YANKEE ATOMIC ELECTRIC COMPANY Telephone (413) 424-5261

49 Yankee Road, Rowe, Massachusetts 01367

August 16, 2006
BYR 2006-071

U.S. Nuclear Regulatory Commission
Attention: Document Control Desk
Washington, D.C. 20555-001

Reference: Letter, USNRC to YAEC, "Yankee (Rowe) Nuclear Power Station – Request for Additional Information Re: Final Status Surveys", dated July 12, 2006.

Subject: Submittal of Responses to NRC Request for Additional Information Regarding the Use of *In Situ* Gamma Spectroscopy for Final Status Surveys

Enclosed please find Yankee Atomic Electric Company's (YAEC's) response to the NRC's request for additional information regarding final status surveys, dated July 12, 2006.

We trust that this information is satisfactory; however if you should have any questions or require any additional information, please contact Alice Carson at (301) 916-3995 or the undersigned at (413) 424-2261.

Sincerely,

YANKEE ATOMIC ELECTRIC COMPANY

Joseph R. Lynch
Regulatory Affairs Manager

Enclosure: As stated.

cc (w/o encl): J. Hickman, NRC Project Manager

NMSS01

Response to NRC Request for Additional Information
Dated July 12, 2006

Comments: General Use of ISGRS for 100% Scans of Class 1 Areas

NRC Comment 1: The documentation and discussion of the current TBD should be expanded. Some of the assumptions are not immediately obvious, and the discussions are difficult to follow.

YAEC Response: The TBD will be revised to list the assumptions separately and, during that revision, particular attention will be paid to discussion clarity.

NRC Comment 2: Several suggested requirements for successful application of the ISGRS in this manner are:

a. The use of accurate and representative values in the determination of an "effective" investigation level.
b. Ensuring that the system is applied in a manner consistent with the TBD values and assumptions, such as:
    i. MDC values under actual operating conditions are at or below the effective investigation level for each radionuclide of concern.
    ii. Adequate correction factors are used, such as for moisture self-attenuation.

These requirements should be addressed in greater detail, either in the TBD, in quality control documents, or operating procedures.

YAEC Response: The use of accurate and representative information, as specified by the LTP, and the establishment of MDC values to meet LTP requirements is set forth by the LTP and associated implementing procedures. There are procedures that specifically address the use and calibration of ISOCS as applied to FSS. These procedures will be reviewed to ensure the adequate application of correction factors.

NRC Comment 3: In general, the TBD method of determining investigation levels results in effective investigation levels below the $DCGL_W$. If contamination is routinely present in the survey unit below the $DCGL_W$, such that the survey unit should pass, but above the effective investigation level, many unnecessary investigations may result. As a result, use of ISGRS will likely be limited operationally to situations where the average concentration is well below both the $DCGL_w$ and the effective investigation level.

YAEC Response: Field experience indicates that, while investigations are sometimes initiated based on FSS with ISOCS that may not have been initiated based on FSS with hand-held instrument scanning, the investigation rate in areas prepared for FSS is acceptable and does not negate the benefits of ISOCS.

NRC Comment 4: In section 1.2.7, the rational for the correction for soil moisture should be expanded to include correction factors for other conditions that were encountered at the Yankee Rowe site, such as ice and/or snow cover, varying soil types, etc.

YAEC Response: This comment has already been implemented administratively. FSS ISOCS data acquisition is not allowed for media under standing (or flowing) snow, ice or water. Implementing documents will be reviewed to ensure such factors are adequately communicated.

Questions: General Use of ISGRS for 100% Scans of Class 1 Areas

NRC Question 1: Regarding requirement (2.b.i) above, the three final status summary (FSS) reports reviewed state that the ISOCS scan MDC was set at the 1 m^2 $DCGL_{emc}$ (Ref 3 page 8, Ref 4 page 26, Ref 5 page 13). It is unclear why the MDC was not set at the effective investigation level. If the investigation level is the value that will trigger further action, then it would intuitively require the equipment to be sensitive enough to detect that value. Please address this discrepancy between suggested requirement (2.b.i) and the FSS statements.

YAEC Response: In implementing the License Termination Plan (LTP) and associated implementing procedures, YNPS must investigate any elevated measurement in excess of $DCGL_{EMC}$ in a Class 1 area. As is the case for conventional FSS with hand-held instrument scans, the $DCGL_{EMC}$ is applied as an *a priori* value and survey data processed after acquisition are evaluated with actual, *a posteriori* $DCGL_{EMC}$ values, when applicable. The License Termination Plan specifies investigation in the survey areas of concern at ">$DCGL_{EMC}$," and not in terms of an effective investigation level; therefore, FSS plans and reports should also address investigations on the basis of $DCGL_{EMC}$ (for Class 1 areas) to demonstrate LTP compliance.

Question 2: In sections 1.2.3 and 1.2.4, 1 m^2 is selected as the "smallest area of concern." Setting the area as small as 1 m^2 provides a comparatively large $DCGL_{emc}$ compared to traditional $DCGL_{emc}$ values based on the area between sampling points. Please provide further justification for the size of the area of concern.

YAEC Response: The concern expressed in the question appears to stem from the use of the term "$DCGL_{EMC}$" in Sections 1.2.3 and 1.2.4 of the subject report. It is agreed that it would not be appropriate to evaluate areas of elevated measurements against the criteria as determined through the use of a 1m^2 area factor (unless it has indeed been demonstrated with survey measurements that the bounded area is 1m^2 or smaller) for the evaluation of FSS results. However, the context of the use of the term under discussion is as an *a opriori* evaluation of the sensitivity of the ISOCS and does not establish procedure or policy for the *a posteriori* evaluation of FSS results. The subject report is intended to demonstrate that the ISOCS sensitivity during FSS would lead to the detection of elevated measurements in excess of applicable *a opriori* $DCGL_{EMC}$ values. As an example, the following table lists the ISOCS-based FSS 1 m^2 $DCGL_{EMC}$ in comparison to a number of *a opriori* $DCGL_{EMC}$ values.

Radionuclide	MDCos[1] (pCi/g)	Investigation Level (pCi/g)	$DCGL_{EMC}$ for Areas with Conventional Elevated Measurement Bounding Techniques: $DCGL_{EMC}$, $2m^2$(pCi/g)	$DCGL_{EMC}$ for Areas with Conventional Elevated Measurement Bounding Techniques: $DCGL_{EMC}$, 12.6 m^2 (pCi/g)
Co-60	1.86E+00	1.0E+00	9.14E+00	2.53E+00
Cs-137	2.78E+00	4.3E+00	3.89E+01	1.11E+01
Cs-134	2.90E+00	1.8E+00	1.69E+01	4.70E+00
Ag-108m	2.82E+00	1.5E+00	1.40E+01	3.81E+00
Eu-152	7.60E+00	2.4E+00	2.01E+01	5.39E+00
Eu-154	5.33E+00	2.3E+00	1.86E+01	4.98E+00
Eu-155	9.13E+00	8.7E+01	6.94E+02	2.08E+02
Nb-94	2.38E+00	1.5E+00	1.39E+01	3.78E+00
Cm-243	1.34E+01	2.3E+01	2.00E+02	5.45E+01
Sb-125	8.86E+00	6.8E+00	6.03E+01	1.67E+01

[1] MDC_{OS} is the ICOCS MDC (effective MDC) assuming source term activity is distributed in a 1m^2 offset at the edge of the FOV.

As with hand-held instrument FSS measurements, if the data indicate that results are ≥ *a opriori* $DCGL_{EMC}$ values, then *a posteriori* $DCGL_{EMC}$ values must be determined and the survey unit will only "pass" if it is below the elevated measurement comparison criteria.

NRC Question 3:
In section 1.2.4, it appears that the investigation level being derived is an "effective" investigation level. Is it an observed value that correlates to the expected reading for a 1 m^2 offset area at the $DCGL_{emc}$?

YAEC Response: Yes, the value correlates to the expected reading for a 1 m^2 offset area at the $DCGL_{EMC}$. A number of measurements have led to empirical, or observed values that validate the level discussed in section 1.2.4 of the subject report.

A 2 meter by 2.3 meter (4.6 m^2) area identified in Survey Unit NOL-01-02 bounded by soil samples had an average elevated concentration within identified area of 0.25 pCi/g and 0.84 pCi/g for Co-60 and Cs-137, respectively. The ISOCS scan that triggered the investigation in this area indicated a Co-60 concentration of 0.8 pCi/g and a Cs-137 concentration of 1.2 pCi/g.

NRC Question 4: In general, the MDC is a situation-dependent statistical value determined in part by the background count rate, the count time, and the efficiency. It is true the MDC must be below the value you are trying to detect. However, when using an effective reading X to infer an activity Y in a different geometry (and therefore different efficiency), the correction factor intuitive to use would be the ratio of the efficiencies.

In section 1.2.4, when deriving the effective investigation level, why is the area correction factor (CF) determined by the ratio of the MDCs instead of the ratio of the 1 m^2 offset efficiency to the 12.6 m^2 direct-view efficiency?

YAEC Response: In this instance, the ratio operation was performed after determining the MDC values, instead of using only the efficiency values. With MDC being a function of the efficiency in both cases of concern, the outcome is not altered by determining the ratio based on MDC values versus efficiency values.

NRC Question 5: In section 1.2.5, regarding the statement, "Count times will be adjusted as necessary ...", clarify what the criteria is. (i.e., count until the MDC is lower than what?)

YAEC Response: As with all instrumentation in FSS applications, the criteria are set by the LTP and associated implementing procedures as a function of DCGL. For example, the criterion for a Class 1 survey unit is that the MDC is $\leq DCGL_{EMC}$.

<u>**Comments: Impact of Discrete Particles**</u>

NRC Comment 1: Based on the information provided, it appears that ISGRS is capable of detection at levels low enough to meet the effective investigation level, and thus at the $DCGL_{EMC}$ for activity in a 1 m^2 offset area. However, there is insufficient data to support the TBD statement in Section 1.2.8 that the activity of discrete particles will be readily detectable. There should be further evaluation of discrete particle detectability if unfavorable conditions are introduced (i.e. geometry, isotope, environmental factors, etc.).

YAEC Response: YA-REPT-00-016-06 has been written to address ISOCS detection capabilities considering additional geometries, differing environmental factor (i.e., presence of soil cover) and an additional isotope (Cs-137).

NRC Comment 2: The modeling used to derive DCGLs does not directly apply to hot particles treated as distributed over an area. The exposure pathways are based on mobility and resuspension factors for an evenly distributed contaminant. In addition, when the area of concern becomes increasingly small, such as 1 m^2, the typical scenario of a resident farmer is no longer realistic. Further evaluation should be provided for future FSSs.

YAEC Discussion: YA-REPT-00-016-06 has been written to address exposure related to a discrete particle.

NRC Comment 3: Given the limitations of the current method of determining DCGL values, it is beneficial to consider alternate risk scenarios when determining acceptable residual levels of discrete particles. Alternate scenarios provide a better approach than averaging the activity over 1 m^2, and the *in situ* technical basis would need to be updated to reflect any changes in detection criteria. (See the NUREG-1757 guidance for alternate scenarios).

YAEC Response: YAEC has given consideration to alternate scenarios in its evaluation of dose due to a discrete particle, as documented in YA-00-016-06.

Questions: Impact of Discrete Particles

NRC Question 1: The TBD makes a statement at the beginning of the second paragraph of section 1.2.8, that a discrete particle activity exceeding 3.2 µCi would be readily detected. Please provide more discussion and supporting data. Please address the cases that the 3.2 µCi particle is in the center of the FOV or edge of the FOV and if the particle in underneath 15 cm of moist, dense soil at the edge of the FOV?

YAEC Response: YA-REPT-00-016-06 addresses the conditions requested in the subject question.

NRC Question 2:
What activity particle is likely to be detected for one of the radionuclides that is not Co-60? Co-60 appears to represent the optimistic case, since it has two photons per decay, with each emitted at a high energy.

YAEC Response: YA-REPT-00-016-06 evaluates the activity of Cs-137 particle under the same considerations as requested of Co-60, in the previous question.

References (from July 12, 2006 Correspondence):

1. YA-REPT-00-018-05; Use of *In situ* Gamma Spectrum Analysis to Perform Elevated Measurement Comparisons in Support of Final Status Surveys.
2. Yankee Nuclear Plant Station license Termination Plan, Yankee Atomic Electric Company, Rev. 1. (November 2004).
3. YNPS-FSS-WST01-00; Yankee Nuclear Power Station Final Status Survey Report (April 13,2006).
4. YNPS-FSS-NOL01-00; Yankee Nuclear Power Station Final Status Survey Report. (March 29, 2006).

5. YNPS-FSS-TBN01-00; Yankee Nuclear Power Station Final Status Survey Report. (February 21, 2005).

6. *In situ* (ISOCS) Gamma Spectrum Assay System Calibration Procedure; YNPS Procedure # DP-8869, Rev. 1. (July 2005).

7. Operation of the Canberra Portable ISOCS Assay System; YNPS Procedure # DP-8871, Rev. 2. (October 2005).

8. Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM), NUREG-1575, Rev. 1 (August 2000).

YA-REPT-00-016-06

Discrete Particle Detection

In the Performance of Final Status Surveys

At Yankee Nuclear Power Station

August 2006

Approvals		Print & Sign Name
Preparer: Eric Darois		Date: 8/14/06
Reviewer::		Date: 8-15-06
Approver (Cognizant Manager):		Date: 8/15/06

Table of Contents

1 Summary

The Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM) allows a Class 1 area to have residual radioactivity levels which could be above the average Derived Concentration Guideline Value ($DCGL_W$); however, the levels are limited to the maximum radioactivity level specified by a defined area called the $DCGL_{EMC}$ or elevated measurement comparison. MARSSIM is based on the premise that the residual contamination is horizontally distributed relatively uniformly and, therefore, does not consider the presence of discrete particles. Since the occasional presence of discrete particles has been identified during the Yankee decommissioning, methods for the detection and dose considerations of these particles are needed. A technical basis document was developed at Yankee Nuclear Power Station to address scanning surveys in a Class 1 survey area with an In-Situ Gamma Ray Spectroscopy System (ISGRS) and its ability to detect discrete particles. Subsequently, issues about discrete particle detection were identified during a review of several Final Status Survey reports. This technical basis document and YA-REPT-00-012-06, "Instrument Detection Sensitivity for Scan Instrumentation Used in Final Status Survey at Yankee Rowe" has been written to address those issues.

2 Introduction

YA-REPT-00-018-05, "Use of In-Situ Gamma Spectrum Analysis To Perform Elevated Measurement Comparisons In Support of Final Status Surveys", Reference 1, was written to address the capabilities of the ISGRS to detect small areas of elevated residual radioactivity. In this document the issue of discrete particle detection was discussed.

The Nuclear Regulatory Commission (NRC) issued a Request for Additional Information (RAI) on July 12, 2006, Reference 2, after reviewing several Final Status Survey reports and the Reference 1 technical basis document. The RAI asked for additional information regarding the use and performance of ISGRS to perform scanning surveys in Class 1 areas in the presence of discrete particles.

3 Background

Traditional scanning in Class 1 land areas is performed by moving a sodium iodide (NaI) detector close to the surface of the ground while walking at a slow pace. Due to the background radiation interference problems associated with the Independent Spent Fuel Storage Installation (ISFSI) at Yankee Nuclear Power Station (YNPS), the use of the ISGRS to perform scanning surveys in Class 1 areas was evaluated.

The ISGRS system at is comprised of a High-Purity Germanium (HPGe) or Reversed-Electrode Germanium (REGe) detector coupled with associated electronics and a personal computer configured with a wireless network card to allow remote control of the system.

The detectors are calibrated by Canberra Industries using the Monte Carlo Neutral Particle (MCNP) computer code to establish calibration curves. Geometries are defined by the user, prior to taking measurements to estimate or predict the instrument response to the source.

The ISGRS is typically deployed 2 meters above the ground with a 90 degree collimator in place. This geometry yields a nominal Field of View (FOV) of approximately 12.6 m^2. An investigation level was established (the $DCGL_{EMC}$) corresponding to a 1 m^2 area at the edge of the FOV.

Reference 1 describes the technique in deriving the value for the investigation level and the potential detection ability of the ISGRS for discrete particles in a 1 m^2 area on the surface of the soil. This document did not address the presence of particles beneath the ground surface and the potential dose consequences to a future receptor. This technical support document evaluates these parameters.

4 Discussion

The approach to the solution was to use the computer code Microshield. A soil source, represented by a 1 m^2 area and a depth of 0.15 m at the edge of the 12.6 m^2 field of view (FOV), was modeled. The source material used in the code was concrete. Although not specifically soil, concrete has high concentrations of silicone and oxygen which are also found in soil. The density of the concrete was 2.08 g/cc (the value of saturated soil taken from Reference 1). A nominal radioactivity level of 3.2 µCi Co-60 was used in the source to calculate the uncollided exposure rate at the detector. The 3.2 µCi of Co-60 would be the radioactivity level of a discrete particle if the 1 pCi/g investigation level from Table 2 in Reference 1 was present in the 12.6 m^2 FOV. The uncollided exposure rate from a 3.2 µCi Co-60 point source placed on the surface of the soil at the edge of the FOV was also calculated. To evaluate unfavorable measurement conditions the same point source was placed under 0.15 m of soil at the edge ofthe FOV. The same three exposure scenarios were run with a nominal quantity of 13.8 µCi of Cs-137. This value corresponds to the radioactivity level of a Cs-137 discrete particle if the 4.3 pCi/g investigation level from Table 2 in Reference 1 was present in the 12.6 m^2 FOV.

The following input values were used in the Microshield runs:

Table 1
Input Parameters for Microshield Runs

Source Description	X Direction Distance (cm)	Y Direction Distance (cm)	Z Direction Distance (cm)
Particle on Surface	200	200	0
Particle under 15 cm soil	200	215	0
1 m^2 by 0.15 m deep soil (cylindrical) source	143.6	215	0

The resulting uncollided exposure rate to radioactivity ratios were normalized to determine the point source radioactivity required to create the same exposure rate from the 1 m^2 by 0.15 m deep investigation level soil source at the edge of the 12.6 m^2 FOV.

The potential impact of the radioactivity levels of the discrete particles was determined by calculating the Effective Dose Equivalent (EDE) using conversion factors listed in a paper written by X. George Xu, "The Effective Dose Equivalent and Effective Dose for Hot Particles on the Skin", Reference 3.

5 Results

The outputs from the Microshield runs are presented in Appendix 1. The results have been summarized in Table 2. The exposure rate column is the uncollided exposure rate from the Microshield outputs. The second column presents the ratio each of the exposure rates to the 1 square meter source exposure rate, as provided in Reference 1. The last column presents the radioactivity level of the discrete particles required to produce the same exposure rate as the 1 square meter source. The radioactivity of the discrete particle is obtained by multiplying the 1 square meter radioactivity MDC determined from Reference 1 by the ratio. This corresponds to the investigation level which results in additional measurements to be obtained in determining the cause of the elevated detection.

Table 2
Discrete Particle MDC Determination for ISGRS

Co-60 - 3.2uCi	**Exposure rate (mr/h)**	**Ratio to 1 sq m source**	**MDC of Discrete Particle (uCi)**
Point source - on soil surface	5.092E-04	5.32E-01	1.70
Point source – under 15 cm soil	3.505E-05	7.72E+00	24.71
1 sq m source	2.707E-04	1.00E+00	3.20

Cs-137 - 13.8 uCi	**Exposure rate (mr/h)**	**Ratio to 1 sq m source**	**MDC of Discrete Particle (uCi)**
Point source - on soil surface	5.479E-04	4.18E-01	5.77
Point source – under 15 cm soil	1.455E-05	1.57E+01	217.20
1 sq m source	2.290E-04	1.00E+00	13.80

The Effective Dose Equivalent (EDE) for Cs-137 was taken from Table 6 of Reference 3. The maximum value for the EDE is located on the center upper chest, with a value of 11.904 µrem/h/µCi.

The EDE for Co-60 was taken from Table 9 of Reference 3. The maximum value for the EDE is also located on the center upper chest, with a value of 48.631 µrem/h/µCi.

Table 3 presents the EDE in µrem from a 24 hour exposure to an unattenuated point source (e.g. on the surface of the ground and deposited on the skin).

Table 3
Dose Assessment for Discrete Particles Detected on Ground Surface

Radionuclide	Max EDE (μrem/h/μCi)	Point source act (μCi)	EDE rate (μrem/hr)	Exposure time (hrs)	EDE (μrem)
Co-60	48.631	1.7	82.67	24	1984
Cs-137	11.904	5.77	68.69	24	1648

Table 4 presents the EDE in μrem from a 24 hour exposure to an attenuated point source (e.g. point source located 15 cm below the surface of the ground and deposited on the skin.

Table 4
Dose Assessment for Discrete Particles at 15 cm Below Ground Surface

Radionuclide	Max EDE (μrem/h/μCi)	Point source act (μCi)	EDE rate (μrem/hr)	Exposure time (hrs)	EDE (μrem)
Co-60	48.631	24.71	1201	24	28,840
Cs-137	11.904	217.2	2585	24	62,051

6 Conclusion

As can be seen from the data in Tables 3 and 4, the maximum effective dose equivalent from Table 4 is 62 mrem. This value is approximately 60 percent of the 100 mrem whole body limit for members of the public. However, it is highly unlikely that a particle would become lodged directly on the skin from 15 cm below the surface for a twenty-four hour period. This unlikely scenario does not apply to the average member of the critical group as required by 10CFR20 Subpart E for license termination. The more realistic scenario comes from Table 3 where the maximum effective dose equivalent of 2 mrem represents approximately 2 percent of the100 mrem limit for members of the public and less than 10% of the 25 mrem limit to the average member of the critical group as required by 10CFR20 Subpart B.

7 References

Reference 1	YA-REPT-00-018-05, "Use of In-Situ Gamma Spectrum Analysis To Perform Elevated Measurement Comparisons In Support of Final Status Surveys",
Reference 2	Yankee (Rowe) Nuclear Power Station – Request for Additional Information Re: Final Status Surveys (TAC No. L52675), dated July 12, 2006
Reference 3	X. George Xu, "The Effective Dose Equivalent and Effective Dose for Hot Particles on the Skin", published in the Health Physics Society July 2005, Volume 89.

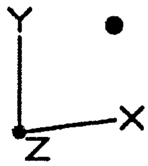
Appendix 1: MicroShield Runs

MicroShield v5.05 (5.05-00268)
RSCS, INC

Page : 1
DOS File : CASE1.MS5
Run Date: August 9, 2006
Run Time: 4:44:33 PM
Duration : 00:00:00

File Ref: ____________
Date: ____________
By: ____________
Checked: ____________

Case Title: Co-60 in air
Description: Co-60 at edge of FOV no attenuation
Geometry: 1 - Point



Dose Points

	X	Y	Z
# 1	200 cm	200 cm	0 cm
	6 ft 6.7 in	6 ft 6.7 in	0.0 in

Shields

Shield Name	Material	Density
Air Gap	Air	0.00122

Source Input
Grouping Method : Actual Photon Energies

Nuclide	curies	becquerels
Co-60	3.2000e-006	1.1840e+005

Buildup
The material reference is : Air Gap

Results

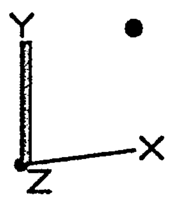
Energy MeV	Activity photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.6938	1.931e+01	1.299e-05	1.328e-05	2.507e-08	2.563e-08
1.1732	1.184e+05	1.354e-01	1.375e-01	2.420e-04	2.456e-04
1.3325	1.184e+05	1.540e-01	1.561e-01	2.672e-04	2.708e-04
TOTALS:	2.368e+05	2.894e-01	2.936e-01	5.092e-04	5.165e-04

MicroShield v5.05 (5.05-00268)
RSCS, INC

Page : 1
DOS File : CASE2.MS5
Run Date: August 9, 2006
Run Time: 4:45:42 PM
Duration : 00:00:00

File Ref: ____________
Date: ____________
By: ____________
Checked: ____________

Case Title: Co-60 @15cm
Description: Co-60 at edge of FOV under 15 cm attenuation
Geometry: 1 - Point



Dose Points

	X	Y	Z
# 1	200 cm	215 cm	0 cm
	6 ft 6.7 in	7 ft 0.6 in	0.0 in

Shields

Shield Name	Dimension	Material	Density
Shield 1	15.0 cm	Concrete	2.08
Air Gap		Air	0.00122

Source Input
Grouping Method : Actual Photon Energies

Nuclide	curies	becquerels
Co-60	3.2000e-006	1.1840e+005

Buildup
The material reference is : Air Gap

Results

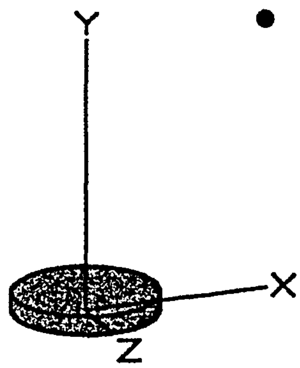
Energy MeV	Activity photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.6938	1.931e+01	3.772e-07	3.079e-06	7.282e-10	5.945e-09
1.1732	1.184e+05	8.500e-03	3.841e-02	1.519e-05	6.865e-05
1.3325	1.184e+05	1.144e-02	4.575e-02	1.986e-05	7.937e-05
TOTALS:	2.368e+05	1.995e-02	8.417e-02	3.505e-05	1.480e-04

MicroShield v5.05 (5.05-00268)
RSCS, INC

Page : 1
DOS File : CASE3.MS5
Run Date: August 9, 2006
Run Time: 4:47:48 PM
Duration : 00:00:03

File Ref: ____________
Date: ____________
By: ____________
Checked: ____________

Case Title: 1 sq m Co-60 in soil
Description: 15 cm by 1 sq m soil with Co-60
Geometry: 7 - Cylinder Volume - Side Shields



Source Dimensions

Height	15.0 cm	5.9 in
Radius	56.4 cm	1 ft 10.2 in

Dose Points

	X	Y	Z
# 1	143.6 cm	215 cm	0 cm
	4 ft 8.5 in	7 ft 0.6 in	0.0 in

Shields

Shield Name	Dimension	Material	Density
Source	1.50e+05 cm³	Concrete	2.08
Transition		Air	0.00122
Air Gap		Air	0.00122
Immersion		Air	0.00122

Source Input
Grouping Method : Actual Photon Energies

Nuclide	curies	becquerels	μCi/cm³	Bq/cm³
Co-60	3.2000e-006	1.1840e+005	2.1348e-005	7.8986e-001

Buildup
The material reference is : Air Gap

Integration Parameters

Radial	20
Circumferential	20
Y Direction (axial)	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	1.931e+01	5.593e-06	1.181e-05	1.080e-08	2.280e-08
1.1732	1.184e+05	7.031e-02	1.224e-01	1.256e-04	2.187e-04
1.3325	1.184e+05	8.358e-02	1.396e-01	1.450e-04	2.421e-04

DOS File : CASE3.MS5
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Run Time: 4:47:48 PM
Duration : 00:00:03

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
TOTALS:	2.368e+05	1.539e-01	2.619e-01	2.707e-04	4.608e-04

MicroShield v5.05 (5.05-00268)
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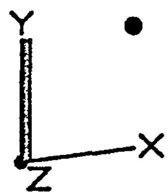
Page : 1
DOS File : CASE4.MS5
Run Date: August 9, 2006
Run Time: 5:01:07 PM
Duration : 00:00:00

File Ref: ____________
Date: ____________
By: ____________
Checked: ____________

Case Title: Cs-137 @15cm
Description: Cs-137 at edge of FOV under 15 cm attenuation
Geometry: 1 - Point



Dose Points

	X	Y	Z
# 1	200 cm	215 cm	0 cm
	6 ft 6.7 in	7 ft 0.6 in	0.0 in

Shields

Shield Name	Dimension	Material	Density
Shield 1	15.0 cm	Concrete	2.08
Air Gap		Air	0.00122

Source Input
Grouping Method : Actual Photon Energies

Nuclide	curies	becquerels
Ba-137m	1.3055e-005	4.8303e+005
Cs-137	1.3800e-005	5.1060e+005

Buildup
The material reference is : Air Gap

Results

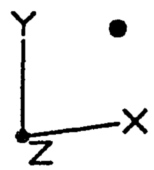
Energy MeV	Activity photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.0318	1.000e+04	8.022e-24	3.969e-22	6.682e-26	3.306e-24
0.0322	1.845e+04	5.641e-23	2.887e-21	4.540e-25	2.324e-23
0.0364	6.714e+03	1.968e-18	1.477e-16	1.118e-20	8.392e-19
0.6616	4.346e+05	7.507e-03	6.503e-02	1.455e-05	1.261e-04
TOTALS:	4.698e+05	7.507e-03	6.503e-02	1.455e-05	1.261e-04

MicroShield v5.05 (5.05-00268)
RSCS, INC

Page : 1
DOS File : CASE5.MS5
Run Date: August 9, 2006
Run Time: 5:02:35 PM
Duration : 00:00:00

File Ref: ______________
Date: ______________
By: ______________
Checked: ______________

Case Title: Cs-137 in air
Description: Cs-137 at edge of FOV no attenuation
Geometry: 1 - Point



Dose Points

	X	Y	Z
# 1	200 cm	200 cm	0 cm
	6 ft 6.7 in	6 ft 6.7 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	1.3055e-005	4.8303e+005
Cs-137	1.3800e-005	5.1060e+005

Buildup
The material reference is : Air Gap

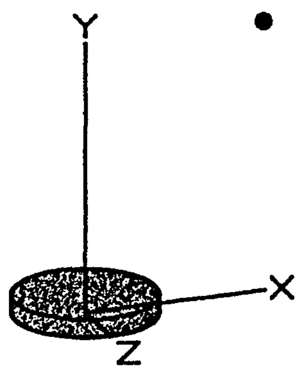
Results

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	1.000e+04	2.855e-04	3.241e-04	2.378e-06	2.700e-06
0.0322	1.845e+04	5.339e-04	6.060e-04	4.296e-06	4.877e-06
0.0364	6.714e+03	2.227e-04	2.527e-04	1.265e-06	1.436e-06
0.6616	4.346e+05	2.786e-01	2.850e-01	5.400e-04	5.525e-04
TOTALS:	4.698e+05	2.796e-01	2.862e-01	5.479e-04	5.615e-04

MicroShield v5.05 (5.05-00268)
RSCS, INC

Page : 1	File Ref: ________
DOS File : CASE6.MS5	Date: ________
Run Date: August 9, 2006	By: ________
Run Time: 5:04:01 PM	Checked: ________
Duration : 00:00:04	

Case Title: 1 sqm Cs-137 in soil
Description: 15 cm by 1 sq m soil with Cs-137
Geometry: 7 - Cylinder Volume - Side Shields



Source Dimensions

Height	15.0 cm	5.9 in
Radius	56.4 cm	1 ft 10.2 in

Dose Points

	X	Y	Z
# 1	143.6 cm	215 cm	0 cm
	4 ft 8.5 in	7 ft 0.6 in	0.0 in

Shields

Shield Name	Dimension	Material	Density
Source	1.50e+05 cm³	Concrete	2.08
Transition		Air	0.00122
Air Gap		Air	0.00122
Immersion		Air	0.00122

Source Input
Grouping Method : Actual Photon Energies

Nuclide	curies	becquerels	μCi/cm³	Bq/cm³
Ba-137m	1.3055e-005	4.8303e+005	8.7091e-005	3.2223e+000
Cs-137	1.3800e-005	5.1060e+005	9.2062e-005	3.4063e+000

Buildup
The material reference is : Air Gap

Integration Parameters

Radial	20
Circumferential	20
Y Direction (axial)	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
0.0318	1.000e+04	1.062e-05	2.657e-05	8.847e-08	2.213e-07
0.0322	1.845e+04	2.047e-05	5.214e-05	1.647e-07	4.196e-07
0.0364	6.714e+03	1.154e-05	3.564e-05	6.558e-08	2.025e-07

Page : 2
DOS File : CASE6.MS5
Run Date: August 9, 2006
Run Time: 5:04:01 PM
Duration : 00:00:04

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
0.6616	4.346e+05	1.179e-01	2.542e-01	2.287e-04	4.927e-04
TOTALS:	4.698e+05	1.180e-01	2.543e-01	2.290e-04	4.936e-04