards and Technology.

North American Scientific, Inc. actively participates in the Radioactivity Measurements Assurance Program conducted by the National Institute of Standards and Technology in cooperation with the Nuclear Energy Institute.

Jay Fan, Ph.D.
Calibration Laboratory Manager

October 8, 1996

Date

REFERENCES

- (1) Table of Radioactive Isotopes, 7th edition, 1993.

• LEAK TEST CERTIFICATION ON REVERSE •

North American Scientific, Inc. 7435 Greenbush Ave., North Hollywood, CA 91605 (818) 503-9201 Fax (818) 503-0764

CERTIFICATE OF CALIBRATION

MODEL ENV4057 LINE SOURCE

SERIAL NUMBER E840

Reference Date October 1, 1996

Radionuclide	Activity	Total Uncertainty (%)	Half Life ⁽¹⁾
Am-241	222.8 kBq (6.022 μ Ci)	3.17%	432.7 $\pm$ 0.5 years
Ba-133	240.6 kBq (6.509 μ Ci)	3.32%	10.54 $\pm$ 0.03 years
Cs-137	37.08 kBq (1.002 μ Ci)	3.61%	30.0 $\pm$ 0.2 years
Co-60	36.63 kBq (995.5 nCi)	3.41%	5.271 $\pm$ 0.001 years

PRINCIPLE EMISSIONS^m

	Type	Energy (keV)	Intensity (%)
Am-241	gamma	59.5364	35.7
Ba-133	gamma	80.969	34.2
		276.388	7.09
		302.851	18.4
		355.999	62.2
		383.841	8.92
Cs-137	gamma	661.660	85.21
Co-60	gamma	1173.237	99.90
		1332.501	99.9824

SOURCE DESCRIPTION

The activity is uniformly distributed in an epoxy matrix with a density of 1.07 g/cc and cast in a 9.53 mm (0.375") O.D. by 813 mm (32.0") long Aluminum tube with 0.89 mm (0.035") thick walls. 2 mm (0.080") end plugs are placed at both ends of the tube to give an active length of 809 mm (31.84").

METHOD OF CALIBRATION

The source was calibrated on a high purity Germanium detector against an NIST traceable standard in a similar geometry. The activity of the standard was determined using an energy vs. efficiency curve established through ongoing intercomparisons with the National Institute of Standards and Technology. This standard is indirectly (implicitly) traceable to the National Institute of Standards and Technology.

North American Scientific, Inc. actively participates in the Radioactivity Measurements Assurance Program conducted by the National Institute of Standards and Technology in cooperation with the Nuclear Energy Institute.

Jay Fan

Jay Fan, Ph.D.
Calibration Laboratory Manager

October 8, 1996

Date

REFERENCES

- (1) Table of Radioactive Isotopes, 7th edition, 1986.

• LEAK TEST CERTIFICATION ON REVERSE •

North American Scientific, Inc. 7435 Greenbush Ave., North Hollywood, CA 91605 (818) 503-9201 Fax (818) 503-0764

CERTIFICATE OF CALIBRATION

MODEL ENV4057 LINE SOURCE

SERIAL NUMBER E841

Reference Date October 1, 1996

<u>Radionuclide</u>	<u>Activity</u>	<u>Total Uncertainty (%)</u>	<u>Half Life⁽¹⁾</u>
Am-241	223.7 kBq (6.046 μ Ci)	3.18%	432.7 $\pm$ 0.5 years
Ba-133	240.6 kBq (6.503 μ Ci)	3.33%	10.54 $\pm$ 0.03 years
Cs-137	37.18 kBq (1.005 μ Ci)	3.89%	30.0 $\pm$ 0.2 years
Co-60	36.69 kBq (991.5 nCi)	3.48%	5.271 $\pm$ 0.001 years

PRINCIPLE EMISSIONS⁽¹⁾

	<u>Type</u>	<u>Energy (keV)</u>	<u>Intensity (%)</u>
Am-241	gamma	59.5364	35.7
Ba-133	gamma	80.989	34.2
		276.388	7.09
		302.851	18.4
		355.969	62.2
Cs-137	gamma	383.841	8.92
		661.680	85.21
Co-60	gamma	1173.237	99.90
		1332.501	99.9824

SOURCE DESCRIPTION

The activity is uniformly distributed in an epoxy matrix with a density of 1.07 g/cc and cast in a 9.53 mm (0.375") O.D. by 813 mm (32.0") long Aluminum tube with 0.89 mm (0.035") thick walls. 2 mm (0.080") end plugs are placed at both ends of the tube to give an active length of 809 mm (31.84").

METHOD OF CALIBRATION

The source was calibrated on a high purity Germanium detector against an NIST traceable standard in a similar geometry. The activity of the standard was determined using an energy vs. efficiency curve established through ongoing intercomparisons with the National Institute of Standards and Technology. This standard is indirectly (implicitly) traceable to the National Institute of Standards and Technology.

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Jay Fan, Ph.D.
Calibration Laboratory Manager

October 8, 1996

Date

REFERENCES

- (1) Table of Radioactive Isotopes, 7th edition, 1996.

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North American Scientific, Inc. 7435 Greenbush Ave., North Hollywood, CA 91605 (818) 503-9201 Fax (818) 503-0764

CERTIFICATE OF CALIBRATION

MODEL ENV4057 LINE SOURCE

SERIAL NUMBER E842

Reference Date October 1, 1998

<u>Radionuclide</u>	<u>Activity</u>	<u>Total Uncertainty (%)</u>	<u>Half Life⁽¹⁾</u>
Am-241	225.0 kBq (6.082 μ Ci)	3.18%	432.7 $\pm$ 0.5 years
Ba-133	240.8 kBq (6.510 μ Ci)	3.33%	10.54 $\pm$ 0.03 years
Cs-137	37.13 kBq (1.003 μ Ci)	3.88%	30.0 $\pm$ 0.2 years
Co-60	37.07 kBq (1.002 μ Ci)	3.47%	5.271 $\pm$ 0.001 years

PRINCIPLE EMISSIONS⁽¹⁾

	<u>Type</u>	<u>Energy (keV)</u>	<u>Intensity (%)</u>
Am-241	gamma	59.5364	35.7
Ba-133	gamma	80.989	34.2
		276.388	7.09
		302.851	18.4
		355.999	62.2
		363.841	8.92
Cs-137	gamma	661.660	85.21
Co-60	gamma	1173.237	99.90
		1332.501	99.9824

SOURCE DESCRIPTION

The activity is uniformly distributed in an epoxy matrix with a density of 1.07 g/cc and cast in a 9.53 mm (0.375") O.D. by 813 mm (32.0") long Aluminum tube with 0.89 mm (0.035") thick walls. 2 mm (0.080") end plugs are placed at both ends of the tube to give an active length of 809 mm (31.84").

METHOD OF CALIBRATION

The source was calibrated on a high purity Germanium detector against an NIST traceable standard in a similar geometry. The activity of the standard was determined using an energy vs. efficiency curve established through ongoing intercomparisons with the National Institute of Standards and Technology. This standard is indirectly (implicitly) traceable to the National Institute of Standards and Technology.

North American Scientific, Inc. actively participates in the Radioactivity Measurements Assurance Program conducted by the National Institute of Standards and Technology in cooperation with the Nuclear Energy Institute.

Jay Fan, Ph.D.
Calibration Laboratory Manager

October 8, 1998

Date

REFERENCES

- (1) Table of Radioactive Isotopes, 7th edition, 1986.

• LEAK TEST CERTIFICATION ON REVERSE •

North American Scientific, Inc. 7435 Greenbush Ave., North Hollywood, CA 91605 (818) 503-9201 Fax (818) 503-0764

CERTIFICATE OF CALIBRATION

MODEL ENV4057 LINE SOURCE

SERIAL NUMBER E843

Reference Date October 1, 1996

Radionuclide	Activity	Total Uncertainty (%)	Half Life ⁽¹⁾
Am-241	224.5 kBq (6.067 μ Ci)	3.19%	432.7 $\pm$ 0.5 years
Ba-133	241.3 kBq (6.523 μ Ci)	3.34%	10.54 $\pm$ 0.03 years
Cs-137	36.58 kBq (988.6 nCi)	3.98%	30.0 $\pm$ 0.2 years
Co-60	36.81 kBq (994.9 nCi)	3.54%	5.271 $\pm$ 0.001 years

PRINCIPLE EMISSIONS⁽¹⁾

	Type	Energy (keV)	Intensity (%)
Am-241	gamma	59.5364	35.7
Ba-133	gamma	80.989	34.2
		276.388	7.09
		302.851	18.4
		355.989	62.2
		383.841	8.92
Cs-137	gamma	661.660	85.21
Co-60	gamma	1173.237	99.90
		1332.501	99.9824

SOURCE DESCRIPTION

The activity is uniformly distributed in an epoxy matrix with a density of 1.07 g/cc and cast in a 9.53 mm (0.375") O.D. by 813 mm (32.0") long Aluminum tube with 0.89 mm (0.035") thick walls. 2 mm (0.080") end plugs are placed at both ends of the tube to give an active length of 809 mm (31.84").

METHOD OF CALIBRATION

The source was calibrated on a high purity Germanium detector against an NIST traceable standard in a similar geometry. The activity of the standard was determined using an energy vs. efficiency curve established through ongoing intercomparisons with the National Institute of Standards and Technology. This standard is indirectly (implicitly) traceable to the National Institute of Standards and Technology.

North American Scientific, Inc. actively participates in the Radioactivity Measurements Assurance Program conducted by the National Institute of Standards and Technology in cooperation with the Nuclear Energy Institute.

Jay Fan, Ph.D.
Calibration Laboratory Manager

October 8, 1996

Date

REFERENCES

- (1) Table of Radioactive Isotopes, 7th edition, 1986.

• LEAK TEST CERTIFICATION ON REVERSE •

North American Scientific, Inc. 7435 Greenbush Ave., North Hollywood, CA 91605 (818) 503-9201 Fax (818) 503-0764

APPENDIX C

GWAS Detectors

Specifications

DETECTOR SPECIFICATION AND PERFORMANCE DATA

Specifications

DETECTOR MODEL GC1018S SERIAL NUMBER 3963626
 CRYOSTAT MODEL 7935-7S PREAMPLIFIER MODEL 2002CSL

The purchase specification and therefore the warranted performance of this detector are as follows:
 (Electric cooling may degrade performance by as much as 10%.)

Active Volume 1.8 cc Relative Efficiency 10 %
 Resolution 1.8 keV (FWHM) at 1.33 MeV
0.70 keV (FWHM) at 1.33 MeV
0.70 keV (FWHM) at 122 keV
 Peak / Compton 1 Cryostat well diameter 5 mm Cryostat well depth 5 mm
 Cryostat description if special _____

Physical Characteristics

Geometry Closed-end coaxial
 Diameter 45.5 mm Active Volume 1.8 cc
 Length 30 mm Well Depth 5 mm
 Distance from window 5 mm Well Diameter 5 mm

Electrical Characteristics

Depletion voltage (+)1200 V dc
 Recommended bias voltage (+)3000 V dc
 Leakage current at recommended bias 0.01 nA
 Preamplifier test point voltage at recommended voltage (-)0.28 V dc
 Capacitance at recommended bias ~9 pF

Resolution and Efficiency

With amplifier time constant of 4 microseconds

Isotope	⁵⁷ Co	⁶⁰ Co			
Energy (KeV)	122	1332			
FWHM (KeV)	0.69	1.74			
FWTM (KeV)	1.27	3.25			
Peak / Compton		38.0:1			
Rel. Efficiency %		10.0			

Cool Down Time 4 hours. Cryostat Liquid Nitrogen Consumption Rate <1.5 Liters per Day.

Tested by: Peter Elmer Date: March 11, 1996

Approved by: M. J. Smith Date: March 11, 1996

800 Research Parkway, Meriden CT. U.S.A. 06450 Tel. 203-238-2351/Fax 203-235-1347

Det_Spec_1 10/95 JMT

Detector sent to Canberra for repair.

DETECTOR SPECIFICATION AND PERFORMANCE DATA

Specifications

DETECTOR MODEL GC1018S SERIAL NUMBER 3963627
CRYOSTAT MODEL 7935-7S PREAMPLIFIER MODEL 2002CSL

The purchase specification and therefore the warranted performance of this detector are as follows:
(Electric cooling may degrade performance by as much as 10%.)

Active Volume   cc Relative Efficiency 10 %
Resolution 1.8 keV (FWHM) at 1.33 MeV.
       keV (FWTM) at 1.33 MeV
0.70 keV (FWHM) at 122 keV
       keV (FWTM) at

Peak / Compton   :1 Cryostat well diameter   mm Cryostat well depth   mm
Cryostat description if special

Physical Characteristics

Geometry Closed-end coaxial
Diameter 46 mm Active Volume   cc
Length 28 mm Well Depth   mm
Distance from window 6 mm Well Diameter   mm

Electrical Characteristics

Depletion voltage (+)3000 V dc
Recommended bias voltage (+)3000 V dc
Leakage current at recommended bias 0.02 nA
Preamplifier test point voltage at recommended voltage (-)0.82 V dc
Capacitance at recommended bias ~9 pF

Resolution and Efficiency

With amplifier time constant of 4 microseconds

Isotope	⁵⁷ Co	⁶⁰ Co			
Energy (KeV)	122	1332			
FWHM (KeV)	0.69	1.69			
FWTM (KeV)	1.27	3.16			
Peak / Compton		40.0:1			
Rel. Efficiency %		10.0			

Cool Down Time 4 hours. Cryostat Liquid Nitrogen Consumption Rate <1.5 Liters per Day.

Tested by: Peter Elmer Date: March 11, 1996

Approved by: Marvin J. Lintell Date: March 11, 1996

800 Research Parkway, Meriden CT. U.S.A. 06450 Tel. 203-238-2351/Fax 203-235-1347

Det_spec_1 10/95 JMT

Detector assigned to GEA-A, LEGe 6.

DETECTOR SPECIFICATION AND PERFORMANCE DATA

Specifications

DETECTOR MODEL GC1018/S SERIAL NUMBER 12953631

CRYOSTAT MODEL 7935-7S PREAMPLIFIER MODEL 2002CSL

The purchase specification and therefore the warranted performance of this detector are as follows:
(Electric cooling may degrade performance by as much as 10%.)

Active Volume   cc Relative Efficiency 10 %

Resolution 1.8 keV (FWHM) at 1.83 MeV

       keV (FWTM) at 1.83 MeV

< 700 keV (FWHM) at 122 keV

       keV (FWTM) at

Peak / Compton   :1 Cryostat well diameter   mm Cryostat well depth   mm

Cryostat description if special

Physical Characteristics

Geometry Closed-end coaxial

Diameter 46 mm

Length 29.5 mm

Distance from window 5 mm

Active Volume   cc

Well Depth   mm

Well Diameter   mm

Electrical Characteristics

Depletion voltage (+)1000 V dc

Recommended bias voltage (+)1500 V dc

Leakage current at recommended bias 0.02 nA

Preamplifier test point voltage at recommended voltage (-)1.59 V dc

Capacitance at recommended bias ~9 pF

Resolution and Efficiency

With amplifier time constant of 4 microseconds

Isotope	⁵⁷ Co	⁶⁰ Co			
Energy (KeV)	122	1332			
FWHM (KeV)	0.70	1.75			
FWTM (KeV)	1.32	3.26			
Peak / Compton		88.9:1			
Rel. Efficiency %		10.1			

Cool Down Time 4 hours. Cryostat Liquid Nitrogen Consumption Rate <1.5 Liters per Day.

Tested by: Randall Peel Date: December 22, 1995

Approved by: [Signature] Date: December 22, 1995

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Det_spec_1 10/95 JMT

DETECTOR SPECIFICATION AND PERFORMANCE DATA

Specifications

DETECTOR MODEL GC1018/SSERIAL NUMBER 12953636CRYOSTAT MODEL 7935-7SPREAMPLIFIER MODEL 2002CSL

The purchase specification and therefore the warranted performance of this detector are as follows:
(Electric cooling may degrade performance by as much as 10%.)

Active Volume   cc Relative Efficiency 10 %Resolution 1.8 keV (FWHM) at 1.33 MeV   keV (FWTM) at 1.33 MeV< 700 keV (FWHM) at 122 keV   keV (FWTM) at   Peak / Compton   :1 Cryostat well diameter   mm Cryostat well depth   mmCryostat description if special

Physical Characteristics

Geometry Closed-end coaxialDiameter 46 mmLength 29 mmDistance from window 5 mmActive Volume   ccWell Depth   mmWell Diameter   mm

Electrical Characteristics

Depletion voltage (+)1200 V dcRecommended bias voltage (+)3000 V dcLeakage current at recommended bias 0.01 nAPreamplifier test point voltage at recommended voltage (-)2.16 V dcCapacitance at recommended bias ~8 pF

Resolution and Efficiency

With amplifier time constant of 4 microseconds

Isotope	⁵⁷ Co	⁶⁰ Co			
Energy (KeV)	122	1332			
FWHM (KeV)	0.67	1.76			
FWTM (KeV)	1.24	3.35			
Peak / Compton		37.2:1			
Rel. Efficiency %		10.1			

Cool Down Time 4 hours. Cryostat Liquid Nitrogen Consumption Rate <1.5 Liters per Day.Tested by: Randall Pech Date: December 22, 1995Approved by: Margaret J. Smith Date: December 22, 1995

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Det_Spec_1 10/95 JMT

DETECTOR SPECIFICATION AND PERFORMANCE DATA

Specifications

DETECTOR MODEL GC2020SERIAL NUMBER 12953589CRYOSTAT MODEL 7935-7SPREAMPLIFIER MODEL 2101PCSL

The purchase specification and therefore the warranted performance of this detector are as follows:

(Electric cooling may degrade performance by as much as 10%.)

Active Volume   cc Relative Efficiency 20 %Resolution 20 keV (FWHM) at 1.33 MeV   keV (FWTM) at 1.33 MeV   keV (FWHM) at   keV (FWTM) at   Peak / Compton   :1 Cryostat well diameter   mm Cryostat well depth   mmCryostat description if special

Physical Characteristics

Geometry Closed-end coaxialDiameter 53 mmLength 44 mmDistance from window 5 mmActive Volume   ccWell Depth   mmWell Diameter   mm

Electrical Characteristics

Depletion voltage (+13300) V dcRecommended bias voltage (+3500) V dcLeakage current at recommended bias   nAReset rate at recommended voltage 0.4 secCapacitance at recommended bias ~19 pF

Resolution and Efficiency

With amplifier time constant of 4 microseconds

Isotope	⁵⁷ Co	⁶⁰ Co			
Energy (KeV)	122	1332			
FWHM (KeV)	0.74	1.68			
FWTM (KeV)	1.36	3.10			
Peak / Compton		68.0			
Rel. Efficiency %		23.9			

Cool Down Time 4 hours. Cryostat Liquid Nitrogen Consumption Rate <1.4 Liters per Day.Tested by: Randall Peck Date: December 22, 1995Approved by: M. J. Smith Date: December 22, 1995

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Det_Spec_1 10/95 JMT

DETECTOR SPECIFICATION AND PERFORMANCE DATA

Specifications

DETECTOR MODEL GC2020SERIAL NUMBER 12953590CRYOSTAT MODEL 7935-7SPREAMPLIFIER MODEL 2101PCSL

The purchase specification and therefore the warranted performance of this detector are as follows:

(Electric cooling may degrade performance by as much as 10%.)

Active Volume   cc Relative Efficiency 20 %Resolution 2.0 keV (FWHM) at 1.33 MeV   keV (FWTM) at 1.33 MeV   keV (FWHM) at   keV (FWTM) at   Peak / Compton   :1 Cryostat well diameter   mm Cryostat well depth   mmCryostat description if special

Physical Characteristics

Geometry Closed-end coaxialDiameter 53 mmLength 45.5 mmDistance from window 5 mmActive Volume   ccWell Depth   mmWell Diameter   mm

Electrical Characteristics

Depletion voltage (+)2400 V dcRecommended bias voltage (+)3000 V dcLeakage current at recommended bias   nAReset rate at recommended voltage 0.6 secCapacitance at recommended bias ~19 pF

Resolution and Efficiency

With amplifier time constant of 4 microseconds

Isotope	⁵⁷ Co	⁶⁰ Co			
Energy (KeV)	122	1332			
FWHM (KeV)	0.82	1.77			
FWTM (KeV)	1.53	3.35			
Peak / Compton		54.9			
Rel. Efficiency %		24.0			

Cool Down Time 4 hours. Cryostat Liquid Nitrogen Consumption Rate <1.4 Liters per Day.Tested by: Randall Perch Date: December 22, 1995Approved by: Manning Date: December 22, 1995

800 Research Parkway, Meriden CT. U.S.A. 06450 Tel. 203-238-2351/Fax 203-235-1347

Det_Spec_1 10/93 JMT

DETECTOR SPECIFICATION AND PERFORMANCE DATA

Specifications

DETECTOR MODEL GC2020SERIAL NUMBER 12953692CRYOSTAT MODEL 7985-7SPREAMPLIFIER MODEL 2101PSL

The purchase specification and therefore the warranted performance of this detector are as follows:
(Electric cooling may degrade performance by as much as 10%.)

Active Volume   cc Relative Efficiency 20 %Resolution 2.0 keV (FWHM) at 1.33 MeV   keV (FWTM) at 1.33 MeV   keV (FWHM) at   keV (FWTM) at   Peak / Compton   :1 Cryostat well diameter   mm Cryostat well depth   mmCryostat description if special

Physical Characteristics

Geometry Closed-end coaxialDiameter 53.5 mmLength 44.5 mmDistance from window 5 mmActive Volume   ccWell Depth   mmWell Diameter   mm

Electrical Characteristics

Depletion voltage (+)3800 V dcRecommended bias voltage (+)4000 V dcLeakage current at recommended bias 0.01 nAReset rate at recommended bias voltage 0.5 secCapacitance at recommended bias ~16 pF

Resolution and Efficiency

With amplifier time constant of 4 microseconds

Isotope	⁵⁷ Co	⁶⁰ Co			
Energy (KeV)	122	1332			
FWHM (KeV)	0.69	1.66			
FWTM (KeV)	1.29	3.03			
Peak / Compton		58.2:1			
Rel. Efficiency %		24.2			

Cool Down Time 4 hours. Cryostat Liquid Nitrogen Consumption Rate <1.4 Liters per Day.Tested by: John M. Barta Date: December 22, 1995Approved by: William J. Barta Date: December 22, 1995

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Det_spec_1 10/93 JMT

DETECTOR SPECIFICATION AND PERFORMANCE DATA

Specifications

DETECTOR MODEL GC2020 SERIAL NUMBER 12953596
 CRYOSTAT MODEL 7935-7S PREAMPLIFIER MODEL 2101P

The purchase specification and therefore the warranted performance of this detector are as follows:
 (Electric cooling may degrade performance by as much as 10%.)

Active Volume   cc Relative Efficiency 20 %
 Resolution 2.0 keV (FWHM) at 1.33 MeV
                          keV (FWTM) at 1.33 MeV
                          keV (FWHM) at
                          keV (FWTM) at
 Peak / Compton 46 :1 Cryostat well diameter   mm Cryostat well depth   mm
 Cryostat description if special

Physical Characteristics

Geometry Closed-end coaxial
 Diameter 53 mm Active Volume   cc
 Length 43.5 mm Well Depth   mm
 Distance from window 5 mm Well Diameter   mm

Electrical Characteristics

Depletion voltage (+)1500 V dc
 Recommended bias voltage (+)2500 V dc
 Leakage current at recommended bias — nA
 Reset rate at recommended voltage 0.6 sec
 Capacitance at recommended bias ~18 pF

Resolution and Efficiency

With amplifier time constant of 4 microseconds

Isotope	⁵⁷ Co	⁶⁰ Co			
Energy (KeV)	122	1332			
FWHM (KeV)	0.73	1.72			
FWTM (KeV)	1.33	3.18			
Peak / Compton		55.6			
Rel. Efficiency %		22.3			

Cool Down Time 4 hours. Cryostat Liquid Nitrogen Consumption Rate <1.4 Liters per Day.

Tested by: Randall Peak Date: December 22, 1995

Approved by: Marvin S. Smith Date: December 22, 1995

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Det_Spec_1 10/95 JHT

DETECTOR SPECIFICATION AND PERFORMANCE DATA

Specifications

DETECTOR MODEL GC2020 SERIAL NUMBER 3963597
 CRYOSTAT MODEL 7935-7S PREAMPLIFIER MODEL 2101PCSL

The purchase specification and therefore the warranted performance of this detector are as follows:
 (Electric cooling may degrade performance by as much as 10%.)

Active Volume   cc Relative Efficiency 20 %
 Resolution 2.0 keV (FWHM) at 1.33 MeV
                          keV (FWTM) at 1.33 MeV
                          keV (FWHM) at
                          keV (FWTM) at
 Peak / Compton   :1 Cryostat well diameter   mm Cryostat well depth   mm
 Cryostat description if special Big Mac

Physical Characteristics

Geometry Closed-end coaxial
 Diameter 55 mm Active Volume   cc
 Length 42 mm Well Depth   mm
 Distance from window 5 mm Well Diameter   mm

Electrical Characteristics

Depletion voltage (+)3500 V dc
 Recommended bias voltage (+)4000 V dc
 Reset rate at recommended bias 1.0 sec
 Preamplifier test point voltage at recommended voltage — V dc
 Capacitance at recommended bias ~18 pF

Resolution and Efficiency

With amplifier time constant of 4 microseconds

Isotope	⁵⁷ Co	⁶⁰ Co			
Energy (KeV)	122	1332			
FWHM (KeV)	0.79	1.75			
FWTM (KeV)	1.46	3.24			
Peak / Compton		53.5:1			
Rel. Efficiency %		23.5			

Cool Down Time 4 hours. Cryostat Liquid Nitrogen Consumption Rate <1.4 Liters per Day.

Tested by: Peter G. Jones Date: March 11, 1996

Approved by: Marjorie L. Smith Date: March 11, 1996

800 Research Parkway, Meriden CT. U.S.A. 06450 Tel. 203-238-2351/Fax 203-235-1347

DETECTOR SPECIFICATION AND PERFORMANCE DATA

Specifications

DETECTOR MODEL GC2020 SERIAL NUMBER 8963606
 CRYOSTAT MODEL 7935-7S PREAMPLIFIER MODEL 2101P

The purchase specification and therefore the warranted performance of this detector are as follows:
 (Electric cooling may degrade performance by as much as 10%.)

Active Volume   cc Relative Efficiency 20 %
 Resolution 2.0 keV (FWHM) at 1.33 MeV
                          keV (FWTM) at 1.33 MeV
                          keV (FWHM) at
                          keV (FWTM) at
 Peak / Compton   :1 Cryostat well diameter   mm Cryostat well depth   mm
 Cryostat description if special

Physical Characteristics

Geometry Closed-end coaxial
 Diameter 56 mm Active Volume   cc
 Length 43.5 mm Well Depth   mm
 Distance from window 5 mm Well Diameter   mm

Electrical Characteristics

Depletion voltage (+1300) V dc
 Recommended bias voltage (+2500) V dc
 Leakage current at recommended bias — nA
 Preamplifier test point voltage at recommended voltage — V dc
 Capacitance at recommended bias -27 pF
 Reset Rate 0.2 sec

Resolution and Efficiency

With amplifier time constant of 4 microseconds

Isotope	⁵⁷ Co	⁶⁰ Co			
Energy (KeV)	122	1332			
FWHM (KeV)	0.76	1.90			
FWTM (KeV)	1.42	3.65			
Peak / Compton		51.4:1			
Rel. Efficiency %		25.5			

Cool Down Time 4 hours. Cryostat Liquid Nitrogen Consumption Rate <1.5 Liters per Day.

Tested by: Mark Beatty Date: March 11, 1996

Approved by: [Signature] Date: March 11, 1996

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Det_Spec_1 10/95 JMT

DETECTOR SPECIFICATION AND PERFORMANCE DATA

Specifications

DETECTOR MODEL GC2020 SERIAL NUMBER 8963611
 CRYOSTAT MODEL 7935-7S PREAMPLIFIER MODEL 2101PCSL

The purchase specification and therefore the warranted performance of this detector are as follows:
 (Electric cooling may degrade performance by as much as 10%.)

Active Volume   cc Relative Efficiency 20 %
 Resolution 2.0 keV (FWHM) at 1.33 MeV
                          keV (FWHM) at 1.33 MeV
                          keV (FWHM) at
                          keV (FWHM) at
 Peak / Compton   :1 Cryostat well diameter   mm Cryostat well depth   mm
 Cryostat description if special

Physical Characteristics

Geometry Closed-end coaxial
 Diameter 55 mm Active Volume   cc
 Length 43.5 mm Well Depth   mm
 Distance from window 5 mm Well Diameter   mm

Electrical Characteristics

Depletion voltage (+)2400 V dc
 Recommended bias voltage (+)3000 V dc
 Reset rate at recommended bias 0.5 sec
 Preamplifier test point voltage at recommended voltage   V dc
 Capacitance at recommended bias ~ 19 pF

Resolution and Efficiency

With amplifier time constant of 4 microseconds

Isotope	⁵⁷ Co	⁶⁰ Co			
Energy (KeV)	122	1332			
FWHM (KeV)	0.76	1.88			
FWTM (KeV)	1.41	3.43			
Peak / Compton		52.1			
Rel. Efficiency %		25.2			

Cool Down Time 4 hours. Cryostat Liquid Nitrogen Consumption Rate <1.4 Liters per Day.

Tested by: Peter Palmer Date: March 11, 1996

Approved by: Manning Lindahl Date: March 11, 1996

800 Research Parkway, Meriden CT. U.S.A. 06450 Tel. 203-238-2351/Fax 203-235-1347

Det_Spec_1 10/95 JHT

DETECTOR SPECIFICATION AND PERFORMANCE DATA

Specifications

DETECTOR MODEL GC2020 SERIAL NUMBER 3963617
 CRYOSTAT MODEL 7935-7S PREAMPLIFIER MODEL 2101PCSL

The purchase specification and therefore the warranted performance of this detector are as follows:
 (Electric cooling may degrade performance by as much as 10%.)

Active Volume   cc Relative Efficiency 20 %

Resolution 2.0 keV (FWHM) at 1.33 MeV

       keV (FWTM) at 1.33 MeV

       keV (FWHM) at

       keV (FWTM) at

Peak / Compton   :1 Cryostat well diameter   mm Cryostat well depth   mm

Cryostat description if special

Physical Characteristics

Geometry Closed-end coaxial

Diameter 53.5 mm

Length 43 mm

Distance from window 5 mm

Active Volume   cc

Well Depth   mm

Well Diameter   mm

Electrical Characteristics

Depletion voltage (+) 5000 V dc

Recommended bias voltage (+) 5000 V dc

Reset rate at recommended bias 0.4 sec

Preamplifier test point voltage at recommended voltage   V dc

Capacitance at recommended bias ~19 pF

Resolution and Efficiency

With amplifier time constant of 4 microseconds

Isotope	⁵⁷ Co	⁶⁰ Co			
Energy (KeV)	122	1332			
FWHM (KeV)	0.84	1.73			
FWTM (KeV)	1.57	3.17			
Peak / Compton		56.1:1			
Rel. Efficiency %		23.9			

Cool Down Time 4 hours. Cryostat Liquid Nitrogen Consumption Rate <1.4 Liters per Day.

Tested by: Randall Park Date: March 11, 1996

Approved by: Manning Lockhart Date: March 11, 1996

800 Research Parkway, Meriden CT. U.S.A. 06450 Tel. 203-238-2351/Fax 203-235-1347

Det_Spec_1 10/95 JMT

APPENDIX D

Energy and FWHM

Data and Curves

HNF-5148, Rev. 1

Energy Calibration Report 12-20-99 11:59:21 AM Page I
 E N B R G Y C A L I B R A T I O N R E P O R T

Identification Number : CALCOUNT
 Description/Title : Calibration Count Counter : GEA - A
 Arrangement : 55-gal. drums Calibration for : SEGE1
 Acquisition Started : 12-20-99 11:31:21 AM
 Live Time 595.4 seconds Real Time 600.0 seconds

ENERGY CALIBRATION COEFFICIENTS

Energy Calibrate Performed on: 12-20-99 11:59:16 AM by: System Manager
 Energy Calibrate Type: POLY

$$\text{Energy(keV)} = -0.983 + 0.500 \cdot \text{ch} + -1.68\text{E-}07 \cdot \text{ch}^2 + 0.00\text{E+}00 \cdot \text{ch}^3$$

SHAPE CALIBRATION COEFFICIENTS

Shape Calibrate Performed on: 12-20-99 11:59:16 AM
 by: System Manager

FWHM 0.534 + 0.030*E^{1/2}
 LOW TAIL 0.0E+00 + 0.0E+00*E

ENERGY CALIBRATION RESULTS TABLE

Centroid Channel	Centroid error	Energy (keV)
121.12	0.03	59.54
164.04	0.01	81.00
555.15	0.03	276.40
608.05	0.02	302.84
714.44	0.01	356.01
770.21	0.03	383.85
1326.44	0.03	661.66
2351.34	0.06	1173.24
2670.46	0.06	1332.50

SHAPE CALIBRATION RESULTS TABLE

Energy (keV)	FWHM channels	FWHM error	TAIL channels	TAIL error
59.54	1.63	0.06	0.00	0.00
81.00	1.63	0.03	0.00	0.00
276.40	2.11	0.07	0.00	0.00
302.84	2.05	0.04	0.00	0.00
356.01	2.15	0.02	0.00	0.00
383.85	2.21	0.07	0.00	0.00
661.66	2.67	0.07	0.00	0.00
1173.24	3.33	0.11	0.00	0.00
1332.50	3.43	0.11	0.00	0.00

HNF-5148, Rev. 1

Energy Calibration Report 12-20-99 11:57:24 AM Page I
 ENERGY CALIBRATION REPORT

identification Number : CALCOUNT
 Description/Title : Calibration Count Counter : GEA - A
 Arrangement : 55-gal. drums Calibration for : SEGE2
 Acquisition Started : 12-20799 11:31:21 AM
 Live Time 592.5 seconds Real Time 600.0 seconds

ENERGY CALIBRATION COEFFICIENTS

Energy Calibrate Performed on: 12-20-99 11:57:18 AM by: System Manager
 Energy Calibrate Type: POLY

$$\text{Energy(keV)} = -0.757 + 0.500 \cdot \text{ch} + -1.72\text{E-}07 \cdot \text{ch}^2 + 0.00\text{E+}00 \cdot \text{ch}^3$$

SHAPE CALIBRATION COEFFICIENTS

Shape Calibrate Performed on: 12-20-99 11:57:18 AM
 by: System Manager

$$\begin{aligned} \text{FWHM} &= 0.387 + 0.039 \cdot \text{E}^{1/2} \\ \text{LOW TAIL} &= 0.0 \cdot \text{E} + 0.0 \cdot \text{ENERGY} \end{aligned}$$

CALIBRATION RESULTS TABLE

Centroid Channel	Centroid error	Energy (keV)
120.52	0.02	59.54
163.46	0.01	81.00
554.12	0.02	276.40
607.06	0.01	302.84
713.37	0.01	356.01
769.07	0.02	383.85
1324.89	0.02	661.66
2348.89	0.04	1173.24
2667.67	0.05	1332.50

SHAPE CALIBRATION RESULTS TABLE

Energy (keV)	FWHM channels	FWHM error	TAIL channels	TAIL error
59.54	1.64	0.04	0.00	0.00
81.00	1.50	0.02	0.00	0.00
276.40	2.09	0.04	0.00	0.00
302.84	2.11	0.02	0.00	0.00
356.01	2.22	0.01	0.00	0.00
383.85	2.28	0.04	0.00	0.00
661.66	2.79	0.04	0.00	0.00
1173.24	3.80	0.08	0.00	0.00
1332.50	4.16	0.09	0.00	0.00

HNF-5148, Rev. 1

Energy Calibration Report 12-20-99 11:55:41 AM Page I
 E N E R G Y C A L I B R A T I O N R E P O R T

Identification Number : CALCOUNT
 Description/Title : Calibration Count Counter : GEA - A
 Arrangement : 55-gal. drums Calibration for : 8EGE3
 Acquisition Started : 12-20-99 11:31:21 AM
 Live Time 592.6 seconds Real Time 600.0 seconds

ENERGY CALIBRATION COEFFICIENTS

Energy Calibrate Performed on: 12-20-99 11:55:36 AM by: System Manager
 Energy Calibrate Type: POLY

Energy(keV) = $-0.693 + 0.500 \cdot \text{ch} + -1.64\text{E-}07 \cdot \text{ch}^2 + 0.00\text{E+}00 \cdot \text{ch}^3$

SHAPE CALIBRATION COEFFICIENTS

Shape Calibrate Performed on: 12-20-99 11:55:36 AM
 by: System Manager

FWHM = $0.543 + 0.032 \cdot E^{1/2}$
 LOW TAIL = $0.0\text{E+}00 + 0.0\text{E+}00 \cdot E$

ENERGY CALIBRATION RESULTS TABLE

Centroid Channel	Centroid error	Energy (keV)
120.45	0.02	59.54
163.40	0.01	81.00
554.23	0.02	276.40
607.17	0.01	302.84
713.55	0.01	356.01
769.22	0.02	383.85
1325.28	0.02	661.66
2349.63	0.04	1173.24
2668.63	0.04	1332.50

SHAPE CALIBRATION RESULTS TABLE

Energy (keV)	FWHM channels	FWHM error	TAIL channels	TAIL error
59.54	1.72	0.04	0.00	0.00
81.00	1.68	0.02	0.00	0.00
276.40	2.12	0.04	0.00	0.00
302.84	2.18	0.02	0.00	0.00
356.01	2 '25	0.01	0.00	0.00
383.85	2.20	0.04	0.00	0.00
661.66	2.76	0.04	0.00	0.00
1173.24	3.48	0.07	0.00	0.00
1332.50	3.73	0.08	0.00	0.00

HNF-5148, Rev. 1

Energy Calibration Report   12-20-99 11:53:53 AM   Page I
 E N E R G Y   C A L I B R A T I O N   R E P O R T

identification Number   CALCOUNT
 Description/Title   Calibration Count Counter   GEA - A
 Arrangement   55-gal. drums Calibration for   SEGE4

Acquisition   Started   12-20-99 11:31:21 AM Live Time
 595.0 seconds Real Time   600.0 seconds

ENERGY CALIBRATION COEFFICIENTS

Energy Calibrate Performed on: 12-20-99 11:53:48 AM by: System Manager
 Energy Calibrate Type: POLY

$$\text{Energy(keV)} = -1.687 + 0.501 \cdot \text{ch} + -1.51\text{E-}07 \cdot \text{ch}^2 + 0.00\text{E+}00 \cdot \text{ch}^3$$

SHAPE CALIBRATION COEFFICIENTS

Shape Calibrate Performed on: 12-20-99 11:53:48 AM
 by: System Manager 9*EA

$$\begin{aligned} \text{FWHM} &= 0.529 + 0.02 \cdot \text{E}^{1/2} \\ \text{LOW TAIL} &= 0.0\text{E+}00 + 0.0\text{E+}00 \cdot \text{E} \end{aligned}$$

ENERGY CALIBRATION RESULTS TABLE

Centroid Channel	Centroid error	Energy (keV)
122.31	0.02	59.54
165.21	0.01	81.00
555.68	0.03	276.40
608.49	0.02	302.84
714.77	0.01	356.01
770.34	0.03	383.85
1325.81	0.03	661.66
2348.89	0.05	1173.24
2667.71	0.05	1332.50

SHAPE CALIBRATION RESULTS   TABLE

Energy (keV)	FWHM channels	FWHM error	TAIL channels	TAIL error
59.54	1.61	0.05	0.00	0.00
81.00	1.59	0.02	1.00	0.00
276.40	2.00	0.06	0.00	0.00
302.84	2.05	0.03	0.00	0.00
356.01	2.13	0.02	0.00	0.00
383.85	2.16	0.06	0.00	0.00
661.66	2.52	0.05	0.00	0.00
1173.24	3.21	0.09	0.00	0.00
1332.50	3.33	0.09	0.00	0.00

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Energy Calibration Report   12-20-99 12:01:44 PM   Page 1
 E N E R G Y   C A L I B R A T I O N   R E P O R T

Identification Number   : CALCOUNT
 Description/Title   : Calibration Count Counter : GEA - A
 Arrangement   : 55-gal. drums Calibration for : SEGES
 Acquisition Started   : 12-20-99 11:31:21 AM
 Live Time   595.0 seconds   Real Time   600.0 seconds

ENERGY CALIBRATION COEFFICIENTS

Energy Calibrate Performed on: 12-20-99 12:01:35 PM by: System Manager
 Energy Calibrate Type: POLY

$$\text{Energy(keV)} = -1.691 + 0.501 \cdot \text{ch} + -1.54\text{E-}07 \cdot \text{ch}^2 + 0.00\text{E+}00 \cdot \text{ch}^3$$

SHAPE CALIBRATION COEFFICIENTS

Shape Calibrate Performed on: 12-20-99 12:01:35 PM
 by: System Manager

$$\text{FWHM} = 0.605 + 0.033 \cdot \text{E}^{\wedge}1/2$$

$$\text{LOW TAIL} = 0.0\text{E+}00 + 0.0\text{E+}00 \cdot \text{E}$$

ENERGY CALIBRATION RESULTS TABLE

Centroid Channel	Centroid error	Energy (keV)
122.31	0.01	59.54
165.22	0.01	81.00
555.64	0.01	276.40
608.51	0.01	302.84
714.76	0.00	356.01
770.38	0.01	383.85
1325.82	0.01	661.66
2348.98	0.02	1173.24
2667.61	0.02	1332.50

SHAPE CALI13RATION RESULTS TABLE

Energy (keV)	FWHM channels	FWHM error	TAIL channels	TAIL error
59.54	1.86	0.03	0.00	0.00
81.00	1.80	0.01	0.00	0.00
276.40	2.35	0.03	0.00	0.00
302.84	2.36	0.02	0.00	0.00
356.01	2.41	0.01	0.00	0.00
383.85	2.40	0.03	0.00	0.00
661.66	2.85	0.02	0.00	0.00
1173.24	3.63	0.04	0.00	0.00
1332.50	3.81	0.04	0.00	0.00

Energy Calibration Report

1-31-00 10:47:11 AM

Page I

E N E R G Y C A L I B R A T I O N R E P O R T

Identification Number : CA-LCOUNT
 Description/Title : Calibration Count Counter : GEA - A
 Arrangement : 55-gal. drums.
 Calibration for : LEGE5
 Acquisition Started : 1-31-00 10:33:40 AM
 Live Time 299.8 seconds Real Time 306.4 seconds

ENERGY CALIBRATION COEFFICIENTS

Energy Calibrate Performed on: 1-31-00 10:46:44 AM
 by: System Manager
 Energy Calibrate Type: POLY

Energy(keV) = $0.145 + 0.077 \cdot ch + 0.00E+00 \cdot ch^2 + 0.00E+00 \cdot ch^3$

SHAPE CALIBRATION COEFFICIENTS

Shape Calibrate Performed on: 1-31-00 10:46:44 AM
 by: System Manager

FWHM = $0.306 + 0.032 \cdot E^{1/2}$
 LOW TAIL = $0.0E+00 + 0.0E+00 \cdot E$

ENERGY CALIBRATION RESULTS TABLE

Centroid Channel	Centroid error	Energy (keV)
774.51	0.46	59.54
1054.24	0.11	81.00
3601.60	0.12	276.40
3946.74	0.07	302.84

SHAPE CALIBRATION RESULTS TABLE

Energy (keV)	FWHM channels	FWHM error	TAIL channels	TAIL error
59.54	5.61	1.05	0.00	0.00
81.00	7.80	0.23	0.00	0.00
276.40	11.38	0.25	0.00	0.00
302.84	11.13	0.14	0.00	0.00

Energy Calibration Report

1-31-00 10:53:25 AM

Page I

E N E R G Y C A L I B R A T I O N R E P O R T

Identification Number :CALCOUNT
 Description/Title :Calibration Count Counter :GEA - A
 Arrangement :55-gal. drums Calibration for :LEGE6
 Acquisition Started 1-31-00 10:33:40 AM
 Live Time 300.6 seconds Real Time 306.8 seconds

ENERGY CALIBRATION COEFFICIENTS

Energy Calibrate Performed on: 1-31-00 10:53:13 AM
 by: System Manager
 Energy Calibrate Type: POLY

Energy(keV) = $0.118 + 0.076 \cdot \text{ch} + 0.00\text{E}+00 \cdot \text{ch}^2 + 0.00\text{E}+00 \cdot \text{ch}^3$

SHAPE CALIBRATION COEFFICIENTS

Shape Calibrate Performed on: 1-31-00 10:53:13 AM
 by: System Manager

FWHM = $0.241 + 0.040 \cdot E^{1/2}$
 LOW TAIL = $0.0\text{E}+00 + 0.0\text{E}+00 \cdot E$

ENERGY CALIBRATION RESULTS TABLE

Centroid Channel	Centroid error	Energy (keV)
778.08	0.67	59.54
1058.65	0.11	81.00
3616.11	0.13	276.40
3962.30	0.08	302.84

SHAPE CALIBRATION RESULTS TABLE

Energy (keV)	FWHM channels	FWHM error	TAIL channels	TAIL error
59.54	4.90	1.38	0.00	0.00
81.00	8.00	0.24	0.00	0.00
276.40	11.72	0.25	0.00	0.00
302.84	12.40	0.15	0.00	0.00

APPENDIX E

SEGe Efficiency

Data and Curves

Foam Drum, density = 0.01346 gms/cc, No Shield (collimator). Spectrum Seq # 3988

Seg 2, SEGe 4, Drum position 2.

Seg 3, SEGe 4, Drum position 3.

Foam Drum, density = 0.01346 gms/cc, No Shield (collimator). Spectrum Seq # 3988

Seg 4, SEGe 3, Drum position 1.

Seg 5, SEGe 3, Drum position 2.

Foam Drum, density = 0.01346 gms/cc, No Shield (collimator). Spectrum Seq # 3988

Seg 6, SEGe 3, Drum position 3.

Seg 7, SEGe 2, Drum position 1.

Foam Drum, density = 0.01346 gms/cc, No Shield (collimator). Spectrum Seq # 3988

Datasource: C:\WAS\TEMP\EFF642.TEM
 $\ln(\text{Eff}) = -1.787\text{e}+02 + 1.086\text{e}+02 \cdot \ln(E) - 2.545\text{e}+01 \cdot \ln(E)^2 + 2.621\text{e}+00 \cdot \ln(E)^3 - 1.009\text{e}-01 \cdot \ln(E)^4$

Seg 8, SEGe 2, Drum position 2.

Datasource: C:\WAS\TEMP\EFF642.TEM
 $\ln(\text{Eff}) = -2.074\text{e}+02 + 1.293\text{e}+02 \cdot \ln(E) - 3.095\text{e}+01 \cdot \ln(E)^2 + 3.264\text{e}+00 \cdot \ln(E)^3 - 1.287\text{e}-01 \cdot \ln(E)^4$

Seg 9, SEGe 2, Drum position 3.

Foam Drum, density = 0.01346 gms/cc, No Shield (collimator). Spectrum Seq # 3988

Seg 10, SEGe 1, Drum position 1.

Seg 11, SEGe 1, Drum position 2.

Foam Drum, density = 0.01346 gms/cc, No Shield (collimator). Spectrum Seq # 3988

DataSource: C:\WAS\TEMP\EFF842.TEM

$$\ln(\text{Eff}) = -1.374e+02 + 8.105e+01 \cdot \ln(E) - 1.824e+01 \cdot \ln(E)^2 + 1.793e+00 \cdot \ln(E)^3 - 6.551e-02 \cdot \ln(E)^4$$

Sum Segments.

Foam Drum, density = 0.01346 gms/cc, Shield (collimator). Spectrum Seq # 3989

Datasource: C:\WAS\TEMP\EFF642.TEM
 $\ln(\text{Eff}) = -9.958e+01 + 4.232e+01 \ln(E) - 6.565e+00 \ln(E)^2 + 3.365e-01 \ln(E)^3$

Seg 2, SEGe 4, Drum position 2.

Datasource: C:\WAS\TEMP\EFF642.TEM
 $\ln(\text{Eff}) = -6.420e+01 + 2.566e+01 \ln(E) - 4.001e+00 \ln(E)^2 + 2.061e-01 \ln(E)^3$

Seg 3, SEGe 4, Drum position 3.

Foam Drum, density = 0.01346 gms/cc, Shield (collimator). Spectrum Seq # 3989

Data source: C:\WAS\TEMP\EFF642.TEM
 $\ln(\text{Eff}) = -5.473e+01 + 2.092e+01 \ln(E) - 3.175e+00 \ln(E)^2 + 1.589e-01 \ln(E)^3$

Seg 4, SEGe 3, Drum position 1.

Data source: C:\WAS\TEMP\EFF642.TEM
 $\ln(\text{Eff}) = -8.927e+01 + 3.665e+01 \ln(E) - 5.556e+00 \ln(E)^2 + 2.786e-01 \ln(E)^3$

Seg 5, SEGe 3, Drum position 2.

Foam Drum, density = 0.01346 gms/cc, Shield (collimator). Spectrum Seq # 3989

Seg 6, SEGe 3, Drum position 3.

Seg 7, SEGe 2, Drum position 1.

Foam Drum, density = 0.01346 gms/cc, Shield (collimator). Spectrum Seq # 3989

Datasource: C:\WAS\TEMP\EFF642.TEM
 $\ln(\text{Eff}) = -5.166\text{e}+02 + 3.223\text{e}+02 \cdot \ln(E) - 7.862\text{e}+01 \cdot \ln(E)^2 + 8.080\text{e}+00 \cdot \ln(E)^3$
 $-3.190\text{e}-01 \cdot \ln(E)^4$

Seg 8, SEGe 2, Drum position 2.

Datasource: C:\WAS\TEMP\EFF642.TEM
 $\ln(\text{Eff}) = -1.893\text{e}+01 + 3.569\text{e}+00 \cdot \ln(E) - 3.903\text{e}-01 \cdot \ln(E)^2 + 1.070\text{e}-02 \cdot \ln(E)^3$

Seg 9, SEGe 2, Drum position 3.

Foam Drum, density = 0.01346 gms/cc, Shield (collimator). Spectrum Seq # 3989

Datasource: C:\WAS\TEMP\EFF642.TEM
 $\ln(\text{Eff}) = -4.623e+01 + 1.693e+01 \ln(E) - 2.573e+00 \ln(E)^2 + 1.284e-01 \ln(E)^3$

Seg 10, SEGe 1, Drum position 1.

Datasource: C:\WAS\TEMP\EFF642.TEM
 $\ln(\text{Eff}) = -5.738e+01 + 3.434e+01 \ln(E) - 9.082e+00 \ln(E)^2 + 1.046e+00 \ln(E)^3 - 4.452e-02 \ln(E)^4$

Seg 11, SEGe 1, Drum position 2.

Foam Drum, density = 0.01346 gms/cc, Shield (collimator). Spectrum Seq # 3989

Homosote Drum, density = 0.43029 gms/cc, No Shield (collimator). Spectrum Seq # 3994

Data source: C:\WAS\TEMP\EFF478.TEM

$$\ln(\text{Eff}) = -7.528e+01 + 3.279e+01 \ln(E) - 5.305e+00 \ln(E)^2 + 2.802e-01 \ln(E)^3$$

Seg 2, SEGe 4, Drum position 2.

Data source: C:\WAS\TEMP\EFF478.TEM

$$\ln(\text{Eff}) = -7.233e+01 + 3.153e+01 \ln(E) - 5.089e+00 \ln(E)^2 + 2.677e-01 \ln(E)^3$$

Seg 3, SEGe 4, Drum position 3.

Homosote Drum, density = 0.43029 gms/cc, No Shield (collimator). Spectrum Seq # 3994

Seg 4, SEGe 3, Drum position 1.

Seg 5, SEGe 3, Drum position 2.

Homosote Drum, density = 0.43029 gms/cc, No Shield (collimator). Spectrum Seq # 3994

Seg 6, SEGe 3, Drum position 3.

Seg 7, SEGe 2, Drum position 1.

Homosote Drum, density = 0.43029 gms/cc, No Shield (collimator). Spectrum Seq # 3994

Seg 8, SEGe 2, Drum position 2.

Seg 9, SEGe 2, Drum position 3.

Homosote Drum, density = 0.43029 gms/cc, No Shield (collimator). Spectrum Seq # 3994

Seg 10, SEGe 1, Drum position 1.

Seg 11, SEGe 1, Drum position 2.

Homosote Drum, density = 0.43029 gms/cc, No Shield (collimator). Spectrum Seq # 3994

Datasource: C:\WAS\TEMP\EFF478.TEM

$\ln(\text{Eff}) = -3.182e+01 + 9.945e+00 \ln(E) - 1.161e+00 \ln(E)^2 + 3.601e-02 \ln(E)^3$

Sum Segments

Homosote Drum, density = 0.43029 gms/cc, Shield (collimator). Spectrum Seq # 3995

Datasource: C:\WAS\TEMP\EFF478.TEM

$$\ln(\text{Eff}) = -5.468\text{e}+01 + 1.913\text{e}+01 \cdot \ln(E) - 2.751\text{e}+00 \cdot \ln(E)^2 + 1.314\text{e}-01 \cdot \ln(E)^3$$

Seg 2, SEGe 4, Drum position 2,

Datasource: C:\WAS\TEMP\EFF478.TEM

$$\ln(\text{Eff}) = -1.110\text{e}+03 + 6.916\text{e}+02 \cdot \ln(E) - 1.626\text{e}+02 \cdot \ln(E)^2 + 1.695\text{e}+01 \cdot \ln(E)^3 - 6.613\text{e}-01 \cdot \ln(E)^4$$

Seg 3, SEGe 4, Drum position 3

Homosote Drum, density = 0.43029 gms/cc, Shield (collimator). Spectrum Seq # 3995

Seg 4, SEGe 3, Drum position 1.

Seg 5, SEGe 3, Drum position 2.

Homosote Drum, density = 0.43029 gms/cc, Shield (collimator). Spectrum Seq # 3995

Seg 6, SEGe 3, Drum position 3.

Seg 7, SEGe 2, Drum position 1.

Homosote Drum, density = 0.43029 gms/cc, Shield (collimator). Spectrum Seq # 3995

Seg 8, SEGe 2, Drum position 2.

Seg 9, SEGe 2, Drum position 3.

Homosote Drum, density = 0.43029 gms/cc, Shield (collimator). Spectrum Seq # 3995

Seg 10, SEGe 1, Drum position 1.

Seg 11, SEGe 1, Drum position 2.

Homosote Drum, density = 0.43029 gms/cc, Shield (collimator). Spectrum Seq # 3995

Datasource: C:\WAS\TEMP\EFF478.TEM

$\ln(\text{Eff}) = -1.259\text{e}+01 + 1.391\text{e}+00 \cdot \ln(E) - 1.002\text{e}-01 \cdot \ln(E)^2$

Sum Segments.

Particle Board Drum, density = 0.65625 gms/cc, No Shield (collimator). Spectrum Seq # 3992

Seg 2, SEGe 4, Drum position 2.

Seg 3, SEGe 4, Drum position 3.

Particle Board Drum, density = 0.65625 gms/cc, No Shield (collimator). Spectrum Seq # 3992

Datasource: C:\WAS\TEMP\EFF039.TEM
 $\ln(\text{Eff}) = -1.377\text{e}+02 + 7.760\text{e}+01 \cdot \ln(E) - 1.720\text{e}+01 \cdot \ln(E)^2 + 1.670\text{e}+00 \cdot \ln(E)^3$
 $- 6.032\text{e}-02 \cdot \ln(E)^4$

Seg 4, SEGe 3, Drum position 1.

Datasource: C:\WAS\TEMP\EFF039.TEM
 $\ln(\text{Eff}) = -1.654\text{e}+02 + 1.133\text{e}+02 \cdot \ln(E) - 2.692\text{e}+01 \cdot \ln(E)^2 + 2.819\text{e}+00 \cdot \ln(E)^3$
 $- 1.103\text{e}-01 \cdot \ln(E)^4$

Seg 5, SEGe 3, Drum position 2.

Particle Board Drum, density = 0.65625 gms/cc, No Shield (collimator). Spectrum Seq # 3992

Seg 6, SEGe 3, Drum position 3.

Seg 7, SEGe 2, Drum position 1.

Particle Board Drum, density = 0.65625 gms/cc, No Shield (collimator). Spectrum Seq # 3992

Seg 8, SEGe 2, Drum position 2.

Seg 9, SEGe 2, Drum position 3.

Particle Board Drum, density = 0.65625 gms/cc, No Shield (collimator). Spectrum Seq # 3992

Seg 10, SEGe 1, Drum position 1.

Seg 11, SEGe 1, Drum position 2.

Particle Board Drum, density = 0.65625 gms/cc, No Shield (collimator). Spectrum Seq # 3992

Particle Board Drum, density = 0.65625 gms/cc, No Shield (collimator). Spectrum Seq # 3993

Seg 2, SEGe 4, Drum position 2.

Seg 3, SEGe 1, Drum position 3.

Particle Board Drum, density = 0.65625 gms/cc, No Shield (collimator). Spectrum Seq # 3993

Seg 4, SEGe 3, Drum position 1.

Seg 5, SEGe 3, Drum position 2.

Particle Board Drum, density = 0.65625 gms/cc, No Shield (collimator). Spectrum Seq # 3993

Seg 6, SEGe 3, Drum position 3.

Seg 7, SEGe 2, Drum position 1.

Particle Board Drum, density = 0.65625 gms/cc, No Shield (collimator). Spectrum Seq # 3993

Seg 8, SEGe 2, Drum position 2.

Seg 9, SEGe 2, Drum position 3.

Particle Board Drum, density = 0.65625 gms/cc, No Shield (collimator). Spectrum Seq # 3993

Seg 10, SEGe 1, Drum position 1.

Seg 11, SEGe 1, Drum position 2.

Particle Board Drum, density = 0.65625 gms/cc, No Shield (collimator). Spectrum Seq # 3993

Sand Drum, density = 1.5601 gms/cc, No Shield (collimator). Spectrum Seq # 3991

Datasource: C:\WAS\TEMP\EFF039.TEM

$\ln(\text{Eff}) = -7.228e+01 + 2.937e+01 \ln(E) - 4.532e+00 \ln(E)^2 + 2.287e-01 \ln(E)^3$

Seg 2, SEGe 4, Drum position 2.

Datasource: C:\WAS\TEMP\EFF039.TEM

$\ln(\text{Eff}) = -2.179e+02 + 1.348e+02 \ln(E) - 3.229e+01 \ln(E)^2 + 3.423e+00 \ln(E)^3 - 1.357e-01 \ln(E)^4$

Seg 3, SEGe 4, Drum position 3.

Sand Drum, density = 1.5601 gms/cc, No Shield (collimator). Spectrum Seq # 3991

Seg 4, SEGe 3, Drum position 1.

Seg 5, SEGe 3, Drum position 2.

Sand Drum, density = 1.5601 gms/cc, No Shield (collimator). Spectrum Seq # 3991

Seg 6, SEGe 3, Drum position 3.

Seg 7, SEGe 2, Drum position 1.

Sand Drum, density = 1.5601 gms/cc, No Shield (collimator). Spectrum Seq # 3991

Seg 8, SEGe 2, Drum position 2.

Seg 9, SEGe 2, Drum position 3.

Sand Drum, density = 1.5601 gms/cc, No Shield (collimator). Spectrum Seq # 3991

Datasource: C:\WAS\TEMP\EFF039.TEM
 $\ln(\text{Eff}) = -7.297\text{e}+01 + 3.019\text{e}+01 \cdot \ln(E)$

$-4.708\text{e}+00 \cdot \ln(E)^2 + 2.398\text{e}-01 \cdot \ln(E)^3$

Seg 10, SEGe 1, Drum position 1.

Datasource: C:\WAS\TEMP\EFF039.TEM
 $\ln(\text{Eff}) = -9.209\text{e}+01 + 4.011\text{e}+01 \cdot \ln(E)$

$-6.435\text{e}+00 \cdot \ln(E)^2 + 3.385\text{e}-01 \cdot \ln(E)^3$

Seg 11, SEGe 1, Drum position 2

Sand Drum, density = 1,5601 gms/cc, No Shield (collimator). Spectrum Seq # 3991

Datasource: C:\WAS\TEMP\EFF039.TEM

$$\ln(\text{Eff}) = -4.273e+01 + 1.457e+01 \ln(E) - 1.868e+00 \ln(E)^2 + 7.481e-02 \ln(E)^3$$

Sum Segments

Sand Drum, density = 1.5601 gms/cc Shield (collimator). Spectrum Seq # 3990

Seg 2, SEGe 4, Drum position 2.

Seg 3, SEGe 4, Drum position 3.

Sand Drum, density = 1.5601 gms/cc Shield (collimator). Spectrum Seq # 3990

Seg 4, SEGe 3, Drum position 1.

Seg 5, SEGe 3, Drum position 2.

Sand Drum, density = 1.5601 gms/cc Shield (collimator). Spectrum Seq # 3990

Seg 6, SEGe 3, Drum position 3.

Seg 7, SEGe 2, Drum position 1.

Sand Drum, density = 1.5601 gms/cc Shield (collimator). Spectrum Seq # 3990

Seg 8, SEGe 2, Drum position 2.

Seg 9, SEGe 2, Drum position 3.

Sand Drum, density = 1.5601 gms/cc Shield (collimator). Spectrum Seq # 3990

Data source: C:\WAS\TEMP\EFF039.TEM

$$\ln(\text{Eff}) = -5.284e+01 + 1.926e+01 \cdot \ln(E) - 2.988e+00 \cdot \ln(E)^2 + 1.552e-01 \cdot \ln(E)^3$$

Seg 10, SEGe 1, Drum position 1.

Data source: C:\WAS\TEMP\EFF039.TEM

$$\ln(\text{Eff}) = -4.933e+02 + 3.271e+02 \cdot \ln(E) - 8.256e+01 \cdot \ln(E)^2 + 9.186e+00 \cdot \ln(E)^3 - 3.802e-01 \cdot \ln(E)^4$$

Seg 11, SEGe 1, Drum position 2.

Sand Drum, density = 1.5601 gms/cc Shield (collimator). Spectrum Seq # 3990

Summed Spectra, low density, 0.0135, no shield.

Summed Spectra, 2nd density, 0.430, no shield.

Summed Spectra, 3rd density, 0.656, no shield.

Summed Spectra, heavy density, 1.56, no shield.

APPENDIX F

Spreadsheets

Spreadsheet for Figure 2

Activity and Count response for 1-2000 cal

Daily Source Drum

COUNTS										
Seg #	Seg	59 k'eV	Sequence number					AVG	Dev	% err
		4106	4107	4108	4109	4110				
11-Top	S12	4542	4583	4537	4331	4617	4522.0	111.64	2.47	
10	S13	6777	6588	6669	9834	6678	7309.2	1413.00	19.33	
9	S21	7964	8149	8377	8470	8370	8266.0	205.94	2.49	
8	S22	7992	8244	7991	8124	8320	8134.2	147.82	1.82	
7	S23	8686	8591	8359	8416	8572	8524.8	134.09	1.57	
6	S31	7949	8185	8197	8296	8269	8179.2	136.98	1.67	
5	S32	7504	7763	7784	7625	7416	7618.4	160.02	2.10	
4	S33	7134	7406	7283	6855	7064	7148.4	210.88	2.95	
3	S41	5330	5732	5591	5716	5701	5614.0	168.14	2.99	
2	S42	3138	3322	3358	3273	3209	3260.0	88.18	2.70	
A04		69025	69620	70322	70768	70642	70075.4	736.93	1.05	
Sum		67016	68563	68146	70940	68216	68576.2			
% Diff		2.91	1.52	3.09	-0.24	3.43	2.14			

ACTIVITY										
Seg #	Seg	59 k'eV	Sequence number					AVG	Dev	% err
		4106	4107	4108	4109	4110				
11	S12	4.034	4.076	4.036	3.853	4.106	4.021	0.10	2.46	
10	S13	3.765	3.660	3.705	3.797	3.711	3.728	0.05	1.44	
9	S21	3.634	3.717	3.821	3.864	3.819	3.771	0.09	2.49	
8	S22	3.831	3.952	3.831	3.895	3.988	3.899	0.07	1.82	
7	S23	3.564	3.525	3.430	3.453	3.517	3.498	0.06	1.58	
6	S31	3.512	3.616	3.621	3.665	3.653	3.613	0.06	1.67	
5	S32	3.761	3.891	3.901	3.822	3.717	3.818	0.08	2.10	
4	S33	3.794	3.938	3.873	3.645	3.756	3.801	0.11	2.95	
3	S41	3.275	3.522	3.436	3.512	3.503	3.449	0.10	3.00	
2	S42	3.404	3.603	3.642	3.550	3.481	3.536	0.10	2.70	
A04		36.707	37.024	37.398	37.635	37.568	37.266	0.39	1.05	
Sum		36.573	37.501	37.297	37.055	37.251	37.135			
% Diff		0.37	-1.29	0.27	1.54	0.84	0.35			

Activity and Count response for 1-2000 cal

Daily Source Drum

COUNTS										
Seg #	Seg	81 keV	Sequence number					AVG	Dev	% err
		4106	4107	4108	4109	4110				
11-Top	S12	12013	11293	12379	12377	11693	11951.0	465.84	3.90	
10	S13	18923	18848	18870	18727	19251	18923.8	196.49	1.04	
9	S21	19042	22199	18865	20424	18564	19818.8	1509.91	7.62	
8	S22	19992	20528	19281	21952	22377	20826.0	1308.13	6.28	
7	S23	18957	20505	20621	20572	19577	20046.4	745.63	3.72	
6	S31	19310	19039	19336	18760	19429	19174.8	273.58	1.43	
5	S32	18497	18676	18039	18786	18423	18484.2	287.22	1.55	
4	S33	16774	17488	17278	17679	17312	17306.2	337.67	1.95	
3	S41	13183	11923	15999	16188	11539	13766.4	2210.68	16.06	
2	S42	7167	9236	9220	9042	7973	8527.6	922.59	10.82	
A04		149800	115291	150812	151217	151793	143782.6	15943.88	11.09	
Sum		163858	169735	169888	174507	166138	168825.2			
% Diff		-9.38	-47.22	-12.65	-15.40	-9.45	-17.42			

ACTIVITY										
Seg #	Seg	81 keV	Sequence number					AVG	Dev	% err
		4106	4107	4108	4109	4110				
11	S12	4.483	4.214	4.620	4.619	4.363	4.460	0.17	3.90	
10	S13	3.579	3.565	3.569	3.542	3.641	3.579	0.04	1.04	
9	S21	2.899	3.380	2.872	3.109	2.827	3.017	0.23	7.61	
8	S22	3.395	3.486	3.274	3.728	3.800	3.537	0.22	6.28	
7	S23	3.152	3.410	3.429	3.412	3.256	3.332	0.12	3.68	
6	S31	3.476	3.427	3.480	3.376	3.497	3.451	0.05	1.43	
5	S32	3.522	3.556	3.435	3.577	3.508	3.520	0.05	1.55	
4	S33	3.196	3.332	3.292	3.368	3.298	3.297	0.06	1.95	
3	S41	2.996	2.710	3.637	3.680	2.623	3.129	0.50	16.06	
2	S42	3.019	3.891	3.884	3.809	3.359	3.592	0.39	10.82	
A04		34.010	34.349	34.240	34.332	34.463	34.279	0.17	0.50	
Sum		33.717	34.970	35.492	36.220	34.171	34.914			
% Diff		0.86	-1.81	-3.66	-5.50	0.85	-1.85			

Activity and Count response for I-2000 cal

Daily Source Drum

COUNTS

Seg #	Seg	356 keV		Sequence number			AVG	Dev	% err
		4106	4107	4108	4109	4110			
11-Top	S12	25224	25856	25486	25891	25730	25637.4	280.4	1.09
10	S13	38324	39185	38780	38893	38746	38785.6	310.5	0.80
9	S21	43236	42259	43578	43350	43331	43150.8	514.1	1.19
8	S22	43600	43748	43871	44066	44089	43874.8	208.6	0.48
7	S23	44396	43356	44099	44096	43949	43979.2	384.4	0.87
6	S31	46295	46896	46348	46799	47071	46681.8	343.6	0.74
5	S32	46082	45829	45734	46506	45967	46023.6	300.4	0.65
4	S33	43308	43777	43397	43272	43427	43436.2	200.7	0.46
3	S41	32772	33185	32852	32872	32803	32896.8	165.9	0.50
2	S42	19447	19879	19622	19376	19497	19564.2	197.6	1.01
A04		382713	385298	383730	385822	386017	384716	1435.2	0.37
Sum		382684	383970	383767	385121	384610	384030.4		
% Diff		0.01	0.34	-0.01	0.18	0.36	0.18		

ACTIVITY

Seg #	Seg	356 keV		Sequence number			AVG	Dev	% err
		4106	4107	4108	4109	4110			
11	S12	3.080	3.157	3.113	3.162	3.142	3.131	0.034	1.09
10	S13	3.045	3.113	3.081	3.090	3.078	3.082	0.025	0.80
9	S21	3.139	3.141	3.164	3.148	3.146	3.148	0.010	0.31
8	S22	3.104	3.114	3.124	3.137	3.139	3.124	0.015	0.48
7	S23	3.161	3.087	3.140	3.140	3.130	3.132	0.027	0.87
6	S31	3.118	3.159	3.122	3.152	3.171	3.144	0.023	0.73
5	S32	3.186	3.168	3.162	3.215	3.178	3.182	0.021	0.65
4	S33	3.099	3.133	3.106	3.097	3.108	3.108	0.014	0.46
3	S41	3.149	3.189	3.157	3.159	3.152	3.161	0.016	0.51
2	S42	3.206	3.277	3.235	3.193	3.214	3.225	0.033	1.02
A04		31.944	32.160	32.030	32.204	32.221	32.112	0.120	0.37
Sum		31.288	31.540	31.404	31.492	31.458	31.436		
% Diff		2.05	1.93	1.95	2.21	2.37	2.10		

Activity and Count response for 1-2000 cal

Daily Source Drum

COUNTS									
Seg #	Seg	661 keV	Sequence number				AVG	Dev	% err
		4106	4107	4108	4109	4110			
11-Top	S12	4062	4026	3939	3922	3983	3986.4	58.50	1.47
10	S13	5767	5929	6034	6082	5894	5941.2	123.65	2.08
9	S21	6856	6646	6685	6695	6719	6720.2	80.35	1.20
8	S22	6873	6657	6908	6733	6641	6762.4	122.62	1.81
7	S23	6936	6945	6769	6850	6845	6869.0	72.80	1.06
6	S31	7308	7204	7178	7225	7250	7233.0	49.61	0.69
5	S32	7323	7143	7162	7121	7291	7208.0	92.23	1.28
4	S33	6624	6741	6815	6914	6799	6778.6	106.52	1.57
3	S41	4957	5035	4980	5032	5024	5005.6	35.06	0.70
2	S42	2991	2943	3046	3061	3021	3012.4	47.01	1.56
A04		59842	59656	59766	59750	59553	59713.4	111.43	0.19
Sum		59697	59269	59516	59635	59467	59516.8		
% Diff		0.24	0.65	0.42	0.19	0.14	0.33		

ACTIVITY									
Seg #	Seg	661 keV	Sequence number				AVG	Dev	% err
		4106	4107	4108	4109	4110			
11	S12	0.589	0.584	0.572	0.562	0.578	0.577	0.011	1.89
10	S13	0.531	0.546	0.556	0.560	0.543	0.547	0.011	2.08
9	S21	0.575	0.557	0.560	0.561	0.563	0.563	0.007	1.20
8	S22	0.589	0.570	0.592	0.577	0.569	0.579	0.010	1.81
7	S23	0.575	0.575	0.561	0.567	0.567	0.569	0.006	1.06
6	S31	0.608	0.599	0.597	0.601	0.603	0.601	0.004	0.69
5	S32	0.597	0.582	0.584	0.580	0.594	0.588	0.008	1.28
4	S33	0.544	0.553	0.560	0.568	0.558	0.557	0.009	1.57
3	S41	0.557	0.566	0.560	0.566	0.565	0.562	0.004	0.70
2	S42	0.562	0.553	0.573	0.575	0.568	0.566	0.009	1.56
A04		5.948	5.929	5.940	5.939	5.919	5.935	0.011	0.19
Sum		5.726	5.687	5.713	5.717	5.708	5.710		
% Diff		3.72	4.09	3.83	3.73	3.57	3.79		

Activity and Count response for 1-2000 cal

Daily Source Drum

COUNTS									
Seg #	Seg	1332.5 keV					AVG	Dev	% err
		Sequence number							
11-Top	S12	4106	4107	4108	4109	4110	1927.2	31.01	1.61
10	S13	1966	1903	1921	1952	1894	2846.0	45.67	1.60
9	S21	2780	2894	2854	2823	2879	3211.6	43.96	1.37
8	S22	3219	3150	3196	3222	3271	3211.6	43.96	1.37
8	S22	3219	3150	3196	3222	3271	3211.6	43.96	1.37
8	S22	3219	3150	3196	3222	3271	3211.6	43.96	1.37
7	S23	3244	3263	3297	3346	3177	3265.4	62.80	1.92
7	S23	3244	3263	3297	3346	3177	3265.4	62.80	1.92
7	S23	3244	3263	3297	3346	3177	3265.4	62.80	1.92
6	S31	3388	3339	3362	3343	3360	3358.4	19.40	0.58
6	S31	3388	3339	3362	3343	3360	3358.4	19.40	0.58
6	S31	3388	3339	3362	3343	3360	3358.4	19.40	0.58
6	S31	3388	3339	3362	3343	3360	3358.4	19.40	0.58
6	S31	3388	3339	3362	3343	3360	3358.4	19.40	0.58
6	S31	3388	3339	3362	3343	3360	3358.4	19.40	0.58
5	S32	3493	3448	3520	3544	3428	3486.6	48.41	1.39
5	S32	3493	3448	3520	3544	3428	3486.6	48.41	1.39
5	S32	3493	3448	3520	3544	3428	3486.6	48.41	1.39
5	S32	3493	3448	3520	3544	3428	3486.6	48.41	1.39
5	S32	3493	3448	3520	3544	3428	3486.6	48.41	1.39
5	S32	3493	3448	3520	3544	3428	3486.6	48.41	1.39
5	S32	3493	3448	3520	3544	3428	3486.6	48.41	1.39
4	S33	3438	3356	3443	3472	3490	3439.8	51.46	1.50
4	S33	3438	3356	3443	3472	3490	3439.8	51.46	1.50
4	S33	3438	3356	3443	3472	3490	3439.8	51.46	1.50
4	S33	3438	3356	3443	3472	3490	3439.8	51.46	1.50
4	S33	3438	3356	3443	3472	3490	3439.8	51.46	1.50
 
3	S41	3241	3263	3295	3197	3147	3228.6	57.89	1.79
 									

ACTIVITY									
Seg #	Seg	1332.5 keV					AVG	Dev	% err
		Sequence number							
		4106	4107	4108	4109	4110			
11	S12	0.4158	0.4024	0.4063	0.4130	0.4007	0.4076	0.0066	1.61
10	S13	0.3647	0.3797	0.3745	0.3703	0.3777	0.3734	0.0060	1.61
9	S21	0.3964	0.3879	0.3936	0.3968	0.4027	0.3955	0.0054	1.37
8	S22	0.3916	0.3940	0.3980	0.4040	0.3835	0.3942	0.0076	1.93
7	S23	0.4115	0.4055	0.4083	0.4060	0.4081	0.4079	0.0024	0.58
6	S31	0.3845	0.3795	0.3874	0.3900	0.3772	0.3837	0.0053	1.39
5	S32	0.4103	0.4006	0.4109	0.4143	0.4165	0.4105	0.0061	1.49
4	S33	0.3899	0.3926	0.3963	0.3845	0.3786	0.3884	0.0070	1.79
3	S41	0.4070	0.3901	0.3993	0.3998	0.4055	0.4003	0.0067	1.66
2	S42	0.3665	0.3723	0.3699	0.3494	0.3724	0.3661	0.0096	2.64
A04		4.0484	4.0128	4.0627	4.0366	4.0356	4.0392	0.0184	0.45
Sum		3.9382	3.9046	3.9445	3.9281	3.9231	3.9277		
% Diff		2.72	2.70	2.91	2.69	2.79	2.76		

Calculation of microCris per segment detector:

Seg#	Seg	59keV		81keV		355keV		661keV		1332.5keV	
		AVG	%err	AVG	%err	AVG	%err	AVG	%err	AVG	%err
11	S12	402	2.46	4.46	3.90	3.13	1.61	0.577	1.89	0.408	1.61
10	S13	373	1.44	3.58	1.04	3.08	1.61	0.547	2.08	0.373	1.61
9	S21	377	2.49	3.02	7.61	3.15	1.37	0.563	1.20	0.395	1.37
8	S22	390	1.82	3.54	6.28	3.12	1.93	0.579	1.81	0.394	1.93
7	S23	350	1.58	3.33	3.68	3.13	0.58	0.569	1.06	0.408	0.58
6	S31	361	1.67	3.45	1.43	3.14	1.39	0.601	0.69	0.384	1.39
5	S32	382	2.10	3.52	1.55	3.18	1.49	0.588	1.28	0.411	1.49
4	S33	380	2.95	3.30	1.95	3.11	1.79	0.557	1.57	0.388	1.79
3	S41	345	3.00	3.13	16.06	3.16	1.66	0.562	0.70	0.400	1.66
2	S42	354	2.70	3.59	10.82	3.22	2.64	0.566	1.56	0.366	2.64

Comparison of Segment Summation to the Summed Spectrum results

A04		3727	1.05	3428	0.50	3211	0.45	593	0.19	404	0.45
Sum	%Diff	3714	0.35	3491	-1.85	3144	2.10	571	3.79	393	2.76

Ratio to NSI source Activity

StcAd		3697	2.77	3162	2.91	3162	2.91	557	3.42	394	3.05
Ratio A04/Sd		1.036		1.084		1.016		1.066		1.025	
Sum/Sd		1.032		1.104		0.994		1.025		0.997	

Density	Detector	Drum Position	No Detector Shield (Coll=0) Coefficients					f
			a	b	c	d	e	
0.01346	SEGe-4	2	-1.348E+02	7.694E+01	-1.713E+01	1.644E+00	-6.016E-02	
	SEGe-4	3	-2.314E+02	1.462E+02	-3.530E+00	3.751E+00	-1.488E-01	
	SEGe-3	1	-2.567E+02	1.650E+02	-4.040E+01	4.356E+00	-1.753E-01	
	SEGe-3	2	-2.085E+02	1.295E+02	-3.076E+01	3.210E+00	-1.249E-01	
	SEGe-3	3	-1.841E+02	1.139E+02	-2.712E+01	2.841E+00	-1.113E-01	
	SEGe-2	1	-1.415E+02	8.126E+01	-1.794E+01	1.714E+00	-6.022E-03	
	SEGe-2	2	-1.787E+02	1.086E+02	-2.545E+01	2.621E+00	-1.009E-01	
	SEGe-2	3	-2.074E+02	1.293E+02	-3.095E+01	3.264E+00	-1.287E-01	
	SEGe-1	1	-2.103E+02	1.317E+02	-3.170E+01	3.360E+00	-1.331E-01	
	SEGe-1	2	-1.854E+02	1.134E+02	-2.679E+01	2.783E+00	-1.079E-01	
	Summed		-1.374E+02	8.105E+01	-1.824E+01	1.793E+00	-6.551E-02	
0.43029	SEGe-4	2	-7.526E+01	3.279E+01	-5.305E+00	2.802E-01		
	SEGe-4	3	-7.233E+01	3.153E+01	-5.089E+00	2.677E-01		
	SEGe-3	1	-9.277E+01	4.810E+01	-9.974E+00	8.926E-01	-2.929E-02	
	SEGe-3	2	-7.058E+01	3.039E+01	-4.849E+00	2.520E-01		
	SEGe-3	3	-6.257E+01	2.616E+01	-4.123E+00	2.113E-01		
	SEGe-2	1	-2.659E+02	1.685E+02	-4.084E+01	4.359E+00	-1.734E-01	
	SEGe-2	2	-7.354E+01	3.199E+01	-5.135E+00	2.690E-01		
	SEGe-2	3	-1.167E+02	6.400E+01	-1.390E+01	1.320E+00	-4.664E-02	
	SEGe-1	1	-1.253E+02	7.022E+01	-1.558E+01	1.519E+00	-5.546E-02	
	SEGe-1	2	-6.935E+01	2.906E+01	-4.584E+00	2.354E-01		
	Summed		-3.182E+01	9.945E+01	-1.161E+00	3.601E-01		
0.65625	SEGe-4	2	-1.389E+02	7.910E+01	-1.773E+01	1.735E+00	6.289E-02	
	SEGe-4	3	-2.480E+02	1.562E+02	-3.779E+01	4.029E+00	-1.602E-01	
	SEGe-3	1	-1.377E+02	7.760E+01	-1.720E+01	1.670E+00	-6.032E-02	
	SEGe-3	2	-1.854E+02	1.133E+02	-2.692E+01	2.819E+00	1.103E-01	
	SEGe-3	3	-1.925E+02	1.179E+02	-2.801E+01	2.933E+00	-1.147E-01	
	SEGe-2	1	-7.015E+01	2.983E+01	-4.745E+00	2.469E-01		
	SEGe-2	2	1.889E+02	2.096E+02	9.263E+01	-1.549E+01	1.400E+00	-4.926E-02
	SEGe-2	3	-1.561E+02	9.162E+01	-2.111E+01	2.145E+00	-8.160E-02	
	SEGe-1	1	-1.474E+02	8.440E+01	-1.901E+01	1.852E+00	-6.963E-02	
	SEGe-1	2	-2.128E+02	1.300E+02	-3.080E+01	3.217E+00	-1.255E-01	
	Summed		-1.686E+02	1.021E+02	-2.382E+01	2.446E+00	-9.376E-02	
1.56010	SEGe-4	2	-7.228E+01	2.937E+01	-4.532E+00	2.287E-01		
	SEGe-4	3	-2.179E+02	1.346E+02	-3.229E+01	3.523E+00	-1.357E-01	
	SEGe-3	1	-1.574E+02	8.997E+01	-2.015E+01	1.975E+00	-7.186E-02	
	SEGe-3	2	-2.116E+02	1.290E+02	-3.059E+01	3.202E+00	-1.253E-01	
	SEGe-3	3	-1.738E+02	1.021E+02	-2.349E+01	2.378E+00	-8.979E-02	
	SEGe-2	1	-6.852E+01	2.813E+01	-4.383E+00	2.234E-01		
	SEGe-2	2	-6.891E+01	2.805E+01	-4.336E+00	2.193E-01		
	SEGe-2	3	-2.239E+02	1.364E+02	-3.220E+01	3.354E+00	-1.305E-01	
	SEGe-1	1	-7.297E+01	3.019E+01	-4.708E+00	2.398E-01		
	SEGe-1	2	-9.201E+01	4.011E+01	-6.435E+00	3.385E-01		
	Summed		-4.273E+01	1.457E+01	-1.888E+00	7.481E-02		
0.01346	Summed		-1.397E+02	8.105E+01	-1.824E+01	1.793E+00	-6.551E-02	
0.43029	Summed		-2.260E+02	1.417E+02	-3.423E+01	3.644E+00	-1.449E-01	
0.65625	Summed		-1.709E+02	1.021E+02	-2.382E+01	2.446E+00	-9.367E-02	
1.56010	Summed		-2.595E+02	1.628E+02	-3.937E+01	4.197E+00	-1.670E-01	

Detector Shield (Coll=1)

Density	Detector	Drum Position	Coefficients				
			a	b	c	d	e
0.01346	SEGe-4	2	-6.420E+01	2.566E+01	-4.001E+00	2.061E-01	
	SEGe-4	3	-9.956E+01	4.232E+01	-6.565E+00	3.365E-01	
	SEGe-3	1	-5.473E+01	2.092E+01	-3.175E+00	1.589E-01	
	SEGe-3	2	-8.927E+01	3.665E+01	-5.556E+00	2.786E-01	
	SEGe-3	3	-2.638E+02	-1.657E+02	-4.030E+01	4.346E+00	-1.754E-01
	SEGe-2	1	-5.764E+01	2.261E+01	-3.490E+00	1.779E-01	
	SEGe-2	2	-5.166E+02	3.223E+02	-7.662E+01	8.080E+00	-3.190E-01
	SEGe-2	3	-1.893E+01	3.569E+00	-3.903E-01	1.070E-02	
	SEGe-1	1	-4.623E+01	1.693E+01	-2.573E+00	1.284E-01	
	SEGe-1	2	-5.738E+01	3.434E+01	-9.082E+00	1.046E+00	-4.452E-02
	Summed		-4.043E+01	1.530E+01	-2.311E+00	1.147E-01	
0.43029	SEGe-4	2	-5.468E+01	1.913E+01	-2.751E+00	1.314E-01	
	SEGe-4	3	-1.110E+03	6.916E+02	-1.626E+02	1.695E+01	-6.613E-01
	SEGe-3	1	-1.527E+01	1.589E+00	-1.182E-01		
	SEGe-3	2	-3.973E+02	2.539E+02	-6.238E+01	6.797E+00	-2.770E-01
	SEGe-3	3	-1.234E+02	7.655E+02	-1.792E+02	1.861E+01	-7.232E-01
	SEGe-2	1	-1.959E+01	2.939E+00	-2.223E-01		
	SEGe-2	2	-1.993E+01	3.047E+00	-2.318E-01		
	SEGe-2	3	-1.602E+01	1.747E+00	-1.250E-01		
	SEGe-1	1	-7.623E+02	4.539E+02	-1.025E+02	1.026E+01	-3.843E-01
	SEGe-1	2	-1.740E+01	1.851E+00	-1.279E-01		
	Summed		-1.259E+01	1.391E+00	-1.002E-01		
0.65625	SEGe-4	2	-2.284E+01	3.564E+00	-2.599E-01		
	SEGe-4	3	-1.439E+01	1.249E+00	-9.517E-02		
	SEGe-3	1	-4.610E+02	2.824E+02	-6.626E+01	6.902E+00	-2.690E-01
	SEGe-3	2	-2.031E+01	3.018E+00	-2.244E-01		
	SEGe-3	3	-1.263E+03	7.705E+02	-1.775E+02	1.814E+01	-6.944E-01
	SEGe-2	1	-9.370E+01	5.363E+01	-1.302E+01	1.413E+00	-5.762E-02
	SEGe-2	2	-1.920E+01	2.662E+00	-1.949E-01		
	SEGe-2	3	-1.985E+01	2.861E+00	-2.108E-01		
	SEGe-1	1	-2.343E+03	1.450E+03	-3.374E+02	3.481E+01	-1.344E+00
	SEGe-1	2	-1.158E+03	7.239E+02	-1.709E+02	1.789E+01	-6.999E-01
	Summed		-1.233E+02	6.828E+01	-1.522E+01	1.510E+00	-5.626E-02
1.56010	SEGe-4	2	-2.284E+01	3.564E+00	-2.599E-01		
	SEGe-4	3	-1.439E+01	1.249E+00	-9.517E-02		
	SEGe-3	1	-4.610E+02	2.824E+02	-6.626E+01	6.902E+00	-2.690E-01
	SEGe-3	2	-2.031E+01	3.018E+00	-2.244E-01		
	SEGe-3	3	-1.263E+01	7.705E+02	-1.775E+02	1.814E+01	-6.944E-01
	SEGe-2	1	-9.370E+01	5.363E+01	-1.302E+01	1.413E+00	-5.762E-02
	SEGe-2	2	-1.920E+01	2.660E+00	-1.949E-01		
	SEGe-2	3	-1.985E+01	2.861E+00	-2.108E-01		
	SEGe-1	1	-2.343E+03	1.450E+03	-3.374E+02	3.481E+01	-1.344E+00
	SEGe-1	2	-1.158E+03	7.239E+02	-1.709E+02	1.789E+01	-6.999E-01
	Summed		-1.233E+02	6.828E+01	-1.522E+01	1.510E+00	-5.626E-02