May 8, 2012

Mr. John Glenn
U.S. Department of Energy
Oak Ridge Office
P.O. Box 2001
Oak Ridge, TN 37831-0117

DOE CONTRACT NO. DE-AC05-06OR23100
SUBJECT: INDEPENDENT VERIFICATION OF THE BUILDING 3550 SLAB AT
OAK RIDGE NATIONAL LABORATORY, OAK RIDGE, TENNESSEE
DCN 5086-SR-01-0

Dear Mr. Glenn:

The Oak Ridge Institute for Science and Education (ORISE) has completed the independent verification survey of the Building 3550 Slab. The results of this effort are provided in the enclosed final report.

Please direct any additional questions you may have to me via my information below,
Evan Harpenau at 865.241.8793, or Kathy Rollow at 865.574.4390.

Sincerely,

Phyllis C. Weaver
Health Physicist Project Manager
Survey Projects

PCW:fr

Enclosure

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INDEPENDENT VERIFICATION OF THE BUILDING 3550 SLAB AT OAK RIDGE NATIONAL LABORATORY OAK RIDGE, TENNESSEE

P. C. Weaver

Prepared for
U.S. Department of Energy

ORISE

Approved for public release; further dissemination unlimited.

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AT THE OAK RIDGE NATIONAL LABORATORY
OAK RIDGE, TENNESSEE**

Prepared by

P. C. Weaver

Oak Ridge Institute for Science and Education
Oak Ridge, Tennessee 37831-0117

Prepared for the
U.S. Department of Energy

FINAL REPORT

MAY 2012

This report is based on work performed by the Oak Ridge Institute for Science and Education under contract number DE-AC05-06OR23100 with the U.S. Department of Energy

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OAK RIDGE, TENNESSEE**

FINAL REPORT

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ACRONYMS

BKG	background
cm	centimeter
cpm	counts per minute
DOE	U.S. Department of Energy
dpm/100cm ²	disintegration per minute per 100 square centimeters
ELCR	excess lifetime cancer risk
HPS	Health Physics Society
in	inch
IV	independent verification
NaI	sodium iodide
ORNL	Oak Ridge National Laboratory
ORAU	Oak Ridge Associated Universities
ORISE	Oak Ridge Institute for Science and Education
ROD	Record of Decision
VSP	Visual Sample Plan

INDEPENDENT VERIFICATION OF THE BUILDING 3550 SLAB AT THE OAK RIDGE NATIONAL LABORATORY OAK RIDGE, TENNESSEE

1. INTRODUCTION

Building 3550, located at the Oak Ridge National Laboratory (ORNL), was constructed in 1943 as part of the original Clinton Engineering Works and served as the plant's main laboratory building. The facility was used primarily for processing irradiated fuel elements and thorium oxycarbonate; however, it may have been involved in fluoride volatility studies. Building 3550 was used in later years for the cleaning and management of face masks and respirators (UT-B 2008). The original 14,036-ft² structure was primarily of wood construction on a poured concrete slab foundation. The building structure has recently been removed leaving the slab foundation in-place.

The radiological inventory included ¹³⁷Cs, ⁹⁰Sr, ²³²Th, ²³⁵U, ²³⁸U ^{239/240}Pu, and ²⁴¹Am (ORISE 2010). The U.S. Department of Energy (DOE) requires that the "as left" status of the slab condition be verified to ensure that the residual radioactivity is less than the guidance provided in the Bethel Valley Record of Decision (ROD) (DOE 2002). At the request of DOE-Oak Ridge Office, ORISE has been tasked with conducting independent verification of the remaining building slab.

2. SITE DESCRIPTION

ORNL is located in Oak Ridge, Tennessee approximately 25 miles west of Knoxville at the western end of Bethel Valley Road. The site occupies approximately 10,000 acres of the Oak Ridge Reservation and is bounded to the south by the Clinch River and to the north by Bethel Valley Road (Figure A-1). The remaining Building 3550 Slab is located on Central Avenue in the central portion of the main campus between Third and Fifth Streets (Figure A-2). The first floor plan of Building 3550 indicates numerous laboratories particularly along the southern wing of the building (Figure A-3).

3. OBJECTIVE

The objective of this verification survey is to provide independent review and field assessment of remediation actions conducted by Safety and Ecology Corporation (SEC) to document that the final

radiological condition of the slab meets the release guidelines as referenced in the Bethel Valley ROD. ORISE will compare surface activity measurement data to the ROD and any removable activity identified to the DOE Order 458.1 which references DOE Order 5400.5 for allowable alpha and beta removable activity (DOE 1993, 2002 and 2011).

4. PROCEDURES

ORISE conducted verification survey activities on the Building 3550 Slab from July 26, 2011 through July 28, 2011. ORISE survey activities were performed in accordance with the final *Project Specific Plan for Independent Verification of Building Slabs at ORNL* (ORISE 2011a). Procedures supporting the field implementation of the plan were obtained from the Independent Environmental Assessment and Verification Program Survey Procedures Manual and the Oak Ridge Associated Universities (ORAU) Quality Program Manual (ORISE 2008 and ORAU 2011a).

4.1 REFERENCE SYSTEM

Building dimensions were obtained using a hand-held distance meter to establish coordinate locations. The coordinates were then used for identifying sampling and measurement locations. Scan and measurement data were manually recorded and referenced to either a specific coordinate or prominent site feature.

4.2 SURFACE SCANS

High density scans were performed for alpha, alpha plus beta, and gamma radiation on the slab surface that had not been covered with new concrete. Particular attention was given to areas with the highest potential for contamination (i.e., cracks, joints, and surface run-off pathways). A large area gas proportional detector (550 cm²) was used for alpha and alpha plus beta radiation and a 2 inch × 2 inch sodium iodide, thallium-activated [NaI(Tl)] detector was used to detect gamma radiation. All detectors were coupled to ratemeter-scalers with audible indicators. ORISE field personnel relied on the audio output to identify any locations of elevated direct radiation that might suggest the presence of residual contamination. Locations of elevated direct radiation that potentially exceeded surface contamination guidelines were marked and identified for further investigation (Figures A-4 to A-6).

4.3 SURFACE ACTIVITY MEASUREMENTS

Static measurements for alpha and alpha plus beta activity were performed at 12 randomly generated locations. An additional 21 judgmental locations were identified for measurements and sampling where surface scans identified radiation levels potentially above acceptable surface contamination guidelines (Figure A-7). These predetermined random field assessment locations were designed and generated based on a statistical sampling design facilitated by using Visual Sample Plan (VSP) software (version 6.0 or greater). Data quality assessment was performed in accordance with U.S. Environmental Protection Agency (EPA) QA/G-9R *Data Quality Assessment: A Reviewer's Guide* and EPA QA/G-9S *Guidance for Data Quality Assessment* (EPA 2006a and b).

Smears for removable gross alpha and beta contamination were obtained on the original concrete surface. A 47 mm diameter numbered filter paper disk was used to sample an area of 100 cm².

4.4 SAMPLE ANALYSIS AND DATA INTERPRETATION

Smear samples and data were returned to the ORISE facility in Oak Ridge, Tennessee for analysis and interpretation. Smears were analyzed for removable gross alpha and beta in accordance with the ORISE Laboratory Procedures Manual (ORISE 2011b). A low background proportional counter was used to determine gross activity levels. Smear and direct measurement results are reported in units of disintegration per minute per 100 square centimeters (dpm/100cm²). Data collected as part of this survey will be archived by ORISE.

5. APPLICABLE SITE GUIDELINES

For structural surfaces that may remain in place, the “as left” condition must meet industrial surface criteria derived to achieve the same average excess lifetime cancer risk (ELCR) of 1×10^{-4} and the maximum risk level at ten times the average, as specified for the industrial area soils, as defined in the Bethel Valley ROD. The industrial surface criteria are applicable to the entire exposed surface of the slab (DOE 2002).

Surface criteria cited in the Bethel Valley ROD have been derived based on American National Standard Institute /Health Physics Society (HPS) HPS N13.12-1999 (HPS 1999). This standard specifies screening levels for clearance of surfaces containing residual radioactive materials, based on

a dose limit of 1 mrem/year, for several groups of radionuclides. Clearance, as defined by the standard, is “the removal of items or materials that contain residual levels of radioactive materials within authorized practices from any further control of any kind” (DOE 2002). The primary radionuclides of concern specified for building surfaces in Bethel Valley are classified in Group 2 per the Standard (DOE 2002). This includes uranium and selected high dose beta-gamma emitters. However, recent characterization data indicate Group 1 radionuclides radium, thorium, and transuranics (^{232}Th , $^{239/240}\text{Pu}$, and ^{241}Am) are present in the radionuclide mix. The surface activity screening level for Group 1 radionuclides is specified at 600 dpm/100 cm² and Group 2 radionuclides is specified at 6,000 dpm/100 cm² (HPS 1999). This screening level has been used to derive a risk-based surface concentration limit as follows (DOE 2002):

$$\text{RL}_{\text{surf}} = \text{TR} / [\text{DL}/\text{SL} \times \text{R} \times \text{ED}] = 1 \times 10^{-4} \text{ ELCR} / [(1 \text{ mrem/yr}) / (6,000 \text{ dpm}/100 \text{ cm}^2) \times 6 \times 10^{-7} \text{ ELCR}/\text{mrem} \times 25 \text{ years}] = 40,000 \text{ dpm}/100 \text{ cm}^2, \text{ where:}$$

- RL_{surf} = remediation levels for residual building surfaces,
- TR = target risk level = 1×10^{-4} ELCR,
- DL = dose limit used to derive surface screening level = 1 mrem/year
- SL = surface activity screening level for Group 2 radionuclides = 6,000 dpm/100 cm²
- R = cancer risk per unit dose for surface-deposited radioactivity (conservatively based on radionuclide-specific slope factor and external dose coefficient for $^{137}\text{Cs}+\text{D}$) = 6×10^{-7} ELCR/mrem
- ED = exposure duration = 25 years for industrial scenario.

NOTE: The derived RL_{surf} value is based on the assumption that a worker could potentially be located directly above the building surfaces for 2,000 hours per year. Since it is unlikely that any worker would actually occupy this location for such an extended period of time, this estimate is considered conservative and any actual risk may be well below the target level of 1×10^{-4} ELCR. Additional conservative assumptions are the absence of any consideration of (1) the decreasing concentrations of radionuclides on the building surfaces due to radioactive decay, and (2) shielding effects from backfill of basements and other subsurface structures (DOE 2002).

6. FINDINGS AND RESULTS

6.1 SURFACE SCANS

Surface scans were performed over the entire pad with the exception of areas that had been covered with new concrete. Alpha activity scans ranged from 0 cpm to 17,000 cpm and alpha plus beta activity scans ranged from 3,000 cpm to 57,000 cpm. Gamma activity scans over the surface of the slab ranged from 30,000 cpm to 95,000 cpm. This scan data is used as a qualitative indication to identify areas with radioactivity levels that require additional investigations (Figures A-4 to A-6). Static measurements are required to provide a quantitative determination of the guideline acceptance criteria. Much of the elevated radioactivity was identified in what would have been primarily laboratory areas in the southern wing of the building. This included rooms 19, 19B, 21, 21A, 23, 24, 24A, 25, 25A, 26, 27, 27A, 28, 28A, 28B, 29, 30, 31, 32, 32A, 34, and 36 (Figure A-3). Surveyors noted that cracks and joint areas in the slab had higher activity levels.

6.2 SURFACE ACTIVITY MEASUREMENTS

Static surface measurements were obtained for alpha and alpha plus beta at each randomly generated and judgmental location. Surface activity measurements are presented in Table B-1. The net total activity is reported in dpm/100 cm² after subtracting gross ambient background from the gross static measurement count rate. Random generated measurements for alpha activity ranged from 49 dpm/100 cm² to 610,000 dpm/100 cm², and alpha plus beta measurements ranged from 560 dpm/100 cm² to 290,000 dpm/100 cm². Surface activity for judgmental locations for alpha activity ranged from 16 dpm/100 cm² to 2,600 dpm/100 cm² and alpha plus beta measurements ranged from 430 dpm/100 cm² to 52,000 dpm/100 cm². The highest activity measurement was sample location 5086R0006 collected in the area of what was once Room 28A.

6.3 REMOVABLE ACTIVITY

Removable alpha activity ranged from -0.4 dpm/100 cm² to 310 dpm/100 cm² and removable beta activity ranged from -2.6 dpm/100 cm² to 9.9 dpm/100 cm² for randomly generated sampling locations. Removable activity at judgmental locations ranged from -0.4 dpm/100 cm² to 28 dpm/100 cm² for alpha and -4.7 dpm/100 cm² to 19 dpm/100 cm² for beta.

6.4 COMPARISON WITH GUIDELINES

The remediation level guideline for Group 2 radionuclides is 40,000 dpm/100 cm² for activity that can remain. This was exceeded at two locations for alpha plus beta; 5086R0006 (290,000 dpm/100 cm²) and 5086R0013 (52,000 dpm/100 cm²). This guidance is not specific as to the type of radiation. However, Group 1 radionuclides were present and identified in this facility during characterization efforts (ORISE 2010). The guideline for Group 1 radionuclides is 4,000 dpm/100 cm².

Removable contamination activity levels were compared with the DOE Order 5400.5 guidance for acceptable activity levels because HPS N13.12-1999 does not provide remediation guidelines for removable activity. Allowable alpha removable surface activity per DOE Order 5400.5 is 20 dpm/100 cm². Based on the results, removable alpha contamination was identified at locations 5086R0006 (310 dpm/100 cm²), 5086R0009 (45 dpm/100 cm²), 5086R0055 (19 dpm/100 cm²) and 5086R0056 (28 dpm/100 cm²). Three of the four locations exceeded the 20 dpm/100 cm² guidance while location 5086R0055 is just below at 19 dpm/100 cm².

7. SUMMARY

During the period of July 26, 2011 through July 28, 2011, ORISE conducted verification survey activities on the Building 3550 Slab that included scans, measurements, and the collection of smears. Scans for alpha, alpha plus beta, and gamma activity identified several areas that were investigated. Two measurement locations exceeded the 40,000 dpm/100 cm² surface remediation level guidelines and three measurements exceeded the DOE Order 5400.5 guidance for removable contamination. Although removable activity is not specifically addressed by the guidance in the Bethel Valley ROD, ORISE is of the opinion that the removable activity should be addressed by the contractor along with the surface measurements exceeding the guidance.

8. REFERENCES

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- UT-B 2008. *Preliminary Hazard Screening for the 3550 Complex, Oak Ridge National Laboratory, Oak Ridge, Tennessee*, PHS-OR-3550-Complex, Rev. 0, prepared for DOE-EM, February.

APPENDIX A
FIGURES

Figure A-1. Overview of Oak Ridge National Laboratory Central Campus

Figure A-2. Plot of Building 3550 Slab

Figure A-3. Former Building 3550 Floor Plan

Figure A-4. Building 3550 Slab Alpha Scan

Figure A-5. Building 3550 Slab Alpha Plus Beta Scan

Figure A-6. Building 3550 Slab Gamma Scan

Figure A-7. Building 3550 Slab Measurement and Sample Locations

APPENDIX B

TABLES

Table B-1. Surface Activity for the Building 3550 Slab
Oak Ridge National Laboratory
Oak Ridge, Tennessee

Measurement and Smear Location	Direct Measurements		Direct Measurements		Analytical Results	
	Alpha		Alpha + Beta		Removable Activity	
	Gross Activity (cpm)	Total Activity (dpm/ 100 cm ²)	Gross Activity (cpm)	Total Activity (dpm/ 100 cm ²)	Alpha Activity (dpm/ 100 cm ²)	Beta Activity (dpm/ 100 cm ²)
Random Systematic Locations						
5086R0001	8	49	820	1,200	1.7	2.6
5086R0002	12	81	596	560	-0.4	4.7
5086R0003	235	1,900	896	1,400	3.9	-2.6
5086R0004	398	3,200	1,327	2,700	1.7	0.5
5086R0005	130	1,000	1,808	4,100	3.9	4.7
5086R0006	75,166	610,000	99,378	290,000	310	9.9
5086R0007	93	740	5,018	14,000	1.7	-0.5
5086R0008	130	1,000	1,533	3,300	1.7	-2.6
5086R0009	1,700	14,000	5,666	16,000	45	5.7
5086R0010	650	5,300	4,170	11,000	6.1	1.6
5086R0011	36	280	3,173	8,100	3.9	-0.5
5086R0012	76	600	5,178	14,000	1.7	-1.6
Judgmental Locations						
5086R0013	57	450	18,249	52,000	1.7	-0.5
5086R0014	11	73	11,689	33,000	1.7	0.5
5086R0015	39	300	8,876	25,000	-0.4	-2.6
5086R0016	45	350	3,489	9,100	1.7	6.8
5086R0017	12	81	3,732	9,800	-0.4	-1.6
5086R0018	60	470	2,099	5,000	3.9	2.6
5086R0019	13	90	7,672	21,000	-0.4	2.6
5086R0020	6	33	632	670	-0.4	-0.5
5086R0021	8	49	659	750	-0.4	-3.6
5086R0022	5	24	661	760	6.1	-2.6
5086R0023	7	41	601	580	1.7	1.6
5086R0024	7	41	639	690	-0.4	0.5
5086R0025	20	150	642	700	-0.4	-0.5
5086R0026	7	41	550	430	-0.4	-3.6
5086R0027	7	41	635	680	-0.4	2.6
5086R0028	7	41	843	1,300	1.7	3.6
5086R0029	10	65	708	900	-0.4	-4.7
5086R0030	4	16	552	430	-0.4	-1.6
5086R0031	12	81	610	610	1.7	0.5
5086R0055	91	720	1,462	3,100	19	7.8
5086R0056	320	2,600	7,632	21,000	28	19

APPENDIX C
MAJOR INSTRUMENTATION

C.1 SCANNING AND MEASUREMENT INSTRUMENT/DETECTOR COMBINATIONS

C.1.1 ALPHA PLUS BETA

Ludlum Floor Monitor Model 239-1
combined with
Ludlum Ratemeter-Scaler Model 2221
coupled to
Ludlum Gas Proportional Detector Model 43-37, Physical Area: 550 cm²
(Ludlum Measurements, Inc., Sweetwater, TX)

C.1.2 GAMMA

Ludlum NaI Scintillation Detector Model 44-10, Crystal: 5.1 cm x 5.1 cm
(Ludlum Measurements, Inc., Sweetwater, TX)
coupled to:
Ludlum Ratemeter-scaler Model 2221
(Ludlum Measurements, Inc., Sweetwater, TX)

C.2 DIRECT MEASUREMENT INSTRUMENT/DETECTOR COMBINATIONS

C.2.1 ALPHA AND BETA

Ludlum Ratemeter-Scaler Model 2221
coupled to
Ludlum Gas Proportional Detector Model 43-68, Physical Area: 126 cm²
(Ludlum Measurements, Inc., Sweetwater, TX)

C.3 LABORATORY ANALYTICAL INSTRUMENTATION

Low background alpha/beta counting system
Canberra/Tennelec LB5100W Eclipse Software
(Canberra, Inc., Meriden, CT)

APPENDIX D

SURVEY AND ANALYTICAL PROCEDURES

D.1 PROJECT HEALTH AND SAFETY

Survey activities were conducted in accordance with the ORAU/ORISE overall health and safety program (HASP) and radiological protection program manuals (ORAU 2011b and ORISE 2011c). Pre-survey activities included an overview of potential health and safety issues. Potential health and safety issues that were identified were appropriately addressed by the ORISE HASP, site-specific Integrated Safety Management (ISM) pre-job hazard checklist, and an activity hazard analysis (AHA) prior to beginning site work.

D.2 QUALITY ASSURANCE

Analytical and field survey activities were conducted in accordance with procedures from the following ORAU and ORISE documents:

- Survey Procedures Manual (ORISE 2008)
- Laboratory Procedures Manual (ORISE 2011b)
- Quality Program Manual (ORAU 2011)

The procedures contained in these manuals were developed to meet the requirements of 10 CFR 830 Subpart A, *Quality Assurance Requirements*, Department of Energy Order 414.1C, *Quality Assurance*, and the U.S. Nuclear Regulatory Commission, *Quality Assurance Manual for the Office of Nuclear Material Safety and Safeguards*, and contain measures to assess processes during their performance.

Quality control procedures include:

- Daily instrument background and check-source measurements to confirm that equipment operation is within acceptable statistical fluctuations.
- Participation in Mixed Analyte Performance Evaluation Program (MAPEP), National Institute for Standards and Technology (NIST) Radiochemistry Intercomparison Program (NRIP), and Intercomparison Testing Program (ITP) Laboratory Quality Assurance Programs.
- Training and certification of all individuals performing procedures.
- Periodic internal and external audits.

D.3 CALIBRATION

Detectors used for assessing surface activity were calibrated in accordance with ISO-7503¹ recommendations. Total alpha and beta efficiencies (ϵ_{total}) were determined for each instrument/detector combination and consisted of the product of the 2π instrument efficiency (ϵ_i) and surface efficiency (ϵ_s): $\epsilon_{\text{total}} = \epsilon_i \times \epsilon_s$. Beta total efficiencies were determined based on a beta energy multi-point calibration, development of instrument efficiency to beta energy calibration curves, and the calculation of the weighted efficiency representing the Th-232 decay series. Included in the weighted efficiency was an empirically determined correction for disequilibrium in the decay series that results from Rn-220 loss. A 3.8 mg/cm² density thickness mylar window was used on the beta detectors to block detector response contributions from alpha radiation.

Th-230 was selected as the alpha calibration source. The 2π alpha instrument efficiency (ϵ_i) factor was 0.39 for the gas proportional detector. C-14, Tc-99, Tl-204, and Sr/Y-90 were selected as the beta calibration sources to represent the energy distribution of the detectable beta-emitters in the Th-232 decay series. The 2π interpolated ϵ_i factors for the detectable beta-emitters ranged from 0.34 to 0.56 for the gas proportional detector. ISO-7503 recommends an ϵ_s of 0.25 for alpha emitters and also beta emitters with a maximum energy of less than 0.4 MeV and an ϵ_s of 0.5 for maximum beta energies greater than 0.4 MeV. The thorium series alpha efficiency is 0.10. The total weighted beta efficiency for the beta detectors ranged from 0.08 to 0.28.

Calibration of all field and laboratory instrumentation was based on standards/sources, traceable to NIST, when such standards/sources were available. In cases where they were not available, standards of an industry-recognized organization were used.

D.4 SURVEY PROCEDURES

D.4.1 SURFACE SCANS

Scans for elevated gamma radiation were performed by passing the detector slowly over the surface, the distance between the detector and the surface was maintained at a minimum—nominally about 1 cm or as close to the surface as possible. A NaI scintillation detector was used to scan for elevated gamma radiation throughout the slab. The scan minimum detectable concentrations (MDCs) for the

¹International Standard. ISO 7503-1, Evaluation of Surface Contamination - Part 1: Beta-emitters (maximum beta energy greater than 0.15 MeV) and alpha-emitters. August 1, 1988.

NaI scintillation detector for the contaminants of concern for a concrete surface were obtained directly from NUREG-1507² when available or estimated using the calculation approach described in NUREG-1507. A typical NaI 2-in x 2-in detector MDC is 6.4 pCi/g for cesium-137. Audible increases in the activity rate are investigated by ORISE. It is standard procedure for ORISE staff to pause and investigate any locations where gamma radiation is distinguishable from background levels.

D.4.2 SURFACE ACTIVITY MEASUREMENTS

Measurements of total alpha and total beta surface activity levels were performed using hand-held scintillation detectors coupled to portable ratemeter-scalers. Count rates (cpm), which were integrated over one minute with the detector held in a static position, were converted to activity levels (dpm/100 cm²) by dividing the count rate by the total static efficiency ($\epsilon_i \times \epsilon_s$) and correcting for the physical area of the detector.

The *a priori* MDC for surface activity measurements was calculated using the following equation:

$$MDC = \frac{3 + (4.65\sqrt{B})}{Tx\epsilon_{Tot}xG}$$

Where:

B	=	background (total counts) in time interval, T
T	=	count time (min) used for field instruments
ϵ_{Tot}	=	total efficiency = $\epsilon_i \times \epsilon_s$
ϵ_i	=	instrument efficiency
ϵ_s	=	source efficiency
G	=	geometry (physical detector area cm ² /100)

The *a priori* alpha static MDC was approximately 76 dpm/100 cm² using the total efficiency of 0.10 and an instrument background of 2 cpm. The physical surface area assessed by the scintillation detector used was 100 cm². The *a priori* beta static MDC was approximately 284 dpm/100 cm² using the total efficiency of 0.27 and the nominal instrument background of 404 cpm. The physical surface area assessed by the detector used was 126 cm².

²NUREG-1507. Minimum Detectable Concentrations With Typical Radiation Survey Instruments for Various Contaminants and Field Conditions. U.S. Nuclear Regulatory Commission. Washington, DC; June 1998.

D.4.3 REMOVABLE ACTIVITY MEASUREMENTS

Smear samples for removable gross alpha and gross beta contamination were obtained from each measurement location. Removable activity samples were collected using numbered filter paper disks, 47 mm in diameter. Moderate pressure was applied to the smear and approximately 100 cm² of the surface was wiped. Smears were placed in labeled envelopes with the location and other pertinent information recorded.

D.5 RADIOLOGICAL ANALYSIS

D.5.1 GROSS ALPHA/BETA

Smears were counted on a low-background gas proportional system for gross alpha and beta activity. The MDCs of the procedure were 9 dpm/100 cm² and 15 dpm/100 cm² for a 2-minute count time for gross alpha and gross beta, respectively.

D.5.2 DETECTION LIMITS

Detection limits, referred to as MDC, were based on 3 plus 4.65 times the standard deviation of the background (BKG) count $[3 + (4.65 (\text{BKG})^{1/2})]$. Because of variations in background levels, measurement efficiencies, and contributions from other radionuclides in samples, the detection limits differ from sample to sample and instrument to instrument.