INL/EXT-12-27277

Alternative Bench Standards: Sample Production Report

N.R. Mann
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September 2012

The INL is a U.S. Department of Energy National Laboratory
operated by Battelle Energy Alliance

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ABSTRACT

The INL has prepared four standards representing krypton concentrations of 1.1X, 1.54X, 10X and 100X the reported atmospheric value of 70 dpm ^{85}Kr per cubic centimeter of Kr gas at 25 °C (ie. 1.1X is 1.1 x 70, or 77 dpm ^{85}Kr per cubic centimeter of Kr gas at 25 °C). A t-zero date and time of January 1, 2012 at 1200 Zulu was used for all standards. The Alternative Bench Standards (ABS) of 1.1X, 1.54X, 10X and 100X, are designated by titles of ABS-A, ABS-B, ABS-C and ABS-D, respectively. The concentration of Kr in air is 1.14 ppm.

SUMMARY

The INL has prepared four standards representing krypton concentrations of 1.1X, 1.54X, 10X and 100X the reported atmospheric value of 70 dpm ^{85}Kr per cubic centimeter of Kr gas at 25 °C (ie. 1.1X is 1.1 x 70, or 77 dpm ^{85}Kr per cubic centimeter of Kr gas at 25 °C). A t-zero date and time of January 1, 2012 at 1200 Zulu was used for all standards.

The activity of ^{85}Kr of each ABS standard is as follows:

ABS-A
77 ± 4 dpm/cc @ 25 °C and 760 Torr
t_0 of January 1, 2012 at 1200 Zulu

ABS-B
108 ± 5 dpm/cc @ 25 °C and 760 Torr
t_0 of January 1, 2012 at 1200 Zulu

ABS-C
703 ± 17 dpm/cc @ 25 °C and 760 Torr
t_0 of January 1, 2012 at 1200 Zulu

ABS-D
7024 ± 182 dpm/cc @ 25 °C and 760 Torr
t_0 of January 1, 2012 at 1200 Zulu

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FIGURES

TABLES

ACRONYMS AND NOMENCLATURE

ABS-A	1.1 X
ABS-B	1.54X
ABS-C	10X
ABS-D	100X
dpm	Disintegrations per minute
LANL	Los Alamos National Laboratory

Alternative Bench Standards
Sample Production Report

1. LABORATORY ACTIVITIES

1.1 Bean Production

Utilizing the gas manifold shown in Figure 1, individual ^{85}Kr spikes with activities specific to the ABS-B, ABS-C and ABS-D standards were isolated in glass beans. The minimum activities for the ABS-B, ABS-C and ABS-D standards were calculated based on the requested volumes of 19000, 13000 and 4000 liters, respectively. The following calculation was used to determine the minimum activity needed to make the 1.54X standard (ABS-B). Minimum activities can be calculated for ABS-C and ABS-D by use of the same equations. ABS-A was prepared by dilution of the ABS-B standard to the requested volume of 19000 liters.

Figure 1. Photograph of the gas manifold setup.

^{85}Kr activity at t_0 for air bottled on May 17, 2012 (Julian Date: 138). Compressed air source: Billings, Montana.

$$\frac{70\ dpm}{cc\ Kr}\ e^{\frac{\ln(2)}{10.76\ years}(138\ days)\frac{Years}{365.24\ days}} = \frac{71.73\ dpm}{cc\ Kr}$$

For ABS-B the desired activity is 1.54X the atmospheric value.

$$\left(\frac{70\ dpm}{cc\ Kr} \times 1.54\right) - \frac{71.73\ dpm}{cc\ Kr} = \frac{36.0\ dpm}{cc\ Kr}$$

$$\frac{36.0\ dpm}{cc\ Kr} \times \frac{1.14\ cc\ Kr}{1.0E6\ cc\ air} \times \frac{1000\ cc\ air}{1.0\ L\ air} 19000L\ air = 781\ dpm$$

Thus, the minimum activity needed to produce the standard is 781 dpm ^{85}Kr.

Following production using the gas manifold, the individual beans were assayed to verify the activity using gamma spectroscopy. Assay results are shown in Table 1. It should be noted that, a secondary count of the ABS-D bean was provided by Los Alamos National Laboratory (LANL). Assay results of the secondary count are also shown in Table 1. The nuclear constants for bean assay are shown in Table 2.

Table 1. Assay results for the ABS-B, ABS-C and ABS-D beans.

Standard	Bean #	Isotope	Activity (dpm)	% Uncertainty (1 sigma)
ABS-B	3	^{85}Kr	2250	2.8
ABS-C	4	^{85}Kr	25600	2.6
ABS-D	7	^{85}Kr	263000	2.6
ABS-D (LANL)	7	^{85}Kr	270000	2.2

Table 2. Nuclear constants used.

Isotope	Half Life (units)	Energy (keV)	Branching Ratio (%)
Kr-85	10.76 (Yr)	514.00	0.434
Practical Gamma-ray Spectrometry, Gordon Gilmore, 2nd edition, 2008.			

1.2 Cylinder and Sphere Production

Prior to the production of the ABS-B and ABS-C standards, the 300 L mixing system was filled and evacuated ten times with UHP nitrogen to remove residual krypton without introducing water. A single fill and evacuation course consisted of filling the 300 L mixing tank with 0.1 kg of ultra-high purity nitrogen followed by an evacuation to a maximum pressure of 25 Torr. A schematic and photograph of the 300 L mixing system is shown in Figures 2 and 3.

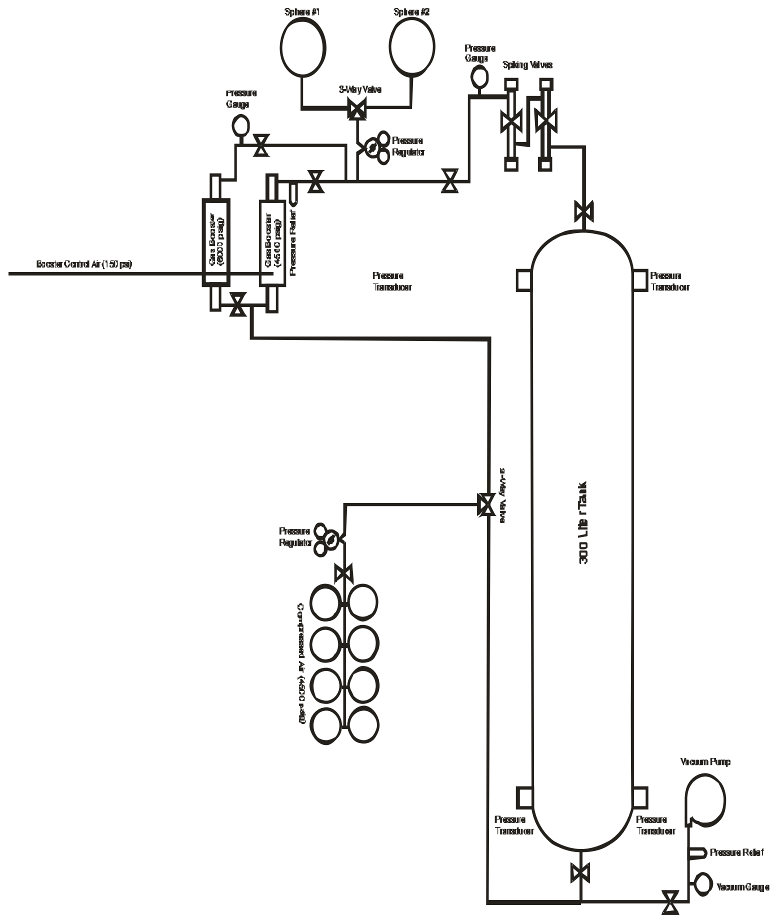

Figure 2. Schematic of the 300 L mixing tank system.

Figure 3. Photograph of the 300 L mixing tank.

The system was then over-filled past a predetermined mass of May 17, 2012 compressed breathing air. The tank is then disconnected to freely float on the balance and air is bled off to the correct mass required to dilute the spike to the correct specific activity requested. Mass calculations are shown below.

The spike bean corresponding to the standard being produced was placed into the spiking valve within the 300 L mixing system. Connections were made so that air would flow from the 300 L cylinder through the booster pump to the spiking valves and back to the other end of the 300 L cylinder. Two filters (440 micron and 140 micron) were placed on the downstream end of the spiking valves to prevent broken glass from entering the mixing tank.

The pressurized 300 L tank was then allowed to equalize pressure throughout the system. The booster pump was then started and valves opened so that the air was pumped in a recycle loop from one end of the 300 L cylinder through the spiking valves back into the other end of the 300 L cylinder. During recycle, a single spiking valve was turned to break the bean and then the valve was returned to the open position. Recycling of the tank is continued for approximately one hour. The evacuated cylinders and spheres were then filled with the mixed gas using the booster pump.

Calculations for the mass of compressed breathing and final activities for the ABS-B, ABS-C and ABS-D standards are presented below.

Calculations applicable to all ABS standards:

Convert 1.2929 kg/SCM at 0°C to 25°C.

$$\frac{1.2929\ \mathrm{kg}}{\mathrm{SCM}} \times \frac{273.15\ \mathrm{K}}{298.15\ \mathrm{K}} = \frac{1.184\ \mathrm{kg}}{\mathrm{SCM}}$$

Convert 70 dpm/cc of ^{85}Kr[a] to dpm/kg of Air at 25 C.

$$\frac{70\ dpm}{cc\ Kr}\frac{1.14\ cc\ Kr}{1E6\ cc\ Air} \times \frac{1E6\ cc\ Air}{SCM} \times \frac{SCM}{1.184\ kg} = \frac{67.4\ dpm}{kg}$$

Convert 73.7 dpm/cc of ^{85}Kr[b] to dpm/kg of Air at 25 C.

$$\frac{73.7\ dpm}{cc\ Kr} \times \frac{1.14\ cc\ Kr}{1E6\ cc\ Air} \times \frac{1E6\ cc\ Air}{SCM} \times \frac{SCM}{1.184\ kg} = \frac{69.0\ dpm}{kg}$$

1.2.1 ABS-B (1.54X)

Final concentration needed in dpm/cc.

$$\frac{70\ \mathrm{dpm}\ {}^{85}_{36}Kr}{\mathrm{cc\ Kr}} \times 1.54 = \frac{108\ \mathrm{dpm}\ {}^{85}_{36}Kr}{\mathrm{cc\ Kr}}$$

Final concentration needed in dpm/kg

$$\frac{67.4\ dpm\ {}^{85}_{36}Kr}{kg\ Air} \times 1.54 = \frac{104\ dpm\ {}^{85}_{36}Kr}{kg\ Air}$$

Net dpm/kg to be added to air

$$\frac{104\ dpm\ {}^{85}_{36}Kr}{kg\ Air} - \frac{69.0\ dpm\ {}^{85}_{36}Kr}{kg\ Air} = \frac{34.7\ dpm\ {}^{85}_{36}Kr}{kg\ Air}$$

a. Provided specific activity of ^{85}Kr in air.

b. Diluent air was bottled on May 17, 2012, and decay corrected to January 1, 2012.

Actual bean activity was 2250 dpm. Thus, the correct amount of air needed is

$$2250\ dpm\ {}^{85}_{36}Kr \times \frac{kg\ Air}{34.72\ dpm\ Kr} = 64.9\ kg$$

The actual air mass that was added was 64.9 kg.

$$\left(\frac{2250\ dpm\ {}^{85}_{36}Kr}{64.9\ kg\ Air} + \frac{69.0\ dpm\ {}^{85}_{36}Kr}{kg\ Air}\right) \times \left(\frac{1.184\ kg\ Air}{SCM\ Air}\frac{SCM\ Air}{1E6\ cc\ Air}\frac{1E6\ cc\ air}{1.14\ cc\ Kr}\right) = \frac{108\ dpm\ {}^{85}_{36}Kr}{cc\ Kr}$$

1.2.2 ABS-C (10X)

Final concentration needed in dpm/cc.

$$\frac{70\ \text{dpm}\ {}^{85}_{36}Kr}{\text{cc Kr}} \times 10.0 = \frac{700.0\ \text{dpm}\ {}^{85}_{36}Kr}{\text{cc Kr}}$$

Final concentration needed in dpm/kg

$$\frac{67.4\ dpm\ {}^{85}_{36}Kr}{kg\ Air} \times 10.0 = \frac{674\ dpm\ {}^{85}_{36}Kr}{kg\ Air}$$

Net dpm/kg to be added to air

$$\frac{674\ dpm\ {}^{85}_{36}Kr}{kg\ Air} - \frac{69.0\ dpm\ {}^{85}_{36}Kr}{kg\ Air} = \frac{605\ dpm\ {}^{85}_{36}Kr}{kg\ Air}$$

Actual bean activity was 25600 dpm. Thus, the correct amount of air needed is

$$25600\ dpm\ {}^{85}_{36}Kr \times \frac{kg\ Air}{605\ dpm\ Kr} = 42.3\ kg$$

The actual air mass that was added was 42.3 kg.

$$\left(\frac{25634\ dpm\ {}^{85}_{36}Kr}{42.3\ kg\ Air} + \frac{69.0\ dpm\ {}^{85}_{36}Kr}{kg\ Air}\right) \times \left(\frac{1.184\ kg\ Air}{SCM\ Air}\frac{SCM\ Air}{1E6\ cc\ Air}\frac{1E6\ cc\ air}{1.14\ cc\ Kr}\right)$$

$$= 703\ \frac{dpm\ {}^{85}_{36}Kr}{cc}$$

1.2.3 ABS-D (100X)

Final concentration needed in dpm/cc.

$$\frac{70\ \text{dpm}\ {}^{85}_{36}Kr}{\text{cc Kr}} \times 100 = \frac{7000\ \text{dpm}\ {}^{85}_{36}Kr}{\text{cc Kr}}$$

Final concentration needed in dpm/kg

$$\frac{67.4\ dpm\ {}^{85}_{36}Kr}{kg\ Air} \times 100 = \frac{6740\ dpm\ {}^{85}_{36}Kr}{kg\ Air}$$

Net dpm/kg to be added to air

$$\frac{6740\ dpm\ {}^{85}_{36}Kr}{kg\ Air} - \frac{69.0\ dpm\ {}^{85}_{36}Kr}{kg\ Air} = \frac{6670\ dpm\ {}^{85}_{36}Kr}{kg\ Air}$$

Actual bean activity was 263000 dpm. Thus, the correct amount of air needed is

$$263000\ dpm\ {}^{85}_{36}Kr \times \frac{kg\ Air}{6670\ dpm\ Kr} = 39.4\ kg$$

The actual air mass that was added was 39.4 kg.

$$\left(\frac{262987\ dpm\ {}^{85}_{36}Kr}{39.4\ kg\ Air} + \frac{69.0\ dpm\ {}^{85}_{36}Kr}{kg\ Air}\right) \times \left(\frac{1.184\ kg\ Air}{SCM\ Air}\frac{SCM\ Air}{1.0E6\ cc\ Air}\frac{1.0E6\ air}{1.14\ cc\ Kr}\right)$$

$$= 7024\ \frac{dpm\ {}^{85}_{36}Kr}{cc}$$

1.2.4 ABS-A (1.1X)

Due to the relatively low activity and lengthy count time of the ABS-A (1.1X) standard, the remaining ABS-B (1.54X) was used as the starting material for the production of the ABS-A standard.

The diluent air mass was calculated using the following equation:

$$A_x + B_y = C_{(x + y)}$$

A = 1.54 (1.54X)

B = 1.025 - ^{85}Kr activity at t_0 for Air bottled on May 17, 2012 12:00 Zulu (70 dpm)/ ^{85}Kr activity at t_0 January 1, 2012 12:00 Zulu (71.728).

C = 1.1 (1.1X)

x = 10.7 kg (mass of 1.54X standard)

y = kg of compressed air added

$$1.54\ (10.7\ kg) + 1.025\ (y\ kg) = 1.1\ (10.7 + y) kg$$

$$y = 62.5\ kg$$

62.5 kg of Air + 10.7 kg of remaining ABS-B (1.54X) = 73.2 kg ABS-A

^{85}Kr activity in 10.7 kg of ABS-B standard:

$$\frac{108\ dpm\ {}^{85}_{36}Kr}{cc\ ABS-B} \times \frac{1.14\ cc\ Kr}{1.0E6\ Air} \times \frac{1.0E6\ cc}{1.0\ SCM} \times \frac{1.0\ SCM}{1.184\ kg} = \frac{103.98\ dpm\ dpm\ {}^{85}_{36}Kr}{kg\ Air}$$

$$10.7\ kg\ \times \left(\frac{103.98\ dpm}{1.0\ kg\ Air}\right) = 1112.59\ dpm$$

^{85}Kr activity from 62.5 kg of diluent air (bottled on May 17, 2012 12:00 Zulu):

$$62.5\ kg\ \times \frac{1.0\ SCM}{1.184\ kg} \times \frac{1.0E6\ cc}{1.0\ SCM} \times \frac{1.14\ cc}{1.0E6\ cc\ Air} \times \frac{71.73\ dpm}{1.0\ cc\ Kr} = 4316.52\ dpm\ {}^{85}_{36}Kr$$

Combined ^{85}Kr activity from 10.7 kg of ABS-B standard and 62.5 kg of diluent air:

$$Total\ {}^{85}_{36}Kr\text{: } 1112.59\ dpm + 4316.52 = 5429.11\ dpm$$

$$\frac{5429.11\ dpm\ {}^{85}_{36}Kr}{73.2\ kg\ Air} \times \frac{1.184\ kg}{1.0\ SCM} \times \frac{1.0\ SCM}{1.0E6\ cc} \times \frac{1.0E6\ cc\ Air}{1.14\ cc\ Kr}$$

$$= \frac{77\ dpm\ {}^{85}_{36}Kr}{cc}$$

1.3 Fill Information

Cylinder and sphere identification and contents in standard cubic meters for ABS-A, ABS-B, ABS-C and ABS-D are shown in Tables 3, 4, 5 and 6 respectively.

Table 3. ABS-A (1.1X)

Fill Order	Cylinder SN	SCM
1	1671594	1.00
2	1847576	0.96
3	1567572	0.95
4	94257Y	0.99
5	1442755	0.97
6	124689	0.99
7	1836337	0.98
8	295547	0.97
9	1635012	1.00
10	K0631/00029	2.63
11	J6616/00030	2.66
12	K0724/00419	2.62
13	J6282/00353	2.66

Table 4. ABS-B (1.54X)

Fill Order	Cylinder SN	SCM
1	275316	1.00
2	E68289	0.97
3	1304764	0.96
4	1130793	0.97
5	136752	0.98
6	295531	0.95
7	2771950	0.94
8	1847443	0.96
9	82004	1.06
10	R0307/00384	2.74
11	K0422/01144	2.74
12	J5007/00190	2.72
13	K0294/00014	2.70

Table 5. ABS-C (10X)

Fill Order	Cylinder SN	SCM
1	E68287	1.00
2	1847399	1.00
3	E898756	1.02
4	1634896	1.00
5	308692	1.01
6	2560008	1.02
7	K0490/01147	2.75
8	K0501/01115	2.75
9	R0221/00778	2.74
10	K0405/00413	2.76

Table 6. ABS-D (100X)

Fill Order	Cylinder SN	SCM
1	1047301	0.98
2	1847616	0.99
3	D36550	1.00
4	1671728	0.99
5	229453D	1.03
6	124541	1.00

2. PROPOGATION OF UNCERTAINTY AND ERROR ANALYSIS

The uncertainty in a concentration of dpm/cc is derived from the uncertainty of the assay, the balance uncertainty, the uncertainty in the conversion of air mass to cc and the concentration of ^{85}Kr in one cc of Kr gas.

2.1 Gamma Assay Error Analysis

$$\text{Activity(Bq)}_{\text{Tzero}} = \frac{n_{Tzero}}{\varepsilon \times p} = \frac{n_{TOC} \times DC}{\varepsilon \times p}$$

n_{Tzero} is the count per second at time T_{zero}.

N_{TOC} is the Area of the peak per live time

Area = fitted 514.0 keV peak area (# of gamma rays detected)

LT = Live time

$$n_{TOC} = \frac{\text{Area}}{\text{LT}}$$

ε is the detector peak efficiency 0.18079 ± 2.3%.

p is ^{85}Kr (514.0 keV) emission probability 0.435 %.

DC is the decay correction.

$$DC = \frac{\lambda \times RT}{e^{-\lambda(\Delta T)} - e^{-\lambda(\Delta T + RT)}}$$

$$\lambda = \frac{\ln(2)}{t_{\frac{1}{2}}}$$

$t_{1/2}$= half-life 10.76 ± 0.0005 days (converted to seconds)

RT = Real time (seconds)

ΔT = time in seconds from acquisition time to T_{zero}

Activity (disintegrations per minute)$_{\text{Tzero}}$ = Activity (Bq)$_{\text{Tzero}}$ × 60

Calculation of Uncertainty of Activity at T_{zero}

$$\sigma_{Act_{Tzero}(dpm)} = Act_{(Tzero)}(dpm) \times \sqrt{\frac{\sigma_{Area}^2}{Area^2} + \frac{\sigma_{\varepsilon}^2}{\varepsilon^2} + \frac{\sigma_{DC}^2}{DC^2} + \frac{\sigma_{t_{\frac{1}{2}}}^2}{t_{\frac{1}{2}}^2} + \frac{\sigma_m^2}{m^2}}$$

$\sigma_{Area} = Poisson$ uncertainty and fit uncertainty

σ_{ε} = uncertainty in peak efficiency \`

$$\sigma_{DC}^2 = \frac{1}{t_{\frac{1}{2}}}[\ln(2) \times \Delta T]^2 \times \sigma_{t_{\frac{1}{2}}}^2$$

$\sigma_{t_{\frac{1}{2}}}$ = 0.0005 days (converted to seconds)

2.2 Balance Uncertainty

The floor balance uncertainty for the mixing cylinder is derived from the balance calibration performed yearly. INL calibration data is shown in Appendix A and is +/- 0.4 lbs at 150 lbs. This is 0.3% uncertainty for the mixing cylinder filled with 100 lbs of air.

The balance that was used is being evaluated for accuracy and precision by placement of a known mass on the balance repeatedly. A control chart that demonstrates the accuracy and precision of the TR-1-NK floor balance is shown in Figure 4.

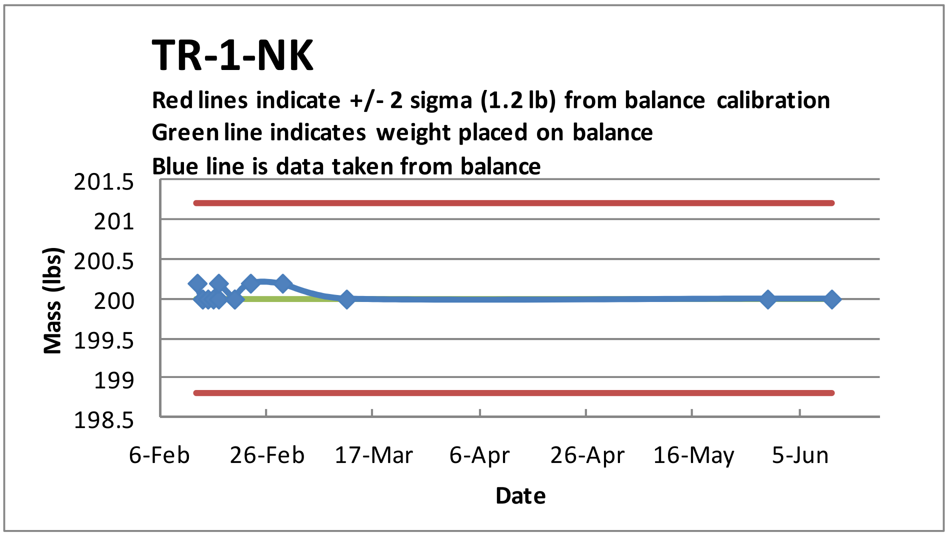

Figure 4. Control chart of the TR-1-NK floor balance.

2.3 Determination of Standard Cubic Meter of Air at 25° C

Density of dry air at 0 °C from CRC *Handbook of Chemistry and Physics 71st ed.* is 1.2929 kg/m^3.

$$1\ m^3 \text{Air} = 1.2929\ kg \pm 0.0005$$

The uncertainty is derived from the difference in density of air having 10 ppm water and dry air.

This constant converted to 25 °C is:

$$\frac{1.2929\ \text{kg}}{\text{SCM}} \times \frac{273.15\ \text{K}}{298.15\ \text{K}} = \frac{1.1845\ \text{kg}}{\text{SCM}} \pm 0.0005$$

2.4 Uncertainty in dpm ^{85}Kr per cc Kr

This value was given to us as 70 ±5 or 7.14% for natural Kr.

2.5 Uncertainty Propagation

The calculation is addition, multiplication and division. The uncertainty involves absolute uncertainty for the addition and relative uncertainty as a decimal for this calculation for multiplication and division. In both cases the square root of the sum of the squares is used.

$$\sigma\%_{\ spike(\frac{dpm}{kg})} = \sqrt{(\sigma\%_{assay}^{2} + \sigma\%_{scale}^{2})}$$

$$\sigma_{\ Total\ (\frac{dpm}{kg})} = \sqrt{\sigma_{\ spike(\frac{dpm}{kg})} + \sigma_{\ natural(\frac{dpm}{kg})}}$$

$$\sigma\%_{\left(\frac{dpm\ {}^{85}_{36}Kr}{cc}\right)} = \sqrt{\sigma\%_{Total\ (\frac{dpm}{kg})} + \sigma\%_{Density\ of\ air}}$$

Appendix A

Balance Calibration

Appendix A

Balance Calibration

INL
CALIBRATION INPUT DATA

8/16/2012

NAME: MATTHEW WATROUS	BADGE: 70173	PH: 526-3955	AREA: REC	BLDG: UB2	RM: 603

ID Number: 728380 Mfr: TARA SYS Model: TR-1-NK Noun Name: ELECTRONIC SCALE Serial #:

Next Cal Due Date: 1/10/2013		**ACTION PERFORMED**		**AS-FOUND CONDITION**
Calibration Date:	1/10/2012	1 ☐ Acceptance Test		1 ○ In Tolerance
Charge Level:	8	2 ☐ Calibration - SCL Specs		2 ○ Out of Tolerance >1x <2x
Repair/Adj/etc C.L:	2	3 ☐ Calibration - MFG Specs		3 ◉ Out of Tolerance >2x <3x
Material Amount:	0	4 ☐ Clean		4 ○ Out of Tolerance >3x <5x
Charge Number:	370273100	5 ☑ Limited Calibration		5 ○ Out of Tolerance >5x
Cal Work Inst ID:	3057AO	6 ☐ Functional Check		6 ○ Out of Tolerance-Undetermined
Outside Vendor:		7 ☐ Performance Check		7 ☐ Inoperative
		8 ☐ Modify		8 ☐ Damaged
		9 ☑ Repair-needs Charge Level		9 ☐ Not Used
		10 ☐ Other		10 ☐ Not Determined
				11 ☐ Excessed
Calibrated By:	Steve Palmer	S#: 56710	Phone: 526-2761	12 ☐ Extension

CALIBRATION STANDARDS USED

720725	720764	707331	707327				

STANDARDS USED ARE TRACEABLE TO THE NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY DERIVED FROM ACCEPTED VALUES FOR NATURAL PHYSICAL CONSTANTS, OR DERIVED FROM THE RATIO TYPE OF SELF CALIBRATION TECHNIQUES.

LABORATORY TEMPERATURE AND HUMIDITY

Physical STD (106C)	(20.0 ± 0.3) °C (40 to 55) %RH	Electronic STD (106D)	(23.0 ± 0.5) °C (30 to 45) %RH
Dimensional STD (106B)	(20.0 ± 0.25) °C (30 to 45) %RH	Electronic CAL (Lab 112)	(23.0 ± 1.0) °C (20 to 50) %RH
Phys/Dim CAL (Lab 111)	(20.0 ± 0.5) °C (20 to 50) %RH	Remaining S&CL calibration areas:	(23.0 +5, -3) °C (20 to 50) %RH

Manufacturer's environmental specifications are evaluated for conformance when calibrations are performed outside the above stated conditions.

OUT OF TOLERANCE CONDITIONS FOUND DURING CALIBRATION

Function Tested	Standard Reading	UUT Reading	UUT Tolerance
Mass (lb)	50.0	49.6	± 0.2 lb
	100.0	99.4	± 0.4 lb
	150.0	149.4	± 0.4 lb

COMMENTS

USED STANDARDS 720725 THROUGH 720764.
Not calibrated above 300 lbs as per John Eisenmenger 1-10-12.
Repaired damaged cable and re-calibrated.
Calibration points found In-tolerance: 1.0, & 10.0 lb.

Appendix B

Gamma Standard

Appendix B

Gamma Standard

Eckert & Ziegler
Analytics

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

CERTIFICATE OF CALIBRATION

Standard Radionuclide Source

80330-370

Kr-85 Gas Standard in 33 mL Glass Sphere

Customer: Battelle Energy Alliance / Idaho National Laboratory
P.O. No.: 00088832, Item 1 (0000165102 4)

This standard radionuclide source was calibrated by comparison to NIST traceable standards in the same geometry using a germanium gamma spectrometer system. This standard was examined for interfering gamma ray emitting impurities using a germanium gamma spectrometer system. At the time of calibration no interfering gamma emmitting impurities could be detected. 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 1, February, 1979, 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.

Calibration Date: August 24, 2009 12:00 PM EST

Isotope	Activity (Bq)	Half-Life	Uncertainty*, (%) Type u_A	u_B	U
Kr-85	4.314E+04	10.752 years	0.7	1.7	3.7

1.2 µCi

***Uncertainty:** U – Relative expanded uncertainty, k=2. See NIST Technical Note 1297, "Guidelines for Evaluating and Expressing the Uncertainty of NIST Measurement Results."

Comments:
Total volume of sphere 3336 including septum side arm is 34.18 cc.

Source Calibrated By: ______________________
J. D. McCorvey, Count Room Supervisor

QA Approved: ______________________ Date: 8-26-09
D. M. Montgomery, QA Manager

ACCREDITED SOURCE CALIBRATION LABORATORY HEALTH PHYSICS SOCIETY FOUNDED 1956

End of Certificate

Corporate Office
24937 Avenue Tibbitts Valencia, California 91355

Laboratory
1380 Seaboard Industrial Blvd. Atlanta, Georgia, 30318