Sta 5
SEP 28 1999

12

ENGINEERING DATA TRANSMITTAL

Page 1 of 1

1. EDT 623537

2. To: (Receiving Organization) Engineering Files		3. From: (Originating Organization) WRAP Engineering		4. Related EDT No.: N/A							
5. Proj./Prog./Dept./Div.: WRAP/WMH		6. Design Authority/Design Agent/Cog. Engr.: CE Wills		7. Purchase Order No.: N/A							
8. Originator Remarks: This EDT is to release supporting documentation for the WRAP Facility to Engineering Files.				9. Equip./Component No.: 104-ND-06-102A							
				10. System/Bldg./Facility: 2336-W							
				12. Major Assm. Dwg. No.: N/A							
				13. Permit/Permit Application No.: N/A							
11. Receiver Remarks:		11A. Design Baseline Document? ☐ Yes ☒ No		14. Required Response Date: N/A							
15. DATA TRANSMITTED											
(A) Item No.	(B) Document/Drawing No.	(C) Sheet No.	(D) Rev. No.	(E) Title or Description of Data Transmitted	(F) Approval Designator	(G) Reason for Transmittal	(H) Originator Disposition	(I) Receiver Disposition			
1	HNF-5148	N/A	0	Calibration Report for GEA	Q	2	1				
16. KEY											
Approval Designator (F)		Reason for Transmittal (G)			Disposition (H) & (I)						
E, S, Q, D OR N/A (See WHC-CM-3-5, Sec. 12.7)		1. Approval 2. Release 3. Information 4. Review 5. Post-Review 6. Dist. (Receipt Acknow. Required)			1. Approved 2. Approved w/comment 3. Disapproved w/comment 4. Reviewed no/comment 5. Reviewed w/comment 6. Receipt acknowledged						
17. SIGNATURE/DISTRIBUTION (See Approval Designator for required signatures)											
(G) Reason	(H) Disp.	(J) Name	(K) Signature	(L) Date	(M) MSIN	(G) Reason	(H) Disp.	(J) Name	(K) Signature	(L) Date	(M) MSIN
		Design Authority				2	1	SPO JL Maupin	<i>JL Maupin</i>	9/27/99	T4-06
		Design Agent									
2	1	Cog. Eng. CE Wills	<i>CE Wills</i>	9/27/99	T4-52						
2	1	Cog. Mgr. JR Weidert	<i>JR Weidert</i>	9/23/99	T4-52						
2	1	QA WR Thackaberry	<i>WR Thackaberry</i>	9/23/99	T4-52						
		Safety									
		Env.									
18. <i>JK Kersten</i> JK Kersten Signature of EDT Originator		19. <i>JR Weidert</i> JR Weidert Authorized Representative for Receiving Organization		20. <i>JR Weidert</i> JR Weidert Design Authority/Cognizant Manager		21. DOE APPROVAL (if required) Ctrl No. _____ ☐ Approved ☐ Approved w/comments ☐ Disapproved w/comments					

S

HNF-5148, Rev. 0

CALIBRATION REPORT FOR THE WRAP FACILITY GAMMA ENERGY ANALYSIS SYSTEM

CE Wills

Waste Management Federal Services of Hanford, Richland, WA 99352
U.S. Department of Energy Contract DE-AC06-96RL13200

EDT/ECN: EDT-623537

UC: 506

Org Code: 32600

Charge Code: AJ60

B&R Code: EW02J126

Total Pages: 152

Key Words: NDA, WRAP, WIPP, TRU, CAO, GEA

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.

- * Genie-PC is a registered trademark of Digital Equipment Corp., Huston, TX.
- * MGA Software is a registered trademark of Mitchell & Gauthier Associates, Inc., Concord, MA.

TRADEMARK DISCLAIMER. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof or its contractors or subcontractors.

Printed in the United States of America. To obtain copies of this document, contact: Document Control Services, P.O. Box 950, Mailstop H6-08, Richland WA 99352, Phone (509) 372-2420; Fax (509) 376-4989.

Release Approval

9/28/99
Date

Approved for Public Release

CALIBRATION REPORT
FOR
GAMMA ENERGY ANALYSIS SYSTEM
104-ND-06-102 A
REVISION 0

Prepared for
Waste Receiving and Processing facility Engineering

Prepared by
Albert I. Davis
Waste Management Technical Services

September 13, 1999

Table of Contents

	Page
Certificate of Calibration	1
1.0 Introduction	2
2.0 Calibration Configuration	2
3.0 Segmented Detectors	2
4.0 Low Energy Detectors	6
5.0 SEGe Efficiency	7
6.0 Comparative Calculations	15
7.0 References	24
Appendix A, Calibration Configuration	A1-A4
Appendix B, Source Certificates	B1-B6
Appendix C, Detector Specifications	C1-C12
Appendix D, Energy & FWHM Data and Curves	D1-D16
Appendix E, SEGe Efficiency Data and Curves	E1-E82

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: 14 October, 1998

Calibration Verification Due date: 14 October, 1999

Limitations: 55 and 85 gallon drums.

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

Calibration Method Specified in Canberra system manuals.

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, Rev 2⁽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: C. Wills Date: 9/22/99

Reference to Out-of-Cal., or non-conformance issues: No issues to date.

1.0 Introduction

In meeting the quality objectives for gamma-ray data analysis at the Waste Receiving And Processing facility (WRAP), the detectors used to produce quantitative results must meet calibration programmatic calibration goals. These goals are modeled after the instrument acceptance criterion developed by the Canberra Corporation. Instruments must meet portions of ANSI N42.14, 1978 guide for Germanium detectors. One aspect of NDA analysis using gamma-ray spectroscopy is the referencing to a NIST traceable line source standard for the detector system calibrations. Counting a drum containing line sources and developing system efficiencies and correction factors are required for the processing of drummed waste materials. The calibration verification is carried out annually as per the requirements of Final Hanford Site transuranic Waste Characterization Quality Assurance Project Plan⁽⁴⁾. Two 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 calibration errors which are to be folded into the Total Measurement Uncertainty (TMU) document. The TMU is developed for the drum package analysis prior to shipment to the Waste Isolation Pilot Plant, (WIPP).

2.0 Calibration Configuration

The two gamma systems 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 the best representation of a homogeneous distribution of activity in the drum; Appendix A. This drum source is the sole calibration source geometry for the GWAS system for the development of efficiency curves; the source certifications are in Appendix B. The uncertainties listed on the certificates are at 2.81σ , per telecom from the supplier.

3.0 Segmented 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 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. The detectors and the drum elevation platform will adequately analyze 55 and 85 gallon drums (208 and 321.5 l). The drum platform elevates in two steps of 8.9 cm each, the platform also continually rotates during analysis and calibration. Figure 1a diagrams the gamma detectors angle of coverage for the drums.

NDA GEA ANALYSIS CHAMBER

Figure 1a

NDA GEA ANALYSIS CHAMBER

Figure 1b

The detector specifications for all the system detectors are in Appendix C and are not identified with a particular system. The net count for each of the SEGe detectors in Table 4 demonstrates the two upper and lower positions view beyond the top and bottom of the drum respectively. The response beyond the drum boundary for the 356 keV γ of ^{133}Ba is also displayed graphically in Figure 2.

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 has a built in function to aid in the zero and gain normalization for this summation. The effectiveness of this summation is demonstrated in Table 1 and its associated graph.

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

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 (c)
SEGe-1	-1.093	+0.4996	-1.635 E-07
SEGe-2	-0.826	+0.500	-1.749 E-07
SEGe-3	-0.7438	+0.4996	-1.634 E-07
SEGe-4	-1.745	+0.4997	-1.498 E-07
Summed	-1.758	+0.4998	-1.481 E-07

The energy plot for the segmented detectors has error bars, the error bars are sufficiently small and therefore are not observed. The FWHM plot does demonstrate some broadening occurs in the spectrum summation, but the summed curve falls within the 2σ error of the averaged value curve. 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.

The FWHM equations are of the form:

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

Detector	intercept (a)	Multiplier (b)
SEGe-1	0.548	0.02883
SEGe-2	0.4268	0.03750
SEGe-3	0.4902	0.03342
SEGe-4	0.4310	0.03384
Summed	0.566	0.03233

4.0 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 unshielded. These detectors are calibrated only for energy and FWHM (Full Width at Half Maximum) parameters. These detectors need to have good resolution and have little degradation with respect to high gamma-ray throughput rates. Figure 1b shows the placement of these detectors⁽⁵⁾.

The LEGe detectors, used for the MGA 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:

$$\text{Energy (keV)} = a + b \cdot \text{Chn}$$

Detector	Intercept (a)	Linear Multiplier (b)
LEGe-5	+0.293	+0.079
LEGe-6	+0.148	+0.076

The FWHM for the LEGe detectors appears to be a single value and a bit large for these detectors; the upper (LEGe-5) is 4.46 keV and the lower (LEGe-6) is 1.00 keV. To date the MGA/MGAU has not been needed due to other information, but, the FWHM value should be below 0.8 keV⁽⁶⁾. The MGA and MGAU program is designed to sort out the peak areas below

200 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.

5.0 SEGe Efficiency

The efficiency calibration data for the segmented detectors is listed in Attachment E. The efficiency curve formulas are the "best fit" selected from the regression analysis contained in the Canberra software. The equations listed below are in two groups; one without the collimators (shields) activated, and the second with the collimators activated.

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

Detector	Drum Position	a	b	c	d	e
SEGe-4	2	-135.018	78.596	-17.887	1.783	-0.066
SEGe-4	3	-184.452	113.949	-27.189	2.861	-0.113
SEGe-3	1	-149.904	88.289	-20.072	1.993	-0.073
SEGe-3	2	-212.288	133.932	-32.458	3.458	-0.139
SEGe-3	3	-218.228	138.066	-33.473	3.574	-0.143
SEGe-2	1	-239.554	152.025	-36.847	3.932	-0.157
SEGe-2	2	-232.940	146.592	-35.211	3.718	-0.146
SEGe-2	3	-218.716	137.037	-32.885	3.474	-0.137
SEGe-1	1	-207.617	129.765	-31.220	3.313	-0.132
SEGe-1	2	-177.407	107.044	-25.009	2.567	-0.098
Sum Spectrum $\rho = 0.0134615 \text{ gms/cc}$		-137.006	79.453	-17.913	1.766	-0.065
Sum Spectrum $\rho = 0.430288 \text{ gms/cc}$		- 36.585	11.216	- 1.376	0.048	
Sum Spectrum $\rho = 0.65625 \text{ gms/cc}$		- 63.146	26.368	- 4.179	0.216	
Sum Spectrum $\rho = 1.5601 \text{ gms/cc}$		-217.663	132.328	-31.191	3.239	-0.125

Detector	Drum Position	a	b	c	d	e
With collimator:						
SEGe-4	2	-13.657	1.360	-0.1182		
SEGe-4	3	-15.716	2.136	-0.178		
SEGe-3	1	-18.038	2.921	-0.241		
SEGe-3	2	-41.434	13.957	-1.978	0.09131	
SEGe-3	3	-11.059	0.658	-0.05866		
SEGe-2	1	-12.197	1.038	-0.090		
SEGe-2	2	-57.853	22.576	-3.466	0.176	
SEGe-2	3	-23.362	5.312	-0.607	0.019	
SEGe-1	1	- 6.537	-0.7329	0.03956		
SEGe-1	2	-13.261	1.104	-0.096		
Sum Spectrum		- 38.508	13.061	- 1.920	0.092	
$\rho = 0.0134615 \text{ gms/cc}$						
Sum Spectrum		- 18.198	2.406	- 0.178		
$\rho = 0.430288 \text{ gms/cc}$						
Sum Spectrum		- 12.902	0.684	- 0.045		
$\rho = 0.65625 \text{ gms/cc}$						
Sum Spectrum		- 9.729	-0.566	0.570		
$\rho = 1.5601 \text{ gms/cc}$						

The attached table (Table 2) contains the efficiency parameters used for the generation of the above curves. Table 3 contains the line source parameters and the associated errors.

The efficiency equations are the "best fit" result of the regression analysis supplied in the Canberra software ⁽⁷⁾. The error associated with each efficiency point also includes the error

Table 2

Gamma Calibration of WRAP GEA-A system
Energy and FWHM Analysis

Energy calibration

Detector Channel Number	Seg. 1	Seg. 2	Seg. 3	Seg. 4	Spectrum Sum	Std Dev.	Avg value KeV	AVG +2 σ	AVG -2 σ
60	28.9	29.2	29.2	28.2	28.2	1.70	28.8	3.4	-3.4
80	38.9	39.2	39.2	38.2	38.2	1.97	38.8	3.9	-3.9
100	48.9	49.2	49.2	48.2	48.2	2.21	48.8	4.4	-4.4
150	73.9	74.2	74.2	73.2	73.2	2.72	73.7	5.4	-5.4
200	98.9	99.2	99.2	98.2	98.2	3.15	98.7	6.3	-6.3
300	148.9	149.2	149.1	148.2	148.2	3.86	148.7	7.7	-7.7
400	198.9	199.1	199.1	198.1	198.2	4.46	198.7	8.9	-8.9
500	248.9	249.1	249.0	248.1	248.2	4.99	248.7	10.0	-10.0
600	298.8	299.1	299.0	298.0	298.2	5.47	298.6	10.9	-10.9
800	398.8	399.1	398.8	397.9	398.1	6.31	398.6	12.6	-12.6
1000	498.7	499.0	498.7	497.8	498.1	7.06	498.5	14.1	-14.1
1150	573.7	573.9	573.6	572.7	573.0	7.57	573.4	15.1	-15.1
1200	598.7	598.9	598.5	597.7	598.0	7.74	598.4	15.5	-15.5
1300	648.6	648.9	648.5	647.6	648.0	8.05	648.3	16.1	-16.1
1400	698.6	698.8	698.4	697.5	698.0	8.36	698.3	16.7	-16.7
1500	748.5	748.8	748.3	747.5	747.9	8.65	748.2	17.3	-17.3
1600	798.5	798.7	798.2	797.4	797.9	8.93	798.1	17.9	-17.9
1800	898.4	898.6	898.0	897.2	897.8	9.48	898.0	19.0	-19.0
2000	998.3	998.5	997.8	997.1	997.7	9.99	997.8	20.0	-20.0
2150	1073.2	1073.4	1072.6	1071.9	1072.6	10.36	1072.7	20.7	-20.7
2200	1098.1	1098.3	1097.8	1096.9	1097.5	10.48	1097.7	21.0	-21.0
2300	1148.0	1148.2	1147.5	1146.8	1147.5	10.71	1147.6	21.4	-21.4
2400	1198.0	1198.2	1197.4	1196.7	1197.4	10.94	1197.5	21.9	-21.9
2500	1247.9	1248.1	1247.2	1246.6	1247.3	11.17	1247.4	22.3	-22.3
2600	1297.8	1298.0	1297.1	1296.5	1297.2	11.39	1297.3	22.8	-22.8
2800	1397.6	1397.8	1396.9	1396.2	1397.1	11.82	1397.1	23.6	-23.6
3000	1497.4	1497.6	1496.6	1496.0	1496.9	12.23	1496.9	24.5	-24.5
3150	1572.3	1572.4	1571.4	1570.8	1571.8	12.54	1571.7	25.1	-25.1
3200	1597.2	1597.4	1596.3	1595.8	1596.7	12.64	1596.7	25.3	-25.3
3300	1647.1	1647.3	1646.2	1645.6	1646.6	12.83	1646.6	25.7	-25.7
3400	1697.0	1697.2	1696.0	1695.5	1696.5	13.02	1696.4	26.0	-26.0
3500	1746.9	1747.0	1745.9	1745.4	1746.4	13.21	1746.3	26.4	-26.4
3600	1796.8	1796.9	1795.7	1795.2	1796.3	13.40	1796.2	26.8	-26.8
3800	1896.6	1896.6	1895.4	1895.0	1896.1	13.77	1895.9	27.5	-27.5
4000	1996.3	1996.4	1995.0	1994.7	1995.9	14.13	1995.6	28.3	-28.3
4065	2043.7	2043.7	2042.4	2042.0	2043.3	14.29	2043.0	28.6	-28.6

Table 2

SEGe Detectors FWHM calibration		FWHM (keV)					Spectrum Sum	Std Dev.	Avg value KeV	AVG +2 σ	AVG -2 σ
Detector Energy (KeV)		Seg. 1	Seg. 2	Seg. 3	Seg. 3	Seg. 3					
30		0.71	0.63	0.62	0.67	0.62	0.74	0.26	0.67	0.512	0.512
40		0.73	0.66	0.65	0.70	0.65	0.77	0.26	0.70	0.523	0.523
50		0.75	0.69	0.67	0.73	0.67	0.79	0.27	0.73	0.533	0.533
60		0.77	0.72	0.69	0.75	0.69	0.81	0.27	0.75	0.541	0.541
80		0.81	0.76	0.73	0.79	0.73	0.85	0.28	0.79	0.556	0.556
100		0.84	0.80	0.77	0.82	0.77	0.89	0.28	0.82	0.569	0.569
150		0.90	0.89	0.85	0.90	0.85	0.96	0.30	0.90	0.595	0.595
200		0.96	0.96	0.91	0.96	0.91	1.02	0.31	0.96	0.616	0.616
300		1.05	1.08	1.02	1.07	1.02	1.12	0.33	1.07	0.650	0.650
400		1.12	1.18	1.11	1.16	1.11	1.21	0.34	1.15	0.677	0.677
500		1.19	1.27	1.19	1.24	1.19	1.28	0.35	1.23	0.701	0.701
600		1.25	1.35	1.26	1.31	1.26	1.35	0.36	1.30	0.721	0.721
800		1.36	1.49	1.39	1.44	1.39	1.47	0.38	1.43	0.756	0.756
1000		1.46	1.61	1.50	1.55	1.50	1.58	0.39	1.54	0.785	0.785
1150		1.53	1.70	1.62	1.62	1.58	1.65	0.40	1.62	0.804	0.804
1200		1.55	1.73	1.65	1.65	1.60	1.67	0.41	1.64	0.810	0.810
1300		1.59	1.78	1.65	1.70	1.65	1.72	0.41	1.69	0.822	0.822
1400		1.63	1.83	1.74	1.74	1.70	1.76	0.42	1.73	0.833	0.833
1500		1.66	1.88	1.78	1.78	1.74	1.81	0.42	1.78	0.844	0.844
1600		1.70	1.93	1.83	1.83	1.78	1.85	0.43	1.82	0.854	0.854
1800		1.77	2.02	1.91	1.91	1.87	1.92	0.44	1.90	0.873	0.873
2000		1.84	2.10	1.98	1.98	1.94	2.00	0.45	1.97	0.891	0.891

Table 2

Energy calibration LEGe		FWHM calibration			
Detector Channel Number	LEGe 5 Upper keV	LEGe 6 Lower keV	Detector Energy (KeV)	LEGe 5 Upper keV	LEGe 6 Lower keV
60	5.0	4.7	30	4.46	1.00
80	6.6	6.3	40	4.46	1.00
100	8.2	7.8	50	4.46	1.00
150	12.1	11.8	60	4.46	1.00
200	16.1	15.4	80	4.46	1.00
300	24.0	23.0	100	4.46	1.00
400	31.9	30.8	150	4.46	1.00
500	39.8	38.2	200	4.46	1.00
600	47.7	45.8	300	4.46	1.00
800	63.5	61.0	400	4.46	1.00
1000	79.3	76.2			
1150	91.1	87.6			
1200	96.1	91.4			
1300	103.0	99.0			
1400	110.9	106.6			
1500	118.8	114.2			
1600	126.7	121.8			
1800	142.5	137.0			
2000	158.3	152.2			
2150	170.1	163.6			
2200	174.1	167.4			
2300	182.0	175.0			
2400	189.9	182.6			
2500	197.8	190.2			
2600	205.7	197.8			
2800	221.5	213.0			
3000	237.3	228.2			
3150	249.1	239.6			
3200	253.1	243.4			
3300	261.0	251.0			
3400	268.9	258.6			
3500	276.8	266.2			
3600	284.7	273.8			
3800	300.5	289.0			
4000	316.3	304.2			
4095	323.8	311.4			

Table 1
GEA-A Seg Detectors Energy Cal.

Table 1

GEA-A FWHM Segmented Detectors

Table 1
GEA-A MGA/MGAU Detectors
LEGe

developed in the regression analysis matrix. The Canberra program results and plots are in Attachment E.

Figure 2 displays the spectral response by drum segment to the calibration drum, the distribution is for the 356 keV peak of ^{133}Ba . The width of the scan zone allows the bottom and top two segments to incorporate volumes beyond the physical drum.

6.0 Comparative Calculations

A hand calculation done for comparison for point and error analysis is shown on Table 4. The hand calculation for efficiency does not take into account the matrix error components that Canberra uses in their parameter modification by the off diagonal elements of the regression matrix. The comparison of the efficiency values in Figure 3 is taken from the values on the bottom of Table 4. The table contains the net peak area from the individual SEGe detectors and the Summed spectrum from the SEGe detectors. There are two totals used for the efficiency calculation; the individual peaks from the SEGe spectra, and the net peak from the totaled spectrum. The efficiency calculation for these two compare within a reasonable five percent except for the 81 keV peak. The comparison to the Canberra calculation shows a bias on their calculation of 15%, which will conservatively calculate a corresponding higher activity. The curves are plotted in Figure 3, the two hand calculations fall practically on top of each other. Canberra's literature indicates the regression matrix contains weighting factors and off-diagonal elements which affect the total result as well.

Table 2

Efficiency of GEA-A
NO COLLIMITER
Detector

Energy keV	SEGe-1 P-3 Top			SEGe-1 P-2 Top-1			SEGe-1 P-1 Top-2			SEGe-2 P-3 Top-3			SEGe-2 P-2 Top-4			SEGe-2 P-1 Top-5		
	Efficiency	Error	1 σ % err	Efficiency	Error	1 σ % err	Efficiency	Error	1 σ % err	Efficiency	Error	1 σ % err	Efficiency	Error	1 σ % err	Efficiency	Error	1 σ % err
59.7	5.21E-05	6.30E-06	12.1	5.21E-05	6.30E-06	12.1	9.05E-05	1.01E-05	11.2	1.19E-04	1.24E-05	10.4	1.24E-04	1.30E-05	10.5	1.26E-04	1.30E-05	10.3
81.0	1.48E-04	1.33E-05	9.0	1.48E-04	1.33E-05	9.0	2.68E-04	2.24E-05	8.4	3.81E-04	3.11E-05	8.2	4.15E-04	3.34E-05	8.0	4.18E-04	3.37E-05	8.1
276.4	2.73E-04	2.78E-05	10.2	2.73E-04	2.78E-05	10.2	4.95E-04	4.57E-05	9.2	6.29E-04	5.86E-05	9.3	7.02E-04	6.37E-05	9.1	6.95E-04	6.11E-05	8.8
302.8	2.70E-04	2.32E-05	8.6	2.70E-04	2.32E-05	8.6	4.39E-04	3.59E-05	8.2	6.08E-04	4.90E-05	8.1	6.27E-04	5.05E-05	8.1	6.06E-04	4.86E-05	8.0
356.0	2.24E-04	1.78E-05	7.9	2.24E-04	1.78E-05	7.9	3.82E-04	3.00E-05	7.9	5.37E-04	4.21E-05	7.8	5.51E-04	4.32E-05	7.8	5.48E-04	4.30E-05	7.8
383.9	1.95E-04	1.90E-05	9.7	1.95E-04	1.90E-05	9.7	3.49E-04	3.13E-05	9.0	4.80E-04	4.12E-05	8.6	5.09E-04	4.36E-05	8.6	5.18E-04	4.34E-05	8.4
661.7	1.41E-04	1.16E-05	8.2	1.41E-04	1.16E-05	8.2	2.40E-04	1.86E-05	7.8	3.20E-04	2.46E-05	7.7	3.25E-04	2.49E-05	7.7	3.35E-04	2.56E-05	7.6
1173.2	8.76E-05	7.28E-06	8.3	8.76E-05	7.28E-06	8.3	1.45E-04	1.12E-05	7.7	1.97E-04	1.47E-05	7.5	2.26E-04	1.65E-05	7.3	2.12E-04	1.56E-05	7.4
1332.5	8.37E-05	6.90E-06	8.2	8.37E-05	6.90E-06	8.2	1.28E-04	9.84E-06	7.7	1.86E-04	1.37E-05	7.4	1.98E-04	1.45E-05	7.3	1.96E-04	1.44E-05	7.3

Summed Spectra Efficiency.
Detector

Summed
spectra
"empty" drum

Energy keV	$\rho = 0.01$ gm/cc			$\rho = 0.43$ gm/cc			$\rho = 0.66$ gm/cc			$\rho = 1.56$ gm/cc		
	Efficiency	Error	1 σ % err	Efficiency	Error	1 σ % err	Efficiency	Error	1 σ % err	Efficiency	Error	1 σ % err
59.7	1.19E-04	9.77E-06	8.2	3.78E-05	3.49E-06	9.2	3.05E-05	2.96E-06	9.7	8.88E-06	1.33E-06	15.0
81.0	3.00E-04	2.34E-05	7.8	2.91E-05	3.25E-06	11.2	4.07E-06	2.14E-06	52.6	N/D	N/D	
276.4	5.72E-04	4.56E-05	8.0	2.53E-04	2.07E-05	8.2	1.91E-04	1.56E-05	8.2	9.71E-05	8.73E-06	9.0
302.8	5.25E-04	4.09E-05	7.8	2.30E-04	1.80E-05	7.8	1.75E-04	1.38E-05	7.9	8.98E-05	7.10E-06	7.9
356.0	4.68E-04	3.63E-05	7.8	2.10E-04	1.63E-05	7.8	1.60E-04	1.25E-05	7.8	8.54E-05	6.65E-06	7.8
383.9	4.23E-04	3.33E-05	7.9	1.99E-04	1.61E-05	8.1	1.51E-04	1.21E-05	8.0	7.91E-05	6.57E-06	8.3
661.7	2.83E-04	2.04E-05	7.2	1.46E-04	1.06E-05	7.3	1.16E-04	8.43E-06	7.3	6.15E-05	4.53E-06	7.4
1173.2	1.82E-04	1.24E-05	6.8	1.06E-04	7.11E-06	6.7	8.58E-05	5.79E-06	6.7	4.87E-05	3.32E-06	6.8
1332.5	1.66E-04	1.11E-05	6.7	1.01E-04	6.77E-06	6.7	8.44E-05	5.67E-06	6.7	4.72E-05	3.20E-06	6.8

Table 2

NO COLLIMITER Detector																			
SEGe-3 P-3 Top-6				SEGe-3 P-2 Top-7				SEGe-3 P-1 Top-8				SEGe-4 P-3 Top-9				SEGe-4 P-2 Top-10			
Efficiency		Error	1 σ err	Efficiency		Error	1 σ err	Efficiency		Error	1 σ err	Efficiency		Error	1 σ err	Efficiency		Error	1 σ err
1.43E-04		1.42E-05	9.9	1.30E-04		1.34E-05	10.3	1.48E-04		1.46E-05	9.8	1.17E-04		1.16E-05	9.9	8.62E-05		9.00E-06	10.4
4.22E-04		3.41E-05	8.1	3.93E-04		3.20E-05	8.1	3.90E-04		3.18E-05	8.2	3.23E-04		2.87E-05	8.3	2.11E-04		1.81E-05	8.6
6.50E-04		5.71E-05	8.8	5.85E-04		5.68E-05	9.7	6.99E-04		6.21E-05	8.9	5.80E-04		5.14E-05	9.2	3.49E-04		3.50E-05	10.0
6.14E-04		4.93E-05	8.0	6.27E-04		5.10E-05	8.1	6.25E-04		5.01E-05	8.0	5.29E-04		4.29E-05	8.1	3.44E-04		2.86E-05	8.3
5.58E-04		4.37E-05	7.8	5.59E-04		4.38E-05	7.8	5.53E-04		4.33E-05	7.8	4.72E-04		3.70E-05	7.8	3.13E-04		2.47E-05	7.9
4.80E-04		4.25E-05	8.9	5.24E-04		4.51E-05	8.6	4.94E-04		4.34E-05	8.8	4.28E-04		3.68E-05	8.6	3.01E-04		2.78E-05	9.2
3.37E-04		2.60E-05	7.7	3.41E-04		2.59E-05	7.6	3.35E-04		2.55E-05	7.6	2.90E-04		2.24E-05	7.7	1.86E-04		1.48E-05	8.0
2.24E-04		1.65E-05	7.4	2.21E-04		1.62E-05	7.3	2.06E-04		1.53E-05	7.4	1.81E-04		1.36E-05	7.5	1.27E-04		9.93E-06	7.8
1.99E-04		1.46E-05	7.3	2.00E-04		1.47E-05	7.4	2.03E-04		1.48E-05	7.3	1.61E-04		1.21E-05	7.5	1.14E-04		8.91E-06	7.8

Table 2

WITH COLLIMITER (SHIELD)

Energy keV	SEGe-1 P-3 Top		SEGe-1 P-2 Top-1		SEGe-1 P-1 Top-2		SEGe-2 P-3 Top-3		SEGe-2 P-2 Top-4		SEGe-2 P-1 Top-5	
	Efficiency	Error	1 σ % err	Efficiency	Error	1 σ % err	Efficiency	Error	1 σ % err	Error	Efficiency	Error
59.7	0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00	0.00E+00
81.0	0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00	0.00E+00
276.4	4.33E-05	1.25E-05	28.9	1.14E-04	1.77E-05	15.5	8.41E-05	1.66E-05	19.7	1.10E-04	2.02E-05	18.4
302.8	4.23E-05	5.86E-06	13.9	6.64E-05	8.15E-06	12.3	9.50E-05	8.85E-06	9.3	9.25E-05	9.01E-06	9.7
356.0	4.18E-05	3.56E-06	8.5	7.31E-05	6.04E-06	8.3	9.84E-05	8.04E-06	8.2	1.04E-04	8.42E-06	8.1
383.9	3.70E-05	7.21E-06	19.5	7.82E-05	1.04E-05	13.3	8.81E-05	1.12E-05	12.7	9.79E-05	1.06E-05	10.8
661.7	4.14E-05	4.10E-06	9.9	8.84E-05	6.06E-06	8.9	9.60E-05	8.05E-06	8.4	9.45E-05	8.38E-06	8.9
1173.2	3.28E-05	3.20E-06	9.8	5.88E-05	5.04E-06	8.6	7.94E-05	6.38E-06	8.0	8.42E-05	6.71E-06	8.0
1332.5	3.59E-05	3.31E-06	9.2	5.70E-05	4.73E-06	8.3	7.63E-05	6.03E-06	7.9	8.54E-05	6.66E-06	7.8

Summed Spectra Efficiency/
DetectorSummed
spectra
"empty" drum

Energy keV	p = 0.01 gm/cc		p = 0.43 gm/cc		p = 0.66 gm/cc		p = 1.56 gm/cc	
	Efficiency	Error	1 σ % err	Efficiency	Error	1 σ % err	Efficiency	Error
59.7	0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00
81.0	0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00
276.4	8.26E-05	8.01E-06	9.7	8.62E-05	8.01E-06	9.3	1.73E-05	3.18E-06
302.8	8.50E-05	6.91E-06	8.1	3.55E-05	3.11E-06	8.8	2.83E-05	2.89E-06
356.0	8.80E-05	6.87E-06	7.8	3.89E-05	3.06E-06	7.9	2.91E-05	2.30E-06
383.9	8.70E-05	7.13E-06	8.2	3.97E-05	3.78E-06	9.5	2.94E-05	2.55E-06
661.7	8.39E-05	6.18E-06	7.4	4.14E-05	3.12E-06	7.5	3.25E-05	2.46E-06
1173.2	7.07E-05	4.79E-06	6.8	4.26E-05	2.92E-06	6.9	1.89E-05	1.36E-06
1332.5	7.08E-05	4.76E-06	6.7	4.24E-05	2.89E-06	6.8	1.97E-05	1.39E-06

WITH COLLIMITER (SHIELD)
Detector

SEG-3 P-3 Top-6			SEG-3 P-2 Top-7			SEG-3 P-1 Top-8			SEG-4 P-3 Top-9			SEG-4 P-2 Top-10		
Efficiency	Error	1 σ err	Efficiency	Error	1 σ err	Efficiency	Error	1 σ err	Efficiency	Error	1 σ err	Efficiency	Error	1 σ err
0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00	
0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00	
7.79E-05	1.56E-05	20.0	9.58E-05	1.72E-05	18.0	8.45E-05	1.78E-05	21.1	4.47E-05	1.07E-05	23.9	8.86E-05	1.33E-05	15.0
1.02E-04	1.07E-05	10.5	9.81E-05	9.23E-06	9.4	1.03E-04	1.02E-05	9.9	5.98E-05	6.74E-06	11.3	8.54E-05	8.61E-06	10.1
1.02E-04	8.32E-06	8.2	1.04E-04	8.46E-06	8.1	1.03E-04	8.34E-06	8.1	6.10E-05	5.08E-06	8.3	9.14E-05	7.44E-06	8.1
1.05E-04	1.28E-05	12.2	1.03E-04	1.19E-05	11.8	1.03E-04	1.15E-05	11.2	5.63E-05	7.06E-06	12.5	9.81E-05	1.07E-05	11.1
9.35E-05	8.02E-06	8.6	1.01E-04	8.61E-06	8.5	9.86E-05	8.19E-06	8.3	5.42E-05	5.17E-06	9.5	8.51E-05	7.21E-06	8.5
8.36E-05	6.70E-06	8.0	8.76E-05	6.92E-06	7.9	7.97E-05	6.47E-06	8.1	4.59E-05	4.12E-06	9.0	7.29E-05	5.96E-06	8.2
9.00E-05	6.95E-06	7.7	8.32E-05	6.53E-06	7.8	7.71E-05	6.08E-06	7.9	4.71E-05	4.11E-06	8.7	7.13E-05	5.70E-06	8.0

Table 3

WRAP Linear Sources for calibration

Isotope	Time zero 3/1/96		Analysis date 10/13/98		Time of count activity		γ Eng keV	γ /sec
	Activity	% err @ 2.81 σ	$T_{1/2}$ Yrs	ΔT Yrs	Decay d/s	γ yield		
241-Am	148.5	3.25	432.7	2.62	0.99582	734513.77	59.5	263690
	150.4	3.25						
	145.1	3.24						
	146.4	3.26						
	147.2	3.25						
133-Ba	737.6	52.81						
		7.27 % *						
	204.9	3.19	10.54	2.62	0.84187	865018.45	81	294625
	205.4	3.2					276.4	61970
	206.3	3.19					302.9	158558
137-Cs	205.5	3.21					356	536744
	205.4	3.19					383.8	77333
	1027.5	51.07						
		7.15 % *						
	38.1	2.86	30.07	2.62	0.94145	178131.53	661.66	151786
60-Co	38.27	2.89						
	37.44	2.85						
	37.39	3.01						
	38.01	2.86						
	189.21	41.89						
60-Co		6.47 % *						
	38.65	2.63	5.2714	2.62	0.70861	136317.38	1173.23	136281
	38.35	2.66					1332.5	136298
	38.3	2.6						
	38.52	2.74						
60-Co	38.5	2.63						
	192.32	35.18						
		5.93 % *						

* Source term error is @3 σ (2.81 σ) per telecom by vendor

Raw Count data from the calibration spectra

File Name	Detector	Live time seconds	Isotope/Energy (keV)		241-Am		133-Ba		276		302.2		356		385		137-Cs		60-Co		1332.54	
			Count	% err	Count	% err	Count	% err	Count	% err	Count	% err	Count	% err	Count	% err	Count	% err	Count	% err	Count	% err
111101140.A04	Summed Spectra	297.32	11146	1.57	33343	0.8	12185	1.42	28834	0.66	89553	0.36	11397	1.1	15350	0.85	5807	1.12	8060	1.12	1332.54	Count
																					1332.54	% err
	Individual Spectra																					
111101140.S12	SEGs-1	297.32	810	5.56	2340	2.98	746	5.24	1895	2.7	5780	1.37	804	4.29	1011	3.31	614	4.17	554	4.28	1332.54	Count
111101140.S13	SEGs-1	296.52	1086	4.82	3558	2.36	1175	4.12	2907	2.12	8884	1.11	1148	3.34	1571	2.73	878	3.62	780	3.62	1332.54	% err
111101140.S21	SEGs-2	296	1367	4.55	4268	2.1	1448	3.67	3413	1.89	10201	1.04	1320	3.47	1809	2.48	968	3.29	963	3.23	1332.54	Count
111101140.S22	SEGs-2	295.93	1210	5.16	4303	2.1	1244	4.83	3423	2.11	10297	1.03	1396	3.26	1843	2.43	1088	3.17	989	3.25	1332.54	% err
111101140.S23	SEGs-2	295.95	1334	4.72	4809	1.82	1378	3.58	3354	1.94	10282	1.01	1281	3.57	1822	2.66	1075	3.22	983	3.25	1332.54	Count
111101140.S31	SEGs-3	295.96	1172	5.24	4587	1.83	1454	3.55	3318	1.93	10112	1.04	1379	3.03	1805	2.61	1027	3.24	948	3.27	1332.54	% err
111101140.S32	SEGs-3	296.01	1168	5.22	4644	1.8	1468	3.77	3422	1.95	10194	1.03	1381	3.19	1749	2.69	1063	3.14	968	3.25	1332.54	Count
111101140.S33	SEGs-3	296.15	1105	6.41	4167	2.12	1334	4.11	3304	2.01	9805	1.05	1278	3.29	1728	2.58	967	3.37	902	3.35	1332.54	% err
111101140.S41	SEGs-4	296.32	846	6.14	2944	2.82	1054	4.19	2395	2.36	7550	1.24	927	4.04	1301	2.86	793	3.52	820	4.04	1332.54	Count
111101140.S42	SEGs-4	297.66	488	7.55	1630	3.71	581	5.71	1487	3.19	4153	1.62	525	5.22	761	3.88	427	4.97	408	4.97	1332.54	% err
	Averaged live time	298.444																				
	Summed spectra peak counts		10811		36830		11900		29806		86938		11419		15396		8838		8085			
	Σ Individual spectra																					
			2.7243	30.91	7.8763	8.94	2.5091	27.46	8.3400	7.29	19.4403	1.86	2.7042	18.40	3.4004	10.95	2.0851	17.39	1.8933	18.15		
			3.6802	24.21	11.9982	6.97	3.9526	16.97	9.8037	4.49	29.2854	1.23	3.8716	11.16	5.2981	7.45	2.8543	12.39	2.6305	13.10		
			4.8658	20.70	14.5189	4.41	4.8919	13.47	11.0304	3.97	34.4628	1.06	4.4695	12.04	8.1115	6.10	3.3716	10.82	3.3209	10.43		
			4.0868	28.63	14.5408	4.41	4.2037	20.82	11.8699	4.46	34.7424	1.02	4.7173	10.63	8.2278	5.80	3.8880	10.05	3.2744	10.58		
			4.8075	22.28	15.5738	3.89	4.9894	12.82	11.2030	3.78	34.7424	1.02	4.6991	9.18	8.0884	6.86	3.8534	10.37	3.2539	10.86		
			3.9697	27.46	18.4301	3.72	4.9125	12.80	11.2102	3.80	34.4389	1.08	4.8978	10.18	8.0986	6.71	3.8624	10.60	3.2264	10.56		
			3.7512	28.27	14.0708	3.81	5.0289	14.81	11.1604	4.04	33.4498	1.10	4.3164	10.82	8.8281	6.66	3.2315	11.36	3.0456	11.22		
			2.8594	37.70	14.0708	4.49	4.8045	16.89	11.1695	4.04	33.4498	1.10	4.3164	10.82	8.8281	6.66	3.2315	11.36	3.0456	11.22		
			1.8365	57.00	5.4790	13.76	1.9519	32.80	4.8896	10.18	13.8890	2.82	1.7638	27.25	2.9595	19.05	1.4345	24.70	2.0881	16.32		
	CPs Total		36.8113	303.40	124.8463	59.47	40.1622	185.11	97.5629	50.88	292.4044	13.88	38.5391	138.72	51.9876	80.19	29.8282	132.80	27.2870	136.31		
	Total count		10818.04		36860.34		11905.85		29821.95		86981.54		11424.86		15405.874		8842.4043		8089.0583			
	1 % err		5.03			2.23	3.93			2.08		1.07		3.40		2.59		3.33		3.37		
	Eff Σ pk		1.37E-04		4.21E-04		6.59E-04		6.19E-04		6.43E-04		4.98E-04		3.42E-04		2.19E-04		2.05E-04			
	Eff Σ spectra		1.43E-04		3.79E-04		6.87E-04		6.08E-04		6.42E-04		4.97E-04		3.40E-04		2.19E-04		1.90E-04			
	Eff Canberra Calc		1.19E-04		3.00E-04		5.72E-04		5.25E-04		4.68E-04		4.23E-04		2.83E-04		1.82E-04		1.86E-04			
	Ratio Canberra/Σ spectra		8.32E-01		7.91E-01		8.57E-01		8.62E-01		8.84E-01		8.61E-01		8.32E-01		8.37E-01		8.32E-01			
	Eff err% @ 1σ Σ Spectra		3.46		2.76		2.93		2.65		2.59		2.79		2.47		2.39		2.39			
	Eff err% @ 7σ Canberra		8.21		7.80		7.97		7.79		7.76		7.87		7.21		6.86		6.86			

Figure 2
Counts/300 sec Real Time

Figure 3
Efficiency

7.0 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).
4. Hanford Site Transuranic Waste Characterization Quality Assurance Project Plan, HNF-2599, Rev 1, Final 8/4/99.
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.

APPENDIX A

Calibration Configuration

Q2 SYSTEM CALIBRATION AND SOURCE CERTIFICATION

Calibration Drum Description

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

- 1) polyurethane foam (0.014 g/cc)
- 2) soft board (homosote) (0.470 g/cc)
- 3) particle board (0.76 g/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 drum matrix to allow the insertion of a small diameter calibration sources 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 Figure 1.

In order to simulate routine sample counting conditions during the calibration process, the drums were placed on the turntable platform and rotated at constant speed during all 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) position 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 6 shells simulate a homogeneous source distribution throughout the matrix.

Figure 1: Top View Cross-Section of
Canberra Q² Calibration Drums.

Each calibration drum is divided into 6 shells of equal volume labeled A, B, C, D, E, and F. The individual source tubes are numbered 1-9. The radial distance from the drum center to the center of each of these hollow source tubes is provided in the table below.

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

Calibration Source Set Description

Line Sources

A matched set of six calibrated line sources was used to perform the energy, full-width-half-maximum (FWHM), and the four efficiency calibrations. The calibration certificate for each of the sources in the set is included as part of this section.

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, therefore, be calculated using the following equation:

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

where

efficiency is given in units of counts per gamma emitted from a uniform source matrix, and

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

B3 = measured counts per second with the line source in tube 3 (shell B)

C4 = measured counts per second with the line source in tube 4 (shell C)

D5 = measured counts per second with the line source in tube 5 (shell D)

E6 = measured counts per second with the line source in tube 6 (shell E)

F9 = measured counts per second with the line source in tube 9 (shell F)

activity = decay-corrected activity of the calibration source

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 to be used. This is just the sum of the 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 sources uncertainties.

The certificate file used is included below.

APPENDIX B

Source Certificates

CERTIFICATE OF CALIBRATION

96-146

MODEL ENV4057 LINE SOURCE

SERIAL NUMBER D846

Reference Date March 1, 1996

Radionuclide	Activity	Total Uncertainty (%)	Half Life ⁽¹⁾
23.922 Am-241	147.7 kBq (3.991 μ Ci) 23.922 μ Ci	3.27%	432.7 $\pm$ 0.5 years
Ba-133	206.7 kBq (5.587 μ Ci) 33.358 μ Ci	3.22%	10.64 $\pm$ 0.03 years
Cs-137	38.54 kBq (1.042 μ Ci) 6.135 μ Ci	3.07%	30.0 $\pm$ 0.2 years
Co-60	38.66 kBq (1.045 μ Ci) 6.243 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
		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

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

96-156

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 μ Ci)	3.25%	432.7 $\pm$ 0.5 years
Ba-133	204.9 kBq (5.538 μ Ci)	3.19%	10.54 $\pm$ 0.03 years
Cs-137	38.10 kBq (1.030 μ Ci)	2.86%	30.0 $\pm$ 0.2 years
Co-60	38.65 kBq (1.045 μ Ci)	2.63%	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
		355.999	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

CERTIFICATE OF CALIBRATION

96-166

MODEL ENV4057 LINE SOURCE

SERIAL NUMBER D848

Reference Date March 1, 1996

Radionuclide	Activity	Total Uncertainty (%)	Half Life ⁽¹⁾
Am-241	150.4 kBq (4.065 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 (1.036 μ Ci)	2.66%	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
		355.999	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

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

96-176

MODEL ENV4057 LINE SOURCE

SERIAL NUMBER D849

Reference Date March 1, 1996

Radionuclide	Activity	Total Uncertainty (%)	Half Life ⁽¹⁾
Am-241	145.1 kBq (3.920 μ Ci)	3.24%	432.7 $\pm$ 0.5 years
Ba-133	206.3 kBq (5.575 μ Ci)	3.19%	10.54 $\pm$ 0.03 years
Cs-137	37.44 kBq (1.012 μ Ci)	2.83%	30.0 $\pm$ 0.2 years
Co-60	38.30 kBq (1.035 μ Ci)	2.60%	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
		355.999	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

CERTIFICATE OF CALIBRATION

MODEL ENV4057 LINE SOURCE

SERIAL NUMBER D850

Reference Date March 1, 1996

Radionuclide	Activity	Total Uncertainty (%)	Half Life ¹¹
Am-241	148.4 kBq (3.956 μ CI)	3.26%	432.7 $\pm$ 0.5 years
Ba-133	205.5 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 EMISSIONS¹¹

	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
		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

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

96-196

CERTIFICATE OF CALIBRATION

MODEL ENV4057 LINE SOURCE

SERIAL NUMBER D851

Reference Date: March 1, 1996

Radionuclide	Activity	Total Uncertainty (%)	Half Life ⁽¹⁾
Am-241	147.2 kBq (3.977 μ Cl)	3.25%	432.7 $\pm$ 0.5 years
Ba-133	205.4 kBq (5.553 μ Cl)	3.19%	10.54 $\pm$ 0.03 years
Cs-137	38.01 kBq (1.027 μ Cl)	2.86%	30.0 $\pm$ 0.2 years
Co-60	38.50 kBq (1.041 μ Cl)	2.63%	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
		355.999	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

APPENDIX C

Detector Specifications

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		87.2:1			
Rel. Efficiency %		10.1			

Cool Down Time 4 hours. Cryostat Liquid Nitrogen Consumption Rate <1.5 Liters per Day.Tested by: Randall Peck Date: December 22, 1995Approved by: Margie Fackell Date: December 22, 1995

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

Det_spec_1 10/95 JMC

DETECTOR SPECIFICATION AND PERFORMANCE DATA

Specifications

DETECTOR MODEL GC1018/SSERIAL NUMBER 12953631CRYOSTAT 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 29.5 mmDistance from window 5 mmActive Volume ccWell Depth mmWell Diameter mm

Electrical Characteristics

Depletion voltage (+)1000 V dcRecommended bias voltage (+)1500 V dcLeakage current at recommended bias 0.02 nAPreamplifier test point voltage at recommended voltage (-)1.59 V dcCapacitance 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		38.9:1			
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, 1995Approved by: [Signature] Date: December 22, 1995

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

Det_Spec_1 10/95 JMT

Specifications

CRYOSTAT MODEL 7935-7S PREAMPLIFIER MODEL 2002CSL

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

keV (FWTM) at

Cryostat description if special

Well Diameter mm

Capacitance at recommended bias ~9 pF

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			

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

Det_Spec_1 10/95 JMT

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

Length 28 mm

Distance from window 5 mm

Active Volume _____ cc

Well Depth _____ 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 L. 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 10/93 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 (FWHM) at 1.33 MeV keV (FWHM) at keV (FWHM) 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 (+)3300 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)	1.86	3.10			
Peak / Compton		58.0			
Rel. Efficiency %		23.9			

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

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

Det_Spec_1 10/95 JMT

DETECTOR SPECIFICATION AND PERFORMANCE DATA

Specifications

DETECTOR MODEL GC2020 SERIAL NUMBER 3963617CRYOSTAT 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 1.83 MeV keV (FWHM) at 1.83 MeV keV (FWHM) at keV (FWHM) at Peak / Compton :1 Cryostat well diameter mm Cryostat well depth mmCryostat description if special

Physical Characteristics

Geometry Closed-end coaxialDiameter 53.5 mmLength 43 mmDistance from window 5 mmActive Volume ccWell Depth mmWell Diameter mm

Electrical Characteristics

Depletion voltage (+)5000 V dcRecommended bias voltage (+)5000 V dcReset rate at recommended bias 0.4 secPreamplifier test point voltage at recommended voltage V dcCapacitance 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, 1996Approved by: Manning 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 JWC

DETECTOR SPECIFICATION AND PERFORMANCE DATA

Specifications

DETECTOR MODEL GC2020 SERIAL NUMBER 3963611CRYOSTAT 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 mmCryostat description if special

Physical Characteristics

Geometry Closed-end coaxialDiameter 55 mmLength 43.5 mmDistance from window 5 mmActive Volume ccWell Depth mmWell Diameter mm

Electrical Characteristics

Depletion voltage (+)2400 V dcRecommended bias voltage (+)3000 V dcReset rate at recommended bias 0.5 secPreamplifier test point voltage at recommended voltage V dcCapacitance 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	1.83			
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, 1996Approved by: Manning Lichfield 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

Specifications

CRYOSTAT MODEL 7935-7S PREAMPLIFIER MODEL 2101P

keV (FWTM) at _____

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

Distance from window 5 mm

Well Diameter mm

Reset Rate 0.2 sec

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			

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

Det_Spec_1 10/95 JMT

DETECTOR SPECIFICATION AND PERFORMANCE DATA

Specifications

DETECTOR MODEL GC2020 SERIAL NUMBER 12953590
 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 mm Active Volume cc
 Length 45.5 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
 Leakage current at recommended bias .. nA
 Reset rate at recommended voltage 0.6 sec
 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)	0.82	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 Perle Date: December 22, 1995

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

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

Det_Spec_1 10/95 JMT

DETECTOR SPECIFICATION AND PERFORMANCE DATA

Specifications

DETECTOR MODEL GC2020 SERIAL NUMBER 3963597CRYOSTAT 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 mmCryostat description if special Big Mac

Physical Characteristics

Geometry Closed-end coaxialDiameter 55 mmLength 42 mmDistance from window 5 mmActive Volume ccWell Depth mmWell Diameter mm

Electrical Characteristics

Depletion voltage (+)3500 V dcRecommended bias voltage (+)4000 V dcReset rate at recommended bias 1.0 secPreamplifier test point voltage at recommended voltage V dcCapacitance 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, 1996Approved by: Manning 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 GC2020SERIAL NUMBER 12953596CRYOSTAT MODEL 7935-7SPREAMPLIFIER 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 mmCryostat description if special

Physical Characteristics

Geometry Closed-end coaxialDiameter 53 mmLength 43.5 mmDistance from window 5 mmActive Volume ccWell Depth mmWell Diameter mm

Electrical Characteristics

Depletion voltage (+)1500 V dcRecommended bias voltage (+)2500 V dcLeakage current at recommended bias -- nAReset rate at recommended voltage 0.6 secCapacitance 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: Candace Peak Date: December 22, 1995Approved by: [Signature] Date: December 22, 1995

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

Det_Spec_1 10/95 JMT

DETECTOR SPECIFICATION AND PERFORMANCE DATA

Specifications

DETECTOR MODEL GC2020 SERIAL NUMBER 12953592
 CRYOSTAT MODEL 7935-7S PREAMPLIFIER 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 (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 53.5 mm

Length 44.5 mm

Distance from window 5 mm

Active Volume cc

Well Depth mm

Well Diameter mm

Electrical Characteristics

Depletion voltage (+)3800 V dc

Recommended bias voltage (+)4000 V dc

Leakage current at recommended bias 0.01 nA

Reset rate at recommended bias voltage 0.5 sec

Capacitance 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. Bortz Date: December 22, 1995

Approved by: Margaret Bortz Date: December 22, 1995

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

Det_spec_1 10/95 JMT

APPENDIX D

Energy and Full Width at Half Maximum (FWHM)

Data and Curves

 ENERGY CALIBRATION REPORT

Identification Number : CALCOUNT
 Description/Title : Calibration Count
 Counter : GEA - A
 Arrangement : 55-gal. drums
 Calibration for : SEGE1
 Acquisition Started : 5-24-99 10:23:37 AM
 Live Time : 595.1 seconds
 Real Time : 600.0 seconds

***** ENERGY CALIBRATION COEFFICIENTS *****

Energy Calibrate Performed on: 5-24-99 10:36:31 AM
 by: System Manager
 Energy Calibrate Type: POLY

$$\text{Energy(keV)} = -1.093 + 0.500 \cdot \text{ch} + -1.63\text{E-}07 \cdot \text{ch}^2 + 0.00\text{E+}00 \cdot \text{ch}^3$$

***** SHAPE CALIBRATION COEFFICIENTS *****

Shape Calibrate Performed on: 5-24-99 10:36:31 AM
 by: System Manager

$$\text{FWHM} = 0.548 + 0.029 \cdot \text{E}^{1/2}$$

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

* ***** ENERGY CALIBRATION RESULTS TABLE *****

Centroid Channel	Centroid error	Energy (keV)
121.43	0.02	59.54
164.31	0.01	81.00
555.55	0.03	276.40
608.50	0.02	302.84
714.95	0.01	356.01
770.71	0.03	383.85
1327.24	0.03	661.66
2352.48	0.05	1173.24
2671.69	0.06	1332.50

***** SHAPE CALIBRATION RESULTS TABLE *****

Energy (keV)	FWHM channels	FWHM error	TAIL channels	TAIL error
59.54	1.56	0.05	0.00	0.00
81.00	1.65	0.03	0.00	0.00
276.40	2.06	0.06	0.00	0.00
302.84	2.09	0.03	0.00	0.00
356.01	2.15	0.02	0.00	0.00
383.85	2.29	0.06	0.00	0.00
661.66	2.60	0.06	0.00	0.00
1173.24	3.12	0.10	0.00	0.00
1332.50	3.54	0.11	0.00	0.00

Datasource: C:\WAS\CTRS\CTR1\SEGE1.DEN
 Energy = -1.093e+00 keV +4.996e-01*Ch -1.635e-07*Ch^2
 FWHM = 5.478e-01 keV +2.883e-02*E^1/2

Datasource: C:\WAS\CTRS\CTR1\SEGE1.DEN
 Energy = $-1.093e+00 \text{ keV} + 4.996e-01 \cdot \text{Ch} - 1.635e-07 \cdot \text{Ch}^2$
 FWHM = $5.478e-01 \text{ keV} + 2.883e-02 \cdot E^{1/2}$

 ***** ENERGY CALIBRATION REPORT *****

Identification Number : CALCOUNT
 Description/Title : Calibration Count
 Counter : GEA - A
 Arrangement : 55-gal. drums
 Calibration for : SEGE2
 Acquisition Started : 5-24-99 10:23:37 AM
 Live Time : 591.4 seconds
 Real Time : 600.0 seconds

***** ENERGY CALIBRATION COEFFICIENTS *****

Energy Calibrate Performed on: 5-21-99 9:27:51 AM
 by: ??????????????????????
 Energy Calibrate Type: POLY

$$\text{Energy(keV)} = -0.826 + 0.500 \cdot \text{ch} + -1.75\text{E-}07 \cdot \text{ch}^2 + 0.00\text{E+}00 \cdot \text{ch}^3$$

***** SHAPE CALIBRATION COEFFICIENTS *****

Shape Calibrate Performed on: 5-21-99 9:27:51 AM
 by: ??????????????????????

$$\text{FWHM} = 0.427 + 0.038 \cdot \text{E}^{1/2}$$

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

* ***** ENERGY CALIBRATION RESULTS TABLE *****

Centroid Channel	Centroid error	Energy (keV)
????????	??????	0.00

***** SHAPE CALIBRATION RESULTS TABLE *****

Energy (keV)	FWHM channels	FWHM error	TAIL channels	TAIL error
0.00	??????	??????	??????	??????

Datasource: C:\WAS\CTRS\CTR1\SEGE2.DEN
 Energy = $-8.260\text{e-}01$ keV $+5.000\text{e-}01 \cdot \text{Ch}$ $-1.749\text{e-}07 \cdot \text{Ch}^2$
 FWHM = $4.268\text{e-}01$ keV $+3.750\text{e-}02 \cdot \text{E}^{1/2}$

Datasource: C:\WAS\CTRS\CTR1\SEGE2.DEN
 Energy = -8.260e-01 keV +5.000e-01*Ch -1.749e-07*Ch^2
 FWHM = 4.268e-01 keV +3.750e-02*E^1/2

 ***** ENERGY CALIBRATION REPORT *****

Identification Number : CALCOUNT
 Description/Title : Calibration Count
 Counter : GEA - A
 Arrangement : 55-gal. drums
 Calibration for : SEGE3
 Acquisition Started : 5-24-99 10:23:37 AM
 Live Time : 591.7 seconds
 Real Time : 600.0 seconds

***** ENERGY CALIBRATION COEFFICIENTS *****

Energy Calibrate Performed on: 5-21-99 9:30:10 AM
 by: ??????????????????????
 Energy Calibrate Type: POLY

$$\text{Energy(keV)} = -0.744 + 0.500 \cdot \text{ch} + -1.63\text{E-}07 \cdot \text{ch}^2 + 0.00\text{E+}00 \cdot \text{ch}^3$$

***** SHAPE CALIBRATION COEFFICIENTS *****

Shape Calibrate Performed on: 5-21-99 9:30:10 AM
 by: ??????????????????????

$$\text{FWHM} = 0.490 + 0.033 \cdot \text{E}^{1/2}$$

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

* ***** ENERGY CALIBRATION RESULTS TABLE *****

Centroid Channel	Centroid error	Energy (keV)
????????	??????	0.00

***** SHAPE CALIBRATION RESULTS TABLE *****

Energy (keV)	FWHM channels	FWHM error	TAIL channels	TAIL error
0.00	??????	??????	??????	??????

Datasource: C:\WAS\CTRS\CTR1\SEGE3.DEN
 Energy = $-7.438\text{e-}01$ keV $+4.996\text{e-}01 \cdot \text{Ch}$ $-1.634\text{e-}07 \cdot \text{Ch}^2$
 FWHM = $4.902\text{e-}01$ keV $+3.342\text{e-}02 \cdot \text{E}^{1/2}$

Datasource: C:\WAS\CTRS\CTR1\SEGE3.DEN
 Energy = $-7.438e-01$ keV $+4.996e-01 \cdot \text{Ch}$ $-1.634e-07 \cdot \text{Ch}^2$
 FWHM = $4.902e-01$ keV $+3.342e-02 \cdot E^{1/2}$

 ***** ENERGY CALIBRATION REPORT *****

Identification Number : CALCOUNT
 Description/Title : Calibration Count
 Counter : GEA - A
 Arrangement : 55-gal. drums
 Calibration for : SEGE4
 Acquisition Started : 5-24-99 10:23:37 AM
 Live Time : 595.5 seconds
 Real Time : 600.0 seconds

***** ENERGY CALIBRATION COEFFICIENTS *****

Energy Calibrate Performed on: 5-21-99 9:33:01 AM
 by: ??????????????????????
 Energy Calibrate Type: POLY

$$\text{Energy(keV)} = -1.745 + 0.500 \cdot \text{ch} + -1.50\text{E-}07 \cdot \text{ch}^2 + 0.00\text{E+}00 \cdot \text{ch}^3$$

***** SHAPE CALIBRATION COEFFICIENTS *****

Shape Calibrate Performed on: 5-21-99 9:33:01 AM
 by: ??????????????????????

$$\text{FWHM} = 0.431 + 0.034 \cdot \text{E}^{1/2}$$

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

• ***** ENERGY CALIBRATION RESULTS TABLE *****

Centroid Channel	Centroid error	Energy (keV)
????????	??????	0.00

***** SHAPE CALIBRATION RESULTS TABLE *****

Energy (keV)	FWHM channels	FWHM error	TAIL channels	TAIL error
0.00	??????	??????	??????	??????

Datasource: C:\WAS\CTRS\CTR1\SEGE4.DEN
 Energy = $-1.745\text{e}+00$ keV $+4.997\text{e}-01 \cdot \text{Ch}$ $-1.498\text{e}-07 \cdot \text{Ch}^2$
 FWHM = $4.310\text{e}-01$ keV $+3.384\text{e}-02 \cdot \text{E}^{1/2}$

Datasource: C:\WAS\CTRS\CTR1\SEGE4.DEN
 Energy = -1.745e+00 keV +4.997e-01*Ch -1.498e-07*Ch^2
 FWHM = 4.310e-01 keV +3.384e-02*E^1/2

 ***** ENERGY CALIBRATION REPORT *****

Identification Number : sss
 Description/Title :
 Counter : GEA
 Arrangement : 55-gal. drums
 Calibration for : SeGes
 Acquisition Started : 5-24-99 10:23:37 AM
 Live Time : 595.5 seconds
 Real Time : 600.0 seconds

***** ENERGY CALIBRATION COEFFICIENTS *****

Energy Calibrate Performed on: 5-24-99 10:39:25 AM
 by: System Manager
 Energy Calibrate Type: POLY

$$\text{Energy(keV)} = -1.758 + 0.500 \cdot \text{ch} + -1.48\text{E-}07 \cdot \text{ch}^2 + 0.00\text{E+}00 \cdot \text{ch}^3$$

***** SHAPE CALIBRATION COEFFICIENTS *****

Shape Calibrate Performed on: 5-24-99 10:39:25 AM
 by: System Manager

$$\text{FWHM} = 0.566 + 0.032 \cdot \text{E}^{1/2}$$

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

* ***** ENERGY CALIBRATION RESULTS TABLE *****

Centroid Channel	Centroid error	Energy (keV)
122.66	0.01	59.54
165.60	0.01	81.00
556.66	0.01	276.40
609.60	0.01	302.84
716.01	0.00	356.01
771.72	0.01	383.85
1328.01	0.01	661.66
2352.75	0.02	1173.24
2671.84	0.02	1332.50

***** SHAPE CALIBRATION RESULTS TABLE *****

Energy (keV)	FWHM channels	FWHM error	TAIL channels	TAIL error
59.54	1.76	0.02	0.00	0.00
81.00	1.76	0.01	0.00	0.00
276.40	2.16	0.02	0.00	0.00
302.84	2.21	0.01	0.00	0.00
356.01	2.31	0.01	0.00	0.00
383.85	2.36	0.02	0.00	0.00
661.66	2.92	0.02	0.00	0.00
1173.24	3.63	0.04	0.00	0.00
1332.50	3.87	0.04	0.00	0.00

Datasource: C:\WAS\CTRS\CTR1\ARR1\DG01.GEN
 Energy = -1.758e+00 keV +4.998e-01*Ch -1.481e-07*Ch^2
 FWHM = 5.658e-01 keV +3.233e-02*E^1/2

 **** ENERGY CALIBRATION REPORT ****

Identification Number : CALCOUNT
 Description/Title : Calibration Count
 Counter : GEA - A
 Arrangement : 55-gal. drums
 Calibration for : LEGES
 Acquisition Started : 5-24-99 10:23:31 AM
 Live Time : 592.5 seconds
 Real Time : 607.0 seconds

***** ENERGY CALIBRATION COEFFICIENTS *****

Energy Calibrate Performed on: 5-21-99 3:18:54 PM
 by: ??????????????????????
 Energy Calibrate Type: POLY

Energy(keV) = 0.293 + 0.079*ch + 0.00E+00*ch^2 + 0.00E+00*ch^3

***** SHAPE CALIBRATION COEFFICIENTS *****

Shape Calibrate Performed on: 5-21-99 10:28:08 AM
 by: ??????????????????????

FWHM = 4.342 + 0.013*E^1/2

LOW TAIL = 0.0E+00 + 0.0E+00*E

** ***** ENERGY CALIBRATION RESULTS TABLE *****

Centroid Channel	Centroid error	Energy (keV)
????????	??????	0.00

***** SHAPE CALIBRATION RESULTS TABLE *****

Energy (keV)	FWHM channels	FWHM error	TAIL channels	TAIL error
0.00	??????	??????	??????	??????

 **** ENERGY CALIBRATION REPORT ****

Identification Number : CALCOUNT
 Description/Title : Calibration Count
 Counter : GEA - A
 Arrangement : 55-gal. drums
 Calibration for : LEGE6
 Acquisition Started : 5-24-99 10:23:31 AM
 Live Time : 590.3 seconds
 Real Time : 607.3 seconds

***** ENERGY CALIBRATION COEFFICIENTS *****

Energy Calibrate Performed on: 5-21-99 3:21:17 PM
 by: ??????????????????????
 Energy Calibrate Type: POLY

Energy(keV) = 0.148 + 0.076*ch + 0.00E+00*ch^2 + 0.00E+00*ch^3

***** SHAPE CALIBRATION COEFFICIENTS *****

Shape Calibrate Performed on: 5-21-99 10:30:16 AM
 by: ??????????????????????

FWHM = 0.790 + 0.023*E^{1/2}

LOW TAIL = 0.0E+00 + 0.0E+00*E

***** ENERGY CALIBRATION RESULTS TABLE *****

Centroid Channel	Centroid error	Energy (keV)
????????	??????	0.00

***** SHAPE CALIBRATION RESULTS TABLE *****

Energy (keV)	FWHM channels	FWHM error	TAIL channels	TAIL error
0.00	??????	??????	??????	??????

APPENDIX E

SEGe Efficiency

Data and Curves

 ***** EFFICIENCY CALIBRATION REPORT *****

=====
 Calibration Record No. : 1
 =====

Identification Number : EFFCAL1A
 Description/Title : eff cal 55 gal lt drum no coll
 :
 Location :
 Container : 55 gal container
 Weight, %Full : 2.80 (kg), 100.00 (%),
 Volume, Density : 208.00 (l), 0.01 (kg/l)

Comment:

Reference Date : 10-13-98 2:39:40 PM
 Acquisition Started : 10-13-98 2:44:59 PM
 Live Time : 297.3 seconds
 Real Time : 300.0 seconds

Detector Group : SeGes
 Detector : SEGE4
 Scan Platform Position : 2
 Geometry/Collimator Position : 0

Geometry Description : Distributed
 Spectrum File Name : C:\WAS\CALIB\CR1AR1\ES120001.C01
 Energy Calibration Performed on : 10-12-98 2:49:39 PM
 Efficiency Calibration Performed on: 10-13-98 6:30:12 PM
 by: System Manager
 Efficiency Calibration Approved on : 10-13-98 6:36:44 PM
 by: System Manager

Efficiency Triplets
 =====

Energy	Efficiency	Error
59.54	8.62E-05	9.00E-06
81.00	2.11E-04	1.81E-05
276.40	3.49E-04	3.50E-05
302.84	3.44E-04	2.86E-05
356.01	3.13E-04	2.47E-05
383.85	3.01E-04	2.76E-05
661.66	1.86E-04	1.48E-05
1173.24	1.27E-04	9.93E-06
1332.50	1.14E-04	8.91E-06

DUAL Efficiency Calibration Equation

=====

Single Equation Terms ->	Offset:	-135.018
	Slope:	78.596
	Quadratic:	-17.887
	Cubic:	1.783
	4th Order:	-0.066
	5th Order:	0.000
	6th Order:	0.000
	7th Order:	0.000
	8th Order:	0.000
	9th Order:	0.000

EMPIRICAL Efficiency Calibration Equation

=====

Empirical Equation Terms ->	Scaling:	696.018
	Offset:	-8.609
	Slope:	0.769
	Quadratic:	0.081
	Cubic:	-0.047
	4th Order:	-0.066
	5th Order:	0.000

LINEAR Efficiency Calibration Equation

=====

Linear Equation Terms ->	Offset:	-0.000
	Slope:	-3.880
	Quadratic:	207.505
	Cubic:	-22094.213
	4th Order:	542916.375
	5th Order:	0.000
	6th Order:	0.000
	7th Order:	0.000
	8th Order:	0.000
	9th Order:	0.000

Datasource: C:\WAS\CALIB\CR1AR1\ES120001.C01

$$\ln(\text{Eff}) = -1.350\text{e}+02 + 7.860\text{e}+01 \cdot \ln(E) - 1.789\text{e}+01 \cdot \ln(E)^2 + 1.783\text{e}+00 \cdot \ln(E)^3 - 6.630\text{e}-02 \cdot \ln(E)^4$$

Detector 5EGe 4 Drum pos = 2

 ***** EFFICIENCY CALIBRATION REPORT *****

=====
 Calibration Record No. : 1
 =====

Identification Number : EFFCAL1A
 Description/Title : eff cal 55 gal 1t drum no coll
 :
 Location :
 Container : 55 gal container
 Weight, %Full : 2.80 (kg), 100.00 (%),
 Volume, Density : 208.00 (l), 0.01 (kg/l)

Comment:

Reference Date : 10-13-98 2:39:40 PM
 Acquisition Started : 10-13-98 2:50:19 PM
 Live Time : 296.5 seconds
 Real Time : 300.0 seconds

Detector Group : SeGes
 Detector : SEGE4
 Scan Platform Position : 3
 Geometry/Collimator Position : 0

Geometry Description : Distributed
 Spectrum File Name : C:\WAS\CALIB\CR1AR1\ES130001.C01
 Energy Calibration Performed on : 10-12-98 2:49:39 PM
 Efficiency Calibration Performed on: 10-13-98 6:30:53 PM
 by: System Manager
 Efficiency Calibration Approved on : 10-13-98 6:36:49 PM
 by: System Manager

Efficiency Triplets
 =====

Energy	Efficiency	Error
59.54	1.17E-04	1.16E-05
81.00	3.23E-04	2.67E-05
276.40	5.60E-04	5.14E-05
302.84	5.29E-04	4.29E-05
356.01	4.72E-04	3.70E-05
383.85	4.28E-04	3.66E-05
661.66	2.90E-04	2.24E-05
1173.24	1.81E-04	1.36E-05
1332.50	1.61E-04	1.21E-05

DUAL Efficiency Calibration Equation

=====

Single Equation Terms ->	Offset:	-184.452
	Slope:	113.949
	Quadratic:	-27.189
	Cubic:	2.861
	4th Order:	-0.113
	5th Order:	0.000
	6th Order:	0.000
	7th Order:	0.000
	8th Order:	0.000
	9th Order:	0.000

EMPIRICAL Efficiency Calibration Equation

=====

Empirical Equation Terms ->	Scaling:	696.018
	Offset:	-8.192
	Slope:	0.771
	Quadratic:	-0.000
	Cubic:	0.092
	4th Order:	-0.113
	5th Order:	0.000

LINEAR Efficiency Calibration Equation

=====

Linear Equation Terms ->	Offset:	-0.000
	Slope:	-3.649
	Quadratic:	192.040
	Cubic:	-19988.918
	4th Order:	451956.375
	5th Order:	0.000
	6th Order:	0.000
	7th Order:	0.000
	8th Order:	0.000
	9th Order:	0.000

Datasource: C:\WAS\CALIB\CR1AR1\ES130001.C01
 $\ln(\text{Eff}) = -1.845\text{e}+02 + 1.139\text{e}+02 \cdot \ln(E) - 2.719\text{e}+01 \cdot \ln(E)^2 + 2.861\text{e}+00 \cdot \ln(E)^3 - 1.128\text{e}-01 \cdot \ln(E)^4$

Detector SEGe 4 Drum pos 3

 ***** EFFICIENCY CALIBRATION REPORT *****

=====
 Calibration Record No. : 1
 =====

Identification Number : EFFCAL1A
 Description/Title : eff cal 55 gal lt drum no coll
 :
 Location :
 Container : 55 gal container
 Weight, %Full : 2.80 (kg), 100.00 (%),
 Volume, Density : 208.00 (l), 0.01 (kg/l)

Comment:

Reference Date : 10-13-98 2:39:40 PM
 Acquisition Started : 10-13-98 2:39:37 PM
 Live Time : 296.0 seconds
 Real Time : 300.0 seconds

Detector Group : SeGes
 Detector : SEGE3
 Scan Platform Position : 1
 Geometry/Collimator Position : 0

Geometry Description : Distributed
 Spectrum File Name : C:\WAS\CALIB\CR1AR1\ES210001.C01
 Energy Calibration Performed on : 10-12-98 2:52:27 PM
 Efficiency Calibration Performed on: 10-13-98 6:31:25 PM
 by: System Manager
 Efficiency Calibration Approved on : 10-13-98 6:36:52 PM
 by: System Manager

Efficiency Triplets
 =====

Energy	Efficiency	Error
59.54	1.48E-04	1.45E-05
81.00	3.90E-04	3.18E-05
276.40	6.99E-04	6.21E-05
302.84	6.25E-04	5.01E-05
356.01	5.53E-04	4.33E-05
383.85	4.94E-04	4.34E-05
661.66	3.35E-04	2.55E-05
1173.24	2.06E-04	1.53E-05
1332.50	2.03E-04	1.49E-05

DUAL Efficiency Calibration Equation

=====

Single Equation Terms ->	Offset:	-149.904
	Slope:	88.289
	Quadratic:	-20.072
	Cubic:	1.993
	4th Order:	-0.073
	5th Order:	0.000
	6th Order:	0.000
	7th Order:	0.000
	8th Order:	0.000
	9th Order:	0.000

EMPIRICAL Efficiency Calibration Equation

=====

Empirical Equation Terms ->	Scaling:	696.018
	Offset:	-8.077
	Slope:	0.805
	Quadratic:	0.163
	Cubic:	-0.068
	4th Order:	-0.073
	5th Order:	0.000

LINEAR Efficiency Calibration Equation

=====

Linear Equation Terms ->	Offset:	-0.000
	Slope:	-3.765
	Quadratic:	262.305
	Cubic:	-27284.699
	4th Order:	682345.750
	5th Order:	0.000
	6th Order:	0.000
	7th Order:	0.000
	8th Order:	0.000
	9th Order:	0.000

Datasource: C:\WAS\CALIB\CR1AR1\ES210001.C01

$$\ln(\text{Eff}) = -1.499\text{e}+02 + 8.829\text{e}+01 \cdot \ln(E) - 2.007\text{e}+01 \cdot \ln(E)^2 + 1.993\text{e}+00 \cdot \ln(E)^3 - 7.350\text{e}-02 \cdot \ln(E)^4$$

Detector SEGc 3 Drum Pos 1.

 ***** EFFICIENCY CALIBRATION REPORT *****

=====
 Calibration Record No. : 1
 =====

Identification Number : EFFCAL1A
 Description/Title : eff cal 55 gal lt drum no coll
 :
 Location :
 Container : 55 gal container
 Weight, %Full : 2.80 (kg), 100.00 (%),
 Volume, Density : 208.00 (l), 0.01 (kg/l)

Comment:

Reference Date : 10-13-98 2:39:40 PM
 Acquisition Started : 10-13-98 2:44:59 PM
 Live Time : 295.9 seconds
 Real Time : 300.0 seconds

Detector Group : SeGes
 Detector : SEGE3
 Scan Platform Position : 2
 Geometry/Collimator Position : 0

Geometry Description : Distributed
 Spectrum File Name : C:\WAS\CALIB\CR1AR1\ES220001.C01
 Energy Calibration Performed on : 10-12-98 2:52:27 PM
 Efficiency Calibration Performed on: 10-13-98 6:31:55 PM
 by: System Manager
 Efficiency Calibration Approved on : 10-13-98 6:36:56 PM
 by: System Manager

Efficiency Triplets

=====

Energy	Efficiency	Error
59.54	1.30E-04	1.34E-05
81.00	3.93E-04	3.20E-05
276.40	5.85E-04	5.68E-05
302.84	6.27E-04	5.10E-05
356.01	5.59E-04	4.38E-05
383.85	5.24E-04	4.51E-05
661.66	3.41E-04	2.59E-05
1173.24	2.21E-04	1.62E-05
1332.50	2.00E-04	1.47E-05

DUAL Efficiency Calibration Equation

=====

Single Equation Terms ->	Offset:	-212.288
	Slope:	133.932
	Quadratic:	-32.458
	Cubic:	3.469
	4th Order:	-0.139
	5th Order:	0.000
	6th Order:	0.000
	7th Order:	0.000
	8th Order:	0.000
	9th Order:	0.000

EMPIRICAL Efficiency Calibration Equation

=====

Empirical Equation Terms ->	Scaling:	696.018
	Offset:	-8.008
	Slope:	0.695
	Quadratic:	0.000
	Cubic:	0.164
	4th Order:	-0.139
	5th Order:	0.000

LINEAR Efficiency Calibration Equation

=====

Linear Equation Terms ->	Offset:	-0.000
	Slope:	-3.508
	Quadratic:	156.195
	Cubic:	-15374.139
	4th Order:	284616.906
	5th Order:	0.000
	6th Order:	0.000
	7th Order:	0.000
	8th Order:	0.000
	9th Order:	0.000

Datasource: C:\WAS\CALIB\CR1AR1\ES220001.C01

$$\ln(\text{Eff}) = -2.123\text{e}+02 + 1.339\text{e}+02 \cdot \ln(E) - 3.246\text{e}+01 \cdot \ln(E)^2 + 3.469\text{e}+00 \cdot \ln(E)^3 - 1.388\text{e}-01 \cdot \ln(E)^4$$

Detector SEGe 3 Drum Pos. 2

 ***** EFFICIENCY CALIBRATION REPORT *****

=====
 Calibration Record No. : 1
 =====

Identification Number : EFFCAL1A
 Description/Title : eff cal 55 gal lt drum no coll
 :
 Location :
 Container : 55 gal container
 Weight, %Full : 2.80 (kg), 100.00 (%),
 Volume, Density : 208.00 (l), 0.01 (kg/l)

Comment:

Reference Date : 10-13-98 2:39:40 PM
 Acquisition Started : 10-13-98 2:50:19 PM
 Live Time : 296.0 seconds
 Real Time : 300.0 seconds

Detector Group : SeGes
 Detector : SEGE3
 Scan Platform Position : 3
 Geometry/Collimator Position : 0

Geometry Description : Distributed
 Spectrum File Name : C:\WAS\CALIB\CR1AR1\ES230001.C01
 Energy Calibration Performed on : 10-12-98 2:52:27 PM
 Efficiency Calibration Performed on: 10-13-98 6:32:21 PM
 by: System Manager
 Efficiency Calibration Approved on : 10-13-98 6:37:16 PM
 by: System Manager

Efficiency Triplets
 =====

Energy	Efficiency	Error
59.54	1.43E-04	1.42E-05
81.00	4.22E-04	3.41E-05
276.40	6.50E-04	5.71E-05
302.84	6.14E-04	4.93E-05
356.01	5.58E-04	4.37E-05
383.85	4.80E-04	4.25E-05
661.66	3.37E-04	2.60E-05
1173.24	2.24E-04	1.65E-05
1332.50	1.99E-04	1.46E-05

DUAL Efficiency Calibration Equation

=====

Single Equation Terms -> Offset: -218.228
 Slope: 138.066
 Quadratic: -33.473
 Cubic: 3.574
 4th Order: -0.143
 5th Order: 0.000
 6th Order: 0.000
 7th Order: 0.000
 8th Order: 0.000
 9th Order: 0.000

EMPIRICAL Efficiency Calibration Equation

=====

Empirical Equation Terms -> Scaling: 696.018
 Offset: -8.032
 Slope: 0.683
 Quadratic: 0.057
 Cubic: 0.159
 4th Order: -0.143
 5th Order: 0.000

LINEAR Efficiency Calibration Equation

=====

Linear Equation Terms -> Offset: -0.000
 Slope: -3.630
 Quadratic: 199.243
 Cubic: -19335.150
 4th Order: 401311.375
 5th Order: 0.000
 6th Order: 0.000
 7th Order: 0.000
 8th Order: 0.000
 9th Order: 0.000

Datasource: C:\WAS\CALIB\CR1AR1\ES230001.C01

$$\ln(\text{Eff}) = -2.182e+02 + 1.381e+02 \cdot \ln(E) - 3.347e+01 \cdot \ln(E)^2 + 3.574e+00 \cdot \ln(E)^3 - 1.426e-01 \cdot \ln(E)^4$$

Detector SEGe 3 Drum Pos 3

 ***** EFFICIENCY CALIBRATION REPORT *****

=====
 Calibration Record No. : 1
 =====

Identification Number : EFFCAL1A
 Description/Title : eff cal 55 gal lt drum no coll
 :
 Location :
 Container : 55 gal container
 Weight, %Full : 2.80 (kg), 100.00 (%),
 Volume, Density : 208.00 (l), 0.01 (kg/l)

Comment:

Reference Date : 10-13-98 2:39:40 PM
 Acquisition Started : 10-13-98 2:39:37 PM
 Live Time : 296.0 seconds
 Real Time : 300.0 seconds

Detector Group : SeGes
 Detector : SEGE2
 Scan Platform Position : 1
 Geometry/Collimator Position : 0

Geometry Description : Distributed
 Sample File Name : C:\WAS\CALIB\CR1AR1\ES310001.C01
 Energy Calibration Performed on : 10-12-98 2:55:29 PM
 Efficiency Calibration Performed on: 10-13-98 6:32:53 PM
 by: System Manager
 Efficiency Calibration Approved on : 10-13-98 6:37:28 PM
 by: System Manager

Efficiency Triplets

=====

Energy	Efficiency	Error
59.54	1.26E-04	1.30E-05
81.00	4.18E-04	3.37E-05
276.40	6.95E-04	6.11E-05
302.84	6.06E-04	4.86E-05
356.01	5.48E-04	4.30E-05
383.85	5.16E-04	4.34E-05
661.66	3.35E-04	2.56E-05
1173.24	2.12E-04	1.56E-05
1332.50	1.96E-04	1.44E-05

DUAL Efficiency Calibration Equation

=====

Single Equation Terms ->	Offset:	-239.554
	Slope:	152.025
	Quadratic:	-36.847
	Cubic:	3.932
	4th Order:	-0.157
	5th Order:	0.000
	6th Order:	0.000
	7th Order:	0.000
	8th Order:	0.000
	9th Order:	0.000

EMPIRICAL Efficiency Calibration Equation

=====

Empirical Equation Terms ->	Scaling:	696.018
	Offset:	-8.049
	Slope:	0.716
	Quadratic:	0.082
	Cubic:	0.171
	4th Order:	-0.157
	5th Order:	0.000

LINEAR Efficiency Calibration Equation

=====

Linear Equation Terms ->	Offset:	-0.000
	Slope:	-3.654
	Quadratic:	214.266
	Cubic:	-20649.354
	4th Order:	419740.500
	5th Order:	0.000
	6th Order:	0.000
	7th Order:	0.000
	8th Order:	0.000
	9th Order:	0.000

Datasource: C:\WAS\CALIB\CR1AR1\ES310001.C01

$$\ln(\text{Eff}) = -2.396\text{e}+02 + 1.520\text{e}+02 \cdot \ln(E) - 3.685\text{e}+01 \cdot \ln(E)^2 + 3.932\text{e}+00 \cdot \ln(E)^3 - 1.567\text{e}-01 \cdot \ln(E)^4$$

Detector SEGe 2 Drum Pos 1.

 ***** EFFICIENCY CALIBRATION REPORT *****

=====
 Calibration Record No. : 1
 =====

Identification Number : EFFCAL1A
 Description/Title : eff cal 55 gal lt drum no coll
 :
 Location :
 Container : 55 gal container
 Weight, %Full : 2.80 (kg), 100.00 (%),
 Volume, Density : 208.00 (l), 0.01 (kg/l)

Comment:

Reference Date : 10-13-98 2:39:40 PM
 Acquisition Started : 10-13-98 2:44:59 PM
 Live Time : 296.0 seconds
 Real Time : 300.0 seconds

Detector Group : SeGes
 Detector : SEGE2
 Scan Platform Position : 2
 Geometry/Collimator Position : 0

Geometry Description : Distributed
 Spectrum File Name : C:\WAS\CALIB\CR1AR1\ES320001.C01
 Energy Calibration Performed on : 10-12-98 2:55:29 PM
 Efficiency Calibration Performed on: 10-13-98 6:33:20 PM
 by: System Manager
 Efficiency Calibration Approved on : 10-13-98 6:37:32 PM
 by: System Manager

Efficiency Triplets
 =====

Energy	Efficiency	Error
59.54	1.25E-04	1.30E-05
81.00	4.15E-04	3.34E-05
276.40	7.02E-04	6.37E-05
302.84	6.27E-04	5.05E-05
356.01	5.51E-04	4.32E-05
383.85	5.09E-04	4.36E-05
661.66	3.25E-04	2.49E-05
1173.24	2.26E-04	1.65E-05
1332.50	1.98E-04	1.45E-05

DUAL Efficiency Calibration Equation

=====

Single Equation Terms ->	Offset:	-232.940
	Slope:	146.592
	Quadratic:	-35.211
	Cubic:	3.718
	4th Order:	-0.146
	5th Order:	0.000
	6th Order:	0.000
	7th Order:	0.000
	8th Order:	0.000
	9th Order:	0.000

EMPIRICAL Efficiency Calibration Equation

=====

Empirical Equation Terms ->	Scaling:	696.018
	Offset:	-8.060
	Slope:	0.711
	Quadratic:	0.157
	Cubic:	0.116
	4th Order:	-0.146
	5th Order:	0.000

LINEAR Efficiency Calibration Equation

=====

Linear Equation Terms ->	Offset:	-0.000
	Slope:	-3.760
	Quadratic:	254.223
	Cubic:	-24851.244
	4th Order:	549583.188
	5th Order:	0.000
	6th Order:	0.000
	7th Order:	0.000
	8th Order:	0.000
	9th Order:	0.000

Datasource: C:\WAS\CALIB\CR1AR1\ES320001.C01

$$\ln(\text{Eff}) = -2.329\text{e}+02 + 1.466\text{e}+02 \cdot \ln(E) - 3.521\text{e}+01 \cdot \ln(E)^2 + 3.718\text{e}+00 \cdot \ln(E)^3 - 1.465\text{e}-01 \cdot \ln(E)^4$$

Detector SE Ge 2 Drum Pos.: 2.

 ***** EFFICIENCY CALIBRATION REPORT *****

=====
 Calibration Record No. : 1
 =====

Identification Number : EFFCAL1A
 Description/Title : eff cal 55 gal lt drum no coll
 :
 Location :
 Container : 55 gal container
 Weight, %Full : 2.80 (kg), 100.00 (%),
 Volume, Density : 208.00 (l), 0.01 (kg/l)

Comment:

Reference Date : 10-13-98 2:39:40 PM
 Acquisition Started : 10-13-98 2:50:19 PM
 Live Time : 296.2 seconds
 Real Time : 300.0 seconds

Detector Group : SeGes
 Detector : SEGE2
 Scan Platform Position : 3
 Geometry/Collimator Position : 0

Geometry Description : Distributed
 Spectrum File Name : C:\WAS\CALIB\CR1AR1\ES330001.C01
 Energy Calibration Performed on : 10-12-98 2:55:29 PM
 Efficiency Calibration Performed on: 10-13-98 6:33:48 PM
 by: System Manager
 Efficiency Calibration Approved on : 10-13-98 6:37:35 PM
 by: System Manager

Efficiency Triplets
 =====

Energy	Efficiency	Error
59.54	1.19E-04	1.24E-05
81.00	3.81E-04	3.11E-05
276.40	6.29E-04	5.86E-05
302.84	6.08E-04	4.90E-05
356.01	5.37E-04	4.21E-05
383.85	4.80E-04	4.12E-05
661.66	3.20E-04	2.46E-05
1173.24	1.97E-04	1.47E-05
1332.50	1.86E-04	1.37E-05

DUAL Efficiency Calibration Equation

=====

Single Equation Terms ->	Offset:	-218.716
	Slope:	137.037
	Quadratic:	-32.885
	Cubic:	3.474
	4th Order:	-0.137
	5th Order:	0.000
	6th Order:	0.000
	7th Order:	0.000
	8th Order:	0.000
	9th Order:	0.000

EMPIRICAL Efficiency Calibration Equation

=====

Empirical Equation Terms ->	Scaling:	696.018
	Offset:	-8.101
	Slope:	0.752
	Quadratic:	0.083
	Cubic:	0.116
	4th Order:	-0.137
	5th Order:	0.000

LINEAR Efficiency Calibration Equation

=====

Linear Equation Terms ->	Offset:	-0.000
	Slope:	-3.668
	Quadratic:	215.345
	Cubic:	-21334.590
	4th Order:	454460.219
	5th Order:	0.000
	6th Order:	0.000
	7th Order:	0.000
	8th Order:	0.000
	9th Order:	0.000

Datasource: C:\WAS\CALIB\CR1AR1\ES330001.C01

$$\ln(\text{Eff}) = -2.187\text{e}+02 + 1.370\text{e}+02 \cdot \ln(E) - 3.289\text{e}+01 \cdot \ln(E)^2 + 3.474\text{e}+00 \cdot \ln(E)^3 - 1.371\text{e}-01 \cdot \ln(E)^4$$

Detector Se Ge 2 Drum Pos 3

 ***** EFFICIENCY CALIBRATION REPORT *****

=====
 Calibration Record No. : 1
 =====

Identification Number : EFFCAL1A
 Description/Title : eff cal 55 gal lt drum no coll
 :
 Location :
 Container : 55 gal container
 Weight, %Full : 2.80 (kg), 100.00 (%),
 Volume, Density : 208.00 (l), 0.01 (kg/l)

Comment:

Reference Date : 10-13-98 2:39:40 PM
 Acquisition Started : 10-13-98 2:39:37 PM
 Live Time : 296.9 seconds
 Real Time : 300.0 seconds

Detector Group : SeGes
 Detector : SEGE1
 Scan Platform Position : 1
 Geometry/Collimator Position : 0

Geometry Description : Distributed
 Spectrum File Name : C:\WAS\CALIB\CR1AR1\ES410001.C01
 Energy Calibration Performed on : 10-12-98 2:58:16 PM
 Efficiency Calibration Performed on: 10-13-98 6:34:17 PM
 by: System Manager
 Efficiency Calibration Approved on : 10-13-98 6:37:38 PM
 by: System Manager

Efficiency Triplets

=====

Energy	Efficiency	Error
59.54	9.05E-05	1.01E-05
81.00	2.68E-04	2.24E-05
276.40	4.95E-04	4.57E-05
302.84	4.39E-04	3.59E-05
356.01	3.82E-04	3.00E-05
383.85	3.46E-04	3.13E-05
661.66	2.40E-04	1.86E-05
1173.24	1.45E-04	1.12E-05
1332.50	1.28E-04	9.84E-06

DUAL Efficiency Calibration Equation

=====

Single Equation Terms ->	Offset:	-207.617
	Slope:	129.765
	Quadratic:	-31.220
	Cubic:	3.313
	4th Order:	-0.132
	5th Order:	0.000
	6th Order:	0.000
	7th Order:	0.000
	8th Order:	0.000
	9th Order:	0.000

EMPIRICAL Efficiency Calibration Equation

=====

Empirical Equation Terms ->	Scaling:	696.018
	Offset:	-8.395
	Slope:	0.785
	Quadratic:	-0.005
	Cubic:	0.134
	4th Order:	-0.132
	5th Order:	0.000

LINEAR Efficiency Calibration Equation

=====

Linear Equation Terms ->	Offset:	-0.000
	Slope:	-3.764
	Quadratic:	207.517
	Cubic:	-21363.756
	4th Order:	479931.375
	5th Order:	0.000
	6th Order:	0.000
	7th Order:	0.000
	8th Order:	0.000
	9th Order:	0.000

Datasource: C:\WAS\CALIB\CR1AR1\ES410001.C01

$$\ln(\text{Eff}) = -2.076e+02 + 1.298e+02 \cdot \ln(E) - 3.122e+01 \cdot \ln(E)^2 + 3.313e+00 \cdot \ln(E)^3 - 1.316e-01 \cdot \ln(E)^4$$

Detector SEGe 1 Drum Pos 1

 ***** EFFICIENCY CALIBRATION REPORT *****

=====
 Calibration Record No. : 1
 =====

Identification Number : EFFCAL1A
 Description/Title : eff cal 55 gal lt drum no coll
 :
 Location :
 Container : 55 gal container
 Weight, %Full : 2.80 (kg), 100.00 (%),
 Volume, Density : 208.00 (l), 0.01 (kg/l)

Comment:

Reference Date : 10-13-98 2:39:40 PM
 Acquisition Started : 10-13-98 2:44:59 PM
 Live Time : 297.7 seconds
 Real Time : 300.0 seconds

Detector Group : SeGes
 Detector : SEGE1
 Scan Platform Position : 2
 Geometry/Collimator Position : 0

Geometry Description : Distributed
 Spectrum File Name : C:\WAS\CALIB\CR1AR1\ES420001.C01
 Energy Calibration Performed on : 10-12-98 2:58:16 PM
 Efficiency Calibration Performed on: 10-13-98 6:34:43 PM
 by: System Manager
 Efficiency Calibration Approved on : 10-13-98 6:37:41 PM
 by: System Manager

Efficiency Triplets
 =====

Energy	Efficiency	Error
59.54	5.21E-05	6.30E-06
81.00	1.48E-04	1.33E-05
276.40	2.73E-04	2.78E-05
302.84	2.70E-04	2.32E-05
356.01	2.24E-04	1.78E-05
383.85	1.95E-04	1.90E-05
661.66	1.41E-04	1.16E-05
1173.24	8.76E-05	7.26E-06
1332.50	8.37E-05	6.90E-06

DUAL Efficiency Calibration Equation

=====

Single Equation Terms ->	Offset:	-177.407
	Slope:	107.044
	Quadratic:	-25.009
	Cubic:	2.567
	4th Order:	-0.098
	5th Order:	0.000
	6th Order:	0.000
	7th Order:	0.000
	8th Order:	0.000
	9th Order:	0.000

EMPIRICAL Efficiency Calibration Equation

=====

Empirical Equation Terms ->	Scaling:	696.018
	Offset:	-8.938
	Slope:	0.761
	Quadratic:	0.111
	Cubic:	0.008
	4th Order:	-0.098
	5th Order:	0.000

LINEAR Efficiency Calibration Equation

=====

Linear Equation Terms ->	Offset:	-0.000
	Slope:	-4.100
	Quadratic:	241.515
	Cubic:	-25259.254
	4th Order:	610387.813
	5th Order:	0.000
	6th Order:	0.000
	7th Order:	0.000
	8th Order:	0.000
	9th Order:	0.000

Datasource: C:\WAS\CALIB\CR1AR1\ES420001.C01

$$\ln(\text{Eff}) = -1.774e+02 + 1.070e+02 \cdot \ln(E) - 2.501e+01 \cdot \ln(E)^2 + 2.567e+00 \cdot \ln(E)^3 - 9.835e-02 \cdot \ln(E)^4$$

Detector SEGe 1 Drum Pos 2

 ***** EFFICIENCY CALIBRATION REPORT *****

=====
 Calibration Record No. : 1
 =====

Identification Number : EFFCAL1A
 Description/Title : eff cal 55 gal lt drum no coll
 :
 Location :
 Container : 55 gal container
 Weight, %Full : 2.80 (kg), 100.00 (%),
 Volume, Density : 208.00 (l), 0.00 (kg/l)

Comment:

Reference Date : 10-13-98 2:39:40 PM
 Acquisition Started : 10-13-98 2:44:59 PM
 Live Time : 297.3 seconds
 Real Time : 300.0 seconds

Detector Group : Multi-Density, Sum Segments
 Detector :
 Scan Platform Position : 0
 Geometry/Collimator Position : 0

Geometry Description : Distributed
 Spectrum File Name : C:\WAS\CALIB\CR1AR1\EA040005.C01
 Energy Calibration Performed on : 10-12-98 3:07:20 PM
 Efficiency Calibration Performed on: 10-13-98 7:55:21 PM
 by: System Manager
 Efficiency Calibration Approved on : 10-13-98 7:56:36 PM
 by: System Manager

Efficiency Triplets
 =====

Energy	Efficiency	Error
59.54	1.19E-04	9.77E-06
81.00	3.00E-04	2.34E-05
276.40	5.72E-04	4.56E-05
302.84	5.25E-04	4.09E-05
356.01	4.68E-04	3.63E-05
383.85	4.23E-04	3.33E-05
661.66	2.83E-04	2.04E-05
1173.24	1.82E-04	1.21E-05
1332.50	1.66E-04	1.11E-05

DUAL Efficiency Calibration Equation

=====

Single Equation Terms ->	Offset:	-137.006
	Slope:	79.453
	Quadratic:	-17.913
	Cubic:	1.766
	4th Order:	-0.065
	5th Order:	0.000
	6th Order:	0.000
	7th Order:	0.000
	8th Order:	0.000
	9th Order:	0.000

EMPIRICAL Efficiency Calibration Equation

=====

Empirical Equation Terms ->	Scaling:	696.018
	Offset:	-8.222
	Slope:	0.810
	Quadratic:	0.096
	Cubic:	-0.069
	4th Order:	-0.065
	5th Order:	0.000

LINEAR Efficiency Calibration Equation

=====

Linear Equation Terms ->	Offset:	-0.000
	Slope:	-3.775
	Quadratic:	240.738
	Cubic:	-25952.219
	4th Order:	661964.938
	5th Order:	0.000
	6th Order:	0.000
	7th Order:	0.000
	8th Order:	0.000
	9th Order:	0.000

HNF-5148, Rev. 0

=====
Calibration Record No. : 2
=====

Identification Number : EFFCAL1A
Description/Title : eff cal 55 gal lt drum no coll
:
Location :
Container : 55 gal container
Weight, %Full : 2.80 (kg), 100.00 (%),
Volume, Density : 208.00 (l), 0.01 (kg/l)

Comment:

Reference Date : 10-13-98 2:39:40 PM
Acquisition Started : 10-13-98 2:44:59 PM
Live Time : 297.3 seconds
Real Time : 300.0 seconds

Detector Group : Multi-Density, Sum Segments
Detector :
Scan Platform Position : 0
Geometry/Collimator Position : 0

Geometry Description : Distributed
Spectrum File Name : C:\WAS\CALIB\CR1AR1\EA040005.C01
Energy Calibration Performed on : 10-12-98 3:07:20 PM
Efficiency Calibration Performed on: 10-13-98 7:55:21 PM
by: System Manager
Efficiency Calibration Approved on : 10-13-98 7:56:36 PM
by: System Manager

Efficiency Triplets

=====

Energy	Efficiency	Error
59.54	1.19E-04	9.77E-06
81.00	3.00E-04	2.34E-05
276.40	5.72E-04	4.56E-05
302.84	5.25E-04	4.09E-05
356.01	4.68E-04	3.63E-05
383.85	4.23E-04	3.33E-05
661.66	2.83E-04	2.04E-05
1173.24	1.82E-04	1.21E-05
1332.50	1.66E-04	1.11E-05

DUAL Efficiency Calibration Equation

=====

Single Equation Terms -> Offset: -137.006
 Slope: 79.453
 Quadratic: -17.913
 Cubic: 1.766
 4th Order: -0.065
 5th Order: 0.000
 6th Order: 0.000
 7th Order: 0.000
 8th Order: 0.000
 9th Order: 0.000

EMPIRICAL Efficiency Calibration Equation

=====

Empirical Equation Terms -> Scaling: 696.018
 Offset: -8.222
 Slope: 0.810
 Quadratic: 0.096
 Cubic: -0.069
 4th Order: -0.065
 5th Order: 0.000

LINEAR Efficiency Calibration Equation

=====

Linear Equation Terms -> Offset: -0.000
 Slope: -3.775
 Quadratic: 240.738
 Cubic: -25952.219
 4th Order: 661964.938
 5th Order: 0.000
 6th Order: 0.000
 7th Order: 0.000
 8th Order: 0.000
 9th Order: 0.000

HNF-5148, Rev. 0

=====
Calibration Record No. : 3
=====

Identification Number : EFFCAL1A
Description/Title : eff cal 55 gal lt drum no coll
:
Location :
Container : 55 gal container
Weight, %Full : 2.80 (kg), 100.00 (%),
Volume, Density : 208.00 (l), 0.43 (kg/l)

Comment:

Reference Date : 10-13-98 2:39:40 PM
Acquisition Started : 10-13-98 2:44:59 PM
Live Time : 297.3 seconds
Real Time : 300.0 seconds

Detector Group : Multi-Density, Sum Segments
Detector :
Scan Platform Position : 0
Geometry/Collimator Position : 0

Geometry Description : Distributed
Spectrum File Name : C:\WAS\CALIB\CR1AR1\EA040005.C01
Energy Calibration Performed on : 10-12-98 3:07:20 PM
Efficiency Calibration Performed on: 10-13-98 7:55:21 PM
by: System Manager
Efficiency Calibration Approved on : 10-13-98 7:56:36 PM
by: System Manager

Efficiency Triplets =====

Energy	Efficiency	Error
59.54	3.78E-05	3.49E-06
81.00	2.91E-05	3.25E-06
276.40	2.53E-04	2.07E-05
302.84	2.30E-04	1.80E-05
356.01	2.10E-04	1.63E-05
383.85	1.99E-04	1.61E-05
661.66	1.46E-04	1.06E-05
1173.24	1.06E-04	7.11E-06
1332.50	1.01E-04	6.77E-06

DUAL Efficiency Calibration Equation

=====

Single Equation Terms ->	Offset:	-36.585
	Slope:	11.216
	Quadratic:	-1.376
	Cubic:	0.048
	4th Order:	0.000
	5th Order:	0.000
	6th Order:	0.000
	7th Order:	0.000
	8th Order:	0.000
	9th Order:	0.000

EMPIRICAL Efficiency Calibration Equation

=====

Empirical Equation Terms ->	Scaling:	696.018
	Offset:	-8.904
	Slope:	1.148
	Quadratic:	0.173
	Cubic:	-1.341
	4th Order:	0.404
	5th Order:	0.000

LINEAR Efficiency Calibration Equation

=====

Linear Equation Terms ->	Offset:	0.000
	Slope:	-4.308
	Quadratic:	360.457
	Cubic:	-55226.941
	4th Order:	1985492.000
	5th Order:	0.000
	6th Order:	0.000
	7th Order:	0.000
	8th Order:	0.000
	9th Order:	0.000

HNF-5148, Rev. 0

=====
Calibration Record No. : 4
=====

Identification Number : EFFCAL1A
Description/Title : eff cal 55 gal lt drum no coll
:
Location :
Container : 55 gal container
Weight, %Full : 2.80 (kg), 100.00 (%),
Volume, Density : 208.00 (l), 0.66 (kg/l)

Comment:

Reference Date : 10-13-98 2:39:40 PM
Acquisition Started : 10-13-98 2:44:59 PM
Live Time : 297.3 seconds
Real Time : 300.0 seconds

Detector Group : Multi-Density, Sum Segments
Detector :
Scan Platform Position : 0
Geometry/Collimator Position : 0

Geometry Description : Distributed
Spectrum File Name : C:\WAS\CALIB\CR1ARI\EA040005.C01
Energy Calibration Performed on : 10-12-98 3:07:20 PM
Efficiency Calibration Performed on: 10-13-98 7:55:21 PM
by: System Manager
Efficiency Calibration Approved on : 10-13-98 7:56:36 PM
by: System Manager

Efficiency Triplets

=====

Energy	Efficiency	Error
59.54	3.05E-05	2.96E-06
81.00	4.07E-06	2.14E-06
276.40	1.91E-04	1.56E-05
302.84	1.75E-04	1.38E-05
356.01	1.60E-04	1.25E-05
383.85	1.51E-04	1.21E-05
661.66	1.16E-04	8.43E-06
1173.24	8.58E-05	5.79E-06
1332.50	8.44E-05	5.67E-06

DUAL Efficiency Calibration Equation
=====

Single Equation Terms ->	Offset:	-63.146
	Slope:	26.368
	Quadratic:	-4.179
	Cubic:	0.216
	4th Order:	0.000
	5th Order:	0.000
	6th Order:	0.000
	7th Order:	0.000
	8th Order:	0.000
	9th Order:	0.000

EMPIRICAL Efficiency Calibration Equation
=====

Empirical Equation Terms ->	Scaling:	696.018
	Offset:	-9.139
	Slope:	1.014
	Quadratic:	0.187
	Cubic:	-1.182
	4th Order:	0.346
	5th Order:	0.000

LINEAR Efficiency Calibration Equation
=====

Linear Equation Terms ->	Offset:	0.000
	Slope:	-4.717
	Quadratic:	540.562
	Cubic:	-93560.102
	4th Order:	3693790.500
	5th Order:	0.000
	6th Order:	0.000
	7th Order:	0.000
	8th Order:	0.000
	9th Order:	0.000

=====
 Calibration Record No. : 5
 =====

Identification Number : EFFCAL1A
 Description/Title : eff cal 55 gal 1t drum no coll
 :
 Location :
 Container : 55 gal container
 Weight, %Full : 2.80 (kg), 100.00 (%),
 Volume, Density : 208.00 (l), 1.56 (kg/l)

Comment:

Reference Date : 10-13-98 2:39:40 PM
 Acquisition Started : 10-13-98 2:44:59 PM
 Live Time : 297.3 seconds
 Real Time : 300.0 seconds

Detector Group : Multi-Density, Sum Segments
 Detector :
 Scan Platform Position : 0
 Geometry/Collimator Position : 0

Geometry Description : Distributed
 Spectrum File Name : C:\WAS\CALIB\CR1AR1\EA040005.C01
 Energy Calibration Performed on : 10-12-98 3:07:20 PM
 Efficiency Calibration Performed on: 10-13-98 7:55:21 PM
 by: System Manager
 Efficiency Calibration Approved on : 10-13-98 7:56:36 PM
 by: System Manager

Efficiency Triplets

=====

Energy	Efficiency	Error
59.54	8.88E-06	1.33E-06
276.40	9.71E-05	8.73E-06
302.84	8.98E-05	7.10E-06
356.01	8.54E-05	6.65E-06
383.85	7.91E-05	6.57E-06
661.66	6.15E-05	4.53E-06
1173.24	4.87E-05	3.32E-06
1332.50	4.72E-05	3.20E-06

DUAL Efficiency Calibration Equation

=====

Single Equation Terms -> Offset: -217.563
 Slope: 132.328
 Quadratic: -31.191
 Cubic: 3.239
 4th Order: -0.125
 5th Order: 0.000
 6th Order: 0.000
 7th Order: 0.000
 8th Order: 0.000
 9th Order: 0.000

EMPIRICAL Efficiency Calibration Equation

=====

Empirical Equation Terms -> Scaling: 696.018
 Offset: -9.727
 Slope: 0.421
 Quadratic: 0.160
 Cubic: 0.046
 4th Order: -0.125
 5th Order: 0.000

LINEAR Efficiency Calibration Equation

=====

Linear Equation Terms -> Offset: -0.000
 Slope: -4.387
 Quadratic: 149.529
 Cubic: -12658.311
 4th Order: 83877.445
 5th Order: 0.000
 6th Order: 0.000
 7th Order: 0.000
 8th Order: 0.000
 9th Order: 0.000

45

Dual Efficiency Calibration Curve

Summed Spectra

• $\rho = 0.00, 0.01346 \dots \text{gm/cc}$

• $\rho = 0.430288 \text{ gm/cc}$

• $\rho = 0.65625 \text{ gm/cc}$

• $\rho = 1.5601 \text{ gm/cc}$

 ***** EFFICIENCY CALIBRATION REPORT *****

=====
 Calibration Record No. : 1
 =====

Identification Number : EFFCAL1B
 Description/Title : eff cal 55 gal lt drum w/ coll
 :
 Location :
 Container : 55 gal container
 Weight, %Full : 2.80 (kg), 100.00 (%),
 Volume, Density : 208.00 (l), 0.01 (kg/l)

Comment:

Reference Date : 10-13-98 2:59:45 PM
 Acquisition Started : 10-13-98 3:07:04 PM
 Live Time : 418.1 seconds
 Real Time : 420.0 seconds

Detector Group : SeGes
 Detector : SEGE1
 Scan Platform Position : 2
 Geometry/Collimator Position : 1

Geometry Description : Distributed
 Drum File Name : C:\WAS\CALIB\CR1AR1\ES421001.C01
 Energy Calibration Performed on : 10-12-98 2:58:16 PM
 Efficiency Calibration Performed on: 10-13-98 6:44:39 PM
 by: System Manager
 Efficiency Calibration Approved on : 10-13-98 6:45:57 PM
 by: System Manager

Efficiency Triplets
 =====

Energy	Efficiency	Error
276.40	4.33E-05	1.25E-05
302.84	4.23E-05	5.86E-06
356.01	4.18E-05	3.56E-06
383.85	3.70E-05	7.21E-06
661.66	4.14E-05	4.10E-06
1173.24	3.28E-05	3.20E-06
1332.50	3.59E-05	3.31E-06

HNF-5148, Rev. 0

DUAL Efficiency Calibration Equation

=====

Single Equation Terms ->	Offset:	-13.261
	Slope:	1.104
	Quadratic:	-0.096
	Cubic:	0.000
	4th Order:	0.000
	5th Order:	0.000
	6th Order:	0.000
	7th Order:	0.000
	8th Order:	0.000
	9th Order:	0.000

EMPIRICAL Efficiency Calibration Equation

=====

Empirical Equation Terms ->	Scaling:	804.448
	Offset:	-10.178
	Slope:	0.210
	Quadratic:	-0.021
	Cubic:	-0.107
	4th Order:	0.000
	5th Order:	0.000

LINEAR Efficiency Calibration Equation

=====

Linear Equation Terms ->	Offset:	-0.000
	Slope:	-4.302
	Quadratic:	-20.334
	Cubic:	2336.421
	4th Order:	0.000
	5th Order:	0.000
	6th Order:	0.000
	7th Order:	0.000
	8th Order:	0.000
	9th Order:	0.000

Datasource: C:\WAS\CALIB\CR1AR1\ES421001.C01
 $\ln(\text{Eff}) = -1.326\text{e}+01 + 1.104\text{e}+00 \cdot \ln(E) - 9.587\text{e}-02 \cdot \ln(E)^2$

Detector SEGR 1 Drum Pos 2 w/c

 ***** EFFICIENCY CALIBRATION REPORT *****

=====
 Calibration Record No. : 1
 =====

Identification Number : EFFCAL1B
 Description/Title : eff cal 55 gal lt drum w/ coll
 :
 Location :
 Container : 55 gal container
 Weight, %Full : 2.80 (kg), 100.00 (%),
 Volume, Density : 208.00 (l), 0.01 (kg/l)

Comment:

Reference Date : 10-13-98 2:59:45 PM
 Acquisition Started : 10-13-98 2:59:42 PM
 Live Time : 417.8 seconds
 Real Time : 420.0 seconds

Detector Group : SeGes
 Detector : SEGE1
 Scan Platform Position : 1
 Geometry/Collimator Position : 1

Geometry Description : Distributed
 Spectrum File Name : C:\WAS\CALIB\CR1AR1\ES411001.C01
 Energy Calibration Performed on : 10-12-98 2:58:16 PM
 Efficiency Calibration Performed on: 10-13-98 6:43:56 PM
 by: System Manager
 Efficiency Calibration Approved on : 10-13-98 6:45:55 PM
 by: System Manager

Efficiency Triplets
 =====

Energy	Efficiency	Error
276.40	1.14E-04	1.77E-05
302.84	6.64E-05	8.15E-06
356.01	7.31E-05	6.04E-06
383.85	7.82E-05	1.04E-05
661.66	6.84E-05	6.06E-06
1173.24	5.88E-05	5.04E-06
1332.50	5.70E-05	4.73E-06

HNF-5148, Rev. 0

DUAL Efficiency Calibration Equation

=====

Single Equation Terms ->	Offset:	-6.537
	Slope:	-0.733
	Quadratic:	0.040
	Cubic:	0.000
	4th Order:	0.000
	5th Order:	0.000
	6th Order:	0.000
	7th Order:	0.000
	8th Order:	0.000
	9th Order:	0.000

EMPIRICAL Efficiency Calibration Equation

=====

Empirical Equation Terms ->	Scaling:	804.448
	Offset:	-9.601
	Slope:	0.052
	Quadratic:	-0.384
	Cubic:	0.548
	4th Order:	0.000
	5th Order:	0.000

LINEAR Efficiency Calibration Equation

=====

Linear Equation Terms ->	Offset:	-0.000
	Slope:	-3.446
	Quadratic:	-419.355
	Cubic:	79609.305
	4th Order:	0.000
	5th Order:	0.000
	6th Order:	0.000
	7th Order:	0.000
	8th Order:	0.000
	9th Order:	0.000

Datasource: C:\WAS\CALIB\CR1AR1\ES411001.C01
 $\ln(\text{Eff}) = -6.537\text{e}+00 - 7.329\text{e}-01 \cdot \ln(E) + 3.956\text{e}-02 \cdot \ln(E)^2$

Detector SEGe-1 Drum Pos 1 w/c

 ***** EFFICIENCY CALIBRATION REPORT *****

=====
 Calibration Record No. : 1
 =====

Identification Number : EFFCAL1B
 Description/Title : eff cal 55 gal lt drum w/ coll
 :
 Location :
 Container : 55 gal container
 Weight, %Full : 2.80 (kg), 100.00 (%),
 Volume, Density : 208.00 (l), 0.01 (kg/l)

Comment:

Reference Date : 10-13-98 2:59:45 PM
 Acquisition Started : 10-13-98 3:14:25 PM
 Live Time : 417.4 seconds
 Real Time : 420.0 seconds

Detector Group : SeGes
 Detector : SEGE2
 Scan Platform Position : 3
 Geometry/Collimator Position : 1

Geometry Description : Distributed
 Spectrum File Name : C:\WAS\CALIB\CR1AR1\ES331001.C01
 Energy Calibration Performed on : 10-12-98 2:55:29 PM
 Efficiency Calibration Performed on: 10-13-98 6:43:06 PM
 by: System Manager
 Efficiency Calibration Approved on : 10-13-98 6:45:51 PM
 by: System Manager

Efficiency Triplets

=====

Energy	Efficiency	Error
276.40	8.41E-05	1.66E-05
302.84	9.50E-05	8.85E-06
356.01	9.84E-05	8.04E-06
383.85	8.81E-05	1.12E-05
661.66	9.60E-05	8.05E-06
1173.24	7.94E-05	6.39E-06
1332.50	7.63E-05	6.03E-06

DUAL Efficiency Calibration Equation

=====

Single Equation Terms ->	Offset:	-23.362
	Slope:	5.312
	Quadratic:	-0.607
	Cubic:	0.019
	4th Order:	0.000
	5th Order:	0.000
	6th Order:	0.000
	7th Order:	0.000
	8th Order:	0.000
	9th Order:	0.000

EMPIRICAL Efficiency Calibration Equation

=====

Empirical Equation Terms ->	Scaling:	804.448
	Offset:	-9.303
	Slope:	0.257
	Quadratic:	-0.225
	Cubic:	-0.019
	4th Order:	0.000
	5th Order:	0.000

LINEAR Efficiency Calibration Equation

=====

Linear Equation Terms ->	Offset:	-0.000
	Slope:	-3.868
	Quadratic:	-16.843
	Cubic:	-5020.874
	4th Order:	0.000
	5th Order:	0.000
	6th Order:	0.000
	7th Order:	0.000
	8th Order:	0.000
	9th Order:	0.000

Datasource: C:\WAS\CALIB\CR1AR1\ES331001.C01

$\ln(\text{Eff}) = -2.336e+01 + 5.312e+00 \cdot \ln(E) - 6.073e-01 \cdot \ln(E)^2 + 1.905e-02 \cdot \ln(E)^3$

Detector SEGe 2 Drum Pos 3 w/c

 ***** EFFICIENCY CALIBRATION REPORT *****

=====
 Calibration Record No. : 1
 =====

Identification Number : EFFCAL1B
 Description/Title : eff cal 55 gal lt drum w/ coll
 :
 Location :
 Container : 55 gal container
 Weight, %Full : 2.80 (kg), 100.00 (%),
 Volume, Density : 208.00 (l), 0.01 (kg/l)

Comment:

Reference Date : 10-13-98 2:59:45 PM
 Acquisition Started : 10-13-98 3:07:04 PM
 Live Time : 417.4 seconds
 Real Time : 420.0 seconds

Detector Group : SeGes
 Detector : SEGE2
 Scan Platform Position : 2
 Geometry/Collimator Position : 1

Geometry Description : Distributed
 Spectrum File Name : C:\WAS\CALIB\CR1AR1\ES321001.C01
 Energy Calibration Performed on : 10-12-98 2:55:29 PM
 Efficiency Calibration Performed on: 10-13-98 6:42:34 PM
 by: System Manager
 Efficiency Calibration Approved on : 10-13-98 6:45:47 PM
 by: System Manager

Efficiency Triplets
 =====

Energy	Efficiency	Error
276.40	1.10E-04	2.02E-05
302.84	9.25E-05	9.01E-06
356.01	1.04E-04	8.42E-06
383.85	9.79E-05	1.06E-05
661.66	9.45E-05	8.38E-06
1173.24	8.42E-05	6.71E-06
1332.50	8.54E-05	6.66E-06

HNF-5148, Rev. 0

DUAL Efficiency Calibration Equation

=====

```
Single Equation Terms -> Offset:      -57.853
                          Slope:       22.576
                          Quadratic:   -3.466
                          Cubic:       0.176
                          4th Order:    0.000
                          5th Order:    0.000
                          6th Order:    0.000
                          7th Order:    0.000
                          8th Order:    0.000
                          9th Order:    0.000
```

EMPIRICAL Efficiency Calibration Equation

=====

```
Empirical Equation Terms -> Scaling:   804.448
                          Offset:      -9.314
                          Slope:       0.200
                          Quadratic:   0.061
                          Cubic:       -0.176
                          4th Order:    0.000
                          5th Order:    0.000
```

LINEAR Efficiency Calibration Equation

=====

```
Linear Equation Terms -> Offset:       0.000
                          Slope:       -4.151
                          Quadratic:   109.546
                          Cubic:      -19898.291
                          4th Order:    0.000
                          5th Order:    0.000
                          6th Order:    0.000
                          7th Order:    0.000
                          8th Order:    0.000
                          9th Order:    0.000
```

Datasource: C:\WAS\CALIB\CR1AR1\ES321001.C01

$$\ln(\text{Eff}) = -5.785e+01 + 2.258e+01 \cdot \ln(E) - 3.466e+00 \cdot \ln(E)^2 + 1.757e-01 \cdot \ln(E)^3$$

Detector SEGe 2 Drum Pos 2 w/c

 ***** EFFICIENCY CALIBRATION REPORT *****

=====
 Calibration Record No. : 1
 =====

Identification Number : EFFCAL1B
 Description/Title : eff cal 55 gal lt drum w/ coll
 :
 Location :
 Container : 55 gal container
 Weight, %Full : 2.80 (kg), 100.00 (%),
 Volume, Density : 208.00 (l), 0.01 (kg/l)

Comment:

Reference Date : 10-13-98 2:59:45 PM
 Acquisition Started : 10-13-98 2:59:40 PM
 Live Time : 417.3 seconds
 Real Time : 420.0 seconds

Detector Group : SeGes
 Detector : SEGE2
 Scan Platform Position : 1
 Geometry/Collimator Position : 1

Geometry Description : Distributed
 Spectrum File Name : C:\WAS\CALIB\CR1AR1\ES311001.C01
 Energy Calibration Performed on : 10-12-98 2:55:29 PM
 Efficiency Calibration Performed on: 10-13-98 6:42:13 PM
 by: System Manager
 Efficiency Calibration Approved on : 10-13-98 6:45:44 PM
 by: System Manager

Efficiency Triplets
 =====

Energy	Efficiency	Error
276.40	9.12E-05	1.31E-05
302.84	1.05E-04	1.13E-05
356.01	1.05E-04	8.56E-06
383.85	9.75E-05	1.03E-05
661.66	9.62E-05	8.21E-06
1173.24	8.49E-05	6.76E-06
1332.50	8.63E-05	6.76E-06

HNF-5148, Rev. 0

DUAL Efficiency Calibration Equation

=====

Single Equation Terms -> Offset: -12.197
Slope: 1.038
Quadratic: -0.090
Cubic: 0.000
4th Order: 0.000
5th Order: 0.000
6th Order: 0.000
7th Order: 0.000
8th Order: 0.000
9th Order: 0.000

EMPIRICAL Efficiency Calibration Equation

=====

Empirical Equation Terms -> Scaling: 804.448
Offset: -9.308
Slope: 0.236
Quadratic: 0.121
Cubic: -0.267
4th Order: 0.000
5th Order: 0.000

LINEAR Efficiency Calibration Equation

=====

Linear Equation Terms -> Offset: 0.000
Slope: -4.300
Quadratic: 206.906
Cubic: -37198.074
4th Order: 0.000
5th Order: 0.000
6th Order: 0.000
7th Order: 0.000
8th Order: 0.000
9th Order: 0.000

Datasource: C:\WAS\CALIB\CR1AR1\ES311001.C01
 $\ln(\text{Eff}) = -1.220\text{e}+01 + 1.038\text{e}+00 \cdot \ln(E) - 8.981\text{e}-02 \cdot \ln(E)^2$

Detector SEGe 2 Drum Pos 1 w/c

 ***** EFFICIENCY CALIBRATION REPORT *****

=====
 Calibration Record No. : 1
 =====

Identification Number : EFFCAL1B
 Description/Title : eff cal 55 gal lt drum w/ coll
 :
 Location :
 Container : 55 gal container
 Weight, %Full : 2.80 (kg), 100.00 (%),
 Volume, Density : 208.00 (l), 0.01 (kg/l)

Comment:

Reference Date : 10-13-98 2:59:45 PM
 Acquisition Started : 10-13-98 3:14:25 PM
 Live Time : 417.3 seconds
 Real Time : 420.0 seconds

Detector Group : SeGes
 Detector : SEGE3
 Scan Platform Position : 3
 Geometry/Collimator Position : 1

Geometry Description : Distributed
 Spectrum File Name : C:\WAS\CALIB\CR1AR1\ES231001.C01
 Energy Calibration Performed on : 10-12-98 2:52:27 PM
 Efficiency Calibration Performed on: 10-13-98 6:41:39 PM
 by: System Manager
 Efficiency Calibration Approved on : 10-13-98 6:45:41 PM
 by: System Manager

Efficiency Triplets

=====

Energy	Efficiency	Error
276.40	7.79E-05	1.56E-05
302.84	1.02E-04	1.07E-05
356.01	1.02E-04	8.32E-06
383.85	1.05E-04	1.28E-05
661.66	9.35E-05	8.02E-06
1173.24	8.36E-05	6.70E-06
1332.50	9.00E-05	6.95E-06

HNF-5148, Rev. 0

DUAL Efficiency Calibration Equation

=====

Single Equation Terms ->	Offset:	-11.059
	Slope:	0.658
	Quadratic:	-0.059
	Cubic:	0.000
	4th Order:	0.000
	5th Order:	0.000
	6th Order:	0.000
	7th Order:	0.000
	8th Order:	0.000
	9th Order:	0.000

EMPIRICAL Efficiency Calibration Equation

=====

Empirical Equation Terms ->	Scaling:	804.448
	Offset:	-9.361
	Slope:	0.323
	Quadratic:	0.450
	Cubic:	-0.689
	4th Order:	0.000
	5th Order:	0.000

LINEAR Efficiency Calibration Equation

=====

Linear Equation Terms ->	Offset:	0.000
	Slope:	-4.819
	Quadratic:	512.902
	Cubic:	-91040.133
	4th Order:	0.000
	5th Order:	0.000
	6th Order:	0.000
	7th Order:	0.000
	8th Order:	0.000
	9th Order:	0.000

Datasource: C:\WAS\CALIB\CR1AR1\ES231001.C01
 $\ln(\text{Eff}) = -1.106e+01 + 6.582e-01 \cdot \ln(E) - 5.866e-02 \cdot \ln(E)^2$

Detector SEGe 3 Drum Pos 3 w/c

 ***** EFFICIENCY CALIBRATION REPORT *****

=====
 Calibration Record No. : 1
 =====

Identification Number : EFFCAL1B
 Description/Title : eff cal 55 gal lt drum w/ coll
 :
 Location :
 Container : 55 gal container
 Weight, %Full : 2.80 (kg), 100.00 (%),
 Volume, Density : 208.00 (l), 0.01 (kg/l)

Comment:

Reference Date : 10-13-98 2:59:45 PM
 Acquisition Started : 10-13-98 3:07:03 PM
 Live Time : 417.3 seconds
 Real Time : 420.0 seconds

Detector Group : SeGes
 Detector : SEGE3
 Scan Platform Position : 2
 Geometry/Collimator Position : 1

Geometry Description : Distributed
 Spectrum File Name : C:\WAS\CALIB\CR1AR1\ES221001.C01
 Energy Calibration Performed on : 10-12-98 2:52:27 PM
 Efficiency Calibration Performed on: 10-13-98 6:41:03 PM
 by: System Manager
 Efficiency Calibration Approved on : 10-13-98 6:45:38 PM
 by: System Manager

Efficiency Triplets
 =====

Energy	Efficiency	Error
276.40	9.58E-05	1.72E-05
302.84	9.81E-05	9.23E-06
356.01	1.04E-04	8.46E-06
383.85	1.03E-04	1.19E-05
661.66	1.01E-04	8.61E-06
1173.24	8.76E-05	6.92E-06
1332.50	8.32E-05	6.53E-06

HNF-5148, Rev. 0

DUAL Efficiency Calibration Equation

=====

Single Equation Terms ->	Offset:	-41.434
	Slope:	13.957
	Quadratic:	-1.978
	Cubic:	0.091
	4th Order:	0.000
	5th Order:	0.000
	6th Order:	0.000
	7th Order:	0.000
	8th Order:	0.000
	9th Order:	0.000

EMPIRICAL Efficiency Calibration Equation

=====

Empirical Equation Terms ->	Scaling:	804.448
	Offset:	-9.241
	Slope:	0.246
	Quadratic:	-0.145
	Cubic:	-0.091
	4th Order:	0.000
	5th Order:	0.000

LINEAR Efficiency Calibration Equation

=====

Linear Equation Terms ->	Offset:	-0.000
	Slope:	-3.954
	Quadratic:	43.590
	Cubic:	-14871.601
	4th Order:	0.000
	5th Order:	0.000
	6th Order:	0.000
	7th Order:	0.000
	8th Order:	0.000
	9th Order:	0.000

Datasource: C:\WAS\CALIB\CR1AR1\ES221001.C01

$\ln(\text{Eff}) = -4.143\text{e}+01 + 1.396\text{e}+01 \cdot \ln(E) - 1.978\text{e}+00 \cdot \ln(E)^2 + 9.131\text{e}-02 \cdot \ln(E)^3$

Detector SEGe3 Drum Pos 2 w/c

 ***** EFFICIENCY CALIBRATION REPORT *****

=====
 Calibration Record No. : 1
 =====

Identification Number : EFFCAL1B
 Description/Title : eff cal 55 gal lt drum w/ coll
 :
 Location :
 Container : 55 gal container
 Weight, %Full : 2.80 (kg), 100.00 (%),
 Volume, Density : 208.00 (l), 0.01 (kg/l)

Comment:

Reference Date : 10-13-98 2:59:45 PM
 Acquisition Started : 10-13-98 2:59:40 PM
 Live Time : 417.4 seconds
 Real Time : 420.0 seconds

Detector Group : SeGes
 Detector : SEGE3
 Scan Platform Position : 1
 Geometry/Collimator Position : 1

Geometry Description : Distributed
 Spectrum File Name : C:\WAS\CALIB\CR1AR1\ES211001.C01
 Energy Calibration Performed on : 10-12-98 2:52:27 PM
 Efficiency Calibration Performed on: 10-13-98 6:40:44 PM
 by: System Manager
 Efficiency Calibration Approved on : 10-13-98 6:45:35 PM
 by: System Manager

Efficiency Triplets

=====

Energy	Efficiency	Error
276.40	8.45E-05	1.78E-05
302.84	1.03E-04	1.02E-05
356.01	1.03E-04	8.34E-06
383.85	1.03E-04	1.15E-05
661.66	9.86E-05	8.19E-06
1173.24	7.97E-05	6.47E-06
1332.50	7.71E-05	6.08E-06

HNF-5148, Rev. 0

DUAL Efficiency Calibration Equation

=====

Single Equation Terms ->	Offset:	-18.038
	Slope:	2.921
	Quadratic:	-0.241
	Cubic:	0.000
	4th Order:	0.000
	5th Order:	0.000
	6th Order:	0.000
	7th Order:	0.000
	8th Order:	0.000
	9th Order:	0.000

EMPIRICAL Efficiency Calibration Equation

=====

Empirical Equation Terms ->	Scaling:	804.448
	Offset:	-9.296
	Slope:	0.358
	Quadratic:	-0.090
	Cubic:	-0.204
	4th Order:	0.000
	5th Order:	0.000

LINEAR Efficiency Calibration Equation

=====

Linear Equation Terms ->	Offset:	-0.000
	Slope:	-4.086
	Quadratic:	133.051
	Cubic:	-30499.229
	4th Order:	0.000
	5th Order:	0.000
	6th Order:	0.000
	7th Order:	0.000
	8th Order:	0.000
	9th Order:	0.000

Datasource: C:\WAS\CALIB\CR1AR1\ES211001.C01
 $\ln(\text{Eff}) = -1.804\text{e}+01 + 2.921\text{e}+00 \cdot \ln(E) - 2.407\text{e}-01 \cdot \ln(E)^2$

Detector SEGe 3 Drum Pos 1 u/c

 ***** EFFICIENCY CALIBRATION REPORT *****

=====
 Calibration Record No. : 1
 =====

Identification Number : EFFCAL1B
 Description/Title : eff cal 55 gal lt drum w/ coll
 :
 Location :
 Container : 55 gal container
 Weight, %Full : 2.80 (kg), 100.00 (%),
 Volume, Density : 208.00 (l), 0.01 (kg/l)

Comment:

Reference Date : 10-13-98 2:59:45 PM
 Acquisition Started : 10-13-98 3:14:25 PM
 Live Time : 417.7 seconds
 Real Time : 420.0 seconds

Detector Group : SeGes
 Detector : SEGE4
 Scan Platform Position : 3
 Geometry/Collimator Position : 1

Geometry Description : Distributed
 Spectrum File Name : C:\WAS\CALIB\CR1AR1\ES131001.C01
 Energy Calibration Performed on : 10-12-98 2:49:39 PM
 Efficiency Calibration Performed on: 10-13-98 6:40:04 PM
 by: System Manager
 Efficiency Calibration Approved on : 10-13-98 6:45:32 PM
 by: System Manager

Efficiency Triplets
 =====

Energy	Efficiency	Error
276.40	8.86E-05	1.33E-05
302.84	8.54E-05	8.61E-06
356.01	9.14E-05	7.44E-06
383.85	9.61E-05	1.07E-05
661.66	8.51E-05	7.21E-06
1173.24	7.29E-05	5.96E-06
1332.50	7.13E-05	5.70E-06

HNF-5148, Rev. 0

DUAL Efficiency Calibration Equation

=====

Single Equation Terms ->	Offset:	-15.716
	Slope:	2.136
	Quadratic:	-0.178
	Cubic:	0.000
	4th Order:	0.000
	5th Order:	0.000
	6th Order:	0.000
	7th Order:	0.000
	8th Order:	0.000
	9th Order:	0.000

EMPIRICAL Efficiency Calibration Equation

=====

Empirical Equation Terms ->	Scaling:	804.448
	Offset:	-9.428
	Slope:	0.316
	Quadratic:	0.026
	Cubic:	-0.259
	4th Order:	0.000
	5th Order:	0.000

LINEAR Efficiency Calibration Equation

=====

Linear Equation Terms ->	Offset:	-0.000
	Slope:	-4.237
	Quadratic:	168.270
	Cubic:	-33718.695
	4th Order:	0.000
	5th Order:	0.000
	6th Order:	0.000
	7th Order:	0.000
	8th Order:	0.000
	9th Order:	0.000

Datasource: C:\WAS\CALIB\CR1AR1\ES131001.C01
 $\ln(\text{Eff}) = -1.572e+01 + 2.136e+00 \cdot \ln(E) - 1.780e-01 \cdot \ln(E)^2$

Detector SGL 4 Drum Pos 3 w/c

 ***** EFFICIENCY CALIBRATION REPORT *****

=====
 Calibration Record No. : 1
 =====

Identification Number : EFFCAL1B
 Description/Title : eff cal 55 gal lt drum w/ coll
 :
 Location :
 Container : 55 gal container
 Weight, %Full : 2.80 (kg), 100.00 (%),
 Volume, Density : 208.00 (l), 0.01 (kg/l)

Comment:

Reference Date : 10-13-98 2:59:45 PM
 Acquisition Started : 10-13-98 3:07:02 PM
 Live Time : 418.0 seconds
 Real Time : 420.0 seconds

Detector Group : SeGes
 Detector : SEGE4
 Scan Platform Position : 2
 Geometry/Collimator Position : 1

Geometry Description : Distributed
 Spectrum File Name : C:\WAS\CALIB\CR1AR1\ES121001.C01
 Energy Calibration Performed on : 10-12-98 2:49:39 PM
 Efficiency Calibration Performed on: 10-13-98 6:39:16 PM
 by: System Manager
 Efficiency Calibration Approved on : 10-13-98 6:45:27 PM
 by: System Manager

Efficiency Triplets
 =====

Energy	Efficiency	Error
276.40	4.47E-05	1.07E-05
302.84	5.98E-05	6.74E-06
356.01	6.10E-05	5.08E-06
383.85	5.63E-05	7.06E-06
661.66	5.42E-05	5.17E-06
1173.24	4.59E-05	4.12E-06
1332.50	4.71E-05	4.11E-06

DUAL Efficiency Calibration Equation
=====

Single Equation Terms ->	Offset:	-13.657
	Slope:	1.360
	Quadratic:	-0.118
	Cubic:	0.000
	4th Order:	0.000
	5th Order:	0.000
	6th Order:	0.000
	7th Order:	0.000
	8th Order:	0.000
	9th Order:	0.000

EMPIRICAL Efficiency Calibration Equation
=====

Empirical Equation Terms ->	Scaling:	804.448
	Offset:	-9.909
	Slope:	0.356
	Quadratic:	0.238
	Cubic:	-0.482
	4th Order:	0.000
	5th Order:	0.000

LINEAR Efficiency Calibration Equation
=====

Linear Equation Terms ->	Offset:	0.000
	Slope:	-4.794
	Quadratic:	374.398
	Cubic:	-67973.398
	4th Order:	0.000
	5th Order:	0.000
	6th Order:	0.000
	7th Order:	0.000
	8th Order:	0.000
	9th Order:	0.000

Datasource: C:\WAS\CALIB\CR1AR1\ES121001.C01
 $\ln(\text{Eff}) = -1.366e+01 + 1.360e+00 \cdot \ln(E) - 1.182e-01 \cdot \ln(E)^2$

Detector SEGe 4 Drum Pos 2 w/c.

 ***** EFFICIENCY CALIBRATION REPORT *****

=====
 Calibration Record No. : 1
 =====

Identification Number : EFFCAL1B
 Description/Title : eff cal 55 gal lt drum w/ coll
 :
 Location :
 Container : 55 gal container
 Weight, %Full : 2.80 (kg), 100.00 (%),
 Volume, Density : 208.00 (l), 0.00 (kg/l)

Comment:

Reference Date : 10-13-98 2:59:45 PM
 Acquisition Started : 10-13-98 3:07:02 PM
 Live Time : 418.0 seconds
 Real Time : 420.0 seconds

Detector Group : Multi-Density, Sum Segments
 Detector :
 Scan Platform Position : 0
 Geometry/Collimator Position : 1

Geometry Description : Distributed
 Spectrum File Name : C:\WAS\CALIB\CR1AR1\EA041005.C01
 Energy Calibration Performed on : 10-12-98 3:07:20 PM
 Efficiency Calibration Performed on: 10-13-98 7:56:20 PM
 by: System Manager
 Efficiency Calibration Approved on : 10-13-98 7:56:39 PM
 by: System Manager

Efficiency Triplets
 =====

Energy	Efficiency	Error
276.40	8.62E-05	8.01E-06
302.84	8.50E-05	6.91E-06
356.01	8.80E-05	6.87E-06
383.85	8.70E-05	7.13E-06
661.66	8.39E-05	6.18E-06
1173.24	7.07E-05	4.79E-06
1332.50	7.08E-05	4.76E-06

HNF-5148, Rev. 0

DUAL Efficiency Calibration Equation

=====

Single Equation Terms -> Offset: -38.508
 Slope: 13.061
 Quadratic: -1.920
 Cubic: 0.092
 4th Order: 0.000
 5th Order: 0.000
 6th Order: 0.000
 7th Order: 0.000
 8th Order: 0.000
 9th Order: 0.000

EMPIRICAL Efficiency Calibration Equation

=====

Empirical Equation Terms -> Scaling: 804.448
 Offset: -9.442
 Slope: 0.240
 Quadratic: -0.068
 Cubic: -0.092
 4th Order: 0.000
 5th Order: 0.000

LINEAR Efficiency Calibration Equation

=====

Linear Equation Terms -> Offset: -0.000
 Slope: -4.058
 Quadratic: 40.527
 Cubic: -10206.854
 4th Order: 0.000
 5th Order: 0.000
 6th Order: 0.000
 7th Order: 0.000
 8th Order: 0.000
 9th Order: 0.000

=====
 Calibration Record No. : 2
 =====

Identification Number : EFFCAL1B
 Description/Title : eff cal 55 gal 1t drum w/ coll
 :
 Location :
 Container : 55 gal container
 Weight, %Full : 2.80 (kg), 100.00 (%),
 Volume, Density : 208.00 (l), 0.01 (kg/l)

Comment:

Reference Date : 10-13-98 2:59:45 PM
 Acquisition Started : 10-13-98 3:07:02 PM
 Live Time : 418.0 seconds
 Real Time : 420.0 seconds

Detector Group : Multi-Density, Sum Segments
 Detector :
 Scan Platform Position : 0
 Geometry/Collimator Position : 1

Geometry Description : Distributed
 Spectrum File Name : C:\WAS\CALIB\CR1AR1\EA041005.C01
 Energy Calibration Performed on : 10-12-98 3:07:20 PM
 Efficiency Calibration Performed on: 10-13-98 7:56:20 PM
 by: System Manager
 Efficiency Calibration Approved on : 10-13-98 7:56:39 PM
 by: System Manager

Efficiency Triplets

=====

Energy	Efficiency	Error
276.40	8.62E-05	8.01E-06
302.84	8.50E-05	6.91E-06
356.01	8.80E-05	6.87E-06
383.85	8.70E-05	7.13E-06
661.66	8.39E-05	6.18E-06
1173.24	7.07E-05	4.79E-06
1332.50	7.08E-05	4.76E-06

DUAL Efficiency Calibration Equation

=====

Single Equation Terms ->	Offset:	-38.508
	Slope:	13.061
	Quadratic:	-1.920
	Cubic:	0.092
	4th Order:	0.000
	5th Order:	0.000
	6th Order:	0.000
	7th Order:	0.000
	8th Order:	0.000
	9th Order:	0.000

EMPIRICAL Efficiency Calibration Equation

=====

Empirical Equation Terms ->	Scaling:	804.448
	Offset:	-9.442
	Slope:	0.240
	Quadratic:	-0.068
	Cubic:	-0.092
	4th Order:	0.000
	5th Order:	0.000

LINEAR Efficiency Calibration Equation

=====

Linear Equation Terms ->	Offset:	-0.000
	Slope:	-4.058
	Quadratic:	40.527
	Cubic:	-10206.854
	4th Order:	0.000
	5th Order:	0.000
	6th Order:	0.000
	7th Order:	0.000
	8th Order:	0.000
	9th Order:	0.000

HNF-5148, Rev. 0

=====
Calibration Record No. : 3
=====

Identification Number : EFFCAL1B
Description/Title : eff cal 55 gal lt drum w/ coll
:
Location :
Container : 55 gal container
Weight, %Full : 2.80 (kg), 100.00 (%),
Volume, Density : 208.00 (l), 0.43 (kg/l)

Comment:

Reference Date : 10-13-98 2:59:45 PM
Acquisition Started : 10-13-98 3:07:02 PM
Live Time : 418.0 seconds
Real Time : 420.0 seconds

Detector Group : Multi-Density, Sum Segments
Detector :
Scan Platform Position : 0
Geometry/Collimator Position : 1

Geometry Description : Distributed
Spectrum File Name : C:\WAS\CALIB\CR1AR1\EA041005.C01
Energy Calibration Performed on : 10-12-98 3:07:20 PM
Efficiency Calibration Performed on: 10-13-98 7:56:20 PM
by: System Manager
Efficiency Calibration Approved on : 10-13-98 7:56:39 PM
by: System Manager

Efficiency Triplets

=====

Energy	Efficiency	Error
276.40	3.18E-05	3.73E-06
302.84	3.55E-05	3.11E-06
356.01	3.89E-05	3.06E-06
383.85	3.97E-05	3.78E-06
661.66	4.14E-05	3.12E-06
1173.24	4.26E-05	2.92E-06
1332.50	4.24E-05	2.89E-06

DUAL Efficiency Calibration Equation

=====

Single Equation Terms -> Offset: -18.198
 Slope: 2.406
 Quadratic: -0.178
 Cubic: 0.000
 4th Order: 0.000
 5th Order: 0.000
 6th Order: 0.000
 7th Order: 0.000
 8th Order: 0.000
 9th Order: 0.000

EMPIRICAL Efficiency Calibration Equation

=====

Empirical Equation Terms -> Scaling: 804.448
 Offset: -10.092
 Slope: 0.061
 Quadratic: 0.093
 Cubic: -0.337
 4th Order: 0.000
 5th Order: 0.000

LINEAR Efficiency Calibration Equation

=====

Linear Equation Terms -> Offset: 0.000
 Slope: -4.660
 Quadratic: 196.626
 Cubic: -44200.457
 4th Order: 0.000
 5th Order: 0.000
 6th Order: 0.000
 7th Order: 0.000
 8th Order: 0.000
 9th Order: 0.000

HNF-5148, Rev.0

=====
Calibration Record No. : 4
=====

Identification Number : EFFCAL1B
Description/Title : eff cal 55 gal lt drum w/ coll
:
Location :
Container : 55 gal container
Weight, %Full : 2.80 (kg), 100.00 (%),
Volume, Density : 208.00 (l), 0.66 (kg/l)

Comment:

Reference Date : 10-13-98 2:59:45 PM
Acquisition Started : 10-13-98 3:07:02 PM
Live Time : 418.0 seconds
Real Time : 420.0 seconds

Detector Group : Multi-Density, Sum Segments
Detector :
Scan Platform Position : 0
Geometry/Collimator Position : 1

Geometry Description : Distributed
Spectrum File Name : C:\WAS\CALIB\CR1AR1\EA041005.C01
Energy Calibration Performed on : 10-12-98 3:07:20 PM
Efficiency Calibration Performed on: 10-13-98 7:56:20 PM
by: System Manager
Efficiency Calibration Approved on : 10-13-98 7:56:39 PM
by: System Manager

Efficiency Triplets

=====

Energy	Efficiency	Error
276.40	3.18E-05	4.15E-06
302.84	2.83E-05	2.69E-06
356.01	2.91E-05	2.30E-06
383.85	2.84E-05	2.55E-06
661.66	3.25E-05	2.46E-06
1173.24	3.53E-05	2.45E-06
1332.50	3.21E-05	2.22E-06

DUAL Efficiency Calibration Equation

=====

Single Equation Terms ->	Offset:	-12.902
	Slope:	0.684
	Quadratic:	-0.045
	Cubic:	0.000
	4th Order:	0.000
	5th Order:	0.000
	6th Order:	0.000
	7th Order:	0.000
	8th Order:	0.000
	9th Order:	0.000

EMPIRICAL Efficiency Calibration Equation

=====

Empirical Equation Terms ->	Scaling:	804.448
	Offset:	-10.260
	Slope:	-0.233
	Quadratic:	-0.477
	Cubic:	0.548
	4th Order:	0.000
	5th Order:	0.000

LINEAR Efficiency Calibration Equation

=====

Linear Equation Terms ->	Offset:	-0.000
	Slope:	-3.788
	Quadratic:	-425.449
	Cubic:	69234.383
	4th Order:	0.000
	5th Order:	0.000
	6th Order:	0.000
	7th Order:	0.000
	8th Order:	0.000
	9th Order:	0.000

HNF-5148, Rev. 0

=====
 Calibration Record No.* : 5
 =====

Identification Number : EFFCAL1B
 Description/Title : eff cal 55 gal lt drum w/ coll
 :
 Location :
 Container : 55 gal container
 Weight, %Full : 2.80 (kg), 100.00 (%),
 Volume, Density : 208.00 (l), 1.56 (kg/l)

Comment:

Reference Date : 10-13-98 2:59:45 PM
 Acquisition Started : 10-13-98 3:07:02 PM
 Live Time : 418.0 seconds
 Real Time : 420.0 seconds

Detector Group : Multi-Density, Sum Segments
 Detector :
 Scan Platform Position : 0
 Geometry/Collimator Position : 1

Geometry Description : Distributed
 Spectrum File Name : C:\WAS\CALIB\CR1AR1\EA041005.C01
 Energy Calibration Performed on : 10-12-98 3:07:20 PM
 Efficiency Calibration Performed on: 10-13-98 7:56:20 PM
 by: System Manager
 Efficiency Calibration Approved on : 10-13-98 7:56:39 PM
 by: System Manager

Efficiency Triplets

Energy	Efficiency	Error
276.40	1.73E-05	3.18E-06
302.84	1.48E-05	1.39E-06
356.01	1.52E-05	1.22E-06
383.85	1.57E-05	1.85E-06
661.66	1.72E-05	1.42E-06
1173.24	1.89E-05	1.36E-06
1332.50	1.97E-05	1.39E-06

DUAL Efficiency Calibration Equation

=====

Single Equation Terms ->	Offset:	-9.729
	Slope:	-0.566
	Quadratic:	0.057
	Cubic:	0.000
	4th Order:	0.000
	5th Order:	0.000
	6th Order:	0.000
	7th Order:	0.000
	8th Order:	0.000
	9th Order:	0.000

EMPIRICAL Efficiency Calibration Equation

=====

Empirical Equation Terms ->	Scaling:	804.448
	Offset:	-10.934
	Slope:	-0.245
	Quadratic:	-0.060
	Cubic:	0.157
	4th Order:	0.000
	5th Order:	0.000

LINEAR Efficiency Calibration Equation

=====

Linear Equation Terms ->	Offset:	-0.000
	Slope:	-4.535
	Quadratic:	-182.476
	Cubic:	30937.787
	4th Order:	0.000
	5th Order:	0.000
	6th Order:	0.000
	7th Order:	0.000
	8th Order:	0.000
	9th Order:	0.000

with collimator.

DISTRIBUTION SHEET

To Distribution	From WRAP Engineering	Page 1 of 1
		Date 09/22/99
Project Title/Work Order CALIBRATION REPORT FOR THE WRAP FACILITY GEA SYSTEM, HNF-5148		EDT No. N/A
		ECN No. EDT-623537

Name	MSIN	Text With All Attach.	Text Only	Attach./ Appendix Only	EDT/ECN Only
------	------	-----------------------------	-----------	------------------------------	-----------------

AI Davis	T4-52	X			
WG Jasen	T4-05	X			
JK Kersten	T4-52	X			
JA Maupin L.	T4-06	X			
MA Purcell	T6-50	X			
WR Thackaberry	T4-52				X
CE Taylor	T4-52				X
JR Weidert	T4-52				X
CE Wills	T4-52	X			
DOE/RL Reading Room	H2-53	X			
Engineering Files	B1-07	X			