



facility 755652

facility 755653

project 10243

Gamma Spectroscopy

Case Narrative

COGCC

PW NORM 2017 – 10048

Work Order Number: 1706286

1. This report consists of analytical results and supporting documentation for two water samples received by ALS on 06/13/2017.
2. These samples were prepared according to the current revision of SOP739.
3. The samples were analyzed for the presence of gamma emitting radionuclides according to the current revision of SOP713. The analyses were completed on 06/18/2017.
4. The analysis results for these samples are reported in units of pCi/L. The samples were filtered prior to analysis.
5. Technical considerations made in the creation of the gamma spectroscopy library used in this analysis are detailed in the document "Technical Comments Regarding Gamma Spectroscopy Libraries" found in Section 5.
6. Radium-226 quantification based on the 186.21 keV photon suffers from interference with the 185.72 keV photon emitted by ^{235}U . Due to the high abundance of this photon in ^{235}U emissions, even small amounts of ^{235}U may bias the ^{226}Ra results high. Thus, any measured activity for ^{226}Ra has been flagged with an "SI" qualifier, denoting spectral interference.
7. In cases where there are no peaks found in the peak search routine, the software performs a net quantification. This indicates that nuclides are not detected or supported at any level above the reported MDC. Consequently, these nuclides are flagged with an "NQ" qualifier on the final reports. Please refer to the Technical Bulletin Addendum in section 5 of this report.
8. No further problems were encountered with either the client samples or the associated quality control samples. All remaining quality control criteria were met.



The data contained in the following report have been reviewed and approved by the personnel listed below. In addition, ALS certifies that the analyses reported herein are true, complete and correct within the limits of the methods employed.

Jean Anderson
Radiochemistry Primary Data Reviewer

7/24/17

Date

Radiochemistry Final Data Reviewer

7/26/17

Date

Section 1

CHAIN OF CUSTODY

ALS -- Fort Collins

Sample Number(s) Cross-Reference Table

OrderNum: 1706286

Client Name: COGCC

Client Project Name: PW NORM 2017

Client Project Number: 10048

Client PO Number: CT 2017-3066

Client Sample Number	Lab Sample Number	COC Number	Matrix	Date Collected	Time Collected
755652 Coalview	1706286-1		WATER	13-Jun-17	10:16
755652 Coalview	1706286-2		WATER	13-Jun-17	10:16
755653 Oscar Y	1706286-3		WATER	13-Jun-17	11:36
755653 Oscar Y	1706286-4		WATER	13-Jun-17	11:36



Turnaround time for samples received after 2 p.m. will be calculated beginning from the next business day.

Chain-of-Custody

ALS WORKORDER #

Turnaround time for samples received after 2 p.m. will be calculated beginning from the next business day.

[illegible]

NOTES		REPORT LEVEL / QC REQUIRED		Form 2029	
6010 total = B, Be, Ca, Cr, Fe, K, Li, Mg, Na, Ni, P, S, Si, V 6020 total = Al, Ag, As, Ba, Cd, Co, Cu, Mo, Mn, Na, Pb, Se, Sr, Th, Tl, Zn dissolved = Ba, Ca, Fe, K, Mg, Na, Si, Sr Dissolved = filter and preserve upon receipt at lab		Summary (Standard QC)	RELINQUISHED BY	SIGNATURE	PRINTED NAME
		LEVEL II (Standard QC)	RECEIVED BY		Peter Gintautas
		LEVEL III (Std QC + forms)	RELINQUISHED BY		
		LEVEL IV (Std QC + forms + raw data)	RECEIVED BY		
		X	RELINQUISHED BY		
PRESERVATION KEY 1-HCl 2-HNO3 3-H2SO4 4-NaOH 5-NaOH/NaAcetate 6-NaHSO4 7-4°C 8-Other		DATE	TIME		



TF: (800) 443-1511 PH: (970) 490-1511 FX: (970) 490-1522

ALS WORKORDER #

[illegible]



ALS Environmental - Fort Collins
CONDITION OF SAMPLE UPON RECEIPT FORM

Client: COGCC

Workorder No: 1706286

Project Manager: SS

Initials: JNS

Date: 6/13/17

1. Does this project require any special handling in addition to standard ALS procedures?		YES	<u>NO</u>
2. Are custody seals on shipping containers intact?	<u>NONE</u>	YES	NO
3. Are Custody seals on sample containers intact?	<u>NONE</u>	YES	NO
4. Is there a COC (Chain-of-Custody) present or other representative documents?		<u>YES</u>	NO
5. Are the COC and bottle labels complete and legible?		<u>YES</u>	NO
6. Is the COC in agreement with samples received? (IDs, dates, times, no. of samples, no. of containers, matrix, requested analyses, etc.)		<u>YES</u>	NO
7. Were airbills / shipping documents present and/or removable?	<u>DROP OFF</u>	YES	NO
8. Are all aqueous samples requiring preservation preserved correctly? (excluding volatiles)	N/A	<u>YES</u>	NO
9. Are all aqueous non-preserved samples pH 4-9?	N/A	<u>YES</u>	NO
10. Is there sufficient sample for the requested analyses?		<u>YES</u>	NO
11. Were all samples placed in the proper containers for the requested analyses?		<u>YES</u>	NO
12. Are all samples within holding times for the requested analyses?		<u>YES</u>	NO
13. Were all sample containers received intact? (not broken or leaking, etc.)		<u>YES</u>	NO
14. Are all samples requiring no headspace (VOC, GRO, RSK/MEE, Rx CN/S, radon) headspace free? Size of bubble: <u> </u> < green pea <u> </u> > green pea	N/A	<u>YES</u>	NO
15. Do any water samples contain sediment? Amount of sediment: <u> </u> dusting <u>X</u> moderate <u> </u> heavy	N/A	<u>YES</u>	NO
16. Were the samples shipped on ice?		<u>YES</u>	NO
17. Were cooler temperatures measured at 0.1-6.0°C? IR gun used*: #2 <u>#4</u>	RAD ONLY	<u>YES</u>	NO
Cooler #:	<u>1</u>	<u>2</u>	<u>3</u>
Temperature (°C):	<u>amb</u>	<u>amb</u>	<u>4</u>
No. of custody seals on cooler:	<u>0</u>	<u>0</u>	<u>0</u>
External µR/hr reading:	<u>1.2</u>		
Background µR/hr reading:	<u>10</u>		
Were external µR/hr readings ≤ two times background and within DOT acceptance criteria? YES / NO <u>NA</u> (If no, see Form 008.)			

Additional Information: PROVIDE DETAILS BELOW FOR A NO RESPONSE TO ANY QUESTION ABOVE, EXCEPT #1 AND #16.

If applicable, was the client contacted? YES / NO NA Contact: Philab Date/Time:

Project Manager Signature / Date: Philab

Section 2



SAMPLE RESULTS SUMMARY

Due to the nature of gamma spectroscopy data, a summary report is not provided.

Please refer to the individual sample results in Section 4.

Section 3

QC RESULTS SUMMARY

3

Gamma Spectroscopy Results

PAI 713 Rev 14

Method Blank Results

Lab Name: ALS -- Fort Collins

Work Order Number: 1706286

Client Name: COGCC

ClientProject ID: PW NORM 2017 10048

Lab ID: GS170615-2AMB

Library: NATURAL+RA22

Sample Matrix: WATER

Prep SOP: PAI 739 Rev 12

Date Collected: 15-Jun-17

Date Prepared: 15-Jun-17

Date Analyzed: 18-Jun-17

Prep Batch: GS170615-2

QCBatchID: GS170615-2-1

Run ID: GS170615-2A

Count Time: 500 minutes

Final Aliquot: 1000 ml

Result Units: pCi/l

File Name: 170665d07A

CASNO	Target Nuclide	Result +/- 2 s TPU	MDC	Requested MDC	DL	Lab Qualifier
14596-10-2	Am-241	-7E+00 +/- 2.1E+01	3.7E+01		NA	U
14913-49-6	Bi-212	3.3E+01 +/- 5.5E+01	9.1E+01		NA	U
14733-03-0	Bi-214	5.7E+00 +/- 8.4E+00	1.38E+01		NA	U
10198-40-0	Co-60	-2.5E+00 +/- 4.6E+00	8.3E+00		NA	U
10045-97-3	Cs-137	-2.2E+00 +/- 3.6E+00	6.4E+00	1E+01	NA	U
13966-00-2	K-40	-2.9E+01 +/- 8.7E+01	1.49E+02		NA	U
15092-94-1	Pb-212	1.7E+00 +/- 8.9E+00	1.48E+01		NA	U
15067-28-4	Pb-214	0E+00 +/- 1E+01	1.8E+01		NA	U
13982-63-3	Ra-226	-5E+00 +/- 9.5E+01	1.59E+02		NA	U,SI
14331-83-0	Ac-228	7E+00 +/- 2.2E+01	3.6E+01		NA	U
15100-28-4	Pa-234m	4.4E+02 +/- 6.9E+02	1.14E+03		NA	U
15262-20-1	Ra-228	7E+00 +/- 2.2E+01	3.6E+01		NA	U
15065-10-8	Th-234	-3.9E+01 +/- 8.7E+01	1.46E+02		NA	U
15117-96-1	U-235	-8E+00 +/- 2.8E+01	4.7E+01		NA	U

Comments:

Qualifiers/Flags:

U - Result is less than the sample specific MDC or less than the associated TP

Y1

Y1 - Chemical Yield is in control at 100-110%. Quantitative Yield is assumed.

Y2 - Chemical Yield outside default limits.

LT - Result is less than Requested MDC, greater than sample specific MDC.

SQ - Spectral quality prevents accurate quantitation.

SI - Nuclide identification and/or quantitation is tentative.

TI - Nuclide identification is tentative.

R - Nuclide has exceeded 8 half-lives.

M - Requested MDC not met.

B - Analyte concentration greater than MDC.

B3 - Analyte concentration greater than MDC but less than Requested MDC.

DL - Decision Level

Abbreviations:

TPU - Total Propagated Uncertainty

MDC - Sample specific Minimum Detectable Concentration

BDL - Below Detection Limit

Data Package ID: GSW1706286-1

Gamma Spectroscopy Results

PAI 713 Rev 14

Laboratory Control Sample(s)

Lab Name: ALS -- Fort Collins

Work Order Number: 1706286

Client Name: COGCC

ClientProject ID: PW NORM 2017 10048

Lab ID: GS170615-2LCS

Library: ANALYTICAL.LI

Sample Matrix: WATER

Prep SOP: PAI 739 Rev 12

Date Collected: 15-Jun-17

Date Prepared: 15-Jun-17

Date Analyzed: 18-Jun-17

Prep Batch: GS170615-2

QCBatchID: GS170615-2-1

Run ID: GS170615-2A

Count Time: 30 minutes

Final Aliquot: 1000 ml

Result Units: pCi/l

File Name: 170663d07

CASNO	Target Nuclide	Results +/- 2s TPU	MDC	Spike Added	% Rec	Control Limits	Lab Qualifier
14596-10-2	Am-241	9.7E+04 +/- 1.2E+04	2E+03	9.960E+04	97.5	85 - 115	P
10198-40-0	Co-60	4.08E+04 +/- 4.8E+03	2E+02	4.120E+04	98.9	85 - 115	P
10045-97-3	Cs-137	3.83E+04 +/- 4.5E+03	2E+02	3.770E+04	101	85 - 115	P,M3

Comments:

Qualifiers/Flags:

U - Result is less than the sample specific MDC or less than the associated TPU

LT - Result is less than Requested MDC, greater than sample specific MDC.

Y1 - Chemical Yield is in control at 100-110%. Quantitative Yield is assumed.

Y2 - Chemical Yield outside default limits.

L - LCS Recovery below lower control limit.

H - LCS Recovery above upper control limit.

P - LCS Recovery within control limits.

M - The requested MDC was not met.

M3 - The requested MDC was not met, but thereported activity is greater than the reported MDC.

Abbreviations:

TPU - Total Propagated Uncertainty

MDC - Minimum Detectable Concentration

SQ - Spectral quality prevents accurate quantitation.

SI - Nuclide identification and/or quantitation is tentative.

TI - Nuclide identification is tentative.

R - Nuclide has exceeded 8 half-lives.

Data Package ID: GSW1706286-1

Date Printed: Wednesday, July 05, 2017

ALS -- Fort Collins

LIMS Version: 6.843

Page 1 of 1

Section 4

INDIVIDUAL SAMPLE RESULTS



Gamma Spectroscopy Results

PAI 713 Rev 14

Sample Results

Lab Name: ALS -- Fort Collins

Work Order Number: 1706286

Client Name: COGCC

ClientProject ID: PW NORM 2017 10048

Field ID: 755652 Coalview

Lab ID: 1706286-1

Library: NATURAL+RA22

Sample Matrix: WATER

Prep SOP: PAI 739 Rev 12

Date Collected: 13-Jun-17

Date Prepared: 15-Jun-17

Date Analyzed: 18-Jun-17

Prep Batch: GS170615-2

QCBatchID: GS170615-2-1

Run ID: GS170615-2A

Count Time: 500 minutes

Report Basis: Filtered

Final Aliquot: 1000 ml

Prep Basis: Filtered

Moisture(%): NA

Result Units: pCi/l

File Name: 170826d03

CASNO	Target Nuclide	Result +/- 2 s TPU	MDC	Requested MDC	DL	Lab Qualifier
14596-10-2	Am-241	-3E+00 +/- 3.4E+01	5.8E+01		NA	U
14913-49-6	Bi-212	7E+00 +/- 6E+01	1.02E+02		NA	U
14733-03-0	Bi-214	4.8E+01 +/- 1.4E+01	2.1E+01		NA	
10198-40-0	Co-60	-1.9E+00 +/- 5E+00	9E+00		NA	U
10045-97-3	Cs-137	-2.6E+00 +/- 4E+00	7.1E+00	1E+01	NA	U
13966-00-2	K-40	9E+00 +/- 9.2E+01	1.56E+02		NA	U
15092-94-1	Pb-212	-1.4E+00 +/- 7.7E+00	1.29E+01		NA	U
15067-28-4	Pb-214	4.2E+01 +/- 1.3E+01	2.5E+01		NA	
13982-63-3	Ra-226	6E+01 +/- 1.1E+02	1.9E+02		NA	U,SI
14331-83-0	Ac-228	2E+00 +/- 2.7E+01	4.6E+01		NA	U
15100-28-4	Pa-234m	2.9E+02 +/- 6.9E+02	1.16E+03		NA	U
15262-20-1	Ra-228	2E+00 +/- 2.7E+01	4.6E+01		NA	U
15065-10-8	Th-234	8E+00 +/- 9.1E+01	1.52E+02		NA	U
15117-96-1	U-235	1.2E+01 +/- 2.6E+01	5.1E+01		NA	U

Comments: This sample was filtered prior to analysis.

Qualifiers/Flags:

U - Result is less than the sample specific MDC or less than the associated TP

II

Y1 - Chemical Yield is in control at 100-110%. Quantitative Yield is assumed.

Y2 - Chemical Yield outside default limits.

LT - Result is less than Requested MDC, greater than sample specific MDC.

M3 - The requested MDC was not met, but the reported activity is greater than the reported MDC.

M - The requested MDC was not met.

SQ - Spectral quality prevents accurate quantitation.

SI - Nuclide identification and/or quantitation is tentative.

TI - Nuclide identification is tentative.

R - Nuclide has exceeded 8 half-lives.

G - Sample density differs by more than 15% of LCS density.

Abbreviations:

TPU - Total Propagated Uncertainty

MDC - Sample specific Minimum Detectable Concentration

BDL - Below Detection Limit

DL - Decision Level

Data Package ID: GSW1706286-1

Gamma Spectroscopy Results

PAI 713 Rev 14

Sample Results

Lab Name: ALS -- Fort Collins
 Work Order Number: 1706286
 Client Name: COGCC
 ClientProject ID: PW NORM 2017 10048

Field ID:	755653 Oscar Y
Lab ID:	1706286-3

Library: NATURAL+RA22

Sample Matrix: WATER
 Prep SOP: PAI 739 Rev 12
 Date Collected: 13-Jun-17
 Date Prepared: 15-Jun-17
 Date Analyzed: 18-Jun-17

Prep Batch: GS170615-2
 QCBatchID: GS170615-2-1
 Run ID: GS170615-2A
 Count Time: 500 minutes
 Report Basis: Filtered

Final Aliquot: 1000 ml
 Prep Basis: Filtered
 Moisture(%): NA
 Result Units: pCi/l
 File Name: 171129d04

CASNO	Target Nuclide	Result +/- 2 s TPU	MDC	Requested MDC	DL	Lab Qualifier
14596-10-2	Am-241	4E+00 +/- 4.2E+01	6.9E+01		NA	U
14913-49-6	Bi-212	7.6E+01 +/- 6.9E+01	1.1E+02		NA	U
14733-03-0	Bi-214	1.5E+01 +/- 1.1E+01	1.7E+01		NA	U
10198-40-0	Co-60	-4.1E+00 +/- 6.4E+00	1.15E+01		NA	U
10045-97-3	Cs-137	1.3E+00 +/- 5.2E+00	8.7E+00	1E+01	NA	U
13966-00-2	K-40	1.86E+02 +/- 8.6E+01	1.26E+02		NA	NQ
15092-94-1	Pb-212	2.4E+00 +/- 8.7E+00	1.44E+01		NA	U
15067-28-4	Pb-214	6E+00 +/- 1.2E+01	2.1E+01		NA	U
13982-63-3	Ra-226	2E+01 +/- 1.2E+02	2.1E+02		NA	U,SI
14331-83-0	Ac-228	-6E+00 +/- 3.4E+01	5.8E+01		NA	U
15100-28-4	Pa-234m	7.8E+02 +/- 8.7E+02	1.42E+03		NA	U
15262-20-1	Ra-228	-6E+00 +/- 3.4E+01	5.8E+01		NA	U
15065-10-8	Th-234	-8E+01 +/- 1.1E+02	1.8E+02		NA	U
15117-96-1	U-235	9E+00 +/- 3E+01	5E+01		NA	U

Comments: This sample was filtered prior to analysis.

Qualifiers/Flags:

U - Result is less than the sample specific MDC or less than the associated TP
 Y1 - Chemical Yield is in control at 100-110%. Quantitative Yield is assumed.
 Y2 - Chemical Yield outside default limits.
 LT - Result is less than Requested MDC, greater than sample specific MDC.
 M3 - The requested MDC was not met, but the reported activity is greater than the reported MDC.
 M - The requested MDC was not met.

Abbreviations:

TPU - Total Propagated Uncertainty
 MDC - Sample specific Minimum Detectable Concentration
 BDL - Below Detection Limit
 DL - Decision Level

SQ - Spectral quality prevents accurate quantitation.
 SI - Nuclide identification and/or quantitation is tentative.
 TI - Nuclide identification is tentative.
 R - Nuclide has exceeded 8 half-lives.
 G - Sample density differs by more than 15% of LCS density.

Data Package ID: GSW1706286-1

Section 5

RAW DATA

5

SEEKER G A M M A A N A L Y S I S R E S U L T S PS Version 1.8.4

ALS Laboratory Group - Fort Collins
GammaScan

Geo 1 / Water

Sample ID: 1706286-1 GS170615-2

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-----
Sampling Start: 06/18/2017 11:00:00 | Counting Start: 06/18/2017 11:20:26
Sampling Stop: 06/18/2017 11:00:00 | Decay Time. . . . . 3.41E-001 Hrs
Buildup Time. . . . . 0.00E+000 Hrs | Live Time . . . . . 30000 Sec
Sample Size . . . . . 1.00E+000 L | Real Time . . . . . 30086 Sec
Collection Efficiency . . . . 1.0000 | Spc. File . . . . . 170826D03.SPC
-----

```

Detector #: 3 (Detector 3)

Energy(keV)= -1.70 + 0.501*Ch + 0.00E+00*Ch^2 + 0.00E+00*Ch^3 06/18/2017

FWHM(keV) = 0.73 + 0.017*En + 8.16E-04*En^2 + 0.00E+00*En^3 11/04/2016

Where En = Sqrt(Energy in keV)

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Search Sensitivity: 1.00 | Sigma Multiplier: 2.00 | Search Start/End: 80/4000
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PEAK SEARCH RESULTS

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PK. #	ENERGY (keV)	ADDRESS CHANNEL	NET/MDA COUNTS	UN- CERTAINTY	C.L. COUNTS	BKG COUNTS	FWHM (keV)	FLAG
1	46.91	97.03	43	65	52	503	0.91	a NET< CL
2	53.34	109.87	82	95	77	822	1.63	a Wide Pk
3	65.96	135.05	130	88	70	779	1.25	a HiResid
4	66.72	136.58	142	48	34	292	0.51	b HiResid
5	68.94	141.00	1	42	34	292	0.46	c NET< CL HiResid
6	92.53	188.11	162	61	46	419	0.90	a
7	139.95	282.78	191	67	50	469	1.04	a
8	154.45	311.72	71	87	70	683	1.64	a
9	161.59	325.96	38	46	36	290	0.70	a
10	186.02	374.74	219	77	59	545	1.34	a
11	198.40	399.45	246	63	45	377	1.01	a
12	209.50	421.62	62	64	51	442	1.08	a
13	238.62	479.74	92	53	40	344	0.97	a
14	242.05	486.58	69	52	40	344	1.05	b
15	295.05	592.39	175	57	42	343	1.18	a
16	351.87	705.82	368	61	39	288	1.35	a
17	510.97	1023.43	721	82	51	389	2.45	a Wide Pk
18	558.50	1118.31	181	49	33	206	1.57	a
19	583.45	1168.13	49	31	23	116	1.09	a
20	596.19	1193.55	94	49	37	250	1.63	a

PEAK SEARCH RESULTS

PK. #	ENERGY (keV)	ADDRESS CHANNEL	NET/MDA COUNTS	UN- CERTAINTY	C.L. COUNTS	BKG COUNTS	FWHM (keV)	FLAG
21	609.38	1219.90	283	52	33	199	1.66	a
22	803.43	1607.27	64	37	27	132	2.12	a
23	911.12	1822.25	51	28	20	85	1.27	a
24	1120.31	2239.85	74	36	26	111	2.38	a
25	1461.24	2920.45	105	34	22	84	2.28	a
26	1764.82	3526.49	68	34	25	76	3.92	a

SEEKER B A C K G R O U N D S U B T R A C T R E S U L T S Vers. 2.2.1

ALS Laboratory Group - Fort Collins

GammaScan

Background File: DET030614.BKG (061417-3 WEEKLY BKG)

Bkg.File Detector #: 3

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BACKGROUND SUBTRACT RESULTS

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PK#	ENERGY (keV)	OLD NET COUNTS	OLD UN- CERTAINTY	OLD CR.LEVEL	NEW NET COUNTS	NEW UN- CERTAINTY	NEW CR.LEVEL	FLAG
3	65.96	130	88	70	31	124	101	NET<CL
5	68.94	1	42	34	-18	66	55	NET<CL
6	92.53	162	61	46	10	104	85	NET<CL
7	139.95	191	67	50	112	98	79	
10	186.02	219	77	59	62	114	93	NET<CL
11	198.40	246	63	45	170	97	77	
13	238.62	92	53	40	-15	81	67	NET<CL
15	295.05	175	57	42	144	76	60	
16	351.87	368	61	39	323	107	83	
17	510.97	721	82	51	-37	142	117	NET<CL
18	558.50	181	49	33	111	70	55	
19	583.45	49	31	23	-11	68	56	NET<CL
20	596.19	94	49	37	62	66	53	
21	609.38	283	52	33	238	74	55	
22	803.43	64	37	27	1	59	49	NET<CL
23	911.12	51	28	20	5	57	47	NET<CL
25	1461.24	105	34	22	5	55	45	NET<CL

SEEKER

F I N A L A C T I V I T Y R E P O R T

Version 2.2.1

ALS Laboratory Group - Fort Collins

GammaScan

Geo 1 / Water

Sample ID: 1706286-1 GS170615-2

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Sampling Start:    06/18/2017 11:00:00 | Counting Start:    06/18/2017 11:20:26
Sampling Stop:     06/18/2017 11:00:00 | Decay Time. . . . . 3.41e-001 Hrs
Buildup Time. . . . . 0.00e+000 Hrs | Live Time . . . . . 30000 Sec
Sample Size . . . . . 1.00e+000 L | Real Time . . . . . 30086 Sec
Collection Efficiency . . . . . 1.0000 | Spectrum File . . . . . 170826D03.SPC
Cr. Level Confidence Interval: 95 % | Det. Limit Confidence Interval: 95 %
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```

Detector #: 3 (Detector 3)

Efficiency File: (D03)(Sh01).EFF (Geo 1 Eff Cal)

Eff=10^[-6.81E+01 +8.58E+01*L +-3.67E+01*L^2 +5.20E+00*L^3] 11/04/2016

Eff.=10^[-6.20E+00 +6.10E+00*L +-2.43E+00*L^2 +2.82E-01*L^3] Above 300.00 keV

Library File: NATURAL+RA226(SUBRA22 (Natural+Ra226.LIB)

MEASURED or MDA CONCENTRATIONS

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N
Nuclide    ENERGY E    Concentration    Critical    Halflife
          (keV) T (pCi/L)          MDA        Level    (hrs)
-----
Th-234     92.50 N 8.46E+00 +- 9.13E+01  1.52E+02   7.50E+01   3.92E+13
U-235      Average:x 1.20E+01 +- 2.56E+01  . . . . .  . . . . . 6.17E+12
          163.35 2.61E+01 +- 3.09E+01  5.08E+01   2.45E+01   6.17E+12
          143.76 N-1.85E+01 +- 4.56E+01  7.63E+01b  3.77E+01   6.17E+12
Ra-226     186.21 N 6.28E+01 +- 1.15E+02  1.90E+02   9.34E+01   1.40E+07
Pb-212     238.63 N-1.41E+00 +- 7.68E+00  1.30E+01   6.35E+00   1.27E+14
Pb-214      Average:x 4.16E+01 +- 1.18E+01  . . . . .  . . . . . 1.40E+07
          295.22 3.40E+01 +- 1.81E+01  2.89E+01   1.41E+01   1.40E+07
          351.99 4.73E+01 +- 1.56E+01  2.46E+01   1.21E+01   1.40E+07
Bi-214      Average:x 4.82E+01 +- 1.29E+01  . . . . .  . . . . . 1.40E+07
          609.32 4.45E+01 +- 1.39E+01  2.13E+01   1.04E+01   1.40E+07
          1120.28 7.19E+01 +- 3.51E+01  5.35E+01   2.54E+01   1.40E+07
Ra-228     911.07 N 2.28E+00 +- 2.73E+01  4.60E+01   2.24E+01   5.04E+04
K-40      1460.75 N 9.13E+00 +- 9.21E+01  1.55E+02   7.55E+01   1.12E+13
Pb-210     46.50 N 1.06E+03 +- 1.10E+03  1.80E+03   8.75E+02   1.95E+05
Am-241     59.54 N-3.21E+00 +- 3.40E+01  5.76E+01   2.81E+01   3.80E+06
Th-227     236.00 N-4.98E+00 +- 2.85E+01  4.82E+01R  2.36E+01   1.90E+05
Tl-208     583.14 N 4.33E+00 +- 3.86E+00  6.24E+00   2.99E+00   1.27E+14
Cs-137     661.62 N-2.62E+00 +- 3.99E+00  7.09E+00   3.40E+00   2.64E+05
Bi-212     727.17 N 7.22E+00 +- 6.00E+01  1.02E+02   4.90E+01   1.27E+14
Pa-234m    1001.03 N 2.95E+02 +- 6.87E+02  1.16E+03   5.49E+02   3.92E+13

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MEASURED or MDA CONCENTRATIONS

Nuclide	ENERGY E (keV)	N T	Concentration (pCi/L)	MDA	Critical Level	Half-life (hrs)
Co-60	1332.51	N-1.92E+00	+/- 5.03E+00	8.95E+00	4.24E+00	4.62E+04

MEASURED TOTAL: 1.55E+03 +/- 2.23E+03 pCi/L

UNKNOWN, SUM or ESCAPE PEAKS

PK. #	ENERGY (keV)	ADDRESS CHANNEL	NET COUNTS	UN- CERTAINTY	C.L. COUNTS	BKG COUNTS	FWHM (keV)	FLAG
1	46.91	97.03	43	65	52	503	0.91	Deleted
2	53.34	109.87	82	95	77	822	1.63	Unknown
3	65.96	135.05	31	124	101	779	1.25	Deleted
4	66.72	136.58	142	48	34	292	0.51	Unknown
5	68.94	141.00	-18	66	55	292	0.46	Deleted
7	139.95	282.78	112	98	79	469	1.04	Unknown
8	154.45	311.72	71	87	70	683	1.64	Unknown
11	198.40	399.45	170	97	77	377	1.01	Unknown
12	209.50	421.62	62	64	51	442	1.08	Unknown
14	242.05	486.58	69	52	40	344	1.05	Unknown
17	510.97	1023.43	-37	142	117	389	2.45	Deleted
18	558.50	1118.31	111	70	55	206	1.57	Unknown
19	583.45	1168.13	-11	68	56	116	1.09	Deleted
20	596.19	1193.55	62	66	53	250	1.63	Unknown
22	803.43	1607.27	1	59	49	132	2.12	Deleted
26	1764.82	3526.49	68	34	25	76	3.92	Unknown

c:\SEEKER\BIN\170826d03.res Analysis Results Saved.

SEEKER G A M M A A N A L Y S I S R E S U L T S PS Version 1.8.4

ALS Laboratory Group - Fort Collins

GammaScan

Geo 1 / Water

Sample ID: 1706286-3 GS170615-2

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Sampling Start:    06/18/2017 11:00:00 | Counting Start:    06/18/2017 11:20:38
Sampling Stop:     06/18/2017 11:00:00 | Decay Time. . . . . 3.44E-001 Hrs
Buildup Time. . . . . 0.00E+000 Hrs | Live Time . . . . . 30000 Sec
Sample Size . . . . . 1.00E+000 L | Real Time . . . . . 30086 Sec
Collection Efficiency . . . . 1.0000 | Spc. File . . . . . 171129D04.SPC
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Detector #: 4 (Detector 4)

Energy(keV)= -1.53 + 0.501*Ch + 0.00E+00*Ch^2 + 0.00E+00*Ch^3 06/18/2017

FWHM(keV) = 0.80 + 0.010*En + 1.10E-03*En^2 + 0.00E+00*En^3 01/10/2017

Where En = Sqrt(Energy in keV)

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Search Sensitivity: 1.00 | Sigma Multiplier: 2.00 | Search Start/End: 80/4000
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PEAK SEARCH RESULTS
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PK. #	ENERGY (keV)	ADDRESS CHANNEL	NET/MDA COUNTS	UN- CERTAINTY	C.L. COUNTS	BKG COUNTS	FWHM (keV)	FLAG
1	63.00	128.76	173	103	82	871	1.77	a Wide Pk
2	66.18	135.10	260	83	63	633	1.34	b
3	92.39	187.40	219	70	52	497	1.03	a
4	122.59	247.67	36	37	29	204	0.52	a
5	139.80	282.02	175	70	53	478	1.18	a
6	174.77	351.80	37	49	39	309	0.84	a NET< CL
7	185.55	373.30	198	65	49	403	1.22	a
8	198.32	398.78	206	66	49	411	1.07	a
9	238.52	478.99	69	51	39	326	0.95	a
10	282.17	566.10	36	34	26	172	0.64	a
11	295.19	592.07	62	45	35	253	0.99	a
12	351.75	704.94	97	37	26	151	0.89	a
13	499.71	1000.18	40	28	21	108	0.81	a
14	510.97	1022.66	541	77	51	366	2.63	a Wide Pk
15	558.27	1117.04	123	42	29	163	1.49	a
16	596.04	1192.40	68	33	24	133	1.05	a Wide Pk
17	597.48	1195.29	21	103	85	663	4.93	b NET< CL
18	609.17	1218.61	50	36	27	161	1.07	a
19	868.38	1735.83	13	20	16	61	1.02	a NET< CL
20	1460.43	2917.23	51	42	33	134	3.81	a HiResid

171129D04.SPC Analyzed by

SEEKER BACKGROUND SUBTRACT RESULTS Vers. 2.2.1

ALS Laboratory Group - Fort Collins

GammaScan

Background File: DET040614.BKG (061417-4 WEEKLY BKG)

Bkg.File Detector #: 4

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BACKGROUND SUBTRACT RESULTS

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PK#	ENERGY (keV)	OLD NET COUNTS	OLD UN- CERTAINTY	OLD CR.LEVEL	NEW NET COUNTS	NEW UN- CERTAINTY	NEW CR.LEVEL	FLAG
1	63.00	173	103	82	45	127	104	NET<CL
2	66.18	260	83	63	183	110	88	
3	92.39	219	70	52	-88	123	102	NET<CL
5	139.80	175	70	53	115	100	81	
7	185.55	198	65	49	17	107	88	NET<CL
8	198.32	206	66	49	124	96	77	
9	238.52	69	51	39	21	76	62	NET<CL
11	295.19	62	45	35	41	75	61	NET<CL
12	351.75	97	37	26	32	68	55	NET<CL
14	510.97	541	77	51	-146	143	119	NET<CL
15	558.27	123	42	29	53	67	54	NET<CL
18	609.17	50	36	27	-11	71	59	NET<CL
20	1460.43	51	42	33	-47	63	53	NET<CL

SEEKER

F I N A L A C T I V I T Y R E P O R T

Version 2.2.1

ALS Laboratory Group - Fort Collins

GammaScan

Geo 1 / Water

Sample ID: 1706286-3 GS170615-2

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Sampling Start:    06/18/2017 11:00:00 | Counting Start:    06/18/2017 11:20:38
Sampling Stop:     06/18/2017 11:00:00 | Decay Time. . . . . 3.44e-001 Hrs
Buildup Time. . . . . 0.00e+000 Hrs | Live Time . . . . . 30000 Sec
Sample Size . . . . . 1.00e+000 L | Real Time . . . . . 30086 Sec
Collection Efficiency . . . . . 1.0000 | Spectrum File . . . . . 171129D04.SPC
Cr. Level Confidence Interval: 95 % | Det. Limit Confidence Interval: 95 %
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Detector #: 4 (Detector 4)

Efficiency File: (D04)(Sh01).EFF (Geo 1 Eff Cal)

Eff=10^[-6.94E+01 +8.84E+01*L + -3.82E+01*L^2 +5.45E+00*L^3] 03/20/2017

Eff.= EXP[-2.79E-01 + -5.09E-01 * En + -3.05E-02 * En^2] Above 300.00 keV

Library File: NATURAL+RA226(SUBRA22 (Natural+Ra226.LIB)

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MEASURED or MDA CONCENTRATIONS

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Nuclide	ENERGY E (keV)	N T	Concentration (pCi/L)	MDA	Critical Level	Half-life (hrs)
Th-234	92.50	N	7.70E+01 +- 1.07E+02	1.80E+02	8.90E+01	3.92E+13
Ra-226	186.21	N	1.95E+01 +- 1.25E+02	2.08E+02	1.02E+02	1.40E+07
Pb-212	238.63	N	2.40E+00 +- 8.65E+00	1.44E+01	7.07E+00	1.27E+14
Pb-214	351.99	N	5.85E+00 +- 1.24E+01	2.06E+01	1.00E+01	1.40E+07
Pb-210	46.50	N	2.57E+02 +- 1.79E+03	3.00E+03	1.48E+03	1.95E+05
Am-241	59.54	N	4.29E+00 +- 4.16E+01	6.94E+01R	3.40E+01	3.80E+06
U-235	143.76	N	8.56E+00 +- 3.03E+01	5.05E+01b	2.48E+01	6.17E+12
Th-227	236.00	N	5.59E+00 +- 3.22E+01	5.36E+01R	2.63E+01	1.90E+05
Tl-208	583.14	N	6.50E-01 +- 9.12E+00	1.54E+01	7.52E+00	1.27E+14
Bi-214	609.32	N	1.54E+01 +- 1.07E+01	1.72E+01	8.25E+00	1.40E+07
Cs-137	661.62	N	1.30E+00 +- 5.16E+00	8.75E+00	4.19E+00	2.64E+05
Bi-212	727.17	N	7.56E+01 +- 6.84E+01	1.10E+02	5.26E+01	1.27E+14
Ra-228	911.07	N	6.08E+00 +- 3.43E+01	5.84E+01	2.84E+01	5.04E+04
Pa-234m	1001.03	N	7.85E+02 +- 8.69E+02	1.42E+03	6.70E+02	3.92E+13
Co-60	1332.51	N	4.07E+00 +- 6.33E+00	1.15E+01	5.44E+00	4.62E+04
K-40	1460.75	N	1.86E+02 +- 8.34E+01	1.26E+02	5.98E+01	1.12E+13

MEASURED TOTAL: 1.11E+03 +- 1.29E+03 pCi/L

171129D04.SPC Analyzed by

UNKNOWN,SUM or ESCAPE PEAKS

PK. #	ENERGY (keV)	ADDRESS CHANNEL	NET COUNTS	UN- CERTAINTY	C.L. COUNTS	BKG COUNTS	FWHM (keV)	FLAG
1	63.00	128.76	45	127	104	871	1.77	Deleted
2	66.18	135.10	183	110	88	633	1.34	Unknown
4	122.59	247.67	36	37	29	204	0.52	Unknown
5	139.80	282.02	115	100	81	478	1.18	Unknown
6	174.77	351.80	37	49	39	309	0.84	Deleted
8	198.32	398.78	124	96	77	411	1.07	Unknown
10	282.17	566.10	36	34	26	172	0.64	Unknown
11	295.19	592.07	41	75	61	253	0.99	Deleted
13	499.71	1000.18	40	28	21	108	0.81	Unknown
14	510.97	1022.66	-146	143	119	366	2.63	Deleted
15	558.27	1117.04	53	67	54	163	1.49	Deleted
16	596.04	1192.40	68	33	24	133	1.05	Unknown
17	597.48	1195.29	21	103	85	663	4.93	Deleted
18	609.17	1218.61	-11	71	59	161	1.07	Deleted
19	868.38	1735.83	13	20	16	61	1.02	Deleted
20	1460.43	2917.23	-47	63	53	134	3.81	Deleted

c:\SEEKER\BIN\171129d04.res Analysis Results Saved.

SEEKER G A M M A A N A L Y S I S R E S U L T S PS Version 1.8.4

ALS Laboratory Group - Fort Collins

GammaScan

Geo 1 / Water

Sample ID: GS170615-2AMB GS170615-2

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Sampling Start:   06/18/2017 11:00:00 | Counting Start:   06/18/2017 11:21:43
Sampling Stop:    06/18/2017 11:00:00 | Decay Time. . . . . 3.62E-001 Hrs
Buildup Time. . . . . 0.00E+000 Hrs | Live Time . . . . . 30000 Sec
Sample Size . . . . . 1.00E+000 L | Real Time . . . . . 30030 Sec
Collection Efficiency . . . . 1.0000 | Spc. File . . . . . 170665D07.SPC
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Detector #: 7 (Detector 7)

Energy(keV)= -2.34 + 0.501*Ch + 0.00E+00*Ch^2 + 0.00E+00*Ch^3 06/18/2017

FWHM(keV) = 0.65 + 0.008*En + 1.26E-03*En^2 + 0.00E+00*En^3 11/08/2016

Where En = Sqrt(Energy in keV)

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Search Sensitivity: 1.00 | Sigma Multiplier: 2.00 | Search Start/End: 80/4000
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PEAK SEARCH RESULTS

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PK.   ENERGY   ADDRESS   NET/MDA   UN-      C.L.      BKG      FWHM
#     (keV)     CHANNEL   COUNTS   CERTAINTY COUNTS    COUNTS   (keV)   FLAG
-----
 1    46.57      97.64      52        32        23       148     0.39 a
 2    53.02     110.51     79        53        41       334     0.82 a
 3    63.25     130.93    126        60        45       416     0.80 a
 4    66.22     136.88    246        64        45       416     0.89 b
 5    74.87     154.15     46        39        31       230     0.45 a
 6    77.01     158.40     60        40        31       230     0.41 b
 7    87.07     178.48     25        38        30       218     0.47 a NET< CL
 8    92.56     189.46    195        65        48       433     1.03 a
 9   139.77     283.70    202        63        46       389     0.92 a
10   175.06     354.16     58        57        46       384     1.02 a
11   179.44     362.90     32        57        46       384     1.00 b NET< CL
12   185.66     375.31    161        55        41       331     0.90 a
13   198.41     400.77    203        55        39       308     0.87 a
14   238.50     480.80    151        63        48       391     1.22 a
15   352.18     707.73     76        36        26       157     0.78 a
16   392.76     788.75     43        37        29       176     0.95 a
17   511.18    1025.16    800        87        54       364     2.59 a Wide Pk
18   558.75    1120.13    192        42        26       144     1.25 a
19   569.86    1142.30     35        32        25       134     1.21 a
20   583.36    1169.25     57        32        23       125     0.92 a
21   596.38    1195.25     88        46        34       231     1.54 a

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PEAK SEARCH RESULTS

PK. #	ENERGY (keV)	ADDRESS CHANNEL	NET/MDA COUNTS	UN- CERTAINTY	C.L. COUNTS	BKG COUNTS	FWHM (keV)	FLAG
22	609.31	1221.06	44	44	34	230	1.54	a
23	803.56	1608.85	44	36	28	141	1.98	a
24	911.29	1823.90	45	28	20	89	1.46	a
25	1461.12	2921.56	96	35	24	93	2.56	a

SEEKER B A C K G R O U N D S U B T R A C T R E S U L T S Vers. 2.2.1

ALS Laboratory Group - Fort Collins

GammaScan

Background File: DET070614.BKG (061417-7 WEEKLY BKG)

Bkg.File Detector #: 7

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BACKGROUND SUBTRACT RESULTS

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PK#	ENERGY (keV)	OLD NET COUNTS	OLD UN- CERTAINTY	OLD CR.LEVEL	NEW NET COUNTS	NEW UN- CERTAINTY	NEW CR.LEVEL	FLAG
1	46.57	52	32	23	29	61	49	NET<CL
2	53.02	79	53	41	57	85	69	NET<CL
3	63.25	126	60	45	59	88	72	NET<CL
4	66.22	246	64	45	170	91	72	
5	74.87	46	39	31	-16	76	62	NET<CL
6	77.01	60	40	31	11	93	76	NET<CL
8	92.56	195	65	48	-48	108	89	NET<CL
9	139.77	202	63	46	111	118	95	
12	185.66	161	55	41	-5	101	83	NET<CL
13	198.41	203	55	39	96	99	80	
14	238.50	151	63	48	19	97	79	NET<CL
15	352.18	76	36	26	-3	73	60	NET<CL
17	511.18	800	87	54	-19	153	126	NET<CL
18	558.75	192	42	26	98	70	56	
19	569.86	35	32	25	4	68	56	NET<CL
20	583.36	57	32	23	-9	63	52	NET<CL
22	609.31	44	44	34	-27	71	59	NET<CL
23	803.56	44	36	28	-31	63	52	NET<CL
24	911.29	45	28	20	15	50	40	NET<CL
25	1461.12	96	35	24	-20	58	49	NET<CL

SEEKER

F I N A L A C T I V I T Y R E P O R T

Version 2.2.1

ALS Laboratory Group - Fort Collins

GammaScan

Geo 1 / Water

Sample ID: GS170615-2AMB GS170615-2

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Sampling Start:    06/18/2017 11:00:00 | Counting Start:    06/18/2017 11:21:43
Sampling Stop:     06/18/2017 11:00:00 | Decay Time. . . . . 3.62e-001 Hrs
Buildup Time. . . . . 0.00e+000 Hrs | Live Time . . . . . 30000 Sec
Sample Size . . . . . 1.00e+000 L | Real Time . . . . . 30030 Sec
Collection Efficiency . . . . . 1.0000 | Spectrum File . . . . . 170665D07.SPC
Cr. Level Confidence Interval: 95 % | Det. Limit Confidence Interval: 95 %
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Detector #: 7 (Detector 7)

Efficiency File: (D07)(Sh01).EFF (Geo 1 Eff CaL)

Eff.=1/[3.90E-03*En^-3.75E+00 + 1.34E+02*En^7.94E-01] 11/08/2016

Library File: NATURAL+RA226(SUBRA22 (Natural+Ra226.LIB)

===== MEASURED or MDA CONCENTRATIONS =====

Nuclide	ENERGY E (keV)	N T	Concentration (pCi/L)	MDA	Critical Level	Half-life (hrs)
Pb-210	46.50	N	2.61E+02 +- 5.36E+02	8.92E+02	4.34E+02	1.95E+05
Th-234	92.50	N	3.86E+01 +- 8.69E+01	1.46E+02	7.21E+01	3.92E+13
Ra-226	186.21	N	4.94E+00 +- 9.48E+01	1.59E+02	7.80E+01	1.40E+07
Pb-212	238.63	N	1.75E+00 +- 8.85E+00	1.47E+01	7.25E+00	1.27E+14
Pb-214	351.99	N	4.17E-01 +- 1.05E+01	1.76E+01	8.62E+00	1.40E+07
Tl-208	583.14	N	7.97E-01 +- 5.88E+00	9.97E+00	4.86E+00	1.27E+14
Ra-228	911.07	N	6.57E+00 +- 2.17E+01	3.64E+01	1.76E+01	5.04E+04
K-40	1460.75	N	2.94E+01 +- 8.69E+01	1.49E+02	7.23E+01	1.12E+13
Am-241	59.54	N	7.13E+00 +- 2.14E+01	3.68E+01B	1.79E+01	3.80E+06
U-235	143.76	N	8.18E+00 +- 2.80E+01	4.71E+01b	2.32E+01	6.17E+12
Th-227	236.00	N	2.34E+00 +- 2.91E+01	4.90E+01R	2.40E+01	1.90E+05
Bi-214	609.32	N	5.67E+00 +- 8.33E+00	1.38E+01	6.65E+00	1.40E+07
Cs-137	661.62	N	2.15E+00 +- 3.61E+00	6.42E+00	3.07E+00	2.64E+05
Bi-212	727.17	N	3.31E+01 +- 5.46E+01	9.07E+01	4.34E+01	1.27E+14
Pa-234m	1001.03	N	4.40E+02 +- 6.89E+02	1.14E+03	5.44E+02	3.92E+13
Co-60	1332.51	N	2.53E+00 +- 4.64E+00	8.31E+00	3.95E+00	4.62E+04

MEASURED TOTAL: 7.48E+02 +- 1.32E+03 pCi/L

=====
 UNKNOWN, SUM or ESCAPE PEAKS
 =====

PK. #	ENERGY (keV)	ADDRESS CHANNEL	NET COUNTS	UN- CERTAINTY	C.L. COUNTS	BKG COUNTS	FWHM (keV)	FLAG
2	53.02	110.51	57	85	69	334	0.82	Deleted
3	63.25	130.93	59	88	72	416	0.80	Deleted
4	66.22	136.88	170	91	72	416	0.89	Unknown
5	74.87	154.15	-16	76	62	230	0.45	Deleted
6	77.01	158.40	11	93	76	230	0.41	Deleted
7	87.07	178.48	25	38	30	219	0.47	Deleted
9	139.77	283.70	111	118	95	389	0.92	Unknown
10	175.06	354.16	58	57	46	384	1.02	Unknown
11	179.44	362.90	32	57	46	384	1.00	Deleted
13	198.41	400.77	96	99	80	308	0.87	Unknown
16	392.76	788.75	43	37	29	176	0.95	Unknown
17	511.18	1025.16	-19	153	126	364	2.59	Deleted
18	558.75	1120.13	98	70	56	144	1.25	Unknown
19	569.86	1142.30	4	68	56	134	1.21	Deleted
21	596.38	1195.25	88	46	34	231	1.54	Unknown
22	609.31	1221.06	-27	71	59	230	1.54	Deleted
23	803.56	1608.85	-31	63	52	141	1.98	Deleted

c:\SEEKER\BIN\170665d07A.res Analysis Results Saved.

SEEKER G A M M A A N A L Y S I S R E S U L T S PS Version 1.8.4

ALS Laboratory Group - Fort Collins

GammaScan

Geo 1 / Water

Sample ID: GS170615-2LCS GS170615-2

Sampling Start: 06/18/2017 10:00:00 | Counting Start: 06/18/2017 10:30:09
Sampling Stop: 06/18/2017 10:00:00 | Decay Time. 5.02E-001 Hrs
Buildup Time. 0.00E+000 Hrs | Live Time 1800 Sec
Sample Size 1.00E+000 L | Real Time 1823 Sec
Collection Efficiency 1.0000 | Spc. File 170663D07.SPC

Detector #: 7 (Detector 7)

Energy(keV)= -2.34 + 0.501*Ch + 0.00E+00*Ch^2 + 0.00E+00*Ch^3 06/18/2017

FWHM(keV) = 0.65 + 0.008*En + 1.26E-03*En^2 + 0.00E+00*En^3 11/08/2016

Where En = Sqrt(Energy in keV)

Search Sensitivity: 1.00 | Sigma Multiplier: 2.00 | Search Start/End: 80/4000

=====

PEAK SEARCH RESULTS

=====

PK. #	ENERGY (keV)	ADDRESS CHANNEL	NET/MDA COUNTS	UN- CERTAINTY	C.L. COUNTS	BKG COUNTS	FWHM (keV)	FLAG
1	59.41	123.28	13883	274	115	2660	0.77	a
2	66.33	137.09	111	113	91	1668	0.83	a
3	87.94	180.23	10103	228	89	1602	0.80	a
4	99.02	202.35	84	70	56	765	0.43	a
5	118.53	241.30	69	86	70	1077	0.71	a NET< CL
6	121.89	248.01	2000	134	82	1347	0.84	b
7	136.26	276.70	211	88	68	1036	0.61	a
8	217.24	438.36	102	74	59	857	0.53	a
9	254.64	513.02	48	105	85	1343	0.99	a NET< CL
10	326.24	655.95	63	85	69	1005	0.99	a NET< CL
11	511.02	1024.84	91	104	84	1153	1.64	a
12	572.17	1146.92	50	83	67	835	1.65	a NET< CL
13	661.92	1326.09	22444	310	66	795	1.61	a HiResid
14	1173.42	2347.20	17715	274	55	511	2.37	a HiResid
15	1332.53	2664.83	16180	257	30	141	2.60	a HiResid

=====

170663D07.SPC Analyzed by

SEEKER B A C K G R O U N D S U B T R A C T R E S U L T S Vers. 2.2.1

ALS Laboratory Group - Fort Collins

GammaScan

Background File: DET070614.BKG (061417-7 WEEKLY BKG)

Bkg.File Detector #: 7

=====

BACKGROUND SUBTRACT RESULTS

=====

PK#	ENERGY (keV)	OLD NET COUNTS	OLD UN- CERTAINTY	OLD CR.LEVEL	NEW NET COUNTS	NEW UN- CERTAINTY	NEW CR.LEVEL	FLAG
2	66.33	111	113	91	107	113	91	
11	511.02	91	104	84	42	104	85	NET<CL

SEEKER

F I N A L A C T I V I T Y R E P O R T

Version 2.2.1

ALS Laboratory Group - Fort Collins

GammaScan

Geo 1 / Water

Sample ID: GS170615-2LCS GS170615-2

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Sampling Start:    06/18/2017 10:00:00 | Counting Start:    06/18/2017 10:30:09
Sampling Stop:     06/18/2017 10:00:00 | Decay Time. . . . . 5.02e-001 Hrs
Buildup Time. . . . . 0.00e+000 Hrs | Live Time . . . . . 1800 Sec
Sample Size . . . . . 1.00e+000 L | Real Time . . . . . 1823 Sec
Collection Efficiency . . . . . 1.0000 | Spectrum File . . . . . 170663D07.SPC
Cr. Level Confidence Interval: 95 % | Det. Limit Confidence Interval: 95 %
-----

```

Detector #: 7 (Detector 7)

Efficiency File: (D07)(Sh01).EFF (Geo 1 Eff CaL)

Eff.=1/[3.90E-03*En^-3.75E+00 + 1.34E+02*En^7.94E-01] 11/08/2016

Library File:ANALYTICAL.LIB (Analytical)

MEASURED or MDA CONCENTRATIONS

```

=====
              N
      ENERGY E      Concentration      Critical  Halflife
Nuclide   (keV) T (pCi/L) )      MDA      Level      (hrs)
-----
Am-241    59.54    9.71E+04 +- 1.92E+03  1.63E+03  8.03E+02  3.79E+06
Cd-109    88.02    2.24E+05 +- 5.05E+03  4.01E+03  1.97E+03  1.11E+04
Co-57    122.07    1.25E+03 +- 8.37E+01  1.04E+02  5.12E+01  6.50E+03
Cs-137    661.62    3.83E+04 +- 5.29E+02  2.28E+02  1.12E+02  2.64E+05
Co-60     Average:x 4.08E+04 +- 4.52E+02  . . . . .  . . . . . 4.62E+04
           1173.21  4.06E+04 +- 6.29E+02  2.57E+02  1.25E+02  4.62E+04
           1332.48  4.10E+04 +- 6.51E+02  1.58E+02  7.57E+01  4.62E+04
Ce-139    165.85      MDA      . . . . .  1.19E+02  5.85E+01  3.30E+03
Hg-203    279.18      MDA      . . . . .  1.78E+02  8.79E+01  1.12E+03
Sn-113    391.68      MDA      . . . . .  2.46E+02  1.21E+02  2.76E+03
Y-88     898.02      MDA      . . . . .  3.26E+02  1.60E+02  2.56E+03

```

MEASURED TOTAL: 4.01E+05 +- 8.03E+03 pCi/L

UNKNOWN, SUM or ESCAPE PEAKS

```

=====
PK.  ENERGY  ADDRESS      NET      UN-      C.L.      BKG      FWHM
#    (keV)    CHANNEL    COUNTS  CERTAINTY  COUNTS    COUNTS    (keV)    FLAG
-----
  2    66.33   137.09        107      113        91      1668     0.83   Unknown
  4    99.02   202.35         84       70        56       765     0.43   Unknown

```

170663D07.SPC Analyzed by

UNKNOWN,SUM or ESCAPE PEAKS

PK. #	ENERGY (keV)	ADDRESS CHANNEL	NET COUNTS	UN- CERTAINTY	C.L. COUNTS	BKG COUNTS	FWHM (keV)	FLAG
5	118.53	241.30	69	86	70	1077	0.71	Deleted
7	136.26	276.70	211	88	68	1036	0.61	Unknown
8	217.24	438.36	102	74	59	857	0.53	Unknown
9	254.64	513.02	48	105	85	1343	0.99	Deleted
10	326.24	655.95	63	85	69	1005	0.99	Deleted
11	511.02	1024.84	42	104	85	1153	1.64	Deleted
12	572.17	1146.92	50	83	67	835	1.65	Deleted

c:\SEEKER\BIN\170663d07.res Analysis Results Saved.

Gamma Spectrometer Run Log

Date: 6/16/17 / 6/18/17

Reviewed By/Date: JP 6/20/17

Sample ID	Ver. ¹	Det. No.	Geo. ²	Count Dur. (min.) ³	Start Time	Analyst	File ID.SPC	Saved?
GS170611-13MB	JP	5	00	1000	14:51	SG	170663D05	JP
1706185-1	|	4	01	500	14:56	|	171126D04	JP
↓ -3	|	6	|	|	14:57	|	170591D06	JP
1706271-1	|	7	|	|	↓	|	170661D07	JP
↓ -2	|	8	↓	↓	↓	|	170642D08	JP
1706317-3	↓	9	↓	↓	14:58	✓	170574D09	JP
GS170616-1CS	JP	1	13	30	10:29	JP	170682D01	JP
GS170615-2CS	|	7	1	|	10:30	|	170663D07	JP
1706376-1	SG	1	13	1000	11:20	JP	170683D01	SG
↓ -2	SG	2	↓	↓	|	|	170257D02	SG
1706286-1	SG	3	1	500	|	|	170827D03	SG
↓ -3	SG	4	|	|	|	|	171129D04	SG
1706299-1	SG	5	|	|	|	|	170605D05	SG
↓ -2	SG	6	|	|	↓	|	170593D06	SG
1706317-3D	SG	8	|	|	11:21	|	170594D07	SG
1706329-1	SG	9	↓	↓	|	|	170576D09	SG
GS170615-2MB/AMB	SG	7	↓	↓	↓	|	170604D01	SG
JP 6/18/17								

¹ Analyst will verify the position, detector, and geometry when the sample is removed from the detector.

² Calibration geometry.

³ Count duration.

*170644D08

KEY:

* sample was counted on a puck

↑ sample was counted with air flow arrow pointing up

471595 B

Technical Comments Regarding Analysis using the Natural+Ra226(SubRa228).REV1 Gamma Spectroscopy Library

Analysis using the **Natural+Ra226(SubRa228).REV1** library is limited to the list of gamma emitting radionuclides specified by ALS Laboratory Group. ALS Laboratory Group specifies all values assigned to the nuclides in this library. In cases where multiple gamma emissions are used to quantify activity, the most abundant emission is used for quantification in the absence of any supporting gamma emissions. It should be noted that the current software program used for gamma spectroscopic analysis is limited to a +/- 2.0 keV photo-peak resolution tolerance. Thus, any gamma emissions occurring within the same +/- 2.0 keV range will suffer interference, consequently preventing accurate quantification. Nuclide specific information regarding analysis using the **Natural+Ra226(SubRa228).REV1** library is as follows:

Nuclide: ^{228}Ra Energy: various Photon Abundance: various

All activity values for ^{228}Ra are calculated using the emissions of the ^{228}Ac daughter. It is assumed that secular equilibrium is achieved between the ^{228}Ra parent and the ^{228}Ac progeny.

Nuclide: ^{212}Bi , ^{212}Pb , ^{208}Tl Energy: various Photon Abundance: various

All activity values for ^{212}Bi , ^{212}Pb , and ^{208}Tl are calculated using the half-life, $t_{1/2}=1.45\text{E}+10$ years, of the long-lived ^{232}Th parent. It is assumed that secular equilibrium is achieved between the ^{232}Th parent and the ^{212}Bi , ^{212}Pb , ^{208}Tl progeny.

Nuclide: ^{214}Bi , ^{214}Pb Energy: various Photon Abundance: various

All activity values for ^{214}Bi and ^{214}Pb are calculated using the half-life, $t_{1/2}=1600$ years, of the long-lived ^{226}Ra parent. It is assumed that secular equilibrium is achieved between the ^{226}Ra parent and the ^{214}Bi and ^{214}Pb progeny.

Nuclide: ^{137}Cs Energy: 661.62 keV Photon Abundance: 0.8512

^{137}Cs does not emit any gamma photons useful for quantification. However, it can be assumed to be in secular equilibrium with the short-lived $^{137\text{m}}\text{Ba}$ daughter product. Therefore, the activity for ^{137}Cs is determined from the 661.62 keV gamma emission of the $^{137\text{m}}\text{Ba}$ daughter product. The calculated gamma photon abundance used in the library is the product of the 0.8998 abundance of the 661.62 keV $^{137\text{m}}\text{Ba}$ photon and the 0.946 branching ratio between ^{137}Ba and $^{137\text{m}}\text{Ba}$.

Nuclide: ^{40}K Energy: 1460.75 keV Photon Abundance: 0.1100 (γ/dis)

The only gamma emission useful for quantification of this nuclide suffers from possible resolution interference due to the ^{228}Ac gamma emission occurring at 1459.2 keV (0.0104, abundance). Therefore, a possibility of a high bias to the ^{40}K results may occur in the presence of elevated ^{228}Ac activity.

Nuclide: ^{226}Ra Energy: 186.21 Photon Abundance: 0.0359

Quantifying ^{226}Ra activity using the 186.21 keV photo-peak is vulnerable to a significant high bias due to interference from gamma emissions from ^{235}U occurring at 185.72 keV (0.5720,

abundance). Therefore this nuclide will be "SI" flagged, indicating that significant spectral interference prohibits accurate quantification.

Nuclide: ^{234}Th & $^{234\text{m}}\text{Pa}$ Energy: various Photon Abundance: various

^{234}Th and $^{234\text{m}}\text{Pa}$ are assumed to be in secular equilibrium with their parent, ^{238}U . The activities for these nuclides are therefore calculated using the half-life of the parent, which is $t_{1/2}=4.468\text{E}+9$ years.

Nuclide: ^{227}Th Energy: 236.00 Photon Abundance: 0.1230

All activity values for ^{227}Th are calculated using the half-life, $t_{1/2}=21.7$ yrs, of the long-lived ^{227}Ac parent. It is assumed that secular equilibrium is achieved between the ^{227}Ac parent and the ^{227}Th progeny.

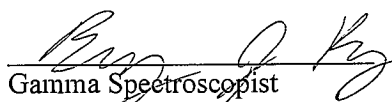
Nuclide: ^{234}Th Energy: 92.50 Photon Abundance: 0.0553

The 92.50 keV photo-peak used in this library for ^{234}Th quantification is actually two separate photo-peaks, occurring at 92.4 keV and 92.8 keV. The current software used for gamma spectroscopic analysis cannot resolve two photo-peaks that occur within the 2-keV resolution tolerance. Therefore, these two photopeaks are observed as a single photo-peak. Therefore, the average of the two photo-peak energies is used in this library. Also, the sum of the two photo-peak abundances, 0.0553, is used in the activity calculations for this observed 'single' photo-peak.

All activity values for ^{234}Th are calculated using the half-life, $t_{1/2}=4.468\text{E}+09$ yrs, of the long-lived ^{238}U parent. It is assumed that secular equilibrium is achieved between the ^{238}U parent and the ^{234}Th progeny.

Nuclide: ^{235}U Energy: 185.72 Photon Abundance: 0.5720

Quantifying ^{235}U activity using the 185.72 keV photo-peak is vulnerable to a significant high bias due to interference from gamma emissions from ^{226}Ra occurring at 186.21 keV (0.0328, abundance). Therefore, this emission will be used as an identifier only and not in the activity calculations for this nuclide.


Gamma Spectroscopist
Radiochemistry Instrumentation Laboratory

10-5-12
Date


Radiochemistry Manager

10-8-12
Date

Pk. #	Energy (keV)	Isotope Name	2ndary Pk #	Type	Gamma Fraction	Halflife
=====						
1	59.54	Am-241	0	NET	0.3590	4.3310E+02 yrs
20	727.17	Bi-212	0	NET	0.0658	1.4500E+10 yrs
18	609.32	Bi-214	25	NET	0.4609	1.6000E+03 yrs
25	1120.28	Bi-214	18	QUANT	0.1510	1.6000E+03 yrs
26	1173.23	Co-60	27	QUANT	0.9997	5.2721E+00 yrs
27	1332.51	Co-60	26	NET	0.9998	5.2721E+00 yrs
19	661.62	Cs-137	0	NET	0.8512	3.0104E+01 yrs
28	1460.75	K-40	0	NET	0.1100	1.2800E+09 yrs
24	1001.03	Pa-234m	0	NET	0.0059	4.4680E+09 yrs
4	115.18	Pb-212	11	QUANT	0.0059	1.4500E+10 yrs
11	238.63	Pb-212	14	NET	0.4330	1.4500E+10 yrs
14	300.09	Pb-212	4	QUANT	0.0327	1.4500E+10 yrs
13	295.22	Pb-214	16	QUANT	0.1920	1.6000E+03 yrs
16	351.99	Pb-214	13	NET	0.3710	1.6000E+03 yrs
8	186.21	Ra-226	0	NET	0.0359	1.6000E+03 yrs
15	338.40	Ra-228	22	QUANT	0.1127	5.7500E+00 yrs
22	911.07	Ra-228	23	NET	0.2580	5.7500E+00 yrs
23	968.90	Ra-228	15	QUANT	0.1580	5.7500E+00 yrs
10	236.00	Th-227	0	NET	0.1230	2.1700E+01 yrs
2	63.29	Th-234	3	QUANT	0.0390	4.4680E+09 yrs
3	92.50	Th-234	2	NET	0.0553	4.4680E+09 yrs
12	277.36	Tl-208	17	QUANT	0.0631	1.4500E+10 yrs
17	583.14	Tl-208	21	NET	0.8450	1.4500E+10 yrs
21	860.47	Tl-208	12	QUANT	0.1242	1.4500E+10 yrs
5	143.76	U-235	6	NET	0.1096	7.0379E+08 yrs
6	163.35	U-235	7	QUANT	0.0508	7.0379E+08 yrs
7	185.72	U-235	9	ID	0.5720	7.0379E+08 yrs
9	205.31	U-235	5	QUANT	0.0501	7.0379E+08 yrs

TECHNICAL BULLETIN ADDENDUM

The library used for analysis defines the gamma emission(s) to be used for analysis of each nuclide. If multiple gamma emissions are used for quantification, then a 'NET' quantification emission (or peak) must be defined in the library. This designation provides for the calculation of nuclide activity concentrations and detection limits in the case of non-presence of the nuclide. When the nuclide is not present, or the software is unable to resolve a peak at the library defined 'NET' energy, the software evaluates the 'NET' region of interest ('NET' peak energy ± 2 keV) by performing a summation of the net counts above the background level. This 'NET' quantification can result in net negative, zero, or positive activity results, and is highly dependent on the spectral distribution in the region of interest of the 'NET' peak. In cases where only the 'NET' peak is found, and the software performs a net quantification, the nuclide result will be flagged with an 'NQ' qualifier on the final reports. This indicates that the nuclide is not detected or supported at any level above the reported MDC. Results are submitted without further qualification.

All nuclides specified in the library of analysis for gamma spectroscopy are evaluated for positive OR tentative identification on the following criteria:

- The individual abundances for the gamma emissions specified for each nuclide are summed to obtain a total nuclide abundance.
- From the total nuclide abundance, a positive identification criterion is set as 75% of this total nuclide abundance.
- For all nuclide peaks that are not net quantified, those peak abundances are summed. The total non-net quantified peak sum is compared to the calculated 75% abundance criterion. If this sum is greater than the 75% criterion, the nuclide is considered to be positively identified at the reported concentration. If the sum is less than the 75% criterion, the nuclide is tentatively identified at the reported concentration. These results will be flagged with a 'TI' qualifier on the final reports to indicate that the 75% abundance criterion was not met.

Section 6

QUALITY ASSURANCE SUMMARY REPORTS

6

No *NON-CONFORMANCE REPORTS* or *QUALITY ASSURANCE SUMMARY SHEETS* are included in this data package.

Section 7

LABORATORY BENCH SHEETS



Radiochemistry Instrument Worksheet

ALS -- Fort Collins

Prep Batch: GS170615-2

Prep Procedure: GAMMASCAN

Analytical QASS / NCR? Y / N

Prep Num	Lab ID	QC Type	Init Aliq	Fin Aliq	Units Geo.	Report Units	Cnt 1 File Cnt Dur (min)	Cnt 1 Inst/Det	Cnt 1 Count Date	Cnt 2 File Cnt Dur (min)	Cnt 2 Inst/Det	Cnt 2 Count Date	Cnt 3 File Cnt Dur (min)	Cnt 3 Inst/Det	Cnt 3 Count Date	Notes
1	1706185-1	SMP	1000	1000	ml	pCili	500	4	6/10/17							
1	1706185-3	SMP	1000	1000	ml	pCili		6								
1	1706271-1	SMP	1000	1000	ml	pCili		7								
1	1706271-2	SMP	1000	1000	ml	pCili		8								
1	1706286-1	SMP	1000	1000	ml	pCili		3	6/18/17							
1	1706286-3	SMP	1000	1000	ml	pCili		4								
1	1706299-1	SMP	1000	1000	ml	pCili		5								
1	1706299-2	SMP	1000	1000	ml	pCili		6								
1	1706317-3	SMP	1000	1000	ml	pCili		9	6/10/17							
1	1706317-3	DUP	1000	1000	ml	pCili		8	6/16/17							Count Duplicate
1	1706329-1	SMP	1000	1000	ml	pCili		9								
1	1706329-2	SMP	1000	1000	ml	pCili		3	6/19/17							
1	GS170615-2A	MB	1000	1000	ml	pCili	500	7	6/18/17							Natural + R226 (Substrate). LIB
1	GS170615-2B	MB	1000	1000	ml	pCili	500	7	6/18/17							BTC - CoCsK. LIB
1	GS170615-2	LCS	1000	1000	ml	pCili	30	7	6/18/17							

Spike Solution Information

Soln #	Nuclide	SolnID	Exp Date	Prep Conc	Units	Prep Date	Aliquot	Units	Pipet ID
S1	Am-241	999		221.057	DPM/ml	06/15/17	1000	ml	N/A
S1	Co-60	999		91.623	DPM/ml	06/15/17	1000	ml	N/A
S1	Cs-137	999		83.780	DPM/ml	06/15/17	1000	ml	N/A

1706185-1 GS170615-2PS1	1706185-3 GS170615-2PS2	1706271-1 GS170615-2PS3
1706271-2 GS170615-2PS4	1706286-1 GS170615-2PS5	1706286-3 GS170615-2PS6
1706299-1 GS170615-2PS7	1706299-2 GS170615-2PS8	1706317-3 GS170615-2PS9
1706317-3DUP GS170615-2PS10	1706329-1 GS170615-2PS11	1706329-2 GS170615-2PS12

Sample Barcodes

317-1 BTC CoCsK. LIB 6060(15) K40(250)

Revised Do Not Delay Collect Natural + R226 Sub (Cs137(10) R226). LIB

*Print Speech

Radiochemistry Instrument Worksheet

ALS -- Fort Collins

Prep Batch: GS170615-2

Prep Procedure: GAMMASCAN

Analytical QASS / NCR? Y

Prep Num	Lab ID	QC Type	Init Aliq	Fin Aliq	Units Geo.	Report Units	Cnt 1 File Cnt Dur (min)	Cnt 1 Inst/Det	Cnt 1 Count Date	Cnt 2 File Cnt Dur (min)	Cnt 2 Inst/Det	Cnt 2 Count Date	Cnt 3 File Cnt Dur (min)	Cnt 3 Inst/Det	Cnt 3 Count Date	Notes
GS170615-2AMB GS170615-2PS13								GS170615-2BMB GS170615-2PS14						GS170615-2LCS GS170615-2PS15		

Reporting Units

LabID:	TstGrpName:	RptUnits:
1706329-1	Gamma_NORM_Ra226_Peter	pCi/l
1706299-1	Gamma_NORM_Ra226_Peter	pCi/l
1706286-1	Gamma_NORM_Ra226_Peter	pCi/l
1706271-1	Gamma_NORM_Ra226_Peter	pCi/l
1706185-1	Gamma_NORM_Ra226_Peter	pCi/l
1706329-2	Gamma_NORM_Ra226_Peter	pCi/l
1706299-2	Gamma_NORM_Ra226_Peter	pCi/l
1706271-2	Gamma_NORM_Ra226_Peter	pCi/l
1706317-3	GAMMA_Cs137_Co60_K40 only	pCi/l
1706286-3	Gamma_NORM_Ra226_Peter	pCi/l
1706185-3	Gamma_NORM_Ra226_Peter	pCi/l

Radiochemistry Prep Worksheet

ALS -- Fort Collins

Prep Batch: GS170615-2

Prep Procedure: GAMMASCAN

Reviewed By: rmo Lmo Review Date: 6/15/2017

Non-Routine Pre-Treatment? Y / (N) Batch: N/A

Prep QASS / NCR? Y / (N) N/A

Prep SOP: PAI 739 Rev: 12

Prep SOP: NONE

Matrix Class: liquid

Prep Analyst: Rebecka M. Olivares Lmo

Prep Date: 6/15/2017

Prep Dept: GM

Balance:

Balance:

Samp Num	Prep Num	LabID	QC Type	Dish No.	Init Alq ml	Fin Alq ml	Prep Basis	Geometry	Standards	Prep Notes
1	1	1706185-1	SMP	N/A	1000	1000	Filtered	01	N/A	
2	1	1706185-3	SMP		1000	1000	Filtered	01		
3	1	1706271-1	SMP		1000	1000	Filtered	01		
4	1	1706271-2	SMP		1000	1000	Filtered	01		
5	1	1706286-1	SMP		1000	1000	Filtered	01		
6	1	1706286-3	SMP		1000	1000	Filtered	01		
7	1	1706299-1	SMP		1000	1000	Unfiltered	01		
8	1	1706299-2	SMP		1000	1000	Unfiltered	01		
9	1	1706317-3	SMP		1000	1000	Unfiltered	01		
10	1	1706317-3	DUP		1000	1000	Unfiltered	01		Count DUP - insufficient sample
11	1	1706329-1	SMP		1000	1000	Unfiltered	01		
12	1	1706329-2	SMP		1000	1000	Unfiltered	01		
13	1	GS170615-2A	MB		1000	1000	Unfiltered	01		
14	1	GS170615-2B	MB		1000	1000	Unfiltered	01		
15	1	GS170615-2	LCS		1000	1000	Unfiltered	01	S1	

Comments

Spiked By: N/A Date: N/A

Witnessed By: N/A Date: N/A

Spike Solution Information						
Soln #	Nuclide	SolnID	Exp Date	Prep Conc	Units	Pipet ID
S1	Am-241	999		221.057	DPM/ml	N/A
S1	Co-60	999		91.623	DPM/ml	N/A
S1	Cs-137	999		83.780	DPM/ml	N/A

Sample Condition Form (Liquid)

Analyst: **RMO**

Analysis Date: **6/15/17**

Method: **prep**

		Sample Condition (Visual Appearance of Analysis Aliquot at Time of Prep)		
Work Order	Sample ID	pH	Color	Remarks
1706185	1	2.2	dark brown	filtered
↓	3	↓	brown-orange	↓
1706271	1	↓	↓	↓
↓	2	↓	↓	↓
1706286	1	↓	clear cloudy	↓
↓	3	↓	orange cloudy	↓
1706299	1	↓	clear	none
↓	2	↓	↓	↓
1706317	3	↓	↓	↓
1706329	1	↓	↓	↓
↓	2	↓	↓	↓
<p>RMO 6/15/17</p>				

Section 8

STANDARDS TRACEABILITY DOCUMENTS





Eckert & Ziegler
Analytics

RSO #
999

Received
2/26/2014
JP

1380 Seaboard Industrial Blvd.
Atlanta, Georgia 30318
Tel 404-352-8677
Fax 404-352-2837
www.analytiscinc.com

CERTIFICATE OF CALIBRATION

Standard Radionuclide Source

95548

1.0 Liter Solid in 138G GA-MA Beaker

Customer: ALS Laboratory Group

P.O. No.: FC000236, Item 1

Product Code 8401-EG-SD

Reference Date: 01-Jan-2014

12:00 PM EST

Grams of Master Source: 0.011697

This standard radionuclide source was prepared using aliquots measured gravimetrically from master radionuclide solutions. Additional radionuclides were added gravimetrically from solutions calibrated by gamma-ray spectrometry, ionization chamber, or liquid scintillation counting. Calibration and purity were checked using a germanium gamma spectrometer system. At the time of calibration no interfering gamma-ray emitting impurities were detected. The gamma-ray emission rates for the most intense gamma-ray lines are given. Eckert & Ziegler Analytics (EZA) maintains traceability to the National Institute of Standards and Technology through a Measurements Assurance Program as described in USNRC Regulatory Guide 4.15, Revision 2, July 2007, and compliance with ANSI N42.22-1995, "Traceability of Radioactive Sources to NIST." EZA is accredited by the Health Physics Society (HPS) for the production of NIST-traceable sources, and this source was produced in accordance with the HPS accreditation requirements. Customers may report any concerns with the accreditation program to the HPS Secretariat, 1313 Dolley Madison Blvd., Ste. 402, McLean, VA 22101.

Density of solid matrix 1.15 g/cc.

Nuclide	Gamma-Ray Energy (keV)	Half-Life, Days	Master Source* γps/gram	This Source γps	Uncertainty*, %			Calibration Method*
					Type	u _A	u _B	U
Am-241	59.5	1.580E+05	—	1.330E+03	0.1	1.6	3.2	4π LS
Cd-109	88.0	4.614E+02	1.627E+05	1.903E+03	0.5	2.0	4.1	HPGe
Co-57	122.1	2.717E+02	8.915E+04	1.043E+03	0.4	1.7	3.5	HPGe
Ce-139	165.9	1.376E+02	1.228E+05	1.436E+03	0.4	1.7	3.5	HPGe
Hg-203	279.2	4.659E+01	2.636E+05	3.083E+03	0.3	1.7	3.5	HPGe
Sn-113	391.7	1.151E+02	1.736E+05	2.031E+03	0.4	1.9	3.9	HPGe
Cs-137	661.7	1.099E+04	1.100E+05	1.287E+03	0.7	1.9	4.0	HPGe
Y-88	898.0	1.066E+02	4.166E+05	4.873E+03	0.5	1.7	3.5	HPGe
Co-60	1173.2	1.925E+03	2.055E+05	2.404E+03	0.6	1.8	3.8	HPGe
Co-60	1332.5	1.925E+03	2.057E+05	2.406E+03	0.7	1.8	3.9	HPGe
Y-88	1836.1	1.066E+02	4.410E+05	5.158E+03	0.7	1.7	3.7	HPGe

* Master Source refers to Analytics' 8-isotope mixture which is calibrated quarterly.

Calibration Methods: 4π LS - 4 pi Liquid Scintillation Counting, HPGe - High Purity Germanium Gamma-Ray Spectrometer, IC - Ionization Chamber. **Uncertainty:** U - Relative expanded uncertainty, k = 2. See NIST Technical Note 1297, "Guidelines for Evaluating and Expressing the Uncertainty of NIST Measurement Results."

(Certificate continued on reverse side)



MGS Certificate Rev 5, 1 October 2013

Corporate Office

24937 Avenue Tibbitts - Valencia, California 91355

Laboratory

1380 Seaboard Industrial Blvd. Atlanta, Georgia 30318

Page 1 of 2

48 of 148

Std ReVerified
3/2/17 JP
New Exp Date
=> 03/02/2018

This standard will expire one year after the reference date.

Source Prepared by:

K. Eardley
K. Eardley, Radiochemist

QA Approved:

J.D. McCorvey
J.D. McCorvey, Counting Room Manager

Date: 24 Feb 14



Section 9

ADDITIONAL SUPPORTING DOCUMENTATION

Gamma Spectroscopy

Initial Calibration Standards Traceability

SEEKER G A M M A A N A L Y S I S R E S U L T S PS Version 1.8.4

ALS Laboratory Group - Fort Collins

GammaScan

Geo 1 / Water

Sample ID: 110416-3 FWHM Cal (1040)

Sampling Start: 01/01/2016 10:00:00 | Counting Start: 11/04/2016 07:22:48
Sampling Stop: 01/01/2016 10:00:00 | Decay Time. 7.39E+003 Hrs
Buildup Time. 0.00E+000 Hrs | Live Time 3600 Sec
Sample Size 1.00E+000 L | Real Time 3779 Sec
Collection Efficiency 1.0000 | Spc. File 161700D03.SPC

Detector #: 3 (Detector 3)

Energy(keV)= -1.63 + 0.501*Ch + 0.00E+00*Ch^2 + 0.00E+00*Ch^3 11/04/2016

FWHM(keV) = 0.72 + 0.015*En + 8.18E-04*En^2 + 0.00E+00*En^3 11/04/2015

Where En = Sqrt(Energy in keV)

Search Sensitivity: 1.00 | Sigma Multiplier: 2.00 | Search Start/End: 80/4000

=====

PEAK SEARCH RESULTS

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PK. #	ENERGY (keV)	ADDRESS CHANNEL	NET/MDA COUNTS	UN- CERTAINTY	C.L. COUNTS	BKG COUNTS	FWHM (keV)	FLAG
1	57.88	118.78	1792	501	406	20296	1.94	a Wide Pk
2	59.51	122.03	22695	415	234	10148	0.92	b
3	87.98	178.84	74430	633	263	12792	0.95	a
4	122.08	246.90	43952	489	207	7910	0.97	a HiResid
5	136.50	275.67	6001	276	188	6510	1.06	a
6	165.88	334.30	29625	423	202	6929	1.09	a
7	255.30	512.76	746	209	166	5438	1.08	a
8	279.26	560.56	2436	228	169	5306	1.30	a
9	350.61	702.96	134	268	219	6770	2.11	a NET< CL Wide Pk
10	391.80	785.16	17411	325	156	4258	1.41	a
11	511.55	1024.13	546	239	193	5016	2.36	a
12	651.53	1303.48	91	125	101	2227	1.13	a NET< CL
13	661.83	1324.05	44899	454	133	3283	1.70	a HiResid
14	814.09	1627.90	151	103	82	1569	0.96	a
15	898.29	1795.93	17857	318	141	3691	1.95	a HiResid
16	1173.51	2345.18	46888	451	103	1810	2.30	a HiResid
17	1332.74	2662.94	41512	423	93	1434	2.43	a HiResid
18	1836.30	3667.89	10546	211	41	249	2.99	a HiResid

 SEEKER C A L I B R A T I O N R E S U L T S Version 2.0.4

Sample ID: 110416-3 FWHM Cal (1040)

Stds. Match Tolerance: 2.00 keV

 Detector Number: 03 Calibration Date. . . 11/04/2016 07:22:48

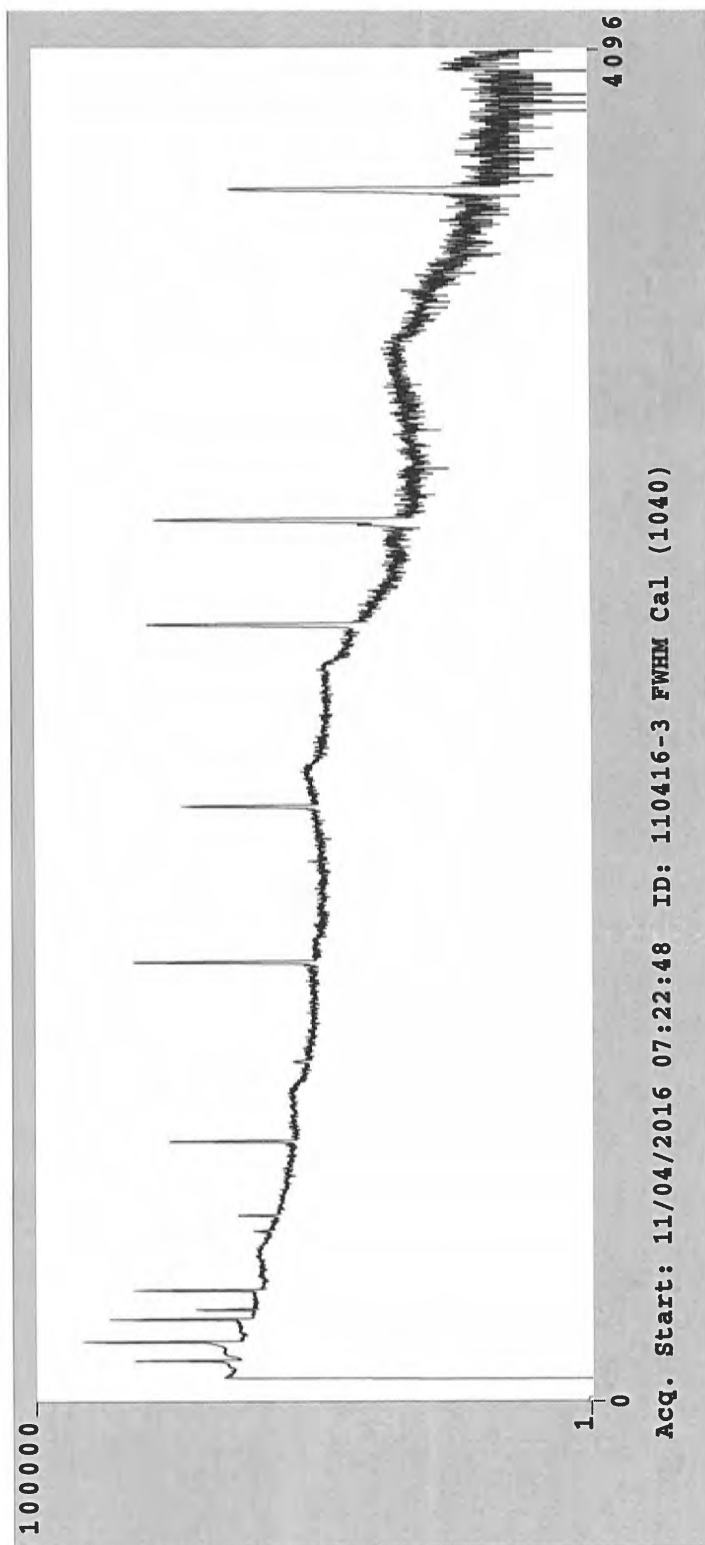
FWHM(keV) = 0.73 + 0.017*En + 8.16e-04*En^2 + 0.00e+00*En^3

(Where En = SQR(Energy in keV))

Pk. #	Energy (kev)	Measured FWHM(keV)	% Diff.	Calculated FWHM(keV)	% Diff.	Prev.Calc. FWHM(kev)
1	59.50	0.923	-1.56	0.909	-2.32	0.888
2	88.04	0.949	1.29	0.961	-2.62	0.937
3	122.06	0.970	4.73	1.018	-2.87	0.990
4	165.85	1.091	-0.50	1.086	-3.10	1.053
5	279.00	1.304	-4.72	1.245	-3.45	1.203
6	391.68	1.409	-1.35	1.391	-3.62	1.342
7	661.64	1.695	1.10	1.714	-3.77	1.652
8	898.02	1.951	1.50	1.981	-3.76	1.909
9	1173.21	2.300	-0.87	2.280	-3.71	2.199
10	1332.48	2.426	0.95	2.450	-3.66	2.363
11	1836.01	2.987	-0.52	2.971	-3.51	2.870

Calibration Results Saved.

OK JP 11/4/16





Eckert & Ziegler
Analytics

#1040
Rec'd
2-25-16

1380 Seaboard Industrial Blvd.
Atlanta, Georgia 30318
Tel 404-352-8677
Fax 404-352-2837
www.ezag.com

CERTIFICATE OF CALIBRATION

Standard Reference Source

SRS Number: 102366

Source Description: 1.0 Liter Solid in 138G GA-MA Beaker

Product Code: 8401-EG-SD

Customer: ALS Laboratory Group

P.O. Number: FC000928, Item 1

This standard radionuclide source was prepared from an aliquot measured gravimetrically from a master radionuclide solution calibrated with a germanium gamma-ray spectrometer system. Additional radionuclides were added gravimetrically from solutions calibrated by gamma-ray spectrometry, ionization chamber, or liquid scintillation counting. Calibration and purity were checked using germanium gamma-ray spectrometry. At the time of calibration no interfering gamma-ray emitting impurities were detected. The gamma-ray emission rates for the most intense gamma-ray lines are given. Eckert & Ziegler Analytics (EZA) maintains traceability to the National Institute of Standards and Technology (NIST) through a Measurements Assurance Program as described in USNRC Regulatory Guide 4.15, Revision 2, July 2007, and compliance with ANSI N42.22-1995, "Traceability of Radioactive Sources to NIST."

Density of solid matrix: 1.17 g/cm³ ± 3 %.

Reference Date: 01-January-2016

12:00 PM EST

MGS Mixture

Isotope	Gamma-Ray Energy, keV	Half-Life, d	Activity, Bq	Flux, s ⁻¹	Uncertainty			Calibration Method**
					u _A , %	u _B , %	U, %*	
Am-241	59.5	1.580E+05	3.768E+03	1.353E+03	0.1	1.8	3.6	4π LS
Cd-109	88.0	4.614E+02	5.156E+04	1.908E+03	0.5	2.0	4.1	HPGe
Co-57	122.1	2.717E+02	1.265E+03	1.083E+03	0.4	1.7	3.4	HPGe
Ce-139	165.9	1.376E+02	1.831E+03	1.465E+03	0.4	1.7	3.6	HPGe
Hg-203	279.2	4.659E+01	3.993E+03	3.257E+03	0.3	1.7	3.5	HPGe
Sn-113	391.7	1.151E+02	3.124E+03	2.030E+03	0.4	1.9	3.9	HPGe
Cs-137	661.7	1.099E+04	1.531E+03	1.303E+03	0.7	1.9	4.1	HPGe
Y-88	898.0	1.066E+02	5.356E+03	5.018E+03	0.7	1.7	3.7	HPGe
Y-88	1836.1	—	—	5.313E+03	0.7	1.7	3.7	—
Co-60	1173.2	1.925E+03	2.453E+03	2.450E+03	0.7	1.8	3.9	HPGe
Co-60	1332.5	—	—	2.453E+03	0.7	1.8	3.9	—

Mixed Gamma (MGS) master solution is EZA's eight isotope mixture which is calibrated quarterly and consists of Cd-109, Co-57, Ce-139, Hg-203, Sn-113, Cs-137, Y-88, and Co-60. ***Uncertainty:** U - Relative expanded uncertainty, k = 2. See NIST Technical Note 1297, "Guidelines for Evaluating and Expressing the Uncertainty of NIST Measurement Results." ****Calibration Methods:** 4π LS - 4π Liquid Scintillation Counting, HPGe - High Purity Germanium Gamma-Ray Spectrometer, IC - Ionization Chamber.

(Certificate continued on reverse side)

SRS Number: 102366

Expiration Date: 24-February-2017

This source was wipe tested in its inactive areas with leak test results < 185 Bq (5 nCi) of removable activity per ISO 9978:1992.

Source Prepared by: 
A. Herron, Radiochemist

QC Approved by:  Date: 24-FEB-16
J. Lahr, Spectroscopist

SEEKER G A M M A A N A L Y S I S R E S U L T S PS Version 1.8.4

ALS Laboratory Group - Fort Collins

GammaScan

Geo.6 / Filter

Sample ID: 011017-4 FWHM Cal (1048) No Puck

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Sampling Start:    07/01/2016 10:00:00 | Counting Start:    01/10/2017 06:49:57
Sampling Stop:    07/01/2016 10:00:00 | Decay Time. . . . . 4.63E+003 Hrs
Buildup Time. . . . . 0.00E+000 Hrs | Live Time . . . . . 1800 Sec
Sample Size . . . . . 1.00E+000 SAMPLE | Real Time . . . . . 1931 Sec
Collection Efficiency . . . . . 1.0000 | Spc. File . . . . . 170029D04.SPC
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Detector #: 4 (Detector 4)

Energy(keV)= -1.60 + 0.501*Ch + 0.00E+00*Ch^2 + 0.00E+00*Ch^3 01/10/2017

FWHM(keV) = 0.88 + 0.001*En + 1.47E-03*En^2 + 0.00E+00*En^3 01/11/2016

Where En = Sqrt(Energy in keV)

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Search Sensitivity: 1.00 | Sigma Multiplier: 2.00 | Search Start/End: 80/4000
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PEAK SEARCH RESULTS

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PK. #	ENERGY (keV)	ADDRESS CHANNEL	NET/MDA COUNTS	UN- CERTAINTY	C.L. COUNTS	BKG COUNTS	FWHM (keV)	FLAG
1	59.53	122.00	28507	432	222	9099	0.92	a HiResid
2	70.87	144.63	515	258	209	8078	0.99	a
3	72.94	148.76	876	261	209	8078	1.06	b
4	86.53	175.87	4794	584	467	22979	2.51	a HiResid Wide Pk
5	88.00	178.82	123495	745	204	7703	0.99	b HiResid
6	122.10	246.86	74178	593	192	6830	0.98	a HiResid
7	136.52	275.64	9633	300	186	5917	1.07	a
8	165.87	334.20	64935	554	179	5450	1.16	a HiResid
9	255.15	512.39	1524	176	129	3536	0.99	a
10	279.20	560.38	14670	306	154	4403	1.33	a HiResid
11	391.75	784.97	34637	412	145	3869	1.34	a HiResid
12	511.61	1024.17	130	122	98	2234	0.96	a
13	661.74	1323.78	42364	450	150	4316	1.83	a HiResid
14	684.80	1369.79	95	150	123	3182	1.54	a NET< CL
15	813.92	1627.46	471	145	114	2623	1.63	a
16	821.00	1641.60	234	181	147	3672	2.35	b
17	898.19	1795.63	29008	389	155	4249	2.08	a HiResid
18	1173.46	2344.97	34897	419	156	4001	2.42	a HiResid
19	1332.74	2662.84	30351	389	143	3352	2.51	a HiResid
20	1836.30	3667.75	14634	270	99	1364	3.28	a HiResid

170029D04.SPC Analyzed by

SEEKER CALIBRATION RESULTS Version 2.0.4

Sample ID: 011017-4 FWHM Cal (1048) No Puck

Stds. Match Tolerance: 2.00 keV

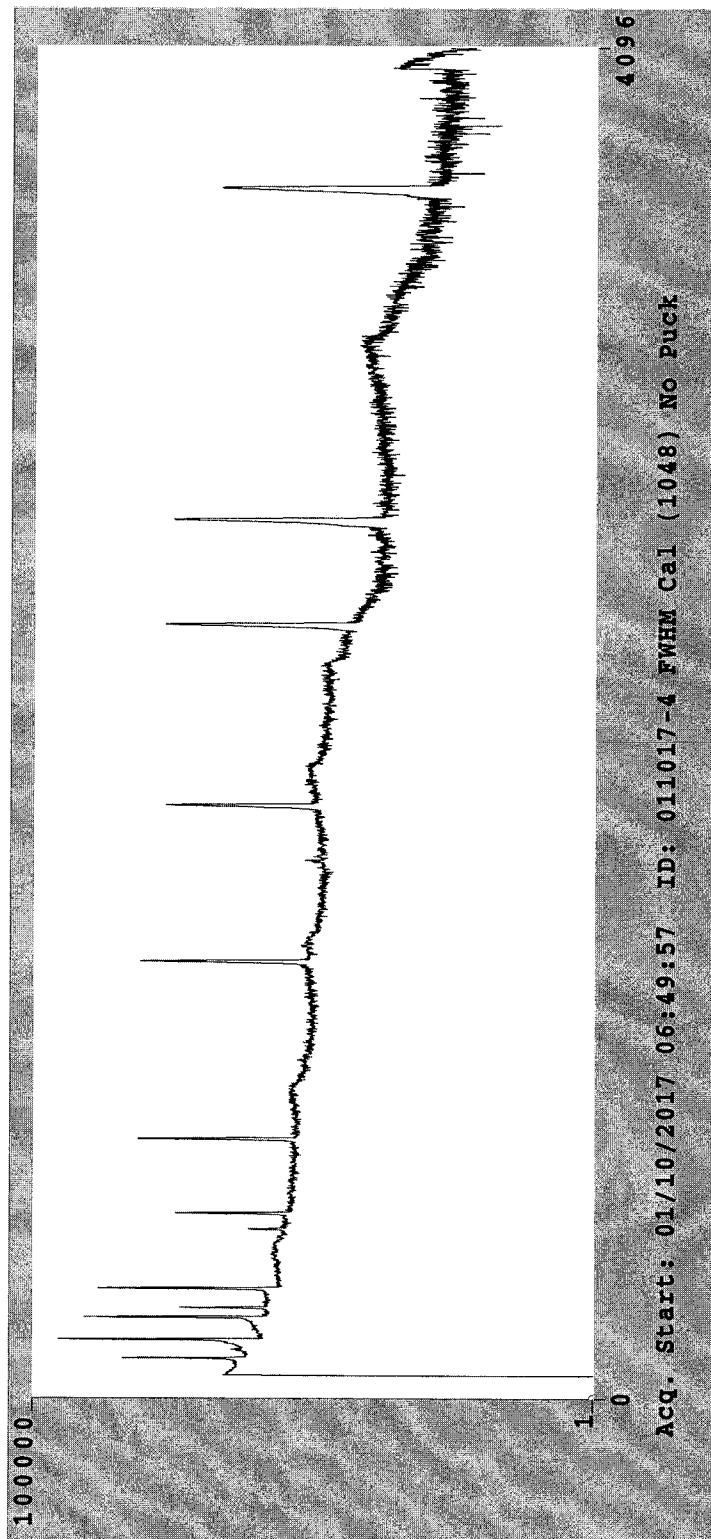
Detector Number: 04 Calibration Date. . . 01/10/2017 06:49:57

FWHM(keV) = 0.80 + 0.010*En + 1.10e-03*En^2 + 0.00e+00*En^3
(Where En = SQR(Energy in keV))

Pk. #	Energy (keV)	Measured FWHM(keV)	% Diff.	Calculated FWHM(keV)	% Diff.	Prev.Calc. FWHM(keV)
1	59.50	0.923	1.63	0.938	4.30	0.980
2	88.04	0.992	-0.66	0.986	3.76	1.024
3	122.06	0.982	5.52	1.039	3.44	1.076
4	165.85	1.160	-4.96	1.105	3.30	1.142
5	279.00	1.332	-5.24	1.266	3.59	1.313
6	391.68	1.345	5.27	1.420	4.24	1.482
7	661.64	1.834	-3.40	1.773	5.99	1.886
8	898.02	2.081	-0.35	2.074	7.37	2.239
9	1173.21	2.424	-0.25	2.418	8.73	2.649
10	1332.48	2.508	4.09	2.614	9.41	2.886
11	1836.01	3.282	-1.65	3.229	11.16	3.634

Calibration Results Saved.

OK OP 1/10/2017





Eckert & Ziegler
Analytics

Rso
#1048
Rec'd 9/18/16

1380 Seaboard Industrial Blvd.
Atlanta, Georgia 30318
Tel 404-352-8677
Fax 404-352-2837
www.ezag.com

CERTIFICATE OF CALIBRATION

Standard Reference Source

SRS Number: 103837

Source Description: 47 mm Diameter Simulated Filter in Stainless Steel Planchet

Product Code: 8401-GF-FP

Customer: ALS Laboratory Group

P.O. Number: FC001106, Item 3

This standard radionuclide source was prepared from an aliquot measured gravimetrically from a master radionuclide solution calibrated with a germanium gamma-ray spectrometer system. Additional radionuclides were added gravimetrically from solutions calibrated by gamma-ray spectrometry, ionization chamber, or liquid scintillation counting. Calibration and purity were checked using germanium gamma-ray spectrometry. At the time of calibration no interfering gamma-ray emitting impurities were detected. The gamma-ray emission rates for the most intense gamma-ray lines are given. Eckert & Ziegler Analytics (EZA) maintains traceability to the National Institute of Standards and Technology (NIST) through a Measurements Assurance Program as described in USNRC Regulatory Guide 4.15, Revision 2, July 2007, and compliance with ANSI N42.22-1995, "Traceability of Radioactive Sources to NIST."

Reference Date: 01-July-2016

12:00 PM EST

MGS Mixture

Isotope	Gamma-Ray Energy, keV	Half-Life, d	Activity, Bq	Flux, s ⁻¹	Uncertainty			Calibration Method**
					u _A , %	u _B , %	U, %*	
Am-241	59.5	1.580E+08	1.794E+03	6.441E+02	0.1	1.8	3.6	4π LS
Cd-109	88.0	4.614E+02	2.482E+04	9.184E+02	0.5	2.0	4.1	HPGe
Co-57	122.1	2.717E+02	5.815E+02	4.978E+02	0.4	1.7	3.4	HPGe
Ce-139	165.9	1.376E+02	8.678E+02	6.943E+02	0.4	1.7	3.6	HPGe
Hg-203	279.2	4.659E+01	1.916E+03	1.563E+03	0.3	1.7	3.5	HPGe
Sn-113	391.7	1.151E+02	1.507E+03	9.793E+02	0.4	1.9	3.9	HPGe
Cs-137	661.7	1.099E+04	7.409E+02	6.305E+02	0.7	1.9	4.1	HPGe
Y-88	898.0	1.066E+02	2.507E+03	2.349E+03	0.7	1.7	3.7	HPGe
Y-88	1836.1			2.487E+03	0.7	1.7	3.7	
Co-60	1173.2	1.925E+03	1.172E+03	1.170E+03	0.7	1.8	3.9	HPGe
Co-60	1332.5			1.172E+03	0.7	1.8	3.9	

Mixed Gamma (MGS) master solution is EZA's eight isotope mixture which is calibrated quarterly and consists of Cd-109, Co-57, Ce-139, Hg-203, Sn-113, Cs-137, Y-88, and Co-60. *Uncertainty: U - Relative expanded uncertainty, k = 2. See NIST Technical Note 1297, "Guidelines for Evaluating and Expressing the Uncertainty of NIST Measurement Results." **Calibration Methods: 4π LS - 4π Liquid Scintillation Counting, HPGe - High Purity Germanium Gamma-Ray Spectrometer, IC - Ionization Chamber.

(Certificate continued on reverse side)

SRS Number: 103837

Comments:

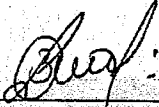
Diameter of active area: 47 mm

Tall smooth bottom planchet

Expiration Date: 16-August-2017

This source was wipe tested in its inactive areas with leak test results $< 185 \text{ Bq}$ (5 nCi) of removable activity per ISO 9978:1992.

Source Prepared by:


Z. Dimitrova, Radiochemist

QC Approved by:


J. Lahr, Spectroscopist

Date: 15-AUG-16

SEEKER G A M M A A N A L Y S I S R E S U L T S PS Version 1.8.4

ALS Laboratory Group - Fort Collins

GammaScan

Geo.9 / CHARC. FLTR

Sample ID: 110816-7 FWHM CAL (1047)

Sampling Start: 07/01/2016 10:00:00 | Counting Start: 11/08/2016 07:29:51
Sampling Stop: 07/01/2016 10:00:00 | Decay Time. 3.12E+003 Hrs
Buildup Time. 0.00E+000 Hrs | Live Time 1800 Sec
Sample Size 1.00E+000 SAMPLE | Real Time 1938 Sec
Collection Efficiency 1.0000 | Spc. File 161193D07.SPC

Detector #: 7 (Detector 7)

Energy(keV)= -2.38 + 0.501*Ch + 0.00E+00*Ch^2 + 0.00E+00*Ch^3 11/08/2016

FWHM(keV) = 0.66 + 0.004*En + 1.28E-03*En^2 + 0.00E+00*En^3 11/11/2015

Where En = Sqrt(Energy in keV)

Search Sensitivity: 1.00 | Sigma Multiplier: 2.00 | Search Start/End: 80/4000

=====

PEAK SEARCH RESULTS

=====

PK. #	ENERGY (keV)	ADDRESS CHANNEL	NET/MDA COUNTS	UN- CERTAINTY	C.L. COUNTS	BKG COUNTS	FWHM (keV)	FLAG
1	59.41	123.38	31064	424	194	7609	0.78	a
2	70.73	145.99	953	210	165	6036	0.74	a
3	72.75	150.02	1603	216	165	6036	0.69	b
4	82.29	169.07	610	259	209	8823	0.76	a
5	87.95	180.37	124458	746	200	8074	0.84	a
6	121.93	248.23	75535	585	164	5410	0.89	a
7	136.35	277.02	9478	286	173	5505	0.92	a
8	165.77	335.78	74439	581	165	5035	0.97	a
9	255.10	514.15	2156	193	139	3593	1.06	a
10	279.18	562.24	32639	401	143	3480	1.14	a
11	391.74	787.02	46363	461	135	3360	1.28	a
12	461.38	926.07	89	120	98	2169	0.90	a NET< CL
13	509.16	1021.49	101	161	131	2989	1.44	a NET< CL
14	511.46	1026.08	525	192	153	3653	1.86	b
15	661.87	1326.44	40139	435	139	3550	1.68	a
16	801.30	1604.87	148	175	143	3129	2.25	a
17	813.76	1629.75	668	150	116	2605	1.85	a
18	898.18	1798.33	45107	454	132	3225	2.01	a HiResid
19	1114.98	2231.26	127	148	120	2568	2.08	a
20	1173.30	2347.72	38669	416	110	1999	2.43	a HiResid
21	1324.69	2650.05	433	119	92	1446	2.23	a

PEAK SEARCH RESULTS

PK. #	ENERGY (keV)	ADDRESS CHANNEL	NET/MDA COUNTS	UN- CERTAINTY	C.L. COUNTS	BKG COUNTS	FWHM (keV)	FLAG
22	1332.43	2665.49	34714	389	92	1346	2.63	a HiResid
23	1835.37	3669.82	24873	323	59	480	3.29	a HiResid

SEEKER

C A L I B R A T I O N R E S U L T S

Version 2.0.4

Sample ID: 110816-7 FWHM CAL (1047)

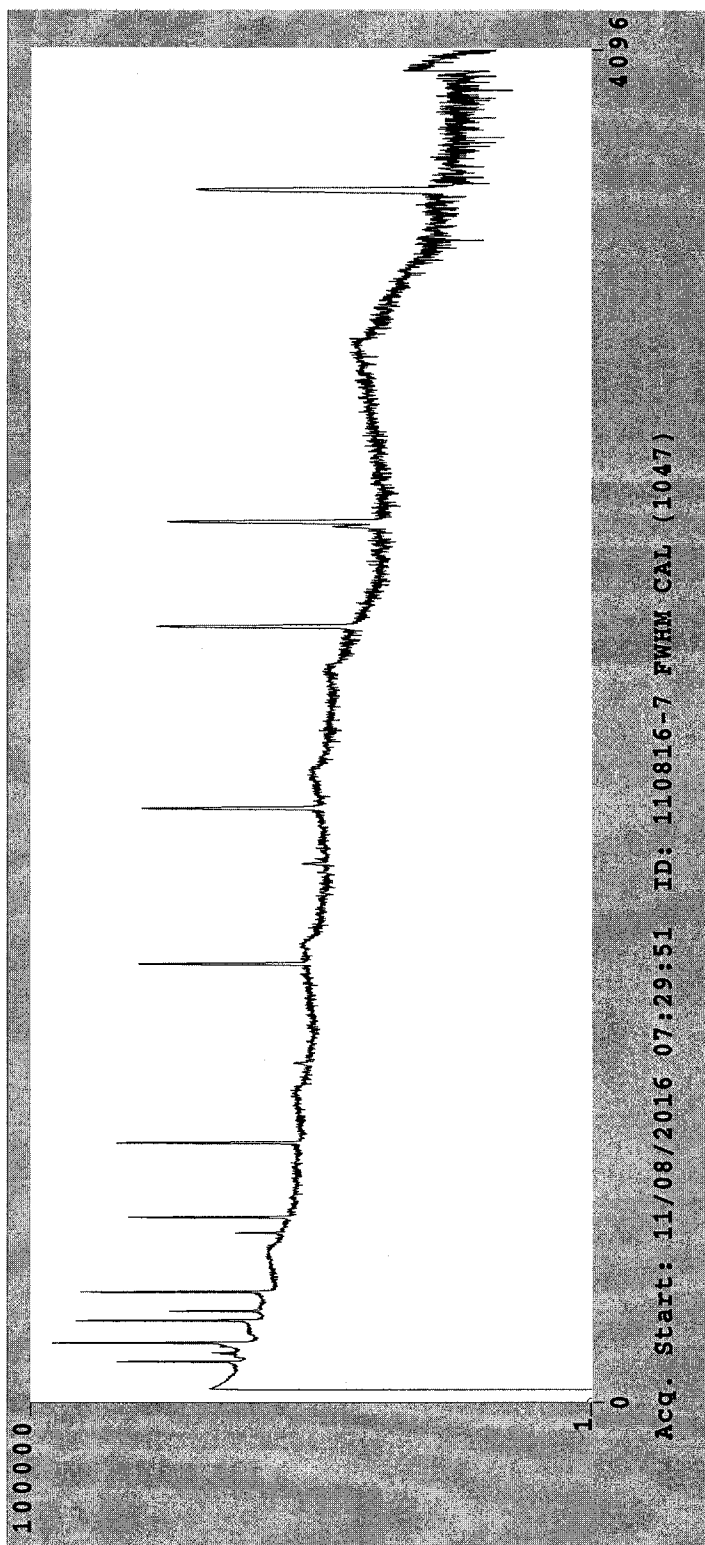
Stds. Match Tolerance: 2.00 keV

Detector Number: 07Calibration Date. . . 11/08/2016 07:29:51
-----FWHM(keV) = 0.65 + 0.008*En + 1.26e-03*En^2 + 0.00e+00*En^3
(Where En = SQR(Energy in keV))

Pk. #	Energy (keV)	Measured FWHM(keV)	% Diff.	Calculated FWHM(keV)	% Diff.	Prev.Calc. FWHM(keV)
1	59.50	0.782	0.45	0.785	-1.19	0.776
2	88.04	0.836	-0.15	0.835	-1.78	0.820
3	122.06	0.895	-0.38	0.891	-2.27	0.871
4	165.85	0.970	-0.88	0.961	-2.70	0.936
5	279.00	1.141	-0.57	1.135	-3.30	1.098
6	391.68	1.284	1.37	1.302	-3.54	1.257
7	661.64	1.677	0.75	1.689	-3.61	1.630
8	898.02	2.008	0.62	2.021	-3.48	1.953
9	1173.21	2.432	-1.26	2.402	-3.27	2.326
10	1332.48	2.633	-0.49	2.620	-3.14	2.541
11	1836.01	3.289	0.48	3.305	-2.77	3.216

Calibration Results Saved.

OK JP
11/8/16



ASD
1047
Rec'd 8/18/16

CERTIFICATE OF CALIBRATION

Standard Reference Source

SRS Number: 103836

Source Description: Face Loaded Yellow Plastic Hi-Q Charcoal Cartridge

Product Code: 8401-EG-CH

Customer: ALS Laboratory Group

P.O. Number: FC001106, Item 2

This standard radionuclide source was prepared from an aliquot measured gravimetrically from a master radionuclide solution calibrated with a germanium gamma-ray spectrometer system. Additional radionuclides were added gravimetrically from solutions calibrated by gamma-ray spectrometry, ionization chamber, or liquid scintillation counting. Calibration and purity were checked using germanium gamma-ray spectrometry. At the time of calibration no interfering gamma-ray emitting impurities were detected. The gamma-ray emission rates for the most intense gamma-ray lines are given. Eckert & Ziegler Analytics (EZA) maintains traceability to the National Institute of Standards and Technology (NIST) through a Measurements Assurance Program as described in USNRC Regulatory Guide 4.15, Revision 2, July 2007, and compliance with ANSI N42.22-1995, "Traceability of Radioactive Sources to NIST."

Reference Date: 01-July-2016 12:00 PM EST

MGS Mixture

Isotope	Gamma-Ray Energy, keV	Half-Life, d	Activity, Bq	Flux, s ⁻¹	Uncertainty			Calibration Method**
					u _A , %	u _B , %	U, %*	
Am-241	59.5	1.580E+08	1.873E+03	6.726E+02	0.1	1.8	3.6	4π LS
Cd-109	88.0	4.614E+02	2.593E+04	9.596E+02	0.5	2.0	4.1	HPGe
Co-57	122.1	2.717E+02	6.076E+02	5.201E+02	0.4	1.7	3.4	HPGe
Ce-139	165.9	1.376E+02	9.068E+02	7.254E+02	0.4	1.7	3.6	HPGe
Hg-203	279.2	4.659E+01	2.002E+03	1.633E+03	0.3	1.7	3.5	HPGe
Sn-113	391.7	1.151E+02	1.575E+03	1.023E+03	0.4	1.9	3.9	HPGe
Cs-137	661.7	1.099E+04	7.742E+02	6.588E+02	0.7	1.9	4.1	HPGe
Y-88	898.0	1.066E+02	2.619E+03	2.454E+03	0.7	1.7	3.7	HPGe
Y-88	1836.1	—	—	2.598E+03	0.7	1.7	3.7	—
Co-60	1173.2	1.925E+03	1.225E+03	1.223E+03	0.7	1.8	3.9	HPGe
Co-60	1332.5	—	—	1.225E+03	0.7	1.8	3.9	—

Mixed Gamma (MGS) master solution is EZA's eight isotope mixture which is calibrated quarterly and consists of Cd-109, Co-57, Ce-139, Hg-203, Sn-113, Cs-137, Y-88, and Co-60. ***Uncertainty:** U - Relative expanded uncertainty, k = 2. See NIST Technical Note 1297, "Guidelines for Evaluating and Expressing the Uncertainty of NIST Measurement Results." ****Calibration Methods:** 4π LS - 4π Liquid Scintillation Counting, HPGe - High Purity Germanium Gamma-Ray Spectrometer, IC - Ionization Chamber.

(Certificate continued on reverse side)

SRS Number: 103836

Comments:

Active material deposited on first 5 mm

Expiration Date: 16-August-2017

This source was wipe tested in its inactive areas with leak test results < 185 Bq (5 nCi) of removable activity per ISO 9978:1992.

Source Prepared by:



Z. Dimitrova, Radiochemist

QC Approved by:



J. Lahr, Spectroscopist

Date: 15-AUG-16

SEEKER

G A M M A A N A L Y S I S R E S U L T S PS Version 1.8.4

ALS Laboratory Group - Fort Collins

GammaScan

Geo 1 / Water

Sample ID: 110416-3 Geo 1 Eff Cal (1040)

```

-----
Sampling Start:    01/01/2016 10:00:00 | Counting Start:    11/04/2016 07:22:48
Sampling Stop:     01/01/2016 10:00:00 | Decay Time. . . . . 7.39E+003 Hrs
Buildup Time. . . . . 0.00E+000 Hrs | Live Time . . . . . 3600 Sec
Sample Size . . . . . 1.00E+000 L | Real Time . . . . . 3779 Sec
Collection Efficiency . . . . . 1.0000 | Spc. File . . . . . 161700D03.SPC
-----

```

Detector #: 3 (Detector 3)

Energy(keV) = -1.63 + 0.501*Ch + 0.00E+00*Ch^2 + 0.00E+00*Ch^3 11/04/2016

FWHM(keV) = 0.72 + 0.015*En + 8.18E-04*En^2 + 0.00E+00*En^3 11/04/2015

Where En = Sqrt(Energy in keV)

```

-----
Search Sensitivity: 1.00 | Sigma Multiplier: 2.00 | Search Start/End: 80/4000
-----

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=====
PEAK SEARCH RESULTS
=====

```

PK. #	ENERGY (keV)	ADDRESS CHANNEL	NET/MDA COUNTS	UN- CERTAINTY	C.L. COUNTS	BKG COUNTS	FWHM (keV)	FLAG
1	57.88	118.78	1792	501	406	20296	1.94	a Wide Pk
2	59.51	122.03	22695	415	234	10148	0.92	b
3	87.98	178.84	74430	633	263	12792	0.95	a
4	122.08	246.90	43952	489	207	7910	0.97	a HiResid
5	136.50	275.67	6001	276	188	6510	1.06	a
6	165.88	334.30	29625	423	202	6929	1.09	a
7	255.30	512.76	746	209	166	5438	1.08	a
8	279.26	560.56 Δ	2436	228	169	5306	1.30	a
9	350.61	702.96	134	268	219	6770	2.11	a NET< CL Wide Pk
10	391.80	785.16	17411	325	156	4258	1.41	a
11	511.55	1024.13	546	239	193	5016	2.36	a
12	651.53	1303.48	91	125	101	2227	1.13	a NET< CL
13	661.83	1324.05	44899	454	133	3283	1.70	a HiResid
14	814.09	1627.90	151	103	82	1569	0.96	a
15	898.29	1795.93	17857	318	141	3691	1.95	a HiResid
16	1173.51	2345.18	46888	451	103	1810	2.30	a HiResid
17	1332.74	2662.94	41512	423	93	1434	2.43	a HiResid
18	1836.30	3667.89	10546	211	41	249	2.99	a HiResid

Less Than 10,000 Counts achieved due to greater than
 5 1/2-lives ~~spc~~ elapsed.
 JP 11/10/16

161700D03.SPC Analyzed by

SEEKER BACKGROUND SUBTRACT RESULTS Version 1.8.2

ALS Laboratory Group - Fort Collins

GammaScan

Background File: DET031103.BKG (110316-3 WEEKLY BKG)

Bkg.File Detector #: 3

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BACKGROUND SUBTRACT RESULTS

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PK#	ENERGY (keV)	OLD NET COUNTS	OLD UN- CERTAINTY	OLD CR.LEVEL	NEW NET COUNTS	NEW UN- CERTAINTY	NEW CR.LEVEL	FLAG
9	350.61	134	268	219	118	268	219	NET<CL
11	511.55	547	239	193	466	240	194	

 SEEKER C A L I B R A T I O N R E S U L T S Version 2.0.4

Sample ID: 110416-3 Geo 1 Eff Cal (1040)

Stds. Match Tolerance: 2.00 keV

 Detector Number: 03 Calibration Date. . . 11/04/2016 07:22:48

Geometry File (D03)(Sh01).EFF ID. Geo 1 Eff Cal

Amount of Std. in Calib. Source: 1.000000 gm

Crossover: 300.00 keV

Below Crossover Efficiency Fit:

Eff = 10 ^ [-6.81e+01 + 8.58e+01*En +-3.67e+01*En^2 + 5.20e+00*En^3]

(Where En = LOG(Energy in keV)) (Polynomial)

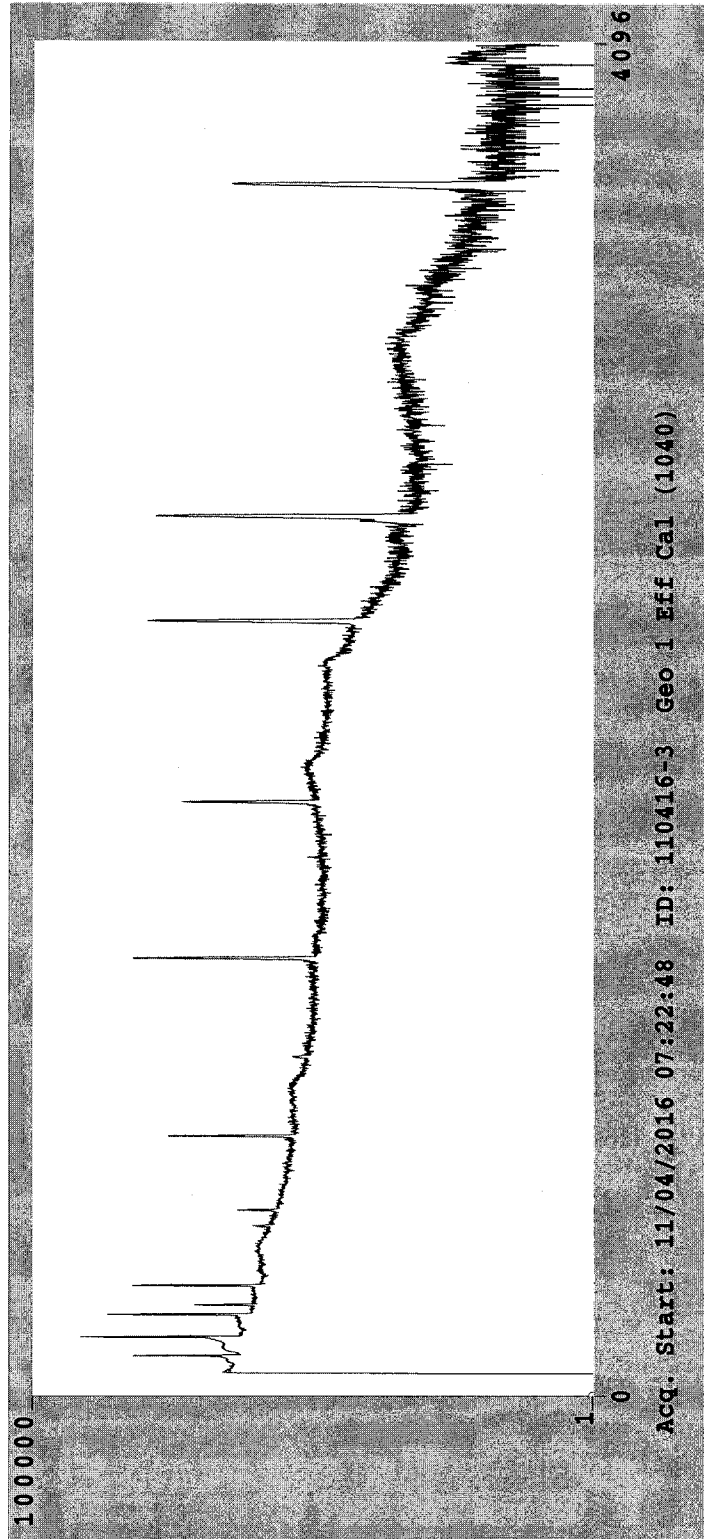
Above Knee Efficiency Fit:

Eff = 10 ^ [-6.20e+00 + 6.10e+00*En +-2.43e+00*En^2 + 2.82e-01*En^3]

(Where En = LOG(Energy in keV)) (Polynomial)

Pk. #	Energy (keV)	Measured Efficiency	% Difference	Calculated Efficiency	% Difference	Prev.Calc. Efficiency
1	59.50	4.67e-03	0.35	4.68e-03	2.80	4.82e-03
2	88.04	1.72e-02	-1.69	1.69e-02	-4.19	1.62e-02
3	122.06	2.47e-02	2.59	2.54e-02	1.32	2.57e-02
4	165.85	2.65e-02	-1.52	2.61e-02	-1.76	2.56e-02
5	279.00	2.02e-02	0.20	2.03e-02	-11.02	1.83e-02
6	391.68	1.52e-02	0.07	1.52e-02	-8.76	1.40e-02
7	661.64	9.76e-03	-0.59	9.70e-03	-5.35	9.21e-03
8	898.02	7.31e-03	1.25	7.40e-03	-2.68	7.21e-03
9	1173.21	5.94e-03	-1.19	5.87e-03	-0.83	5.82e-03
10	1332.48	5.25e-03	0.38	5.27e-03	-0.29	5.26e-03
11	1836.01	4.08e-03	0.06	4.08e-03	-0.42	4.07e-03

Calibration Results Saved.



Gamma Efficiency Calibration - Crossover energy efficiency difference

Calibration 11/4/2016
Detector 3
Geometry 1
Crossover energy=300 keV

	<u>EFF @ CROSSOVER</u>	<u>% DIFF*</u>	<u>MEETS ALS ACCEPTANCE CRITERIA?</u>
LOWER EFFICIENCY CURVE	0.019685	4.78%	OK
UPPER EFFICIENCY CURVE	0.018786	-4.56%	OK

*When a single calibration curve does not meet ALS acceptance criteria, a split-fit efficiency calibration may be employed. This entails the use of two separate energy range calibrations, a low energy efficiency curve and a high energy efficiency curve. A crossover energy must be specified that marks where the software will use either the low energy efficiency curve or the high energy efficiency curve. It should be noted that if a nuclide is specified that has a gamma photon energy that is equal to **OR** within 15 keV of the crossover energy, the potential exists for the calculated efficiencies at the crossover energy to be significantly different than the true detection efficiency of the detector. At times by as much as 20%. This is an artifact of the non-equivalency of the calibration equations specified for each energy range. This may result in an effective high or low bias to the analytical results. This bias is reflected in the above calculated % difference. ALS Environmental Fort Collins will not accept any calibration with an effective % difference of greater than 5% without supervisory approval. Results are submitted without further qualification.

Efficiency equations

Polynomial $10^{(A+B*(\text{LOG}(En))+C*(\text{LOG}(En))^2+D*(\text{LOG}(En))^3)}$
A -6.805418E+01
B 8.578433E+01
C -3.669556E+01
D 5.198629E+00
Calculated efficiency 0.019685

En is energy in keV

Crossover energy 300

Polynomial $10^{(A+B*(\text{LOG}(En))+C*(\text{LOG}(En))^2+D*(\text{LOG}(En))^3)}$
A -6.204802E+00
B 6.101844E+00
C -2.432638E+00
D 2.822783E-01
Calculated efficiency 0.018786

En is energy in keV

Crossover energy 300

OK J11/19/16

Standards File. Gsstd01.std
 Assay Date 01/01/2016 10:00
 ID.: Geo 1 Std#1040 1 L Mari. Mixed Gamma

Pk #	Nuclide	Energy	Halflife	Br.Ratio	dps/gm
=====					
1	Am-241	59.50	4.322E+02 yrs	0.35900	3768.80
2	Cd-109	88.04	4.626E+02 dys	0.03700	51567.57
3	Co-57	122.06	2.718E+02 dys	0.85510	1266.52
4	Ce-139	165.85	1.376E+02 dys	0.80350	1823.27
5	Hg-203	279.00	4.660E+01 dys	0.77300	4213.45
6	Sn-113	391.68	1.151E+02 dys	0.64900	3127.89
7	Cs-137	661.64	3.017E+01 yrs	0.85120	1530.78
8	Y-88	898.02	1.066E+02 dys	0.93400	5372.59
9	Co-60	1173.21	5.271E+00 yrs	0.99980	2450.49
10	Co-60	1332.48	5.271E+00 yrs	0.99990	2453.25
11	Y-88	1836.01	1.066E+02 dys	0.99380	5346.15



Eckert & Ziegler

Analytics

#1040
Rec'd
2-25-16

1380 Seaboard Industrial Blvd.
Atlanta, Georgia 30318
Tel 404-352-8677
Fax 404-352-2837
www.ezag.com

CERTIFICATE OF CALIBRATION

Standard Reference Source

SRS Number: 102366

Source Description: 1.0 Liter Solid in 138G GA-MA Beaker

Product Code: 8401-EG-SD

Customer: ALS Laboratory Group

P.O. Number: FC000928, Item 1

This standard radionuclide source was prepared from an aliquot measured gravimetrically from a master radionuclide solution calibrated with a germanium gamma-ray spectrometer system. Additional radionuclides were added gravimetrically from solutions calibrated by gamma-ray spectrometry, ionization chamber, or liquid scintillation counting. Calibration and purity were checked using germanium gamma-ray spectrometry. At the time of calibration no interfering gamma-ray emitting impurities were detected. The gamma-ray emission rates for the most intense gamma-ray lines are given. Eckert & Ziegler Analytics (EZA) maintains traceability to the National Institute of Standards and Technology (NIST) through a Measurements Assurance Program as described in USNRC Regulatory Guide 4.15, Revision 2, July 2007, and compliance with ANSI N42.22-1995, "Traceability of Radioactive Sources to NIST."

Density of solid matrix: 1.17 g/cm³ ± 3 %.

Reference Date: 01-January-2016

12:00 PM EST

MGS Mixture

Isotope	Gamma-Ray Energy, keV	Half-Life, d	Activity, Bq	Flux, s ⁻¹	Uncertainty			Calibration Method**
					u _A , %	u _B , %	U, %*	
Am-241	59.5	1.580E+05	3.768E+03	1.353E+03	0.1	1.8	3.6	4π LS
Cd-109	88.0	4.614E+02	5.156E+04	1.908E+03	0.5	2.0	4.1	HPGe
Co-57	122.1	2.717E+02	1.265E+03	1.083E+03	0.4	1.7	3.4	HPGe
Ce-139	165.9	1.376E+02	1.831E+03	1.465E+03	0.4	1.7	3.6	HPGe
Hg-203	279.2	4.659E+01	3.993E+03	3.257E+03	0.3	1.7	3.5	HPGe
Sn-113	391.7	1.151E+02	3.124E+03	2.030E+03	0.4	1.9	3.9	HPGe
Cs-137	661.7	1.099E+04	1.531E+03	1.303E+03	0.7	1.9	4.1	HPGe
Y-88	898.0	1.066E+02	5.356E+03	5.018E+03	0.7	1.7	3.7	HPGe
Y-88	1836.1	_____	_____	5.313E+03	0.7	1.7	3.7	_____
Co-60	1173.2	1.925E+03	2.453E+03	2.450E+03	0.7	1.8	3.9	HPGe
Co-60	1332.5	_____	_____	2.453E+03	0.7	1.8	3.9	_____

Mixed Gamma (MGS) master solution is EZA's eight isotope mixture which is calibrated quarterly and consists of Cd-109, Co-57, Ce-139, Hg-203, Sn-113, Cs-137, Y-88, and Co-60. *Uncertainty: U - Relative expanded uncertainty, k = 2. See NIST Technical Note 1297, "Guidelines for Evaluating and Expressing the Uncertainty of NIST Measurement Results." **Calibration Methods: 4π LS - 4π Liquid Scintillation Counting, HPGe - High Purity Germanium Gamma-Ray Spectrometer, IC - Ionization Chamber.

(Certificate continued on reverse side)

SRS Number: 102366

Expiration Date: 24-February-2017

This source was wipe tested in its inactive areas with leak test results < 185 Bq (5 nCi) of removable activity per ISO 9978:1992.

Source Prepared by: 
A. Herron, Radiochemist

QC Approved by:  Date: 24-FEB-16
J. Lahr, Spectroscopist

Geometry 1 Calibration Verification: Gamma Mixed Nuclide Source

1-Liter Water/Liquid Geometry

Detector 3

VERIF SCE: 999				REF DATE : 1/1/2014		Count Date: 11/4/2016						
FROM CALIBRATION CERTIFICATE				FROM ANALYTICS.LIB		EXPECTED ACTIVITY						
Isotope	KeV	Half Life(y)	Gammas/Sec.	Gamma Fraction:	Mass of Standard	DPS		pCi/L	Activity	Recovery	Pass/Fail	# of Half Lives Expired
Am-241	59.5	432.0000	1330	0.3590	1	Am-241	3704.7	100128.0	102000	102%	Pass	0.01
Cd-109	88	1.2666	1903	0.0372		Cd-109	51155.9	1382592.3	1420000	103%	Pass	2.24
Co-57	122	0.7441	1043	0.8551		Co-57	1219.7	32966.0	33000	100%	Pass	3.82
Ce-139	166	0.3768	1436	0.8035		Ce-139	1787.2	48302.2	47100	98%	Pass	7.54
Hg-203	279	0.1276	3083	0.7730		Hg-203	3988.4	107793.4	NC	>5 h-lives	>5 h-lives	22.28
Sn-113	392	0.3151	2031	0.6490		Sn-113	3129.4	84579.2	NC	>5 h-lives	>5 h-lives	9.02
Cs-137	662	30.0700	1287	0.8512		Cs-137	1512.0	40864.4	41100	101%	Pass	0.09
Y-88	898	0.2919	4873	0.9340		Y-88	5217.3	141009.3	NC	>5 h-lives	>5 h-lives	9.73
Co-60	1173	5.2714	2404	0.9998		Co-60	2404.5	64986.0	65500	101%	Pass	0.54
Co-60	1332	5.2714	2406	0.9999		Co-60	2406.2	65033.5	67000	103%	Pass	0.54
Y-88	1836	0.2919	5158	0.9938		Y-88	5190.2	140275.1	NC	>5 h-lives	>5 h-lives	9.73

NC=NOT CALCULATED DUE TO ACTIVITY<MDCa

OK 11/11/16

SEEKER G A M M A A N A L Y S I S R E S U L T S PS Version 1.8.4

ALS Laboratory Group - Fort Collins

GammaScan

Geo 1 / Water

Sample ID: 110416-3A Geo 1 Cal Ver (999)

```
-----
Sampling Start:      01/01/2014 10:00:00 | Counting Start:      11/04/2016 08:45:24
Sampling Stop:       01/01/2014 10:00:00 | Decay Time. . . . . 2.49E+004 Hrs
Buildup Time. . . . . 0.00E+000 Hrs | Live Time . . . . . 1800 Sec
Sample Size . . . . . 1.00E+000 L | Real Time . . . . . 1913 Sec
Collection Efficiency . . . . 1.0000 | Spc. File . . . . . 161701D03.SPC
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```

Detector #: 3 (Detector 3)

Energy(keV)= -1.63 + 0.501*Ch + 0.00E+00*Ch^2 + 0.00E+00*Ch^3 11/04/2016

FWHM(keV) = 0.73 + 0.017*En + 8.16E-04*En^2 + 0.00E+00*En^3 11/04/2016

Where En = Sqrt(Energy in keV)

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-----
Search Sensitivity: 1.00 | Sigma Multiplier: 2.00 | Search Start/End: 80/4000
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PEAK SEARCH RESULTS

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=====
PK.   ENERGY   ADDRESS   NET/MDA   UN-      C.L.      BKG      FWHM
#      (keV)     CHANNEL   COUNTS   CERTAINTY COUNTS    COUNTS   (keV)   FLAG
-----
 1     59.54     122.09    11347     265       130       3135     0.93 a
 2     88.01     178.89    12631     267       118       2592     0.95 a
 3    122.12     246.97     3352     166        98       1762     0.99 a
 4    136.60     275.88     348      110        85       1473     0.76 a
 5    165.78     334.11     353      133       105       1890     1.13 a
 6    182.36     367.19     137      141       115       2083     1.31 a
 7    661.84    1324.07    21188     303        68        859     1.63 a HiResid
 8   1173.52    2345.20    17609     275        59        588     2.26 a HiResid
 9   1332.75    2662.97    16185     257        32        173     2.41 a HiResid
10   1836.36    3667.99      28      18        12        28     1.84 a
=====
```

161701D03.SPC Analyzed by

SEEKER B A C K G R O U N D S U B T R A C T R E S U L T S Vers. 2.2.1

ALS Laboratory Group - Fort Collins

GammaScan

Background File:. DET031103.BKG (110316-3 WEEKLY BKG)

Bkg.File Detector #: 3

=====

BACKGROUND SUBTRACT RESULTS

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PK#	ENERGY (keV)	OLD NET COUNTS	OLD UN- CERTAINTY	OLD CR.LEVEL	NEW NET COUNTS	NEW UN- CERTAINTY	NEW CR.LEVEL	FLAG

SEEKER

F I N A L A C T I V I T Y R E P O R T

Version 2.2.1

ALS Laboratory Group - Fort Collins

GammaScan

Geo 1 / Water

Sample ID: 110416-3A Geo 1 Cal Ver (999)

```

-----
Sampling Start:    01/01/2014 10:00:00 | Counting Start:    11/04/2016 08:45:24
Sampling Stop:     01/01/2014 10:00:00 | Decay Time. . . . . 2.49e+004 Hrs
Buildup Time. . . . . 0.00e+000 Hrs | Live Time . . . . . 1800 Sec
Sample Size . . . . . 1.00e+000 L | Real Time . . . . . 1913 Sec
Collection Efficiency . . . . . 1.0000 | Spectrum File . . . . . 161701D03.SPC
Cr. Level Confidence Interval: 95 % | Det. Limit Confidence Interval: 95 %
-----

```

Detector #: 3 (Detector 3)

Efficiency File: (D03)(Sh01).EFF (Geo 1 Eff Cal)

Eff=10^[-6.81E+01 +8.58E+01*L +-3.67E+01*L² +5.20E+00*L³] 11/04/2016Eff.=10^[-6.20E+00 +6.10E+00*L +-2.43E+00*L² +2.82E-01*L³] Above 300.00 keV

Library File:ANALYTICAL.LIB (Analytical)

=====

MEASURED or MDA CONCENTRATIONS

```

=====
              N
      ENERGY E      Concentration      Critical  Halflife
Nuclide  (keV) T  (pCi/L )      MDA      Level      (hrs)
-----
Am-241    59.54    1.02E+05 +- 2.37E+03  2.35E+03  1.17E+03  3.79E+06
Cd-109     88.02    1.42E+06 +- 3.01E+04  2.70E+04  1.33E+04  1.11E+04
Co-57     122.07    3.30E+04 +- 1.63E+03  1.95E+03  9.62E+02  6.50E+03
Ce-139     165.85    4.71E+04 +- 1.78E+04  2.84E+04  1.40E+04  3.30E+03
Cs-137     661.62    4.11E+04 +- 5.87E+02  2.70E+02  1.32E+02  2.64E+05
Co-60      Average:x 6.62E+04 +- 7.38E+02  . . . . .  . . . . . 4.62E+04
              1173.21 6.55E+04 +- 1.02E+03  4.47E+02  2.18E+02  4.62E+04
              1332.48 6.70E+04 +- 1.07E+03  2.80E+02  1.34E+02  4.62E+04
Hg-203     279.18      MDA      . . . . . 9.39E+08  4.63E+08  1.12E+03
Sn-113     391.68      MDA      . . . . . 1.38E+05  6.77E+04  2.76E+03
Y-88       898.02      MDA      . . . . . 3.07E+05  1.51E+05  2.56E+03

```

MEASURED TOTAL: 1.71E+06 +- 5.32E+04 pCi/L

=====

UNKNOWN,SUM or ESCAPE PEAKS

```

=====
PK.  ENERGY  ADDRESS      NET      UN-      C.L.      BKG      FWHM
#    (keV)    CHANNEL    COUNTS  CERTAINTY  COUNTS    COUNTS    (keV)    FLAG
-----
  4    136.60   275.88        348        110        85       1473     0.76   Unknown

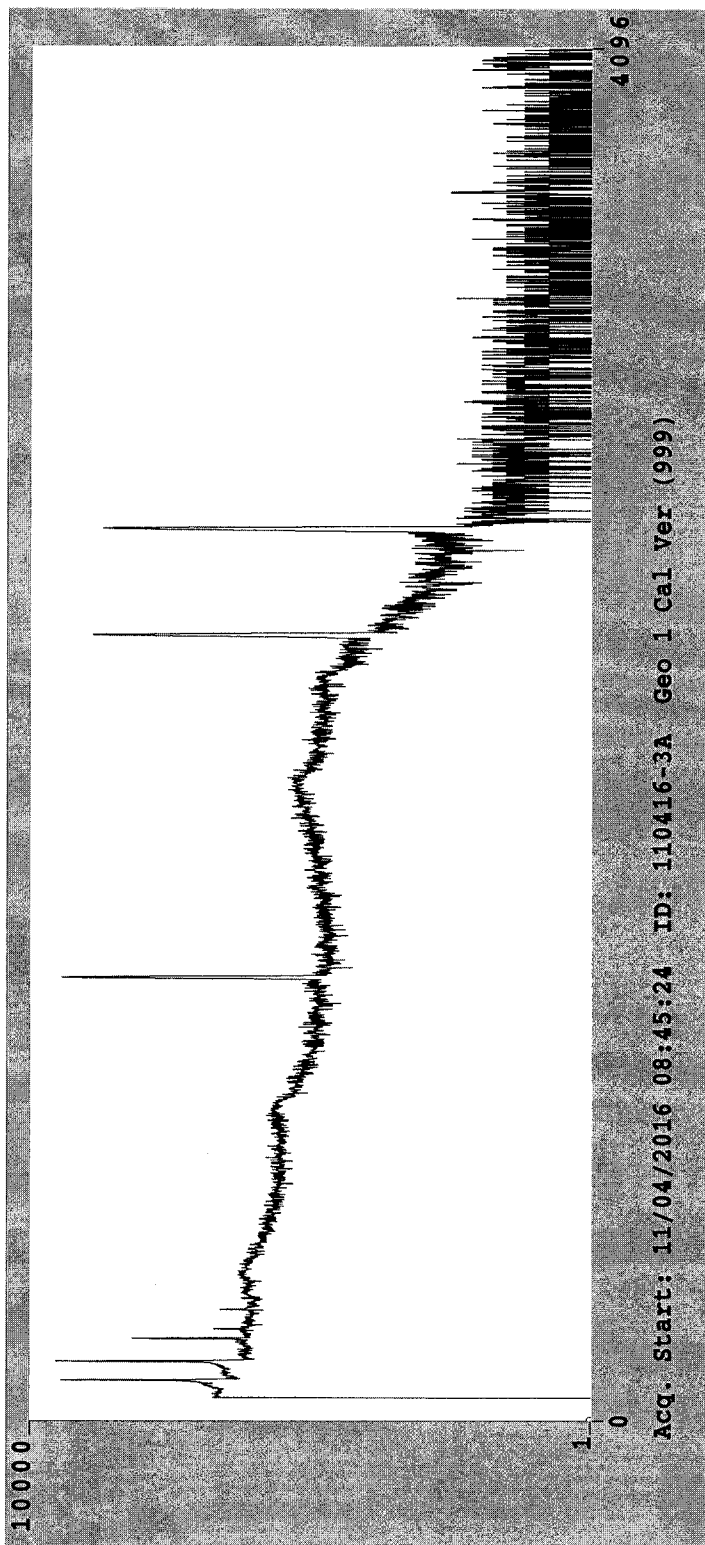
```

161701D03.SPC Analyzed by

UNKNOWN, SUM or ESCAPE PEAKS

PK. #	ENERGY (keV)	ADDRESS CHANNEL	NET COUNTS	UN- CERTAINTY	C.L. COUNTS	BKG COUNTS	FWHM (keV)	FLAG
6	182.36	367.19	137	141	115	2083	1.31	Unknown
10	1836.36	3667.99	28	18	12	28	1.84	Unknown

c:\SEEKER\BIN\161701d03.res Analysis Results Saved.





Eckert & Ziegler
Analytics

RSO #
999

Received
2/26/2014
JP

1380 Seaboard Industrial Blvd.
Atlanta, Georgia 30318
Tel 404-352-8677
Fax 404-352-2837
www.analytiscinc.com

CERTIFICATE OF CALIBRATION

Standard Radionuclide Source

95548

1.0 Liter Solid in 138G GA-MA Beaker

Customer: ALS Laboratory Group

P.O. No.: FC000236, Item 1

Product Code 8401-EG-SD

Reference Date: 01-Jan-2014

12:00 PM EST Grams of Master Source: 0.011697

This standard radionuclide source was prepared using aliquots measured gravimetrically from master radionuclide solutions. Additional radionuclides were added gravimetrically from solutions calibrated by gamma-ray spectrometry, ionization chamber, or liquid scintillation counting. Calibration and purity were checked using a germanium gamma spectrometer system. At the time of calibration no interfering gamma-ray emitting impurities were detected. The gamma-ray emission rates for the most intense gamma-ray lines are given. Eckert & Ziegler Analytics (EZA) maintains traceability to the National Institute of Standards and Technology through a Measurements Assurance Program as described in USNRC Regulatory Guide 4.15, Revision 2, July 2007, and compliance with ANSI N42.22-1995, "Traceability of Radioactive Sources to NIST." EZA is accredited by the Health Physics Society (HPS) for the production of NIST-traceable sources, and this source was produced in accordance with the HPS accreditation requirements. Customers may report any concerns with the accreditation program to the HPS Secretariat, 1313 Dolley Madison Blvd., Ste. 402, McLean, VA 22101.

Density of solid matrix 1.15 g/cc.

Nuclide	Gamma-Ray Energy (keV)	Half-Life, Days	Master Source* yps/gram	This Source yps	Uncertainty*, %			Calibration Method*
					Type	u _A	u _B		U
Am-241	59.5	1.580E+05	—	1.330E+03	0.1	1.6	3.2	4π LS
Cd-109	88.0	4.614E+02	1.627E+05	1.903E+03	0.5	2.0	4.1	HPGe
Co-57	122.1	2.717E+02	8.915E+04	1.043E+03	0.4	1.7	3.5	HPGe
Ce-139	165.9	1.376E+02	1.228E+05	1.436E+03	0.4	1.7	3.5	HPGe
Hg-203	279.2	4.659E+01	2.636E+05	3.083E+03	0.3	1.7	3.5	HPGe
Sn-113	391.7	1.151E+02	1.736E+05	2.031E+03	0.4	1.9	3.9	HPGe
Cs-137	661.7	1.099E+04	1.100E+05	1.287E+03	0.7	1.9	4.0	HPGe
Y-88	898.0	1.066E+02	4.166E+05	4.873E+03	0.5	1.7	3.5	HPGe
Co-60	1173.2	1.925E+03	2.055E+05	2.404E+03	0.6	1.8	3.8	HPGe
Co-60	1332.5	1.925E+03	2.057E+05	2.406E+03	0.7	1.8	3.9	HPGe
Y-88	1836.1	1.066E+02	4.410E+05	5.158E+03	0.7	1.7	3.7	HPGe

* Master Source refers to Analytics' 8-isotope mixture which is calibrated quarterly.

Calibration Methods: 4π LS - 4 pi Liquid Scintillation Counting, HPGe - High Purity Germanium Gamma-Ray Spectrometer, IC - Ionization Chamber. **Uncertainty:** U - Relative expanded uncertainty, k = 2. See NIST Technical Note 1297, "Guidelines for Evaluating and Expressing the Uncertainty of NIST Measurement Results."

(Certificate continued on reverse side)

Standard Re-Verified
3/7/16.

New Expiration
Date => 03/07/2017.

JP 3/18/16



MGS Certificate Rev 5, 1 October 2013

Corporate Office

24937 Avenue Tibbitts - Valencia, California 91355

Laboratory

1380 Seaboard Industrial Blvd. Atlanta, Georgia 30318

Page 1 of 2

This standard will expire one year after the reference date.

Source Prepared by:

K. Eardley
Radiochemist

QA Approved:

J.D. McCorvey
Counting Room Manager

Date: 24 Feb 14



SEEKER G A M M A A N A L Y S I S R E S U L T S PS Version 1.8.4

ALS Laboratory Group - Fort Collins
GammaScan

Geo 1 / Water

Sample ID: 032017-4 GEO1 EFF CAL (1056)

```

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Sampling Start:    01/01/2017 10:00:00 | Counting Start:    03/20/2017 09:25:31
Sampling Stop:    01/01/2017 10:00:00 | Decay Time. . . . . 1.87E+003 Hrs
Buildup Time. . . . . 0.00E+000 Hrs | Live Time . . . . . 1500 Sec
Sample Size . . . . . 1.00E+000 L | Real Time . . . . . 1573 Sec
Collection Efficiency . . . . 1.0000 | Spc. File . . . . . 170523D04.SPC
-----

```

Detector #: 4 (Detector 4)

Energy(keV)= -1.58 + 0.501*Ch + 0.00E+00*Ch^2 + 0.00E+00*Ch^3 03/20/2017

FWHM(keV) = 0.80 + 0.010*En + 1.10E-03*En^2 + 0.00E+00*En^3 01/10/2017

Where En = Sqrt(Energy in keV)

Search Sensitivity: 1.00 | Sigma Multiplier: 2.00 | Search Start/End: 80/4000

PEAK SEARCH RESULTS

```

=====
PK.   ENERGY   ADDRESS   NET/MDA   UN-   C.L.   BKG   FWHM
#     (keV)     CHANNEL   COUNTS   CERTAINTY COUNTS COUNTS (keV)  FLAG
-----
 1    59.43     121.73    11262     318      194    7618   0.77 a HiResid
 2    70.57     143.95     842      247      198    7893   0.79 a
 3    72.80     148.42    1276      251      198    7893   0.79 b
 4    82.77     168.31    2668      548      443   20708   2.51 a HiResid
                               Wide Pk
 5    85.89     174.53    4656      555      443   20708   2.53 b HiResid
 6    87.93     178.61   44587      495      212    8283   0.96 c HiResid
 7   122.06     246.71   28727      413      194    6961   1.02 a HiResid
 8   136.47     275.46    3497      250      181    6059   0.92 a HiResid
 9   165.84     334.07   34276      437      191    6216   1.11 a HiResid
10   255.17     512.33     978      163      124    3245   1.04 a
11   262.05     526.05     72      113      92    2068   0.62 a NET< CL
12   279.22     560.30   24967      360      142    3736   1.29 a HiResid
13   391.75     784.87   23158      334      114    2406   1.38 a HiResid
14   511.08   1022.97     559      176      140    3007   2.26 a
15   587.46   1175.39     86       90       72    1199   1.06 a
16   661.75   1323.62   15222      288      122    2622   1.84 a HiResid
17   813.54   1626.53     492      165      131    2523   2.97 a
18   898.16   1795.36   25012      344      112    2234   2.17 a HiResid
19  1173.45   2344.69   15747      283      108    1835   2.56 a HiResid
20  1328.25   2653.59   1821      202      151    1979   6.34 a HiResid

```

PEAK SEARCH RESULTS

PK. #	ENERGY (keV)	ADDRESS CHANNEL	NET/MDA COUNTS	UN- CERTAINTY	C.L. COUNTS	BKG COUNTS	FWHM (keV)	FLAG
								Wide Pk
21	1332.67	2662.42	14552	256	72	812	2.59	b HiResid
22	1383.95	2764.74	52	60	48	455	1.65	a
23	1836.08	3666.94	13564	246	65	582	3.32	a HiResid

170523D04.SPC Analyzed by

SEEKER BACKGROUND SUBTRACT RESULTS Version 1.8.2

ALS Laboratory Group - Fort Collins
GammaScan

Background File: DET040315.BKG (031517-4 WEEKLY BKG)

Bkg.File Detector #: 4

=====

BACKGROUND SUBTRACT RESULTS

=====

PK#	ENERGY (keV)	OLD NET COUNTS	OLD UN- CERTAINTY	OLD CR.LEVEL	NEW NET COUNTS	NEW UN- CERTAINTY	NEW CR.LEVEL	FLAG
3	72.80	1276	251	198	1274	251	198	
4	82.77	2668	548	443	2666	548	443	
14	511.08	559	176	140	529	176	140	

SEEKER CALIBRATION RESULTS Version 2.0.4

Sample ID: 032017-4 GEO1 EFF CAL (1056)

Stds. Match Tolerance: 2.00 keV

Detector Number: 04 Calibration Date. . . 03/20/2017 09:25:31

Geometry File (D04)(Sh01).EFF ID. Geo 1 Eff Cal

Amount of Std. in Calib. Source: 1.000000 gm

Crossover: 300.00 keV

Below Crossover Efficiency Fit:

$$\text{Eff} = 10 ^ { [-6.94\text{e}+01 + 8.84\text{e}+01*\text{En} + -3.82\text{e}+01*\text{En}^2 + 5.45\text{e}+00*\text{En}^3]}$$

(Where En = LOG(Energy in keV)) (Polynomial)

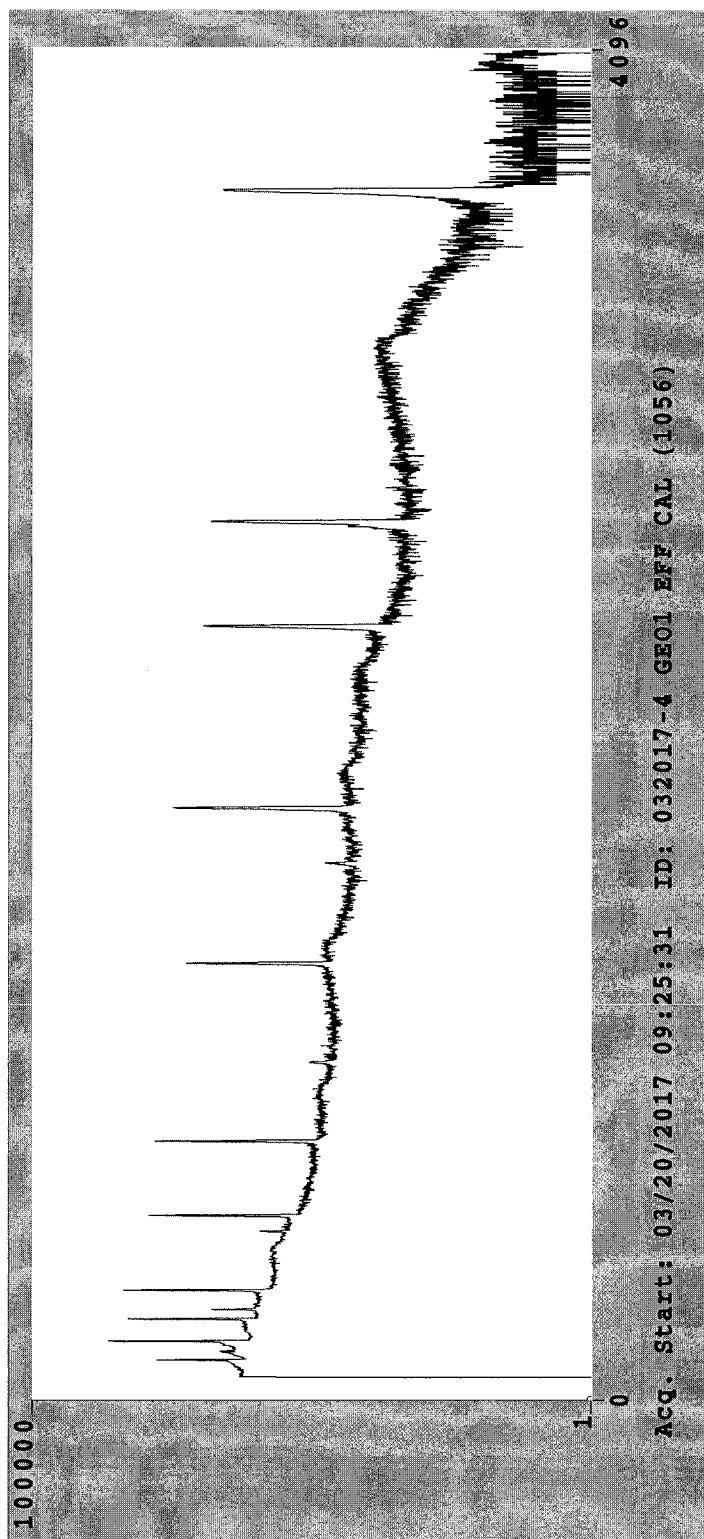
Above Knee Efficiency Fit:

$$\text{Eff} = \exp ^ { [-2.79\text{e}-01 + -5.09\text{e}-01*\text{En} + -3.05\text{e}-02*\text{En}^2]}$$
(Where En = Energy in keV) (Linear/Quad)

Pk. #	Energy (keV)	Measured Efficiency	% Difference	Calculated Efficiency	% Difference	Prev.Calc. Efficiency
1	59.50	5.22e-03	0.54	5.25e-03	-0.01	5.25e-03
2	88.04	1.76e-02	-2.60	1.72e-02	-0.01	1.72e-02
3	122.06	2.29e-02	3.95	2.38e-02	-0.01	2.38e-02
4	165.85	2.35e-02	-2.34	2.29e-02	-0.01	2.29e-02
5	279.00	1.66e-02	0.31	1.67e-02	-0.01	1.67e-02
6	391.68	1.22e-02	0.17	1.22e-02	-0.00	1.22e-02
7	661.64	7.72e-03	-1.09	7.64e-03	-0.00	7.64e-03
8	898.02	5.70e-03	1.29	5.77e-03	-0.00	5.77e-03
9	1173.21	4.43e-03	1.55	4.50e-03	-0.00	4.50e-03
10	1332.48	4.09e-03	-2.48	3.99e-03	-0.00	3.99e-03
11	1836.01	2.92e-03	0.50	2.93e-03	-0.00	2.93e-03

Calibration Results Saved.

OK JP 3/20/17



Gamma Efficiency Calibration - Crossover energy efficiency difference

Calibration 3/20/2017
Detector 4
Geometry 1
Crossover energy=300 keV

	<u>EFF @ CROSSOVER</u>	<u>% DIFF*</u>	<u>MEETS ALS ACCEPTANCE CRITERIA?</u>
LOWER EFFICIENCY CURVE	0.016028	4.42%	OK
UPPER EFFICIENCY CURVE	0.015350	-4.23%	OK

*When a single calibration curve does not meet ALS acceptance criteria, a split-fit efficiency calibration may be employed. This entails the use of two separate energy range calibrations, a low energy efficiency curve and a high energy efficiency curve. A crossover energy must be specified that marks where the software will use either the low energy efficiency curve or the high energy efficiency curve. It should be noted that if a nuclide is specified that has a gamma photon energy that is equal to OR within 15 keV of the crossover energy, the potential exists for the calculated efficiencies at the crossover energy to be significantly different than the true detection efficiency of the detector. At times by as much as 20%. This is an artifact of the non-equivalency of the calibration equations specified for each energy range. This may result in an effective high or low bias to the analytical results. This bias is reflected in the above calculated % difference. ALS Environmental will not accept any calibration with an effective % difference of greater than 5% without supervisory approval. Results are submitted without further qualification.

Efficiency equations

Polynomial $10^{(A+B*(\text{LOG}(En))+C*(\text{LOG}(En))^2+D*(\text{LOG}(En))^3)}$

A -6.940537E+01
B 8.839590E+01
C -3.817472E+01
D 5.453176E+00

Calculated efficiency 0.016028

En is energy in keV

Crossover energy 300

Linear $e^{(A+(B*(\ln(En)))+(C*(\ln(En))^2))}$

A -2.787562E-01
B -5.092880E-01
C -3.052374E-02

Calculated efficiency 0.015350

En is energy in keV

Crossover energy 300

OK JP 3/20/17

Standards File. Gsstd01.std
Assay Date 01/01/2017 10:00
ID.: Geo 1 Std#1056 1 L Mari. Mixed Gamma

Pk #	Nuclide	Energy	Halflife	Br.Ratio	dps/gm
1	Am-241	59.50	4.322E+02 yrs	0.35900	4008.36
2	Cd-109	88.04	4.626E+02 dys	0.03700	51162.16
3	Co-57	122.06	2.718E+02 dys	0.85510	1194.01
4	Ce-139	165.85	1.376E+02 dys	0.80350	1795.67
5	Hg-203	279.00	4.660E+01 dys	0.77300	4135.83
6	Sn-113	391.68	1.151E+02 dys	0.64900	3129.43
7	Cs-137	661.64	3.017E+01 yrs	0.85120	1551.93
8	Y-88	898.02	1.066E+02 dys	0.93400	5199.14
9	Co-60	1173.21	5.271E+00 yrs	0.99980	2437.49
10	Co-60	1332.48	5.271E+00 yrs	0.99990	2440.24
11	Y-88	1836.01	1.066E+02 dys	0.99380	5173.07

CERTIFICATE OF CALIBRATION

Standard Reference Source

SRS Number: 105114

Source Description: 1.0 Liter Solid in 138G GA-MA Beaker

Product Code: 8401-EG-SD

Customer: ALS Laboratory Group

P.O. Number: FC001290, Item 1

This standard radionuclide source was prepared from an aliquot measured gravimetrically from a master radionuclide solution calibrated with a germanium gamma-ray spectrometer system. Additional radionuclides were added gravimetrically from solutions calibrated by gamma-ray spectrometry, ionization chamber, or liquid scintillation counting. Calibration and purity were checked using germanium gamma-ray spectrometry. At the time of calibration no interfering gamma-ray emitting impurities were detected. The gamma-ray emission rates for the most intense gamma-ray lines are given. Eckert & Ziegler Analytics (EZA) maintains traceability to the National Institute of Standards and Technology (NIST) through a Measurements Assurance Program as described in USNRC Regulatory Guide 4.15, Revision 2, July 2007, and compliance with ANSI N42.22-1995, "Traceability of Radioactive Sources to NIST."

Density of solid matrix: 1.17 g/cm³ ± 3 %.

Reference Date: 01-January-2017 12:00 PM EST

MGS Mixture

Isotope	Gamma-Ray Energy, keV	Half-Life, d	Activity, Bq	Flux, s ⁻¹	Uncertainty			Calibration Method**
					u _A , %	u _B , %	U, %*	
Am-241	59.5	1.580E+05	4.008E+03	1.439E+03	0.1	1.8	3.6	4π LS
Cd-109	88.0	4.614E+02	5.115E+04	1.893E+03	0.5	2.0	4.1	HPGe
Co-57	122.1	2.717E+02	1.193E+03	1.021E+03	0.4	1.7	3.4	HPGe
Ce-139	165.9	1.376E+02	1.804E+03	1.443E+03	0.4	1.7	3.6	HPGe
Hg-203	279.2	4.659E+01	3.919E+03	3.197E+03	0.3	1.7	3.5	HPGe
Sn-113	391.7	1.151E+02	3.127E+03	2.031E+03	0.4	1.9	3.9	HPGe
Cs-137	661.7	1.099E+04	1.553E+03	1.321E+03	0.7	1.9	4.1	HPGe
Y-88	898.0	1.066E+02	5.183E+03	4.856E+03	0.7	1.7	3.7	HPGe
Y-88	1836.1	—	—	5.141E+03	0.7	1.7	3.7	—
Co-60	1173.2	1.925E+03	2.440E+03	2.437E+03	0.7	1.8	3.9	HPGe
Co-60	1332.5	—	—	2.440E+03	0.7	1.8	3.9	—

Mixed Gamma (MGS) master solution is EZA's eight isotope mixture which is calibrated quarterly and consists of Cd-109, Co-57, Ce-139, Hg-203, Sn-113, Cs-137, Y-88, and Co-60. ***Uncertainty:** U - Relative expanded uncertainty, k = 2. See NIST Technical Note 1297, "Guidelines for Evaluating and Expressing the Uncertainty of NIST Measurement Results." ****Calibration Methods:** 4π LS - 4π Liquid Scintillation Counting, HPGe - High Purity Germanium Gamma-Ray Spectrometer, IC - Ionization Chamber.

(Certificate continued on reverse side)

SRS Number: 105114

Expiration Date: 27-February-2018

This source was wipe tested in its inactive areas with leak test results < 185 Bq (5 nCi) of removable activity per ISO 9978:1992.

Source Prepared by:



K. Eardley, Radiochemist

QC Approved by:



J. Lahr, Spectroscopist

Date: 26-FEB-17

Geometry 1 Calibration Verification: Gamma Mixed Nuclide Source
1-Liter Water/Liquid Geometry
Detector 4

VERIF SCE: 1021				REF DATE : 1/1/2015				Count Date: 3/20/2017			
FROM CALIBRATION CERTIFICATE				FROM ANALYTICS.LIB				EXPECTED ACTIVITY			
Isotope	KeV	Half Life(y)	Gammas/Sec.	Gamma Fraction:	Mass of Standard	DPS	pCi/L	Activity	Recovery	Pass/Fail	# of Half Lives Expired
Am-241	59.5	432.0000	1353	0.3590	1	3768.8	101859.5	116000	114%	Pass	0.01
Cd-109	88	1.2666	1935	0.0372		52016.1	1405841.3	1430000	102%	Pass	1.75
Co-57	122	0.7441	1054	0.8551		1232.6	33313.6	32900	99%	Pass	2.98
Ce-139	166	0.3768	1482	0.8035		1844.4	49849.5	48000	96%	Pass	5.88
Hg-203	279	0.1276	3177	0.7730		4110.0	111080.0	NC	>5 h-lives	>5 h-lives	17.36
Sn-113	392	0.3151	2087	0.6490		3215.7	86911.3	80800	93%	Pass	7.03
Cs-137	662	30.0700	1323	0.8512		1554.3	42007.5	41900	100%	Pass	0.07
Y-88	898	0.2919	4901	0.9340		5247.3	141819.5	136000	>5 h-lives	>5 h-lives	7.59
Co-60	1173	5.2714	2503	0.9998		2503.5	67662.2	67100	99%	Pass	0.42
Co-60	1332	5.2714	2506	0.9999		2506.3	67736.5	68100	101%	Pass	0.42
Y-88	1836	0.2919	5189	0.9938		5221.4	141118.2	116000	>5 h-lives	>5 h-lives	7.59

NC=NOT CALCULATED DUE TO ACTIVITY<MDCa

OK 3/20/17

SEEKER G A M M A A N A L Y S I S R E S U L T S PS Version 1.8.4

ALS Laboratory Group - Fort Collins
GammaScan

Geo 1 / Water

Sample ID: 032017-4A GEO1 EFF CAL (1021)

Sampling Start: 01/01/2015 10:00:00 | Counting Start: 03/20/2017 10:57:54
Sampling Stop: 01/01/2015 10:00:00 | Decay Time. 1.94E+004 Hrs
Buildup Time. 0.00E+000 Hrs | Live Time 1800 Sec
Sample Size 1.00E+000 L | Real Time 1826 Sec
Collection Efficiency 1.0000 | Spc. File 170525D04.SPC

Detector #: 4 (Detector 4)

Energy(keV)= -1.58 + 0.501*Ch + 0.00E+00*Ch^2 + 0.00E+00*Ch^3 03/20/2017

FWHM(keV) = 0.80 + 0.010*En + 1.10E-03*En^2 + 0.00E+00*En^3 01/10/2017

Where En = Sqrt(Energy in keV)

Search Sensitivity: 1.00 | Sigma Multiplier: 2.00 | Search Start/End: 80/4000

=====

PEAK SEARCH RESULTS

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PK. #	ENERGY (keV)	ADDRESS CHANNEL	NET/MDA COUNTS	UN- CERTAINTY	C.L. COUNTS	BKG COUNTS	FWHM (keV)	FLAG
1	57.76	118.40	1574	349	279	9611	2.00	a Wide Pk
2	59.48	121.83	14492	295	140	3621	0.95	b
3	67.02	136.87	125	117	94	1967	0.68	a
4	86.23	175.22	118	159	129	3380	0.75	a NET< CL
5	87.94	178.63	18255	309	124	2834	0.97	b
6	122.07	246.72	5643	195	102	1914	1.00	a
7	136.49	275.50	709	127	95	1670	0.96	a
8	148.55	299.57	59	84	68	1029	0.65	a NET< CL
9	165.87	334.12	1001	127	90	1506	0.98	a
10	228.74	459.58	49	82	66	1076	0.60	a NET< CL
11	379.89	761.19	56	73	58	778	0.74	a NET< CL
12	391.81	784.98	326	108	84	1309	1.26	a
13	531.47	1063.67	39	71	57	713	1.19	a NET< CL
14	661.78	1323.70	17254	280	80	1120	1.79	a HiResid
15	678.25	1356.56	14	49	40	388	0.90	a NET< CL
16	898.35	1795.75	253	86	66	918	1.50	a
17	1173.46	2344.71	15015	267	87	1254	2.50	a HiResid
18	1332.66	2662.38	13530	240	47	355	2.69	a HiResid
19	1836.01	3666.80	117	29	16	33	3.50	a

170525D04.SPC Analyzed by

SEEKER B A C K G R O U N D S U B T R A C T R E S U L T S Vers. 2.2.1

ALS Laboratory Group - Fort Collins

GammaScan

Background File:. DET040315.BKG (031517-4 WEEKLY BKG)

Bkg.File Detector #: 4

=====

BACKGROUND SUBTRACT RESULTS

=====

PK#	ENERGY (keV)	OLD NET COUNTS	OLD UN- CERTAINTY	OLD CR.LEVEL	NEW NET COUNTS	NEW UN- CERTAINTY	NEW CR.LEVEL	FLAG
3	67.02	125	117	94	122	117	94	
11	379.89	56	73	58	55	73	59	NET<CL

SEEKER

F I N A L A C T I V I T Y R E P O R T

Version 2.2.1

ALS Laboratory Group - Fort Collins

GammaScan

Geo 1 / Water

Sample ID: 032017-4A GEO1 EFF CAL (1021)

```

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Sampling Start:    01/01/2015 10:00:00 | Counting Start:    03/20/2017 10:57:54
Sampling Stop:    01/01/2015 10:00:00 | Decay Time. . . . . 1.94e+004 Hrs
Buildup Time. . . . . 0.00e+000 Hrs | Live Time . . . . . 1800 Sec
Sample Size . . . . . 1.00e+000 L | Real Time . . . . . 1826 Sec
Collection Efficiency . . . . . 1.0000 | Spectrum File . . . . . 170525D04.SPC
Cr. Level Confidence Interval:    95 % | Det. Limit Confidence Interval:    95 %
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```

Detector #: 4 (Detector 4)

Efficiency File: (D04)(Sh01).EFF (Geo 1 Eff Cal)

Eff=10^{[-6.94E+01 +8.84E+01*L + -3.82E+01*L² +5.45E+00*L³] 03/20/2017}Eff.= EXP[-2.79E-01 + -5.09E-01 * En + -3.05E-02 * En²] Above 300.00 keV

Library File:ANALYTICAL.LIB (Analytical)

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MEASURED or MDA CONCENTRATIONS

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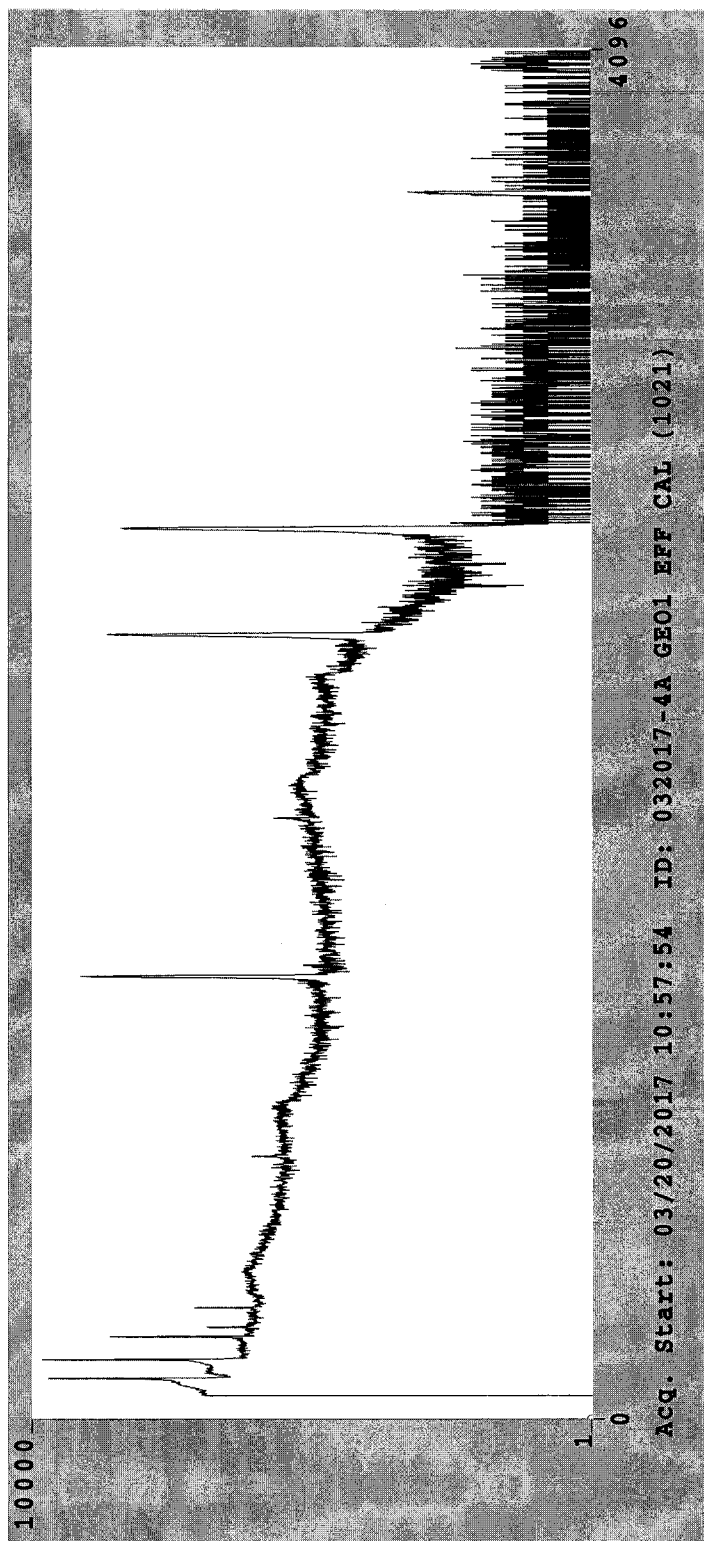
Nuclide	ENERGY E (keV)	N T	Concentration (pCi/L)	MDA	Critical Level	Half-life (hrs)
Am-241	59.54	1.16E+05	+ - 2.35E+03	2.25E+03	1.12E+03	3.79E+06
Cd-109	88.02	1.43E+06	+ - 2.43E+04	1.97E+04	9.73E+03	1.11E+04
Co-57	122.07	3.29E+04	+ - 1.14E+03	1.20E+03	5.94E+02	6.50E+03
Ce-139	165.85	4.80E+04	+ - 6.07E+03	8.78E+03	4.32E+03	3.30E+03
Sn-113	391.68	8.08E+04	+ - 2.69E+04	4.24E+04	2.09E+04	2.76E+03
Cs-137	661.62	4.19E+04	+ - 6.80E+02	3.94E+02	1.94E+02	2.64E+05
Y-88	Average:x	1.21E+05	+ - 2.43E+04	. . . .	. . . .	2.56E+03
	898.02	1.36E+05	+ - 4.62E+04	7.21E+04	3.53E+04	2.56E+03
	1836.01	1.16E+05	+ - 2.86E+04	3.38E+04	1.56E+04	2.56E+03
Co-60	Average:x	6.76E+04	+ - 8.48E+02	. . . .	. . . .	4.62E+04
	1173.21	6.71E+04	+ - 1.19E+03	7.93E+02	3.90E+02	4.62E+04
	1332.48	6.81E+04	+ - 1.21E+03	4.90E+02	2.38E+02	4.62E+04
Hg-203	279.18	MDA	. . . .	3.69E+07	1.82E+07	1.12E+03

MEASURED TOTAL: 1.94E+06 + - 8.66E+04 pCi/L

=====
 UNKNOWN,SUM or ESCAPE PEAKS
 =====

PK. #	ENERGY (keV)	ADDRESS CHANNEL	NET COUNTS	UN- CERTAINTY	C.L. COUNTS	BKG COUNTS	FWHM (keV)	FLAG
1	57.76	118.40	1574	349	279	9611	2.00	Unknown
3	67.02	136.87	122	117	94	1967	0.68	Unknown
4	86.23	175.22	118	159	129	3380	0.75	Deleted
7	136.49	275.50	709	127	95	1670	0.96	Unknown
8	148.55	299.57	59	84	68	1029	0.65	Deleted
10	228.74	459.58	49	82	66	1076	0.60	Deleted
11	379.89	761.19	55	73	59	778	0.74	Deleted
13	531.47	1063.67	39	71	57	713	1.19	Deleted
15	678.25	1356.56	14	49	40	388	0.90	Deleted

c:\SEEKER\BIN\170525d04.res Analysis Results Saved.



**Eckert & Ziegler**

Analytics

RSO #
1021Received
2/26/20151380 Seaboard Industrial Blvd.
Atlanta, Georgia 30318
Tel 404-352-8677
Fax 404-352-2837
www.ezag.com**CERTIFICATE OF CALIBRATION**
Standard Reference Source

99579

1.0 Liter Solid in 138G GA-MA Beaker

Customer: ALS Laboratory Group**P.O. No.:** FC000629, Item 1 **Product Code:** 8401-EG-SD**Reference Date:** 01-Jan-2015 12:00 PM EST **Grams of Master Source:** 0.011886

This standard radionuclide source was prepared using aliquots measured gravimetrically from master radionuclide solutions. Additional radionuclides were added gravimetrically from solutions calibrated by gamma-ray spectrometry, ionization chamber, or liquid scintillation counting. Calibration and purity were checked using a germanium gamma spectrometer system. At the time of calibration no interfering gamma-ray emitting impurities were detected. The gamma-ray emission rates for the most intense gamma-ray lines are given. Eckert & Ziegler Analytics (EZA) maintains traceability to the National Institute of Standards and Technology through a Measurements Assurance Program as described in USNRC Regulatory Guide 4.15, Revision 2, July 2007, and compliance with ANSI N42.22-1995, "Traceability of Radioactive Sources to NIST." Density of solid matrix 1.15 g/cc.

Nuclide	Gamma-Ray Energy (keV)	Half-Life, Days	Master	This Source	Uncertainty*, %			Calibration
			Source*		Type			
			yps/gram	yps	u _A	u _B	U	Method*
Am-241	59.5	1.580E+05	————	1.353E+03	0.1	1.8	3.6	4π LS
Cd-109	88.0	4.614E+02	1.628E+05	1.935E+03	0.5	2.0	4.1	HPGe
Co-57	122.1	2.717E+02	8.868E+04	1.054E+03	0.4	1.7	3.5	HPGe
Ce-139	165.9	1.376E+02	1.246E+05	1.482E+03	0.4	1.7	3.5	HPGe
Hg-203	279.2	4.659E+01	2.673E+05	3.177E+03	0.3	1.7	3.5	HPGe
Sn-113	391.7	1.151E+02	1.756E+05	2.087E+03	0.4	1.9	3.9	HPGe
Cs-137	661.7	1.099E+04	1.113E+05	1.323E+03	0.7	1.9	4.0	HPGe
Y-88	898.0	1.066E+02	4.123E+05	4.901E+03	0.7	1.7	3.7	HPGe
Co-60	1173.2	1.925E+03	2.106E+05	2.503E+03	0.7	1.8	3.9	HPGe
Co-60	1332.5	1.925E+03	2.109E+05	2.506E+03	0.7	1.8	3.9	HPGe
Y-88	1836.1	1.066E+02	4.365E+05	5.189E+03	0.7	1.7	3.7	HPGe

* Master Source refers to Analytics' 8-isotope mixture which is calibrated quarterly.

Calibration Methods: 4π LS - 4 pi Liquid Scintillation Counting, HPGe - High Purity Germanium Gamma-Ray Spectrometer, IC - Ionization Chamber. **Uncertainty:** U - Relative expanded uncertainty, k = 2. See NIST Technical Note 1297, "Guidelines for Evaluating and Expressing the Uncertainty of NIST Measurement Results."

(Certificate continued on reverse side)

This standard will expire one year after the reference date.

Source Prepared by: 
R. Ormsby, Radiochemist

QC Approved: 
J. S. Fahr, Spectroscopist

Date: 20 FEB 15

SEEKER G A M M A A N A L Y S I S R E S U L T S PS Version 1.8.4

ALS Laboratory Group - Fort Collins

GammaScan

Geo 1 / Water

Sample ID: 110816-7 Geo 1 Eff Cal (1040)

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Sampling Start:    01/01/2016 10:00:00 | Counting Start:    11/08/2016 08:52:26
Sampling Stop:     01/01/2016 10:00:00 | Decay Time. . . . . 7.49E+003 Hrs
Buildup Time. . . . . 0.00E+000 Hrs | Live Time . . . . . 3600 Sec
Sample Size . . . . . 1.00E+000 L | Real Time . . . . . 3723 Sec
Collection Efficiency . . . . 1.0000 | Spc. File . . . . . 161195D07.SPC
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```

Detector #: 7 (Detector 7)

Energy(keV)= -2.38 + 0.501*Ch + 0.00E+00*Ch^2 + 0.00E+00*Ch^3 11/08/2016

FWHM(keV) = 0.65 + 0.008*En + 1.26E-03*En^2 + 0.00E+00*En^3 11/08/2016

Where En = Sqrt(Energy in keV)

Search Sensitivity: 1.00 | Sigma Multiplier: 2.00 | Search Start/End: 80/4000

PEAK SEARCH RESULTS

PK. #	ENERGY (keV)	ADDRESS CHANNEL	NET/MDA COUNTS	UN- CERTAINTY	C.L. COUNTS	BKG COUNTS	FWHM (keV)	FLAG
1	59.41	123.38	27658	428	222	9892	0.76	a
2	87.94	180.35	82777	636	224	10085	0.80	a
3	121.93	248.23	47426	488	181	6598	0.84	a
4	136.36	277.03	6101	253	164	5405	0.86	a
5	165.78	335.80	30770	412	178	5823	0.91	a
6	255.07	514.10	670	176	139	3876	0.79	a
7	279.19	562.27 Δ	2335	202	146	3957	1.06	a
8	310.31	624.40	162	120	96	2279	0.59	a
9	391.78	787.10	18026	312	130	3333	1.22	a
10	511.18	1025.52	557	253	204	5353	2.49	a Wide Pk
11	661.91	1326.53	48509	465	123	2928	1.54	a HiResid
12	814.17	1630.58	185	143	115	2676	1.69	a
13	898.23	1798.43	18971	319	132	3375	1.81	a
14	1173.39	2347.90	51379	468	97	1671	2.19	a HiResid
15	1332.51	2665.65	45784	436	69	806	2.37	a HiResid
16	1835.48	3670.04	11190	215	31	143	3.01	a HiResid

Δ less Than 10,000 counts achieved due to greater Than
5 1/2-lives elapsed. JP 11/8/16

161195D07.SPC Analyzed by

SEEKER BACKGROUND SUBTRACT RESULTS Version 1.8.2

ALS Laboratory Group - Fort Collins

GammaScan

Background File:. DET071103.BKG (110316-7 WEEKLY BKG)

Bkg.File Detector #: 7

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BACKGROUND SUBTRACT RESULTS

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PK#	ENERGY (keV)	OLD NET COUNTS	OLD UN- CERTAINTY	OLD CR.LEVEL	NEW NET COUNTS	NEW UN- CERTAINTY	NEW CR.LEVEL	FLAG
2	87.94	82777	636	224	82774	636	224	
3	121.93	47426	488	181	47424	488	181	
10	511.18	557	253	204	465	253	205	
13	898.23	18971	319	132	18968	319	132	

 SEEKER CALIBRATION RESULTS Version 2.0.4

Sample ID: 110816-7 Geo 1 Eff Cal (1040)

Stds. Match Tolerance: 2.00 keV

 Detector Number: 07 Calibration Date. . . 11/08/2016 08:52:26

Geometry File (D07)(Sh01).EFF ID. Geo 1 Eff Cal

Amount of Std. in Calib. Source: 1.000000 gm

Eff = 1 / [3.90e-03*En^-3.75e+00 + 1.34e+02*En^ 7.94e-01]

(Where En = Energy in MeV) (Exponential)

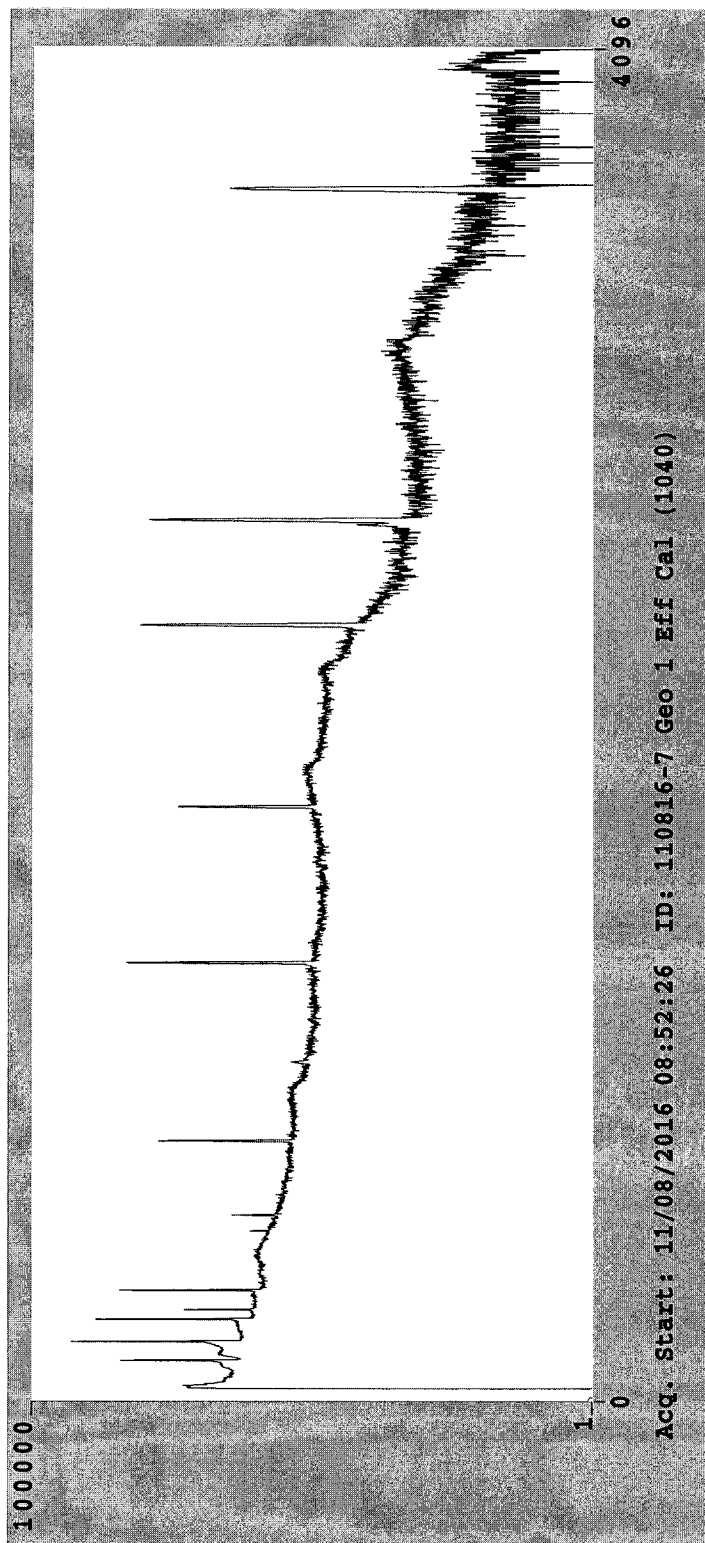
Pk. #	Energy (keV)	Measured Efficiency	% Difference	Calculated Efficiency	% Difference	Prev.Calc. Efficiency
1	59.50	5.69e-03	4.72	5.97e-03	-0.93	5.91e-03
2	88.04	1.92e-02	-5.38 Δ	1.82e-02	-0.19	1.82e-02
3	122.06	2.69e-02	3.88	2.80e-02	-0.00	2.80e-02
4	165.85	2.81e-02	0.20	2.81e-02	-0.09	2.81e-02
5	279.00	2.06e-02	-1.48	2.03e-02	-0.21	2.03e-02
6	391.68	1.61e-02	-3.27	1.56e-02	-0.24	1.56e-02
7	661.64	1.05e-02	-2.12	1.03e-02	-0.27	1.03e-02
8	898.02	7.97e-03	1.61	8.10e-03	-0.28	8.08e-03
9	1173.21	6.52e-03	0.58	6.56e-03	-0.29	6.54e-03
10	1332.48	5.80e-03	2.11	5.93e-03	-0.30	5.91e-03
11	1836.01	4.45e-03	3.24	4.59e-03	-0.31	4.58e-03

Calibration Results Saved.

 Δ Minor Exceedence.

OK per SOP 713

JP 11/8/16



Standards File. Gsstd01.std
Assay Date 01/01/2016 10:00
ID.: Geo 1 Std#1040 1 L Mari. Mixed Gamma

Pk #	Nuclide	Energy	Halflife	Br.Ratio	dps/gm
1	Am-241	59.50	4.322E+02 yrs	0.35900	3768.80
2	Cd-109	88.04	4.626E+02 dys	0.03700	51567.57
3	Co-57	122.06	2.718E+02 dys	0.85510	1266.52
4	Ce-139	165.85	1.376E+02 dys	0.80350	1823.27
5	Hg-203	279.00	4.660E+01 dys	0.77300	4213.45
6	Sn-113	391.68	1.151E+02 dys	0.64900	3127.89
7	Cs-137	661.64	3.017E+01 yrs	0.85120	1530.78
8	Y-88	898.02	1.066E+02 dys	0.93400	5372.59
9	Co-60	1173.21	5.271E+00 yrs	0.99980	2450.49
10	Co-60	1332.48	5.271E+00 yrs	0.99990	2453.25
11	Y-88	1836.01	1.066E+02 dys	0.99380	5346.15



Eckert & Ziegler

Analytics

#1040
Rec'd
2-25-16

1380 Seaboard Industrial Blvd.
Atlanta, Georgia 30318
Tel 404-352-8677
Fax 404-352-2837
www.ezag.com

CERTIFICATE OF CALIBRATION

Standard Reference Source

SRS Number: 102366

Source Description: 1.0 Liter Solid in 138G GA-MA Beaker

Product Code: 8401-EG-SD

Customer: ALS Laboratory Group

P.O. Number: FC000928, Item 1

This standard radionuclide source was prepared from an aliquot measured gravimetrically from a master radionuclide solution calibrated with a germanium gamma-ray spectrometer system. Additional radionuclides were added gravimetrically from solutions calibrated by gamma-ray spectrometry, ionization chamber, or liquid scintillation counting. Calibration and purity were checked using germanium gamma-ray spectrometry. At the time of calibration no interfering gamma-ray emitting impurities were detected. The gamma-ray emission rates for the most intense gamma-ray lines are given. Eckert & Ziegler Analytics (EZA) maintains traceability to the National Institute of Standards and Technology (NIST) through a Measurements Assurance Program as described in USNRC Regulatory Guide 4.15, Revision 2, July 2007, and compliance with ANSI N42.22-1995, "Traceability of Radioactive Sources to NIST."

Density of solid matrix: 1.17 g/cm³ ± 3 %.

Reference Date: 01-January-2016

12:00 PM EST

MGS Mixture

Isotope	Gamma-Ray Energy, keV	Half-Life, d	Activity, Bq	Flux, s ⁻¹	Uncertainty			Calibration Method**
					u _A , %	u _B , %	U, %*	
Am-241	59.5	1.580E+05	3.768E+03	1.353E+03	0.1	1.8	3.6	4π LS
Cd-109	88.0	4.614E+02	5.156E+04	1.908E+03	0.5	2.0	4.1	HPGe
Co-57	122.1	2.717E+02	1.265E+03	1.083E+03	0.4	1.7	3.4	HPGe
Ce-139	165.9	1.376E+02	1.831E+03	1.465E+03	0.4	1.7	3.6	HPGe
Hg-203	279.2	4.659E+01	3.993E+03	3.257E+03	0.3	1.7	3.5	HPGe
Sn-113	391.7	1.151E+02	3.124E+03	2.030E+03	0.4	1.9	3.9	HPGe
Cs-137	661.7	1.099E+04	1.531E+03	1.303E+03	0.7	1.9	4.1	HPGe
Y-88	898.0	1.066E+02	5.356E+03	5.018E+03	0.7	1.7	3.7	HPGe
Y-88	1836.1	—	—	5.313E+03	0.7	1.7	3.7	—
Co-60	1173.2	1.925E+03	2.453E+03	2.450E+03	0.7	1.8	3.9	HPGe
Co-60	1332.5	—	—	2.453E+03	0.7	1.8	3.9	—

Mixed Gamma (MGS) master solution is EZA's eight isotope mixture which is calibrated quarterly and consists of Cd-109, Co-57, Ce-139, Hg-203, Sn-113, Cs-137, Y-88, and Co-60. *Uncertainty: U - Relative expanded uncertainty, k = 2. See NIST Technical Note 1297, "Guidelines for Evaluating and Expressing the Uncertainty of NIST Measurement Results." **Calibration Methods: 4π LS - 4π Liquid Scintillation Counting, HPGe - High Purity Germanium Gamma-Ray Spectrometer, IC - Ionization Chamber.

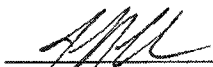
(Certificate continued on reverse side)

SRS Number: 102366

Expiration Date: 24-February-2017

This source was wipe tested in its inactive areas with leak test results $< 185 \text{ Bq}$ (5 nCi) of removable activity per ISO 9978:1992.

Source Prepared by: 
A. Herron, Radiochemist

QC Approved by:  Date: 24-FEB-16
J. Lahr, Spectroscopist

Geometry 1 Calibration Verification: Gamma Mixed Nuclide Source

1-Liter Water/Liquid Geometry

Detector 7

VERIF SCE: 999				REF DATE : 1/1/2014		Count Date: 11/8/2016							
FROM CALIBRATION CERTIFICATE				FROM ANALYTICS LIB		EXPECTED ACTIVITY							
Isotope	KeV	Half Life(y)	Gammas/Sec.	Gamma Fraction:	Mass of Standard				Activity	Recovery	Pass/Fail	# of Half Lives Expired	
Am-241	59.5	432.0000	1330	0.3590	1	L	Am-241	3704.7	100128.0	96900	97%	Pass	0.01
Cd-109	88	1.2666	1903	0.0372			Cd-109	51155.9	1382592.3	1460000	106%	Pass	2.25
Co-57	122	0.7441	1043	0.8551			Co-57	1219.7	32966.0	31700	96%	Pass	3.83
Ce-139	166	0.3768	1436	0.8035			Ce-139	1787.2	48302.2	52000	108%	Pass	7.57
Hg-203	279	0.1276	3083	0.7730			Hg-203	3988.4	107793.4	NC	>5 h-lives	>5 h-lives	22.36
Sn-113	392	0.3151	2031	0.6490			Sn-113	3129.4	84579.2	NC	>5 h-lives	>5 h-lives	9.05
Cs-137	662	30.0700	1287	0.8512			Cs-137	1512.0	40864.4	41900	103%	Pass	0.09
Y-88	898	0.2919	4873	0.9340			Y-88	5217.3	141009.3	NC	>5 h-lives	>5 h-lives	9.77
Co-60	1173	5.2714	2404	0.9998			Co-60	2404.5	64986.0	63000	97%	Pass	0.54
Co-60	1332	5.2714	2406	0.9999			Co-60	2406.2	65033.5	65400	101%	Pass	0.54
Y-88	1836	0.2919	5158	0.9938			Y-88	5190.2	140275.1	NC	>5 h-lives	>5 h-lives	9.77

NC=NOT CALCULATED DUE TO ACTIVITY<MDCa

On JD 11/9/16

SEEKER G A M M A A N A L Y S I S R E S U L T S PS Version 1.8.4

ALS Laboratory Group - Fort Collins
GammaScan

Geo 1 / Water

Sample ID: 110816-7A Geo 1 Cal Ver (999)

Sampling Start: 01/01/2014 10:00:00 | Counting Start: 11/08/2016 09:58:35
Sampling Stop: 01/01/2014 10:00:00 | Decay Time. 2.50E+004 Hrs
Buildup Time. 0.00E+000 Hrs | Live Time 1800 Sec
Sample Size 1.00E+000 L | Real Time 1825 Sec
Collection Efficiency 1.0000 | Spc. File 161196D07.SPC

Detector #: 7 (Detector 7)

Energy(keV)= -2.38 + 0.501*Ch + 0.00E+00*Ch^2 + 0.00E+00*Ch^3 11/08/2016

FWHM(keV) = 0.65 + 0.008*En + 1.26E-03*En^2 + 0.00E+00*En^3 11/08/2016

Where En = Sqrt(Energy in keV)

Search Sensitivity: 1.00 | Sigma Multiplier: 2.00 | Search Start/End: 80/4000

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PEAK SEARCH RESULTS

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PK. #	ENERGY (keV)	ADDRESS CHANNEL	NET/MDA COUNTS	UN- CERTAINTY	C.L. COUNTS	BKG COUNTS	FWHM (keV)	FLAG
1	59.41	123.39	13788	278	122	2987	0.75	a
2	87.94	180.36	13914	265	99	1976	0.78	a
3	103.29	211.00	31	73	60	875	0.43	a NET< CL
4	121.94	248.24	3524	157	85	1453	0.81	a
5	136.42	277.16	442	109	83	1389	0.81	a
6	165.83	335.88	413	105	80	1281	0.75	a
7	367.27	738.14	52	85	69	1010	0.95	a NET< CL
8	391.65	786.84	83	76	61	833	0.74	a
9	661.91	1326.52	22986	313	62	756	1.55	a HiResid
10	679.56	1361.77	41	49	39	367	0.86	a
11	897.93	1797.83	44	103	84	1314	1.94	a NET< CL
12	1173.36	2347.85	18898	283	55	544	2.13	a HiResid
13	1332.51	2665.66	17737	268	25	103	2.39	a HiResid
14	1835.62	3670.33	59	22	14	25	3.44	a

161196D07.SPC Analyzed by

SEEKER B A C K G R O U N D S U B T R A C T R E S U L T S Vers. 2.2.1

ALS Laboratory Group - Fort Collins
GammaScan

Background File:. DET071103.BKG (110316-7 WEEKLY BKG)

Bkg.File Detector #: 7

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BACKGROUND SUBTRACT RESULTS

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PK#	ENERGY (keV)	OLD NET COUNTS	OLD UN- CERTAINTY	OLD CR.LEVEL	NEW NET COUNTS	NEW UN- CERTAINTY	NEW CR.LEVEL	FLAG
2	87.94	13914	265	99	13913	265	99	
4	121.94	3524	157	85	3523	157	85	
11	897.93	44	103	84	42	103	84	NET<CL

 SEEKER FINAL ACTIVITY REPORT Version 2.2.1

ALS Laboratory Group - Fort Collins
 GammaScan

Geo 1 / Water

Sample ID: 110816-7A Geo 1 Cal Ver (999)

 Sampling Start: 01/01/2014 10:00:00 | Counting Start: 11/08/2016 09:58:35
 Sampling Stop: 01/01/2014 10:00:00 | Decay Time. 2.50e+004 Hrs
 Buildup Time. 0.00e+000 Hrs | Live Time 1800 Sec
 Sample Size 1.00e+000 L | Real Time 1825 Sec
 Collection Efficiency 1.0000 | Spectrum File 161196D07.SPC
 Cr. Level Confidence Interval: 95 % | Det. Limit Confidence Interval: 95 %

Detector #: 7 (Detector 7)

Efficiency File: (D07)(Sh01).EFF (Geo 1 Eff Cal)

Eff.=1/[3.90E-03*En^-3.75E+00 + 1.34E+02*En^7.94E-01] 11/08/2016

Library File:ANALYTICAL.LIB (Analytical)

MEASURED or MDA CONCENTRATIONS

=====

Nuclide	ENERGY E (keV)	Concentration (pCi/L)	MDA	Critical Level	Halflife (hrs)
Am-241	59.54	9.69E+04 +- 1.95E+03	1.73E+03	8.55E+02	3.79E+06
Cd-109	88.02	1.46E+06 +- 2.78E+04	2.11E+04	1.04E+04	1.11E+04
Co-57	122.07	3.17E+04 +- 1.42E+03	1.56E+03	7.66E+02	6.50E+03
Ce-139	165.85	5.20E+04 +- 1.33E+04	2.04E+04	1.01E+04	3.30E+03
Cs-137	661.62	4.19E+04 +- 5.69E+02	2.32E+02	1.14E+02	2.64E+05
Co-60	Average:x	6.42E+04 +- 6.83E+02	. . . .	. . . .	4.62E+04
	1173.21	6.30E+04 +- 9.44E+02	3.78E+02	1.85E+02	4.62E+04
	1332.48	6.54E+04 +- 9.89E+02	1.94E+02	9.21E+01	4.62E+04
Hg-203	279.18	MDA	9.65E+08	4.76E+08	1.12E+03
Sn-113	391.68	MDA	8.34E+04r	4.07E+04	2.76E+03
Y-88	898.02	MDA	2.91E+05	1.43E+05	2.56E+03

=====

MEASURED TOTAL: 1.75E+06 +- 4.57E+04 pCi/L

UNKNOWN,SUM or ESCAPE PEAKS

=====

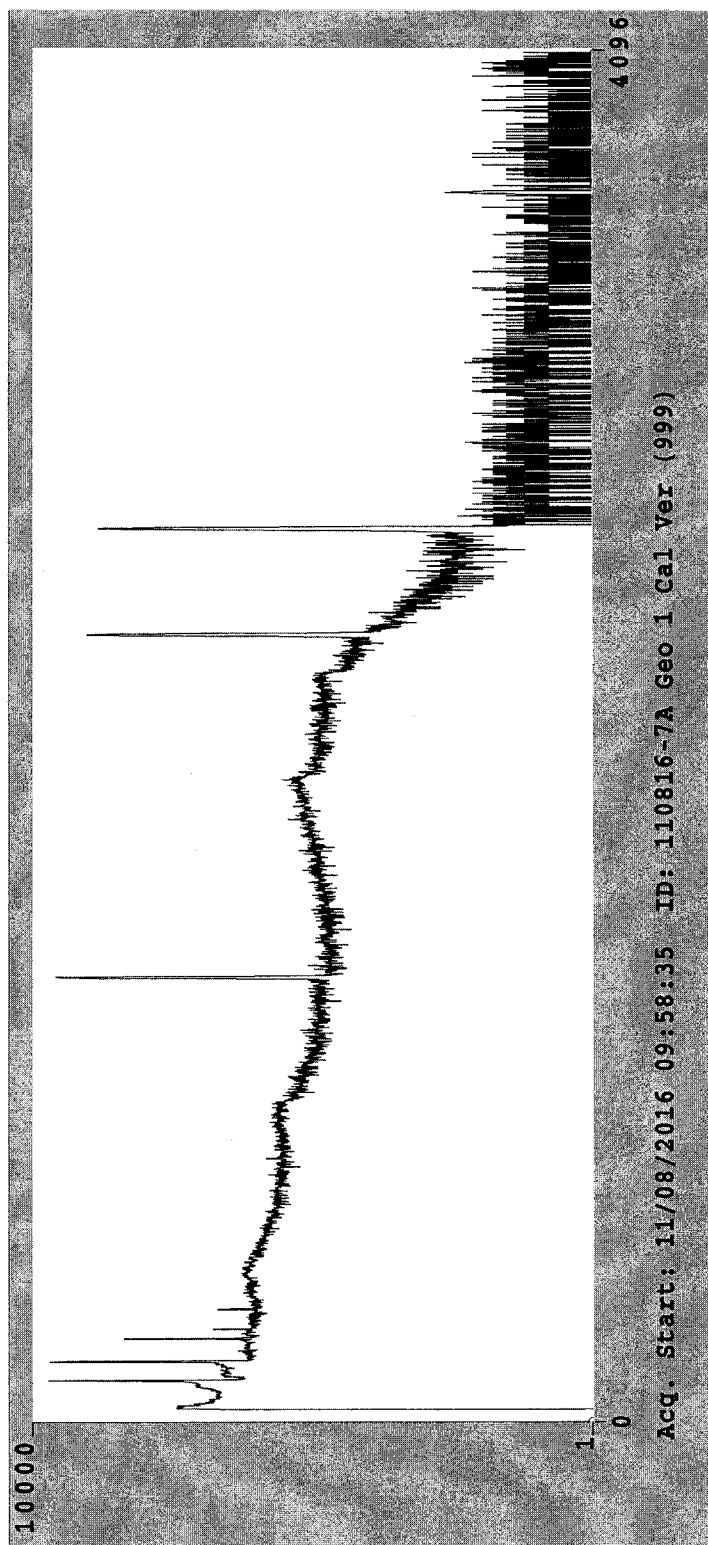
PK. #	ENERGY (keV)	ADDRESS CHANNEL	NET COUNTS	UN- CERTAINTY	C.L. COUNTS	BKG COUNTS	FWHM (keV)	FLAG
3	103.29	211.00	31	73	60	875	0.43	Deleted
5	136.42	277.16	442	109	83	1389	0.81	Unknown

=====

UNKNOWN, SUM or ESCAPE PEAKS

PK. #	ENERGY (keV)	ADDRESS CHANNEL	NET COUNTS	UN- CERTAINTY	C.L. COUNTS	BKG COUNTS	FWHM (keV)	FLAG
7	367.27	738.14	52	85	69	1010	0.95	Deleted
8	391.65	786.84	83	76	61	833	0.74	Unknown
10	679.56	1361.77	41	49	39	367	0.86	Unknown
11	897.93	1797.83	42	103	84	1314	1.94	Deleted
14	1835.62	3670.33	59	22	14	25	3.44	Unknown

c:\SEEKER\BIN\161196d07.res Analysis Results Saved.





Eckert & Ziegler
Analytics

RSO #
999

Received
2/26/2014
JP

1380 Seaboard Industrial Blvd.
Atlanta, Georgia 30318
Tel 404-352-8677
Fax 404-352-2837
www.analytiscinc.com

CERTIFICATE OF CALIBRATION

Standard Radionuclide Source

95548

1.0 Liter Solid in 138G GA-MA Beaker

Customer: ALS Laboratory Group

P.O. No.: FC000236, Item 1

Product Code 8401-EG-SD

Reference Date: 01-Jan-2014

12:00 PM EST Grams of Master Source: 0.011697

This standard radionuclide source was prepared using aliquots measured gravimetrically from master radionuclide solutions. Additional radionuclides were added gravimetrically from solutions calibrated by gamma-ray spectrometry, ionization chamber, or liquid scintillation counting. Calibration and purity were checked using a germanium gamma spectrometer system. At the time of calibration no interfering gamma-ray emitting impurities were detected. The gamma-ray emission rates for the most intense gamma-ray lines are given. Eckert & Ziegler Analytics (EZA) maintains traceability to the National Institute of Standards and Technology through a Measurements Assurance Program as described in USNRC Regulatory Guide 4.15, Revision 2, July 2007, and compliance with ANSI N42.22-1995, "Traceability of Radioactive Sources to NIST." EZA is accredited by the Health Physics Society (HPS) for the production of NIST-traceable sources, and this source was produced in accordance with the HPS accreditation requirements. Customers may report any concerns with the accreditation program to the HPS Secretariat, 1313 Dolley Madison Blvd., Ste. 402, McLean, VA 22101.

Density of solid matrix 1.15 g/cc.

Nuclide	Gamma-Ray Energy (keV)	Half-Life, Days	Master Source* yps/gram	This Source yps	Uncertainty*, %			Calibration Method*
					Type	u _A	u _B	U
Am-241	59.5	1.580E+05	—	1.330E+03	0.1	1.6	3.2	4π LS
Cd-109	88.0	4.614E+02	1.627E+05	1.903E+03	0.5	2.0	4.1	HPGe
Co-57	122.1	2.717E+02	8.915E+04	1.043E+03	0.4	1.7	3.5	HPGe
Ce-139	165.9	1.376E+02	1.228E+05	1.436E+03	0.4	1.7	3.5	HPGe
Hg-203	279.2	4.659E+01	2.636E+05	3.083E+03	0.3	1.7	3.5	HPGe
Sn-113	391.7	1.151E+02	1.736E+05	2.031E+03	0.4	1.9	3.9	HPGe
Cs-137	661.7	1.099E+04	1.100E+05	1.287E+03	0.7	1.9	4.0	HPGe
Y-88	898.0	1.066E+02	4.166E+05	4.873E+03	0.5	1.7	3.5	HPGe
Co-60	1173.2	1.925E+03	2.055E+05	2.404E+03	0.6	1.8	3.8	HPGe
Co-60	1332.5	1.925E+03	2.057E+05	2.406E+03	0.7	1.8	3.9	HPGe
Y-88	1836.1	1.066E+02	4.410E+05	5.158E+03	0.7	1.7	3.7	HPGe

* Master Source refers to Analytics' 8-isotope mixture which is calibrated quarterly.

Calibration Methods: 4π LS - 4 pi Liquid Scintillation Counting, HPGe - High Purity Germanium Gamma-Ray Spectrometer, IC - Ionization Chamber. **Uncertainty:** U - Relative expanded uncertainty, k = 2. See NIST Technical Note 1297, "Guidelines for Evaluating and Expressing the Uncertainty of NIST Measurement Results."

(Certificate continued on reverse side)

Standard Re-Verified
3/7/16.

New Expiration
Date => 03/07/2017.

JP 3/18/16



MGS Certificate Rev 5, 1 October 2013

Corporate Office

24937 Avenue Tibbitts, Valencia, California 91355

Laboratory

1380 Seaboard Industrial Blvd. Atlanta, Georgia 30318

Page 1 of 2

This standard will expire one year after the reference date.

Source Prepared by: K. Eardley
K. Eardley, Radiochemist

QA Approved: J.D. McCorvey
J.D. McCorvey, Counting Room Manager

Date: 24 Feb 14



Gamma Spectroscopy

Quality Control Data

Weekly Background Calibrations

ALS

Gamma Spectrometer Calibration Log

Date: 6/14/17Reviewed By/Date: JP 6/15/17

Det. No.	Out Of Service	Background		Source Check			Repeat Source Check			
		Started	OK	Started	OK	Failed Parameter(s)	OK	Failed Parameter(s)	Corrective Action Taken **	Removed from Service
1.		SG	SG	SG	SG					
2.		|	SG	|	SG					
3.		|	SG	|	/	1002 KEV FWHM	SG			
4.		|	SG	|	SG					
5.		|	SG	|	SG					
6.		|	SG	|	SG					
7.		|	SG	|	/	1332 KEV FWHM	SG			
8.		|	SG	|	SG					
9.		✓	SG	✓	SG					
10.	SG	→	→	→	→					

** Corrective Action:

Δ Recount Split 1460 KEV Peak
JP 6/15/17

*** Due to detector _____ failing two different QC parameters on the first and second daily check, a third daily check was performed. All QC parameters passed for the third daily check. Detector _____ is online for the date of _____.

471589 A

Form 754r16a.doc (10/27/11)

SEEKER G A M M A A N A L Y S I S R E S U L T S PS Version 1.8.4

ALS Laboratory Group - Fort Collins

GammaScan

Weekly Background Check

Sample ID: 061417-3 WEEKLY BKG

```

-----
Sampling Start:    06/14/2017 15:00:00 | Counting Start:    06/14/2017 15:50:05
Sampling Stop:    06/14/2017 15:00:00 | Decay Time. . . . . 8.35E-001 Hrs
Buildup Time. . . . . 0.00E+000 Hrs | Live Time . . . . . 60000 Sec
Sample Size . . . . . 1.00E+000 L | Real Time . . . . . 60117 Sec
Collection Efficiency . . . . 1.0000 | Spc. File . . . . . 170807D03.SPC
-----

```

Detector #: 3 (Detector 3)

Energy(keV)= -1.70 + 0.501*Ch + 0.00E+00*Ch^2 + 0.00E+00*Ch^3 06/14/2017

FWHM(keV) = 0.73 + 0.017*En + 8.16E-04*En^2 + 0.00E+00*En^3 11/04/2016

Where En = Sqrt(Energy in keV)

```

-----
Search Sensitivity: 1.00 | Sigma Multiplier: 2.00 | Search Start/End: 80/4000
-----

```

PEAK SEARCH RESULTS

```

=====

```

PK. #	ENERGY (keV)	ADDRESS CHANNEL	NET/MDA COUNTS	UN- CERTAINTY	C.L. COUNTS	BKG COUNTS	FWHM (keV)	FLAG
1	63.31	129.78	131	105	84	1115	1.38	a
2	66.30	135.75	198	86	67	836	1.00	b
3	69.29	141.72	37	52	41	418	0.47	c NET< CL
4	75.03	153.18	103	93	75	951	1.14	a
5	77.10	157.32	91	53	41	408	0.47	b
6	92.59	188.24	305	84	63	738	0.95	a
7	139.95	282.78	157	72	55	563	1.06	a Wide Pk
8	143.45	289.76	130	134	109	1314	2.35	b
9	185.82	374.36	314	84	63	671	1.20	a
10	198.53	399.72	151	73	57	596	0.97	a
11	212.10	426.83	58	75	60	618	1.13	a NET< CL
12	225.02	452.61	45	46	37	330	0.59	a
13	238.73	479.98	214	61	44	446	0.89	a
14	249.60	501.68	41	52	41	390	0.82	a NET< CL
15	277.69	557.76	41	50	40	360	0.88	a
16	295.31	592.93	63	51	40	357	0.82	a
17	317.55	637.34	36	47	38	321	0.81	a NET< CL
18	338.36	678.88	79	66	52	501	1.34	a
19	344.62	691.38	49	53	42	376	1.06	b
20	352.05	706.21	91	87	70	728	1.97	a
21	370.84	743.71	42	37	29	206	0.69	a

PEAK SEARCH RESULTS

PK. #	ENERGY (keV)	ADDRESS CHANNEL	NET/MDA COUNTS	UN- CERTAINTY	C.L. COUNTS	BKG COUNTS	FWHM (keV)	FLAG
22	511.28	1024.09	1516	116	71	683	2.79	a Wide Pk
23	558.49	1118.34	140	50	37	275	1.35	a
24	569.75	1140.81	51	58	46	390	1.64	a
25	583.73	1168.72	120	60	46	370	1.81	a
26	596.44	1194.09	64	45	34	274	1.06	a
27	598.58	1198.37	91	68	53	502	1.84	b
28	609.47	1220.11	91	53	40	354	1.10	a
29	693.20	1387.27	66	65	52	456	1.90	a
30	803.35	1607.17	126	46	33	225	1.62	a
31	912.22	1824.52	92	50	38	236	2.43	a
32	962.07	1924.02	30	31	24	131	1.09	a
33	1461.47	2921.01	198	43	27	116	2.63	a

170807D03.SPC Analyzed by

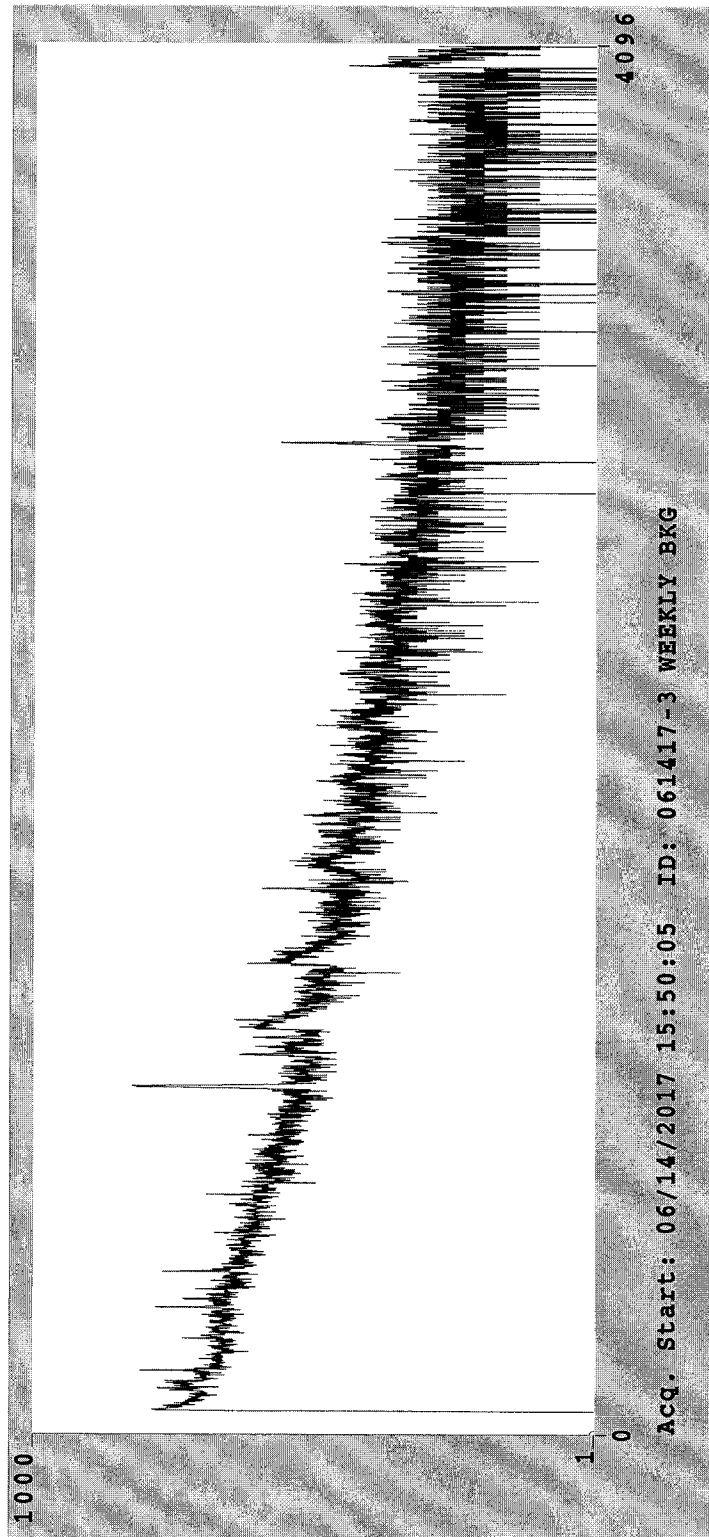
SEEKER B A C K G R O U N D Q . C . A N A L Y S I S Version 2.2.2

ID: 061417-3 WEEKLY BKG

Detector # 3 Background Q.C. Analysis for 06/14/2017 15:50:05

#	Parameter	Value	n Sigma Test	Bounds Test	T- Test
10	50-> 150 keV Bkg	23.723	N.A.	Pass	N.A.
11	150-> 250 keV Bkg	19.457	N.A.	Pass	N.A.
12	250-> 500 keV Bkg	28.708	N.A.	Pass	N.A.
13	500->1000 keV Bkg	29.855	N.A.	Pass	N.A.
14	1000->2000 keV Bkg	16.559	N.A.	Pass	N.A.
15	40-> 50 keV Bkg	3.224	N.A.	Pass	N.A.

Q.C. Results Saved.



SEEKER G A M M A A N A L Y S I S R E S U L T S PS Version 1.8.4

ALS Laboratory Group - Fort Collins
GammaScan

Weekly Background Check

Sample ID: 061417-4 WEEKLY BKG

```

-----
Sampling Start: 06/14/2017 15:00:00 | Counting Start: 06/14/2017 15:01:29
Sampling Stop: 06/14/2017 15:00:00 | Decay Time. . . . . 2.47E-002 Hrs
Buildup Time. . . . . 0.00E+000 Hrs | Live Time . . . . . 60000 Sec
Sample Size . . . . . 1.00E+000 L | Real Time . . . . . 60110 Sec
Collection Efficiency . . . . 1.0000 | Spc. File . . . . . 171075D04.SPC
-----

```

Detector #: 4 (Detector 4)

Energy(keV)= -1.54 + 0.501*Ch + 0.00E+00*Ch^2 + 0.00E+00*Ch^3 06/14/2017

FWHM(keV) = 0.80 + 0.010*En + 1.10E-03*En^2 + 0.00E+00*En^3 01/10/2017

Where En = Sqrt(Energy in keV)

Search Sensitivity: 1.00 | Sigma Multiplier: 2.00 | Search Start/End: 80/4000

PEAK SEARCH RESULTS

```

=====
PK.   ENERGY   ADDRESS   NET/MDA   UN-   C.L.   BKG   FWHM
#     (keV)     CHANNEL   COUNTS   CERTAINTY   COUNTS   COUNTS   (keV)   FLAG
-----
 1    43.47      89.82      58        62        49       537    0.73 a
 2    46.26      95.38      84        92        74       939    1.08 b
 3    53.60     110.03      54        69        55       621    0.82 a NET< CL
 4    63.27     129.34     255        74        55       613    0.80 a
 5    66.56     135.90     153        71        55       613    0.84 b
 6    74.75     152.24      82        87        70       914    1.00 a
 7    92.51     187.68     614       101        72       828    1.29 a
 8    98.41     199.45      30        52        42       387    0.68 a NET< CL
 9   140.04     282.54     120        72        57       596    1.02 a
10   143.74     289.92      65        62        50       497    0.89 b
11   185.77     373.80     363        85        62       658    1.13 a
12   198.25     398.71     163        69        53       522    1.00 a
13   220.76     443.63      36        45        35       310    0.59 a
14   238.54     479.12      96        56        43       430    0.90 a
15   295.56     592.91      41        60        48       456    1.10 a NET< CL
16   337.47     676.56      43        60        48       430    1.26 a NET< CL
17   352.03     705.61     130        57        43       367    1.07 a
18   483.69     968.36      26        34        26       172    0.77 a NET< CL
19   511.05    1022.96    1376       120        78       766    3.06 a Wide Pk
20   558.69    1118.05     139        52        39       289    1.41 a
21   583.49    1167.54      52        62        49       408    1.92 a

```

PEAK SEARCH RESULTS

PK. #	ENERGY (keV)	ADDRESS CHANNEL	NET/MDA COUNTS	UN- CERTAINTY	C.L. COUNTS	BKG COUNTS	FWHM (keV)	FLAG
22	609.50	1219.45	122	61	47	411	1.69	a
23	693.45	1386.98	74	77	62	538	2.61	a
24	803.28	1606.17	126	48	35	227	2.02	a
25	911.38	1821.91	56	43	33	205	1.95	a
26	1460.99	2918.78	196	48	32	138	3.23	a

171075D04.SPC Analyzed by

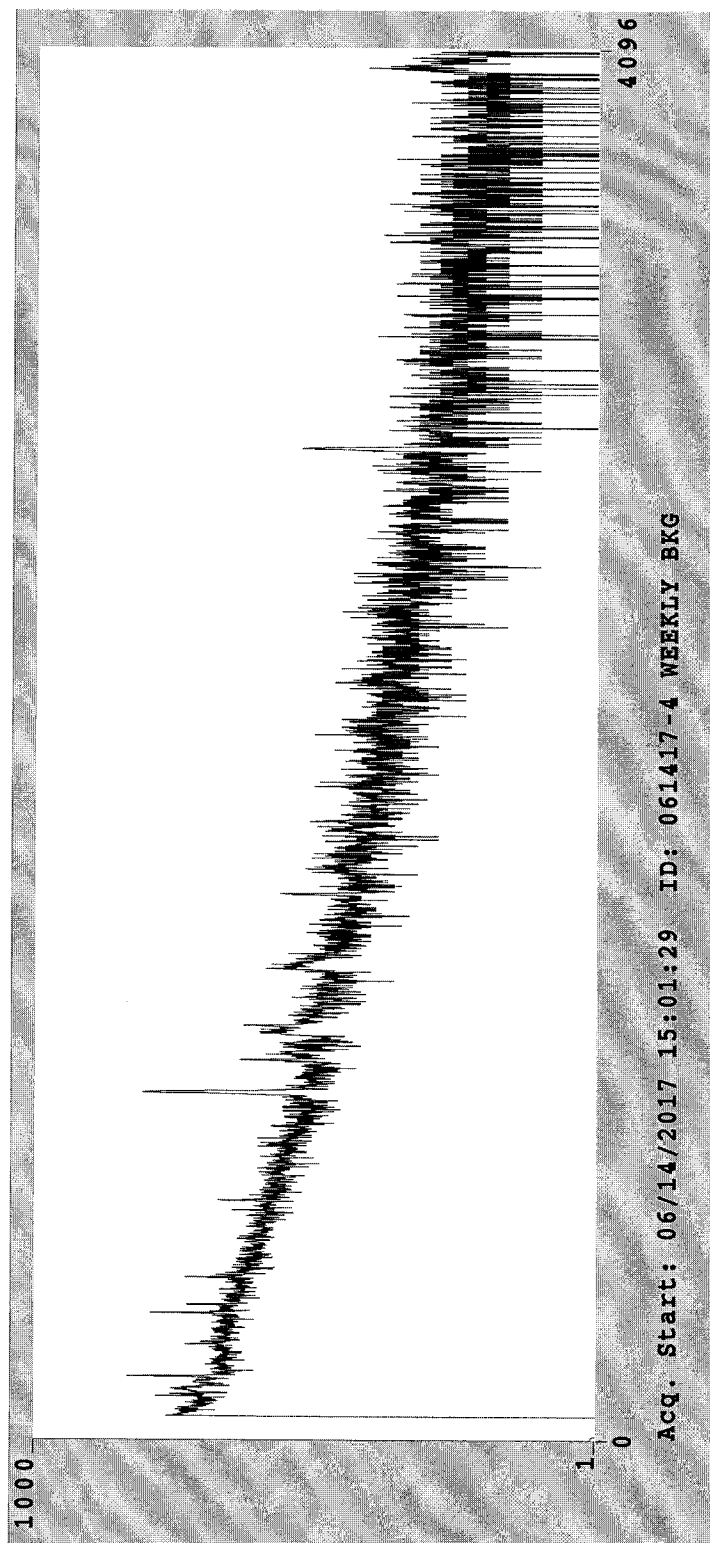
SEEKER B A C K G R O U N D Q. C. A N A L Y S I S Version 2.2.2

ID: 061417-4 WEEKLY BKG

Detector # 4 Background Q.C. Analysis for 06/14/2017 15:01:29

#	Parameter	Value	n Sigma Test	Bounds Test	T- Test
10	50-> 150 keV Bkg	23.351	N.A.	Pass	N.A.
11	150-> 250 keV Bkg	18.066	N.A.	Pass	N.A.
12	250-> 500 keV Bkg	26.083	N.A.	Pass	N.A.
13	500->1000 keV Bkg	26.904	N.A.	Pass	N.A.
14	1000->2000 keV Bkg	15.344	N.A.	Pass	N.A.
15	40-> 50 keV Bkg	3.009	N.A.	Pass	N.A.

Q.C. Results Saved.



SEEKER G A M M A A N A L Y S I S R E S U L T S PS Version 1.8.4

ALS Laboratory Group - Fort Collins

GammaScan

Weekly Background Check

Sample ID: 061417-7 WEEKLY BKG

```

-----
Sampling Start: 06/14/2017 15:00:00 | Counting Start: 06/14/2017 15:03:27
Sampling Stop: 06/14/2017 15:00:00 | Decay Time. . . . . 5.75E-002 Hrs
Buildup Time. . . . . 0.00E+000 Hrs | Live Time . . . . . 60000 Sec
Sample Size . . . . . 1.00E+000 L | Real Time . . . . . 60053 Sec
Collection Efficiency . . . . 1.0000 | Spc. File . . . . . 170650D07.SPC
-----

```

Detector #: 7 (Detector 7)

Energy(keV)= -2.32 + 0.501*Ch + 0.00E+00*Ch^2 + 0.00E+00*Ch^3 06/14/2017

FWHM(keV) = 0.65 + 0.008*En + 1.26E-03*En^2 + 0.00E+00*En^3 11/08/2016

Where En = Sqrt(Energy in keV)

```

-----
Search Sensitivity: 1.00 | Sigma Multiplier: 2.00 | Search Start/End: 80/4000
-----

```

PEAK SEARCH RESULTS

```

=====
PK.   ENERGY   ADDRESS   NET/MDA   UN-      C.L.      BKG      FWHM
#     (keV)     CHANNEL   COUNTS   CERTAINTY COUNTS    COUNTS   (keV)   FLAG
-----
 1    41.62      87.71      21       42        33       309     0.39 a NET< CL
 2    46.58      97.62      45       52        41       416     0.47 a
 3    53.35     111.14      43       67        54       587     0.78 a NET< CL
 4    63.20     130.81     135       65        50       557     0.72 a
 5    66.45     137.30     152       66        50       557     0.73 b
 6    69.40     143.18      12       51        41       418     0.46 c NET< CL
 7    74.88     154.12     124       64        50       548     0.69 a
 8    77.04     158.43      98       83        67       822     1.04 b
 9    84.48     173.30      89       79        63       742     1.02 a
10    92.68     189.65     485       86        60       673     1.05 a
11   112.82     229.88      34       54        43       412     0.70 a NET< CL
12   139.89     283.91     182      100       79       923     1.47 a
13   143.35     290.83      70       81        65       718     1.10 b
14   154.48     313.04      60       70        56       583     0.94 a
15   185.90     375.76     333       84        62       662     1.11 a
16   198.38     400.69     213       82        63       677     1.18 a
17   238.79     481.35     264       73        54       543     0.97 a
18   259.21     522.11      33       55        44       390     0.86 a NET< CL
19   295.51     594.59     110       70        55       511     1.09 a
20   338.85     681.11      78       68        54       546     1.33 a
21   342.14     687.69      20       41        33       273     0.62 b NET< CL

```

=====
 PEAK SEARCH RESULTS
 =====

PK. #	ENERGY (keV)	ADDRESS CHANNEL	NET/MDA COUNTS	UN- CERTAINTY	C.L. COUNTS	BKG COUNTS	FWHM (keV)	FLAG
22	352.25	707.87	158	64	48	455	1.18	a
23	511.25	1025.30	1638	126	80	754	2.84	a Wide Pk
24	558.89	1120.40	187	56	40	318	1.54	a
25	569.92	1142.42	62	60	47	416	1.58	a
26	583.81	1170.16	131	54	40	319	1.48	a
27	598.61	1199.71	130	88	70	716	2.48	a
28	601.28	1205.04	28	44	35	286	1.02	b NET< CL
29	609.87	1222.17	142	56	41	371	1.10	a
30	694.55	1391.24	85	65	51	440	2.01	a
31	803.18	1608.11	151	51	37	265	1.74	a
32	911.67	1824.71	59	41	31	197	1.69	a
33	969.30	1939.76	40	37	29	177	1.46	a
34	1460.99	2921.37	232	46	29	128	2.83	a

170647D07.SPC Analyzed by

SEEKER C A L I B R A T I O N R E S U L T S Version 2.0.4

Sample ID: DAILY CHECK

Stds. Match Tolerance: 2.00 keV

Detector Number: 07 Calibration Date. . . 06/14/2017 08:46:22

Energy(keV) = -2.32 + 0.501*Ch + 0.00e+00*Ch^2 + 0.00e+00*Ch^3

Pk. #	Measured Centroid	Calculated Energy	Energy (keV)	% Difference
1	123.22	59.40	59.50	-0.17
2	1325.91	661.83	661.64	0.03
3	2664.63	1332.39	1332.48	-0.01

Calibration Results Saved.

170650D07.SPC Analyzed by

 SEEKER B A C K G R O U N D Q. C. A N A L Y S I S Version 2.2.2

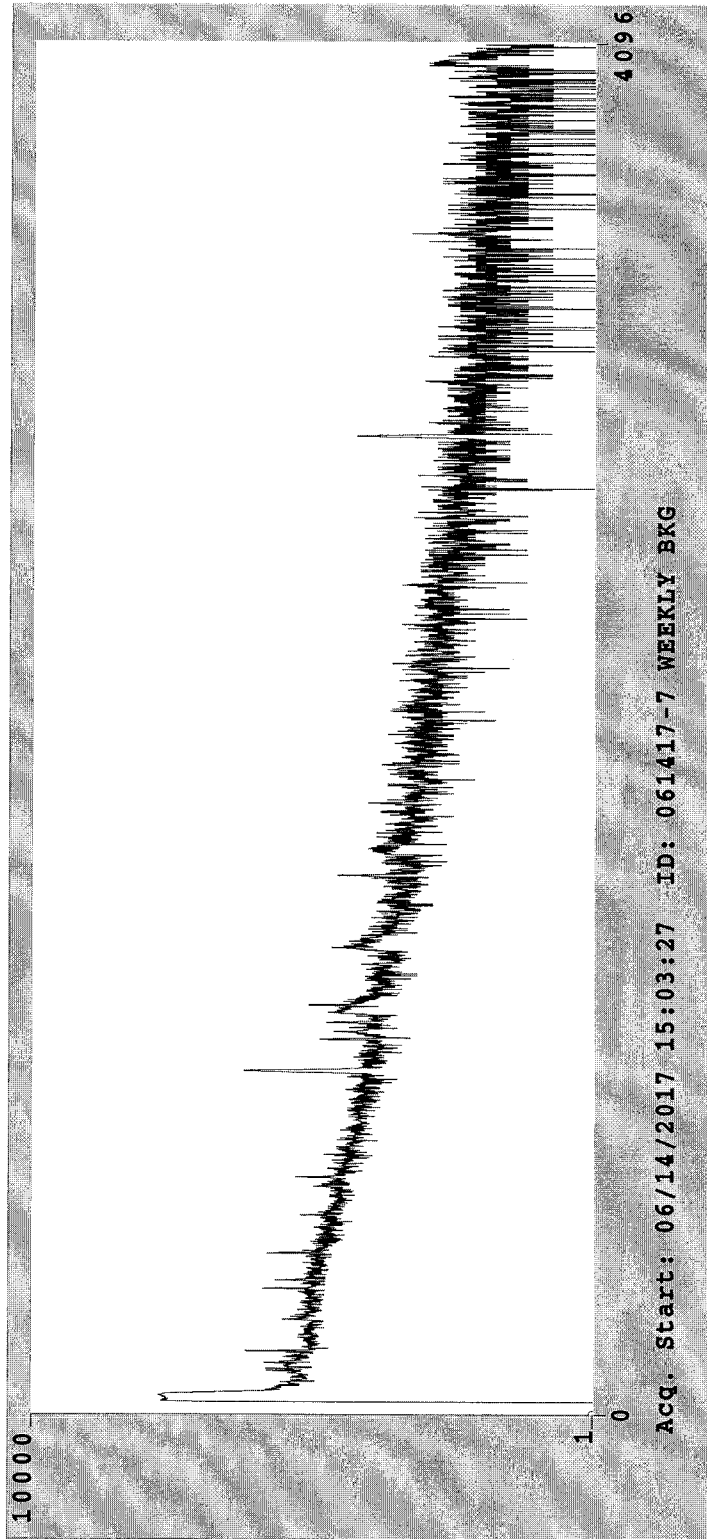
ID: 061417-7 WEEKLY BKG

Detector # 7 Background Q.C. Analysis for 06/14/2017 15:03:27

#	Parameter	Value	n Sigma Test	Bounds Test	T- Test

10	50-> 150 keV Bkg	24.018	N.A.	Pass	N.A.
11	150-> 250 keV Bkg	20.026	N.A.	Pass	N.A.
12	250-> 500 keV Bkg	29.415	N.A.	Pass	N.A.
13	500->1000 keV Bkg	31.127	N.A.	Pass	N.A.
14	1000->2000 keV Bkg	17.289	N.A.	Pass	N.A.
15	40-> 50 keV Bkg	2.977	N.A.	Pass	N.A.

Q.C. Results Saved.



Gamma Spectroscopy

Quality Control Data

Daily Instrument Performance Checks



CERTIFICATE OF CALIBRATION

Standard Radionuclide Source

PAI 0720

66354A-307

215 Grams of Sand in Metal Can

This standard radionuclide source was prepared using aliquots measured gravimetrically from master radionuclide solution sources. The Am-241 was calibrated by 4 pi alpha liquid scintillation counting. All other radionuclides were calibrated using a germanium gamma spectrometer system. Calibration and purity were checked using a germanium gamma spectrometer system. At the time of calibration no interfering gamma-ray emitting impurities were detected. The gamma-ray emission rates for the most intense gamma-ray lines are given. Analytics maintains traceability to the National Institute of Standards and Technology through a Measurements Assurance Program as described in USNRC Regulatory Guide 4.15, Rev. 1, February, 1979.

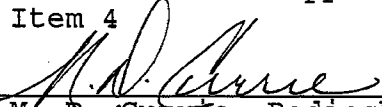
Calibration date: July 1, 2003 12:00 EST

ISOTOPE	GAMMA-RAY ENERGY	HALF-LIFE	GAMMA-RAYS PER SECOND	TOTAL UNCERTAINTY %
Am-241	59.5	432 y	1316	3.0
Cd-109	88	462.6 d	1879	3.3
Co-57	122	271.79 d	1042	2.8
Ce-139	166	137.6 d	1432	2.8
Hg-203	279	46.61 d	3223	2.7
Sn-113	392	115.1 d	1978	2.6
Cs-137	662	30.07 y	1272	3.0
Y-88	898	106.6 d	5106	2.6
Co-60	1173	5.2714 y	2424	2.7
Co-60	1332	5.2714 y	2449	2.6
Y-88	1836	106.6 d	5335	2.6

Approximately 126.5 mL of customer supplied sand.

P O NUMBER EW060303, Item 4

SOURCE PREPARED BY:


M. D. Currie, Radiochemist

Q A APPROVED:

 8-1-03

This standard will expire one year after the calibration date.

RSO # 767
Rec'd 8/13/04
JJB



CERTIFICATE OF CALIBRATION

Standard Radionuclide Source

68681-307

215 Grams of Sand in Metal Can

This standard radionuclide source was prepared using aliquots measured gravimetrically from master radionuclide solution sources. The Am-241 was calibrated by 4 pi alpha liquid scintillation counting. All other radionuclides were calibrated using a germanium gamma spectrometer system. Calibration and purity were checked using a germanium gamma spectrometer system. At the time of calibration no interfering gamma-ray emitting impurities were detected. The gamma-ray emission rates for the most intense gamma-ray lines are given. Analytical maintains traceability to the National Institute of Standards and Technology through a Measurements Assurance Program as described in USNRC Regulatory Guide 4.15, Rev. 1, February, 1979.

Calibration date: July 1, 2004 12:00 EST

ISOTOPE	GAMMA-RAY ENERGY	HALF-LIFE	GAMMA-RAYS PER SECOND	TOTAL UNCERTAINTY %
Am-241	59.5	432 y	1355	3.0
Cd-109	88	462.6 d	1900	3.3
Co-57	122	271.79 d	995.1	3.0
Ce-139	166	137.6 d	1411	2.8
Hg-203	279	46.61 d	3241	2.7
Sn-113	392	115.1 d	1939	2.6
Cs-137	662	30.07 y	1247	3.0
Y-88	898	106.6 d	4853	2.6
Co-60	1173	5.2714 y	2457	2.7
Co-60	1332	5.2714 y	2474	2.6
Y-88	1836	106.6 d	5064	2.6

140 mL of customer supplied sand.

P O NUMBER 70564, Item 4

SOURCE PREPARED BY:

M. D. Currie for
M. D. Currie, Radiochemist

Q A APPROVED:

M. D. Currie 8-9-04

This standard will expire one year after the calibration date.

≈ 203µCi



PAT ID 0636
rec'd 8-02-02

CERTIFICATE OF CALIBRATION

Standard Radionuclide Source

64122-307

215 Grams of Sand in Metal Can

This standard radionuclide source was prepared using aliquots measured gravimetrically from master radionuclide solution sources. The Am-241 was calibrated by 4 pi alpha liquid scintillation counting. All other radionuclides were calibrated using a germanium gamma spectrometer system. Calibration and purity were checked using a germanium gamma spectrometer system. At the time of calibration no interfering gamma-ray emitting impurities were detected. The gamma-ray emission rates for the most intense gamma-ray lines are given. Analytics maintains traceability to the National Institute of Standards and Technology through a Measurements Assurance Program as described in USNRC Regulatory Guide 4.15, Rev. 1, February, 1979.

Calibration date: July 1, 2002 12:00 EST

ISOTOPE	GAMMA-RAY ENERGY	HALF-LIFE	GAMMA-RAYS PER SECOND	TOTAL UNCERTAINTY %
Am-241	59.5	432 y	1301	5.0
Cd-109	88	462.6 d	1882	5.0
Co-57	122	271.79 d	994.2	4.7
Ce-139	166	137.6 d	1420	4.3
Hg-203	279	46.61 d	3085	4.1
Sn-113	392	115.1 d	2094	4.1
Cs-137	662	30.07 y	1320	4.8
Y-88	898	106.6 d	4847	4.2
Co-60	1173	5.2714 y	2354	4.1
Co-60	1332	5.2714 y	2382	4.2
Y-88	1836	106.6 d	5068	4.0

Approximately 140 mL customer supplied sand.

P O NUMBER EW060602, Item 4

SOURCE PREPARED BY:

M. Taskaeva
M. Taskaeva Radiochemist

Q A APPROVED:

Rec'd 7/3/02

This standard will expire one year after the calibration date.

RSO # 720 was opened and split into multiple LSC vials, as shown

720.3020.47	-1	35.8071 g	(Bal 12)
↓	-2	36.1586 g	↓
	-3	36.1325	
	-4	36.0040	
	-5	36.4197	
	-6	34.5663	

These will be used as δ daily check sources

[Signature]
10/30/06

Continued on Page

Read and Understood By

[Signature]

10/30/06

Signed

Date

Signed

Date

RSO #967 was opened and split into multiple LSC vials, to be used as check sources, as shown

767.3020.48-7	36.6640g	(Bal 12)
↓	8 36.1856g	↓
	9 36.3396g	
	10 35.9937g	
	11 36.7952g	
	12 33.1100g	

JES
10/30/06

Continued on Page _____

Read and Understood By _____

[Signature]

10/30/06

Signed

Date

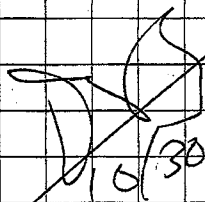
Signed

136 of 148 Date

RSO # 636 was opened and split into multiple LSC vials, to be used as 8 daily check sources, as shown

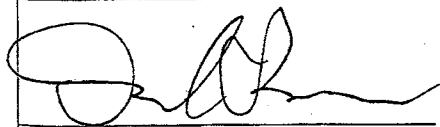
636.3020.49-13	34.2237 g	(Bal 12)
↓ 14	33.7917 g	↓
15	34.6628	
16	34.1622	
17	34.2401	
18	34.6838	

The remaining 9.1386g was transferred to a 200 ml plastic beaker and marked for disposal.


10/30/06

Continued On Page _____

Read and Understood By _____



Signed

10/30/06

Date

Signed

Date

ALS

Gamma Spectrometer Calibration Log

Date:

6/18/17

Reviewed By/Date:

JP 6/18/17

Det. No.	Out Of Service	Background		Source Check			Repeat Source Check			
		Started	OK	Started	OK	Failed Parameter(s)	OK	Failed Parameter(s)	Corrective Action Taken **	Removed from Service
1.				JP	JP					
2.				JP	JP					
3.				JP	JP	1332 Fwim	JP			
4.				JP	JP	1332 Fwim	JP			
5.				JP	JP					
6.				JP	JP					
7.				JP	JP					
8.				JP	JP					
9.				JP	JP					
10.	JP			JP	JP					

.** Corrective Action:

*** Due to detector _____ failing two different QC parameters on the first and second daily check, a third daily check was performed. All QC parameters passed for the third daily check. Detector _____ is online for the date of _____.

471595 A

Form 754r16a.doc (10/27/11)

170823D03.SPC Analyzed by

JM

SEEKER D E T E C T O R Q . C . A N A L Y S I S Version 2.2.2

ID: DAILY CHECK

Detector # 3 Detector Q.C. Analysis for 06/18/2017 09:19:46

Standards File #: 97 (Daily Performance Check(S SOURCES 1-12))

#	Parameter	Value	n Sigma Test	Bounds Test	T- Test
1	60 keV Centroid	122.138	N.A.	Pass	N.A.
2	60 keV FWHM	9.611E-01	N.A.	Pass	N.A.
3	60 keV Efficiency	1.058E-02	N.A.	Pass	N.A.
4	662 keV Centroid	1324.058	N.A.	Pass	N.A.
5	662 keV FWHM	1.884	N.A.	Pass	N.A.
6	662 keV Efficiency	1.542E-02	N.A.	Pass	N.A.
7	1332 keV Centroid	2662.813	N.A.	Pass	N.A.
8	1332 keV FWHM	3.083	N.A.	<FAIL>	N.A.
9	1332 keV Efficiency	7.282E-03	N.A.	Pass	N.A.

JP

 SEEKER D E T E C T O R Q . C . A N A L Y S I S Version 2.2.2

ID: DAILY CHECK

Detector # 3 Detector Q.C. Analysis for 06/18/2017 09:57:26

Standards File #: 97 (Daily Performance Check(S SOURCES 1-12))

#	Parameter	Value	n Sigma Test	Bounds Test	T- Test
1	60 keV Centroid	122.196	N.A.	Pass	N.A.
2	60 keV FWHM	9.430E-01	N.A.	Pass	N.A.
3	60 keV Efficiency	9.971E-03	N.A.	Pass	N.A.
4	662 keV Centroid	1324.156	N.A.	Pass	N.A.
5	662 keV FWHM	1.799	N.A.	Pass	N.A.
6	662 keV Efficiency	1.605E-02	N.A.	Pass	N.A.
7	1332 keV Centroid	2663.442	N.A.	Pass	N.A.
8	1332 keV FWHM	2.865	N.A.	Pass	N.A.
9	1332 keV Efficiency	7.566E-03	N.A.	Pass	N.A.

SEEKER D E T E C T O R Q . C . A N A L Y S I S Version 2.2.2

ID: DAILY CHECK

Detector # 4 Detector Q.C. Analysis for 06/18/2017 09:19:54

Standards File #: 97 (Daily Performance Check(S SOURCES 1-12))

#	Parameter	Value	n Sigma Test	Bounds Test	T- Test
1	60 keV Centroid	121.721	N.A.	Pass	N.A.
2	60 keV FWHM	9.860E-01	N.A.	Pass	N.A.
3	60 keV Efficiency	1.487E-02	N.A.	Pass	N.A.
4	662 keV Centroid	1323.208	N.A.	Pass	N.A.
5	662 keV FWHM	1.850	N.A.	Pass	N.A.
6	662 keV Efficiency	1.466E-02	N.A.	Pass	N.A.
7	1332 keV Centroid	2661.210	N.A.	Pass	N.A.
8	1332 keV FWHM	3.256	N.A.	<FAIL>	N.A.
9	1332 keV Efficiency	6.654E-03	N.A.	Pass	N.A.

Q.C. Results Saved.

SEEKER DETECTOR Q.C. ANALYSIS Version 2.2.2

ID: DAILY CHECK

Detector # 4 Detector Q.C. Analysis for 06/18/2017 10:00:12

Standards File #: 97 (Daily Performance Check(S SOURCES 1-12))

#	Parameter	Value	n Sigma Test	Bounds Test	T- Test
1	60 keV Centroid	121.789	N.A.	Pass	N.A.
2	60 keV FWHM	9.367E-01	N.A.	Pass	N.A.
3	60 keV Efficiency	1.459E-02	N.A.	Pass	N.A.
4	662 keV Centroid	1323.278	N.A.	Pass	N.A.
5	662 keV FWHM	1.922	N.A.	Pass	N.A.
6	662 keV Efficiency	1.479E-02	N.A.	Pass	N.A.
7	1332 keV Centroid	2661.936	N.A.	Pass	N.A.
8	1332 keV FWHM	2.771	N.A.	Pass	N.A.
9	1332 keV Efficiency	6.198E-03	N.A.	Pass	N.A.

SEEKER DETECTOR Q.C. ANALYSIS Version 2.2.2

ID: DAILY CHECK

Detector # 7 Detector Q.C. Analysis for 06/18/2017 09:20:22

Standards File #: 97 (Daily Performance Check(S SOURCES 1-12))

#	Parameter	Value	n Sigma Test	Bounds Test	T- Test
1	60 keV Centroid	123.277	N.A.	Pass	N.A.
2	60 keV FWHM	7.202E-01	N.A.	Pass	N.A.
3	60 keV Efficiency	1.202E-02	N.A.	Pass	N.A.
4	662 keV Centroid	1325.862	N.A.	Pass	N.A.
5	662 keV FWHM	1.772	N.A.	Pass	N.A.
6	662 keV Efficiency	1.860E-02	N.A.	Pass	N.A.
7	1332 keV Centroid	2664.578	N.A.	Pass	N.A.
8	1332 keV FWHM	2.866	N.A.	Pass	N.A.
9	1332 keV Efficiency	9.641E-03	N.A.	Pass	N.A.

Gamma Spectrometer Calibration Log

Date: 6/19/17Reviewed By/Date: JR 6/19/17

Det. No.	Out Of Service	Background		Source Check			Repeat Source Check			
		Started	OK	Started	OK	Failed Parameter(s)	OK	Failed Parameter(s)	Corrective Action Taken **	Removed from Service
1.				SG	SG					
2.				|	SG					
3.				|	/	1332 KeV FWHM	SG			
4.				|	SG					
5.				|	SG					
6.				|	/	1332 KeV FWHM	SG			
7.				|	SG					
8.				|	SG					
9.				↓	/	1332 Cent.	JR		Can Adj	
10.	SG			/	/					

** Corrective Action:

*** Due to detector _____ failing two different QC parameters on the first and second daily check, a third daily check was performed. All QC parameters passed for the third daily check. Detector _____ is online for the date of _____.

471596 A

Form 754r16a.doc (10/27/11)

SEEKER D E T E C T O R Q . C . A N A L Y S I S Version 2.2.2

ID: DAILY CHECK

Detector # 3 Detector Q.C. Analysis for 06/19/2017 08:20:27

Standards File #: 97 (Daily Performance Check(S SOURCES 1-12))

#	Parameter	Value	n Sigma Test	Bounds Test	T- Test
1	60 keV Centroid	122.147	N.A.	Pass	N.A.
2	60 keV FWHM	9.671E-01	N.A.	Pass	N.A.
3	60 keV Efficiency	1.043E-02	N.A.	Pass	N.A.
4	662 keV Centroid	1324.377	N.A.	Pass	N.A.
5	662 keV FWHM	1.930	N.A.	Pass	N.A.
6	662 keV Efficiency	1.572E-02	N.A.	Pass	N.A.
7	1332 keV Centroid	2663.480	N.A.	Pass	N.A.
8	1332 keV FWHM	2.959	N.A.	<FAIL>	N.A.
9	1332 keV Efficiency	7.645E-03	N.A.	Pass	N.A.

SEEKER D E T E C T O R Q . C . A N A L Y S I S Version 2.2.2

ID: DAILY CHECK

Detector # 3 Detector Q.C. Analysis for 06/19/2017 08:51:59

Standards File #: 97 (Daily Performance Check(S SOURCES 1-12))

#	Parameter	Value	n Sigma Test	Bounds Test	T- Test
1	60 keV Centroid	122.154	N.A.	Pass	N.A.
2	60 keV FWHM	9.291E-01	N.A.	Pass	N.A.
3	60 keV Efficiency	1.025E-02	N.A.	Pass	N.A.
4	662 keV Centroid	1324.384	N.A.	Pass	N.A.
5	662 keV FWHM	1.893	N.A.	Pass	N.A.
6	662 keV Efficiency	1.568E-02	N.A.	Pass	N.A.
7	1332 keV Centroid	2663.909	N.A.	Pass	N.A.
8	1332 keV FWHM	2.695	N.A.	Pass	N.A.
9	1332 keV Efficiency	6.563E-03	N.A.	Pass	N.A.

SEEKER D E T E C T O R Q . C . A N A L Y S I S Version 2.2.2

ID: DAILY CHECK

Detector # 4 Detector Q.C. Analysis for 06/19/2017 08:20:35

Standards File #: 97 (Daily Performance Check(S SOURCES 1-12))

#	Parameter	Value	n Sigma Test	Bounds Test	T- Test
1	60 keV Centroid	121.687	N.A.	Pass	N.A.
2	60 keV FWHM	8.230E-01	N.A.	Pass	N.A.
3	60 keV Efficiency	1.347E-02	N.A.	Pass	N.A.
4	662 keV Centroid	1323.061	N.A.	Pass	N.A.
5	662 keV FWHM	1.871	N.A.	Pass	N.A.
6	662 keV Efficiency	1.460E-02	N.A.	Pass	N.A.
7	1332 keV Centroid	2661.572	N.A.	Pass	N.A.
8	1332 keV FWHM	2.656	N.A.	Pass	N.A.
9	1332 keV Efficiency	6.458E-03	N.A.	Pass	N.A.

SEEKER D E T E C T O R Q . C . A N A L Y S I S Version 2.2.2

ID: DAILY CHECK

Detector # 7 Detector Q.C. Analysis for 06/19/2017 08:21:04

Standards File #: 97 (Daily Performance Check(S SOURCES 1-12))

#	Parameter	Value	n Sigma Test	Bounds Test	T- Test
1	60 keV Centroid	123.238	N.A.	Pass	N.A.
2	60 keV FWHM	7.479E-01	N.A.	Pass	N.A.
3	60 keV Efficiency	1.203E-02	N.A.	Pass	N.A.
4	662 keV Centroid	1325.765	N.A.	Pass	N.A.
5	662 keV FWHM	1.721	N.A.	Pass	N.A.
6	662 keV Efficiency	1.777E-02	N.A.	Pass	N.A.
7	1332 keV Centroid	2664.378	N.A.	Pass	N.A.
8	1332 keV FWHM	2.890	N.A.	Pass	N.A.
9	1332 keV Efficiency	9.550E-03	N.A.	Pass	N.A.