ORISE

OAK RIDGE INSTITUTE FOR SCIENCE AND EDUCATION

October 7, 2004

Mr. Thomas Dragoun
NRR/DRIP
U.S. Nuclear Regulatory Commission
475 Allendale Road
King of Prussia, PA 19406

SUBJECT: FINAL REPORT—CONFIRMATORY SURVEY OF THE PENELEC LINE SHACK, SAXTON NUCLEAR EXPERIMENTAL CORPORATION, SAXTON, PENNSYLVANIA (DOCKET NO. 50-146; TASK 1)

Dear Mr. Dragoun:

The Environmental Survey and Site Assessment Program (ESSAP) of the Oak Ridge Institute for Science and Education (ORISE) performed confirmatory survey activities of the Penelec Line Shack at the Saxton Nuclear Experimental Corporation (SNEC) in Saxton, Pennsylvania, during the period July 7 through 8, 2004. Enclosed is the final report

If you have any questions or comments, please direct them to me at (865) 576-3356 or Timothy J. Vitkus at (865) 576-5073.

Sincerely,

Timothy J. Bauer
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TJB:kp

Enclosure

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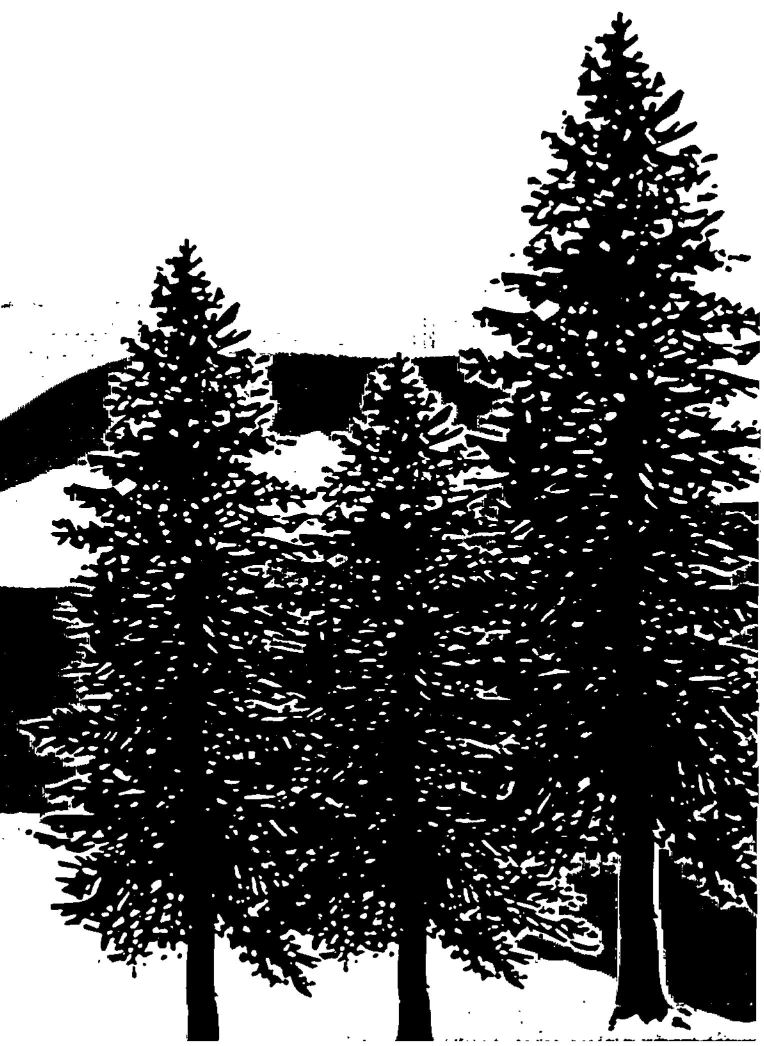
CONFIRMATORY SURVEY
OF THE PENELEC LINE SHACK
SAXTON NUCLEAR EXPERIMENTAL CORPORATION
SAXTON, PENNSYLVANIA
[DOCKET NO. 50-146; TASK 1]

T. J. BAUER

Prepared for the
U.S. Nuclear Regulatory Commission
Office of Nuclear Reactor Regulation



ORISE
OAK RIDGE INSTITUTE FOR SCIENCE AND EDUCATION

Environmental Survey and Site Assessment Program

ORISE 04-1326

CONFIRMATORY SURVEY OF THE PENELEC LINE SHACK SAXTON NUCLEAR EXPERIMENTAL CORPORATION SAXTON, PENNSYLVANIA

Prepared by

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Oak Ridge Institute for Science and Education
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Prepared for the

U.S. Nuclear Regulatory Commission
Office of Nuclear Reactor Regulation

FINAL REPORT

SEPTEMBER 2004

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CONFIRMATORY SURVEY
OF THE PENELEC LINE SHACK
SAXTON NUCLEAR EXPERIMENTAL CORPORATION
SAXTON, PENNSYLVANIA

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ACKNOWLEDGMENTS

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ABBREVIATIONS AND ACRONYMS

ε_i	instrument efficiency
ε_s	surface efficiency
ε_{total}	total efficiency
b_i	number of background counts in the interval
BKG	background
cm	centimeter
cm^2	square centimeter
cpm	counts per minute
CV	containment vessel
d'	index of sensitivity
DCGL	derived concentration guideline level
DOE	Department of Energy
dpm/100 cm^2	disintegrations per minute per 100 square centimeters
ESSAP	Environmental Survey and Site Assessment Program
FSS	final status survey
GPU	GPU Nuclear, Inc.
ISM	Integrated Safety Management
ISO	International Standards Organization
ITP	Intercomparison Testing Program
JHA	job hazard analysis
keV	kiloelectron volts
LTP	license termination plan
MAPEP	Mixed Analyte Performance Evaluation Program
MARSSIM	Multi-Agency Radiation Survey and Site Investigation Manual
MDC	minimum detectable concentration
MDCR	minimum detectable count rate
MeV	million electron volts
min	minute
mm	millimeter
MWTh	megawatt thermal
NaI	sodium iodide
NIST	National Institute of Standards and Technology
NRC	Nuclear Regulatory Commission
NRIP	NIST Radiochemistry Intercomparison Program
NRR	Office of Nuclear Reactor Regulation
ORISE	Oak Ridge Institute for Science and Education
PWR	pressurized water reactor
sec	second
SNEC	Saxton Nuclear Experimental Corporation

CONFIRMATORY SURVEY
OF THE PENELEC LINE SHACK
SAXTON NUCLEAR EXPERIMENTAL CORPORATION
SAXTON, PENNSYLVANIA

INTRODUCTION AND SITE HISTORY

The Saxton Nuclear Experimental Corporation (SNEC) facility, built from 1960 to 1962, was licensed to operate a 23.5-megawatt thermal (MWTh) power pressurized water reactor (PWR). Initial criticality was reached on April 13, 1962 and the facility was shut down on May 1, 1972 after three fuel cycles were completed for a total of 1,005 effective full power days. At shutdown, the facility was placed into a state similar to the now defined U.S. Nuclear Regulatory Commission (NRC) "SAFSTOR" status. The reactor fuel was removed in 1972 and sent to the Atomic Energy Commission's, predecessor to the U.S. Department of Energy (DOE), facility in Savannah River, South Carolina. After the fuel was removed, equipment, tanks, and piping outside of the containment vessel (CV) were removed. From 1972 through 1974, buildings and structures that supported reactor operation were partially decontaminated. The SNEC facility has been maintained in a monitored condition since reactor shutdown.

GPU Nuclear, Inc. (GPU), a subsidiary of FirstEnergy Corporation, was formed in 1980, and became co-licensee with SNEC for the SNEC facility. GPU is currently decommissioning the SNEC facility on behalf of the site owner, SNEC. A variety of decommissioning activities have been performed at the SNEC site since 1980, which included but was not limited to the survey and demolitions of reactor support buildings and structures in 1992, the SNEC Soil Remediation Project completed in 1994, and the SNEC Large Component Removal Project completed in 1998. Most of the decommissioning focus since 1998 has been on the removal of support systems and interior CV concrete.

The Penelec Line Shack, Penelec Garage, Penelec Warehouse, and Penelec Switchyard Building are buildings located on property adjoining the SNEC facility property. While these structures were not directly associated with SNEC facility operation, SNEC used these buildings for storage, staging, and other such activities. A comprehensive final release survey of these buildings was performed from October 1988 to June 1989; however, since the time of the survey, decommissioning activities may have impacted these areas. All of the buildings except for the

Penelec Line Shack will be demolished, leaving it as the only structure remaining above ground on the SNEC site after the release of the site for public use. GPU used the guidance provided in the Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM) to plan and perform the final status survey (FSS) of the Penelec Line Shack building (NRC 2000, GPU 2004a).

At the request of the NRC's Headquarters Office of Nuclear Reactor Regulation (NRR), the Oak Ridge Institute for Science and Education's (ORISE), Environmental Survey and Site Assessment Program (ESSAP) performed confirmatory surveys of the Penelec Line Shack.

SITE DESCRIPTION

The SNEC facility is located at 165 Power Plant Road in Saxton, Pennsylvania (Figure 1). The only SNEC building remaining on the site is the Penelec Line Shack. All other remaining structures are temporary buildings used for decommissioning support activities. The Penelec Line Shack interior and exterior surfaces have been divided into 15 survey units with a total area of approximately 1,750 square meters. The building is constructed of sheet metal walls, steel roofing material, and a poured concrete interior floor. Other construction materials included masonite, cinderblocks, tile, and miscellaneous painted surfaces.

OBJECTIVES

The objectives of the confirmatory survey were to provide independent contractor field data reviews and generate independent radiological data for use by the NRC in evaluating the adequacy and accuracy of the licensee's procedures and FSS results.

DOCUMENT REVIEW

ESSAP reviewed the licensee's final radiological survey data for adequacy and appropriateness taking into account the license termination plan (LTP) and MARSSIM considerations (GPU 2004a and b and NRC 2000).

PROCEDURES

Survey activities were conducted from July 7 through 8, 2004 in accordance with a site-specific survey plan and the ORISE ESSAP Survey Procedures and Quality Assurance Manuals (ORISE 2004a, 2003, and 2004b). Appendices A and B provide additional information on the instrumentation and procedures discussed in this report including minimum detectable concentrations for field and laboratory instruments.

REFERENCE SYSTEM

Measurements and sampling locations were referenced to the existing SNEC-established grid system or prominent building features.

SURFACE SCANS

Interior and exterior surfaces were scanned for total beta radiation using gas proportional detectors and scanned for gamma radiation using NaI scintillation detectors. Total beta and gamma radiation scans were performed on approximately 100% of accessible areas of the floors and interior and exterior lower walls, up to a height of two meters—some areas were inaccessible due to shelving and equipment storage. Particular attention was given to cracks and joints of surfaces and other locations where material may have accumulated. All detectors were coupled to ratemeters or ratemeter-scalers with audible indicators. Locations of potentially significant elevated direct radiation were marked for further investigation.

SURFACE ACTIVITY MEASUREMENTS

Direct measurements of building surfaces for total beta activity were performed at 30 locations which were identified by surface scans or corresponded to judgmental measurement locations (Figures 2 and 3). An area for determining construction material-specific backgrounds for the various materials of the building was not available on site; the off-site location SNEC had used in the past as a background reference area changed ownership and was no longer available. Because construction material-specific backgrounds could not be determined, a shielded and unshielded measurement was performed at each location to correct for ambient gamma background contribution to the measurement count rate. Smear samples, for determining removable activity levels, were collected from each direct measurement location. Measurements were performed using gas proportional detectors coupled to portable ratemeter-scalers.

SAMPLE ANALYSIS AND DATA INTERPRETATION

Samples and data were returned to ORISE's ESSAP laboratory in Oak Ridge, Tennessee for analysis and interpretation. Samples were analyzed in accordance with the ESSAP Laboratory Procedures Manual (ORISE 2004c). Smears were analyzed for gross alpha and gross beta activity using a low-background gas proportional counter. Smear data and direct measurements for surface activity were converted to units of disintegrations per minute per 100 square centimeters (dpm/100 cm^2).

Survey data were then compared with the site-specific derived concentration guideline levels ($DCGL_W$) for the Penelec Line Shack. The primary contaminants of concern were beta-gamma emitters—fission and activation products—resulting from reactor operation. SNEC's NRC-approved gross activity $DCGL_W$ for surfaces of the Penelec Line Shack is 33,325 dpm/100 cm^2 (GPU 2004a).

FINDINGS AND RESULTS

SURFACE SCANS

Beta surface scans of the floors identified three areas distinguishable from background levels. These areas noted on the floor were small in size, generally less than 300 cm^2 in area. Gamma scans did not identify any indications of volumetric or subsurface contamination (i.e., gamma radiation levels were consistently within background ranges).

SURFACE ACTIVITY LEVELS

Results of total and removable surface activity measurements for judgmental locations noted during surface scans and measurements performed at judgmental locations are provided in Table 1 for interior surfaces and Table 2 for exterior surfaces. Total beta surface activity ranged from -230 to 560 dpm/100 cm^2 for both interior and exterior surfaces. Removable surface activity ranged from 0 to 3 dpm/100 cm^2 for gross alpha and -5 to 4 dpm/100 cm^2 for gross beta.

COMPARISON OF RESULTS WITH GUIDELINES

The contaminants of concern for this site are beta-gamma emitters resulting from the operation of the SNEC facility, with Cs-137 as the primary radionuclide. SNEC's NRC-approved gross activity $DCGL_W$ for surfaces of the Penelec Line Shack is 33,325 dpm/100 cm^2. No measurements exceeded the $DCGL_W$.

SUMMARY

At the request of the U.S. Nuclear Regulatory Commission's Office of Nuclear Reactor Regulation, the Environmental Survey and Site Assessment Program of the Oak Ridge Institute for Science and Education conducted a confirmatory survey of the Penelec Line Shack at the Saxton Nuclear Experimental Corporation in Saxton, Pennsylvania. Confirmatory activities performed during the period July 7 through 8, 2004 included reviews of final status survey data, confirmatory scans, and direct surface activity measurements. Overall, the results of the survey activities confirmed that the radiological conditions of the Penelec Line Shack met the approved site-specific criteria.

FIGURES

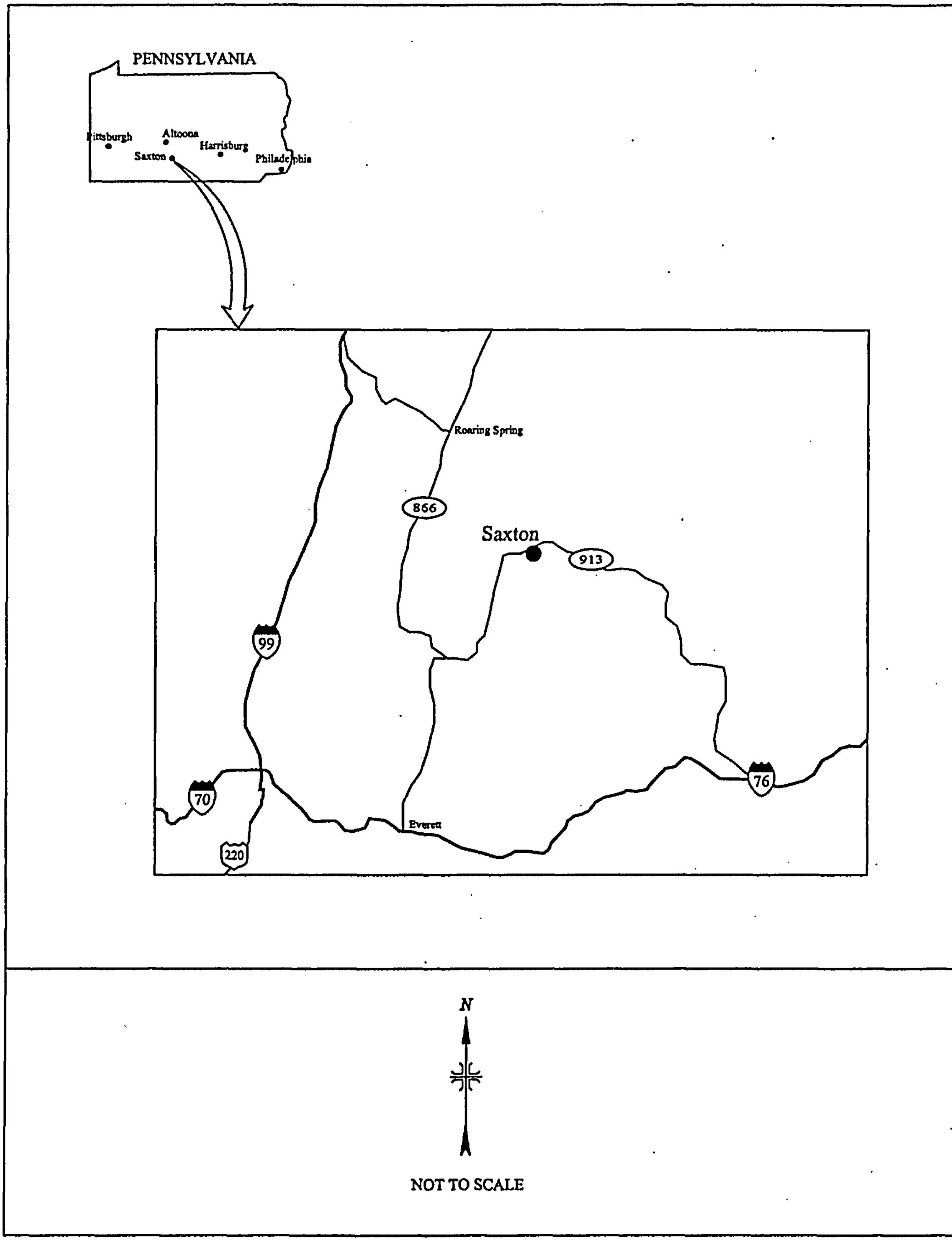

FIGURE 1: Location of the Saxton Nuclear Experimental Corporation - Saxton, Pennsylvania

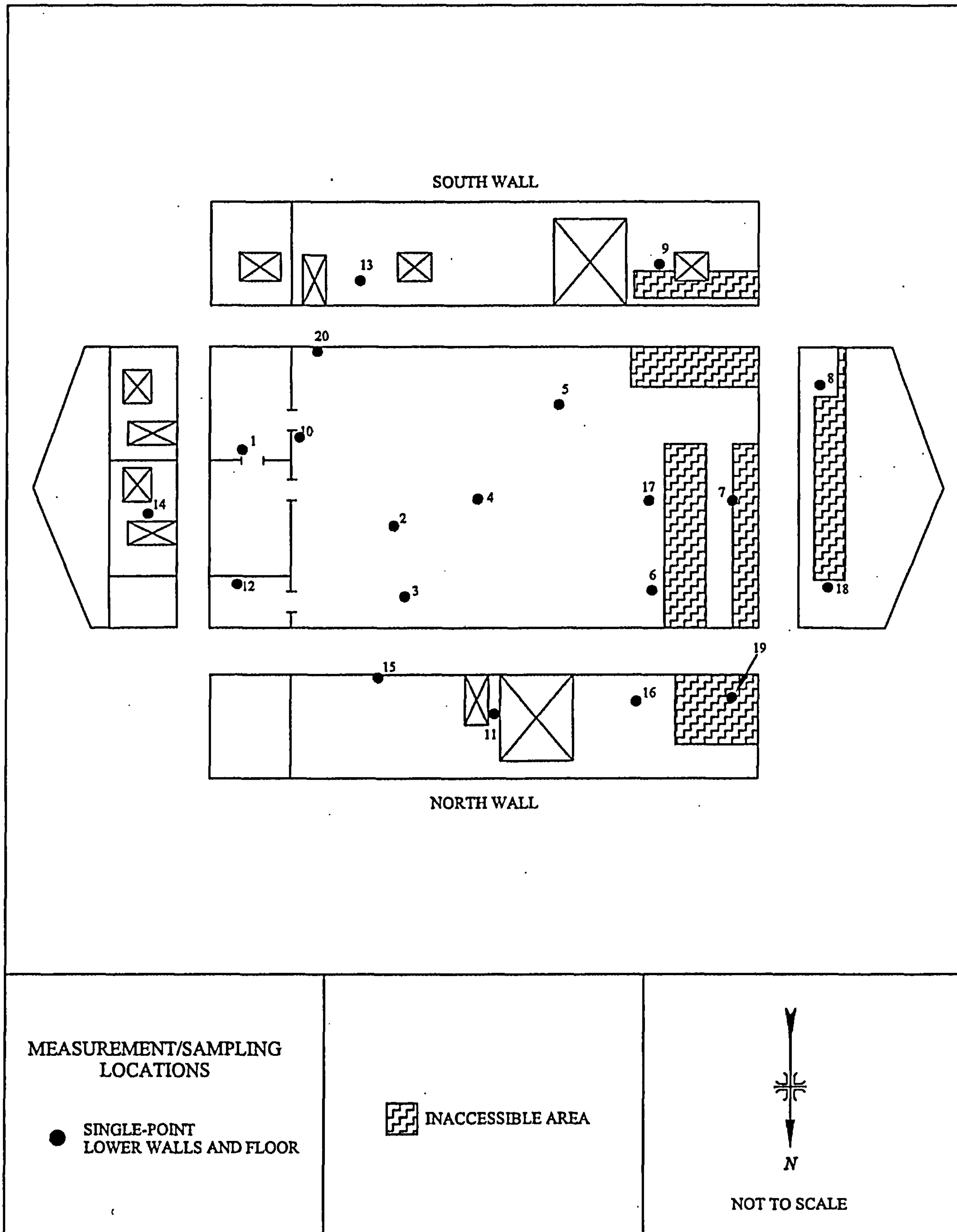

FIGURE 2: Penelec Line Shack Interior - Measurement and Sampling Locations

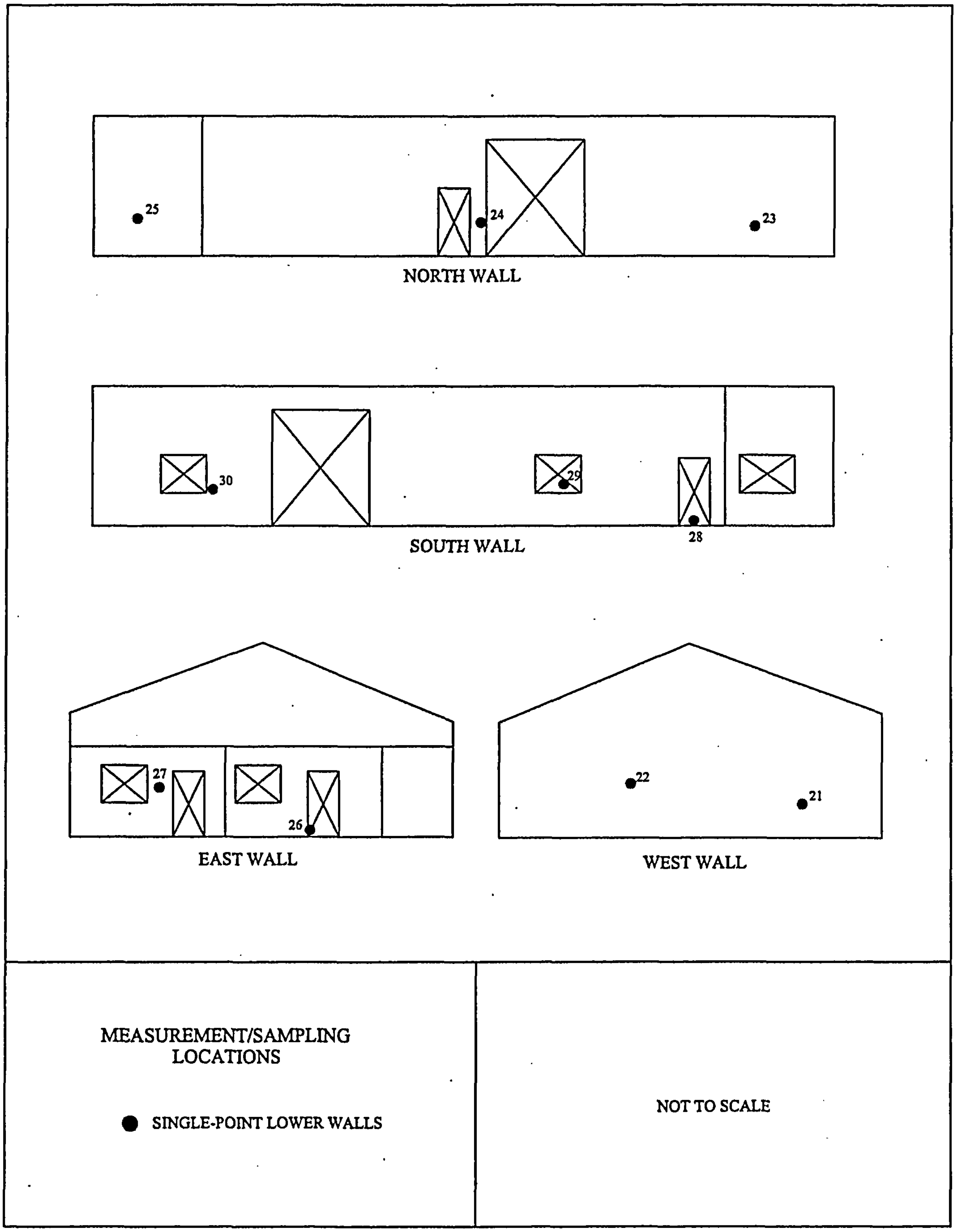

FIGURE 3: Penelec Line Shack Exterior - Measurement and Sampling Locations

TABLES

TABLE 1

SURFACE ACTIVITY LEVELS
PENELEC LINE SHACK INTERIOR
SAXTON NUCLEAR EXPERIMENTAL CORPORATION
SAXTON, PENNSYLVANIA

Location[a]	Description	Total Beta Surface Activity (dpm/100cm^2)	Removable Surface Activity (dpm/100 cm^2)	
			Gross Alpha	Gross Beta
1	Floor	-40	0	-4
2	Floor	220	0	2
3	Floor	44	0	4
4	Floor	320	0	4
5	Floor	280	0	-4
6	Floor	410	3	-3
7	Floor	500	0	-3
8	West Wall	180	0	-2
9	South Wall	-130	0	-3
10	East Wall	200	0	-2
11	North Wall	-83	1	2
12	South Wall	-230	0	2
13	South Wall	-8	0	-4
14	East Wall	52	0	-2
15	North Wall	44	0	-2
16	North Wall	-63	0	1
17	Floor	310	0	1
18	West Wall	130	1	2
19	North Wall	110	0	-3
20	Floor	560	0	-3

[a]See Figure 2.

TABLE 2

SURFACE ACTIVITY LEVELS
PENELEC LINE SHACK EXTERIOR
SAXTON NUCLEAR EXPERIMENTAL CORPORATION
SAXTON, PENNSYLVANIA

Location[a]	Description	Total Beta Surface Activity (dpm/100cm^2)	Removable Surface Activity (dpm/100 cm^2)	
			Gross Alpha	Gross Beta
21	West Wall	48	0	-1
22	West Wall	71	1	-3
23	North Wall	180	1	-2
24	North Wall	120	0	1
25	North Wall	120	1	-3
26	East Wall	180	3	-4
27	East Wall	44	0	-2
28	South Wall	75	0	2
29	South Wall	110	1	-5
30	South Wall	140	0	2

[a]See Figure 3.

REFERENCES

GPU Nuclear, Inc (GPU). Final Status Survey Report Saxton Nuclear Experimental Corporation Penelec Line Shack. Saxton, Pennsylvania; June 2004a.

GPU Nuclear, Inc. Saxton Nuclear Experimental Corporation Facility License Termination Plan. Saxton, Pennsylvania; Revision 3, February 2004b.

Oak Ridge Institute for Science and Education (ORISE). Survey Procedures Manual for the Environmental Survey and Site Assessment Program. Oak Ridge, Tennessee; November 2003.

Oak Ridge Institute for Science and Education. Final Confirmatory Survey Plan for the Penelec Line Shack Building, Saxton Nuclear Experimental Corporation, Saxton, Pennsylvania (Docket No. 50-146; Task 1). Oak Ridge, Tennessee; June 30, 2004a.

Oak Ridge Institute for Science and Education. Quality Assurance Manual for the Environmental Survey and Site Assessment Program. Oak Ridge, Tennessee; January 2004b.

Oak Ridge Institute for Science and Education. Laboratory Procedures Manual for the Environmental Survey and Site Assessment Program. Oak Ridge, Tennessee; March 2004c.

U.S. Nuclear Regulatory Commission (NRC). Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM). Washington, DC; NUREG-1575; Revision 1, August 2000.

APPENDIX A
MAJOR INSTRUMENTATION

APPENDIX A

MAJOR INSTRUMENTATION

The display of a specific product is not to be construed as an endorsement of the product or its manufacturer by the author or his employer.

SCANNING INSTRUMENT/DETECTOR COMBINATIONS

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 cm^2
(Ludlum Measurements, Inc., Sweetwater, TX)

Ludlum Ratemeter-Scaler Model 2221
coupled to
Ludlum Gas Proportional Detector Model 43-68, Physical Area: 126 cm^2
(Ludlum Measurements, Inc., Sweetwater, TX)

Gamma

Eberline Pulse Ratemeter Model PRM-6
(Eberline, Santa Fe, NM)
coupled to
Victoreen NaI Scintillation Detector Model 489-55, Crystal: 3.2 cm x 3.8 cm
(Victoreen, Cleveland, OH)

DIRECT MEASUREMENT INSTRUMENT/DETECTOR COMBINATIONS

Beta

Ludlum Ratemeter-Scaler Model 2221
coupled to
Ludlum Gas Proportional Detector Model 43-68, Physical Area: 126 cm^2
(Ludlum Measurements, Inc., Sweetwater, TX)

LABORATORY ANALYTICAL INSTRUMENTATION

Low-Background Gas Proportional Counter
Model LB-5100-W
(Tennelec/Canberra, Meriden, CT)

APPENDIX B
SURVEY AND ANALYTICAL PROCEDURES

APPENDIX B
SURVEY AND ANALYTICAL PROCEDURES

PROJECT HEALTH AND SAFETY

The proposed survey and sampling procedures were evaluated to ensure that any hazards inherent to the procedures themselves were addressed in current job hazard analyses (JHAs). All survey and laboratory activities were conducted in accordance with ORISE health and safety and radiation protection procedures.

Pre-survey activities included the evaluation and identification of potential health and safety issues through the use of a site-specific Integrated Safety Management (ISM) pre-job hazard checklist. A walkdown of the survey area was performed in order to evaluate and identify potential health and safety issues. Identified hazards fell under the existing JHAs.

CALIBRATION AND QUALITY ASSURANCE

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.

Analytical and field survey activities were conducted in accordance with procedures from the following documents of the Environmental Survey and Site Assessment Program:

- Survey Procedures Manual (November 2003)
- Laboratory Procedures Manual (March 2004)
- Quality Assurance Manual (January 2004)

The procedures contained in these manuals were developed to meet the requirements of Department of Energy (DOE) Order 414.1B 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 MAPEP, NRIP, and ITP Laboratory Quality Assurance Programs.
- Training and certification of all individuals performing procedures.
- Periodic internal and external audits.

Detectors used for assessing surface activity were calibrated in accordance with ISO-7503[1] recommendations. The total beta efficiency (ε_{total}) was determined for each instrument/detector combination and consisted of the product of the 2π instrument efficiency (ε_i) and surface efficiency (ε_s): $\varepsilon_{total} = \varepsilon_i \times \varepsilon_s$.

Technetium-99 was selected as the calibration source as its maximum beta energy of 294 keV is lower than, thus conservative, compared to the maximum beta energy of 514 keV for Cs-137, the primary contaminant. ISO-7503[1] recommends an ε_s of 0.25 for beta emitters with a maximum energy of less than 0.4 MeV (400 keV) and an ε_s of 0.5 for maximum beta energies greater than 0.4 MeV. Since the maximum beta energy for Cs-137 is greater than 0.4 MeV, an ε_s of 0.50 was used to calculate ε_{total}.

Surface Scan Efficiencies

Hand-held detectors were placed on contact with the calibration sources. A postulated hot-spot size of 100 cm^2 was assumed *a priori* for determining scanning instrument efficiencies. The scanning ε_i value ranged from 0.31 to 0.34 for the hand-held gas proportional detectors, with the scanning ε_{total} calculated to range from 0.16 to 0.17. Calibration source emission rates were not corrected for geometry when sources larger than the detectors were used.

[1]International 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.

Surface Activity Measurement Efficiencies

The static ε_i value for the single gas proportional detector used for the confirmatory survey surface activity measurements was 0.40; the static ε_{total} was calculated to be 0.20. The calibration source emission rates were corrected to the physical area of the detectors when the source area exceeded the detector area.

SURVEY PROCEDURES

Surface Scans

Surface scans were performed by passing the detectors slowly over the surface; the distance between the detector and the surface was maintained at a minimum—nominally about 1 cm. A large surface area, gas proportional floor monitor and a NaI scintillation detector were used to scan the floors of the surveyed areas. Lower wall surfaces were scanned using small area (126 cm^2) hand-held detectors. Identification of elevated levels was based on increases in the audible signal from the recording and/or indicating instrument.

Scan minimum detectable concentrations (MDCs) were estimated using the calculational approach described in NUREG-1507[2]. The scan MDC is a function of many variables, including the background level. Typical beta background levels on floors and walls range from 800 to 1,400 cpm for the large surface area, gas proportional detectors (floor monitor) and from 250 to 450 cpm for the hand-held gas proportional detectors. Additional parameters selected for the calculation of scan MDC included a one-second observation interval, a specified level of performance at the first scanning stage of 95% true positive rate and 25% false positive rate, which yields a *d'* value of 2.32 (NUREG-1507, Table 6.1), and a surveyor efficiency of 0.5. To illustrate an example for the floor monitor and hand-held gas proportional detectors, the minimum detectable count rate (MDCR) and scan MDC can be calculated as follows:

$$b_i = (250\ \text{cpm})\ (1\ \text{sec})\ (1\ \text{min}/60\ \text{sec}) = 4.2\ \text{counts}$$
$$\text{MDCR} = (2.32)\ (4.2\ \text{counts})^{1/2}\ [(60\ \text{sec/min}) / (1\ \text{sec})] = 285\ \text{counts}$$
$$\text{MDCR}_{surveyor} = 285 / (0.5)^{1/2} = 403\ \text{cpm}$$

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

The scan MDC is calculated using the lowest calibrated hand-held gas proportional detector scanning ε_{total} of 0.16:

$$Scan\,MDC = \frac{MDCR_{surveyor}}{\varepsilon_{total}}\ \text{dpm}/100\ \text{cm}^2$$

The scanning ε_{total} was determined for the floor monitor in the same fashion as above for the hand-held gas proportional detectors except typical efficiencies for the floor monitor were used rather than specific calibrations for this survey. The scanning ε_i value for Tc-99 for the floor monitor was 0.24; the scanning ε_{total} was calculated to be 0.12. For the given backgrounds, the estimated scan MDC range for the floor monitor is 4,500 to 5,900 dpm/100 cm^2; and 2,500 to 3,400 dpm/100 cm^2 for the hand-held gas proportional detector.

Specific scan MDCs for the NaI scintillation detector for Cs-137 in concrete were not determined as the instrument was used solely as a qualitative means to identify elevated gamma radiation for possible concrete sampling.

Surface Activity Measurements

Measurements of total beta surface activity levels were performed using a gas proportional detector with 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 cm^2) by dividing the net count rate by the total static efficiency ($\varepsilon_i \times \varepsilon_s$) and correcting for the physical area of the detector.

Surface activity measurements were performed on poured concrete, cinderblocks, tile, wall board, and corrugated metal. To account for the ambient gamma background, unshielded and shielded measurements were performed at each location. A 3/8-inch Plexiglas shield was used to determine the gamma count rate associated with the unshielded count rates. This thickness was demonstrated to block the beta particles from Sr-90, including the beta particles from the progeny Y-90. Since Y-90 emits beta particles higher in energy than Cs-137, the Plexiglas shield used completely shielded measurement of the Cs-137 beta emissions. Surface activity was calculated by determining the net count rate, by subtracting the shielded measurement from the unshielded measurement, then correcting for total efficiency and detector area size.

The static beta MDC—calculated using the site background redetermination check-out count rate of 292 cpm—for the single gas proportional detector used for direct measurements was 330 dpm/100 cm^2. The physical surface area assessed by the gas proportional detector used was 126 cm^2.

Removable Activity Measurements

Removable gross alpha and gross beta activity levels were determined using numbered filter paper disks, 47 mm in diameter. Moderate pressure was applied to the smear and approximately 100 cm^2 of the surface was wiped. Smears were placed in labeled envelopes with the location and other pertinent information recorded.

RADIOLOGICAL ANALYSIS

Gross Alpha/Beta

Smears were counted for two minutes on a low-background gas proportional system for gross alpha and beta activity. The MDCs of the procedure were 8 dpm/100 cm^2 and 15 dpm/100 cm^2 for gross alpha and gross beta, respectively.

DETECTION LIMITS

Detection limits, referred to as MDCs, were based on 3 plus 4.65 times the standard deviation of the background count $[3 + (4.65\sqrt{BKG})]$. 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.