KERR-McGEE CORPORATION
1001 EAST DEEP ROCK • CUSHING, OKLAHOMA 74023

August 27, 2003

Mr. Derek Widmayer
Low-Level Waste & Decommissioning Projects Branch
Division of Waste Management
Office of Nuclear Materials Safety & Safeguards
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Re: Docket No. 70-3073
License No. SNM-1999

Dear Mr. Widmayer:

This letter requests NRC approval of the attached Sector 10 Rubble Survey Work Plan and Technical Memorandum. These documents are similar in nature to our June 18, 2003 submittals for Sector 8 which were approved by your letter dated August 15, 2003. The contamination in Sector 10 is primarily SNM, as addressed in the modified Work Plan and Technical Memorandum. However, the procedures and modeling utilize similar concepts which were previously applied toward successfully surveying the Sector 8 rubble materials. We will use the knowledge and lessons learned from the Sector 8 work to ensure that this work is also implemented in a manner that meets all criteria.

We would like to begin work on this project as soon as possible. As the procedures and technical justification are similar in nature to that submitted for the Sector 8 work, we would appreciate your assistance in expediting the review and approval process as much as possible.

Copies of the Work Plan and Technical Memorandum are attached for your review. If you have any questions or comments, please contact Jeff Lux at (918) 223-2522 or call me at (918) 223-2526.

Sincerely,

Karen Morgan
Radiation Safety Officer

Cc: NRC Public Document Room
Cushing Public Repository
Blair Spitzberg, NRC Region IV
Mike Broderick, DEQ Radiation Management Division
George Thomas, DEQ Land Protection Division

SECTOR 10 RUBBLE SEGREGATION AND SURVEY WORK PLAN
KERR-McGEE CUSHING SITE
CUSHING, OKLAHOMA

DRAFT
August 26, 2003

SECTOR 10 RUBBLE SEGREGATION AND SURVEY WORK PLAN
KERR-McGEE CUSHING SITE
CUSHING, OKLAHOMA

Rev. 0

APPROVAL PAGE

Prepared By: _____ Date: _____
HP Manager/Activity Leader (T. J. Keane)

Reviewed By: _____ Date: _____
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Reviewed By: _____ Date: _____
Manager, Planning and Regulatory Compliance (J. J. Lux)

Approved By: _____ Date: _____
Program Manager (D. M. Finch)

TABLE OF CONTENTS

ATTACHMENT: Nextep Environmental, Technical Memorandum 03-24

1.0 PURPOSE

The purpose of this work plan is to provide instructions for segregating and surveying small rubble and debris (e.g., building materials, primarily concrete and brick chunks) found in the Sediment Pile Area of Sector 10 of the Kerr-McGee (KM) Cushing site. This debris has to be removed to complete decommissioning of the soil and structures in Sector 10. This material is more soil-like than equipment-like and the exposure scenario is similar to the soil exposure scenario. Consequently, the volumetric criterion is more appropriate than the surface contamination criterion. Normal swipe, scan, and integrated survey methods are ineffective and impractical on much of this debris due to size and/or irregular shape. The objective is to demonstrate that the material meets the release criteria specified in the Site Decommissioning Plan (SDP) and NRC License SNM-1999.

2.0 HISTORY

The Sediment Pile Area of Sector 10 consists of approximately 250 square meters of property bounded by the Haul Road Corridor on the northwest, west, and south and theRMA-10 on the northeast and east. The area forms a finger off of RMA-10.

During the ELLWaR project the Process Buildings were dismantled. The initial intent was to remove the concrete that exceeded the criteria for disposal as Low Level Radioactive Waste (LLRW) and then remove the non-impacted concrete as industrial waste. However, the concrete became brittle with age and the initial phases of the removal caused large sections of the concrete to shatter into rubble. The large pieces that were identifiable as impacted were stacked for disposal as LLRW. The remaining large pieces have been surveyed using conventional swipe, scan, and integrated survey methods. Approximately 200 cubic yards of small, irregular shaped rubble remains to be surveyed by an alternate method.

3.0 LIKELY CONTAMINANTS

The concrete rubble and debris remaining is not identifiable as being from a particular building surface. Consequently, both uranium and thorium contamination is possible. The uranium contamination could be in the form of natural or enriched uranium. The impacted soil in the area of the Process Buildings showed an average enrichment of 3.5%.

Portions of the buildings were used for refinery operations prior to the nuclear processing years. Thus, TENORM (radium pipe scale) is also a possible contamination source. While not a licensed radioactive material, the TENORM will also have to be remediated to satisfy the Consent Order with the State of Oklahoma and the exposure rate criteria of the SDP.

The thorium and radium are easily detectable with gamma instrumentation. By modifying the procedure used for the Sector 8 rubble as described in Section 6, the uranium can also be reliably detected as shown in the attached Technical Memo.

4.0 ADMINISTRATIVE CONTROLS

4.1 RESPONSIBILITIES

All activities associated with the segregation and survey of rubble and debris will be under the general direction of Construction Management with guidance from the health physics staff. General direction of activities important to radiological safety and license compliance will be provided by the HP Operations Manager and field activities will be under the direction of the HP Field Supervisor assigned to the project.

4.2 PERSONNEL QUALIFICATIONS

Personnel performing survey and sampling activities must be task-qualified Health Physics Technicians (HPT) (or under the direction of a task-qualified HPT) per the Cushing Task Qualification Matrix. Personnel performing critical evaluations must be familiar with the SDP, the Cushing Quality System Manual (QSM), and the Sampling and Analysis Plan (SAP). All personnel performing activities associated with the segregation will be task qualified for the tasks performed.

4.3 TRAINING

Personnel working on the survey of debris and rubble shall have received training on the QSM, SAP, SDP, Radiation Safety Plan (RSP), Health and Safety Plan (HASP), applicable provisions of NRC License SNM-1999, and applicable procedures.

4.4 ASSIGNMENTS

Activities associated with the gathering and lay out (wind rowing) of rubble and debris will be performed by a construction contractor under the direction of Construction Management and HP. Personnel performing these tasks shall receive Radiation Worker Training and General Site Orientation at a minimum. These personnel shall also receive training on the applicable provisions of this Work Plan.

Survey and sampling activities will be performed by (or under the direction of) task-qualified HP Technicians. Personnel assigned to this task will work under the direction of the HP Field Supervisor assigned to the project.

The on-site HP Laboratory will provide field survey instruments that are verified to be within current calibration and that pass daily operational checks in accordance with the established procedures.

Samples will be submitted to the on-site HP Laboratory for analysis.

All survey and sample data will be submitted to the HP Operations Manager for review and release determination.

5.0 PHYSICAL AND HAZARDOUS CHARACTERISTICS

Material that could be encountered includes uranium contaminated materials, thorium contaminated materials, NORM contaminated materials, construction debris from refinery operations, and various solid wastes. Known site hazards are presented in the Site HASP and RSP.

Evaluation of the potential and recognized hazards associated with the characterization of the site will be an ongoing process. Field team personnel must also assume responsibility for evaluating field hazards, and reporting changing field conditions to the field supervisor. The field supervision will work with the health and safety staff, Construction Management, and the HP Operations Manager to define hazards and necessary PPE requirements.

6.0 METHOD OF INVESTIGATION

This section describes the methodology to be used for selection of material to be surveyed, the layout of the material, and the survey and sampling of the material. The specifics will be incorporated into a health physics procedure upon approval of this work plan.

6.1 BACKGROUND DETERMINATION

Select the area where material will be laid out (wind rowed) for survey. Ensure that characterization is complete for the area(s) selected and that no radiological remediation is necessary.

Establish lay down lanes for the material. Scan the lanes using a Ludlum 2221 with a shielded 3" x ½" NaI(Tl) detector (or equivalent).

- Scan Speed: Not to exceed 0.15 meters per second
- Response Setting: Fast
- Window Setting: Out
- Distance: Detector approximately 15 cm (~6") above the surface
- Scan Lane Width: 24"

Record the maximum and average instrument reading along the scan lane on a survey form.

Obtain and record exposure rate measurements at approximately 5 meter intervals along the length of the wind row lane using a Ludlum Model 19 micro-R meter (or equivalent). Take all exposure rate readings at approximately 1 meter above the surface.

If the maximum instrument reading (scan or micro-R) exceeds the average by 25% or more notify the HP Operations Manager.

6.2 MATERIAL SELECTION AND LAYOUT

Material to be surveyed using this methodology shall not include large chunks (greater than 16 inches by 16 inches) that are easily surveyed using standard swipe, scan, and integrated contamination survey methods.

Large chunks that are easily surveyed shall not be broken up to be included in this method.

Lay the material to be surveyed out in wind rows approximately 1 meter wide and 12 inches high.

Visually scan the material. Remove any large chunks (> 16" by 16") and set aside for survey by standard surface contamination survey methods or disposal. Remove any material

with hidden or inaccessible surfaces or rusted metal parts. Remove pipe sections and other metal equipment or components. These pieces (rusted metal or inaccessible surfaces or less than 8 cu ft) will be segregated out for disposal as LLRW.

6.3 DEBRIS SURVEY

Establish scan lanes to guide the survey. Scan the length of each lane, using a Ludlum 2221 with a 3" x ½" Shielded NaI(Tl) detector (or equivalent). (See the attached Technical Memo for instrument specifics.)

- Scan Speed: Not to exceed 0.15 meters per second
- Response Setting: Fast
- Window Setting: Out
- Distance: Detector approximately 15 cm (~ 6") above the surface
- Scan Lane Width: 24"

The scan will take two passes along the length of the material due to the detector height. This may be accomplished with an array of detectors on a fixed arm jig or individual passes. Note any area of increased count rate and obtain and record (on a survey form) a direct reading (2 minute integrated count) at 6 inches above the surface.

Obtain and record exposure rate measurements at approximately 3 meter intervals along the length of the wind-row and at any location with a direct count rate exceeding 650 counts per minute above background, using a Ludlum Model 19 micro-R meter (or equivalent). Take all exposure rate readings at approximately 1 meter above the top of the material.

Obtain and record a direct reading (2 minute integrated count) at 6 inches above the surface using the shielded NaI detector at approximately 3 meter intervals along the length of the wind-row.

Obtain a representative sample at approximately 6 meter intervals along the wind-row (1 sample per ~ 0.75 cuyd) and at any location with an integrated count rate exceeding 650 counts above background in accordance with KM-SAP-101, Surface Soil Sampling. Obtain a minimum of 2 lbs of sample (soil and debris) at each location. Prepare for laboratory analysis in Trailer F (Sample Prep) or at the RMA-3 Access Control Trailer in accordance with ES-RO-371, Preparation of Soil Samples for Analysis. Ensure that all of the material is crushed to a size small enough to fit into a 25 ml vial and thoroughly mixed (homogenized). Obtain two vials per sample location.

Adjustments may be made to the survey and sampling methodology based on actual field and analytical data.

6.4 RELEASE CRITERIA

The criteria for release of the small debris and rubble shall be the criteria listed in the Branch Technical Position, the October 23, 1981, "Disposal or Onsite Storage of Thorium or Uranium Wastes from Past Operations" for soil or soil like materials. This material is more soil-like than equipment-like material and the exposure scenario the same as for soil.

The specific values for licensed materials are:

- Soil: Uranium 30 pCi/g; Thorium 10 pCi/g (net activity)
- Exposure Rate: 10 uR/hr above background at 1 m above the surface

6.5 DATA REVIEW AND MATERIAL RELEASE

All surveys and analytical data for a wind row shall be delivered to the HP Operations Manager for review. All data will be compared to the criteria of license condition 11.N.

The HP Operations Manager will notify Construction Management of the release status of the material.

Material that is not releasable shall be segregated and staged in the RMSA or other designated area for future disposal as LLRW.

Material that is releasable shall be removed from the area to allow additional material to be surveyed. Releasable material will be staged for burial on site.

If the lanes will be reused for additional wind rowing, perform another background scan and exposure rate survey of the scan lane after the material is removed.

7.0 DOCUMENTATION

Documents prepared by field teams will include, but are not limited to; survey forms, sampling records, chain-of-custody forms, and field logbooks. Disposition of each wind-row will be documented by the HP Operations Manager. Documents generated in the performance of this work plan shall be maintained as Quality Records in accordance with the QSM.

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TECHNICAL MEMORANDUM 03-24

August 23, 2003

Originator: Ning Zhang, HP Analyst

Subject: NaI Scan Survey of Concrete Rubble Containing SNM[1] in Sector 10 of the Kerr-McGee Cushing Site

Revision: 0

ENDORSEMENT: This document contains the results of research and technical analysis which have been reviewed and approved for publication by the Technical Director, NEXTEP Environmental, Inc.

H J Newman 8/27/03

Harry J. Newman, CHP, Technical Director — Date

1 INTRODUCTION

The work plan for the Kerr-McGee Cushing Site includes the survey and release of concrete rubble from buildings that were demolished[2]. Technical Memorandum (TM) 03-14 discussed this situation for natural Uranium, natural Thorium and their mixtures under the assumption of equilibrium. The measurement results of sector 10 show that enriched uranium exists in this area and there is no evidence show radiological equilibrium. In this TM, the MCNP[3] code is used to simulate the radiological characteristics and geometry of concrete block and to determine the detection capabilities of the instrumentation that is proposed for the release surveys.

Accordingly, the objectives of this Technical Memo are:

1) Estimate the detection limit L_D for direct measurement and the *a priori* Minimum Detectable Count Rate (MDCR) for scan surveys based upon the predicted background for several detector configurations.

[1] SNM stands for Special Nuclear Material.
[2] Sector 8 Rubble Segregation and Survey work Plan Kerr-McGee Cushing Site, Cushing, Oklahoma, June 5, 2003.
[3] MCNP is the acronym for "Monte Carlo N Particle" software, Los Alamos National Laboratory, Version 4c

2) Simulate the count rate (in units of cpm) that result from different cases of contamination in order to show whether contamination at the release limit can be observed.
3) Recommend a measurement method for the concrete.

2 ANALYSIS OF ON-SITE MEASUREMENT RESULTS

Table 1 shows on-site measurement results from concrete in Sector 10 at the Kerr-McGee Cushing site. From these results, the following conclusions can be made; these conclusions will be applied to the MCNP model construction.

1) The enrichment of U-235 varied from 1.04% to 8.8%.
2) The average enrichment of U-235 is 3.54%.
3) There is no evidence to show that natural uranium (i.e. in equilibrium) is present. The assumption of natural uranium in equilibrium in TM 03-14[4] is invalid for these samples.
4) To verify the reliability of measurement results, the activity percentage of U-234, U-235, and U-238 vs. the enrichment of U-235 was plotted as shown in Figure 1. Figure 1 was compared with Figure 2-2 from the *Health Physics Manual of Good Practices for Uranium Facilities*[5] (see Appendix E, attached). The comparison visually and empirically shows good agreement and implies that the measurement results are reliable.

   The regression trend lines are given for U-234 and U-238. These trend lines will be used to estimate the activity percentage for U-234 and U-238. These percentages will be further used to calculate the activity for each nuclide at various enrichments.

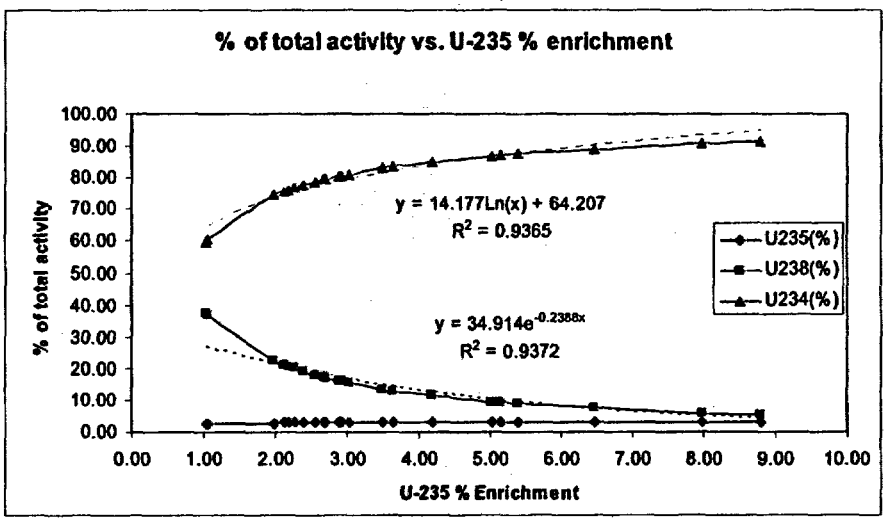


Figure 1
Percentage of total U Activities of U-234, U-235 and U-238 vs. U-235 Enrichment

[4] NEXTEP Tech Memo 0314, NAI Scan Survey of Concrete Rubble in Sector 8 of the Kerr-McGee Cushing Site, N. Zhang.

[5] EGG-2530, *Health Physics Manual of Good Practices for Uranium Facilities*, June 1988. Page 2-10.

Table 1
RMA-10 SNM To Be Remediated

SID	U235 (pCi/g)	U238 (pCi/g)	U234 (pCi/g)	Th232 (pCi/g)	U235S (pCi/g)	U238S (pCi/g)	U234S (pCi/g)	Th232S (pCi/g)	Total U (pCi/g)	Total Th (pCi/g)	FMPC	% Enrich	RA226	U238/Ra226
B101E90S30-005	3.63	5.85	100.80	1.48	0.36	2.64	41.58	0.43	107.52	1.03	3.69	8.80	0.50	11.64
B101E95S40-010	6.59	11.83	181.00	3.34	0.73	5.30	74.71	0.84	196.65	4.76	7.03	7.98	0.92	12.85
B101E80S55-035-D	2.26	5.08	60.25	1.25	0.24	1.84	20.47	0.31	64.81	0.58	2.22	6.47	0.60	8.52
B101E80S55-030	15.11	41.18	401.25	1.64	0.73	5.40	49.77	0.58	454.77	1.36	15.30	5.40	0.79	52.33
B101E85S70-000	0.72	2.06	19.11	3.84	0.24	2.16	8.81	0.47	24.37	7.60	1.57	5.16	0.32	6.36
B101E90S30-000-D	2.51	7.37	66.53	3.47	0.34	2.85	24.44	0.53	73.64	5.01	2.96	5.03	1.01	7.29
B101E80S55-035	2.81	10.04	73.98	0.95	0.28	2.28	16.12	0.34	84.06	-0.02	2.80	4.17	0.73	13.70
B101E90S45-000-D	1.27	5.24	33.28	2.23	0.27	2.35	14.42	0.44	37.01	2.54	1.49	3.63	0.50	10.45
B101E85S50-020	1.37	5.94	35.97	0.81	0.20	1.70	9.95	0.26	40.51	-0.30	1.32	3.47	0.62	9.53
B101E90S45-005	6.66	33.37	173.06	6.26	0.67	5.84	29.40	0.91	210.32	10.60	8.07	3.01	0.63	53.33
B101E85S65-020	1.55	8.06	40.36	1.20	0.36	3.08	14.97	0.52	47.20	0.48	1.62	2.91	1.06	7.59
B101E75S60-005	1.71	8.94	44.30	2.84	0.31	2.69	12.96	0.51	52.18	3.76	2.12	2.89	1.15	7.76
B101E90S45-000	1.10	5.82	28.61	2.13	0.22	1.91	9.10	0.36	32.77	2.34	1.33	2.86	0.82	7.07
B101E95S75-000-D	0.38	2.12	9.71	4.65	0.24	2.31	4.46	0.51	12.36	9.60	1.37	2.68	0.37	5.77
B101E75S60-010	1.76	10.04	45.57	17.03	0.43	4.26	18.83	0.99	54.61	32.14	5.03	2.66	1.69	5.95
B101E85S50-005	2.05	12.23	52.92	3.39	0.24	2.17	9.14	0.38	64.43	4.86	2.63	2.55	0.53	23.07
B101E85S50-010	1.52	9.70	39.15	0.92	0.30	2.71	10.69	0.39	47.60	-0.08	1.58	2.39	0.96	10.15
B101E85S50-005-D	1.70	11.42	43.47	2.20	0.33	3.10	11.53	0.50	53.82	2.49	2.04	2.26	0.88	13.01
B102E00S40-000	1.30	9.09	33.26	3.34	0.26	2.50	8.96	0.46	40.88	4.76	1.84	2.18	0.89	10.17
B101E75S60-000	0.74	5.17	18.90	2.95	0.22	2.07	7.38	0.43	22.04	3.98	1.13	2.18	1.01	5.13
B101E95S40-000	0.81	5.81	20.51	2.03	0.25	2.29	7.91	0.42	24.35	2.14	1.03	2.11	1.42	4.10
B101E75S60-015	2.92	22.48	74.12	1.84	0.42	3.88	12.54	0.55	96.75	1.76	3.40	1.98	0.53	42.29
B102E00S35-010	2.26	32.70	53.51	2.05	0.32	3.53	5.71	0.45	85.71	2.18	3.08	1.06	0.77	42.71
B102E10S40-000	1.32	19.56	31.08	4.19	0.44	4.77	7.50	0.81	49.19	6.47	2.29	1.04	1.96	10.00
Average									82.40	4.58	3.21	3.54	0.86	15.86

5) The average ratio of U-238 to Ra-226 is 15.9. This result indicates that the radiological equilibrium has not been established for U-238.
6) The average activity density of 0.8 pCi/g for Ra-226 shows that the activity of Ra-226 in these samples is at approximately background levels.
7) The average total Uranium for the sample data set is about 90 pCi/g (82.4 pCi/g in Table 1). According to Equation 1 of TM 03-14[6], for the Uranium only case, this amount of Uranium is about 3 FMPC.
8) The average amount of total Thorium for the sample data set is about 5pCi/g (4.58pCi/g in Table 1). This average amount of Thorium is equal to a contamination level of approximately 0.5 FMPC (no background subtraction) for Thorium only and is elevated above background. Table 1 also shows that Thorium was not present in some samples (B101E80S55-035-D, B101E85S50-020, B101E85S50-010, B101E90S45-005, B101E80S55-035). Therefore, in this TM, Thorium-232 will not be included in the MCNP model. This consideration will make the conclusion of this TM more conservative since Thorium is easier to detect than uranium. The presence of even fractional FMPCs of thorium above background can significantly improve detection sensitivity.

3 LAYOUT OF MATERIAL (GENERAL GEOMETRY)

It is assumed that the concrete debris has been broken into small chunk-like pieces and that larger pieces will have been removed[7]. These small chunk-like pieces will be placed together to form a "wind row," which is a long row 1 foot high and 4 feet wide. There will be air gaps within the "wind row" in between the chunks of concrete. In the MCNP model the "wind row" is modeled as a standard 1 meter x 1 meter by 1 foot whole concrete block. Also, for modeling simplification, the physical existence of the air gap within the "wind row" is accounted for by a decrease in the density of the concrete block. In the MCNP model for this TM, it is assumed that 15% of the concrete block volume will be air, so the density of this concrete block is decreased from 2.6g/cm^3 to 2.2g/cm^3.

Figure 2 illustrates the basic geometry for the MCNP model used in this TM. The contaminated layer as depicted can vary in location and be on the top or bottom surface to provide a range of detector sensitivities.

[6] Page 4, TM 03-14, *NaI Scan Survey of Concrete Rubble in Sector 8 of the KM Cushing site*, by Ning Zhang, May, 2003.
[7] Sector 8 Work Plan, ibid.

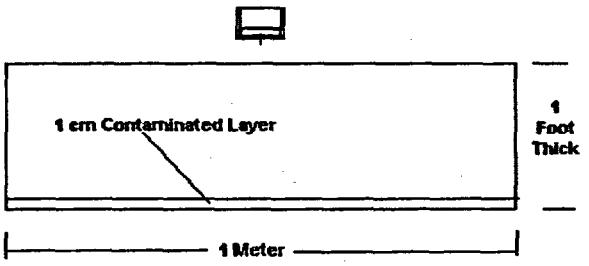


Figure 2
General Geometry of MCNP Model

The detector to be used for surveying the concrete is a 3"x1/2" NaI detector. There are two detector configurations and usage modes which are generally adopted on-site: shielded with measurements made at a height of 6" above the surface, and unshielded with measurments made at a height of 24" above the surface. To study more possible detector configurations, both shielded and unshielded cases as well as the additional measurement heights of 0" (detector placed directly onto surface) and 2" above the surface will be also considered in this TM.

4 REPORTED BACKGROUND COUNTING RATE

According to TM 03-14[8] and TM 03-11[9], 16 m^2 is a large enough surface area for the performance of background simulation modeling. This area is much larger than the effective detectable area for each detector configuration. The MCNP model used for background simulation was very similar to the general model shown in Figure 1, except the dimensions of the concrete block were changed to 4m x 4m x 1 foot.

Table 2 lists the background activity densities assumed for the concrete block. These activities were uniformly distributed throughout the concrete block in the background models.

Table 2
***Activity Density for Background Mixture*[10]**

Nuclide	Activity Density in Concrete (pCi/g)
U-238	0.675
Th-232	0.216
Ra-226	0.6
K-40	1.89

[8] NEXTEP Tech Memo 0314, ibid.
[9] NEXTEP Tech Memo 0311, NAI Scan Survey Survey Thresholds for Uranium and Thorium in Soil at the Kerr-McGee Cushing Site, N. Zhang.
[10] Based on NCRP Report No.94, Exposure of the Population in the United States and Canada From Natural Background Radiation. page 61, using carbonate rocks. The Ra-226 value was assigned using professional judgement.

The total number of photons used to determine background the count rate was 55,794,600 γ/minute (929,950 γ/second). These results were calculated by running the MicroShield code. The output for this result is listed in Attachment A-1, and was obtained by summing the photon emission rate from all available energy bins for each radionuclide.

As in TM 03-14, "an additional count rate of 2,500cpm was added to the (simulated) background to account for other environmental sources of gamma radiation at the site" Table 3 shows the calculated background counting rate for the detector configuration.

Table 3
Simulated Background Counting Rate (cpm)

	Background Simulation Results
0" Shielded	4,235
0" Unshielded	4,900
2", Shielded	4,215
2", Unshielded	4,868
6", Shielded	4,190
24", Unshielded	4,622

5 DETECTION LIMITATION

After the background counting rates are obtained, several important detection limits can be derived according to these background counting rates.

5-1 LD – DETECTION LIMIT FOR DIRECT MEASUREMENT

The theory of Detection Limit can be found in MARSSIM[11] and will be omitted in this section. The equation for calculation of the detection limit is as follows.

Equation 1

$$L_D = 3 + 4.65\sqrt{B}$$

Where

B = Background Counts

The L_D demonstrates the detection capability for *direct measurement* for a certain type of detector. L_D is an a priori estimate of the detection capability of a measurement system and is reported in units of net counts above background. If the measurement count is lower than this number, the source that generated this lower count cannot be distinguished from background and therefore cannot be detected. On the other hand, if the measured counts are higher than this number, there is radioactivity above background.

[11] Multi-Agency Radiation Survey and Site Investigation Manual, (MARSSIM), 6-32 to 6-35.

5-2 MINIMUM DETECTABLE COUNT RATE(MDCR)

The formula for calculating the minimum detectable net count rate (MDCR) of a scanning instrument is given by equation 2.

MDCR is used for scan survey so in its calculation, it considers the factor called surveyor efficiency (p in equation 2).

The observation interval *i* is determined by dividing 1 meter length of concrete block by the survey speed. In this TM, two scan speeds will be assumed, 30cm/seond and 15 cm/second.

Equation 2

$$MDCR = \frac{d'\sqrt{b_i}}{\sqrt{p}} \cdot \frac{60}{i}$$

Where:

MDCR = minimum detectable net count rate (ct/min)
d' = 1.38 when decision error, (α) = 0.60, and correct decision fraction, (1-β) = 0.95[12]
i =observation interval (sec)
b_i = background counts in observation interval
60 = conversion, 60 (sec/min)
p = Surveyor efficiency, assumed[13] to be 0.5.

[12] Abelquist, E.W., Table 6.1 p 6.23
[13] Abelquist, E.W., et.al., §6.7.1.

Table 4
Detection Limit for Direct Measurement and Scan Survey

			Background (counts)	L_D (counts)	L_D (cpm)	MDCR (cpm)
0" Shielded	Measurement Interval (min)	1	4,235	306	306	
		2	8,470	431	216	
		5	21,175	680	136	
	Scan Speed (cm/second)	15	4,235			380
		30	4,235			542
0" Unshielded	Measurement Interval (min)	1	4,900	329	329	
		2	9,800	463	232	
		5	24,500	731	146	
	Scan Speed (cm/second)	15	49,00			409
		30	49,00			583
2" Shielded	Measurement Interval (min)	1	4,215	305	305	
		2	8,430	430	215	
		5	21,075	678	136	
	Scan Speed (cm/second)	15	4,215			379
		30	4,215			540
2" Unshielded	Measurement Interval (min)	1	4,868	327	327	
		2	9,736	462	231	
		5	24,340	728	146	
	Scan Speed (cm/second)	15	4,868			407
		30	4,868			581
6" Shielded	Measurement Interval (min)	1	4190	304	304	
		2	8380	429	215	
		5	21950	676	135	
	Scan Speed (cm/second)	15	4190			378
		30	4190			539
24" Unshielded	Measurement Interval (min)	1	4,622	319	319	
		2	9,264	451	226	
		5	23,160	711	142	
	Scan Speed (cm/second)	15	4,622			397
		30	4,622			566

5-3 RESULTS OF DERIVED DETECTION LIMITATION.

According to the discussion above, the L_D for different counting times and MDCR for different scan speeds are calculated according to the background counting rates listed in Table 3. All the results are listed in Table 4.

From Table 4, it can be seen that the limits of shielded cases are very close, no matter the detector height. The same can be said for the unshielded cases. Based on this fact, Table 4 can be simplified to Table 5. In Table 5, the limits are categorized by shielded and unshielded. For each category, the limit with the largest value from the three heights under each category is reported.

Table 5
Reported Detection Limit

	L_D (Counts)			MDCR (cpm)	
	1 min	**2 min**	**5 min**	**15cm/second**	**30cm/second**
Shielded	306	431	680	380	542
Unshielded	329	463	731	409	583

6 CONTAMINATION

In TM 03-14, to determine the total amount of radioactivity, it was assumed that contamination at the level of either 1 FMPC or 3 FMPC was uniformly distributed throughout the entire concrete block. In this TM, this assumption is still valid and it will be denoted as Assumed Total Activity (ATA). The ATA for different enrichments will be different.

In TM03-14, all the ATA was assigned to a 1cm-contamination layer on the bottom surface. This assumption is also valid in this TM.

However, in this TM, the contamination layer will be assigned to the top surface of the concrete block (least conservative case), bottom surface of concrete block (most conservative case) and randomly assigned within the concrete block (most realistic case).

In this TM, total-U is the only contaminant of concern. The enrichment of U-235 will be the key factor affecting the activity distribution. Four enrichments were selected for modeling and they are listed in Table 5 along with the reason for selection.

If the enrichment of U-235 is known, the activity percentage of each nuclide in the uranium family can be determined. Once the activity for each nuclide is known, the ATA can be calculated by MICROSHIELD code. The results of these calculations are also listed in Table 6.

Table 6
Activity Distribution of Uranium Based on Enrichment At 1.0 FMPC

Enrichment of U-235 (%)	Reason for Being Selected	Activity Percentage(%)*			Activity **(pCi/g)			Gamma Emit Rate (γs/second)
		U-234	U-235	U-238	U-234	U-235	U-238	
8.08	Maximum in Table 1	91.4	3.29	5.3	27.4	0.9	1.7	32,702
3.54	Average in Table 1	82.1	3.18	13.5	24.6	2.1	8.9	39,010
1.04	Minimum in Table 1	59.83	2.57	37.68	3.5	1.7	24.8	54,670
0.72	Natural Uranium	49	2	49	14.34	1.32	14.34	60,980

* The activity percentage for each nuclide at enrichment 3.54 is calculated from the equations in Figure 1. The activity percentage for each nuclide at enrichment of 8.08 and 1.03 are measurements results from Table 1.
** Under the 1 FMPC Uranium Only assumption, the total Uranium will be 30 pCi/g. This value will be used to multiply the activity percentage of each nuclide.

7 SIMULATION RESULTS FOR CONTAMINATED CONCRETE

7-1 CONTAMINATION LAYER LOCATED ON TOP SURFACE OF CONCRETE

In this case, the 1-cm thickness of contamination is located at the top surface of the concrete block. The ATA will be evenly distributed within this layer. Figure 3 illustrates the location of the contamination layer.

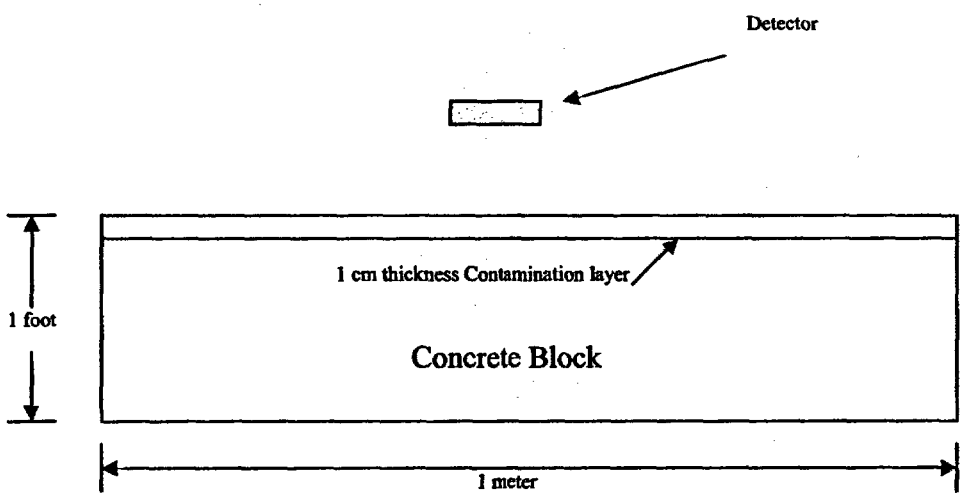


Figure 3
Illustration of Contamination on Top Surface

Table 7 shows the simulation results for this case. Table 7(a) gives the results for 1 FMPC contamination level and Table 7(b) gives the results for 3 FMPC level.

Table 7(a)*

Simulation Results for 1FMPC Total Uranium Only Contamination On Top Surface

Enrichment(%)	0" Shielded	0" Unshielded	2" Shielded	2" Unshielded	6" Shielded	24" Unshielded
8.8	2,989	5,359	2,968	4,882	2,762	1,451
3.54	3,884	6,764	3,827	6,142	3,496	1,791
1.04	6,320	10,470	6,135	9,463	5,426	2,696
0.72	7,121	12,074	7,121	10,876	6,337	3,091

*All units cpm.

Table 7(b)*

Simulation Results for 3FMPC Total Uranium Only Contamination On Top Surface

Enrichment(%)	0" Shielded	0" Unshielded	2" Shielded	2" Unshielded	6" Shielded	24" Unshielded
8.8	8,966	16,077	8,904	14,647	8,287	4,352
3.54	11,653	20,293	11,480	18,426	10,488	5,372
1.04	18,959	31,409	18,404	28,388	16,278	8,089
0.72	21,362	36,222	21,362	32,628	19,011	9,273

*All units cpm.

Comparison of the results in Table 7 with Table 4 show that the contamination can be detected at all enrichments and by all detector types and measurement techniques, whether direct measurement or scan survey.

7-2 CONTAMINATION LAYER LOCATED AT BOTTOM SURFACE OF CONCRETE

In this case, the 1-cm thickness of contamination layer is located at the bottom surface of the concrete block. The ATA will be evenly distributed within this layer. Figure 4 illustrates the location of the contamination layer.

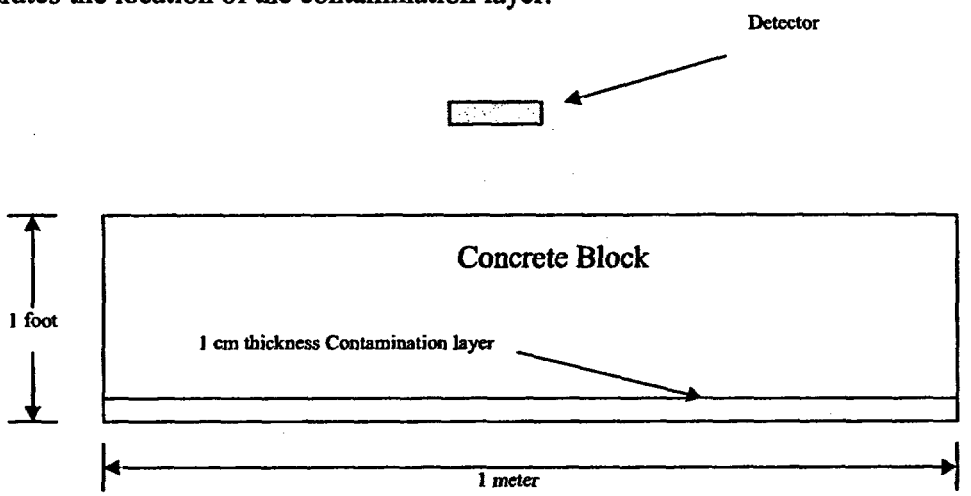


Figure 4
Illustration of Contamination on Bottom Surface

Table 8 shows the simulation results for this case. Table 8(a) gives the results for 1 FMPC contamination level and Table 8(b) gives the results for 3 FMPC level.

Table 8(a)*

Simulation Results for 1FMPC Total Uranium Only Contamination On Bottom Surface

Enrichment(%)	0" Shielded	0" Unshielded	2" Shielded	2" Unshielded	6" Shielded	24" Unshielded
8.8	6	10	6	10	5	6
3.54	13	20	12	20	15	13
1.04	35	47	35	51	32	28
0.72	48	63	46	67	43	35

* All Units cpm

Table 8(b)*

Simulation Results for 3FMPC Total Uranium Only Contamination On Bottom Surface

Enrichment(%)	0" Shielded	0" Unshielded	2" Shielded	2" Unshielded	6" Shielded	24" Unshielded
8.8	19	31	19	31	14	17
3.54	39	60	36	59	45	38
1.04	106	140	104	152	96	83
0.72	145	189	138	200	130	105

* All Units cpm

Comparison of the results in Table 8 with Table 4 shows enriched uranium at the modified concentrations cannot be reliably detected on the bottom surface except in the case of using the unshielded detector at 2" above the surface for a 5 minute measurement. Natural Uranium sensitivity is acceptable for all static configurations except the 6" shielded and 24" unshielded.

7-3 CONTAMINATION RANDOMLY ASSIGNED TO THE CONCRETE BLOCK.

The discussion above assumed the contamination layer was either at the top or bottom of the concrete. Neither of these two cases are realistic. From TM 03-14, it is known that the concrete debris will be broken into small chunks and any chunks that are larger than 16" x 16" will be removed. Any remaining chunks will be dumped into a "wind row." Under this arrangement, the contamination layer will be randomly distributed within the concrete "wind row."

To construct the random distribution model, the concrete block was divided into 27 cells, which is illustrated in Figure 5(a). Number 1 to 6 are assigned to each surface of each cell as shown in Figure 5(b). MS EXCEL was then used to randomly select contamination surfaces for each of 27 cells according to Equation 4.

Equation 4

$$\text{Random Surface Number} = \text{INT}(\text{RAND}()*6+1)$$

Then the ATA was assigned to the 27 randomly selected 1 cm thick surfaces.

For the random case, use of the average results from several model runs will give a better estimate of the mean than if only a single model result is used. The ideal case is to run 30 random models or more and then take the average of these 30 simulation results. However, this is not practicable since there are 4 detector configurations (2" shielded, 2" unshielded, 6" shielded and 24" unshielded) and 4 enrichment arrangements (0.72%, 1.04%, 3.54%, and 8.8%), their combinations would require a total of 480 separate model runs.

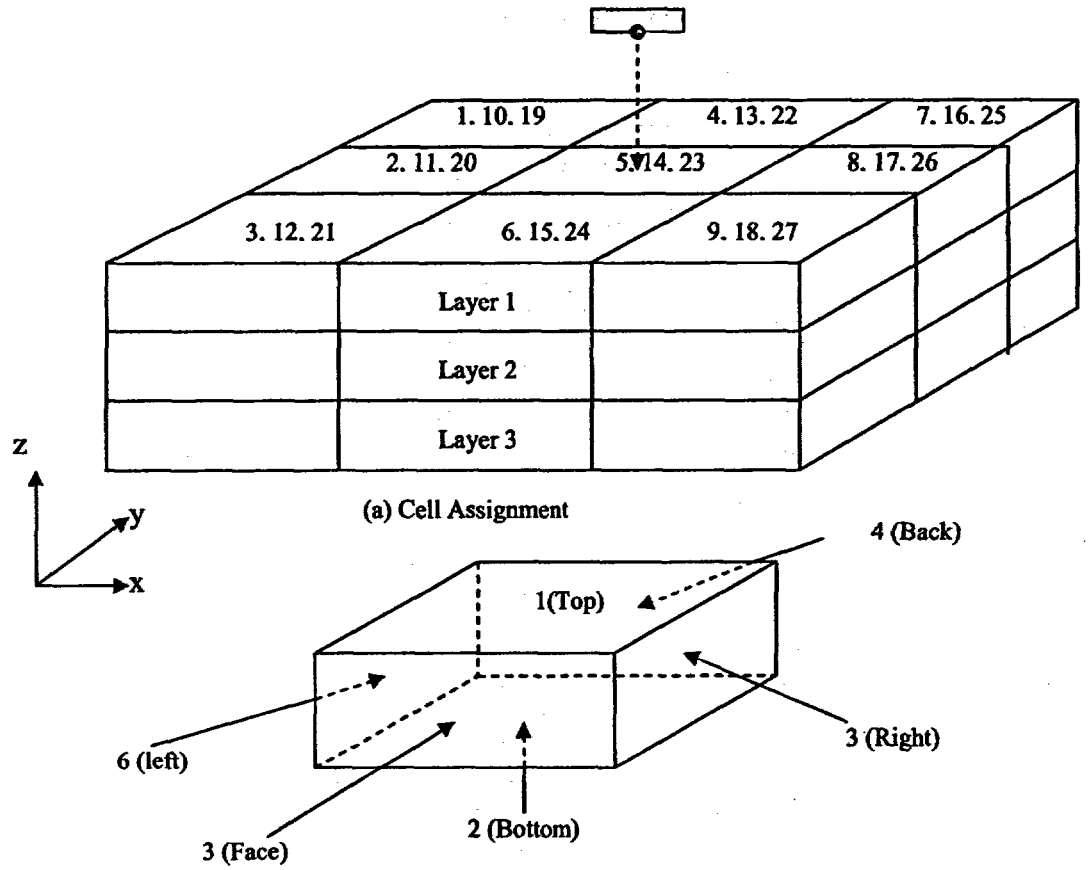


Figure 5
Illustration of Random Distribution of Contamination

To simplify the process, the following procedure was adopted:

1) One random model (baseline) was run for each case. This gave a simulation result for each enrichment case. This random model was called random model-00.

2) Because 3.54% enrichment was the average concrete enrichment, it was selected as the basis for running the 30 random models.

3) For contamination with 3.54% enrichment, 30 random models were run for each of the 4 detector configurations. These models were called random models 01-30 for each configuration.

4) The average result of these 30 random models were then compared with the result from baseline random model-00. The comparison result, i.e., average-to-00 ratio, was then applied to all the other 00 (baseline) results so that corrected results could be obtained for each enrichment. These corrected results were then reported as simulation results.

Table 9 shows the simulation results for the baseline cases. Table 9(a) gives the results for 1 FMPC contamination level and Table 9(b) gives the results for 3 FMPC level.

Table 9(a)*

Simulation Results for 1FMPC Total Uranium Only Contamination Randomly Distributed in the Concrete Block (Baseline Case)

Enrichment(%)	0" Shielded	0" Unshielded	2" Shielded	2" Unshielded	6" Shielded	24" Unshielded
8.8	153	283	216	455	370	313
3.54	237	409	323	623	487	407
1.04	492	767	618	1,100	854	657
0.72	611	931	741	1,299	1,032	772

* All results cpm

Table 9(b)*

Simulation Results for 3FMPC Total Uranium Only Contamination Randomly Distributed in the Concrete Block (Baseline Case)

Enrichment(%)	0" Shielded	0" Unshielded	2" Shielded	2" Unshielded	6" Shielded	24" Unshielded
8.8	460	850	647	1,364	1,109	938
3.54	711	1,227	968	1,869	1,462	1,222
1.04	1,476	2,301	1,854	3,299	2,561	1,972
0.72	1,833	2,792	2,224	3,897	3,095	2,316

* All results cpm

Table 10 shows the simulation results from model-01 to model-30. The bolded number in the row (Enrichment 3.54) is the average value from 30 random samples. All the other values are calculated values.

Table 10(a)*

Corrected Simulation Results for 1FMPC Total Uranium Only Contamination Randomly Distributed in the Concrete Block

Enrichment(%)	0" Shielded	0" Unshielded	2" Shielded	2" Unshielded	6" Shielded	24" Unshielded
8.8	201	329	255	495	411	260
3.54	310	475	382	678	542	338
1.04	644	891	731	1,197	950	546
0.72	799	1,081	877	1,414	1,148	641

* All results cpm

Table 10(b)*

Corrected Simulation Results for 3FMPC Total Uranium Only Contamination Randomly Distributed in the Concrete Block

Enrichment(%)	0" Shielded	0" Unshielded	2" Shielded	2" Unshielded	6" Shielded	24" Unshielded
8.8	602	987	765	1,484	1,234	779
3.54	929	1,425	1,145	2,034	1,627	1,015
1.04	1,931	2,672	2,193	3,590	2,850	1,638
0.72	2,398	3,243	2,630	4,241	3,445	1,923

* All results cpm

Table 10 shows that the 2" unshielded configuration is the best configuration within the six selections. The most difficult case is for 8.8 enrichment. For this case, the predicted counting rate is 495 cpm. This value is larger than the MDCR of 407 with a 15cm/second scan speed. This means if a 15cm/second scan speed is adopted, every enrichment combination can be detected.

The 6" shielded configuration is presently used on site. The results show that the15cm/second scan speed is adequate for detecting 1 FMPC at all enrichments.

An evaluation was performed to evaluate the random partitioning of the contamination. It was found that the values in the Table 10 may be somewhat underestimated due to the following two facts.

One is from the random model itself. For 30 random models, each model has 27 cells. Each cell is assigned a surface number. So, 810 surfaces are selected in total. Figure 6 shows the frequency plot for surface selection. (The arrangement of each surface are listed in Appendix B) Figure 6 shows that the appearances of each surface follows the Binomial distribution. If the probability of each surface appears is equal, the probability for each surface is 1/6=0.17. According to the properties of the binomial distribution, the expected number of appearances should be the total number of samples, (810 in this case) times the associated probability, and should be 135. The standard deviation (1 σ) should be the square root of 135 x (1-0.17) and equal to 10. From appendix B, the number of appearances for each surface, 1 to 6 are: 125, 156, 132, 136, 121 and 140. This result shows that each surface appears evenly from a statistic viewpoint (i.e. within expected statistical deviation).

Figure 6 also shows that surface 2 appears more than the other surfaces. Because surface 2 is at the bottom of each cell, the results from these 30 samples potentially underestimate the counting rate to a small degree.

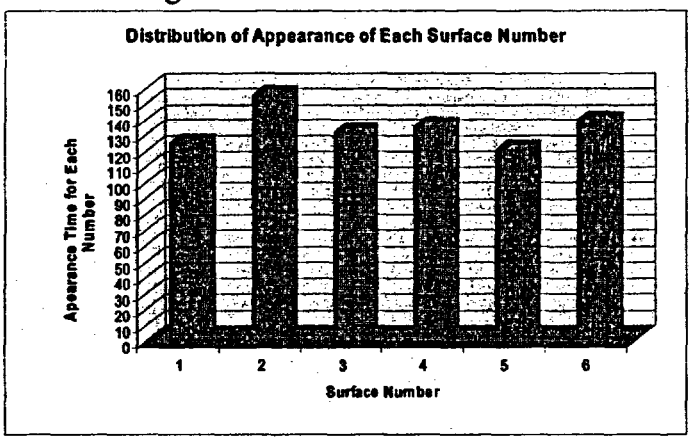


Figure 6
Appearance Frequency for the Contaminated Surface

The second factor is that Thorium was not considered in these models. From Table 1, it can be seen that, although some samples show that there is no Thorium in those samples, the average of total Thorium is about 5 pCi/g. This will contribute 0.5 FMPC to the total contamination. So the counting rate will be larger than those listed in Table 9. Thorium is much easier to detect than Uranium as has been documented in TM 03-14.

Table 11 shows the summary of analysis of 30 random samples for each detector configuration. The detailed data and statistic summary are listed in Appendix C.

Appendix C lists the MCNP simulation results from the 30 sample runs in the left hand columns. The simulated cpm is the modeled count rate at an enrichment of 3.54% and at 1.0 FMPC total uranium above background. In the center of each data summary there is a statistical analysis. The mean count rate can also be found in Table 10(a). At the bottom of each summary page are rows labeled "Limit," "# > limit," and "% > limit." The "Limit" row is equivalent to the highest L_D or MDCR for shielded or unshielded detectors, as applicable from Table 4. The "# > limit" is equal to the number of measurements above the L_D or MDCR, as applicable, for the count time or scan rate of interest. The "% > limit" is equal to the percentage of measurements above the L_D or MDCR, as applicable, for the count time or scan rate of interest.

Table 11
Summary of Analysis of 30 Random Samples (Assumes 3.54% Enrichment)

		Direct Measurement			Scan Survey	
		1 min	2 min	5 min	15 cm/sec	30 cm/sec
0" Shielded	# > limit	4	11	15	N/A	N/A
	%(> limit)	13.3	36.7	50.0	N/A	N/A
0" Unshielded	# > limit	11	17	30	N/A	N/A
	%(> limit)	36.7	56.7	100.0	N/A	N/A
2" Shielded	# > limit	13	26	30	6	3
	%(> limit)	43.3	86.7	100.0	20.0	10.0
2" Unshielded	# > limit	30	30	30	27	17
	%(> limit)	100	100	100	90	56.7
6" Shielded	# > limit	29	30	30	26	11
	%(> limit)	96.7	100	100	86.7	36.7
24" Unshielded	# > limit	24	29	30	5	0
	%(> limit)	80.0	96.7	100	16.7	0

Table 11 shows that for the average enrichment, the 2" unshielded detector configuration has more advantages than other detector configurations. First, for direct measurements, 1 minute is sufficient to detect contamination at 1 FMPC in all cases in the "wind row." Second, if a 15 cm/second scan speed is adopted, the possibility of detecting the contamination by scan survey is larger than 90%.

Table 11 also shows that the 6" shielded configuration is a good choice. 2-minute direct measurements can guarantee finding the contamination at 1 FMPC in the "wind row." Use of a15cm/second scan speed will allow for an 87% success rate in locating contamination at 1 FMPC during scans.

Table 11 suggests that the 2" shielded and 24" unshielded configurations may not be used for scan surveys.

Appendix D contains a listing of all files used to generate this TM. Copies of all files will be maintained by NEXTEP as proprietary material for review as required.

8 CONCLUSIONS

1) If uranium contamination is located on the top surface of a concrete layer, it can be detected using a 3" x 0.5" NaI detector (all configurations).
2) Uranium contamination located on the bottom surface of concrete cannot be detected with confidence.
3) For the general case, if the contamination is randomly distributed on the surface of concrete chunks, it can be detected.
4) The 2" unshielded and 6" Shielded configurations can provide guaranteed detection of uranium at 1 FMPC average concentration and 3.54% enrichment for direct surveys with appropriate measurement time selection and are satisfactory

for on-site survey methods for uranium. For scan surveys, a 15 cm/second scan speed is recommended to obtain up to 87% sensitivity.

9 RECOMMENDATIONS

1) Use of the shielded 3" x 0.5" NaI detector configuration is recommended for scans at a height of 6" above the surface of the concrete. Scans should be performed at a maximum scan speed of 15 cm/sec.
2) Direct measurements at 6" above the surface (shielded detector) should be performed at intervals to provide additional assurance of detecting any spots containing enriched uranium materials. A grid encompassing one survey point each 2-3 meters along the linear window axis would provide over 300 survey points.
3) Samples of the concrete should be collected if any direct measurement exceeds 540 cpm above background plus 2 sigma, which is equivalent to the counts from uranium at 3.54 % enrichment at an average concentration of 1 FMPC. For direct measurements using the 3" x ½" shielded NaI detector, Table 3 gives an *a priori* background of 4,190 cpm. Two sigma of background is 130 cpm. Therefore, the *a priori* threshold for sampling is established as **4850 cpm**. Adjustments can be made in the field as appropriate based upon the actual measured background and/or differences in enrichment or presence of thorium. The decision to dispose of materials rather than perform sampling should be left to the managers discretion.

Appendix A

MICROSHIELD Output

APPENDIX A. MICROSHIELD OUTPUT.

A-1 Background
A-2 Enrichment 0.72
A-3 Enrichment 1.04
A-4 Enrichment 3.54
A-5 Enrichment 8.8

The results from these output are listed as follows:

1. Background
   Block Dimension: 4 meter x 4 meter x 1 foot
   Density: 2.2g/cm^3

	K-40	Ra-226	Th-232	U-235	U-238	Total
Density Activity (pCi/g)	1.89	0.6	0.216	0.0049	0.675	
Gammas/s	80,050	547,700	268,300	2,260	31,640	***929,950***

2. Number of photons from Contaminated Layer
   Layer Dimension: 1 meter x 1 meter x 1 foot
   Density: 2.2 g/cm^3
   Contaminated Level: 1 FMPC Uranium Only (30pCi/g Total Uranium)

Enrichment (%)	Activity Percentage (%)		Gamma Flux (γ's/second)		Total (γ's/second)
	U-235	U-238	U-235	U-238	
8.8	3.29	5.3	28,120	4,652	***32,772***
3.54	3.18	13.5	27,210	11,800	***39,010***
1.04	2.57	37.68	21,630	33,040	***54,670***
0.72	49	2	17,090	43,890	***60,980***

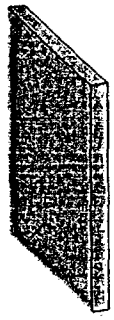
A-1 Background

MicroShield v5.03 (5.03-00027)
NEXTEP ENVIRONMENTAL INC.

Page : 1
DOS File : CONB226.MS5
Run Date : August 13, 2003
Run Time : 2:24:04 PM
Duration : 00:00:01

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

Case Title: Background-K40
Description: Case 1
Geometry: 13 - Rectangular Volume



Source Dimensions

Length	30.48 cm	1 ft
Width	400.0 cm	13 ft 1.5 in
Height	400.0 cm	13 ft 1.5 in

Dose Points

	X	Y	Z
# 1	35.56 cm	200 cm	200 cm
	1 ft 2.0 in	6 ft 6.7 in	6 ft 6.7 in

Shields

Shield Name	Dimension	Material	Density
Source	4.88e+06 cm³	Concrete	2.2
Air Gap		Air	0.00122

Source Input
Grouping Method : Actual Photon Energies

Nuclide	curies	becquerels	µCi/cm³	Bq/cm³
Ac-227				
Ac-228				
Bi-210				
Bi-211				
Bi-212				
Bi-214				
Fr-223				
K-40	2.0278e-005	7.5028e+005	4.1580e-006	1.5385e-001
Pa-231				
Pa-234				
Pa-234m				
Pb-210				
Pb-211				
Pb-212				
Pb-214				
Po-210				
Po-211				
Po-212				
Po-214				
Po-215				
Po-216				
Po-218				

Page : 2
DOS File : CONB226.MS5
Run Date: August 13, 2003
Run Time: 2:24:04 PM
Duration : 00:00:01

Nuclide	curies	becquerels	µCi/cm³	Bq/cm³
Ra-223				
Ra-224				
Ra-226				
Ra-228				
Rn-219				
Rn-220				
Rn-222				
Th-227				
Th-228				
Th-230				
Th-231				
Th-232				
Th-234				
Tl-207				
Tl-208				
U-234				
U-235				
U-238				

Buildup
The material reference is : Source

Integration Parameters

X Direction	10
Y Direction	20
Z Direction	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
1.4608	8.005e+04	1.011e-01	1.929e-01	1.714e-04	3.269e-04
TOTALS:	8.005e+04	1.011e-01	1.929e-01	1.714e-04	3.269e-04

MicroShield v5.03 (5.03-00027)
NEXTEP ENVIRONMENTAL INC.

Page : 1
DOS File : CONB226.MS5
Run Date: August 13, 2003
Run Time: 2:22:21 PM
Duration : 00:00:04

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

Case Title: Background-226
Description: Case 1
Geometry: 13 - Rectangular Volume

Source Dimensions

Length	30.48 cm	1 ft
Width	400.0 cm	13 ft 1.5 in
Height	400.0 cm	13 ft 1.5 in

Dose Points

	X	Y	Z
# 1	35.56 cm	200 cm	200 cm
	1 ft 2.0 in	6 ft 6.7 in	6 ft 6.7 in

Shields

Shield Name	Dimension	Material	Density
Source	4.88e+06 cm³	Concrete	2.2
Air Gap		Air	0.00122

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

Nuclide	curies	becquerels	µCi/cm³	Bq/cm³
Ac-227				
Ac-228				
Bi-210	3.8746e-006	1.4336e+005	7.9449e-007	2.9396e-002
Bi-211				
Bi-212				
Bi-214	6.3530e-006	2.3506e+005	1.3027e-006	4.8200e-002
Fr-223				
Pa-231				
Pa-234				
Pa-234m				
Pb-210	3.8761e-006	1.4342e+005	7.9481e-007	2.9408e-002
Pb-211				
Pb-212				
Pb-214	6.3530e-006	2.3506e+005	1.3027e-006	4.8200e-002
Po-210	3.8317e-006	1.4177e+005	7.8569e-007	2.9071e-002
Po-211				
Po-212				
Po-214	6.3517e-006	2.3501e+005	1.3024e-006	4.8190e-002

Page : 2
DOS File : CONB226.MS5
Run Date : August 13, 2003
Run Time : 2:22:21 PM
Duration : 00:00:04

Nuclide	curies	becquerels	µCi/cm³	Bq/cm³
Po-215				
Po-216				
Po-218	6.3543e-006	2.3511e+005	1.3030e-006	4.8210e-002
Ra-223				
Ra-224				
Ra-226	6.3543e-006	2.3511e+005	1.3030e-006	4.8209e-002
Ra-228				
Rn-219				
Rn-220				
Rn-222	6.3543e-006	2.3511e+005	1.3030e-006	4.8210e-002
Th-227				
Th-228				
Th-230				
Th-231				
Th-232				
Th-234				
Tl-207				
Tl-208				
U-234				
U-235				
U-238				

Buildup
The material reference is : Source

Integration Parameters

X Direction	10
Y Direction	20
Z Direction	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
0.05	8.407e+03	4.132e-05	7.661e-05	1.101e-07	2.041e-07
0.08	5.419e+04	8.989e-04	2.490e-03	1.423e-06	3.941e-06
0.1	3.191e+02	8.053e-06	2.480e-05	1.232e-08	3.794e-08
0.2	2.532e+04	1.818e-03	5.784e-03	3.209e-06	1.021e-05
0.3	4.851e+04	6.134e-03	1.797e-02	1.164e-05	3.408e-05
0.4	8.995e+04	1.705e-02	4.638e-02	3.322e-05	9.038e-05
0.5	4.199e+03	1.093e-03	2.791e-03	2.146e-06	5.479e-06
0.6	1.133e+05	3.835e-02	9.280e-02	7.486e-05	1.811e-04
0.8	2.221e+04	1.143e-02	2.552e-02	2.174e-05	4.855e-05
1.0	7.360e+04	5.268e-02	1.108e-01	9.710e-05	2.042e-04

Page : 3
DOS File : CONB226.MS5
Run Date: August 13, 2003
Run Time: 2:22:21 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
1.5	4.475e+04	5.883e-02	1.115e-01	9.897e-05	1.877e-04
2.0	6.291e+04	1.271e-01	2.265e-01	1.966e-04	3.503e-04
TOTALS:	5.477e+05	3.155e-01	6.427e-01	5.411e-04	1.116e-03

MicroShield v5.03 (5.03-00027)
NEXTEP ENVIRONMENTAL INC.

Page : 1
DOS File : CONB226.MS5
Run Date: August 13, 2003
Run Time: 2:21:14 PM
Duration : 00:00:06

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

Case Title: Background-232
Description: Case 1
Geometry: 13 - Rectangular Volume

Source Dimensions

Length	30.48 cm	1 ft
Width	400.0 cm	13 ft 1.5 in
Height	400.0 cm	13 ft 1.5 in

Dose Points

	X	Y	Z
# 1	35.56 cm	200 cm	200 cm
	1 ft 2.0 in	6 ft 6.7 in	6 ft 6.7 in

Shields

Shield Name	Dimension	Material	Density
Source	4.88e+06 cm³	Concrete	2.2
Air Gap		Air	0.00122

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

Nuclide	curies	becquerels	µCi/cm³	Bq/cm³
Ac-227				
Ac-228	2.2552e-006	8.3441e+004	4.6243e-007	1.7110e-002
Bi-210				
Bi-211				
Bi-212	2.2239e-006	8.2285e+004	4.5602e-007	1.6873e-002
Bi-214				
Fr-223				
Pa-231				
Pa-234				
Pa-234m				
Pb-210				
Pb-211				
Pb-212	2.2239e-006	8.2286e+004	4.5602e-007	1.6873e-002
Pb-214				
Po-210				
Po-211				
Po-212	1.4249e-006	5.2720e+004	2.9217e-007	1.0810e-002
Po-214				

Page : 2
DOS File : CONB226.MS5
Run Date : August 13, 2003
Run Time : 2:21:14 PM
Duration : 00:00:06

Nuclide	curies	becquerels	µCi/cm³	Bq/cm³
Po-215				
Po-216	2.2240e-006	8.2286e+004	4.5603e-007	1.6873e-002
Po-218				
Ra-223				
Ra-224	2.2240e-006	8.2286e+004	4.5603e-007	1.6873e-002
Ra-226				
Ra-228	2.2552e-006	8.3441e+004	4.6243e-007	1.7110e-002
Rn-219				
Rn-220	2.2240e-006	8.2286e+004	4.5603e-007	1.6873e-002
Rn-222				
Th-227				
Th-228	2.2241e-006	8.2292e+004	4.5606e-007	1.6874e-002
Th-230				
Th-231				
Th-232	2.3175e-006	8.5746e+004	4.7520e-007	1.7582e-002
Th-234				
Tl-207				
Tl-208	7.9906e-007	2.9565e+004	1.6385e-007	6.0624e-003
U-234				
U-235				
U-238				

Buildup
The material reference is : Source

Integration Parameters

X Direction	10
Y Direction	20
Z Direction	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
0.04	8.414e+02	1.843e-06	2.878e-06	8.153e-09	1.273e-08
0.06	5.813e+02	4.895e-06	1.099e-05	9.724e-09	2.183e-08
0.08	3.554e+04	5.894e-04	1.633e-03	9.328e-07	2.584e-06
0.1	5.913e+03	1.492e-04	4.595e-04	2.283e-07	7.030e-07
0.15	3.505e+03	1.671e-04	5.455e-04	2.751e-07	8.984e-07
0.2	4.476e+04	3.214e-03	1.022e-02	5.672e-06	1.804e-05
0.3	2.168e+04	2.741e-03	8.029e-03	5.200e-06	1.523e-05
0.4	1.973e+03	3.740e-04	1.017e-03	7.288e-07	1.982e-06
0.5	1.148e+04	2.989e-03	7.630e-03	5.867e-06	1.498e-05
0.6	2.618e+04	8.860e-03	2.144e-02	1.729e-05	4.184e-05

Page : 3
DOS File : CONB232.MS5
Run Date: August 26, 2003
Run Time: 2:20:41 PM
Duration : 00:00:05

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
0.8	2.636e+04	1.356e-02	3.029e-02	2.580e-05	5.761e-05
1.0	4.857e+04	3.477e-02	7.311e-02	6.408e-05	1.348e-04
1.5	1.115e+04	1.466e-02	2.780e-02	2.466e-05	4.677e-05
2.0	2.509e+02	5.072e-04	9.035e-04	7.843e-07	1.397e-06
3.0	2.951e+04	1.081e-01	1.769e-01	1.467e-04	2.400e-04
TOTALS:	2.683e+05	1.907e-01	3.600e-01	2.983e-04	5.768e-04

MicroShield v5.03 (5.03-00027)
NEXTEP ENVIRONMENTAL INC.

Page : 1
DOS File : CONB226.MS5
Run Date: August 13, 2003
Run Time: 2:16:32 PM
Duration : 00:00:06

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

Case Title: Background-235
Description: Case 1
Geometry: 13 - Rectangular Volume

Source Dimensions

Length	30.48 cm	1 ft
Width	400.0 cm	13 ft 1.5 in
Height	400.0 cm	13 ft 1.5 in

Dose Points

	X	Y	Z
# 1	35.56 cm	200 cm	200 cm
	1 ft 2.0 in	6 ft 6.7 in	6 ft 6.7 in

Shields

Shield Name	Dimension	Material	Density
Source	4.88e+06 cm³	Concrete	2.2
Air Gap		Air	0.00122

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

Nuclide	curies	becquerels	µCi/cm³	Bq/cm³
Ac-227	2.9845e-010	1.1043e+001	6.1198e-011	2.2643e-006
Ac-228				
Bi-210				
Bi-211	2.9832e-010	1.1038e+001	6.1171e-011	2.2633e-006
Bi-212				
Bi-214				
Fr-223	4.1186e-012	1.5239e-001	8.4454e-013	3.1248e-008
Pa-231	3.3326e-010	1.2330e+001	6.8335e-011	2.5284e-006
Pa-234				
Pa-234m				
Pb-210				
Pb-211	2.9832e-010	1.1038e+001	6.1171e-011	2.2633e-006
Pb-212				
Pb-214				
Po-210				
Po-211	8.1441e-013	3.0133e-002	1.6700e-013	6.1789e-009
Po-212				
Po-214				

Page : 2
DOS File : CONB226.MS5
Run Date: August 13, 2003
Run Time: 2:16:32 PM
Duration : 00:00:06

Nuclide	curies	becquerels	µCi/cm³	Bq/cm³
Po-215	2.9832e-010	1.1038e+001	6.1171e-011	2.2633e-006
Po-216				
Po-218				
Ra-223	2.9832e-010	1.1038e+001	6.1171e-011	2.2633e-006
Ra-224				
Ra-226				
Ra-228				
Rn-219	2.9832e-010	1.1038e+001	6.1171e-011	2.2633e-006
Rn-220				
Rn-222				
Th-227	2.9425e-010	1.0887e+001	6.0337e-011	2.2325e-006
Th-228				
Th-230				
Th-231	5.2669e-008	1.9488e+003	1.0800e-008	3.9960e-004
Th-232				
Th-234				
Tl-207	2.9751e-010	1.1008e+001	6.1004e-011	2.2572e-006
Tl-208				
U-234				
U-235	5.2669e-008	1.9488e+003	1.0800e-008	3.9960e-004
U-238				

Buildup
The material reference is : Source

Integration Parameters

X Direction	10
Y Direction	20
Z Direction	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
0.015	3.670e+00	7.847e-14	8.527e-14	6.730e-15	7.314e-15
0.02	6.609e-02	8.529e-13	9.770e-13	2.954e-14	3.384e-14
0.03	2.867e+02	1.556e-07	2.042e-07	1.542e-09	2.024e-09
0.04	4.341e-02	9.511e-11	1.485e-10	4.207e-13	6.568e-13
0.05	1.011e+00	4.971e-09	9.217e-09	1.324e-11	2.455e-11
0.06	9.287e+00	7.822e-08	1.756e-07	1.554e-10	3.488e-10
0.08	2.342e+02	3.885e-06	1.076e-05	6.148e-09	1.703e-08
0.1	2.057e+02	5.190e-06	1.598e-05	7.941e-09	2.445e-08
0.15	3.047e+02	1.452e-05	4.743e-05	2.392e-08	7.810e-08
0.2	1.204e+03	6.648e-05	2.751e-04	1.526e-07	4.855e-07

Page : 3
DOS File : CONB235.MS5
Run Date: August 26, 2003
Run Time: 2:20:12 PM
Duration : 00:00:06

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
0.3	6.731e+00	8.512e-07	2.493e-06	1.615e-09	4.729e-09
0.4	2.859e+00	5.419e-07	1.474e-06	1.056e-09	2.872e-09
0.5	5.430e-02	1.414e-08	3.609e-08	2.776e-11	7.085e-11
0.6	1.621e-04	5.486e-11	1.327e-10	1.071e-13	2.591e-13
0.8	4.433e-01	2.281e-07	5.094e-07	4.339e-10	9.689e-10
TOTALS:	2.260e+03	1.119e-04	3.542e-04	1.955e-07	6.161e-07

MicroShield v5.03 (5.03-00027)
NEXTEP ENVIRONMENTAL INC.

Page : 1
DOS File : CONB226.MS5
Run Date: August 13, 2003
Run Time: 2:19:43 PM
Duration : 00:00:06

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

Case Title: Background-238
Description: Case 1
Geometry: 13 - Rectangular Volume

Source Dimensions

Length	30.48 cm	1 ft
Width	400.0 cm	13 ft 1.5 in
Height	400.0 cm	13 ft 1.5 in

Dose Points

	X	Y	Z
# 1	35.56 cm	200 cm	200 cm
	1 ft 2.0 in	6 ft 6.7 in	6 ft 6.7 in

Shields

Shield Name	Dimension	Material	Density
Source	4.88e+06 cm³	Concrete	2.2
Air Gap		Air	0.00122

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

Nuclide	curies	becquerels	µCi/cm³	Bq/cm³
Ac-227				
Ac-228				
Bi-210	6.9200e-017	2.5604e-006	1.4190e-017	5.2502e-013
Bi-211				
Bi-212				
Bi-214	3.5509e-016	1.3138e-005	7.2813e-017	2.6941e-012
Fr-223				
Pa-231				
Pa-234	1.1587e-008	4.2873e+002	2.3760e-009	8.7912e-005
Pa-234m	7.2420e-006	2.6796e+005	1.4850e-006	5.4945e-002
Pb-210	6.9377e-017	2.5669e-006	1.4226e-017	5.2636e-013
Pb-211				
Pb-212				
Pb-214	3.5510e-016	1.3139e-005	7.2814e-017	2.6941e-012
Po-210	6.4588e-017	2.3898e-006	1.3244e-017	4.9003e-013
Po-211				
Po-212				
Po-214	3.5502e-016	1.3136e-005	7.2798e-017	2.6935e-012

Page : 2
DOS File : CONB238.MS5
Run Date: August 26, 2003
Run Time: 3:45:38 PM
Duration : 00:00:06

Nuclide	curies	becquerels	uCi/cm²	Bq/cm²
Po-215				
Po-216				
Po-218	3.4820e-013	1.2883e-002	7.1399e-014	2.6417e-009
Ra-223				
Ra-224				
Ra-226	3.4825e-013	1.2885e-002	7.1409e-014	2.6421e-009
Ra-228				
Rn-219				
Rn-220				
Rn-222	3.4820e-013	1.2883e-002	7.1399e-014	2.6417e-009
Th-227				
Th-228				
Th-230	8.3017e-012	3.0716e-001	1.7023e-012	6.2984e-008
Th-231				
Th-232				
Th-234	7.2420e-006	2.6796e+005	1.4850e-006	5.4945e-002
Tl-207				
Tl-208				
U-234	6.1547e-009	2.2772e+002	1.2620e-009	4.6695e-005
U-235				
U-238	7.2420e-006	2.6796e+005	1.4850e-006	5.4945e-002

Buildup
The material reference is : Source

Integration Parameters

X Direction	10
Y Direction	20
Z Direction	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
0.04	5.248e-01	1.150e-09	1.795e-09	5.085e-12	7.939e-12
0.05	2.692e-01	1.323e-09	2.454e-09	3.525e-12	6.536e-12
0.06	1.049e+04	8.833e-05	1.983e-04	1.755e-07	3.939e-07
0.08	3.809e+02	6.319e-06	1.760e-05	9.999e-09	2.770e-08
0.1	1.645e+04	4.151e-04	1.278e-03	6.350e-07	1.956e-06
0.15	1.352e+02	6.442e-06	2.104e-05	1.061e-08	3.464e-08
0.2	9.044e+01	6.494e-06	2.066e-05	1.146e-08	3.646e-08
0.3	3.114e+01	3.938e-06	1.153e-05	7.469e-09	2.188e-08
0.4	2.633e+01	4.991e-06	1.358e-05	9.725e-09	2.646e-08
0.5	3.910e+01	1.018e-05	2.599e-05	1.998e-08	5.101e-08

Page : 3
DOS File : CONB226.MS5
Run Date: August 13, 2003
Run Time: 2:19:43 PM
Duration : 00:00:06

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
0.6	1.597e+02	5.406e-05	1.308e-04	1.055e-07	2.553e-07
0.8	8.896e+02	4.578e-04	1.022e-03	8.707e-07	1.944e-06
1.0	2.844e+03	2.036e-03	4.281e-03	3.753e-06	7.892e-06
1.5	6.000e+01	7.887e-05	1.496e-04	1.327e-07	2.516e-07
2.0	7.740e+00	1.564e-05	2.787e-05	2.419e-08	4.310e-08
TOTALS:	3.160e+04	3.184e-03	7.199e-03	5.765e-06	1.293e-05

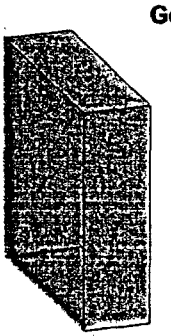
A-2 Enrichment 0.72

MicroShield v5.03 (5.03-00027)
NEXTEP ENVIRONMENTAL INC.

Page : 1
DOS File : RICH2354.MS5
Run Date: August 13, 2003
Run Time: 2:41:54 PM
Duration : 00:00:06

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

Case Title: NaU enrichment U235
Description: Case 1
Geometry: 13 - Rectangular Volume



Source Dimensions

Length	30.48 cm	1 ft
Width	100.0 cm	3 ft 3.4 in
Height	100.0 cm	3 ft 3.4 in

Dose Points

	X	Y	Z
# 1	35.56 cm	50 cm	50 cm
	1 ft 2.0 in	1 ft 7.7 in	1 ft 7.7 in

Shields

Shield Name	Dimension	Material	Density
Source	3.05e+05 cm³	Concrete	2.2
Air Gap		Air	0.00122

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

Nuclide	curies	becquerels	µCi/cm³	Bq/cm³
Ac-227	9.0833e-011	3.3608e+000	2.9801e-010	1.1026e-005
Bi-210				
Bi-211	9.0215e-011	3.3379e+000	2.9598e-010	1.0951e-005
Bi-214				
Fr-223	1.2535e-012	4.6379e-002	4.1125e-012	1.5216e-007
Pa-231	2.5527e-010	9.4448e+000	8.3749e-010	3.0987e-005
Pa-234				
Pa-234m				
Pb-210				
Pb-211	9.0215e-011	3.3379e+000	2.9598e-010	1.0951e-005
Pb-214				
Po-210				
Po-211	2.4629e-013	9.1126e-003	8.0803e-013	2.9897e-008
Po-214				
Po-215	9.0216e-011	3.3380e+000	2.9598e-010	1.0951e-005
Po-218				
Ra-223	9.0216e-011	3.3380e+000	2.9598e-010	1.0951e-005
Ra-226				

Page : 2
DOS File : RICH2354.MS5
Run Date : August 13, 2003
Run Time : 2:41:54 PM
Duration : 00:00:06

Nuclide	curies	becquerels	µCi/cm³	Bq/cm³
Rn-219	9.0216e-011	3.3380e+000	2.9598e-010	1.0951e-005
Rn-222				
Th-227	8.9198e-011	3.3003e+000	2.9264e-010	1.0828e-005
Th-230				
Th-231	4.0234e-007	1.4886e+004	1.3200e-006	4.8840e-002
Th-234				
Tl-207	8.9968e-011	3.3288e+000	2.9517e-010	1.0921e-005
U-234				
U-235	4.0234e-007	1.4886e+004	1.3200e-006	4.8840e-002
U-238				

Buildup
The material reference is : Source

Integration Parameters

X Direction	10
Y Direction	20
Z Direction	20

Results

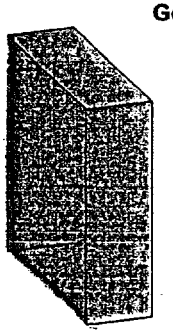
Energy MeV	Activity photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.015	2.800e+01	9.068e-12	9.817e-12	7.778e-13	8.420e-13
0.02	4.001e-02	5.961e-12	6.829e-12	2.065e-13	2.365e-13
0.03	2.182e+03	1.658e-05	2.199e-05	1.644e-07	2.179e-07
0.04	2.166e-02	7.075e-10	1.116e-09	3.129e-12	4.937e-12
0.05	3.185e-01	2.370e-08	4.430e-08	6.312e-11	1.180e-10
0.06	7.075e+01	9.047e-06	2.045e-05	1.797e-08	4.061e-08
0.08	1.748e+03	4.388e-04	1.201e-03	6.943e-07	1.901e-06
0.1	1.557e+03	5.921e-04	1.791e-03	9.059e-07	2.740e-06
0.15	2.319e+03	1.656e-03	5.278e-03	2.727e-06	8.692e-06
0.2	9.187e+03	9.850e-03	3.056e-02	1.738e-05	5.395e-05
0.3	2.491e+00	4.681e-06	1.338e-05	8.880e-09	2.539e-08
0.4	8.744e-01	2.455e-06	6.524e-06	4.783e-09	1.271e-08
0.5	1.642e-02	6.316e-08	1.576e-07	1.240e-10	3.094e-10
0.6	4.903e-05	2.444e-10	5.783e-10	4.771e-13	1.129e-12
0.8	1.341e-01	1.012e-06	2.209e-06	1.925e-09	4.202e-09
TOTALS:	1.709e+04	1.257e-02	3.890e-02	2.191e-05	6.758e-05

MicroShield v5.03 (5.03-00027)
NEXTEP ENVIRONMENTAL INC.

Page : 1
DOS File : RICH2384.MS5
Run Date: August 13, 2003
Run Time: 2:42:31 PM
Duration : 00:00:05

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

Case Title: NaU enrichment U238
Description: Case 1
Geometry: 13 - Rectangular Volume



Source Dimensions

Length	30.48 cm	1 ft
Width	100.0 cm	3 ft 3.4 in
Height	100.0 cm	3 ft 3.4 in

Dose Points

	X	Y	Z
# 1	35.56 cm	50 cm	50 cm
	1 ft 2.0 in	1 ft 7.7 in	1 ft 7.7 in

Shields

Shield Name	Dimension	Material	Density
Source	3.05e+05 cm³	Concrete	2.2
Air Gap		Air	0.00122

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

Nuclide	curies	becquerels	µCi/cm³	Bq/cm³
Bi-210	9.6112e-017	3.5561e-006	3.1533e-016	1.1667e-011
Bi-214	4.9319e-016	1.8248e-005	1.6181e-015	5.9868e-011
Pa-234	1.6093e-008	5.9546e+002	5.2800e-008	1.9536e-003
Pa-234m	1.0058e-005	3.7216e+005	3.3000e-005	1.2210e+000
Pb-210	9.6357e-017	3.5652e-006	3.1613e-016	1.1697e-011
Pb-214	4.9319e-016	1.8248e-005	1.6181e-015	5.9869e-011
Po-210	8.9706e-017	3.3191e-006	2.9431e-016	1.0890e-011
Po-214	4.9308e-016	1.8244e-005	1.6177e-015	5.9856e-011
Po-218	4.9329e-016	1.8252e-005	1.6184e-015	5.9881e-011
Ra-226	4.9404e-016	1.8279e-005	1.6209e-015	5.9972e-011
Rn-222	4.9329e-016	1.8252e-005	1.6184e-015	5.9881e-011
Th-230	1.1477e-013	4.2464e-003	3.7653e-013	1.3932e-008
Th-234	1.0058e-005	3.7216e+005	3.3000e-005	1.2210e+000
U-234	8.5270e-010	3.1550e+001	2.7976e-009	1.0351e-004
U-238	1.0058e-005	3.7216e+005	3.3000e-005	1.2210e+000

Buildup
The material reference is : Source

Page : 2
DOS File : RICH2384.MS5
Run Date: August 13, 2003
Run Time: 2:42:31 PM
Duration : 00:00:05

Integration Parameters

X Direction	10
Y Direction	20
Z Direction	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
0.04	7.288e-01	2.380e-08	3.756e-08	1.053e-10	1.661e-10
0.05	3.723e-02	2.770e-09	5.178e-09	7.378e-12	1.379e-11
0.06	1.457e+04	1.863e-03	4.210e-03	3.700e-06	8.362e-06
0.08	5.291e+02	1.328e-04	3.636e-04	2.102e-07	5.755e-07
0.1	2.284e+04	8.689e-03	2.628e-02	1.329e-05	4.020e-05
0.15	1.877e+02	1.341e-04	4.273e-04	2.208e-07	7.037e-07
0.2	1.256e+02	1.347e-04	4.179e-04	2.377e-07	7.375e-07
0.3	4.324e+01	8.127e-05	2.323e-04	1.542e-07	4.407e-07
0.4	3.656e+01	1.026e-04	2.728e-04	2.000e-07	5.315e-07
0.5	5.430e+01	2.088e-04	5.211e-04	4.099e-07	1.023e-06
0.6	2.219e+02	1.106e-03	2.617e-03	2.159e-06	5.108e-06
0.8	1.236e+03	9.328e-03	2.036e-02	1.774e-05	3.873e-05
1.0	3.950e+03	4.133e-02	8.488e-02	7.618e-05	1.565e-04
1.5	8.333e+01	1.588e-03	2.930e-03	2.671e-06	4.930e-06
2.0	1.075e+01	3.126e-04	5.401e-04	4.833e-07	8.351e-07
TOTALS:	4.389e+04	6.501e-02	1.441e-01	1.177e-04	2.586e-04

A-3 Enrichment 1.04

MicroShield v5.03 (5.03-00027)
NEXTEP ENVIRONMENTAL INC.

Page : 1
DOS File : RICH2353.MS5
Run Date: August 13, 2003
Run Time: 2:40:01 PM
Duration : 00:00:06

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

Case Title: 1.04% enrichment 235
Description: Case 1
Geometry: 13 - Rectangular Volume

Source Dimensions

Length	30.48 cm	1 ft
Width	100.0 cm	3 ft 3.4 in
Height	100.0 cm	3 ft 3.4 in

Dose Points

	X	Y	Z
# 1	35.56 cm	50 cm	50 cm
	1 ft 2.0 in	1 ft 7.7 in	1 ft 7.7 in

Shields

Shield Name	Dimension	Material	Density
Source	3.05e+05 cm³	Concrete	2.2
Air Gap		Air	0.00122

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

Nuclide	curies	becquerels	µCi/cm³	Bq/cm³
Ac-227	1.1490e-010	4.2514e+000	3.7698e-010	1.3948e-005
Bi-210				
Bi-211	1.1412e-010	4.2225e+000	3.7441e-010	1.3853e-005
Bi-214				
Fr-223	1.5857e-012	5.8669e-002	5.2023e-012	1.9248e-007
Pa-231	3.2291e-010	1.1948e+001	1.0594e-009	3.9199e-005
Pa-234				
Pa-234m				
Pb-210				
Pb-211	1.1412e-010	4.2225e+000	3.7442e-010	1.3853e-005
Pb-214				
Po-210				
Po-211	3.1155e-013	1.1527e-002	1.0222e-012	3.7820e-008
Po-214				
Po-215	1.1412e-010	4.2225e+000	3.7442e-010	1.3853e-005
Po-218				
Ra-223	1.1412e-010	4.2225e+000	3.7442e-010	1.3853e-005
Ra-226				

Page : 2
DOS File : RICH2353.MS5
Run Date: August 13, 2003
Run Time: 2:40:01 PM
Duration : 00:00:06

Nuclide	curies	becquerels	µCi/cm³	Bq/cm³
Rn-219	1.1412e-010	4.2225e+000	3.7442e-010	1.3853e-005
Rn-222				
Th-227	1.1284e-010	4.1749e+000	3.7020e-010	1.3697e-005
Th-230				
Th-231	5.0896e-007	1.8831e+004	1.6698e-006	6.1783e-002
Th-234				
Tl-207	1.1381e-010	4.2110e+000	3.7339e-010	1.3816e-005
U-234				
U-235	5.0896e-007	1.8831e+004	1.6698e-006	6.1783e-002
U-238				

Buildup
The material reference is : Source

Integration Parameters

X Direction	10
Y Direction	20
Z Direction	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
0.015	3.542e+01	1.147e-11	1.242e-11	9.839e-13	1.065e-12
0.02	5.061e-02	7.541e-12	8.638e-12	2.612e-13	2.992e-13
0.03	2.760e+03	2.098e-05	2.782e-05	2.079e-07	2.757e-07
0.04	2.740e-02	8.950e-10	1.412e-09	3.958e-12	6.246e-12
0.05	4.029e-01	2.998e-08	5.604e-08	7.985e-11	1.493e-10
0.06	8.950e+01	1.144e-05	2.587e-05	2.273e-08	5.137e-08
0.08	2.211e+03	5.550e-04	1.520e-03	8.783e-07	2.405e-06
0.1	1.969e+03	7.490e-04	2.265e-03	1.146e-06	3.465e-06
0.15	2.933e+03	2.095e-03	6.677e-03	3.449e-06	1.099e-05
0.2	1.162e+04	1.246e-02	3.866e-02	2.199e-05	6.824e-05
0.3	3.151e+00	5.922e-06	1.693e-05	1.123e-08	3.211e-08
0.4	1.106e+00	3.105e-06	8.253e-06	6.051e-09	1.608e-08
0.5	2.078e-02	7.990e-08	1.994e-07	1.568e-10	3.914e-10
0.6	6.202e-05	3.092e-10	7.316e-10	6.035e-13	1.428e-12
0.8	1.696e-01	1.280e-06	2.795e-06	2.435e-09	5.316e-09
TOTALS:	2.163e+04	1.590e-02	4.921e-02	2.772e-05	8.549e-05

MicroShield v5.03 (5.03-00027)
NEXTEP ENVIRONMENTAL INC.

Page : 1
DOS File : RICH2383.MS5
Run Date: August 27, 2003
Run Time: 2:59:16 PM
Duration : 00:00:05

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

Case Title: 1.04% enrichment 238
Description: Case 1
Geometry: 13 - Rectangular Volume

Source Dimensions

Length	30.48 cm	1 ft
Width	100.0 cm	3 ft 3.4 in
Height	100.0 cm	3 ft 3.4 in

Dose Points

	X	Y	Z
# 1	35.56 cm	50 cm	50 cm
	1 ft 2.0 in	1 ft 7.7 in	1 ft 7.7 in

Shields

Shield Name	Dimension	Material	Density
Source	3.05e+05 cm³	Concrete	2.2
Air Gap		Air	0.00122

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

Nuclide	curies	becquerels	µCi/cm³	Bq/cm³
Bi-210	7.2346e-017	2.6768e-006	2.3736e-016	8.7821e-012
Bi-214	3.7124e-016	1.3736e-005	1.2180e-015	4.5065e-011
Pa-234	1.2114e-008	4.4822e+002	3.9744e-008	1.4705e-003
Pa-234m	7.5712e-006	2.8014e+005	2.4840e-005	9.1908e-001
Pb-210	7.2530e-017	2.6836e-006	2.3796e-016	8.8045e-012
Pb-214	3.7124e-016	1.3736e-005	1.2180e-015	4.5065e-011
Po-210	6.7524e-017	2.4984e-006	2.2154e-016	8.1968e-012
Po-214	3.7116e-016	1.3733e-005	1.2177e-015	4.5055e-011
Po-218	3.7131e-016	1.3739e-005	1.2182e-015	4.5074e-011
Ra-226	3.7188e-016	1.3759e-005	1.2201e-015	4.5142e-011
Rn-222	3.7131e-016	1.3739e-005	1.2182e-015	4.5074e-011
Th-230	8.6388e-014	3.1964e-003	2.8342e-013	1.0487e-008
Th-234	7.5712e-006	2.8014e+005	2.4840e-005	9.1908e-001
U-234	6.4185e-010	2.3749e+001	2.1058e-009	7.7915e-005
U-238	7.5712e-006	2.8014e+005	2.4840e-005	9.1908e-001

Buildup
The material reference is : Source

Page : 2
DOS File : RICH2383.MS5
Run Date: August 27, 2003
Run Time: 2:59:16 PM
Duration : 00:00:05

Integration Parameters

X Direction	10
Y Direction	20
Z Direction	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
0.04	5.486e-01	1.792e-08	2.827e-08	7.924e-11	1.250e-10
0.05	2.802e-02	2.085e-09	3.897e-09	5.554e-12	1.038e-11
0.06	1.097e+04	1.402e-03	3.169e-03	2.785e-06	6.294e-06
0.08	3.982e+02	9.996e-05	2.737e-04	1.582e-07	4.332e-07
0.1	1.720e+04	6.541e-03	1.978e-02	1.001e-05	3.026e-05
0.15	1.413e+02	1.009e-04	3.217e-04	1.662e-07	5.297e-07
0.2	9.455e+01	1.014e-04	3.146e-04	1.789e-07	5.552e-07
0.3	3.255e+01	6.118e-05	1.749e-04	1.160e-07	3.317e-07
0.4	2.752e+01	7.726e-05	2.053e-04	1.505e-07	4.001e-07
0.5	4.087e+01	1.572e-04	3.922e-04	3.085e-07	7.699e-07
0.6	1.670e+02	8.326e-04	1.970e-03	1.625e-06	3.845e-06
0.8	9.300e+02	7.021e-03	1.533e-02	1.335e-05	2.915e-05
1.0	2.973e+03	3.111e-02	6.389e-02	5.734e-05	1.178e-04
1.5	6.273e+01	1.195e-03	2.206e-03	2.011e-06	3.711e-06
2.0	8.092e+00	2.353e-04	4.065e-04	3.638e-07	6.286e-07
TOTALS:	3.304e+04	4.893e-02	1.084e-01	8.857e-05	1.947e-04

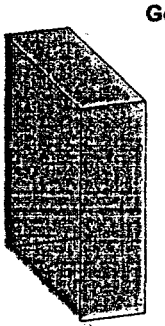
A-4 Enrichment 3.54

MicroShield v5.03 (5.03-00027)
NEXTEP ENVIRONMENTAL INC.

Page : 1
DOS File : RICH2352.MS5
Run Date: August 13, 2003
Run Time: 2:44:16 PM
Duration : 00:00:06

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

Case Title: 3.54% enrichment 235
Description: Case 1
Geometry: 13 - Rectangular Volume



Source Dimensions

Length	30.48 cm	1 ft
Width	100.0 cm	3 ft 3.4 in
Height	100.0 cm	3 ft 3.4 in

Dose Points

	X	Y	Z
# 1	35.56 cm	50 cm	50 cm
	1 ft 2.0 in	1 ft 7.7 in	1 ft 7.7 in

Shields

Shield Name	Dimension	Material	Density
Source	3.05e+05 cm³	Concrete	2.2
Air Gap		Air	0.00122

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

Nuclide	curies	becquerels	µCi/cm³	Bq/cm³
Ac-227	4.6019e-010	1.7027e+001	1.5098e-009	5.5864e-005
Bi-210				
Bi-211	4.5882e-010	1.6976e+001	1.5053e-009	5.5697e-005
Bi-214				
Fr-223	6.3507e-012	2.3497e-001	2.0836e-011	7.7092e-007
Pa-231	8.2558e-010	3.0546e+001	2.7086e-009	1.0022e-004
Pa-234				
Pa-234m				
Pb-210				
Pb-211	4.5882e-010	1.6976e+001	1.5053e-009	5.5697e-005
Pb-214				
Po-210				
Po-211	1.2526e-012	4.6345e-002	4.1095e-012	1.5205e-007
Po-214				
Po-215	4.5882e-010	1.6976e+001	1.5053e-009	5.5697e-005
Po-218				
Ra-223	4.5882e-010	1.6976e+001	1.5053e-009	5.5697e-005
Ra-226				

Page : 2
DOS File : RICH2352.MS5
Run Date: August 13, 2003
Run Time: 2:44:16 PM
Duration : 00:00:06

Nuclide	curies	becquerels	µCi/cm³	Bq/cm³
Rn-219	4.5882e-010	1.6976e+001	1.5053e-009	5.5697e-005
Rn-222				
Th-227	4.5300e-010	1.6761e+001	1.4862e-009	5.4990e-005
Th-230				
Th-231	6.3971e-007	2.3669e+004	2.0988e-006	7.7656e-002
Th-234				
Tl-207	4.5757e-010	1.6930e+001	1.5012e-009	5.5544e-005
U-234				
U-235	6.3971e-007	2.3669e+004	2.0988e-006	7.7656e-002
U-238				

Buildup
The material reference is : Source

Integration Parameters

X Direction	10
Y Direction	20
Z Direction	20

Results

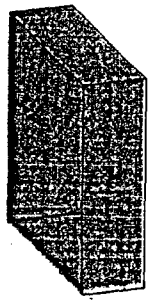
Energy MeV	Activity photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.015	4.453e+01	1.442e-11	1.561e-11	1.237e-12	1.339e-12
0.02	1.422e-01	2.119e-11	2.427e-11	7.340e-13	8.408e-13
0.03	3.471e+03	2.638e-05	3.498e-05	2.615e-07	3.466e-07
0.04	8.406e-02	2.745e-09	4.332e-09	1.214e-11	1.916e-11
0.05	1.581e+00	1.176e-07	2.199e-07	3.134e-10	5.858e-10
0.06	1.125e+02	1.439e-05	3.252e-05	2.858e-08	6.459e-08
0.08	2.785e+03	6.991e-04	1.914e-03	1.106e-06	3.029e-06
0.1	2.477e+03	9.423e-04	2.850e-03	1.442e-06	4.360e-06
0.15	3.688e+03	2.634e-03	8.395e-03	4.337e-06	1.382e-05
0.2	1.461e+04	1.566e-02	4.860e-02	2.765e-05	8.578e-05
0.3	1.128e+01	2.119e-05	6.058e-05	4.020e-08	1.149e-07
0.4	4.417e+00	1.240e-05	3.295e-05	2.416e-08	6.421e-08
0.5	8.352e-02	3.212e-07	8.015e-07	6.305e-10	1.573e-09
0.6	2.493e-04	1.243e-09	2.941e-09	2.426e-12	5.741e-12
0.8	6.818e-01	5.147e-06	1.124e-05	9.790e-09	2.137e-08
TOTALS:	2.721e+04	2.002e-02	6.194e-02	3.489e-05	1.076e-04

MicroShield v5.03 (5.03-00027)
NEXTEP ENVIRONMENTAL INC.

Page : 1
DOS File : RICH2382.MS5
Run Date : August 13, 2003
Run Time : 2:45:26 PM
Duration : 00:00:05

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

Case Title: 3.54% enrichment 235
Description: Case 1
Geometry: 13 - Rectangular Volume



Source Dimensions

Length	30.48 cm	1 ft
Width	100.0 cm	3 ft 3.4 in
Height	100.0 cm	3 ft 3.4 in

Dose Points

	X	Y	Z
# 1	35.56 cm	50 cm	50 cm
	1 ft 2.0 in	1 ft 7.7 in	1 ft 7.7 in

Shields

Shield Name	Dimension	Material	Density
Source	3.05e+05 cm³	Concrete	2.2
Air Gap		Air	0.00122

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

Nuclide	curies	becquerels	µCi/cm³	Bq/cm³
Bi-210	1.5591e-016	5.7687e-006	5.1151e-016	1.8926e-011
Bi-214	4.9947e-016	1.8481e-005	1.6387e-015	6.0632e-011
Pa-234	4.3275e-009	1.6012e+002	1.4198e-008	5.2532e-004
Pa-234m	2.7047e-006	1.0007e+005	8.8737e-006	3.2833e-001
Pb-210	1.5612e-016	5.7765e-006	5.1221e-016	1.8952e-011
Pb-214	4.9948e-016	1.8481e-005	1.6387e-015	6.0632e-011
Po-210	1.5024e-016	5.5589e-006	4.9291e-016	1.8238e-011
Po-214	4.9937e-016	1.8477e-005	1.6384e-015	6.0619e-011
Po-218	4.9958e-016	1.8484e-005	1.6390e-015	6.0644e-011
Ra-226	5.0002e-016	1.8501e-005	1.6405e-015	6.0697e-011
Rn-222	4.9958e-016	1.8484e-005	1.6390e-015	6.0644e-011
Th-230	6.7505e-014	2.4977e-003	2.2147e-013	8.1945e-009
Th-234	2.7047e-006	1.0007e+005	8.8737e-006	3.2833e-001
U-234	3.1996e-010	1.1838e+001	1.0497e-009	3.8840e-005
U-238	2.7047e-006	1.0007e+005	8.8737e-006	3.2833e-001

Buildup
The material reference is : Source

Page : 2
DOS File : RICH2382.MS5
Run Date: August 13, 2003
Run Time: 2:45:26 PM
Duration : 00:00:05

Integration Parameters

X Direction	10
Y Direction	20
Z Direction	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
0.04	1.960e-01	6.401e-09	1.010e-08	2.831e-11	4.467e-11
0.05	1.397e-02	1.039e-09	1.943e-09	2.768e-12	5.176e-12
0.06	3.917e+03	5.009e-04	1.132e-03	9.950e-07	2.249e-06
0.08	1.423e+02	3.571e-05	9.778e-05	5.651e-08	1.547e-07
0.1	6.143e+03	2.337e-03	7.066e-03	3.575e-06	1.081e-05
0.15	5.048e+01	3.605e-05	1.149e-04	5.936e-08	1.892e-07
0.2	3.377e+01	3.621e-05	1.124e-04	6.391e-08	1.983e-07
0.3	1.163e+01	2.185e-05	6.248e-05	4.145e-08	1.185e-07
0.4	9.832e+00	2.760e-05	7.335e-05	5.378e-08	1.429e-07
0.5	1.460e+01	5.615e-05	1.401e-04	1.102e-07	2.750e-07
0.6	5.966e+01	2.974e-04	7.038e-04	5.806e-07	1.374e-06
0.8	3.322e+02	2.508e-03	5.475e-03	4.771e-06	1.041e-05
1.0	1.062e+03	1.111e-02	2.282e-02	2.048e-05	4.207e-05
1.5	2.241e+01	4.269e-04	7.879e-04	7.183e-07	1.326e-06
2.0	2.891e+00	8.405e-05	1.452e-04	1.300e-07	2.246e-07
TOTALS:	1.180e+04	1.748e-02	3.874e-02	3.164e-05	6.955e-05

A-5 Enrichment 8.8

MicroShield v5.03 (5.03-00027)
NEXTEP ENVIRONMENTAL INC.

Page : 1
DOS File : RICH235.MS5
Run Date: August 13, 2003
Run Time: 2:36:52 PM
Duration : 00:00:06

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

Case Title: 8.8% enrichment U235
Description: Case 1
Geometry: 13 - Rectangular Volume

Source Dimensions

Length	30.48 cm	1 ft
Width	100.0 cm	3 ft 3.4 in
Height	100.0 cm	3 ft 3.4 in

Dose Points

	X	Y	Z
# 1	35.56 cm	50 cm	50 cm
	1 ft 2.0 in	1 ft 7.7 in	1 ft 7.7 in

Shields

Shield Name	Dimension	Material	Density
Source	3.05e+05 cm³	Concrete	2.2
Air Gap		Air	0.00122

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

Nuclide	curies	becquerels	μCi/cm³	Bq/cm³
Ac-227	1.4942e-010	5.5285e+000	4.9022e-010	1.8138e-005
Bi-210				
Bi-211	1.4840e-010	5.4909e+000	4.8689e-010	1.8015e-005
Bi-214				
Fr-223	2.0620e-012	7.6293e-002	6.7650e-012	2.5031e-007
Pa-231	4.1991e-010	1.5537e+001	1.3777e-009	5.0974e-005
Pa-234				
Pa-234m				
Pb-210				
Pb-211	1.4840e-010	5.4909e+000	4.8689e-010	1.8015e-005
Pb-214				
Po-210				
Po-211	4.0514e-013	1.4990e-002	1.3292e-012	4.9181e-008
Po-214				
Po-215	1.4840e-010	5.4910e+000	4.8689e-010	1.8015e-005
Po-218				
Ra-223	1.4840e-010	5.4910e+000	4.8689e-010	1.8015e-005
Ra-226				

Page : 2
DOS File : RICH235.MS5
Run Date : August 27, 2003
Run Time : 1:29:10 PM
Duration : 00:00:05

Nuclide	curies	becquerels	µCi/cm³	Bq/cm³
Rn-219	1.4840e-010	5.4910e+000	4.8689e-010	1.8015e-005
Rn-222				
Th-227	1.4673e-010	5.4290e+000	4.8140e-010	1.7812e-005
Th-230				
Th-231	6.6184e-007	2.4488e+004	2.1714e-006	8.0342e-002
Th-234				
Tl-207	1.4800e-010	5.4759e+000	4.8556e-010	1.7966e-005
U-234				
U-235	6.6184e-007	2.4488e+004	2.1714e-006	8.0342e-002
U-238				

Buildup
The material reference is : Source

Integration Parameters

X Direction	10
Y Direction	20
Z Direction	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
0.015	4.606e+01	1.492e-11	1.615e-11	1.279e-12	1.385e-12
0.02	6.582e-02	9.807e-12	1.123e-11	3.397e-13	3.891e-13
0.03	3.589e+03	2.728e-05	3.617e-05	2.704e-07	3.585e-07
0.04	3.564e-02	1.164e-09	1.836e-09	5.147e-12	8.122e-12
0.05	5.240e-01	3.898e-08	7.287e-08	1.038e-10	1.941e-10
0.06	1.164e+02	1.488e-05	3.363e-05	2.956e-08	6.681e-08
0.08	2.875e+03	7.218e-04	1.976e-03	1.142e-06	3.128e-06
0.1	2.561e+03	9.740e-04	2.946e-03	1.490e-06	4.507e-06
0.15	3.814e+03	2.724e-03	8.682e-03	4.485e-06	1.430e-05
0.2	1.511e+04	1.620e-02	5.028e-02	2.860e-05	8.874e-05
0.3	4.098e+00	7.701e-06	2.202e-05	1.461e-08	4.176e-08
0.4	1.438e+00	4.038e-06	1.073e-05	7.868e-09	2.091e-08
0.5	2.702e-02	1.039e-07	2.593e-07	2.039e-10	5.090e-10
0.6	8.065e-05	4.021e-10	9.513e-10	7.848e-13	1.857e-12
0.8	2.205e-01	1.665e-06	3.634e-06	3.167e-09	6.913e-09
TOTALS:	2.812e+04	2.068e-02	6.399e-02	3.604e-05	1.112e-04

MicroShield v5.03 (5.03-00027)
NEXTEP ENVIRONMENTAL INC.

Page : 1
DOS File : RICH238.MS5
Run Date : August 26, 2003
Run Time : 2:26:34 PM
Duration : 00:00:05

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

Case Title: 8.8% enrichment U238
Description: Case 1
Geometry: 13 - Rectangular Volume

Source Dimensions

Length	30.48 cm	1 ft
Width	100.0 cm	3 ft 3.4 in
Height	100.0 cm	3 ft 3.4 in

Dose Points

	X	Y	Z
# 1	35.56 cm	50 cm	50 cm
	1 ft 2.0 in	1 ft 7.7 in	1 ft 7.7 in

Shields

Shield Name	Dimension	Material	Density
Source	3.05e+05 cm³	Concrete	2.2
Air Gap		Air	0.00122

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

Nuclide	curies	becquerels	µCi/cm³	Bq/cm³
Bi-210	1.0188e-017	3.7695e-007	3.3425e-017	1.2367e-012
Bi-214	5.2278e-017	1.9343e-006	1.7152e-016	6.3461e-012
Pa-234	1.7059e-009	6.3118e+001	5.5968e-009	2.0708e-004
Pa-234m	1.0662e-006	3.9449e+004	3.4980e-006	1.2943e-001
Pb-210	1.0214e-017	3.7791e-007	3.3510e-017	1.2399e-012
Pb-214	5.2278e-017	1.9343e-006	1.7152e-016	6.3461e-012
Po-210	9.5088e-018	3.5183e-007	3.1197e-017	1.1543e-012
Po-214	5.2267e-017	1.9339e-006	1.7148e-016	6.3447e-012
Po-218	5.2289e-017	1.9347e-006	1.7155e-016	6.3474e-012
Ra-226	5.2368e-017	1.9376e-006	1.7181e-016	6.3570e-012
Rn-222	5.2289e-017	1.9347e-006	1.7155e-016	6.3474e-012
Th-230	1.2165e-014	4.5011e-004	3.9912e-014	1.4768e-009
Th-234	1.0662e-006	3.9449e+004	3.4980e-006	1.2943e-001
U-234	9.0387e-011	3.3443e+000	2.9654e-010	1.0972e-005
U-238	1.0662e-006	3.9449e+004	3.4980e-006	1.2943e-001

Buildup
The material reference is : Source

Page : 2
DOS File : RICH238.MS5
Run Date : August 26, 2003
Run Time: 2:26:34 PM
Duration : 00:00:05

Integration Parameters

X Direction	10
Y Direction	20
Z Direction	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
0.04	7.726e-02	2.523e-09	3.981e-09	1.116e-11	1.761e-11
0.05	3.946e-03	2.936e-10	5.488e-10	7.821e-13	1.462e-12
0.06	1.544e+03	1.975e-04	4.463e-04	3.922e-07	8.864e-07
0.08	5.608e+01	1.408e-05	3.855e-05	2.228e-08	6.100e-08
0.1	2.421e+03	9.211e-04	2.786e-03	1.409e-06	4.262e-06
0.15	1.990e+01	1.421e-05	4.530e-05	2.340e-08	7.459e-08
0.2	1.331e+01	1.427e-05	4.430e-05	2.519e-08	7.818e-08
0.3	4.584e+00	8.615e-06	2.463e-05	1.634e-08	4.672e-08
0.4	3.876e+00	1.088e-05	2.892e-05	2.120e-08	5.634e-08
0.5	5.756e+00	2.213e-05	5.523e-05	4.345e-08	1.084e-07
0.6	2.352e+01	1.173e-04	2.774e-04	2.289e-07	5.415e-07
0.8	1.310e+02	9.887e-04	2.158e-03	1.881e-06	4.105e-06
1.0	4.187e+02	4.381e-03	8.997e-03	8.075e-06	1.658e-05
1.5	8.833e+00	1.683e-04	3.106e-04	2.832e-07	5.225e-07
2.0	1.140e+00	3.313e-05	5.725e-05	5.123e-08	8.853e-08
TOTALS:	4.652e+03	6.891e-03	1.527e-02	1.247e-05	2.742e-05

Appendix B
Surface Arrangement for the Random Models

Appendix B. Surface Arrangement for the Random Models

Cell	00	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
1	4	3	4	2	4	2	5	2	2	3	5	1	4	4	4	4	3	3	3	6	5	1	2	6	3	6	5	6	3	1	6
2	1	3	2	2	2	6	4	6	1	5	5	3	6	5	5	5	6	1	2	5	5	5	5	6	1	6	4	5	3	2	6
3	3	1	3	5	4	1	3	4	2	6	1	3	3	3	3	3	4	3	5	3	3	4	1	4	5	2	3	5	5	5	2
4	5	3	3	5	1	5	2	1	2	1	5	4	1	5	1	1	2	2	6	6	1	5	6	3	5	4	2	3	2	5	1
5	2	4	2	4	3	6	3	2	4	6	2	5	6	1	4	4	3	2	4	1	4	6	5	2	3	5	2	2	6	1	5
6	4	6	1	2	4	5	5	2	1	4	6	4	2	5	3	3	2	5	6	4	1	5	3	6	3	2	2	5	6	3	1
7	4	6	4	2	4	1	6	6	1	1	4	2	3	6	5	5	1	1	1	1	2	2	1	1	2	4	4	2	5	4	4
8	1	3	3	5	4	2	4	2	2	6	2	3	3	6	5	5	2	2	2	2	2	2	6	5	5	1	4	4	5	6	2
9	6	4	5	2	3	5	5	4	1	6	1	3	3	3	3	3	6	6	1	2	3	1	2	1	5	3	6	1	5	4	5
10	4	2	3	6	1	1	2	1	3	2	6	5	6	2	4	4	2	1	6	6	2	1	4	4	4	1	3	2	4	5	3
11	6	5	6	2	2	5	6	3	3	5	1	3	3	6	2	2	2	1	5	2	4	1	4	3	4	4	6	4	1	5	4
12	2	4	3	6	5	4	1	4	2	2	6	4	2	6	3	3	3	5	6	3	6	4	4	3	2	2	5	5	6	3	2
13	3	1	1	3	6	3	6	3	3	5	6	5	5	4	1	1	2	3	2	6	1	3	4	4	2	1	4	6	6	4	2
14	6	1	2	2	4	5	6	2	2	1	6	6	3	3	6	6	4	3	3	5	1	6	5	1	1	6	6	4	5	2	2
15	4	5	1	3	3	6	5	6	1	4	2	1	5	6	6	6	2	4	4	2	3	6	6	3	2	5	6	4	3	5	6
16	5	5	6	4	2	6	4	6	5	6	2	3	4	6	4	4	3	6	5	6	2	5	6	5	2	1	6	4	4	4	2
17	5	2	6	3	3	1	4	4	3	6	1	6	5	2	2	2	1	4	1	1	3	6	4	1	6	4	2	4	1	5	2
18	6	5	2	6	5	2	1	1	5	4	6	2	6	1	5	5	5	6	2	3	1	6	3	3	2	6	2	4	4	6	1
19	2	3	2	1	2	4	5	6	3	6	2	2	2	3	4	4	6	6	4	2	3	1	5	6	5	2	5	5	2	6	4
20	4	6	2	3	6	1	4	6	1	3	5	3	3	4	6	6	3	2	4	3	6	1	1	1	2	1	2	4	2	2	5
21	2	6	2	6	5	4	2	4	6	1	6	3	2	1	1	1	6	2	5	1	5	2	3	1	3	2	2	5	5	3	4
22	1	2	6	4	2	1	4	4	4	1	2	6	1	3	5	5	1	4	6	3	1	4	1	6	1	5	2	3	2	4	2
23	1	2	2	3	3	5	6	4	4	5	2	6	1	5	2	2	2	3	1	5	2	3	6	2	1	4	3	1	3	2	2
24	5	3	4	2	4	1	5	1	5	1	2	3	6	4	6	6	3	1	3	1	2	1	5	3	6	6	1	4	3	2	4
25	5	6	4	1	2	1	1	5	5	4	2	3	2	3	4	4	4	6	6	4	5	2	5	3	3	6	4	3	6	4	3
26	4	3	2	4	5	4	5	2	5	1	2	6	3	2	1	1	6	4	4	3	2	6	3	3	1	4	4	3	6	1	4
27	3	1	2	5	2	1	6	1	6	4	5	3	1	4	1	1	4	3	3	6	4	5	6	5	2	4	4	4	2	6	3

Appendix C
Data Analysis for the 30 Random Samples

Appendix C
Data Analysis for the 30 Random Samples

Sample #	Simulated cpm
1	234
2	230
3	101
4	77
5	96
6	136
7	216
8	114
9	229
10	182
11	95
12	98
13	1,423
14	103
15	82
16	88
17	227
18	96
19	205
20	1,337
21	126
22	107
23	327
24	230
25	100
26	210
27	259
28	162
29	2,328
30	93

Column1	
Mean	310
Standard Error	91
Median	149
Mode	230
Standard Deviation	496
Sample Variance	245842
Kurtosis	10
Skewness	3
Range	2251
Minimum	77
Maximum	2328
Sum	9311
Count	30

0" Shielded

	1min	2 min	5min	15cm/sec	30 cm/sec
Limit	306	431	680	380	542
# > limit	4	11	15	3	3
%>limit	13.3	36.7	50.0	10.0	10.0

Sample #	Simulated cpm
1	374
2	366
3	163
4	148
5	201
6	274
7	321
8	217
9	381
10	268
11	197
12	180
13	2,412
14	196
15	156
16	160
17	375
18	177
19	332
20	2,317
21	243
22	214
23	481
24	355
25	196
26	322
27	423
28	247
29	2,377
30	187

Column1	
Mean	475
Standard Error	118
Median	258
Mode	#N/A
Standard Deviation	648
Sample Variance	420,183
Kurtosis	6
Skewness	3
Range	2,264
Minimum	148
Maximum	2,412
Sum	14,259
Count	30

0" Unshielded

	1min	2 min	5min	15cm/sec	30 cm/sec
Limit	329	463	731	409	583
# > limit	11	17	30	5	3
%>limit	36.7	56.7	100.0	16.7	10.0

Sample #	Simulated cpm
1	396
2	326
3	199
4	211
5	252
6	348
7	265
8	280
9	396
10	204
11	256
12	227
13	1,389
14	247
15	229
16	207
17	336
18	220
19	347
20	1,237
21	295
22	278
23	372
24	335
25	239
26	275
27	384
28	318
29	1,155
30	242

Column1	
Mean	382
Standard Error	56
Median	279
Mode	#N/A
St. D	305
Variance	93116
Kurtosis	6
Skewness	3
Range	1190
Minimum	199
Maximum	1389
Sum	11465
Count	30

2"
Shielded

	1min	2 min	5min	15cm/sec	30 cm/sec
Limit	306	431	680	380	542
# > limit	13	26	30	6	3
%>limit	43.3	86.7	100.0	20.0	10.0

Sample #	Simulated cpm
1	605
2	376
3	469
4	525
5	685
6	456
7	639
8	769
9	363
10	524
11	479
12	482
13	426
14	619
15	488
16	672
17	1,716
18	612
19	557
20	612
21	629
22	480
23	451
24	667
25	318
26	1,857
27	553
28	551
29	1,992
30	752

Column1	
Mean	678
Standard Error	76
Median	555
Mode	#N/A
St. D	415
Variance	172517
Kurtosis	5
Skewness	2
Range	1674
Minimum	318
Maximum	1992
Sum	20325
Count	30

2" Unshielded

	1min	2 min	5min	15cm/sec	30 cm/sec
Limit	329	463	731	409	583
# > limit	29	30	30	27	14
%>limit	96.7	100.0	100.0	90.0	46.7

Sample #	Simulated cpm
1	627
2	501
3	330
4	413
5	479
6	598
7	397
8	532
9	659
10	290
11	500
12	442
13	1,086
14	498
15	426
16	377
17	543
18	440
19	542
20	842
21	550
22	532
23	493
24	535
25	460
26	369
27	562
28	551
29	1,234
30	469

Column1	
Mean	542
Standard Error	36
Median	500
Mode	532
Standard Deviation	199
Sample Variance	39,714
Kurtosis	6
Skewness	2
Range	944
Minimum	290
Maximum	1,234
Sum	16,271
Count	30

6" Shielded

	1min	2 min	5min	15cm/sec	30 cm/sec
Limit	306	431	680	380	542
# > limit	29	30	30	26	11
%>limit	96.7	100.0	100.0	86.7	36.7

Sample #	Simulated cpm
1	318
2	225
3	330
4	351
5	325
6	293
7	384
8	428
9	297
10	323
11	322
12	387
13	386
14	334
15	298
16	355
17	348
18	346
19	345
20	375
21	352
22	354
23	336
24	309
25	214
26	331
27	407
28	361
29	338
30	373

Column1	
Mean	338
Standard Error	8
Median	341
Mode	#N/A
Standard Deviation	45
Sample Variance	2,046
Kurtosis	2
Skewness	-1
Range	214
Minimum	214
Maximum	428
Sum	10,144
Count	30

24" Unshielded

	1min	2 min	5min	15cm/sec	30 cm/sec
Limit	329	463	731	409	583
# > limit	20	28	30	1	0
%>limit	66.7	93.3	100.0	3.3	0.0

Appendix D
File Name on Data CD

Appendix D File Name on Data CD

1. Background

	0" Shielded	0" Unshielded	2" Shielded	2" Unshielded	6" Shielded	24" Unshielded
Background	CU10BK41	CU10BK51	CU10BK01	CU10BK11	CU10BK21	CU10BK31

2. Contamination on the TOP

Enrichment (%)	0" Shielded	0" Shielded	2" Shielded	2" Unshielded	6" Shielded	24" Unshielded
8.8	CU10ED06	CU10ED16	CU10EU06	CU10EU16	CU10EU26	CU10EU36
3.54	CU10ED07	CU10ED17	CU10EU07	CU10EU17	CU10EU27	CU10EU37
1.04	CU10ED08	CU10ED18	CU10EU08	CU10EU18	CU10EU28	CU10EU38
0.72	CU10ED09	CU10ED19	CU10EU09	CU10EU19	CU10EU29	CU10EU39

3. Contamination on the BOTTOM

Enrichment (%)	0" Shielded	0" Shielded	2" Shielded	2" Unshielded	6" Shielded	24" Unshielded
8.8	CU10ED01	CU10ED11	CU10EU01	CU10EU11	CU10EU21	CU10EU31
3.54	CU10ED02	CU10ED12	CU10EU02	CU10EU12	CU10EU22	CU10EU32
1.04	CU10ED03	CU10ED13	CU10EU03	CU10EU13	CU10EU23	CU10EU33
0.72	CU10ED04	CU10ED14	CU10EU04	CU10EU14	CU10EU24	CU10EU34

4. Contamination randomly distributed within concrete block (Random Model-00)

Enrichment (%)	0" Shielded	0" Shielded	2" Shielded	2" Unshielded	6" Shielded	24" Unshielded
8.8	CU10ED81	CU10ED91	CU10EU41	CU10EU51	CU10EU61	CU10EU71
3.54	CU10ED82	CU10ED92	CU10EU42	CU10EU52	CU10EU62	CU10EU72
1.04	CU10ED83	CU10ED93	CU10EU43	CU10EU53	CU10EU63	CU10EU73
0.72	CU10ED84	CU10ED94	CU10EU44	CU10EU54	CU10EU64	CU10EU74

5. 30 Random Models for Enrichment 3.54%

Sample Number	0" Shielded	0" Shielded	2" Shielded	2" Unshielded	6" Shielded	24" Unshielded
1	Cu10r001	Cu10r031	Cu10rd01	Cu10rd31	Cu10rd61	Cu10re31
2	Cu10r002	Cu10r032	Cu10rd02	Cu10rd32	Cu10rd62	Cu10re32
3	Cu10r003	Cu10r033	Cu10rd03	Cu10rd33	Cu10rd63	Cu10re33
4	Cu10r004	Cu10r034	Cu10rd04	Cu10rd34	Cu10rd64	Cu10re34
5	Cu10r005	Cu10r035	Cu10rd05	Cu10rd35	Cu10rd65	Cu10re35
6	Cu10r006	Cu10r036	Cu10rd06	Cu10rd36	Cu10rd66	Cu10re36
7	Cu10r007	Cu10r037	Cu10rd07	Cu10rd37	Cu10rd67	Cu10re37
8	Cu10r008	Cu10r038	Cu10rd08	Cu10rd38	Cu10rd68	Cu10re38
9	Cu10r009	Cu10r039	Cu10rd09	Cu10rd39	Cu10rd69	Cu10re39
10	Cu10r010	Cu10r040	Cu10rd10	Cu10rd40	Cu10rd70	Cu10re40
11	Cu10r011	Cu10r041	Cu10rd11	Cu10rd41	Cu10rd71	Cu10re41
12	Cu10r012	Cu10r042	Cu10rd12	Cu10rd42	Cu10rd72	Cu10re42
13	Cu10r013	Cu10r043	Cu10rd13	Cu10rd43	Cu10rd73	Cu10re43
14	Cu10r014	Cu10r044	Cu10rd14	Cu10rd44	Cu10rd74	Cu10re44
15	Cu10r015	Cu10r045	Cu10rd15	Cu10rd45	Cu10rd75	Cu10re45
16	Cu10r016	Cu10r046	Cu10rd16	Cu10rd46	Cu10rd76	Cu10re46
17	Cu10r017	Cu10r047	Cu10rd17	Cu10rd47	Cu10rd77	Cu10re47
18	Cu10r018	Cu10r048	Cu10rd18	Cu10rd48	Cu10rd78	Cu10re48
19	Cu10r019	Cu10r049	Cu10rd19	Cu10rd49	Cu10rd79	Cu10re49
20	Cu10r020	Cu10r050	Cu10rd20	Cu10rd50	Cu10rd80	Cu10re50
21	Cu10r021	Cu10r051	Cu10rd21	Cu10rd51	Cu10rd81	Cu10re51
22	Cu10r022	Cu10r052	Cu10rd22	Cu10rd52	Cu10rd82	Cu10re52
23	Cu10r023	Cu10r053	Cu10rd23	Cu10rd53	Cu10rd83	Cu10re53
24	Cu10r024	Cu10r054	Cu10rd24	Cu10rd54	Cu10rd84	Cu10re54
25	Cu10r025	Cu10r055	Cu10rd25	Cu10rd55	Cu10rd85	Cu10re55
26	Cu10r026	Cu10r056	Cu10rd26	Cu10rd56	Cu10rd86	Cu10re56
27	Cu10r027	Cu10r057	Cu10rd27	Cu10rd57	Cu10rd87	Cu10re57
28	Cu10r028	Cu10r058	Cu10rd28	Cu10rd58	Cu10rd88	Cu10re58
29	Cu10r029	Cu10r059	Cu10rd29	Cu10rd59	Cu10rd89	Cu10re59
30	Cu10r030	Cu10r060	Cu10rd30	Cu10rd60	Cu10rd90	Cu10re60

6. MICROSHIELD Input Files

File Name	Specification
CONB40	CONcrete-Background-K40
CONB226	CONcrete-Background-Ra226
CONB232	CONcrete-Background-Th232
CONB235	CONcrete-Background-U235
CONB238	CONcrete-Background-U238
RICH238	U238-for-Enrichment 8.8%
RICH2382	U238-for-Enrichment 3.54%
RICH2383	U238-for-Enrichment 1.04%
RICH2384	U238-for-Enrichment NaU
RICH235	U235-for-Enrichment 8.8%
RICH2352	U235-for-Enrichment 3.54%
RICH2353	U235-for-Enrichment 1.04%
RICH2354	U235-for-Enrichment NaU

APPENDIX E

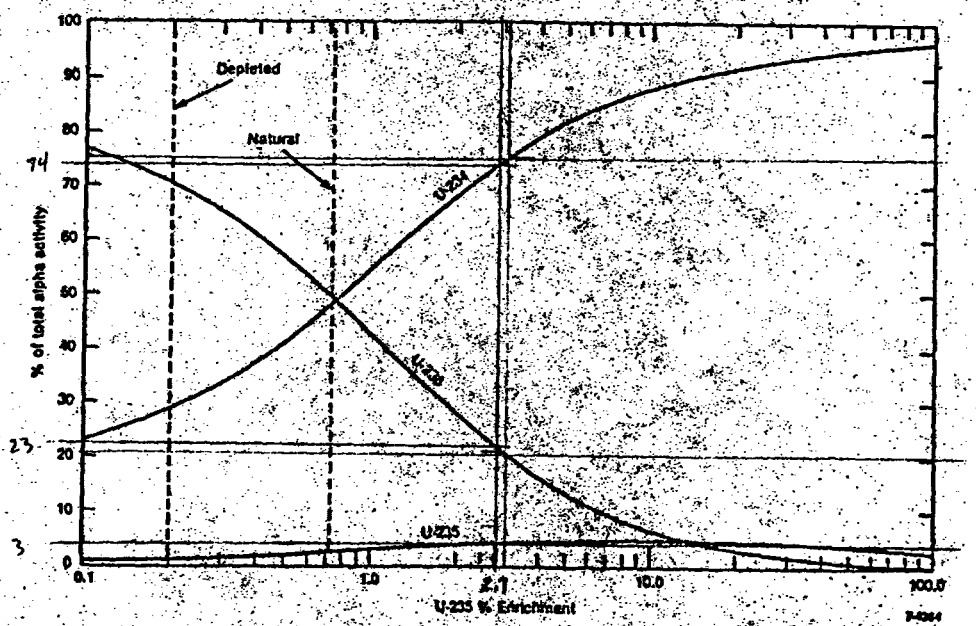


Figure 2-2. Percent of total radioactivity by isotope vs. % weight U-235 enrichment calculated from $S = (0.4 + 0.3\ E + 0.0034E^2)$ 10^{-6} Ci/g (gaseous diffusion process).