Instrument Efficiency Determination for Use in Minimum Detectable Concentration Calculations in Support of the Final Status Survey at HBPP

June 13, 2012

Pacific Gas and Electric Company®

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Reviewed By: _[signature]_ Date: 6-13-12

Approved By: _[signature]_ Date: 7/7/12

Table of Contents

Tables

Executive Summary

The minimum detectable concentration (MDC) of the field survey instrumentation is an important factor affecting the quality of the final status survey (FSS). The efficiency of an instrument inversely impacts the MDC value. The objective of this report is to determine the instrument and source efficiency values used to calculate MDC. Several factors were considered when determining these efficiencies and are discussed in the body of this report. Instrument efficiencies (e_i), and source efficiencies (e_s), for alpha beta detection equipment under various field conditions, and instrument conversion factors (E_i), for gamma scanning detectors were determined and the results are provided herein.

1.0 INTRODUCTION

Before performing Final Status Surveys of building surfaces and land areas, the MDC must be calculated to establish the instrument sensitivity. The Humboldt Bay Power Plant (HBPP) License Termination Plan (LTP) lists the available instrumentation and nominal detection sensitivities; however for the purposes of this basis document, efficiencies for the nominal 100cm^2 gas proportional and the 2"x2" NaI (Tl) detectors will be determined. Efficiencies for the other instrumentation listed in the LTP shall be determined on an as needed basis. The 100 cm^2 gas proportional probe will be used to perform building surface surveys (i.e. fixed point measurements). A 2"x2" NaI (Tl) detector will be used to perform gamma surveys (i.e., surface scans) of portions of land areas and possibly supplemental structural scans at the HBPP site. Although surface scans and fixed point measurements can be performed using the same instrumentation, the calculated MDCs will be quite different. MDC is dependent on many factors and may include but is not limited to:

- Instrument Efficiency
- Background
- Integration Time
- Surface Type
- Source to Detector Geometry
- Source Efficiency

A significant factor in determining an instrument MDC is the total efficiency, which is dependent on the instrument efficiency, the source efficiency and the type and energy of the radiation. MDC values are inversely affected by efficiency, as efficiencies increase, MDC values will decrease. Accounting for both the instrument and source components of the total efficiency provides for a more accurate assessment of surface activity.

2.0 CALIBRATION SOURCES

For accurate measurement of surface activity it is desirable that the field instrumentation be calibrated with source standards similar to the type and energy of the anticipated contamination. The nuclides listed in Table 2.1 illustrate the nuclides found in soil and building surface area DCGL results that are listed in the LTP.

Instrument response varies with incident radiations and energies; therefore, instrumentation selection for field surveys must be modeled on the expected surface activity. For the purposes of this report, isotopes with max beta energies less than that of C-14 (0.158 MeV) will be considered difficult to detect (reference

table 2.1). The detectability of radionuclides with max beta energies less than 0.158 MeV, utilizing gas proportional detectors, will be negligible at typical source to detector distances of approximately 0.5 inches. The source to detector distance of 1.27 cm (0.5 inches) is the distance to the detector with the recommended standoff. Table 2.1 provides a summary of the LTP radionuclides and their detectability using Radiological Health Handbook data.

Table 2. 1 Nuclides and Major Radiations: Approximate Energies

Nuclide	α Energy (MeV)	$E_{\beta max}$ (MeV)	Average E_{β} (MeV)	Photon Energy (MeV)	α Detectable w/Gas Proportional	β Detectable w/Gas Proportional	γ Detectable w/NaI 2x2
H-3		0.018	0.005				
C-14		0.158	0.049				
Ni-59							
Co-60		0.314	0.094	1.173(100%) 1.332(100%)		✓	✓
Ni-63		0.066	0.017				
Sr-90		0.544 2.245(Y-90)	0.200 0.931			✓	
Nb-94		0.50	0.156	0.702(100%) 0.871(100%)		✓	✓
Tc-99		0.295	0.085			✓	
I-129		0.154	0.041	0.039(8%)		✓	
Cs-137		1.167(5.4%) 0.512(95%)	0.195	0.662(85%) Ba-137m X-Rays		✓	✓
Eu-152		1.840	0.288	0.122(37%) 0.245 (8%) 0.344(27%) 0.779(14%) 0.965(15%), 1.087(12%) 1.113((14%) 1.408(22%)		✓	✓
Eu-154		1.850(10%)	0.228	0.143(40%) 1.274(35%)		✓	✓
Np-237	4.79(47%) 4.77(25%) 4.64(6%)				✓		
Pu-238	5.50(72%) 5.46(28%)			0.099(8E-3%) 0.150(1E-3%) 0.77(5E-5%)	✓		
Pu-239	5.16(88%) 5.11(11%)			0.039(0.007%) 0.052(0.20%) 0.129(0.005%)	✓		
Pu-240	5.17(73%) 5.12(27%)				✓		

Nuclide	α Energy (MeV)	$E_{\beta max}$ (MeV)	Average E_{β} (MeV)	Photon Energy (MeV)	α Detectable w/Gas Proportional	β Detectable w/Gas Proportional	γ Detectable w/NaI 2x2
Pu-241	4.90(0.0019%) 4.85(0.0003%)	0.021	0.005	0.145(1.6E-4%)			
Am-241	5.49(85%) 5.44(13%)			0.060(36%) 0.101(0.04%)	✓		
Cm-243	6.06(6%) 5.99(6%) 5.79(73%) 5.74(11.5%)			0.209(4%) 0.228(12%) 0.278(14%)	✓		
Cm-244	5.8(76%) 5.76(24%)				✓		
Cm-245	5.36(93%) 5.3(5%)			0.175(10%)	✓		✓
Cm-246	5.39(82%) 5.34(18%)				✓		

NUREG-1507 and IS0 7503-1 provide guidance for selecting calibration sources and their use in determining total efficiency. It is common practice to calibrate instrument efficiency for a s ingle beta energy; however the energy of this reference source should not be significantly greater than the beta energy of the lowest energy to be measured. Calibration sources should be selected that emit alpha or beta radiation with energies similar to those expected of the contaminant in the field. Cs-137 and Sr-90 are the major beta contributors at HBPP with Cs-137 having the lowest energy.

Cs-137 (0.512MeV at 95% and 1.17Mev at 5.4%) and Am-241 (4.68 MeV at 76% and 5.49 MeV at 85%) have been s elected as the beta and al pha calibration standards respectively, because their energies conservatively approximate the beta and alpha energies of the plant specific radionuclides most prevalent in the field.

3.0 EFFICIENCY DETERMINATION

Typically, using the instrument 4π efficiency exclusively provides a g ood approximation of surface activity. Using these means for calculating the efficiency often results in an under estimate of activity levels in the field. Applying both the instrument 2π efficiency and the surface efficiency components to determine the total efficiency allows for a more accurate measurement due to consideration of the actual characteristics of the source surfaces. IS0 7503-1 recommends that the total surface activity be calculated using:

$$A_s = \frac{R_{S+B} - R_B}{(e_i)(W)(e_s)}$$

where:

A_s is the total surface activity in dprn/cm^2,
R_{S+B} is the gross count rate of the measurement in cpm,
R_B is the background count rate in cpm,
e_i is the instrument or detector 2π efficiency
e_s is the efficiency of the source
W is the area of the detector window (cm^2) (126 cm^2 for the 43-68)

3.1 Alpha and Beta Instrument Efficiency (e_i)

Instrument efficiency (e_i) reflects instrument characteristics and counting geometry, such as source construction, activity distribution, source area, particles

incident on the detector per unit time and therefore source to detector geometry. Theoretically the maximum value of e_s is 1.0, assuming all the emissions from the source are 2π and that all emissions from the source are detected. The ISO 7503-1 methodology for determining the instrument efficiency is similar to the historical 4π approach; however the detector response, in cpm, is divided by the 2π surface emission rate of the calibration source. The instrument efficiency is calculated by dividing the net count rate by the 2π surface emission rate ($q_{2\pi}$) (Includes absorption in detector window, source detector geometry). The instrument efficiency is expressed in IS0 7503- 1 by:

$$e_i = \frac{R_{S+B} - R_B}{q_{2\Pi}}$$

where:

R_{S+B} is the gross count rate of the measurement in cpm,
R_B is the background count rate in cpm,
$q_{2\pi}$ is the 2π surface emission rate in reciprocal seconds

Note that both the 2π surface emission rate and the source activity are usually stated on the certification sheet provided by the calibration source manufacturer and certified as National Institute of Standards and Technology (NIST) traceable. Table 3.1 depicts nominal instrument efficiencies that have been determined during calibration using the 2π surface emission rate of the source.

Table 3. 1 Instrument Efficiencies (e_i)

Source	Emission	Active Area of the Source (cm^2)	Area of the Detector	100 cm^2 Gas Proportional 43-68 Instrument Efficiency (e_i) (Contact)
Cs-137	β	15.2	100 cm^2	0.4800
Am-241	α	15.2	100 cm^2	0.2500

3.2 Source to Detector Distance Considerations

A major factor affecting instrument efficiency is source to detector distance. Consideration must be given to this distance when selecting accurate instrument efficiency. The distance from the source to the detector shall to be as close as practicable to geometric conditions that exist in the field. A range of source to detector distances has been c hosen, taking into account site specific survey

conditions. In an effort to minimize the error associated with geometry, instrument efficiencies have been determined for source to detector distances representative of those survey distances expected in the field. The results shown in Table 3.2 illustrate the imposing reduction in detector response with increased distance from the source. Typically this source to detector distance will be 0.5 inches for fixed point measurements and 0.5 inches for scan surveys on flat surfaces, however they may differ for other surfaces. Table 3.2 makes provisions for the selection of source to detector distances for field survey conditions of up to 2 inches. If surface conditions dictate the placement of the detector at distances greater than 2 inches instrument efficiencies will be determined on an as needed basis.

3.2.1 Methodology

The practical application of choosing the proper instrument efficiency may be determined by averaging the surface variation (peaks and valleys narrower than the length of the detector) and adding 0.5 inches, the spacing that should be maintained between the detector and the highest peaks of the surface. The source-to-detector distance was evaluated using a Ludlum 43-68 gas proportional detector with a 0.8 mg/cm^2 window for Cs-137 and Am-241. Five 1 minute measurements were made on contact and at distances of 0.5, 1 and 2 centimeters. Measurement results are contained in Attachment 1.

Select the source to detector distance from Table 3.2 that best reflects this pre-determined geometry.

Table 3. 2 Source to Detector Distance
Effects on Instrument Efficiencies for α - β Emitters

Source to Detector Distance (cm)	Instrument Efficiency (e_i)	
	Cs-137 Distributed	**Am-241 Disc**
Contact	1	1
0.5	0.8935±0.019*	0.8331±0.007
1.0	0.8159±0.021	0.7244±0.007
2.0	0.6592±0.023	0.3615±0.010

*Uncertainties represent the 95% confidence interval. Based on propagating the counting errors in each measurement

3.3 Source (or surface) Efficiency (e_s) Determination

Source efficiency (e_s), reflects the physical characteristics of the surface and any surface coatings. The source efficiency is the ratio between the number of particles emerging from surface and the total number of particles released within the source. The source efficiency accounts for attenuation and backscatter. e_s is nominally 0.5 (no self-absorption/attenuation, no backscatter)-backscatter

increases the value, self-absorption decreases the value. Source efficiencies may either be derived experimentally or simply selected from the guidance contained in ISO 7503-1. ISO 7503-1 takes a c onservative approach by recommending the use of factors to correct for alpha and beta self-absorption/attenuation when determining surface activity. However, this approach may prove to be too conservative for radionuclides with max beta energies that are marginally lower than 0.400 MeV, such as Co-60 with a β_{max} of 0.314 MeV. In this situation, it may be more appropriate to determine the source efficiency by considering the energies of other beta emitting radionuclides. Using this approach it is possible to determine weighted average source efficiency. For example, a source efficiency of 0.375 may be calculated based on a 50/50 mix of Co-60 and Cs-137. The source efficiencies for Co-60 and Cs-137 are 0.25 and 0.5 respectively, since the radionuclide fraction for Co-60 and Cs-137 is 50% for each, the weighted average source efficiency for the mix may be calculated in the following manner:

$$(0.25)(0.5)+(0.5)(0.5)=0.375$$

Table 3.3 lists guidance on source efficiencies from IS0 7503-1.

Table 3. 3 Source Efficiencies as Listed in ISO 7503-1

	> 0.400 MeV$_{max}$	**≤ 0.400 MeV$_{max}$**
Beta Emitters	e_s = 0.5	e_s = 0.25
Alpha Emitters	e_s = 0.25	e_s = 0.25

It should be noted that source efficiency is not typically addressed for gamma detectors as the value is effectively unity.

4.0 INSTRUMENT CONVERSION FACTOR (E_i) (INSTRUMENT EFFICIENCY FOR SCANNING)

Separate modeling analysis (Microshield™) was conducted using the common gamma emitters with a c oncentration of 1 pC i/g of uniformly distributed contamination throughout the volume. Microshield is a c omprehensive photon/gamma ray shielding and dose assessment program, which is widely used throughout the radiological safety community. An activity concentration of 1 pCi/g for the nuclides was entered as the source term. The radial dimension of the cylindrical source was 28 cm, the depth was 15 cm, and the dose point above the surface was 10 cm with a soil density of 1.6 g/cm^3. The instrument efficiency when scanning, E_i, is the product of the modeled exposure rate (Microshield™) mRhr^{-1}/pCi/g and the energy response factor in cpm/mR/hr as derived from the energy response curve provided by Ludlum Instruments (Appendix A). Table 4.1 demonstrates the derived efficiencies for the major gamma emitting isotopes listed in Table 2.1.

Table 4. 1 Energy Response and Efficiency for Photon Emitting Isotopes

Isotope	E_i (cpm/pCi/g)
Co-60	315
Nb-94	387
Cs-137	202
Eu-152	419
Eu-154	230

When performing gamma scan measurements on soil surfaces the effective source to detector geometry is as close as is reasonably possible (less than 3 inches).

5.0 APPLYING EFFICIENCY CORRECTIONS BASED ON THE EFFECTS OF FIELD CONDITIONS FOR TOTAL EFFICIENCY

The total efficiency for any given condition can now be c alculated from the product of the instrument efficiency e_i and the source efficiency e_s.

$$E_{total} = e_i \times e_s$$

The following example illustrates the process of determining total efficiency. For this example we will assume the following:

- Surface activity readings need to be made in the HBPP Security Building concrete wall surfaces using the 2350-1 and 43-68 gas proportional detector.
- Data obtained from characterization results from the security building indicate the presence of beta emitters with energies greater than 0.400 MeV.
- The source (activity on the wall) to detector distance is 0.5 inch detector stand off. To calculate the total efficiency, e_{total}, refer to Table 3.2 "*Source to Detector Distance Effects on Instrument Efficiencies for α – β Emitters*" to obtain the appropriate e_i value.
- Contamination on all surfaces is distributed relative to the effective detector area.

- When performing fixed-point measurements with gas proportional instrumentation the effective source-to-detector geometry is representative of the calibrated geometries listed in Table 3.1.
- Correction for pressure and temperature are not substantial.

In this example, the 2π value for e_i is 0.48 as depicted in Table 3.1 "*Instrument Efficiencies*". The source-to-detector correction for 0.5 inches is 0.8935 as depicted in Table 3.2 "*Source to Detector Distance Effects on Instrument Efficiencies for α- β Emitters*". The e_s value of 0.5 is chosen refer to Table 3.3 "*Source Efficiencies as listed in ISO 7503-1*". Therefore the total efficiency for this condition becomes = $e_i \times e_s$ = 0.48 x 0.8935 x 0.5 = 0.214 or 21.4%.

6.0 CONCLUSION

Field conditions may significantly influence the usefulness of a survey instrument. When applying the instrument and source efficiencies in MDC calculations, field conditions must be considered. Tables have been constructed to assist in the selection of appropriate instrument and source efficiencies. Table 3.2 "*Source to Detector Distance Effects on Instrument Efficiencies for a-p Emitters*" lists instrument efficiencies (e_i) at various source to detector distances for alpha and beta emitters. The appropriate e_i value should be applied, accounting for the field condition, i.e. the relation between the detector and the surface to be measured.

Source efficiencies shall be selected from Table 3.3 "*Source Efficiencies as listed in ISO 7503- 1* ". This table lists conservative e_s values that correct for self-absorption and attenuation of surface activity. Table 5.1 "Energy Response and Efficiency for Photon Emitting Isotopes" lists E_i values that apply to scanning MDC calculations. The Microshield™ model code was used to determine instrument efficiency assuming contamination conditions and detector geometry cited in section 5.4.4.4.5 "*MDCs for Gamma Scans of Land Areas*" of the License Termination Plan.

Detector and source conditions equivalent to those modeled herein may directly apply to the results of this report.

7.0 REFERENCES

7.1 NUREG- 1507, "Minimum Detectable Concentrations with Typical Radiation Survey Instruments for Various contaminants and Field Conditions," 1998

7.2 ISO 7503- 1, "Evaluation of Surface Contamination - Part I: Beta Emitters and Alpha Emitters," 1988-08-01.

7.3 ISO 8769, "Reference Sources for the Calibration of Surface Contamination Monitors-Beta-emitters (maximum beta energy greater O.15MeV) and Alpha-emitters," 1988-06- 15.

7.4 "Radiological Health Handbook," Revised Edition 1970.

Appendix A
Microshield^{TM} and
Excel Forms

MicroShield 8.03
Pacific Gas and Electric Co. (8.03-0000)

Date	By	Checked

Filename	Run Date	Run Time	Duration
HBPP Co60 eff.msd	February 9, 2012	10:58:03 AM	00:00:00

Project Info

Case Title	44-10 eff Co-60
Description	HBPP 44-10 eff for Co-60
Geometry	8 - Cylinder Volume - End Shields

Source Dimensions

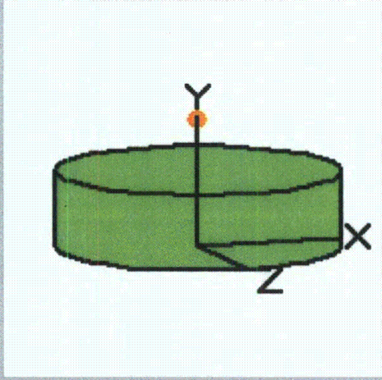
Height	15.0 cm (5.9 in)
Radius	28.0 cm (11.0 in)

Dose Points

A	X	Y	Z
#1	0.0 cm (0 in)	25.0 cm (9.8 in)	0.0 cm (0 in)

Shields

Shield N	Dimension	Material	Density
Source	3.69e+04 cm³	Mixed ->	1.60122
		Air	0.00122
		SOIL	1.6
Air Gap		Air	0.00122



Source Input: Grouping Method - Actual Photon Energies

Nuclide	Ci	Bq	μCi/cm³	Bq/cm³
Co-60	3.6945e-008	1.3670e+003	1.0000e-006	3.7000e-002

Buildup: The material reference is Source
Integration Parameters

Radial	20
Circumferential	10
Y Direction (axial)	10

Results

Energy (MeV)	Activity (Photons/sec)	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.6938	2.230e-01	9.138e-06	1.881e-05	1.764e-08	3.633e-08
1.1732	1.367e+03	1.107e-01	1.777e-01	1.978e-04	3.175e-04
1.3325	1.367e+03	1.303e-01	2.020e-01	2.261e-04	3.504e-04
Totals	**2.734e+03**	**2.410e-01**	**3.796e-01**	**4.239e-04**	**6.679e-04**

Co-60
Microsoft Excel E_i Calculation Sheet

Energy (MeV)	Energy (keV)	Exposure Rate (mR/hr-1 pCi/g)	Energy Response cpm/mR/hr)	E_i (cpm/pCi/g)
0.6938	694	6.63E-08	810,000	0
1.1732	1173	3.18E-04	495,000	157
1.3325	1333	3.50E-04	450,000	158
			E_i Total	315

Date	By	Checked

Filename	Run Date	Run Time	Duration
HBPP Nb94 eff.msd	February 9, 2012	11:54:43 AM	00:00:00

Project Info	
Case Title	44-10 eff Nb-94
Description	HBPP 44-10 eff for Nb-94
Geometry	8 - Cylinder Volume - End Shields

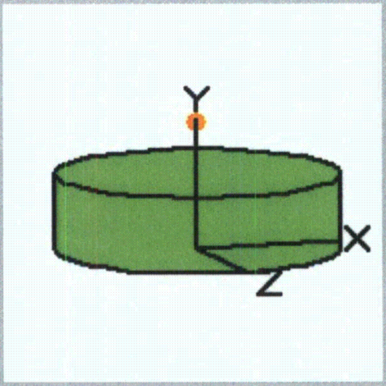
Source Dimensions	
Height	15.0 cm (5.9 in)
Radius	28.0 cm (11.0 in)

Dose Points

A	X	Y	Z
#1	0.0 cm (0 in)	25.0 cm (9.8 in)	0.0 cm (0 in)

Shields

Shield N	Dimension	Material	Density
Source	3.69e+04 cm³	Mixed ->	1.60122
		Air	0.00122
		SOIL	1.6
Air Gap		Air	0.00122



Source Input: Grouping Method - Actual Photon Energies

Nuclide	Ci	Bq	µCi/cm³	Bq/cm³
Nb-94	3.6945e-008	1.3670e+003	1.0000e-006	3.7000e-002

Buildup: The material reference is Source
Integration Parameters

Radial	20
Circumferential	10
Y Direction (axial)	10

Results

Energy (MeV)	Activity (Photons/sec)	Fluence Rate	Fluence Rate MeV/cm²/sec	Exposure Rate	Exposure Rate

		MeV/cm²/sec No Buildup	With Buildup	mR/hr No Buildup	mR/hr With Buildup
0.0023	9.067e-02	8.023e-11	2.388e-10	1.073e-10	3.195e-10
0.0174	4.834e-01	5.289e-09	1.831e-08	2.855e-10	9.884e-10
0.0175	9.260e-01	1.038e-08	3.627e-08	5.499e-10	1.921e-09
0.0196	2.720e-01	4.802e-09	2.057e-08	1.773e-10	7.595e-10
0.7026	1.367e+03	5.695e-02	1.166e-01	1.098e-04	2.248e-04
0.8711	1.367e+03	7.530e-02	1.381e-01	1.417e-04	2.600e-04
Totals	**2.736e+03**	**1.322e-01**	**2.547e-01**	**2.515e-04**	**4.848e-04**

Nb-94

Microsoft Excel E_i Calculation Sheet

Energy (MeV)	Energy (keV)	Exposure Rate (mR/hr-1 pCi/g)	Energy Response cpm/mR/hr)	E_i (cpm/pCi/g)
0.0023	2	3.20E-10		0
0.0174	17	9.88E-10		0
0.0175	18	1.92E-09		0
0.0196	20	7.60E-10		0
0.7026	703	2.25E-04	846,000	190
0.8711	871	2.60E-04	756,000	197
			E_i Total	387

MicroShield 8.03
Pacific Gas and Electric Co. (8.03-0000)

Date	By	Checked

Filename	Run Date	Run Time	Duration
HBPP Cs137eff.msd	February 9, 2012	12:17:17 PM	00:00:00

Project Info	
Case Title	44-10 eff Cs-137
Description	HBPP 44-10 eff for Cs-137
Geometry	8 - Cylinder Volume - End Shields

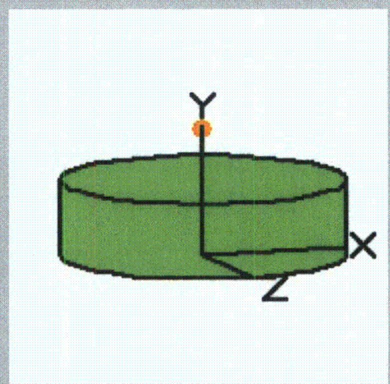
Source Dimensions	
Height	15.0 cm (5.9 in)
Radius	28.0 cm (11.0 in)

Dose Points

A	X	Y	Z
#1	0.0 cm (0 in)	25.0 cm (9.8 in)	0.0 cm (0 in)

Shields

Shield N	Dimension	Material	Density
Source	3.69e+04 cm³	Mixed ->	1.60122
		Air	0.00122
		SOIL	1.6
Air Gap		Air	0.00122



Source Input: Grouping Method - Actual Photon Energies

Nuclide	Ci	Bq	μCi/cm³	Bq/cm³
Ba-137m	3.4950e-008	1.2932e+003	9.4600e-007	3.5002e-002
Cs-137	3.6945e-008	1.3670e+003	1.0000e-006	3.7000e-002

Buildup: The material reference is Source
Integration Parameters

Radial	20
Circumferential	10
Y Direction (axial)	10

Results

Energy (MeV)	Activity (Photons/sec)	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.0045	1.342e+01	2.319e-08	6.901e-08	1.589e-08	4.730e-08
0.0318	2.677e+01	3.001e-06	3.558e-05	2.499e-08	2.964e-07
0.0322	4.939e+01	5.782e-06	7.018e-05	4.653e-08	5.648e-07
0.0364	1.797e+01	3.281e-06	5.035e-05	1.864e-08	2.860e-07
0.6616	1.164e+03	4.482e-02	9.434e-02	8.690e-05	1.829e-04
Totals	**1.271e+03**	**4.484e-02**	**9.450e-02**	**8.701e-05**	**1.841e-04**

Cs-137

Microsoft Excel E_i Calculation Sheet

Energy (MeV)	Energy (keV)	Exposure Rate (mR/hr-1 pCi/g)	Energy Response cpm/mR/hr)	E_i (cpm/pCi/g)
0.0045	5	3.20E-10		0
0.0318	32	9.88E-10		0
0.0322	32	1.92E-09		0
0.0364	36	7.60E-10		0
0.6616	662	2.25E-04	900,000	202

			E_i Total	202

MicroShield 8.03 Pacific Gas and Electric Co. (8.03-0000)			
Date	**By**	**Checked**	
Filename	**Run Date**	**Run Time**	**Duration**
HBPP Eu152 eff.msd	February 9, 2012	12:21:22 PM	00:00:00
Project Info			
Case Title	44-10 effEu-152		
Description	HBPP 44-10 eff for Eu-152		

Geometry	8 - Cylinder Volume - End Shields

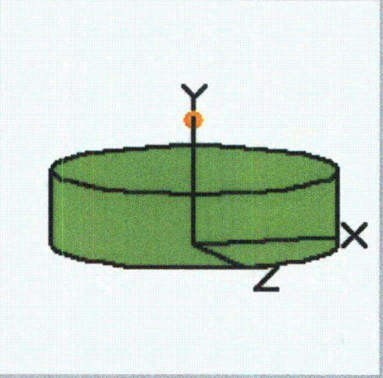
Source Dimensions	
Height	15.0 cm (5.9 in)
Radius	28.0 cm (11.0 in)

Dose Points

A	X	Y	Z
#1	0.0 cm (0 in)	25.0 cm (9.8 in)	0.0 cm (0 in)

Shields

Shield N	Dimension	Material	Density
Source	3.69e+04 cm³	Mixed ->	1.60122
		Air	0.00122
		SOIL	1.6
Air Gap		Air	0.00122



Source Input: Grouping Method - Standard Indices
Number of Groups: 25
Lower Energy Cutoff: 0.015
Photons < 0.015: Included
Library: Grove

Nuclide	Ci	Bq	µCi/cm³	Bq/cm³
Eu-152	3.6945e-008	1.3670e+003	1.0000e-006	3.7000e-002

Buildup: The material reference is Source
Integration Parameters

Radial	20
Circumferential	10
Y Direction (axial)	10

Results

Energy (MeV)	Activity (Photons/sec)	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.015	2.077e+02	1.204e-06	3.583e-06	1.033e-07	3.073e-07
0.04	8.088e+02	2.054e-04	3.698e-03	9.082e-07	1.635e-05

0.05	2.022e+02	1.067e-04	2.522e-03	2.841e-07	6.719e-06
0.1	3.887e+02	1.090e-03	1.656e-02	1.667e-06	2.534e-05
0.2	1.024e+02	8.179e-04	4.688e-03	1.443e-06	8.274e-06
0.3	3.696e+02	5.060e-03	1.857e-02	9.598e-06	3.522e-05
0.4	8.590e+01	1.715e-03	5.247e-03	3.342e-06	1.022e-05
0.5	7.711e+00	2.061e-04	5.042e-04	4.046e-07	9.897e-07
0.6	5.797e+01	1.966e-03	4.324e-03	3.837e-06	8.441e-06
0.8	2.434e+02	1.200e-02	2.305e-02	2.283e-05	4.384e-05
1.0	5.849e+02	3.853e-02	6.582e-02	7.102e-05	1.213e-04
1.5	3.171e+02	3.515e-02	5.314e-02	5.914e-05	8.940e-05
Totals	**3.376e+03**	**9.685e-02**	**1.981e-01**	**1.746e-04**	**3.664e-04**

Eu-152

Microsoft Excel E_i Calculation Sheet

Energy (MeV)	Energy (keV)	Exposure Rate (mR/hr-1 pCi/g)	Energy Response cpm/mR/hr)	E_i (cpm/pCi/g)
0.015	15	3.07E-07		0
0.04	40	1.64E-05		0
0.05	50	6.72E-06		0
0.1	100	2.53E-05	4,680,000	119
0.2	200	8.27E-06	3,420,000	28
0.3	300	3.52E-05	2,610,000	92
0.4	400	1.02E-05	2,070,000	21
0.5	500	9.90E-07	1,575,000	2
0.6	600	8.44E-06	1,080,000	9
0.8	800	4.38E-05	765,000	34
1	1000	1.21E-04	630,000	76
1.5	1500	8.94E-05	425,000	38

			E_i Total	419

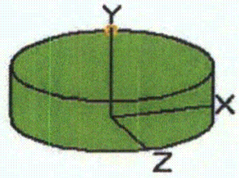
MicroShield 8.03
Pacific Gas and Electric Co. (8.03-0000)

Date	By	Checked

Filename	Run Date	Run Time	Duration
HBPP Eu154 eff.msd	June 12, 2012	1:24:05 PM	00:00:00

Project Info	
Case Title	44-10 effEu-154
Description	HBPP 44-10 eff for Eu-154
Geometry	8 - Cylinder Volume - End Shields

Source Dimensions	
Height	15.0 cm (5.9 in)
Radius	28.0 cm (11.0 in)



Dose Points			
A	X	Y	Z
#1	0.0 cm (0 in)	25.0 cm (9.8 in)	0.0 cm (0 in)

Shield N	Dimension	Material	Density
Source	3.69e+04 cm³	Mixed ->	1.60122
		Air	0.00122
		SOIL	1.6
Air Gap		Air	0.00122

Source Input: Grouping Method - Standard Indices
Number of Groups: 25
Lower Energy Cutoff: 0.015
Photons < 0.015: Included
Library: ICRP-38

Nuclide	Ci	Bq	µCi/cm³	Bq/cm³
Eu-154	3.6945e-008	1.3670e+003	1.0000e-006	3.7000e-002

Buildup: The material reference is Source
Integration Parameters

Radial	20
Circumferential	10
Y Direction (axial)	10

Results

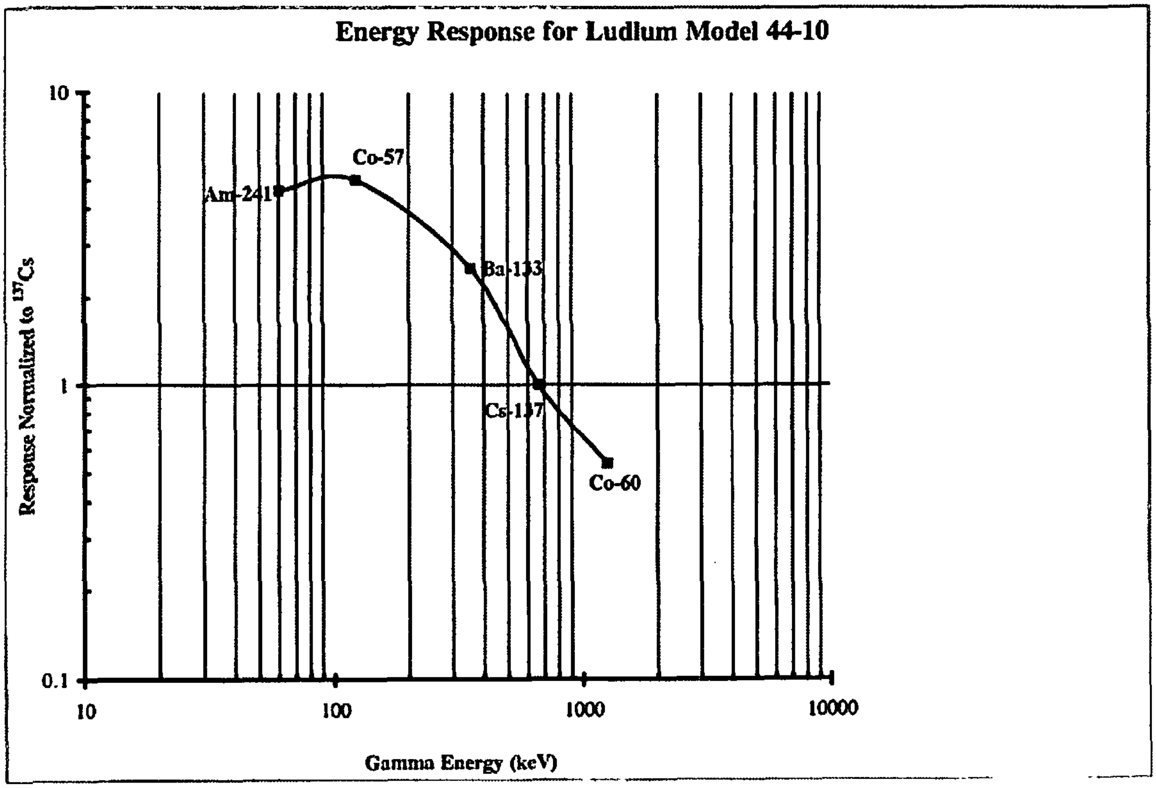
Energy (MeV)	Activity (Photons/sec)	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.015	9.493e+01	5.502e-07	5.664e-07	4.720e-08	4.858e-08
0.04	3.013e+02	7.651e-05	1.057e-04	3.384e-07	4.674e-07
0.05	7.422e+01	3.914e-05	6.382e-05	1.043e-07	1.700e-07
0.06	5.337e-02	4.787e-08	9.413e-08	9.508e-11	1.870e-10

0.08	8.433e-02	1.526e-07	3.710e-07	2.414e-10	5.871e-10
0.1	5.531e+02	1.551e-03	4.134e-03	2.373e-06	6.325e-06
0.15	1.569e+00	8.386e-06	2.272e-05	1.381e-08	3.741e-08
0.2	9.397e+01	7.503e-04	1.925e-03	1.324e-06	3.397e-06
0.3	2.894e+00	3.962e-05	9.062e-05	7.515e-08	1.719e-07
0.4	1.103e+01	2.203e-04	4.604e-04	4.292e-07	8.971e-07
0.5	6.104e+00	1.632e-04	3.171e-04	3.203e-07	6.224e-07
0.6	8.886e+01	3.013e-03	5.521e-03	5.882e-06	1.078e-05
0.8	5.145e+02	2.538e-02	4.266e-02	4.827e-05	8.114e-05
1.0	4.249e+02	2.799e-02	4.426e-02	5.159e-05	8.158e-05
1.5	5.353e+02	5.934e-02	8.482e-02	9.983e-05	1.427e-04
2.0	2.329e-02	3.702e-06	5.007e-06	5.725e-09	7.743e-09
Totals	**2.703e+03**	**1.186e-01**	**1.844e-01**	**2.106e-04**	**3.284e-04**

Eu-154

Microsoft Excel E_i Calculation Sheet

Energy (MeV)	Energy (keV)	Exposure Rate (mR/hr-1 pCi/g)	Energy Response cpm/mR/hr)	E_i (cpm/pCi/g)
0.015	15	4.86E-08		0
0.04	40	4.67E-07		0
0.05	50	1.70E-07		0
0.06	60	1.87E-10	4,320,000	0
0.08	80	5.87E-10	4,500,000	0
0.1	100	6.33E-06	4,680,000	30
0.15	150	3.74E-08	4,770,000	0
0.2	200	3.40E-06	3,420,000	12
0.3	300	1.72E-07	2,610,000	0
0.4	400	8.97E-07	2,070,000	2
0.5	500	6.22E-07	1,575,000	1
0.6	600	1.08E-05	1,080,000	12
0.8	800	8.11E-05	765,000	62
1	1000	8.16E-05	630,000	51
1.5	1500	1.43E-04	425000	61
2	2000	7.74E-09	333,000	0
			E_i Total	230



Energy Response for Ludlum Model 44-10
Response Normalized to 137Cs
10
1
0.1
10
100
1000
10000
Gamma Energy (keV)
Am-241
Co-57
Ba-133
Cs-137
Co-60

Attachment 1
Cs-137 and Am-241
Source-to-Detector
Distance Effects

Experiment Data Sheet

Date 5/25/2012					
Time Started 1247					
FEET: 6.5 MM	Detector	Model	S/N	Data logger S/N	Cal Due
Det. A 25' CABLE	SET 4	43-68	161411	203484	12/14/2012
Det B. 25' CABLE	SET 21	43-68	148626	149802	6/18/2012

Background - Feet	Det. A	Det. B
1	2	4
2	3	7
3	3	0
4	0	1
5	2	1
6	0	2
7	0	0
8	2	1
9	1	1
10	0	1

Source	ID
Am-241	HBS-568

Contact	Det. A	Det. B
1	27733	29429
2	27800	29773
3	27876	29207
4	27833	29372
5	27776	29239

feet	Det. A	Det. B
1	22985	24481
2	23241	24538
3	23299	24759
4	22726	24685
5	22927	24696

DR 5-25-12

~~feet~~ +1 cm	Det. A	Det. B
1	19992	21323
2	20263	21220
3	20032	21471
4	19975	21552
5	19940	21469

DR 5-25-12

~~feet~~ +2 cm	Det. A	Det. B
1	9665	10923
2	9836	10908
3	9721	11025
4	9651	11041
5	9647	11104

All counts are for 1 min.

Technician ______________

Technician ______________

Experiment Data Sheet

Date 5/24/2012					
Time Started 1045					
Name	Detector	Model	S/N	Data logger S/N	Cal Due
Det. A 25'CABLE	SET 4	43-68	161411	203484	12/14/12
Det B. 25'CABLE	SET 21	43-68	148626	149802	6/18/12

FEET ON

Background - 1 min.	Det. A	Det. B
1	187	216
2	314	202
3	192	215
4	175	204
5	182	193
6	138	181
7	160	200
8	194	217
9	204	195
10	210	215

Source	ID
Cs-137	HBS - 509

Contact - 1 min.	Det. A	Det. B
1	3005	3141
2	2980	3232
3	3003	3205
4	3026	3132
5	2990	3215

Feet: 6.5mm

feet - 1 min.	Det. A	Det. B
1	2709	2845
2	2760	2801
3	2740	2876
4	2736	2843
5	2726	2803

~~feet~~ +1 cm - 1 min.	Det. A	Det. B
1	2552	2565
2	2465	2548
3	2432	2711
4	2526	2579
5	2518	2706

~~feet~~ +2 cm - 1 min	Det. A	Det. B
1	2075	2098
2	2140	2089
3	2053	2212
4	2103	2118
5	2103	2072

Technician ____________________

Technician ____________________

Gross Activity DCGL in Support of the Final Status Survey at HBPP

July 11, 2012