LACBWR
Technical Support Document

ENERGYSOLUTIONS

RS-TD-313196-006
Ludlum Model 44-10 Detector Sensitivity
Revision 0

Originator: _____ Date: 10/06/15
Dave Wojtkowiak

Reviewed By: _____ Date: 10/6/15
Bob Yetter

Approved By: _____ Date: 10/8/15
Donald E. (Nick) Williams

Summary of Changes in this Revision:

- Revision 0 – Initial Issuance

Ludlum Model 44-10 Detector Sensitivity

1.0 Executive Summary

This Technical Support Document evaluates the sensitivity of the Ludlum Model 44-10 2.0" x 2.0" (5.08 x 5.08 cm) NaI detector when used to scan open land areas as a function of background, scan speed, and radionuclide mixture. Graphs of detector MDC as a function of background for various scan speeds are presented for Co-60, Cs-137, and a mixture of Co-60 and Cs-137.

2.0 Introduction

The calculations exemplify the MARSSIM based determination for Minimum Detectable Concentration (MDC) for land areas. There are two principle objectives. The first objective is to qualify the response of the vendors NaI detector to Cs-137 and Co-60 sources based on a study performed at a previous reactor decommissioning. The second is to identify detectable residual soil concentrations for Co-60 and Cs-137 radionuclides at the La Cross Boiling Water Reactor (LACBWR) where the soil nuclide fractions are consistent with the data provided in this document. The evaluation includes consideration for using Co-60 or Cs-137 as surrogate radionuclides.

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4.0 Background

Published sensitivity for the Ludlum 44-10 detector is listed in the manufacturer's literature as 900 cpm/μR/hr for Cs-137. Table 6.7of NUREG-1575 lists the Co-60 and Cs-137 sensitivity for a 5.08 by 5.08 cm NaI detector as 430 and 900 cpm/μR/hr, respectively. A study was performed (See Section 4.2) at the Rancho Seco Nuclear

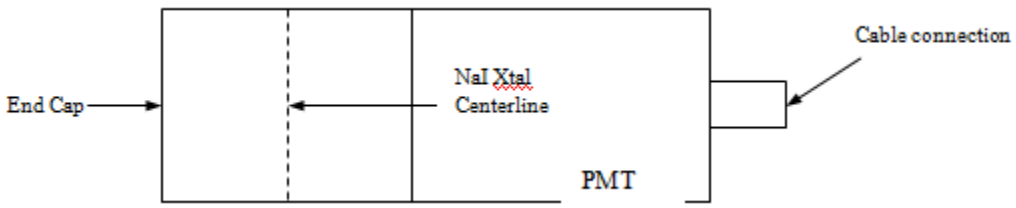
Generating Station (RSNGS) to confirm the manufacturer's literature. The values derived from the study will be used in this TSD as they were derived empirically.

4.1 Limitations

The conclusions of this TSD are limited to (2" x 2") 5.08 by 5.08 cm NaI detectors.

4.2 Response Factor

Determination of detector response factors at the RSNGS were conducted for both the Eberline Model SPA-3 and Ludlum Model 44-10 detectors. Only the information relative to the response of the Ludlum Model 44-10 will be addressed at this time. Two NIST traceable sources were used, Co-60 and Cs-137. For both sealed sources the active area is very small when compared to the detector size and the distance from the source face to the detector centerline (located at 2.54 cm beyond the detector end cap).



The evaluation process to determine detector response factors for Cs-137 and Co-60 are provided in Attachment 8.1. The results are presented in Table 1.0 below.

Table 1.0
NaI Response Factors for Ludlum Model 44-10 Detector

Source to Detector Distance (cm)	Microshield™ Derived μR/h		44-10 (5.08 x 5.08 cm) CPM/μR/h	
	Co-60	Cs-137	Co-60	Cs-137
7.62	24.12	--	410.1	--
15.24	6.032	128.1	387.3	868.4
30.48	1.508	32.01	502.5	933.1
60.96	--	8.001	--	1021.7
Average			433.3	941.1

The average Cs-137 response factor for the 44-10 NaI detector is 941.0 cpm/μR/h. The value is consistent with the results found in NUREG-1575 Table 6.7. The average Co-60 value for the 44-10 NaI detector is 433 cpm/μR/h. This result is also consistent with the value reported in Table 6.7 of NUREG-1575. It is important to note that the principle gamma energy response for Cs-137 and Co-60 are in air and from a point source. The NaI detectors response will be greater for the lower energy gammas resulting from the scattering processes associated with the nuclides being distributed in soil media.

5.0 Model for Determination of NaI Detector Soil MDC

The MARSSIM suggested scan speed of 0.5 m/s is used with the elevated (soil) area of interest being 0.196 m^2 that relates to contaminants in a 50 cm diameter region that is 15 cm deep. The depth is consistent with the EPA and NRC definition of surface soils. The soil density is assumed at 1.6 g/cm^3 and the composition used for the MicroShield™ custom material soil model is composed of silicon oxide (sand). Recent acquisition of surface and subsurface soil sampling at LACBWR indicate construction grade soils consisting primarily of loamy clay, sand and gravels that are of similar density values. The NaI detector height from the surface is varied and assumes surface to detector center distances of 3.0 (7.62 cm), 4.0 (10.16 cm) and 6.0 (15.24 cm) inches (2.0, 3.0, and 5.0 inches from the detector end cap). These distances provide reasonable estimates of the variation of detector height above the surface during scanning operations. The 50-centimeter diameter area is selected to provide a detector residence time of one second using a scan rate of 0.5 meters per second. It should be noted that soil scan surveys can result in detector residence times greater than one second. To this end, scan measurements are expected to result in conservative MDC values. The Model 44-10 NaI count rate conversion to exposure rate from Table 1.0 is used for each of the principle gamma emitting radionuclides. A surveyor efficiency of 0.5 and a d' (index of sensitivity) of 1.38 is included in the MDC determination. Inclusion of the surveyor efficiency and training of the surveyors to both listen for the instrument count rate and perform specific investigations following instrument alarms add conservatism to the MDC determination. Finally, the 50 cm diameter by 15 cm thick soil media assumes uniform distribution of the suspect radionuclides.

6.0 Soil Radionuclide Distribution

The soil nuclide fraction for Co-60 is assumed to be 0.10 with Cs-137 comprising the remaining fraction. Values are also included for soils containing 100 percent Co-60 or Cs-137. As soil characterization progresses the MDC values provided in this TSD may be adjusted if significant nuclide fraction differences (±20%) are noted. Other soil nuclide compositions and subsequent action levels will be developed based or soil characterization results.

7.0 MicroShield™ Code Runs and Derived MDC Values

Specific MicroShield™ code runs (See Attachment 8.2) were conducted to determine the exposure rate for the individual or combined nuclides. The code runs are based on the above dimensions, soil composition and density for a 1.0 pCi/g concentration. These values are consistent with guidance provided in NUREG-1575 and 1757 Volume 2 Rev 1.

The data in Attachment 8.2 presents the exposure rate results for various Cs-137 and Co-60 soil nuclide mixtures. The nuclide mix is used in the Microshield™ code runs to derive exposure rate values based on the source to detector geometry. The spreadsheets in Attachments 8.3 utilized the MARSSIM guidance and formula, the detector response to the gamma emitting nuclides and, the conversion basis for detector cpm to soil pCi/g concentration. Graphical presentation of the results is included. Table 2.0 compares the derived MDC results for the varied nuclide fractions and assumes an ambient background of 6,000 cpm for the Ludlum Model 44-10 (for the formula see Attachment 8.4, Scan MDC Formula and pCi/g Determination Example). Detector response to Co-60 (1.0 nuclide fraction) results in a higher response (sensitivity) than for Cs-137 (1.0 nuclide fraction) and illustrates that if the Co-60 nuclide fraction increases the MDC will decrease.

Table 2.0
44-10 Detector Scan MDC (pCi/g)*
for Varied Cs-137 and Co-60 Nuclide Fractions
Scan Speed = 0.5 m/s

Detector Distance** Inches (cm)	Nuclide Fraction Cs-137 95% Co-60 5%	Nuclide Fraction Cs-137 90% Co-60 10%	Nuclide Fraction Cs-137 100%	Nuclide Fraction Co-60 100%
2.0 (5.08)	4.35	4.1	4.7	2.5
3.0 (7.62)	5.2	4.8	5.7	3.0
6.0 (15.24)	7.2	6.7	7.8	4.2

*Detector Background assumed at 6,000 cpm.
**Distance from detector end-cap to soil surface

7.1 Observations and Results

Table 2.0 above presents the evaluation results. The results show that as the Co-60 nuclide fraction increases the MDC decreases. At other reactor decommissioning sites Cs-137 was the dominant radionuclide. Both Maine Yankee and Rancho Seco reported an averaged soil Cs-137 content of ≥ 90 percent. This radionuclide distribution is also applicable to LACBWR. Site characterization data will be continually assessed and used to update the soil or structure radionuclide mixture MDC and action levels.

7.2 Survey Techniques

Detector background during land scanning operations is expected to range between 4.00E+03 and 6.00E+03 cpm. Tables 2.0 and 3.0 illustrate the MDCs (in pCi/g) for various distances and scan speeds. Identification of regions of potential contamination is based on the ability of the surveyor to distinguish an increase in count rate during the scanning operation. The surveyor is required to maintain the selected scan speed and detector distance from the suspect surface. Surveyor scanning sensitivity is discussed in chapter 6.0 of NUREG-1575 and NUREG-1507. Other survey techniques that may improve scan sensitivity include: use of the latching mode parameter of the data logging survey instrument (Ludlum 2350-1) to capture the maximum count rate when scanning a suspect surface, changing the instrument (Ludlum 2350-1) time

constant from variable to a fixed 1.0 second time constant to increase the instruments response rate and setting the instrument alarm level. Each of the above features augments the surveyor's efficiency for detecting areas of elevated activity.

Table 3.0
Ludlum 44-10 Detector MDC (pCi/g)*
(Cs-137 Nuclide Fraction 1.0)

Detector Distance** Inches (cm)	Scan Speed 0.5 m/s	Scan Speed 0.25 m/s
2.0 (5.08)	4.7	3.4
3.0 (7.62)	5.7	4.0
6.0 (15.24)	7.8	5.5

*Detector background assumed at 6,000 cpm.
**Distance from detector end-cap to soil surface

8.0 Attachments

8.1 Co-60 and Cs-137 Response Factor Determination Instructions and Results

- Evaluation of SPA-3 and Ludlum 44-10 cpm per μR/h Response Factors for Co-60
- Microshield™ runs for 7.62, 15.24 and 30.48 cm for Co-60
- Source Certificate for Co-60 Serial Number 214-17-195 (SCN 335)
- Evaluation of SPA-3 and Ludlum 44-10 cpm per μR/h Response Factors for Cs-137
- Microshield™ runs for 15.24, 30.48 and 60.96 cm for Cs-137
- Source Certificate for Cs-137 Serial Number LY 376 (SCN 618)
- NaI Response Factors for SPA-3 and 44-10 Detectors for Co-60
- NaI Response Factors for SPA-3 and 44-10 Detectors for Cs-137

8.2 MicroShield™ Code Runs for Various Distances and Nuclide Fractions

- Co-60 nuclide fraction equals 1.0. Distance equals 7.62, 10.16 and 15.24 centimeters from detector centerline.
- Cs-137 nuclide fraction equals 1.0. Distance equals 7.62, 10.16 and 15.24 centimeters from detector centerline.
- Co-60 nuclide fraction equals 0.05 and Cs-137 nuclide fraction equals 0.95. Distance equals 7.62, 10.16 and 15.24 centimeters from detector centerline.
- Co-60 nuclide fraction equals 0.10 and Cs-137 nuclide fraction equals 0.90. Distance equals 7.62, 10.16 and 15.24 centimeters from detector centerline.

8.3 Scan MDC (pCi/g) for Various Nuclide Fractions of Co-60 and Cs-137

- Co-60 nuclide fraction equals 1.0. Distance is as noted in Section 8.2. Scan speed equals 0.5 m/s.
- Cs-137 nuclide fraction equals 1.0. Distance is as noted in Section 8.2. Scan speed equals 0.5 m/s.
- Cs-137 nuclide fraction equals 1.0. Distance is as noted in Section 8.2. Scan speed equals 0.25 m/s.
- Co-60 nuclide fraction equals 0.05 and Cs-137 nuclide fraction equals 0.95. Distance is as noted in Section 8.2. Scan speed equals 0.5 m/s.
- Co-60 nuclide fraction equals 0.10 and Cs-137 nuclide fraction equals 0.90. Distance is as noted in Section 8.2. Scan speed equals 0.5 m/s.
- Co-60 nuclide fraction equals 0.10 and Cs-137 nuclide fraction equals 0.90. Distance is as noted in Section 8.2. Scan speed equals 0.25 m/s.

8.4 Scan MDC Formula and pCi/g Determination Example

9.0 References

9.1 Decommissioning Technical Basis Document DTBD-05-012 V-0, 11/7/05 (Evaluation of Eberline SPA-3 and Ludlum 44-10 cpm per μR/h Response Factors Robert F. Decker, August 19, 2004), Rancho Seco Nuclear Generating Station

9.2 NUREG-1575 “Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM)” Rev. 1 August 2000.

9.3 NUREG-1757 V2 Rev 1.0 “Consolidated Decommissioning Guidance: Characterization, Surveys and Determination of Radiological Criteria” September 2006.

9.4 NUREG-1505 Rev 1, “A Nonparametric Statistical Methodology for the Design and Analysis of Final Status Decommissioning Surveys” June 1998

Evaluation of Eberline SPA-3 and Ludlum 44-10 cpm per μR/h Response Factors
August 19, 2004 RFD

The NaI detectors provided by Eberline and Ludlum include cpm per μR/h response factors for specific nuclides. The instructions below are used to evaluate the response of both detectors to Co-60. The results of the evaluation are to confirm manufacturer results or modify the response factors accordingly.

Equipment:

- Calibrated Eberline E-600 and Ludlum 2350-1
- Eberline SPA-3 and Ludlum 44-10 detectors
- IPL Co-60 Source 214-17-195 8/1/1988 0.891 μCi
- Tape measure
- Materials to position the source and detector approximately 3 feet above the floor
- Materials to record the results of testing (utilize data logging features) and boxes provided in the table below.

Co-60 source: 0.891 μCi on 8-1-88. Decay corrected activity is 3.995 kBq (0.108 μCi) on 8-19-04.

Microshield™ runs attached for point source at 7.62, 15.24 and 30.48 cm (3, 6 & 12 inches to centerline of detector active area)

NaI Response Factors for SPA-3 and 44-10 Detectors

Distance (cm)	Derived μR/h	SPA-3 Estimate	SPA-3 Observed	44-10 Estimated	44-10 Observed
7.62	24.12	1.447E+04 cpm	9.3217E+03 cpm	1.0372E+04 cpm	9.8920E+03 cpm
15.24	6.032	3.619E+03 cpm	2.7440E+03 cpm	2.5938E+03 cpm	2.3361E+03 cpm
30.48	1.508	9.048E+02 cpm	6.8530E+01 cpm	6.4844E+02 cpm	7.5780E+02 cpm
Estimates based on vendor value of 600 and 430 cpm/μR/h for SPA-3 and 44-10, respectively.					

Determination is conducted in an open area with the detector and source elevated 1.0 meter above the surface. Walls and other solid obstructions should be at least 2 meters from the source and detector. The objective is to minimize scattering effects.

Each measurement is conducted in the scaler mode for the instrument and the measurement (count) time is 10 minutes.

Background is evaluated by performing a 10-minute count prior to the tests and with the source removed from the area.

Background cpm value: SPA-3 – 8525, 44-10 - 8661

To determine the response to Co-60 the net counts per minute are divided by the μR/h provided for the specific distance.

MicroShield v5.05 (5.05-00488)
Sacramento Municipal Uitility District

Page : 1
DOS File : Case1
Run Date : August 24, 2004
Run Time: 7:45:23 AM
Duration : 00:00:00

File Ref: _____
Date: _____
By: _____
Checked: _____

Case Title: Co-60
Description: NaI Response Check @ 7.62 cm
Geometry: 3 - Disk

Source Dimensions

Radius	0.238 cm	0.1 in

Dose Points

	X	Y	Z
# 1	7.62 cm	0 cm	0 cm
	3.0 in	0.0 in	0.0 in

Shields

Shield Name	Material	Density
Air Gap	Air	0.00122

Source Input
Grouping Method : Actual Photon Energies

Nuclide	curies	becquerels	µCi/cm²	Bq/cm²
Co-60	1.0797e-007	3.9950e+003	6.0931e-001	2.2544e+004

Buildup
The material reference is : Air Gap

Integration Parameters

Radial	20
Circumferential	20

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	6.517e-01	6.189e-04	6.193e-04	1.195e-06	1.196e-06
1.1732	3.995e+03	6.417e+00	6.419e+00	1.147e-02	1.147e-02
1.3325	3.995e+03	7.288e+00	7.291e+00	1.264e-02	1.265e-02
TOTALS:	7.991e+03	1.371e+01	1.371e+01	2.411e-02	2.412e-02

MicroShield v5.05 (5.05-00488)
Sacramento Municipal Uitility District

Page : 1
DOS File : Case1
Run Date : August 24, 2004
Run Time : 7:47:04 AM
Duration : 00:00:00

File Ref: _____
Date: _____
By: _____
Checked: _____

Case Title: Co-60
Description: NaI Response Check @ 15.24 cm
Geometry: 3 - Disk

Source Dimensions

Radius	0.238 cm	0.1 in

Dose Points

	X	Y	Z
# 1	15.24 cm	0 cm	0 cm
	6.0 in	0.0 in	0.0 in

Shields

Shield Name	Material	Density
Air Gap	Air	0.00122

Source Input
Grouping Method : Actual Photon Energies

Nuclide	curies	becquerels	µCi/cm²	Bq/cm²
Co-60	1.0797e-007	3.9950e+003	6.0931e-001	2.2544e+004

Buildup
The material reference is : Air Gap

Integration Parameters

Radial	20
Circumferential	20

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	6.517e-01	1.547e-04	1.549e-04	2.986e-07	2.990e-07
1.1732	3.995e+03	1.604e+00	1.605e+00	2.866e-03	2.869e-03
1.3325	3.995e+03	1.822e+00	1.823e+00	3.161e-03	3.163e-03
TOTALS:	7.991e+03	3.426e+00	3.429e+00	6.027e-03	6.032e-03

MicroShield v5.05 (5.05-00488)
Sacramento Municipal Uitility District

Page : 1
DOS File : Case1
Run Date : August 24, 2004
Run Time : 7:48:15 AM
Duration : 00:00:00

File Ref: _____
Date: _____
By: _____
Checked: _____

Case Title: Co-60
Description: NaI Response Check @ 30.48 cm
Geometry: 3 - Disk

Source Dimensions

Radius	0.238 cm	0.1 in

Dose Points

	X	Y	Z
# 1	30.48 cm	0 cm	0 cm
	1 ft	0.0 in	0.0 in

Shields

Shield Name	Material	Density
Air Gap	Air	0.00122

Source Input
Grouping Method : Actual Photon Energies

Nuclide	curies	becquerels	µCi/cm²	Bq/cm²
Co-60	1.0797e-007	3.9950e+003	6.0931e-001	2.2544e+004

Buildup
The material reference is : Air Gap

Integration Parameters

Radial	20
Circumferential	20

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	6.517e-01	3.862e-05	3.871e-05	7.456e-08	7.474e-08
1.1732	3.995e+03	4.006e-01	4.012e-01	7.158e-04	7.170e-04
1.3325	3.995e+03	4.550e-01	4.557e-01	7.895e-04	7.906e-04
TOTALS:	7.991e+03	8.557e-01	8.570e-01	1.505e-03	1.508e-03

8/18/88 cf

CERTIFICATE OF GAMMA STANDARD SOURCE

Radionuclide: Co-60 Half-life: 5.2714 ± 0.0005 y

Customer: SACRAMENTO MUNICIPAL ~~UTILIES DISTRICT~~ P.O. No.: RN 880525589

Catalog No.: GF-060 Source No.: 214-17-195 Reference Date: AUG. 1, 1988

Contained Radioactivity: 0.891 uCi

Description of Source

a. Capsule type: D
b. Nature of active deposit: EVAPORATED METALLIC SALTS
c. Active diameter: 0.187"
d. Backing: N/A
e. Cover: N/A

Radioimpurities

NONE DETECTED

Method of Calibration

(X) The source was assayed by gamma spectrometry, integrating under the 1.173 & 1.332 Mev peak(s). The branching ratio(s) used was/were 1.0 & 1.0 gamma rays per decay.

( ) The source was prepared from a weight aliquot of solution whose activity in uCi/gram was determined by the method above.

Uncertainty of Measurement

a. Systematic uncertainty in instrument calibration: ± 1.3 %
b. Random uncertainty
1. In assay: ± 1.1 %
2. In weighing(s): ± ____ %
c. Total Uncertainty: ± 2.4 % at the 99% confidence level.

NBS Traceability

This calibration is implicitly traceable to the National Bureau of Standards.

Notes

1. Nuclear data were taken from "Table of Isotopes", Seventh Edition, edited by C. Michael Lederer et al.
2. IPL participates in an NBS measurement assurance program to establish and maintain implicit traceability for a number of nuclides, based on the blind assay (and later NBS certification) of Standard Reference Materials. (As in NRC Regulatory Guide 4.15)

Michael Devine
Quality Control

ISOTOPE PRODUCTS LABORATORIES
1800 No. Keystone St., Burbank, California 91504
(818) 843-7000

Evaluation of Eberline SPA-3 and Ludlum 44-10 cpm per µR/h Response Factors
August 19, 2004
RFD

The NaI detector s provided by Eberline and Ludlum include cpm per µR/j response factors for specific nuclides. The instructions below are used to evaluate the response of both detectors to Cs-137. The results of the evaluation are to confirm manufacturer results or modify the response factors accordingly.

Equipment:

- Calibrated Eberline E-600 and Ludlum 2350-1
- Eberline SPA-3 and Ludlum 44-10 detectors
- AEA Cs-137 Source 68970 – LY 376
- Tape Measure
- Material to position the source and detector approximately 3 feet above the floor
- Material to record the results of testing (utilize data logging features) and boxes provided in table below.

Cs-137 Source: 344 kBq (9.297 µCi) on 10/1/03. Decay corrected is 337.1 kBq (9.111 µCi) on 8/18/04

MicroShield™ runs attached fro point source at 15.24, 30.48 and 60.96 cm (6,12 & 24 inches to centerline of detector active area.

NaI Response Factors for SPA-3 and 44-10 Detectors

Distance (cm)	Derived µR/h	SPA-3 Estimate	SPA-3 Observed	44-10 Estimate	44-10 Observed
15.24	128.1	1.537E+05	1.3642E+05	1.153E+05	1.228E+05
30.48 32	.01	3.841E+04	4.361E+04	2.881E+04	4.143E+04
60.96 8.	001	9.601E+03	9.601E+03	7.201E+03	1.974E+04
Estimates based on 1200 and 900 cpm for SPA-3 and 44-10, respectively					

Determination is conducted in an open area with th e detector and source elev ated 1.0 m eter above the surface. Walls and oth er obstruc tions should be at least 2 m eters form the source and detector. The objective is to minimize scattering effects.

Each m easurement is conducted in the scalar mode for the instrum ent and the m easurement (count) time is 10.0 minutes.

Background is evaluated by perform ing a 10 m inute count prior to the tests and with the source removed from the area.

Background cpm value: SPA-3 = 8525, 44-10 = 8661

To determine the r esponse to Cs-13 7 the net counts per m inute are divided by the µR/h provided for the specific distance.

MicroShield v5.05 (5.05-00488)
Sacramento Municipal Uitility District

Page : 1
DOS File : Case1
Run Date : August 17, 2004
Run Time : 11:31:58 AM
Duration : 00:00:00

File Ref: _____
Date: _____
By: _____
Checked: _____

Case Title: 9.11 uCi Cs-137
Description: Point Source at 15.24 cm
Geometry: 1 - Point

Dose Points

	X	Y	Z
# 1	15.24 cm	0 cm	0 cm
	6.0 in	0.0 in	0.0 in

Shields

Shield Name	Material	Density
Air Gap	Air	0.00122

Source Input
Grouping Method : Actual Photon Energies

Nuclide	curies	becquerels
Ba-137m	8.6188e-006	3.1890e+005
Cs-137	9.1108e-006	3.3710e+005

Buildup
The material reference is : Air Gap

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
0.0318	6.602e+03	7.157e-02	7.206e-02	5.962e-04	6.003e-04
0.0322	1.218e+04	1.336e-01	1.345e-01	1.075e-03	1.083e-03
0.0364	4.433e+03	5.502e-02	5.540e-02	3.126e-04	3.147e-04
0.6616	2.869e+05	6.496e+01	6.504e+01	1.259e-01	1.261e-01
TOTALS:	3.102e+05	6.522e+01	6.530e+01	1.279e-01	1.281e-01

MicroShield v5.05 (5.05-00488)
Sacramento Municipal Uitility District

Page : 1
DOS File : Case1
Run Date: August 17, 2004
Run Time: 11:29:10 AM
Duration : 00:00:00

File Ref: _____
Date: _____
By: _____
Checked: _____

Case Title: 9.11 uCi Cs-137
Description: Point Source at 30.48 cm
Geometry: 1 - Point

Dose Points

	X	Y	Z
# 1	30.48 cm	0 cm	0 cm
	1 ft	0.0 in	0.0 in

Shields

Shield Name	Material	Density
Air Gap	Air	0.00122

Source Input
Grouping Method : Actual Photon Energies

Nuclide	curies	becquerels
Ba-137m	8.6188e-006	3.1890e+005
Cs-137	9.1108e-006	3.3710e+005

Buildup
The material reference is : Air Gap

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
0.0318	6.602e+03	1.779e-02	1.804e-02	1.482e-04	1.503e-04
0.0322	1.218e+04	3.323e-02	3.368e-02	2.674e-04	2.711e-04
0.0364	4.433e+03	1.369e-02	1.388e-02	7.779e-05	7.885e-05
0.6616	2.869e+05	1.622e+01	1.626e+01	3.144e-02	3.151e-02
TOTALS:	3.102e+05	1.628e+01	1.632e+01	3.193e-02	3.201e-02

MicroShield v5.05 (5.05-00488)
Sacramento Municipal Uitility District

Page : 1
DOS File : Case1
Run Date: August 17, 2004
Run Time: 11:30:55 AM
Duration : 00:00:00

File Ref: _____
Date: _____
By: _____
Checked: _____

Case Title: 9.11 uCi Cs-137
Description: Point Source at 60.96 cm
Geometry: 1 - Point

Dose Points

	X	Y	Z
# 1	60.96 cm	0 cm	0 cm
	2 ft	0.0 in	0.0 in

Shields

Shield Name	Material	Density
Air Gap	Air	0.00122

Source Input
Grouping Method : Actual Photon Energies

Nuclide	curies	becquerels
Ba-137m	8.6188e-006	3.1890e+005
Cs-137	9.1108e-006	3.3710e+005

Buildup
The material reference is : Air Gap

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
0.0318	6.602e+03	4.399e-03	4.521e-03	3.665e-05	3.766e-05
0.0322	1.218e+04	8.216e-03	8.444e-03	6.612e-05	6.795e-05
0.0364	4.433e+03	3.391e-03	3.484e-03	1.926e-05	1.980e-05
0.6616	2.869e+05	4.042e+00	4.062e+00	7.837e-03	7.875e-03
TOTALS:	3.102e+05	4.058e+00	4.079e+00	7.959e-03	8.001e-03

Receipt # 03-027

461, Issue 4, 03-01-03

AEA Technology QSA GmbH

Gieselweg 1
38110 Braunschweig
Postfach 11 37
38001 Braunschweig
Germany
Tel. +49 (0) 5307 932-0
Fax +49 (0) 5307 932-194

17 September 2003

CERTIFICATE

No. 68970 - LY 376

for a Sealed Radioactive Source

Source Type: Reference Source

Product code	CDRX1476
Drawing	VZ-477/2
Source no.	LY 376
Nuclide	Caesium-137

Measurement Data

Activity	344 kBq
Uncertainty*	3%
Reference date	1 October 2003
Traceability*	Defined on page 2
Radioactive impurities	Related to Cs-137 (equal 100 %) the following radioactive impurities were detected: Cs-134 < 0.1 %

Leakage and Contamination Test/s

Test method/s*	II and I
Test/s passed on	16 September 2003

Additional Information

ISO classification*	C.34313

* see page 2 for explanation

AEA Technology QSA GmbH

i.A. [illegible]
(Production Manager)

SCN 618

Receipt # 03-027

Explanations for Certificates (Page 2 of Certificates)

Uncertainty

The reported uncertainty is based on standard uncertainty multiplied by a coverage factor k = 2, providing a level of confidence of approximately 95 %. (ISO Guide, 1995)

Traceability

This certificate documents the traceability of measurement results to national standards, standard measuring equipment and methods for the realisation of physical units of measurement according to the International System of Units (SI).
Traceability is defined as 'the property of a result of a measurement whereby it can be related to appropriate standards, generally international or national standards, through an unbroken chain of comparisons'.

AEA Technology QSA GmbH has been accredited as DKD (Deutscher Kalibrierdienst) calibration laboratory by the Physikalisch-Technische Bundesanstalt (PTB) and is authorized to issue reference sources which are traceable to national standards held at the PTB in Germany.
Because of the European co-operation for Accreditation (EA) mutual recognition agreement the certificates are also accepted by all EA-members (e. g. NAMAS, UK).

This product complies with the requirements for traceability to NIST specified in the American National Standard "Traceability of Radioactive Sources to the NIST and Associated Instrument Quality Control (ANSI N42.22-1995)".
As a requirement for the ANSI N42.22-1995 AEA Technology QSA participates in the NEI/NIST Measurements Assurance Pro-gram of the Nuclear Power Industry.

Leakage and contamination tests

Stringent tests for leakage are an essential feature of radioactive sources production. They are based on ISO 9978. Some standard methods used for testing radiation sources are listed below.

Wipe test I

The source is wiped with a swab or tissue, moistened with ethanol or water, the activity removed is measured.
Limit: 200 Bq
(Limit USA: 5 nCi)

Immersion test II

The source is immersed in a suitable liquid at 50 °C for at least 4 hours and the activity removed is measured.
Limit: 185 Bq

Bubble test III

The source is immersed in water or a suitable liquid and the pressure in the vessel reduced to 13 kPa (100 mm Hg). No bubbles must be observed.

ISO classification

The International Organization for Standardization (ISO) has proposed a system of classification of sealed radioactive sources based on safety requirements for typical uses (see ISO 2919). This system provides a manufacturer of sealed radioactive sources with a set of tests to evaluate the safety of his products. It also assists a user of such sealed sources to select types which suit the application he has in mind. The tests to which specimen sources are subjected are listed in the following table.

Classification of sealed source performance standard according to ISO 2919

	Class 1	2	3	4	5	6	X
Temperature	No test	- 40 °C (20 min) + 80 °C (1 h)	- 40 °C (20 min) + 180 °C (1 h)	- 40 °C (20 min) + 400 °C (1 h) and thermal shock 400 °C to 20 °C	- 40 °C (20 min) + 600 °C (1 h) and thermal shock 600 °C to 20 °C	- 40 °C (20 min) + 800 °C (1 h) and thermal shock 800 °C to 20 °C	Special test
External Pressure	No test	25 kPa absolute	25 kPa absolute to 2 MPa absolute	25 kPa absolute to 7 MPa absolute	25 kPa absolute to 70 MPa absolute	25 kPa absolute to 170 MPa absolute	
Impact	No test	50 g from 1 m	200 g from 1 m	2 kg from 1 m	5 kg from 1 m	20 kg from 1 m	
Vibration	No test	3 x 10 min 25 - 500 Hz at 5 g peak amplitude	3 x 10 min 25 - 50 Hz at 5 g peak amplitude and 50 - 90 Hz at 0.635 mm amplitude peak to peak and 90 - 500 Hz at 10 g peak amplitude	3 x 30 min 25 - 80 Hz at 1.5 mm amplitude peak to peak and 80 - 2000 Hz at 20 g peak amplitude			
Puncture	No test	1 g from 1 m	10 g from 1 m	50 g from 1 m	300 g from 1 m	1 kg from 1 m	

Special applications

No test programme can cover all possible combinations of environments to which a source may be exposed.
Users should therefore consult our experts before using sources in potentially adverse environments.

IAEA Special Form

'Special Form' is a test specification for sealed sources given in the IAEA transport regulations (IAEA Safety Series No. 6, 1985, revised edition).
It is used in determining the maximum acceptable activities for various types of transport containers.

Quality assurance System

The quality assurance system of AEA Technology QSA GmbH was certified by Lloyd's Register Quality Assurance (LRQA) according to ISO 9001, issue 1994. Isotrak products meet the requirements of 10CFR50 Appendix B.

LLOYD'S REGISTER QUALITY ASSURANCE ISO9001

RE1, Issue 3, 2003-03-27

AEA TECHNOLOGY QSA

Co-60
NaI Response Factors for SPA-3 and 44-10 Detectors

Gross Data

Instrument	Serial Number	Background*	7.62 cm*	15.24 cm*	30.48 cm*
SPA-3	406074	85249	178466	112689	92102
44-10	211672	86613	185533	109974	94191

*Ten-minute count results

Net Counts

Distance (cm)	Derived μ/h	SPA-3 Estimated	SPA-3 Observed	44-10 Estimated	44-10 Observed
7.62	24.12	1.4472E+04	9.3217E+03	1.0372E+04	9.8920E+03
15.24	6.032	3.6192E+03	2.7440E+03	2.5938E+03	2.3361E+03
30.48	1.508	9.0480E+02	6.8530E+02	6.4844E+02	7.5780E+02
Estimates based on vendor values of 600 and 430 cpm/μ/R/h for SPA-3 and 44-10 respectively					

CPM/μR/h

Instrument	7.62 cm	15.24 cm	30.48 cm	Average
SPA-3	386	455	454	**432**
44-10	410	387	503	**433**

Cs-137
NaI Response Factors for SPA-3 and 44-10 Detectors

Gross Data

Instrument	Serial Number	Background	15.24 cm*	30.48 cm	60.96 cm
SPA-3	406074	114876	682101	436075	197493
44-10	211672	115620	613988	414299	197366

*5-minute count used for the 6" (15.24 cm) measurement due to high count rate
Instrument maxed out with approximately 1.5 minutes to go in a 10 minute count.

Net Counts

Distance (cm)	Derived μ/h	SPA-3 Estimated	SPA-3 Observed	44-10 Estimated	44-10 Observed
15.24	128.1	1.5370E+05	1.2493E+05	1.1530E+05	1.1124E+05
30.48	32.01	3.8410E+04	3.2120E+04	2.8810E+04	2.9868E+04
60.96	8.001	9.6010E+03	8.2617E+03	7.2010E+03	8.1746E+03
Estimates based on vendor values of 600 and 430 cpm/μ/R/h for SPA-3 and 44-10 respectively					

CPM/μR/h

Instrument	7.62 cm	15.24 cm	30.48 cm	Average
SPA-3	975	1003	1033	**1004**
44-10	868	933	1022	**941**

MicroShield 8.03
EnergySolutions (8.03-0000)

Date	By	Checked
12/2/2011	R. F. Decker	

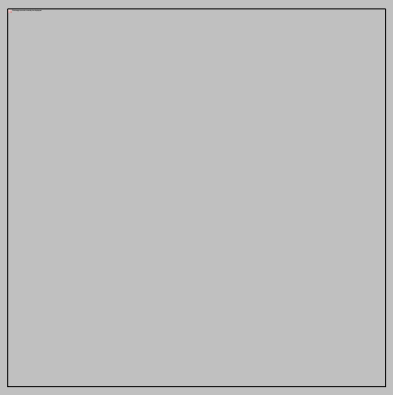
Filename	Run Date	Run Time	Duration
Case1	December 2, 2011	12:14:20 PM	00:00:00

Project Info	
Case Title	Co-60 100%
Description	Co-60 100% 2.54, 7.62 and 12.7 cm
Geometry	8 - Cylinder Volume - End Shields

Source Dimensions	
Height	15.24 cm (6.0 in)
Radius	25.0 cm (9.8 in)

Dose Points			
A	X	Y	Z
#1	0.0 cm (0 in)	20.32 cm (8.0 in)	0.0 cm (0 in)

Shields			
Shield N	Dimension	Material	Density
Source	2.99e+04 cm³	Sand	1.6
Air Gap		Air	0.00122



Source Input: Grouping Method - Actual Photon Energies				
Nuclide	Ci	Bq	µCi/cm³	Bq/cm³
Co-60	4.7878e-008	1.7715e+003	1.6000e-006	5.9200e-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	2.890e-01	1.824e-05	3.278e-05	3.521e-08	6.329e-08
1.1732	1.771e+03	2.224e-01	3.441e-01	3.974e-04	6.150e-04
1.3325	1.771e+03	2.623e-01	3.929e-01	4.550e-04	6.816e-04
Totals	**3.543e+03**	**4.847e-01**	**7.370e-01**	**8.525e-04**	**1.297e-03**
	Sensitivity	**Variable**	**Y Dose Point 1**	**(1 of 5)**	**(20.32 cm)**
0.6938	2.890e-01	1.824e-05	3.278e-05	3.521e-08	6.329e-08
1.1732	1.771e+03	2.224e-01	3.441e-01	3.974e-04	6.150e-04
1.3325	1.771e+03	2.623e-01	3.929e-01	4.550e-04	6.816e-04
Totals	**3.543e+03**	**4.847e-01**	**7.370e-01**	**8.525e-04**	**1.297e-03**
	Sensitivity	**Variable**	**Y Dose Point 1**	**(2 of 5)**	**(22.86 cm)**
0.6938	2.890e-01	1.547e-05	2.720e-05	2.986e-08	5.251e-08
1.1732	1.771e+03	1.873e-01	2.846e-01	3.347e-04	5.086e-04
1.3325	1.771e+03	2.205e-01	3.247e-01	3.826e-04	5.633e-04
Totals	**3.543e+03**	**4.079e-01**	**6.093e-01**	**7.174e-04**	**1.072e-03**
	Sensitivity	**Variable**	**Y Dose Point 1**	**(3 of 5)**	**(25.4 cm)**
0.6938	2.890e-01	1.318e-05	2.282e-05	2.544e-08	4.407e-08
1.1732	1.771e+03	1.588e-01	2.383e-01	2.838e-04	4.259e-04
1.3325	1.771e+03	1.868e-01	2.718e-01	3.241e-04	4.715e-04
Totals	**3.543e+03**	**3.456e-01**	**5.101e-01**	**6.079e-04**	**8.975e-04**
	Sensitivity	**Variable**	**Y Dose Point 1**	**(4 of 5)**	**(27.94 cm)**
0.6938	2.890e-01	1.128e-05	1.934e-05	2.179e-08	3.734e-08
1.1732	1.771e+03	1.356e-01	2.017e-01	2.422e-04	3.604e-04
1.3325	1.771e+03	1.593e-01	2.299e-01	2.764e-04	3.988e-04
Totals	**3.543e+03**	**2.949e-01**	**4.316e-01**	**5.186e-04**	**7.593e-04**
	Sensitivity	**Variable**	**Y Dose Point 1**	**(5 of 5)**	**(30.48 cm)**
0.6938	2.890e-01	9.718e-06	1.653e-05	1.876e-08	3.192e-08
1.1732	1.771e+03	1.165e-01	1.723e-01	2.081e-04	3.079e-04
1.3325	1.771e+03	1.368e-01	1.963e-01	2.373e-04	3.406e-04
Totals	**3.543e+03**	**2.533e-01**	**3.686e-01**	**4.455e-04**	**6.485e-04**

Sensitivity Analysis Summary - Y Dose Point 1

Dose Point #	Sensitivity	Sensitivity Dimension	Fluence Rate MeV/cm²/sec	Fluence Rate MeV/cm²/sec	Exposure Rate mR/hr	Exposure Rate mR/hr

			No Buildup	With Buildup	No Buildup	With Buildup
1	(1 of 5)	(20.32 cm)	4.847e-01	7.370e-01	8.525e-04	1.297e-03
1	(2 of 5)	(22.86 cm)	4.079e-01	6.093e-01	7.174e-04	1.072e-03
1	(3 of 5)	(25.4 cm)	3.456e-01	5.101e-01	6.079e-04	8.975e-04
1	(4 of 5)	(27.94 cm)	2.949e-01	4.316e-01	5.186e-04	7.593e-04
1	(5 of 5)	(30.48 cm)	2.533e-01	3.686e-01	4.455e-04	6.485e-04

Filename	Run Date	Run Time	Duration
Case1	December 2, 2011	12:29:22 PM	00:00:00

Project Info	
Case Title	Cs-137 100%
Description	Cs-137 100% 2.54 - 12.7 cm
Geometry	8 - Cylinder Volume - End Shields

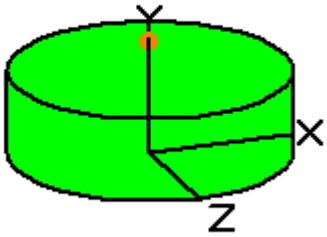
Source Dimensions	
Height	15.24 cm (6.0 in)
Radius	25.0 cm (9.8 in)

Dose Points

A	X	Y	Z
#1	0.0 cm (0 in)	20.32 cm (8.0 in)	0.0 cm (0 in)

Shields

Shield N	Dimension	Material	Density
Source	2.99e+04 cm³	Sand	1.6
Air Gap		Air	0.00122



Source Input: Grouping Method - Actual Photon Energies

Nuclide	Ci	Bq	µCi/cm³	Bq/cm³
Ba-137m	4.5292e-008	1.6758e+003	1.5136e-006	5.6003e-002
Cs-137	4.7878e-008	1.7715e+003	1.6000e-006	5.9200e-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	1.740e+01	7.481e-08	7.709e-08	5.127e-08	5.284e-08
0.0318	3.469e+01	9.338e-06	1.152e-05	7.778e-08	9.599e-08
0.0322	6.401e+01	1.797e-05	2.232e-05	1.446e-07	1.797e-07
0.0364	2.329e+01	1.002e-05	1.339e-05	5.691e-08	7.606e-08
0.6616	1.508e+03	8.942e-02	1.631e-01	1.734e-04	3.162e-04
Totals	**1.647e+03**	**8.946e-02**	**1.632e-01**	**1.737e-04**	**3.166e-04**
	Sensitivity	**Variable**	**Y Dose Point 1**	**(1 of 5)**	**(20.32 cm)**
0.0045	1.740e+01	7.481e-08	7.709e-08	5.127e-08	5.284e-08
0.0318	3.469e+01	9.338e-06	1.152e-05	7.778e-08	9.599e-08
0.0322	6.401e+01	1.797e-05	2.232e-05	1.446e-07	1.797e-07
0.0364	2.329e+01	1.002e-05	1.339e-05	5.691e-08	7.606e-08
0.6616	1.508e+03	8.942e-02	1.631e-01	1.734e-04	3.162e-04
Totals	**1.647e+03**	**8.946e-02**	**1.632e-01**	**1.737e-04**	**3.166e-04**
	Sensitivity	**Variable**	**Y Dose Point 1**	**(2 of 5)**	**(22.86 cm)**
0.0045	1.740e+01	6.603e-08	6.801e-08	4.526e-08	4.662e-08
0.0318	3.469e+01	8.221e-06	1.014e-05	6.848e-08	8.448e-08
0.0322	6.401e+01	1.582e-05	1.964e-05	1.273e-07	1.581e-07
0.0364	2.329e+01	8.800e-06	1.175e-05	5.000e-08	6.675e-08
0.6616	1.508e+03	7.588e-02	1.354e-01	1.471e-04	2.625e-04
Totals	**1.647e+03**	**7.592e-02**	**1.354e-01**	**1.474e-04**	**2.628e-04**
	Sensitivity	**Variable**	**Y Dose Point 1**	**(3 of 5)**	**(25.4 cm)**
0.0045	1.740e+01	5.793e-08	5.966e-08	3.971e-08	4.089e-08
0.0318	3.469e+01	7.200e-06	8.880e-06	5.997e-08	7.397e-08
0.0322	6.401e+01	1.385e-05	1.719e-05	1.115e-07	1.384e-07
0.0364	2.329e+01	7.697e-06	1.027e-05	4.373e-08	5.835e-08
0.6616	1.508e+03	6.468e-02	1.136e-01	1.254e-04	2.203e-04
Totals	**1.647e+03**	**6.470e-02**	**1.137e-01**	**1.256e-04**	**2.206e-04**

	Sensitivity	Variable	Y Dose Point 1	(4 of 5)	(27.94 cm)
0.0045	1.740e+01	5.066e-08	5.216e-08	3.472e-08	3.575e-08
0.0318	3.469e+01	6.290e-06	7.757e-06	5.240e-08	6.461e-08
0.0322	6.401e+01	1.210e-05	1.501e-05	9.738e-08	1.208e-07
0.0364	2.329e+01	6.719e-06	8.961e-06	3.818e-08	5.092e-08
0.6616	1.508e+03	5.540e-02	9.629e-02	1.074e-04	1.867e-04
Totals	**1.647e+03**	**5.542e-02**	**9.632e-02**	**1.076e-04**	**1.869e-04**
	Sensitivity	**Variable**	**Y Dose Point 1**	**(5 of 5)**	**(30.48 cm)**
0.0045	1.740e+01	4.423e-08	4.554e-08	3.032e-08	3.122e-08
0.0318	3.469e+01	5.493e-06	6.773e-06	4.576e-08	5.642e-08
0.0322	6.401e+01	1.057e-05	1.311e-05	8.504e-08	1.055e-07
0.0364	2.329e+01	5.865e-06	7.819e-06	3.332e-08	4.442e-08
0.6616	1.508e+03	4.771e-02	8.233e-02	9.250e-05	1.596e-04
Totals	**1.647e+03**	**4.774e-02**	**8.236e-02**	**9.269e-05**	**1.598e-04**

Sensitivity Analysis Summary - Y Dose Point 1

Dose Point #	Sensitivity	Sensitivity Dimension	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
1	(1 of 5)	(20.32 cm)	8.946e-02	1.632e-01	1.737e-04	3.166e-04
1	(2 of 5)	(22.86 cm)	7.592e-02	1.354e-01	1.474e-04	2.628e-04
1	(3 of 5)	(25.4 cm)	6.470e-02	1.137e-01	1.256e-04	2.206e-04
1	(4 of 5)	(27.94 cm)	5.542e-02	9.632e-02	1.076e-04	1.869e-04
1	(5 of 5)	(30.48 cm)	4.774e-02	8.236e-02	9.269e-05	1.598e-04

MicroShield 8.03
EnergySolutions (8.03-0000)

Date	By	Checked
12/2/2011	Robert F. Decker	

Filename	Run Date	Run Time	Duration

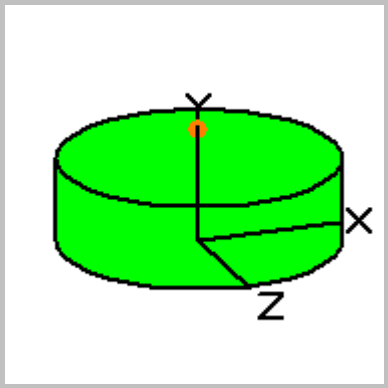
Case1	December 2, 2011	12:50:29 PM	00:00:00

Project Info	
Case Title	95% Cs-137 5% Co-60
Description	Cs-137/Co-60 2.54 - 12.7 cm
Geometry	8 - Cylinder Volume - End Shields

Source Dimensions	
Height	15.24 cm (6.0 in)
Radius	25.0 cm (9.8 in)

Dose Points			
A	**X**	**Y**	**Z**
#1	0.0 cm (0 in)	20.32 cm (8.0 in)	0.0 cm (0 in)

Shields			
Shield N	**Dimension**	**Material**	**Density**
Source	2.99e+04 cm³	Sand	1.6
Air Gap		Air	0.00122



Source Input: Grouping Method - Actual Photon Energies				
Nuclide	**Ci**	**Bq**	**µCi/cm³**	**Bq/cm³**
Ba-137m	4.3028e-008	1.5920e+003	1.4379e-006	5.3203e-002
Co-60	2.3939e-009	8.8574e+001	8.0000e-008	2.9600e-003
Cs-137	4.5484e-008	1.6829e+003	1.5200e-006	5.6240e-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	1.653e+01	7.107e-08	7.323e-08	4.871e-08	5.020e-08
0.0318	3.296e+01	8.871e-06	1.095e-05	7.389e-08	9.119e-08
0.0322	6.081e+01	1.707e-05	2.121e-05	1.374e-07	1.707e-07

0.0364	2.213e+01	9.516e-06	1.272e-05	5.407e-08	7.226e-08
0.6616	1.433e+03	8.495e-02	1.550e-01	1.647e-04	3.004e-04
0.6938	1.445e-02	9.120e-07	1.639e-06	1.761e-09	3.165e-09
1.1732	8.857e+01	1.112e-02	1.721e-02	1.987e-05	3.075e-05
1.3325	8.857e+01	1.311e-02	1.964e-02	2.275e-05	3.408e-05
Totals	**1.742e+03**	**1.092e-01**	**1.919e-01**	**2.076e-04**	**3.656e-04**
	Sensitivity	**Variable**	**Y Dose Point 1**	**(1 of 5)**	**(20.32 cm)**
0.0045	1.653e+01	7.107e-08	7.323e-08	4.871e-08	5.020e-08
0.0318	3.296e+01	8.871e-06	1.095e-05	7.389e-08	9.119e-08
0.0322	6.081e+01	1.707e-05	2.121e-05	1.374e-07	1.707e-07
0.0364	2.213e+01	9.516e-06	1.272e-05	5.407e-08	7.226e-08
0.6616	1.433e+03	8.495e-02	1.550e-01	1.647e-04	3.004e-04
0.6938	1.445e-02	9.120e-07	1.639e-06	1.761e-09	3.165e-09
1.1732	8.857e+01	1.112e-02	1.721e-02	1.987e-05	3.075e-05
1.3325	8.857e+01	1.311e-02	1.964e-02	2.275e-05	3.408e-05
Totals	**1.742e+03**	**1.092e-01**	**1.919e-01**	**2.076e-04**	**3.656e-04**
	Sensitivity	**Variable**	**Y Dose Point 1**	**(2 of 5)**	**(22.86 cm)**
0.0045	1.653e+01	6.273e-08	6.461e-08	4.300e-08	4.429e-08
0.0318	3.296e+01	7.810e-06	9.635e-06	6.505e-08	8.026e-08
0.0322	6.081e+01	1.503e-05	1.866e-05	1.209e-07	1.502e-07
0.0364	2.213e+01	8.360e-06	1.116e-05	4.750e-08	6.341e-08
0.6616	1.433e+03	7.209e-02	1.286e-01	1.398e-04	2.493e-04
0.6938	1.445e-02	7.734e-07	1.360e-06	1.493e-09	2.626e-09
1.1732	8.857e+01	9.365e-03	1.423e-02	1.673e-05	2.543e-05
1.3325	8.857e+01	1.103e-02	1.623e-02	1.913e-05	2.817e-05
Totals	**1.742e+03**	**9.251e-02**	**1.591e-01**	**1.759e-04**	**3.033e-04**
	Sensitivity	**Variable**	**Y Dose Point 1**	**(3 of 5)**	**(25.4 cm)**
0.0045	1.653e+01	5.504e-08	5.668e-08	3.773e-08	3.885e-08
0.0318	3.296e+01	6.840e-06	8.436e-06	5.697e-08	7.027e-08
0.0322	6.081e+01	1.316e-05	1.633e-05	1.059e-07	1.314e-07
0.0364	2.213e+01	7.312e-06	9.757e-06	4.155e-08	5.543e-08
0.6616	1.433e+03	6.144e-02	1.079e-01	1.191e-04	2.093e-04

0.6938	1.445e-02	6.589e-07	1.141e-06	1.272e-09	2.203e-09
1.1732	8.857e+01	7.941e-03	1.192e-02	1.419e-05	2.130e-05
1.3325	8.857e+01	9.340e-03	1.359e-02	1.620e-05	2.357e-05
Totals	**1.742e+03**	**7.875e-02**	**1.335e-01**	**1.498e-04**	**2.544e-04**
	Sensitivity	**Variable**	**Y Dose Point 1**	**(4 of 5)**	**(27.94 cm)**
0.0045	1.653e+01	4.812e-08	4.955e-08	3.299e-08	3.396e-08
0.0318	3.296e+01	5.976e-06	7.369e-06	4.978e-08	6.138e-08
0.0322	6.081e+01	1.149e-05	1.426e-05	9.251e-08	1.148e-07
0.0364	2.213e+01	6.383e-06	8.513e-06	3.627e-08	4.837e-08
0.6616	1.433e+03	5.263e-02	9.147e-02	1.020e-04	1.773e-04
0.6938	1.445e-02	5.642e-07	9.669e-07	1.089e-09	1.867e-09
1.1732	8.857e+01	6.778e-03	1.008e-02	1.211e-05	1.802e-05
1.3325	8.857e+01	7.965e-03	1.149e-02	1.382e-05	1.994e-05
Totals	**1.742e+03**	**6.739e-02**	**1.131e-01**	**1.282e-04**	**2.156e-04**
	Sensitivity	**Variable**	**Y Dose Point 1**	**(5 of 5)**	**(30.48 cm)**
0.0045	1.653e+01	4.202e-08	4.326e-08	2.880e-08	2.966e-08
0.0318	3.296e+01	5.219e-06	6.434e-06	4.347e-08	5.360e-08
0.0322	6.081e+01	1.004e-05	1.245e-05	8.078e-08	1.002e-07
0.0364	2.213e+01	5.571e-06	7.428e-06	3.165e-08	4.220e-08
0.6616	1.433e+03	4.533e-02	7.821e-02	8.787e-05	1.516e-04
0.6938	1.445e-02	4.859e-07	8.267e-07	9.381e-10	1.596e-09
1.1732	8.857e+01	5.824e-03	8.614e-03	1.041e-05	1.539e-05
1.3325	8.857e+01	6.840e-03	9.816e-03	1.187e-05	1.703e-05
Totals	**1.742e+03**	**5.801e-02**	**9.667e-02**	**1.103e-04**	**1.843e-04**

Sensitivity Analysis Summary - Y Dose Point 1

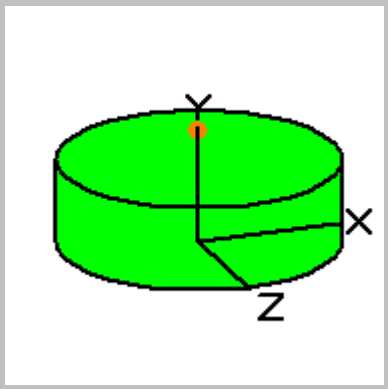
Dose Point #	Sensitivity	Sensitivity Dimension	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
1	(1 of 5)	(20.32 cm)	1.092e-01	1.919e-01	2.076e-04	3.656e-04
1	(2 of 5)	(22.86 cm)	9.251e-02	1.591e-01	1.759e-04	3.033e-04
1	(3 of 5)	(25.4 cm)	7.875e-02	1.335e-01	1.498e-04	2.544e-04
1	(4 of 5)	(27.94 cm)	6.739e-02	1.131e-01	1.282e-04	2.156e-04
1	(5 of 5)	(30.48 cm)	5.801e-02	9.667e-02	1.103e-04	1.843e-04

MicroShield 8.03 EnergySolutions (8.03-0000)			
Date	**By**		**Checked**
12/2/2011	Robert F. Decker		
Filename	**Run Date**	**Run Time**	**Duration**
Case1	December 2, 2011	12:58:06 PM	00:00:00
Project Info			
Case Title	90% Cs-137 10% Co-6		
Description	Cs-137/Co-60 2.54 - 12.7 cm		
Geometry	8 - Cylinder Volume - End Shields		

Source Dimensions	
Height	15.24 cm (6.0 in)
Radius	25.0 cm (9.8 in)

Dose Points			
A	**X**	**Y**	**Z**
#1	0.0 cm (0 in)	20.32 cm (8.0 in)	0.0 cm (0 in)

Shields			
Shield N	**Dimension**	**Material**	**Density**
Source	2.99e+04 cm³	Sand	1.6
Air Gap		Air	0.00122



Source Input: Grouping Method - Actual Photon Energies				
Nuclide	**Ci**	**Bq**	**µCi/cm³**	**Bq/cm³**
Ba-137m	4.0763e-008	1.5082e+003	1.3622e-006	5.0403e-002
Co-60	4.7878e-009	1.7715e+002	1.6000e-007	5.9200e-003
Cs-137	4.3090e-008	1.5943e+003	1.4400e-006	5.3280e-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	1.566e+01	6.733e-08	6.938e-08	4.615e-08	4.756e-08
0.0318	3.123e+01	8.404e-06	1.037e-05	7.000e-08	8.639e-08
0.0322	5.761e+01	1.617e-05	2.009e-05	1.302e-07	1.617e-07
0.0364	2.096e+01	9.015e-06	1.205e-05	5.122e-08	6.846e-08
0.6616	1.357e+03	8.048e-02	1.468e-01	1.560e-04	2.846e-04
0.6938	2.890e-02	1.824e-06	3.278e-06	3.521e-09	6.329e-09
1.1732	1.771e+02	2.224e-02	3.441e-02	3.974e-05	6.150e-05
1.3325	1.771e+02	2.623e-02	3.929e-02	4.550e-05	6.816e-05

Totals	**1.837e+03**	**1.290e-01**	**2.206e-01**	**2.416e-04**	**4.146e-04**
	Sensitivity	**Variable**	**Y Dose Point 1**	**(1 of 5)**	**(20.32 cm)**
0.0045	1.566e+01	6.733e-08	6.938e-08	4.615e-08	4.756e-08
0.0318	3.123e+01	8.404e-06	1.037e-05	7.000e-08	8.639e-08
0.0322	5.761e+01	1.617e-05	2.009e-05	1.302e-07	1.617e-07
0.0364	2.096e+01	9.015e-06	1.205e-05	5.122e-08	6.846e-08
0.6616	1.357e+03	8.048e-02	1.468e-01	1.560e-04	2.846e-04
0.6938	2.890e-02	1.824e-06	3.278e-06	3.521e-09	6.329e-09
1.1732	1.771e+02	2.224e-02	3.441e-02	3.974e-05	6.150e-05
1.3325	1.771e+02	2.623e-02	3.929e-02	4.550e-05	6.816e-05
Totals	**1.837e+03**	**1.290e-01**	**2.206e-01**	**2.416e-04**	**4.146e-04**
	Sensitivity	**Variable**	**Y Dose Point 1**	**(2 of 5)**	**(22.86 cm)**
0.0045	1.566e+01	5.943e-08	6.121e-08	4.073e-08	4.196e-08
0.0318	3.123e+01	7.399e-06	9.128e-06	6.163e-08	7.603e-08
0.0322	5.761e+01	1.424e-05	1.768e-05	1.146e-07	1.423e-07
0.0364	2.096e+01	7.920e-06	1.057e-05	4.500e-08	6.007e-08
0.6616	1.357e+03	6.830e-02	1.218e-01	1.324e-04	2.362e-04
0.6938	2.890e-02	1.547e-06	2.720e-06	2.986e-09	5.251e-09
1.1732	1.771e+02	1.873e-02	2.846e-02	3.347e-05	5.086e-05
1.3325	1.771e+02	2.205e-02	3.247e-02	3.826e-05	5.633e-05
Totals	**1.837e+03**	**1.091e-01**	**1.828e-01**	**2.044e-04**	**3.437e-04**
	Sensitivity	**Variable**	**Y Dose Point 1**	**(3 of 5)**	**(25.4 cm)**
0.0045	1.566e+01	5.214e-08	5.369e-08	3.574e-08	3.680e-08
0.0318	3.123e+01	6.480e-06	7.992e-06	5.398e-08	6.657e-08
0.0322	5.761e+01	1.247e-05	1.547e-05	1.003e-07	1.245e-07
0.0364	2.096e+01	6.928e-06	9.243e-06	3.936e-08	5.252e-08
0.6616	1.357e+03	5.821e-02	1.023e-01	1.128e-04	1.982e-04
0.6938	2.890e-02	1.318e-06	2.282e-06	2.544e-09	4.407e-09
1.1732	1.771e+02	1.588e-02	2.383e-02	2.838e-05	4.259e-05
1.3325	1.771e+02	1.868e-02	2.718e-02	3.241e-05	4.715e-05
Totals	**1.837e+03**	**9.280e-02**	**1.533e-01**	**1.739e-04**	**2.883e-04**
	Sensitivity	**Variable**	**Y Dose Point 1**	**(4 of 5)**	**(27.94 cm)**

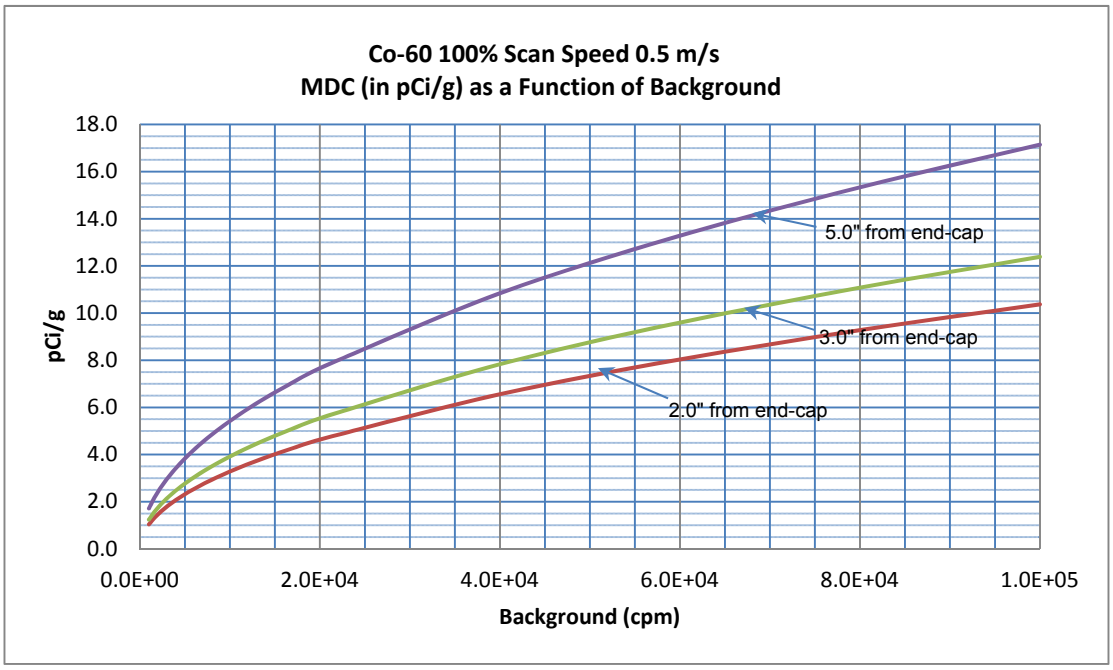
0.0045	1.566e+01	4.559e-08	4.694e-08	3.125e-08	3.218e-08
0.0318	3.123e+01	5.661e-06	6.981e-06	4.716e-08	5.815e-08
0.0322	5.761e+01	1.089e-05	1.351e-05	8.764e-08	1.088e-07
0.0364	2.096e+01	6.047e-06	8.065e-06	3.436e-08	4.582e-08
0.6616	1.357e+03	4.986e-02	8.666e-02	9.666e-05	1.680e-04
0.6938	2.890e-02	1.128e-06	1.934e-06	2.179e-09	3.734e-09
1.1732	1.771e+02	1.356e-02	2.017e-02	2.422e-05	3.604e-05
1.3325	1.771e+02	1.593e-02	2.299e-02	2.764e-05	3.988e-05
Totals	**1.837e+03**	**7.937e-02**	**1.298e-01**	**1.487e-04**	**2.442e-04**
	Sensitivity	**Variable**	**Y Dose Point 1**	**(5 of 5)**	**(30.48 cm)**
0.0045	1.566e+01	3.981e-08	4.099e-08	2.729e-08	2.809e-08
0.0318	3.123e+01	4.944e-06	6.096e-06	4.118e-08	5.078e-08
0.0322	5.761e+01	9.510e-06	1.180e-05	7.653e-08	9.496e-08
0.0364	2.096e+01	5.278e-06	7.037e-06	2.999e-08	3.998e-08
0.6616	1.357e+03	4.294e-02	7.410e-02	8.325e-05	1.436e-04
0.6938	2.890e-02	9.718e-07	1.653e-06	1.876e-09	3.192e-09
1.1732	1.771e+02	1.165e-02	1.723e-02	2.081e-05	3.079e-05
1.3325	1.771e+02	1.368e-02	1.963e-02	2.373e-05	3.406e-05
Totals	**1.837e+03**	**6.829e-02**	**1.110e-01**	**1.280e-04**	**2.087e-04**

Sensitivity Analysis Summary - Y Dose Point 1

Dose Point #	Sensitivity	Sensitivity Dimension	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
1	(1 of 5)	(20.32 cm)	1.290e-01	2.206e-01	2.416e-04	4.146e-04
1	(2 of 5)	(22.86 cm)	1.091e-01	1.828e-01	2.044e-04	3.437e-04
1	(3 of 5)	(25.4 cm)	9.280e-02	1.533e-01	1.739e-04	2.883e-04
1	(4 of 5)	(27.94 cm)	7.937e-02	1.298e-01	1.487e-04	2.442e-04
1	(5 of 5)	(30.48 cm)	6.829e-02	1.110e-01	1.280e-04	2.087e-04

Soil Scan MDC For Ludlum 44-10 NaI Detector
100% Co-60 1.0 pCi/g Scan Rate 0.5 m/s d' 1.38
Detector end-cap 2.0" above Soil Surface @ Detector Centerline (7.62cm)

12/8/2011				Detectable Exp. Rate	Detec table Exp. Rate		µR/h/pCi/g Microshield	
44-10 Bkg	Counts per 1.0 second	MDCR	cpm/uR/h =>	430 Co-60	940 Cs-137	Detectable Exp. Rate	Results	Scan MDC
cpm			$MDCR_{surveyor}$	µR/h	µR/h Total	µR/h	@ 7.62 cm	pCi/g
1.00E+03	1.67E+01	3.38E+02	4.78E+02	1.11E+00	0.00E+00	1.11E+00	1.072	1.0
2.00E+03	3.33E+01	4.78E+02	6.76E+02	1.57E+00	0.00E+00	1.57E+00	1.072	1.47
4.00E+03	6.67E+01	6.76E+02	9.56E+02	2.22E+00	0.00E+00	2.22E+00	1.072	2.07
6.00E+03	1.00E+02	8.28E+02	1.17E+03	2.72E+00	0.00E+00	2.72E+00	1.072	2.54
8.00E+03	1.33E+02	9.56E+02	1.35E+03	3.14E+00	0.00E+00	3.14E+00	1.072	2.93
1.00E+04	1.67E+02	1.07E+03	1.51E+03	3.52E+00	0.00E+00	3.52E+00	1.072	3.28
1.20E+04	2.00E+02	1.17E+03	1.66E+03	3.85E+00	0.00E+00	3.85E+00	1.072	3.59
1.40E+04	2.33E+02	1.26E+03	1.79E+03	4.16E+00	0.00E+00	4.16E+00	1.072	3.88
1.80E+04	3.00E+02	1.43E+03	2.03E+03	4.72E+00	0.00E+00	4.72E+00	1.072	4.40
2.00E+04	3.33E+02	1.51E+03	2.14E+03	4.97E+00	0.00E+00	4.97E+00	1.072	4.64
4.00E+04	6.67E+02	2.14E+03	3.02E+03	7.03E+00	0.00E+00	7.03E+00	1.072	6.56
6.00E+04	1.00E+03	2.62E+03	3.70E+03	8.61E+00	0.00E+00	8.61E+00	1.072	8.03
8.00E+04	1.33E+03	3.02E+03	4.28E+03	9.94E+00	0.00E+00	9.94E+00	1.072	9.28
1.00E+05	1.67E+03	3.38E+03	4.78E+03	1.11E+01	0.00E+00	1.11E+01	1.072	10.37



Soil Scan MDC For Ludlum 44-10 NaI Detector
100% Co-60 1.0 pCi/g Scan Rate 0.5 m/s d' 1.38
Detector end-cap 3.0" above Soil Surface @ Detector Centerline (10.16cm)

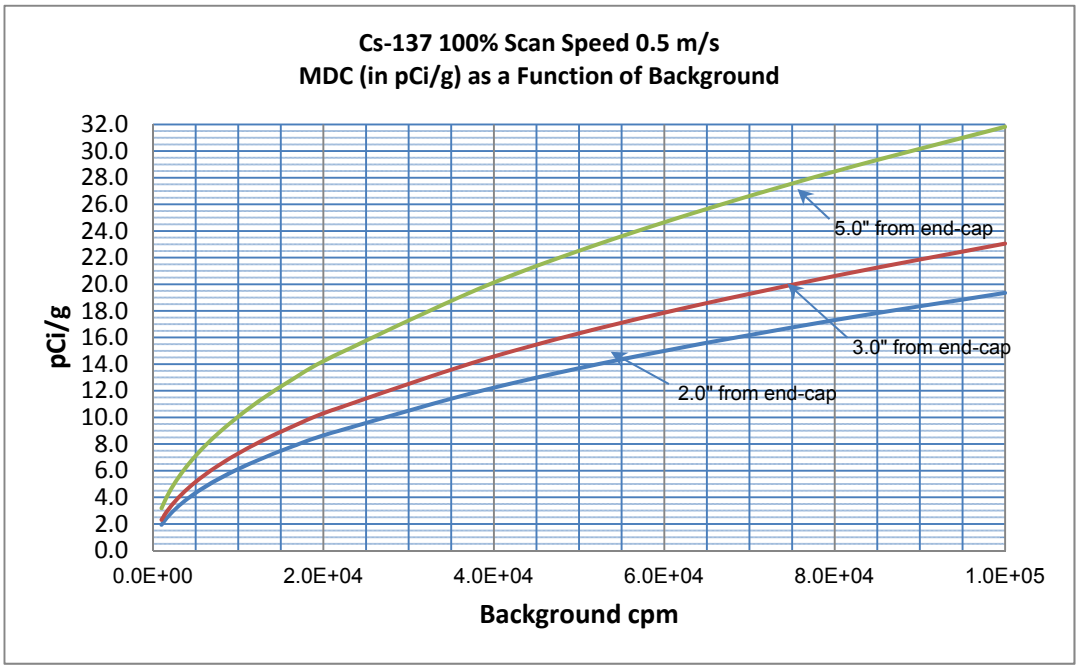
12/8/2011				Detectable Exp. Rate	Detec table Exp. Rate	Detectable	µR/h/pCi/g Microshield	
44-10 Bkg	Counts per 1.0		cpm/uR/h =>	430 Co-60	940 Cs-137	Exp. Rate	Results	Scan MDC
cpm	second MDCR		$MDCR_{surveyor}$	µR/h	µR/h Total	µR/h	@ 10.16 cm	pCi/g
1.00E+03	1.67E+01	3.38E+02	4.78E+02	1.11E+00	0.00E+00	1.11E+00	0.8975	1.2
2.00E+03	3.33E+01	4.78E+02	6.76E+02	1.57E+00	0.00E+00	1.57E+00	0.8975	1.75
4.00E+03	6.67E+01	6.76E+02	9.56E+02	2.22E+00	0.00E+00	2.22E+00	0.8975	2.48
6.00E+03	1.00E+02	8.28E+02	1.17E+03	2.72E+00	0.00E+00	2.72E+00	0.8975	3.03
8.00E+03	1.33E+02	9.56E+02	1.35E+03	3.14E+00	0.00E+00	3.14E+00	0.8975	3.50
1.00E+04	1.67E+02	1.07E+03	1.51E+03	3.52E+00	0.00E+00	3.52E+00	0.8975	3.92
1.20E+04	2.00E+02	1.17E+03	1.66E+03	3.85E+00	0.00E+00	3.85E+00	0.8975	4.29
1.40E+04	2.33E+02	1.26E+03	1.79E+03	4.16E+00	0.00E+00	4.16E+00	0.8975	4.63
1.80E+04	3.00E+02	1.43E+03	2.03E+03	4.72E+00	0.00E+00	4.72E+00	0.8975	5.26
2.00E+04	3.33E+02	1.51E+03	2.14E+03	4.97E+00	0.00E+00	4.97E+00	0.8975	5.54
4.00E+04	6.67E+02	2.14E+03	3.02E+03	7.03E+00	0.00E+00	7.03E+00	0.8975	7.83
6.00E+04	1.00E+03	2.62E+03	3.70E+03	8.61E+00	0.00E+00	8.61E+00	0.8975	9.59
8.00E+04	1.33E+03	3.02E+03	4.28E+03	9.94E+00	0.00E+00	9.94E+00	0.8975	11.08
1.00E+05	1.67E+03	3.38E+03	4.78E+03	1.11E+01	0.00E+00	1.11E+01	0.8975	12.39

Soil Scan MDC For Ludlum 44-10 NaI Detector
100% Co-60 1.0 pCi/g Scan Rate 0.5 m/s d' 1.38
Detector end-cap 5.0" above Soil Surface @ Detector Centerline (15.24cm)

12/8/2011				Detectable Exp. Rate	Detec table Exp. Rate	Detectable	µR/h/pCi/g Microshield	
44-10 Bkg	Counts per 1.0		cpm/uR/h =>	430 Co-60	940 Cs-137	Exp. Rate	Results	Scan MDC
cpm	second MDCR		$MDCR_{surveyor}$	µR/h	µR/h Total	µR/h	@ 15.24 cm	pCi/g
1.00E+03	1.67E+01	3.38E+02	4.78E+02	1.11E+00	0.00E+00	1.11E+00	0.6485	1.7
2.00E+03	3.33E+01	4.78E+02	6.76E+02	1.57E+00	0.00E+00	1.57E+00	0.6485	2.42
4.00E+03	6.67E+01	6.76E+02	9.56E+02	2.22E+00	0.00E+00	2.22E+00	0.6485	3.43
6.00E+03	1.00E+02	8.28E+02	1.17E+03	2.72E+00	0.00E+00	2.72E+00	0.6485	4.20
8.00E+03	1.33E+02	9.56E+02	1.35E+03	3.14E+00	0.00E+00	3.14E+00	0.6485	4.85
1.00E+04	1.67E+02	1.07E+03	1.51E+03	3.52E+00	0.00E+00	3.52E+00	0.6485	5.42
1.20E+04	2.00E+02	1.17E+03	1.66E+03	3.85E+00	0.00E+00	3.85E+00	0.6485	5.94
1.40E+04	2.33E+02	1.26E+03	1.79E+03	4.16E+00	0.00E+00	4.16E+00	0.6485	6.41
1.80E+04	3.00E+02	1.43E+03	2.03E+03	4.72E+00	0.00E+00	4.72E+00	0.6485	7.27
2.00E+04	3.33E+02	1.51E+03	2.14E+03	4.97E+00	0.00E+00	4.97E+00	0.6485	7.67
4.00E+04	6.67E+02	2.14E+03	3.02E+03	7.03E+00	0.00E+00	7.03E+00	0.6485	10.84
6.00E+04	1.00E+03	2.62E+03	3.70E+03	8.61E+00	0.00E+00	8.61E+00	0.6485	13.28
8.00E+04	1.33E+03	3.02E+03	4.28E+03	9.94E+00	0.00E+00	9.94E+00	0.6485	15.33
1.00E+05	1.67E+03	3.38E+03	4.78E+03	1.11E+01	0.00E+00	1.11E+01	0.6485	17.14

Soil Scan MDC For Ludlum 44-10 NaI Detector
100% Cs-137 1.0 pCi/g d' = 1.38 Scan Speed = 0.5 m/s
Detector end-cap 2.0" above Soil Surface @ Detector Centerline (7.62cm)
Area of interest = 50 cm dia.; d' = 1.38

12/8/2011 44-10 Bkg cpm	Counts per 1.0 second	MDCR	cpm/uR/h => $MDCR_{surveyor}$	Detectable Exp. Rate 430 Co-60 µR/h	Detectable Exp. Rate 940 Cs-137 µR/h Total	Detectable Exp. Rate µR/h	µR/h/pCi/g Microshield Results @ 7.62 cm	Scan MDC pCi/g
1.00E+03	1.67E+01	3.38E+02	4.78E+02	0.00E+00	5.09E-01	5.09E-01	0.2628	1.9
2.00E+03	3.33E+01	4.78E+02	6.76E+02	0.00E+00	7.19E-01	7.19E-01	0.2628	2.74
4.00E+03	6.67E+01	6.76E+02	9.56E+02	0.00E+00	1.02E+00	1.02E+00	0.2628	3.87
6.00E+03	1.00E+02	8.28E+02	1.17E+03	0.00E+00	1.25E+00	1.25E+00	0.2628	4.74
8.00E+03	1.33E+02	9.56E+02	1.35E+03	0.00E+00	1.44E+00	1.44E+00	0.2628	5.47
1.00E+04	1.67E+02	1.07E+03	1.51E+03	0.00E+00	1.61E+00	1.61E+00	0.2628	6.12
1.20E+04	2.00E+02	1.17E+03	1.66E+03	0.00E+00	1.76E+00	1.76E+00	0.2628	6.70
1.40E+04	2.33E+02	1.26E+03	1.79E+03	0.00E+00	1.90E+00	1.90E+00	0.2628	7.24
1.80E+04	3.00E+02	1.43E+03	2.03E+03	0.00E+00	2.16E+00	2.16E+00	0.2628	8.21
2.00E+04	3.33E+02	1.51E+03	2.14E+03	0.00E+00	2.27E+00	2.27E+00	0.2628	8.65
4.00E+04	6.67E+02	2.14E+03	3.02E+03	0.00E+00	3.22E+00	3.22E+00	0.2628	12.24
6.00E+04	1.00E+03	2.62E+03	3.70E+03	0.00E+00	3.94E+00	3.94E+00	0.2628	14.99
8.00E+04	1.33E+03	3.02E+03	4.28E+03	0.00E+00	4.55E+00	4.55E+00	0.2628	17.31
1.00E+05	1.67E+03	3.38E+03	4.78E+03	0.00E+00	5.09E+00	5.09E+00	0.2628	19.35



Soil Scan MDC For Ludlum 44-10 NaI Detector
100% Cs-137 1.0 pCi/g d' = 1.38 Scan Speed = 0.5 m/s
Detector end-cap 3.0" above Soil Surface @ Detector Centerline (10.16cm)

12/8/2011				Detectable Exp. Rate	Detec table Exp. Rate	Detectable	µR/h/pCi/g Microshield	
44-10 Bkg	Counts per 1.0 second		cpm/uR/h =>	430 Co-60	940 Cs-137	Exp. Rate	Results	Scan MDC
cpm	MDCR		$MDCR_{surveyor}$	µR/h	µR/h Total	µR/h	@ 10.16 cm	pCi/g
1.00E+03	1.67E+01	3.38E+02	4.78E+02	0.00E+00	5.09E-01	5.09E-01	0.2206	2.3
2.00E+03	3.33E+01	4.78E+02	6.76E+02	0.00E+00	7.19E-01	7.19E-01	0.2206	3.26
4.00E+03	6.67E+01	6.76E+02	9.56E+02	0.00E+00	1.02E+00	1.02E+00	0.2206	4.61
6.00E+03	1.00E+02	8.28E+02	1.17E+03	0.00E+00	1.25E+00	1.25E+00	0.2206	5.65
8.00E+03	1.33E+02	9.56E+02	1.35E+03	0.00E+00	1.44E+00	1.44E+00	0.2206	6.52
1.00E+04	1.67E+02	1.07E+03	1.51E+03	0.00E+00	1.61E+00	1.61E+00	0.2206	7.29
1.20E+04	2.00E+02	1.17E+03	1.66E+03	0.00E+00	1.76E+00	1.76E+00	0.2206	7.99
1.40E+04	2.33E+02	1.26E+03	1.79E+03	0.00E+00	1.90E+00	1.90E+00	0.2206	8.63
1.80E+04	3.00E+02	1.43E+03	2.03E+03	0.00E+00	2.16E+00	2.16E+00	0.2206	9.78
2.00E+04	3.33E+02	1.51E+03	2.14E+03	0.00E+00	2.27E+00	2.27E+00	0.2206	10.31
4.00E+04	6.67E+02	2.14E+03	3.02E+03	0.00E+00	3.22E+00	3.22E+00	0.2206	14.58
6.00E+04	1.00E+03	2.62E+03	3.70E+03	0.00E+00	3.94E+00	3.94E+00	0.2206	17.86
8.00E+04	1.33E+03	3.02E+03	4.28E+03	0.00E+00	4.55E+00	4.55E+00	0.2206	20.62
1.00E+05	1.67E+03	3.38E+03	4.78E+03	0.00E+00	5.09E+00	5.09E+00	0.2206	23.05

Soil Scan MDC For Ludlum 44-10 NaI Detector
100% Cs-137 1.0 pCi/g d' = 1.38 Scan Speed = 0.5 m/s
Detector end-cap 5.0" above Soil Surface @ Detector Centerline (15.24 cm)

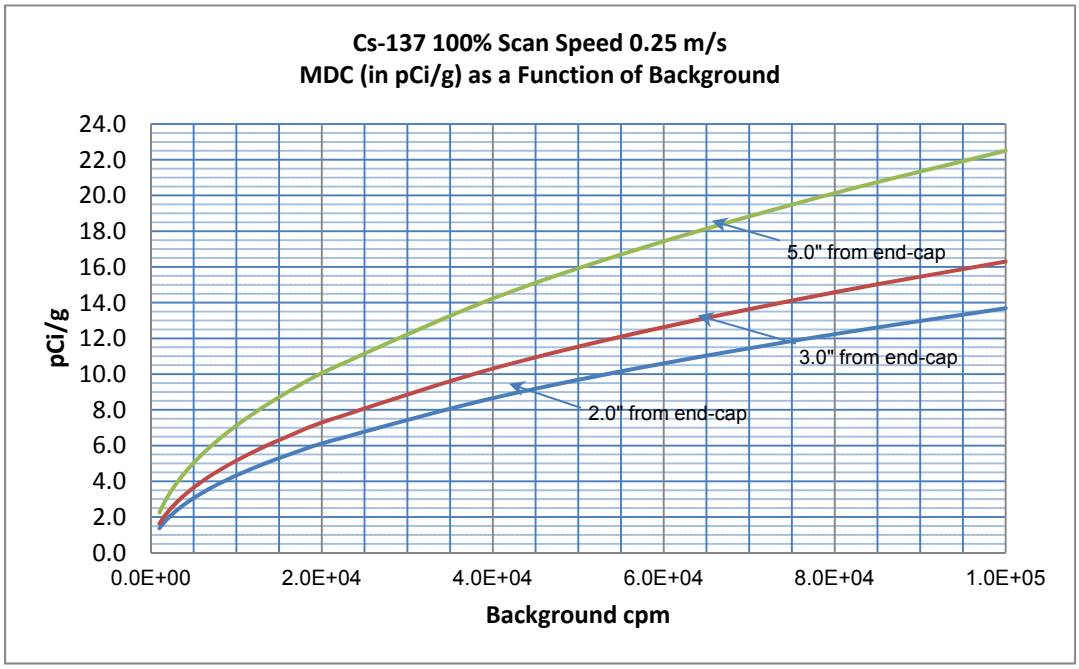
12/8/2011				Detectable Exp. Rate	Detec table Exp. Rate	Detectable	µR/h/pCi/g Microshield	
44-10 Bkg	Counts per 1.0 second		cpm/uR/h =>	430 Co-60	940 Cs-137	Exp. Rate	Results	Scan MDC
cpm	MDCR		$MDCR_{surveyor}$	µR/h	µR/h Total	µR/h	@ 15.24 cm	pCi/g
1.00E+03	1.67E+01	3.38E+02	4.78E+02	0.00E+00	5.09E-01	5.09E-01	0.1598	3.2
2.00E+03	3.33E+01	4.78E+02	6.76E+02	0.00E+00	7.19E-01	7.19E-01	0.1598	4.50
4.00E+03	6.67E+01	6.76E+02	9.56E+02	0.00E+00	1.02E+00	1.02E+00	0.1598	6.36
6.00E+03	1.00E+02	8.28E+02	1.17E+03	0.00E+00	1.25E+00	1.25E+00	0.1598	7.80
8.00E+03	1.33E+02	9.56E+02	1.35E+03	0.00E+00	1.44E+00	1.44E+00	0.1598	9.00
1.00E+04	1.67E+02	1.07E+03	1.51E+03	0.00E+00	1.61E+00	1.61E+00	0.1598	10.06
1.20E+04	2.00E+02	1.17E+03	1.66E+03	0.00E+00	1.76E+00	1.76E+00	0.1598	11.02
1.40E+04	2.33E+02	1.26E+03	1.79E+03	0.00E+00	1.90E+00	1.90E+00	0.1598	11.91
1.80E+04	3.00E+02	1.43E+03	2.03E+03	0.00E+00	2.16E+00	2.16E+00	0.1598	13.50
2.00E+04	3.33E+02	1.51E+03	2.14E+03	0.00E+00	2.27E+00	2.27E+00	0.1598	14.23
4.00E+04	6.67E+02	2.14E+03	3.02E+03	0.00E+00	3.22E+00	3.22E+00	0.1598	20.13
6.00E+04	1.00E+03	2.62E+03	3.70E+03	0.00E+00	3.94E+00	3.94E+00	0.1598	24.65
8.00E+04	1.33E+03	3.02E+03	4.28E+03	0.00E+00	4.55E+00	4.55E+00	0.1598	28.46
1.00E+05	1.67E+03	3.38E+03	4.78E+03	0.00E+00	5.09E+00	5.09E+00	0.1598	31.82

Soil Scan MDC For Ludlum 44-10 NaI Detector

100% Cs-137 1.0 pCi/g Scan Rate = 0.25 m/s d' = 1.38

Detector end-cap 2.0" above Soil Surface @ Detector Centerline (7.62 cm)

12/8/2011 44-10 Bkg cpm	Counts per 0.5 second	MDCR	cpm/uR/h => $MDCR_{surveyor}$	Detectable Exp. Rate 430 Co-60 µR/h	Detectable Exp. Rate 940 Cs-137 µR/h Total	Detectable Exp. Rate µR/h	µR/h/pCi/g Microshield Results @ 7.62 cm	Scan MDC pCi/g
1.00E+03	8.33E+00	2.39E+02	3.38E+02	0.00E+00	3.60E-01	3.60E-01	0.2628	1.4
2.00E+03	1.67E+01	3.38E+02	4.78E+02	0.00E+00	5.09E-01	5.09E-01	0.2628	1.94
4.00E+03	3.33E+01	4.78E+02	6.76E+02	0.00E+00	7.19E-01	7.19E-01	0.2628	2.74
6.00E+03	5.00E+01	5.85E+02	8.28E+02	0.00E+00	8.81E-01	8.81E-01	0.2628	3.35
8.00E+03	6.67E+01	6.76E+02	9.56E+02	0.00E+00	1.02E+00	1.02E+00	0.2628	3.87
1.00E+04	8.33E+01	7.56E+02	1.07E+03	0.00E+00	1.14E+00	1.14E+00	0.2628	4.33
1.20E+04	1.00E+02	8.28E+02	1.17E+03	0.00E+00	1.25E+00	1.25E+00	0.2628	4.74
1.40E+04	1.17E+02	8.94E+02	1.26E+03	0.00E+00	1.35E+00	1.35E+00	0.2628	5.12
1.80E+04	1.50E+02	1.01E+03	1.43E+03	0.00E+00	1.53E+00	1.53E+00	0.2628	5.81
2.00E+04	1.67E+02	1.07E+03	1.51E+03	0.00E+00	1.61E+00	1.61E+00	0.2628	6.12
4.00E+04	3.33E+02	1.51E+03	2.14E+03	0.00E+00	2.27E+00	2.27E+00	0.2628	8.65
6.00E+04	5.00E+02	1.85E+03	2.62E+03	0.00E+00	2.79E+00	2.79E+00	0.2628	10.60
8.00E+04	6.67E+02	2.14E+03	3.02E+03	0.00E+00	3.22E+00	3.22E+00	0.2628	12.24
1.00E+05	8.33E+02	2.39E+03	3.38E+03	0.00E+00	3.60E+00	3.60E+00	0.2628	13.68



Soil Scan MDC For Ludlum 44-10 NaI Detector
100% Cs-137 1.0 pCi/g Scan Rate = 0.25 m/s d' = 1.38
Detector end-cap 3.0" above Soil Surface @ Detector Centerline (10.16cm)

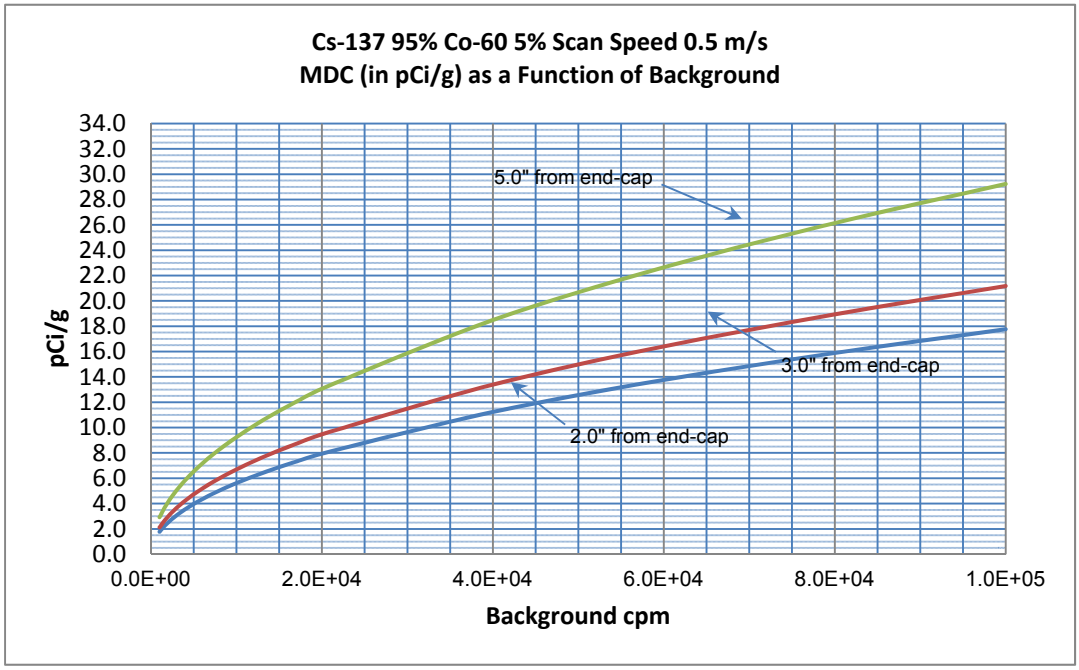
12/8/2011				Detectable Exp. Rate	Detec table Exp. Rate		µR/h/pCi/g Microshield	
44-10 Bkg	Counts per 0.5		cpm/uR/h =>	430 Co-60	940 Cs-137	Exp. Rate	Results	Scan MDC
cpm	second MDCR		$MDCR_{surveyor}$	µR/h	µR/h Total	µR/h	@ 10.16 cm	pCi/g
1.00E+03	8.33E+00	2.39E+02	3.38E+02	0.00E+00	3.60E-01	3.60E-01	0.2206	1.6
2.00E+03	1.67E+01	3.38E+02	4.78E+02	0.00E+00	5.09E-01	5.09E-01	0.2206	2.31
4.00E+03	3.33E+01	4.78E+02	6.76E+02	0.00E+00	7.19E-01	7.19E-01	0.2206	3.26
6.00E+03	5.00E+01	5.85E+02	8.28E+02	0.00E+00	8.81E-01	8.81E-01	0.2206	3.99
8.00E+03	6.67E+01	6.76E+02	9.56E+02	0.00E+00	1.02E+00	1.02E+00	0.2206	4.61
1.00E+04	8.33E+01	7.56E+02	1.07E+03	0.00E+00	1.14E+00	1.14E+00	0.2206	5.15
1.20E+04	1.00E+02	8.28E+02	1.17E+03	0.00E+00	1.25E+00	1.25E+00	0.2206	5.65
1.40E+04	1.17E+02	8.94E+02	1.26E+03	0.00E+00	1.35E+00	1.35E+00	0.2206	6.10
1.80E+04	1.50E+02	1.01E+03	1.43E+03	0.00E+00	1.53E+00	1.53E+00	0.2206	6.92
2.00E+04	1.67E+02	1.07E+03	1.51E+03	0.00E+00	1.61E+00	1.61E+00	0.2206	7.29
4.00E+04	3.33E+02	1.51E+03	2.14E+03	0.00E+00	2.27E+00	2.27E+00	0.2206	10.31
6.00E+04	5.00E+02	1.85E+03	2.62E+03	0.00E+00	2.79E+00	2.79E+00	0.2206	12.63
8.00E+04	6.67E+02	2.14E+03	3.02E+03	0.00E+00	3.22E+00	3.22E+00	0.2206	14.58
1.00E+05	8.33E+02	2.39E+03	3.38E+03	0.00E+00	3.60E+00	3.60E+00	0.2206	16.30

Soil Scan MDC For Ludlum 44-10 NaI Detector
100% Cs-137 1.0 pCi/g Scan Rate = 0.25 m/s d' = 1.38
Detector end-cap 5.0" above Soil Surface @ Detector Centerline (12.7cm)

12/8/2011				Detectable Exp. Rate	Detec table Exp. Rate		µR/h/pCi/g Microshield	
44-10 Bkg	Counts per 0.5		cpm/uR/h =>	430 Co-60	940 Cs-137	Exp. Rate	Results	Scan MDC
cpm	second MDCR		$MDCR_{surveyor}$	µR/h	µR/h Total	µR/h	@ 15.24 cm	pCi/g
1.00E+03	8.33E+00	2.39E+02	3.38E+02	0.00E+00	3.60E-01	3.60E-01	0.1598	2.3
2.00E+03	1.67E+01	3.38E+02	4.78E+02	0.00E+00	5.09E-01	5.09E-01	0.1598	3.18
4.00E+03	3.33E+01	4.78E+02	6.76E+02	0.00E+00	7.19E-01	7.19E-01	0.1598	4.50
6.00E+03	5.00E+01	5.85E+02	8.28E+02	0.00E+00	8.81E-01	8.81E-01	0.1598	5.51
8.00E+03	6.67E+01	6.76E+02	9.56E+02	0.00E+00	1.02E+00	1.02E+00	0.1598	6.36
1.00E+04	8.33E+01	7.56E+02	1.07E+03	0.00E+00	1.14E+00	1.14E+00	0.1598	7.12
1.20E+04	1.00E+02	8.28E+02	1.17E+03	0.00E+00	1.25E+00	1.25E+00	0.1598	7.80
1.40E+04	1.17E+02	8.94E+02	1.26E+03	0.00E+00	1.35E+00	1.35E+00	0.1598	8.42
1.80E+04	1.50E+02	1.01E+03	1.43E+03	0.00E+00	1.53E+00	1.53E+00	0.1598	9.55
2.00E+04	1.67E+02	1.07E+03	1.51E+03	0.00E+00	1.61E+00	1.61E+00	0.1598	10.06
4.00E+04	3.33E+02	1.51E+03	2.14E+03	0.00E+00	2.27E+00	2.27E+00	0.1598	14.23
6.00E+04	5.00E+02	1.85E+03	2.62E+03	0.00E+00	2.79E+00	2.79E+00	0.1598	17.43
8.00E+04	6.67E+02	2.14E+03	3.02E+03	0.00E+00	3.22E+00	3.22E+00	0.1598	20.13
1.00E+05	8.33E+02	2.39E+03	3.38E+03	0.00E+00	3.60E+00	3.60E+00	0.1598	22.50

Soil Scan MDC For Ludlum 44-10 NaI Detector
95% Cs-137, 5% Co-60 1.0 pCi/g d' =1.38 Scan Speed 0.5 m/s
Detector end-cap 2.0" above Soil Surface @ Detector Centerline (7.62 cm)

12/8/2011 44-10 Bkg cpm	Counts per 1.0 second	MDCR	cpm/uR/h => MDCR$_{surveyor}$	Detectable Exp. Rate 430 Co-60 µR/h	Detectable Exp. Rate 940 Cs-137 µR/h Total	Detectable Exp. Rate µR/h	µR/h/pCi/g Microshield Results @ 7.62 cm	Scan MDC pCi/g
1.00E+03	1.67E+01	3.38E+02	4.78E+02	5.56E-02	4.83E-01	5.39E-01	0.3033	1.8
2.00E+03	3.33E+01	4.78E+02	6.76E+02	7.86E-02	6.83E-01	7.62E-01	0.3033	2.51
4.00E+03	6.67E+01	6.76E+02	9.56E+02	1.11E-01	9.66E-01	1.08E+00	0.3033	3.55
6.00E+03	1.00E+02	8.28E+02	1.17E+03	1.36E-01	1.18E+00	1.32E+00	0.3033	4.35
8.00E+03	1.33E+02	9.56E+02	1.35E+03	1.57E-01	1.37E+00	1.52E+00	0.3033	5.02
1.00E+04	1.67E+02	1.07E+03	1.51E+03	1.76E-01	1.53E+00	1.70E+00	0.3033	5.62
1.20E+04	2.00E+02	1.17E+03	1.66E+03	1.93E-01	1.67E+00	1.87E+00	0.3033	6.15
1.40E+04	2.33E+02	1.26E+03	1.79E+03	2.08E-01	1.81E+00	2.02E+00	0.3033	6.65
1.80E+04	3.00E+02	1.43E+03	2.03E+03	2.36E-01	2.05E+00	2.29E+00	0.3033	7.54
2.00E+04	3.33E+02	1.51E+03	2.14E+03	2.49E-01	2.16E+00	2.41E+00	0.3033	7.94
4.00E+04	6.67E+02	2.14E+03	3.02E+03	3.52E-01	3.06E+00	3.41E+00	0.3033	11.23
6.00E+04	1.00E+03	2.62E+03	3.70E+03	4.31E-01	3.74E+00	4.17E+00	0.3033	13.76
8.00E+04	1.33E+03	3.02E+03	4.28E+03	4.97E-01	4.32E+00	4.82E+00	0.3033	15.89
1.00E+05	1.67E+03	3.38E+03	4.78E+03	5.56E-01	4.83E+00	5.39E+00	0.3033	17.76



Soil Scan MDC For Ludlum 44-10 NaI Detector
95% Cs-137, 5% Co-60 1.0 pCi/g d' =1.38 Scan Speed 0.5 m/s
Detector end-cap 3.0" above Soil Surface @ Detector Centerline (10.16 cm)

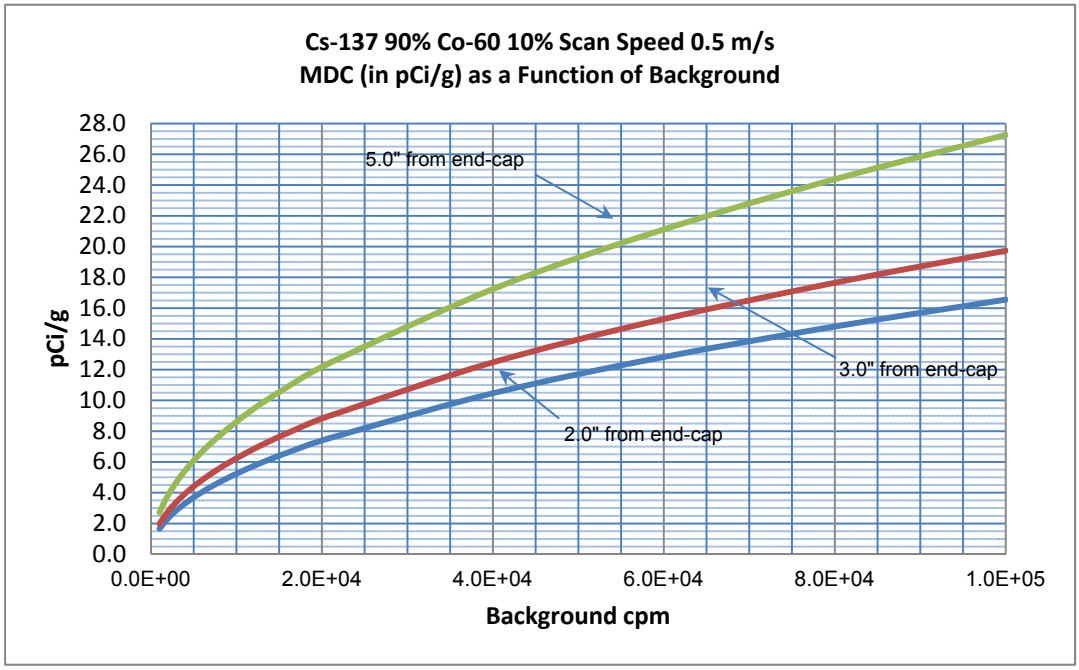
12/8/2011				Detectable Exp. Rate	Detec table Exp. Rate	Detectable	µR/h/pCi/g Microshield	
44-10 Bkg	Counts per 1.0 second		cpm/uR/h =>	430 Co-60	940 Cs-137	Exp. Rate	Results	Scan MDC
cpm	MDCR		$MDCR_{surveyor}$	µR/h	µR/h Total	µR/h	@10.16 cm	pCi/g
1.00E+03	1.67E+01	3.38E+02	4.78E+02	5.56E-02	4.83E-01	5.39E-01	0.2544	2.1
2.00E+03	3.33E+01	4.78E+02	6.76E+02	7.86E-02	6.83E-01	7.62E-01	0.2544	2.99
4.00E+03	6.67E+01	6.76E+02	9.56E+02	1.11E-01	9.66E-01	1.08E+00	0.2544	4.24
6.00E+03	1.00E+02	8.28E+02	1.17E+03	1.36E-01	1.18E+00	1.32E+00	0.2544	5.19
8.00E+03	1.33E+02	9.56E+02	1.35E+03	1.57E-01	1.37E+00	1.52E+00	0.2544	5.99
1.00E+04	1.67E+02	1.07E+03	1.51E+03	1.76E-01	1.53E+00	1.70E+00	0.2544	6.70
1.20E+04	2.00E+02	1.17E+03	1.66E+03	1.93E-01	1.67E+00	1.87E+00	0.2544	7.34
1.40E+04	2.33E+02	1.26E+03	1.79E+03	2.08E-01	1.81E+00	2.02E+00	0.2544	7.92
1.80E+04	3.00E+02	1.43E+03	2.03E+03	2.36E-01	2.05E+00	2.29E+00	0.2544	8.98
2.00E+04	3.33E+02	1.51E+03	2.14E+03	2.49E-01	2.16E+00	2.41E+00	0.2544	9.47
4.00E+04	6.67E+02	2.14E+03	3.02E+03	3.52E-01	3.06E+00	3.41E+00	0.2544	13.39
6.00E+04	1.00E+03	2.62E+03	3.70E+03	4.31E-01	3.74E+00	4.17E+00	0.2544	16.40
8.00E+04	1.33E+03	3.02E+03	4.28E+03	4.97E-01	4.32E+00	4.82E+00	0.2544	18.94
1.00E+05	1.67E+03	3.38E+03	4.78E+03	5.56E-01	4.83E+00	5.39E+00	0.2544	21.18

Soil Scan MDC For Ludlum 44-10 NaI Detector
95% Cs-137, 5% Co-60 1.0 pCi/g d' =1.38 Scan Speed 0.5 m/s
Detector end-cap 5.0" above Soil Surface @ Detector Centerline (15.24 cm)

12/8/2011				Detectable Exp. Rate	Detec table Exp. Rate	Detectable	µR/h/pCi/g Microshield	
44-10 Bkg	Counts per 1.0 second		cpm/uR/h =>	430 Co-60	940 Cs-137	Exp. Rate	Results	Scan MDC
cpm	MDCR		$MDCR_{surveyor}$	µR/h	µR/h Total	µR/h	@ 15.24 cm	pCi/g
1.00E+03	1.67E+01	3.38E+02	4.78E+02	5.56E-02	4.83E-01	5.39E-01	0.1843	2.9
2.00E+03	3.33E+01	4.78E+02	6.76E+02	7.86E-02	6.83E-01	7.62E-01	0.1843	4.13
4.00E+03	6.67E+01	6.76E+02	9.56E+02	1.11E-01	9.66E-01	1.08E+00	0.1843	5.85
6.00E+03	1.00E+02	8.28E+02	1.17E+03	1.36E-01	1.18E+00	1.32E+00	0.1843	7.16
8.00E+03	1.33E+02	9.56E+02	1.35E+03	1.57E-01	1.37E+00	1.52E+00	0.1843	8.27
1.00E+04	1.67E+02	1.07E+03	1.51E+03	1.76E-01	1.53E+00	1.70E+00	0.1843	9.24
1.20E+04	2.00E+02	1.17E+03	1.66E+03	1.93E-01	1.67E+00	1.87E+00	0.1843	10.13
1.40E+04	2.33E+02	1.26E+03	1.79E+03	2.08E-01	1.81E+00	2.02E+00	0.1843	10.94
1.80E+04	3.00E+02	1.43E+03	2.03E+03	2.36E-01	2.05E+00	2.29E+00	0.1843	12.40
2.00E+04	3.33E+02	1.51E+03	2.14E+03	2.49E-01	2.16E+00	2.41E+00	0.1843	13.07
4.00E+04	6.67E+02	2.14E+03	3.02E+03	3.52E-01	3.06E+00	3.41E+00	0.1843	18.49
6.00E+04	1.00E+03	2.62E+03	3.70E+03	4.31E-01	3.74E+00	4.17E+00	0.1843	22.64
8.00E+04	1.33E+03	3.02E+03	4.28E+03	4.97E-01	4.32E+00	4.82E+00	0.1843	26.14
1.00E+05	1.67E+03	3.38E+03	4.78E+03	5.56E-01	4.83E+00	5.39E+00	0.1843	29.23

Soil Scan MDC For Ludlum 44-10 NaI Detector
90% Cs-137, 10% Co-60 1.0 pCi/g d' = 1.38 Scan Speed 0.5 m/s
Detector end-cap 2.0" above Soil Surface @ Detector Centerline (7.62 cm)

12/8/2011 44-10 Bkg cpm	Counts per 1.0 second	MDCR	cpm/uR/h => MDCR$_{surveyor}$	Detectable Exp. Rate 430 Co-60 µR/h	Detec table Exp. Rate 940 Cs-137 µR/h Total	Detectable Exp. Rate µR/h	µR/h/pCi/g Microshield Results @ 7.62 cm	Scan MDC pCi/g
1.00E+03	1.67E+01	3.38E+02	4.78E+02	1.11E-01	4.58E-01	5.69E-01	0.3437	1.7
2.00E+03	3.33E+01	4.78E+02	6.76E+02	1.57E-01	6.47E-01	8.05E-01	0.3437	2.34
4.00E+03	6.67E+01	6.76E+02	9.56E+02	2.22E-01	9.15E-01	1.14E+00	0.3437	3.31
6.00E+03	1.00E+02	8.28E+02	1.17E+03	2.72E-01	1.12E+00	1.39E+00	0.3437	4.05
8.00E+03	1.33E+02	9.56E+02	1.35E+03	3.14E-01	1.29E+00	1.61E+00	0.3437	4.68
1.00E+04	1.67E+02	1.07E+03	1.51E+03	3.52E-01	1.45E+00	1.80E+00	0.3437	5.23
1.20E+04	2.00E+02	1.17E+03	1.66E+03	3.85E-01	1.59E+00	1.97E+00	0.3437	5.73
1.40E+04	2.33E+02	1.26E+03	1.79E+03	4.16E-01	1.71E+00	2.13E+00	0.3437	6.19
1.80E+04	3.00E+02	1.43E+03	2.03E+03	4.72E-01	1.94E+00	2.41E+00	0.3437	7.02
2.00E+04	3.33E+02	1.51E+03	2.14E+03	4.97E-01	2.05E+00	2.54E+00	0.3437	7.40
4.00E+04	6.67E+02	2.14E+03	3.02E+03	7.03E-01	2.89E+00	3.60E+00	0.3437	10.47
6.00E+04	1.00E+03	2.62E+03	3.70E+03	8.61E-01	3.55E+00	4.41E+00	0.3437	12.82
8.00E+04	1.33E+03	3.02E+03	4.28E+03	9.94E-01	4.09E+00	5.09E+00	0.3437	14.80
1.00E+05	1.67E+03	3.38E+03	4.78E+03	1.11E+00	4.58E+00	5.69E+00	0.3437	16.55



Soil Scan MDC For Ludlum 44-10 NaI Detector
90% Cs-137, 10% Co-60 1.0 pCi/g d' = 1.38 Scan Speed 0.5 m/s
Detector end-cap 3.0" above Soil Surface @ Detector Centerline (10.16 cm)

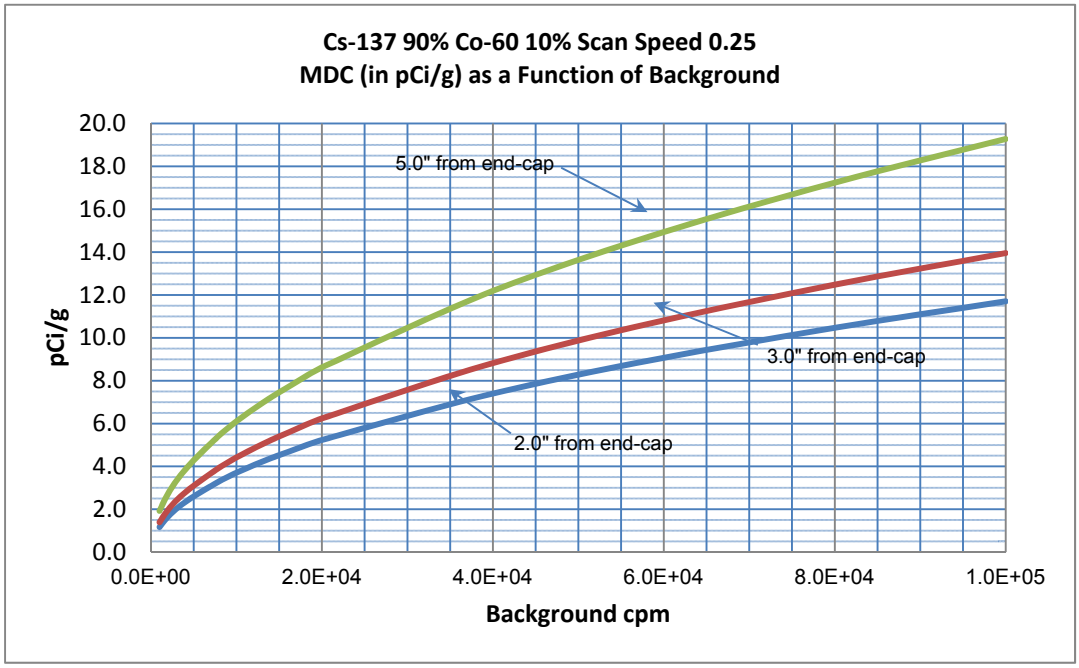
12/8/2011				Detectable Exp. Rate	Detec table Exp. Rate	Detectable	µR/h/pCi/g Microshield	
44-10 Bkg	Counts per 1.0 second		cpm/uR/h =>	430 Co-60	940 Cs-137	Exp. Rate	Results	Scan MDC
cpm	MDCR		$MDCR_{surveyor}$	µR/h	µR/h Total	µR/h	@ 10.16 cm	pCi/g
1.00E+03	1.67E+01	3.38E+02	4.78E+02	1.11E-01	4.58E-01	5.69E-01	0.2883	2.0
2.00E+03	3.33E+01	4.78E+02	6.76E+02	1.57E-01	6.47E-01	8.05E-01	0.2883	2.79
4.00E+03	6.67E+01	6.76E+02	9.56E+02	2.22E-01	9.15E-01	1.14E+00	0.2883	3.95
6.00E+03	1.00E+02	8.28E+02	1.17E+03	2.72E-01	1.12E+00	1.39E+00	0.2883	4.83
8.00E+03	1.33E+02	9.56E+02	1.35E+03	3.14E-01	1.29E+00	1.61E+00	0.2883	5.58
1.00E+04	1.67E+02	1.07E+03	1.51E+03	3.52E-01	1.45E+00	1.80E+00	0.2883	6.24
1.20E+04	2.00E+02	1.17E+03	1.66E+03	3.85E-01	1.59E+00	1.97E+00	0.2883	6.84
1.40E+04	2.33E+02	1.26E+03	1.79E+03	4.16E-01	1.71E+00	2.13E+00	0.2883	7.38
1.80E+04	3.00E+02	1.43E+03	2.03E+03	4.72E-01	1.94E+00	2.41E+00	0.2883	8.37
2.00E+04	3.33E+02	1.51E+03	2.14E+03	4.97E-01	2.05E+00	2.54E+00	0.2883	8.82
4.00E+04	6.67E+02	2.14E+03	3.02E+03	7.03E-01	2.89E+00	3.60E+00	0.2883	12.48
6.00E+04	1.00E+03	2.62E+03	3.70E+03	8.61E-01	3.55E+00	4.41E+00	0.2883	15.28
8.00E+04	1.33E+03	3.02E+03	4.28E+03	9.94E-01	4.09E+00	5.09E+00	0.2883	17.65
1.00E+05	1.67E+03	3.38E+03	4.78E+03	1.11E+00	4.58E+00	5.69E+00	0.2883	19.73

Soil Scan MDC For Ludlum 44-10 NaI Detector
90% Cs-137, 10% Co-60 1.0 pCi/g d' = 1.38 Scan Speed 0.5 m/s
Detector end-cap 5.0" above Soil Surface @ Detector Centerline (15.24cm)

12/8/2011				Detectable Exp. Rate	Detec table Exp. Rate	Detectable	µR/h/pCi/g Microshield	
44-10 Bkg	Counts per 1.0 second		cpm/uR/h =>	430 Co-60	940 Cs-137	Exp. Rate	Results	Scan MDC
cpm	MDCR		$MDCR_{surveyor}$	µR/h	µR/h Total	µR/h	@ 15.24 cm	pCi/g
1.00E+03	1.67E+01	3.38E+02	4.78E+02	1.11E-01	4.58E-01	5.69E-01	0.2087	2.7
2.00E+03	3.33E+01	4.78E+02	6.76E+02	1.57E-01	6.47E-01	8.05E-01	0.2087	3.85
4.00E+03	6.67E+01	6.76E+02	9.56E+02	2.22E-01	9.15E-01	1.14E+00	0.2087	5.45
6.00E+03	1.00E+02	8.28E+02	1.17E+03	2.72E-01	1.12E+00	1.39E+00	0.2087	6.68
8.00E+03	1.33E+02	9.56E+02	1.35E+03	3.14E-01	1.29E+00	1.61E+00	0.2087	7.71
1.00E+04	1.67E+02	1.07E+03	1.51E+03	3.52E-01	1.45E+00	1.80E+00	0.2087	8.62
1.20E+04	2.00E+02	1.17E+03	1.66E+03	3.85E-01	1.59E+00	1.97E+00	0.2087	9.44
1.40E+04	2.33E+02	1.26E+03	1.79E+03	4.16E-01	1.71E+00	2.13E+00	0.2087	10.20
1.80E+04	3.00E+02	1.43E+03	2.03E+03	4.72E-01	1.94E+00	2.41E+00	0.2087	11.56
2.00E+04	3.33E+02	1.51E+03	2.14E+03	4.97E-01	2.05E+00	2.54E+00	0.2087	12.19
4.00E+04	6.67E+02	2.14E+03	3.02E+03	7.03E-01	2.89E+00	3.60E+00	0.2087	17.24
6.00E+04	1.00E+03	2.62E+03	3.70E+03	8.61E-01	3.55E+00	4.41E+00	0.2087	21.11
8.00E+04	1.33E+03	3.02E+03	4.28E+03	9.94E-01	4.09E+00	5.09E+00	0.2087	24.38
1.00E+05	1.67E+03	3.38E+03	4.78E+03	1.11E+00	4.58E+00	5.69E+00	0.2087	27.26

Soil Scan MDC For Ludlum 44-10 NaI Detector
90% Cs-137, 10% Co-60 1.0 pCi/g d' = 1.38 Scan Speed 0.25 m/s
Detector end-cap 2.0" above Soil Surface @ Detector Centerline (7.62 cm)

12/8/2011				Detectable Exp. Rate	Detec table Exp. Rate		µR/h/pCi/g Microshield	
44-10 Bkg	**Counts per 0.5**		**cpm/uR/h =>**	430	940	**Detectable Exp. Rate**	**Results**	**Scan MDC**
cpm	**second MDCR**		**$MDCR_{surveyor}$**	**Co-60 µR/h**	**Cs-137 µR/h Total**	**µR/h**	**@ 7.62 cm**	**pCi/g**
1.00E+03	8.33E+00	2.39E+02	3.38E+02	7.86E-02	3.24E-01	4.02E-01	0.3437	1.2
2.00E+03	1.67E+01	3.38E+02	4.78E+02	1.11E-01	4.58E-01	5.69E-01	0.3437	1.66
4.00E+03	3.33E+01	4.78E+02	6.76E+02	1.57E-01	6.47E-01	8.05E-01	0.3437	2.34
8.00E+03	6.67E+01	6.76E+02	9.56E+02	2.22E-01	9.15E-01	1.14E+00	0.3437	3.31
1.00E+04	8.33E+01	7.56E+02	1.07E+03	2.49E-01	1.02E+00	1.27E+00	0.3437	3.70
1.20E+04	1.00E+02	8.28E+02	1.17E+03	2.72E-01	1.12E+00	1.39E+00	0.3437	4.05
1.40E+04	1.17E+02	8.94E+02	1.26E+03	2.94E-01	1.21E+00	1.51E+00	0.3437	4.38
1.80E+04	1.50E+02	1.01E+03	1.43E+03	3.34E-01	1.37E+00	1.71E+00	0.3437	4.97
2.00E+04	1.67E+02	1.07E+03	1.51E+03	3.52E-01	1.45E+00	1.80E+00	0.3437	5.23
4.00E+04	3.33E+02	1.51E+03	2.14E+03	4.97E-01	2.05E+00	2.54E+00	0.3437	7.40
6.00E+04	5.00E+02	1.85E+03	2.62E+03	6.09E-01	2.51E+00	3.12E+00	0.3437	9.07
8.00E+04	6.67E+02	2.14E+03	3.02E+03	7.03E-01	2.89E+00	3.60E+00	0.3437	10.47
1.00E+05	8.33E+02	2.39E+03	3.38E+03	7.86E-01	3.24E+00	4.02E+00	0.3437	11.70



Soil Scan MDC For Ludlum 44-10 NaI Detector
90% Cs-137, 10% Co-60 1.0 pCi/g d' = 1.38 Scan Speed 0.25 m/s
Detector end-cap 3.0" above Soil Surface @ Detector Centerline (10.16 cm)

12/8/2011				Detectable Detec	table		µR/h/pCi/g	
				Exp. Rate	Exp. Rate	Detectable	Microshield	
44-10 Bkg	Counts per		cpm/uR/h =>	430	940	Exp. Rate	Results	Scan MDC
	0.5			Co-60	Cs-137			
cpm	second MDCR		$MDCR_{surveyor}$	µR/h	µR/h Total	µR/h	@ 10.16 cm	pCi/g
1.00E+03	8.33E+00	2.39E+02	3.38E+02	7.86E-02	3.24E-01	4.02E-01	0.2883	1.4
2.00E+03	1.67E+01	3.38E+02	4.78E+02	1.11E-01	4.58E-01	5.69E-01	0.2883	1.97
4.00E+03	3.33E+01	4.78E+02	6.76E+02	1.57E-01	6.47E-01	8.05E-01	0.2883	2.79
8.00E+03	6.67E+01	6.76E+02	9.56E+02	2.22E-01	9.15E-01	1.14E+00	0.2883	3.95
1.00E+04	8.33E+01	7.56E+02	1.07E+03	2.49E-01	1.02E+00	1.27E+00	0.2883	4.41
1.20E+04	1.00E+02	8.28E+02	1.17E+03	2.72E-01	1.12E+00	1.39E+00	0.2883	4.83
1.40E+04	1.17E+02	8.94E+02	1.26E+03	2.94E-01	1.21E+00	1.51E+00	0.2883	5.22
1.80E+04	1.50E+02	1.01E+03	1.43E+03	3.34E-01	1.37E+00	1.71E+00	0.2883	5.92
2.00E+04	1.67E+02	1.07E+03	1.51E+03	3.52E-01	1.45E+00	1.80E+00	0.2883	6.24
4.00E+04	3.33E+02	1.51E+03	2.14E+03	4.97E-01	2.05E+00	2.54E+00	0.2883	8.82
6.00E+04	5.00E+02	1.85E+03	2.62E+03	6.09E-01	2.51E+00	3.12E+00	0.2883	10.81
8.00E+04	6.67E+02	2.14E+03	3.02E+03	7.03E-01	2.89E+00	3.60E+00	0.2883	12.48
1.00E+05	8.33E+02	2.39E+03	3.38E+03	7.86E-01	3.24E+00	4.02E+00	0.2883	13.95

Soil Scan MDC For Ludlum 44-10 NaI Detector
90% Cs-137, 10% Co-60 1.0 pCi/g d' = 1.38
Detector end-cap 5.0" above Soil Surface @ Detector Centerline (15.24 cm) Scan Speed 0.25 m/s

12/8/2011				Detectable Detec	table		µR/h/pCi/g	
				Exp. Rate	Exp. Rate	Detectable	Microshield	
44-10 Bkg	Counts per		cpm/uR/h =>	430	940	Exp. Rate	Results	Scan MDC
	0.5			Co-60	Cs-137			
cpm	second MDCR		$MDCR_{surveyor}$	µR/h	µR/h Total	µR/h	@ 15.24 cm	pCi/g
1.00E+03	8.33E+00	2.39E+02	3.38E+02	7.86E-02	3.24E-01	4.02E-01	0.2087	1.9
2.00E+03	1.67E+01	3.38E+02	4.78E+02	1.11E-01	4.58E-01	5.69E-01	0.2087	2.73
4.00E+03	3.33E+01	4.78E+02	6.76E+02	1.57E-01	6.47E-01	8.05E-01	0.2087	3.85
8.00E+03	6.67E+01	6.76E+02	9.56E+02	2.22E-01	9.15E-01	1.14E+00	0.2087	5.45
1.00E+04	8.33E+01	7.56E+02	1.07E+03	2.49E-01	1.02E+00	1.27E+00	0.2087	6.10
1.20E+04	1.00E+02	8.28E+02	1.17E+03	2.72E-01	1.12E+00	1.39E+00	0.2087	6.68
1.40E+04	1.17E+02	8.94E+02	1.26E+03	2.94E-01	1.21E+00	1.51E+00	0.2087	7.21
1.80E+04	1.50E+02	1.01E+03	1.43E+03	3.34E-01	1.37E+00	1.71E+00	0.2087	8.18
2.00E+04	1.67E+02	1.07E+03	1.51E+03	3.52E-01	1.45E+00	1.80E+00	0.2087	8.62
4.00E+04	3.33E+02	1.51E+03	2.14E+03	4.97E-01	2.05E+00	2.54E+00	0.2087	12.19
6.00E+04	5.00E+02	1.85E+03	2.62E+03	6.09E-01	2.51E+00	3.12E+00	0.2087	14.93
8.00E+04	6.67E+02	2.14E+03	3.02E+03	7.03E-01	2.89E+00	3.60E+00	0.2087	17.24
1.00E+05	8.33E+02	2.39E+03	3.38E+03	7.86E-01	3.24E+00	4.02E+00	0.2087	19.27

The NaI scan MDC utilizes the same formulas and approach as that found in NUREG -1507, Section 6.8.2 and NUREG-1575, Section 6.7 for open land areas. The following formula parameters are provided:

Scan speed:	0.25 and 0.5 m/s
Area of Interest:	50 cm diameter (0.196 m^2) results in a scan width of 0.5 m
Soil Depth:	6.0 inches (15.24 cm)
Soil Density: 1.6	g/cm^3
Soil Composition:	Sand (SiO_2 Si = 46.74%, O = 53.26%)
Background Count Rate:	6.0E+03 cpm
Surveyor Efficiency:	0.5
Detector Response (Co-60):	430 cpm/μR/h (See Table 1.0 and Attachment 8.1)
Detector Response (Cs-137):	940 cpm/μR/h (See Table 1.0 and Attachment 8.1)
Index of Sensitivity (d'):	1.38
MDCR:	Minimum Detectable Count Rate (cpm)
MicroShield μR/h/pCi/g:	For varying distances and radionuclide mix (See Table below)

MicroShield™ μR/h/pCi/g Values

Detector Distance to end cap Inches (cm)	Nuclide Fraction Cs-137 95% Co-60 5%	Nuclide Fraction Cs-137 90% Co-60 10%	Nuclide Fraction Cs-137 100%	Nuclide Fraction Co-60 100%
2.0 (5.08)	0.3033	0.3437	0.2628	1.0720
3.0 (7.62)	0.2544	0.2883	0.2206	0.8975
4.0 (10.16)	0.2156	0.2442	0.1869	0.7593
5.0 (12.7)	0.1843	0.2087	0.1598	0.6485

To determine the MDC the MDCR must be calculated by first determining the minimum detectable number of net source counts in the interval as given by s_i.

$$s_i = d'\sqrt{b_i}$$

The value of d' is selected from Table 6.5 of NUREG-1575 based on the required true positive and false positive rates and b_i is the number of background counts in the interval. For a background count rate of 6.0E+03 cpm and a scan area of interest 50 cm diameter, a scan rate of 0.5 m/s (resulting in a detector residence time of 1 second) then s_i (MDCR) is 8.28E+02 cpm as determined below:

$$\frac{0.5\ m\ scan\ width}{0.5\frac{m}{s}\ scan\ rate}(6.00E+03\ cpm)\frac{1\ s}{60\frac{s}{m}} = 100\ \frac{counts}{interval} = b_i$$

$$1.38\sqrt{100} = 13.8\ counts\left[\frac{60\ s/m}{1s}\right] = 828\ cpm = MDCR = s_i$$

The MDCR is adjusted using the surveyor efficiency ($MDCR_{surveyor}$) using the following formula:

$$MDCR_{surveyor} = \frac{MDCR}{\sqrt{p}}$$

Where, p is the surveyor efficiency (0.5).

$$\frac{828\ cpm}{\sqrt{0.5}} = 1{,}171\ cpm = MDCR_{surveyor}$$

The $MDCR_{surveyor}$ result is divided by the detector response factor for the radionuclide(s) in order to obtain $\frac{\mu R}{h}$. This illustration assumes 100% Cs-137 and the detector response factor is $940\,\frac{cpm}{\mu R/h}$.

$$\frac{1.171E+03\ cpm}{940\,\frac{cpm}{\mu R/h}} = 1.246\ \mu R/h$$

MicroShield™ runs were performed using the physical and survey parameters provided in this attachment to derive the $\frac{\mu R/h}{pCi/g}$ conversion factors relative to nuclide mixture and detector end cap distance from the soil surface. The Table in this attachment lists the conversion factors for a mixture of 100% Cs-137 at different soil to detector distances. For a soil surface distance of 5 inches to the detector end cap the conversion factor is 0.1598. Based on the above derived $\mu R/h$ value of 1.246 the MDC for a detector background of 6,000 cpm is 7.8 pCi/g.

$$\frac{1.246\,\frac{\mu R}{h}}{0.1598\,\frac{\mu R/h}{pCi/g}} = 7.796\,\frac{pCi}{g} = MDC$$

Attachment 8.3 illustrates the Ludlum Model 44-10 MDC (in pCi/g) for different background values and mixtures of Co-60 and Cs-137.