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Technical Equivalency Documentation for a Newly Acquired Alpha Spectroscopy System

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Introduction

The response of a newly acquired Canberra™ Alpha Analyst (Chamber #'s 137 – 172) used by the Hazards Control, Radiation Safety Section WBC/Spectroscopy Team has been studied with respect to an existing Canberra system. The existing Canberra system consists of thirty-six Model 7401 alpha spectrometry chambers (Chamber #'s 1-36) and has previously been DOELAP qualified for the routine Alpha Spectroscopy program used in LLNL's *in vitro* bioassay program. The newly acquired Alpha Analyst system operates on a network with software that controls and performs analysis of a one-year-old twenty-four chamber Alpha Analyst system (Chamber #'s 101 – 124) that has also been previously evaluated and recently DOELAP accredited. The Alpha Analyst system is an automated system that is controlled by the same software and computer system as that used for the existing Canberra alpha analysis systems. This document compares results from the existing Alpha System with the newer Alpha Analyst system.

History

The newly acquired Alpha Analyst system was acquired from the U.S. Department of Energy Mound Closure Project. Past usage of this system was largely unknown, however the Alpha Analyst technology is newer and has significant improvements over existing LLNL Alpha spectroscopy system consisting of thirty-six Model 7401 alpha spectrometry chambers. Upon receipt at LLNL the newly acquired system was completely cleaned including the interior of the counting chambers and vacuum piping. Dust and dirt was removed from the top of and internal portions of the modular electrical components. All detectors from the system were replaced with new (unused) detectors. Polyvinyl tubing and rubber seal rings were also replaced to assure proper vacuum draw and minimal contamination from previous uses of the system. New vacuum pumps and oil filters were also installed onto the vacuum lines. The system was connected to a VMS network containing the existing 36-chamber Alpha system and an approximately one-year old Alpha Analyst system with 24 chambers.

Methods

Standard quality control measures were evaluated on the newly acquired Alpha Analyst system and compared with the existing Alpha systems. Comparison of the Quality control measures for the following functions was performed: Pulser counts; Background counts; and Calibration/efficiency as measured with NIST traceable standards.

Compared parameters for the Pulser measurements were the full width half-maximum (FWHM), Energy, Centroid, and count rate. The average values of these parameters were compared to the Quality control limits established in Section 8.8 for the WBC/Spectroscopy procedures manual. Average values for these parameters on the older Alpha Spectroscopy system were also provided for comparison.

Compared parameters for the Background measurements were the average counts obtained for a 2.5 day background count in the Pu-239 and Am-241 regions. Background rates for both the older Alpha and newer Alpha Analyst systems are included in this report.

Comparison of Calibration parameters (Primes) was performed by evaluating the deviation of the average activity for the calibration source to the known activities. The average efficiencies were also compared.

Comparison counts of routine samples counts containing known quantities of internal tracer were performed on the existing Alpha system and on the newly acquired Alpha Analyst system (chamber #'s 137 – 172). Each individual AA detector has at least 5 comparative sample counts associated with different detectors from the ALPHA system. Parameters were compared with tracer data (Pu-242) and positive count data for Pu-239, and Pu-238. Comparison was performed by an analysis of variance for the entire system. These tests were followed by subsidiary Analysis of Variance (ANOVA) tests of individual detectors within the AA system when possible.

Over 315 sample count comparisons were made.

Conclusions

The Pulser FWHM, Centroid Energy, Centroid Channel, and Pulser rates for the existing Alpha systems and the newly acquired Alpha Analyst system provide consistent results that are well within established limits for these parameters. Overall, the measured pulse rates for both systems are measured to within a few percent (Tables 1, 2, &3). This demonstrated stability in the pulser signal measurements indicates that the system is stable from count period to count period.

The background for the newly acquired Alpha Analyst system is equal or lower than the background for the existing Alpha system (Tables 4 & 5). The background for the newly acquired Alpha Analyst is, for most chambers, equivalent to the background obtained from the 1 year-old Alpha Analyst system.

The average computed activity when measuring the Prime calibration sources is typically a few percent of the known standard activity (Table 6). The average efficiency for the newly acquired Alpha Analyst system is slightly lower than the average efficiency observed for the existing Alpha system (Table 5), however it is comparable to the 1-year-old Alpha Analyst system. This difference in efficiency could be due to the recoil suppression methodology employed by the Alpha Analyst system or due to slight differences in shelf distance from the source to the detector employed by each system. Regardless, the average efficiency of both systems is adequate to assure detection level (Lc) criteria established by the Internal Dosimetry Team.

Analyses of positive sample results are evaluated for measurements performed on the newly acquired Alpha Analyst System. There was a non-significant difference between the Alpha Analyst measurements for Pu-239 (Figure 1) and Pu-238 (Figure 2) with measurements of the same samples on the existing Alpha system. There were sufficient numbers of comparative sample measurements that contained Pu-242 tracer to evaluate multiple detectors of the Alpha Analyst system with measurements of the same sample sets on detectors of the existing Alpha system. There was a non-significant difference between the Alpha Analyst measurements of Pu-242 and measurements of the same samples performed on the existing Alpha system (ANOVA result tables).

Results

Table 1. Pulser Measurement comparison – Newly Acquired Alpha Analyst System

ID	Avg. FWHM (keV)	1s	Avg. Energy (keV)	1s	Centroid Channel	1s	Rate (cps)	1s
137	13	± 0.2	4993.8	± 9.3	521.1	± 1.3	41.6	± 0.1
138	13.3	± 0.3	5002.9	± 8	529.7	± 0.5	41.5	± 0.1
139	11.2	± 0.3	5014.8	± 8.7	523.5	± 0.9	41.6	± 0.1
140	11.5	± 0.2	5018.5	± 8	529.8	± 0.4	41.6	± 0.1
141	11.5	± 0.2	5022.1	± 10.2	531.9	± 0.3	41.6	± 0.1
142	11.6	± 0.2	5011.2	± 6.7	530.4	± 0.2	41.6	± 0.1
143	11.3	± 0.2	5000.3	± 13.9	527.4	± 0.2	41.6	± 0.1
144	10.9	± 0.2	5004.1	± 9.8	530.9	± 0.2	41.6	± 0.1
145	11	± 0.2	4946	± 3.5	499	± 0.2	41.6	± 0.1
146	11.1	± 0.2	4998.1	± 5.7	519.3	± 0.2	41.6	± 0.1
147	11.14	± 0.2	4981	± 8.1	512.1	± 0.9	41.6	± 0.1
148	11.23	± 0.2	4980.4	± 3.1	512.8	± 0.2	41.6	± 0.1
149	11	± 0.2	4994.3	± 3.1	517.4	± 0.1	41.5	± 0.1
150	11.01	± 0.2	5003.7	± 4.3	520.4	± 0.1	41.5	± 0.1
151	10.8	± 0.3	4986	± 7.8	520.5	± 0.3	41.5	± 0.1
152	10.8	± 0.2	4993.2	± 7.7	519.7	± 0.2	41.5	± 0.1
153	10.8	± 0.2	4991.1	± 10.9	518.6	± 0.1	41.5	± 0.3
154	10.8	± 0.2	4992.3	± 9.4	521.6	± 0.1	41.5	± 0.1
155	11.3	± 0.5	5031.5	± 0.9	526.0	± 0.3	41.5	± 0.1
156	11.7	± 0.2	5023.2	± 8.4	524.8	± 0.2	41.5	± 0.1
157	11.9	± 0.2	5003.7	± 11	521.8	± 0.1	41.5	± 0.2
158	11.16	± 0.1	5008.4	± 10.4	524.6	± 0.2	41.5	± 0.1
159	10.95	± 0.2	4992.4	± 8.3	524.1	± 0.1	41.5	± 0.1
160	11.16	± 0.2	4995.5	± 6.1	522.5	± 0.2	41.5	± 0.1
161	11.52	± 0.2	5006.5	± 4.2	520.8	± 0.2	41.5	± 0.1
162	11.58	± 0.2	5018.5	± 4.7	523.4	± 0.2	41.5	± 0.1
163	11.37	± 0.2	5014.3	± 8.9	520.8	± 0.1	41.5	± 0.1
164	11.35	± 0.2	5026.4	± 8.2	529.1	± 0.1	41.6	± 0.1
165	11.53	± 0.2	4996.5	± 3.7	527.9	± 0.3	41.6	± 0.1
166	11.54	± 0.2	4996.3	± 8.9	529.4	± 0.2	41.6	± 0.1
167	12.1	± 0.3	5018.9	± 7.8	522.4	± 0.1	41.6	± 0.1
168	11.46	± 0.2	5017.3	± 3.8	524.9	± 0.2	41.6	± 0.1
169	11.52	± 0.2	5002.8	± 5.1	522.8	± 0.3	41.6	± 0.1
170	11.33	± 0.2	5007.3	± 1.4	521.1	± 0.2	41.5	± 0.1
171	11.53	± 0.2	5007.7	± 3	519.8	± 0.2	41.5	± 0.1
172	11.61	± 0.2	5004.1	± 3.7	520.9	± 0.2	41.5	± 0.1
Established Limits:	8 - 20 keV		4900 - 5100 keV		480 - 540 keV		39 - 43 cps	

Table 2. Pulser Measurement comparison – Older Alpha System¹

ID	Avg. FWHM (keV)	1s	Avg. Energy (keV)	1s	Centroid Channel	1s	Rate (cps)	1s
1	10.7	± 0.5	4990.1	± 4.4	504.1	± 1.1	509	± 2.6
2	12.2	± 0.3	5031.2	± 3.4	519.2	± 1.3	498.5	± 0.3
3	14	± 3.2	4995.5	± 5.9	502.8	± 1.5	511.7	± 0.3
4	12.2	± 0.4	4999.3	± 3.2	508.7	± 1.1	514.7	± 0.4
5	11.4	± 0.2	5042.8	± 4.4	521.9	± 1.9	495.7	± 0.3
6	11.5	± 0.3	4996.6	± 3.8	502.8	± 1	508.3	± 0.3
7	11.6	± 0.3	5006.8	± 4	506	± 1.2	506.6	± 1.2
8	10.8	± 1.8	5058.7	± 4.5	528.3	± 6.4	511	± 1.5
9	10.9	± 0.3	4967.1	± 4.3	500.8	± 3.6	511.1	± 1.4
10	11	± 0.4	5043.9	± 7.7	517.1	± 2.2	493.9	± 1.6
11	12.8	± 1.2	5049.5	± 5.1	521.5	± 1.2	510.3	± 3
12	11.5	± 1	4982.9	± 10.6	501.9	± 1.8	512	± 0.4
13	10.9	± 2.9	5014.3	± 27.4	515.3	± 12.5	500	± 0.3
14	13.2	± 0.1	4987.4	± 5.1	506.9	± 1	509.9	± 0.3
15	14.6	± 2.4	5049.4	± 8.1	521.4	± 5	499.7	± 2.3
16	13.5	± 3	5054.2	± 8.8	517.1	± 10.5	503.9	± 17
17	12.2	± 0.5	4967	± 5	494.7	± 1.6	511.6	± 0.7
18	16.9	± 2.4	4992.4	± 9.6	508.1	± 4.3	509.1	± 1.7
19	11.3	± 3.3	5050.3	± 9.2	520.1	± 3.2	510	± 3.7
20	11.5	± 0.2	4954.7	± 2.7	510.3	± 0.6	510.7	± 0.3
21	11.6	± 0.2	5044.5	± 2	507.6	± 0.7	498.5	± 0.3
22	12.2	± 1	5048.7	± 8.4	523.7	± 0.9	500.8	± 0.6
23	14.1	± 0.8	4989.8	± 4	503.2	± 2	502.5	± 2.4
24	12.9	± 1.5	5002.3	± 4.7	510	± 0.8	506.1	± 0.3
25	13.9	± 0.2	4962.7	± 44.9	503.9	± 1.8	501.7	± 0.3
26	10.9	± 0.2	5058.9	± 4.8	522.7	± 1.9	513.1	± 0.6
27	14.2	± 0.4	5051.7	± 5.1	521.2	± 1.7	508.2	± 0.8
28	14.4	± 2.4	4983.6	± 5.6	500.5	± 2.3	151.9	± 0.5
29	11.9	± 2.4	4969.2	± 5.2	495.8	± 1	510.1	± 0.4
30	10.2	± 0.3	5057.8	± 5.7	522.7	± 1.5	505.2	± 0.5
31	11	± 0.3	5064.1	± 9.7	520.7	± 3.1	518.4	± 0.4
32	12.9	± 2.1	4974.4	± 6.9	496.3	± 1.2	510.3	± 1.2
33	13.6	± 1.3	4994	± 3.9	506.6	± 1.7	503.4	± 1.2
34	11.7	± 0.2	5029.7	± 50	518.6	± 16.4	502.4	± 0.3
35	12.1	± 1.3	5051.2	± 6.7	520.4	± 4.2	515.3	± 2
36	12.4	± 0.2	4966.4	± 5	498.6	± 1.2	509.1	± 0.3
Established Limits:	8 - 20 keV		4900 - 5100 keV		480 - 540 keV		475 - 525 cps	

¹ The pulser rate for this system is different due to the different clock speeds of the pulse generator contained in each system.

Table 3. Pulser Measurement comparison – 1 Year Old Alpha Analyst System

ID	Avg. FWHM (keV)	1s	Avg. Energy (keV)	1s	Centroid Channel	1s	Rate (cps)	1s
101	11	± 0.2	5048.5	± 0.8	514.7	± 0.2	41.5	± 0.2
102	11.1	± 0.2	4044.1	± 0.9	513.8	± 0.1	41.5	± 0.2
103	11	± 0.1	4997.3	± 0.6	513	± 0.2	41.5	± 0.2
104	11.4	± 0.2	4993.7	± 1.2	513.8	± 0.1	41.5	± 0.1
105	12.1	± 0.3	4996.6	± 1	509.9	± 0.1	41.5	± 0.1
106	11.6	± 0.2	4990.7	± 0.9	511.7	± 0.1	41.5	± 0.1
107	12.4	± 0.8	4997.8	± 1.1	508.9	± 0.1	41.5	± 0.1
108	11	± 0.2	4986.2	± 1	513.1	± 0.1	41.5	± 0.1
109	11.2	± 0.2	4981.9	± 0.7	513.8	± 0.2	41.5	± 0.1
110	11.2	± 0.2	4979.6	± 1.4	514	± 0.2	41.5	± 0.1
111	11.4	± 0.1	4981.3	± 0.9	511.2	± 0.2	41.5	± 0.1
112	11.2	± 0.2	1973.9	± 0.8	512.2	± 0.1	41.5	± 0.1
113	16.9	± 0.3	4991	± 0.5	502.8	± 0.2	41.5	± 0.2
114	11.3	± 0.2	4993	± 1.1	505.6	± 0.2	41.5	± 0.1
115	11.1	± 0.2	4993.4	± 0.6	503.3	± 0.2	41.5	± 0.1
116	12.2	± 0.2	5000.8	± 1.4	505.2	± 0.2	41.5	± 0.1
117	14.6	± 0.3	5003.6	± 0.7	507.5	± 0.2	41.5	± 0.2
118	13.8	± 1.6	4991.8	± 3.8	506.5	± 0.3	41.5	± 0.1
119	13.3	± 0.2	4996.2	± 1.7	504.9	± 0.3	41.5	± 0.1
120	12.2	± 0.2	500	± 1.3	506.1	± 0.1	41.5	± 0.1
121	New Det.							
122	11.8	± 0.2	4982.8	± 1.8	508.1	± 0.2	41.5	± 0.1
123	16.1	± 0.7	4986.1	± 1.7	503.5	± 0.3	41.5	± 0.1
124	13.2	± 0.2	4980.5	± 1.5	503	± 0.1	41.5	± 0.1
Established Limits:	8 - 20 keV		4900 - 5100 keV		480 - 540 keV		39 - 43 cps	

Table 4. Average background for Alpha Analyst Systems (counts per 2.5 days).

Alpha Analyst (~1 yr old) System						Alpha Analyst (newly acquired) System							
Detector	Pu-239		1s	Am-241		1s	Detector	Pu-239		Am-241		1s	
101	1.2	±	1.2	0.7	±	0.9	137	0.8	±	1	0.6	±	0.9
102	1.1	±	1.2	0.8	±	1.1	138	0.8	±	1.1	1.5	±	1.6
103	0.9	±	1.1	0.8	±	0.9	139	1.0	±	0.9	0.6	±	0.7
104	1.0	±	1.1	0.8	±	1.0	140	0.7	±	0.8	0.6	±	0.7
105	1.0	±	1.0	0.3	±	0.5	141	1.2	±	1.2	1	±	1
106	1.1	±	1.0	0.8	±	0.8	142	0.8	±	0.7	0.9	±	1.1
107	0.8	±	0.9	0.4	±	0.6	143	0.6	±	0.8	3.4	±	3.2
108	1.0	±	1.0	0.8	±	0.9	144	0.5	±	0.8	0.5	±	0.7
109	1.2	±	1.2	0.8	±	0.8	145	1.1	±	1	1	±	1.2
110	0.8	±	1.0	0.9	±	0.9	146	1.1	±	0.8	1.2	±	1.1
111	1.2	±	1.2	0.7	±	0.9	147	0.9	±	1	1.1	±	1.1
112	1.2	±	1.0	0.8	±	0.8	148	1.1	±	1.2	0.8	±	0.8
113	1.0	±	1.2	0.8	±	1.0	149	2.1	±	1.6	3.7	±	4.2
114	1.2	±	1.0	0.7	±	0.9	150	1.4	±	0.7	0.8	±	0.6
115	1.0	±	1.2	0.9	±	1.0	151	1.4	±	1.5	1.3	±	1.4
116	0.9	±	1.0	0.4	±	0.5	152	3.6	±	3.3	3.3	±	3.9
117	1.5	±	1.1	0.6	±	0.7	153	2.7	±	2.9	2.5	±	2.7
118	1.4	±	1.3	0.8	±	1.1	154	0.9	±	0.9	1.5	±	1.6
119	1.1	±	1.0	0.5	±	0.6	155	1.1	±	1.5	0.6	±	0.8
120	1.1	±	1.2	0.5	±	0.8	156	1.0	±	0.9	0.7	±	0.9
121	1.1	±	1.2	1.2	±	1.1	157	1.8	±	1.2	0.8	±	0.8
122	1.3	±	0.9	1.0	±	0.9	158	0.6	±	0.8	1.2	±	1.2
123	1.6	±	1.5	1.1	±	1.0	159	0.9	±	0.8	0.5	±	0.7
124	1.3	±	1.1	0.6	±	0.7	160	0.8	±	0.9	0.3	±	0.6
							161	1.3	±	1.2	0.9	±	1.1
							162	0.9	±	0.9	0.7	±	1
							163	1.5	±	1.2	1.5	±	1.5
							164	1.3	±	1.1	0.6	±	0.9
							165	0.7	±	1	1	±	1
							166	0.8	±	0.9	0.7	±	0.9
							167	0.9	±	1.1	0.4	±	0.8
							168	0.6	±	0.8	0.9	±	1.1
							169	0.6	±	0.8	0.7	±	0.8
							170	0.6	±	0.8	0.6	±	0.6
							171	1.2	±	1	1	±	0.9
							172	1.1	±	1.3	0.7	±	0.9

Table 5. Average background for Older Alpha System (counts per 2.5 days)².

Detector	Pu-239			1s	Am-241			1s
1	4.7	±	2.5		3.5	±	2.5	
2	4.5	±	3.2		4.1	±	3.0	
3	4.3	±	2.5		3.2	±	2.4	
4	4.1	±	2.7		3.6	±	4.2	
5	3.5	±	2.1		3.2	±	2.3	
6	5.1	±	2.6		4.2	±	3.0	
7	3.2	±	2.8		3.6	±	2.5	
8	4.0	±	2.6		4.7	±	3.0	
9	3.7	±	2.2		3.0	±	2.2	
10	3.5	±	2.5		3.4	±	2.7	
11	3.5	±	2.5		3.4	±	2.7	
12	3.8	±	2.9		3.6	±	2.8	
13	3.4	±	2.1		3.7	±	2.3	
14	3.3	±	2.3		2.8	±	2.1	
15	4.4	±	2.7		3.7	±	2.8	
16	3.6	±	2.6		3.0	±	2.2	
17	3.8	±	2.9		3.3	±	2.6	
18	5.0	±	3.1		4.1	±	2.7	
19	4.6	±	3.4		4.5	±	3.2	
20	4.0	±	2.9		3.5	±	2.5	
21	2.8	±	2.2		2.7	±	2.3	
22	4.1	±	2.4		3.9	±	2.2	
23	4.0	±	2.8		4.1	±	2.8	
24	3.9	±	2.5		5.4	±	2.8	
25	3.2	±	2.2		2.4	±	2.0	
26	4.5	±	2.9		4.2	±	2.9	
27	4.3	±	2.9		4.0	±	2.9	
28	4.3	±	2.9		4.5	±	2.8	
29	4.2	±	2.6		3.8	±	2.5	
30	4.5	±	2.7		4.2	±	2.5	
31	5.0	±	3.3		4.9	±	2.9	
32	4.9	±	3.2		4.1	±	2.8	
33	2.8	±	2.2		2.7	±	2.2	
34	4.7	±	3.0		4.6	±	3.0	
35	2.7	±	2.0		2.8	±	2.2	
36	3.2	±	2.4		3.3	±	2.5	

² Averages calculated using 8 years of data

Table 6. Percent difference from the average computed activity to the known activity for radionuclides contained in the Prime calibration sources.

Prime Calibration Source ID	AA Detector No.				
		U-238	U-234	Pu-239	Am-241
311	137	2.3%	-2.2%	0.2%	-1.0%
312	138	0.2%	-0.2%	1.0%	-1.6%
313	139	2.7%	1.3%	-2.7%	-1.1%
314	140	-1.1%	0.1%	-0.8%	1.0%
315	141	-0.1%	3.2%	-1.2%	-1.8%
316	142	-0.3%	0.0%	-0.8%	0.4%
317	143	-0.1%	0.6%	-1.0%	0.1%
318	144	3.1%	-0.9%	-3.5%	1.1%
3985	145	-1.9%	0.6%	1.5%	-1.4%
3986	146	-1.2%	-1.6%	1.4%	-0.4%
3987	147	-1.8%	0.4%	0.2%	0.4%
3988	148	-1.4%	-1.1%	1.1%	-0.7%
311	149	1.5%	-0.6%	-0.7%	-0.7%
312	150	0.0%	-0.7%	1.1%	-1.2%
313	151	1.0%	1.3%	-1.2%	-1.2%
314	152	0.6%	1.4%	-2.4%	0.3%
315	153	3.9%	-1.1%	0.1%	-3.1%
316	154	2.4%	1.3%	-3.0%	-0.2%
317	155	0.9%	-0.4%	2.1%	-3.1%
318	156	0.3%	-0.1%	-1.7%	1.3%
3985	157	2.6%	1.7%	-1.2%	-2.0%
3986	158	1.7%	-3.6%	0.5%	-0.5%
3987	159	-0.3%	-4.3%	1.3%	0.8%
3988	160	-2.2%	0.9%	-0.3%	0.3%
311	161	1.8%	-1.2%	0.7%	-2.1%
312	162	0.1%	0.9%	-0.7%	-0.4%
313	163	0.5%	1.4%	-1.5%	-0.6%
314	164	-0.6%	-1.4%	-1.0%	1.4%
315	165	-8.4%	0.1%	-1.3%	0.3%
316	166	2.0%	1.0%	-1.3%	-1.2%
317	167	-0.6%	0.3%	1.1%	-1.4%
318	168	-1.3%	1.1%	-0.5%	0.4%
3985	169	0.7%	2.3%	0.0%	-2.2%
3986	170	2.7%	-3.0%	0.7%	-1.8%
3987	171	-0.5%	-3.3%	1.7%	0.1%
3988	172	1.2%	-0.2%	0.8%	-1.8%

Table 7. Comparison of average Prime source efficiencies for the Alpha and the Alpha Analyst systems.

Calibration Source ID	Alpha Detector No.	Efficiency	AA1 Detector No.	Efficiency	AA2 Detector No.	Efficiency
311	1	0.35	101	0.31	137	0.29
312	2	0.37	102	0.30	138	0.29
313	3	0.35	103	0.30	139	0.29
314	4	0.34	104	0.31	140	0.29
315	5	0.34	105	0.31	141	0.29
316	6	0.35	106	0.31	142	0.29
317	7	0.35	107	0.31	143	0.29
318	8	0.36	108	0.30	144	0.29
3985	9	0.33	109	0.29	145	0.29
3986	10	0.30	110	0.30	146	0.27
3987	11	0.34	111	0.30	147	0.29
3988	12	0.35	112	0.29	148	0.29
311	13	0.36	113	0.30	149	0.31
312	14	0.34	114	0.30	150	0.29
313	15	0.36	115	0.30	151	0.30
314	16	0.32	116	0.30	152	0.30
315	17	0.35	117	0.31	153	0.30
316	18	0.35	118	0.30	154	0.30
317	19	0.37	119	0.30	155	0.29
318	20	0.33	120	0.29	156	0.29
3985	21	0.34	121	0.29	157	0.29
3986	22	0.35	122	0.29	158	0.29
3987	23	0.34	123	0.30	159	0.30
3988	24	0.33	124	0.30	160	0.30
311	25	0.35			161	0.30
312	26	0.36			162	0.30
313	27	0.37			163	0.30
314	28	0.33			164	0.30
315	29	0.34			165	0.29
316	30	0.36			166	0.30
317	31	0.34			167	0.29
318	32	0.34			168	0.31
3985	33	0.35			169	0.29
3986	34	0.35			170	0.29
3987	35	0.35			171	0.30
3988	36	0.37			172	0.30

Figure 1. Measurement results for positive Pu-239 Samples – All Detectors

Figure 2. Measurement results for positive Pu-238 Samples – All Detectors

Pu-242 Tracer Activity ANOVAs – by detector

Detector 137

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
REGRESSION	0.848	1	0.848	141.735	0.000
RESIDUAL	0.048	8	0.006		

Detector 138

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
REGRESSION	0.245	1	0.245	33.670	0.000
RESIDUAL	0.065	9	0.007		

Detector 139

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
REGRESSION	0.102	1	0.102	52.425	0.000
RESIDUAL	0.016	8	0.002		

Detector 140

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
REGRESSION	0.159	1	0.848	80.622	0.000
RESIDUAL	0.014	7	0.002		

Detector 141

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
REGRESSION	0.070	1	0.070	19.400	0.002
RESIDUAL	0.033	9	0.004		

Detector 142

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
REGRESSION	0.096	1	0.096	13.023	0.006
RESIDUAL	0.067	9	0.007		

Detector 143

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
REGRESSION	0.202	1	0.202	72.475	0.000
RESIDUAL	0.025	9	0.002		

Detector 144

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
REGRESSION	0.075	1	0.075	37.981	0.000
RESIDUAL	0.018	9	0.002		

Detector 145

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
REGRESSION	0.061	1	0.061	9.502	0.013
RESIDUAL	0.058	9	0.006		

Detector 146

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
REGRESSION	0.214	1	0.214	29.133	0.001
RESIDUAL	0.059	8	0.007		

Detector 147

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
REGRESSION	0.154	1	0.154	30.519	0.001
RESIDUAL	0.040	8	0.005		

Detector 148

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
REGRESSION	0.069	1	0.069	11.004	0.011
RESIDUAL	0.05	8	0.006		

Detector 149

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
REGRESSION	0.101	1	0.101	26.272	0.001
RESIDUAL	0.027	7	0.004		

Detector 150

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
REGRESSION	0.159	1	0.159	101.039	0.000
RESIDUAL	0.011	7	0.002		

Detector 151

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
REGRESSION	0.133	1	0.133	23.492	0.001
RESIDUAL	0.051	9	0.006		

Detector 152

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
REGRESSION	0.175	1	0.175	35.767	0.000
RESIDUAL	0.039	8	0.005		

Detector 153

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
REGRESSION	0.220	1	0.220	33.613	0.000
RESIDUAL	0.052	8	0.007		

Detector 154

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
REGRESSION	0.215	1	0.215	61.194	0.000
RESIDUAL	0.0028	8	0.004		

Detector 155

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
REGRESSION	0.095	1	.095	6.568	0.050
RESIDUAL	0.073	5	.015		

Detector 156

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
REGRESSION	0.133	1	0.133	7.613	0.025
RESIDUAL	0.139	8	0.017		

Detector 157

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
REGRESSION	0.151	1	0.151	15.314	0.006
RESIDUAL	0.069	7	0.010		

Detector 158

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
REGRESSION	0.097	1	0.097	6.163	0.042
RESIDUAL	0.110	7	0.016		

Detector 159

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
REGRESSION	0.186	1	0.186	14.650	0.005
RESIDUAL	0.101	8	0.013		

Detector 160

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
REGRESSION	0.504	1	0.504	10.051	0.013
RESIDUAL	0.401	7	0.050		

Detector 161

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
REGRESSION	0.320	1	0.320	158.547	0.000
RESIDUAL	0.016	8	0.002		

Detector 162

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
REGRESSION	0.267	1	0.267	41.387	0.000
RESIDUAL	0.052	8	0.006		

Detector 163

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
REGRESSION	0.294	1	0.294	52.363	0.000
RESIDUAL	0.045	8	0.006		

Detector 164

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
REGRESSION	0.353	1	0.353	239.847	0.000
RESIDUAL	0.012	8	0.001		

Detector 165

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
REGRESSION	0.699	1	0.699	51.352	0.000
RESIDUAL	0.109	8	0.014		

Detector 166

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
REGRESSION	0.228	1	0.228	30.546	0.001
RESIDUAL	0.060	8	0.007		

Detector 167

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
REGRESSION	0.244	1	0.244	20.222	0.001
RESIDUAL	0.109	9	0.012		

Detector 168

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
REGRESSION	0.155	1	0.155	47.100	0.000
RESIDUAL	0.023	7	0.003		

Detector 169

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
REGRESSION	0.219	1	0.219	358.9	0.000
RESIDUAL	0.004	7			

Detector 170

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
REGRESSION	0.218	1	0.218	13.676	0.006
RESIDUAL	0.127	8	0.016		

Detector 171

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
REGRESSION	0.230	1	0.230	89.814	0.000
RESIDUAL	1.015	6	0.003		

Detector 172

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
REGRESSION	1.151	1	1.151	5.664	0.042
RESIDUAL	1.836	9	0.204		

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