YANKEE ATOMIC ELECTRIC COMPANY

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September 21, 2006
BYR 2006-083

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

References: (a) License No. DPR-3 (Docket No. 50-29)

(b) BYR 2004-133, Submittal of Revision 1 to the Yankee Nuclear Power Station's License Termination Plan

(c) Yankee Nuclear Power Station – Issuance of Amendment 158 Re: License Termination Plan

Subject: Submittal of YNPS-FSS-SVC01-00, the Final Status Survey Report for Survey Area SVC-01

Dear Madam/Sir:

This letter submits YNPS-FSS-SVC01-00, Final Status Survey Report for SVC-01. This report was written in accordance with Section 5 of the YNPS License Termination Plan, "Final Status Survey Plan," and is consistent with the guidance provided in the Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM).

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

Sincerely,

YANKEE ATOMIC ELECTRIC COMPANY

Alice C C

for
Joseph R. Lynch
Regulatory Affairs Manager

Enclosure: YNPS-FSS-SVC01-00 (2 hard copies plus CD)

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Yankee Nuclear Plant Station Final Status Survey Report For SVC-01

Yankee Atomic Electric Company

YANKEE NUCLEAR POWER STATION
FINAL STATUS SURVEY REPORT

REPORT NO.: YNPS-FSS-SVC-01-00

Prepared by: ______________________ Date: 9-13-06
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Reviewed by: ______________________ Date: 9/13/06
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Approved by: ______________________ Date: 9/13/06
Martin Erickson, FSS Manager

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List of Abbreviations and Acronyms

AL	Action Level
ALARA	As Low As Reasonably Achievable
c/d	Counts per Disintegration
DCGL	Derived Concentration Guideline Level
$DCGL_{EMC}$	DCGL for small areas of elevated activity
$DCGL_{W}$	DCGL for average concentration over a wide area, used with statistical tests
DQO	Data Quality Objectives
EMC	Elevated Measurement Comparison
ETD	Easy-to-Detect
FSS	Final Status Survey
FSSP	Final Status Survey Plan
GPS	Global Positioning System
H_0	Null Hypothesis
HSA	Historical Site Assessment
HTD	Hard-to-Detect
ISOCS	*In-situ* Object Counting System®
LBGR	Lower Bound of the Grey Region
LTP	License Termination Plan
MARSSIM	Multi-Agency Radiation Survey and Site Investigation Manual
MDA	Minimum Detectable Activity
MDC	Minimum Detectable Concentration
PAB	Primary Auxiliary Building
QAPP	Quality Assurance Project Plan
QC	Quality Control
RCA	Radiological Controlled Area
RP	Radiation Protection
RSS	Reactor Support Structure
SFP	Spent Fuel Pool
VC	Vapor Container
VCC	Vertical Concrete Cask
VSP	Visual Sample Plan
YNPS	Yankee Nuclear Power Station

1.0 EXECUTIVE SUMMARY

A Final Status Survey (FSS) was performed of Survey Area SVC-01 in accordance with Yankee Nuclear Power Station's (YNPS) License Termination Plan (LTP). This FSS was conducted as a structure surface FSS with building occupancy Derived Concentration Guideline Levels (DCGLs) even though the SVC-01 structure will be subsurface at license termination. This practice conservatively implements LTP criteria that subsurface structure surfaces be evaluated for the presence of contamination.

1.1 Identification of Survey Area and Unit

SVC-01 is comprised of the service building foundation that was exposed during excavation campaigns to remove radiologically contaminated soil and PCB-contaminated soil from the "alley way", Survey Unit NOL-01-04. Survey Unit SVC-01-18 serves as the north boundary for Survey Unit NOL-01-04. It is approximately 512 ft2 (48m2) of concrete surface area. SVC-01-18 is a portion of the Service Building foundation that remained after demolition of the service building. It is the sole surviving SVC Survey Unit, the remainder was demolished and disposed of as non-radioactive, PCB waste.

1.2 Dates(s) of Survey

Table 1 Date of Surveys

Survey Unit	Survey Start Date	Survey End Date	DQA Date
SVC-01-18	11/17/2005	12/01/2005	9/06/2006

1.3 Number and Types of Measurements Collected

Final Status Survey Plan (FSSP) was developed for this Survey Unit in accordance with YNPS LTP and FSS procedures using the MARSSIM protocol. The planning and design of the survey plan employed the Data Quality Objective (DQO) process, ensuring that the type, quantity and quality of data gathered was appropriate for the decision making process and that the resultant decisions were technically sound and defensible. A total of 25 systematic direct measurement measurements were taken in the Survey Unit, providing data for the non-parametric testing of the Survey Area. In addition to the direct measurement samples, hand-held survey instrument scans were performed to provide 100 percent coverage of the Survey Area.

1.4 Summary of Survey Results

Following the survey, the data were reviewed against the survey design to confirm completeness and consistency, to verify that the results were valid, to ensure that the survey plan objectives were met and to verify Survey Unit classification. Direct measurement surveys indicated that none of the systematic measurements exceeded the $DCGL_W$, depicted in Attachment B. Retrospective power curves were generated and demonstrated that an adequate number of samples were collected to support the Data Quality Objectives. Therefore, the null hypothesis (H_o) (that the Survey Unit exceeds the release criteria) is rejected.

1.5 Conclusions

Based upon the evaluation of the data acquired for the FSS, SVC-01 meets the release requirements set forth in the YNPS LTP. The Total Effective Dose Equivalent (TEDE) to the average member of the critical group does not exceed 25 mRem/yr, including that from groundwater. 10CFR20 Subpart E ALARA requirements have been met as well as the site release criteria for the administrative level DCGLs that ensure that the Massachusetts Department of Public Health's 10 mRem/yr limit will also be met.

2.0 FSS PROGRAM OVERVIEW

2.1 Survey Planning

The YNPS FSS Program employs a strategic planning approach for conducting final status surveys with the ultimate objective to demonstrate compliance with the DCGLs, in accordance with the YNPS LTP. The DQO process is used as a planning technique to ensure that the type, quantity, and quality of data gathered is appropriate for the decision-making process and that the resultant decisions are technically sound and defensible. Other key planning measures are the review of historical data for the Survey Unit and the use of peer review for plan development.

2.2 Survey Design

In designing the FSS, the questions to be answered are: "Does the residual radioactivity, if present in the Survey Unit, exceed the LTP release criteria?" and "Is the potential dose from this radioactivity ALARA?" In order to answer these questions, the radionuclides present in the Survey Unit must be identified, and the Survey Unit classified. Survey Unit are classified with respect to the potential for contamination: the greater the potential for contamination, the more stringent the classification and the more rigorous the survey.

The survey design additionally includes the number, type and locations of direct measurements/samples (as well as any judgmental assessments required), scanning requirements, and instrumentation selection with the required sensitivities or detection levels. DCGLs are developed relative to the surface/material of the Survey Unit and are used to determine the minimum sensitivity required for the survey. Determining the acceptable decision error rates, the lower bound of the gray region (LBGR), statistical test selection and the calculation of the standard deviation and relative shift allows for the development of a prospective power curve plotting the probability of the Survey Unit passing FSS.

2.3 Survey Implementation

Once the planning and development has been completed, the implementation phase of the FSS program begins. Upon completion of remediation and final characterization activities, a final walk down of the Survey Unit is performed. If the unit is determined to be acceptable (i.e. physical condition of the unit is suitable for FSS), it is turned over to the FSS team, and FSS isolation and control measures are established. After the Survey Unit isolation and controls are in place, grid points are identified for the direct measurements/samples, and the area scan grid is identified. Data is collected and any required investigations are performed.

2.4 Survey Data Assessment

The final stage of the FSS program involves assessment of the data collected to ensure the validity of the results, to demonstrate achievement of the survey plan objectives, and to validate Survey Unit classification. During this phase, the DQOs and survey design are reviewed for consistency between DQO output, sampling design and other data collection documents. A preliminary data review is conducted to include: checking for problems or anomalies, calculation of statistical quantities and preparation of graphical representations for data comparison. Statistical tests are performed, if required, and the assumptions for the tests are verified. Conclusions are then drawn from the data, and any deficiencies or recommendations for improvement are documented.

2.5 Quality Assurance and Quality Control Measures

YNPS FSS activities are implemented and performed under approved procedures, and the YNPS Quality Assurance Project Plan (QAPP) assures plans, procedures and instructions have been followed during the course of FSS, as well as providing guidance for implementing quality control measures specified in the YNPS LTP.

3.0 SURVEY AREA INFORMATION

3.1 Survey Area Description

SVC-01 is comprised of the service building foundation that was exposed during excavation campaigns to remove radiologically contaminated soil and PCB-contaminated soil from the “alley way”, Survey Unit NOL-01-04. Survey Unit SVC-

01-18 serves as the north boundary for Survey Unit NOL-01-04. It is approximately 512 ft2 (48m2) of concrete surface area. It is the sole surviving SVC Survey Unit, the remainder was demolished and disposed of as non-radioactive, PCB waste.

3.2 History of Survey Area

The Service Building is a structure that had been divided into three survey areas: SVC-01, SVC-02, and SVC-03. These survey areas are delineated based upon their construction, the systems present and operational history. SVC-02, SVC-03, and SCV-01-01 through SVC-01-17 were demolished and shipped off site as non-radioactive, PCB waste. A small portion of SCV-01 remained, SVC-01-18. The use of the Service Building spaces in survey area SVC-01 has changed over the life of the plant. The spaces identified as SVC-01 have always been maintained as a clean area.

3.3 Division of Survey Area into Survey Units

SVC-01 has a single Survey Unit, SVC-01-18 which is a Class 1 Survey Unit. SCV-01-01 through SVC-01-17 nomenclature was assigned to Survey Units that were demolished and disposed of as non-radioactive, PCB waste. SCV-01-01 through SVC-01-17 no longer exists on site, and will not be addressed.

4.0 SURVEY UNIT INFORMATION

4.1 Summary of Radiological Data Since Historical Site Assessment (HSA)

4.1.1 Chronology and Description of Surveys Since HSA

The FSS survey of SVC-01-18 was performed between November 30th, 2005 and December 1st, 2005.

4.1.2 Radionuclide Selection and Basis

During the initial DQO process, Co-60 was identified as the radiological nuclide of concern due to its more restrictive DCGL value when compared to Cs-137 (sampling of soil adjacent to the concrete indicated a relationship of approximately 80% Co-60 to 20% Cs-137). Characterization and survey data from the SVC building indicate no other LTP-specified radionuclides warrant consideration in the SVC-01 Survey Unit.

4.1.3 Scoping & Characterization

Prior to commencing demolition activities in SVC-01, a pre-demolition survey was performed in accordance with AP-0831, Administrative Program for Radiological and Non-Radiological Characterization Surveys. The results of this survey identified no radiological contamination present within the bounds of SVC-01. This survey also served as the survey needed for free release of the demolition materials. FSS planning for unit SVC-01-18 used the survey data from adjacent Survey Unit SVC-01-10.

4.2 Basis for Classification

Based upon the radiological condition of this Survey Area identified in the operating history and as a result of the decommissioning activities performed to date, Survey Area SVC-01 is identified as a Class 1 Area.

4.3 Remedial Actions and Further Investigations

No remedial action or investigations were required.

4.4 Unique Features of Survey Area

Survey Area SVC-01 exhibited surface characteristics ranging from smooth surfaces to heavily remediated irregular surfaces. Most of the pits and irregularities increased the source-to-detector distance by approximately ¼ - ½ inch, although some increase it as much as 1 - 2 inches. These types of irregularities in the concrete surfaces were taken into account through the efficiency factor applied to the measurements collected with the HP-100. Technical report YA-REPT-00-015-04 (Appendix B) provides instrument efficiency factors (ε_i) for various source-to-detector distances. The ε_i value for a source-to-detector distance of 1 inch was selected as a representative efficiency for data collected with the HP-100 from the irregular surfaces because it accounts for the ½ inch stand-off and the most common depth of pits and surface irregularities (¼ - ½ inch). In contrast to the irregular surfaces, the vertical walls of the structures are relatively smooth. Table 4.2 of the YA-REPT-00-015-04 (Appendix B) provides instrument efficiency factors (ε_i) for various source-to-detector distances. Detector efficiencies (HP-100C) were applied as follows: smooth surface 0.0603 c/d, irregular surface 0.0373 c/d.

4.5 ALARA Practices and Evaluations

An ALARA evaluation was developed for Survey Unit SVC-01-18 which concluded that additional remediation was not warranted. This evaluation is found in Appendix C.

5.0 SURVEY UNIT FINAL STATUS SURVEY

5.1 Survey Planning

5.1.1 Final Status Survey Plan and Associated DQOs

The FSS for SVC-01 Survey Unit was planned and developed in accordance with the LTP using the DQO process. Form DPF-8856.1, found in YNPS Procedure 8856, "*Preparation of Survey Plans*," was used to provide guidance and consistency during development of the FSS Plan. The FSS Plan can be found in Appendix A. The DQO process allows for systematic planning and is specifically designed to address problems that require a decision to be made in a complex survey design and, in turn, provides alternative actions.

The DQO process was used to develop an integrated survey plan providing the Survey Unit identification, sample size, selected analytical techniques, survey instrumentation, and scan coverage. The Sign Test was specified for non-parametric statistical testing for this Survey Unit, if required. The design parameters developed are presented below.

Table 2 Survey Area SVC-01 Design Parameters

Survey Unit	Design Parameter	Value	Basis
SVC-01-18	Area	48 m2	Class 1, ≤2,000 m2
	Number of Direct Measurements	15 (calculated) (with direction to take more as space allows) 15+	α (Type I) = 0.05 β (Type II) = 0.05 σ: 727 dpm Relative Shift: 2 LBGR: 3,200 dpm
	Sample Area	3.2m2	Area / Sample #
	Sample Grid Spacing: Triangular	1.91m	Square Root (Area/(0.866*Sample #))
	Scan area	48 m2	Class 1 Area – 100%
	SPA-3 Scan Investigation Level	> Background Audible	Class 1 Area: > DCGLemc

5.1.2 Deviations from the FSS Plan as Written in the LTP

The FSSP design was performed to the criteria of the LTP; therefore, no LTP deviations with potential impact to this Survey Area need to be evaluated. However, during the DQA process, it was noted that the survey was designed to have a spacing of 6 foot 3 inches, but there was a typographical error in the FSSP that directed the survey to be performed at 63 inches, 12 inches smaller. This is more conservative grid spacing, so it does not affect the quality of the outcome, as 10 additional samples were added to the grid due to the smaller spacing. The result was more sample is a smaller gird pattern, which increases the statistical power of the survey.

5.1.3 DCGL Selection and Use

For the final evaluation of the SVC-01 Survey Area and throughout this report, the administrative acceptance criterion of 8.73 mRem/yr for Building Surface LTP-listed DCGL values has been applied. However, given that all of the remaining slab and foundation structure will be at least a three feet subsurface when site grading is complete and will be in such a state at license termination, the LTP, section 5.6.3.1.2, "Exterior Surfaces of Building Foundations," establishes the applicable guidance, as it addresses methods that may be applied to determine if subsurface structure surfaces will be acceptable by meeting LTP-required concrete volumetric DCGLs.

With the established LTP guidance, given that Co-60 and Cs-137 have been found to be the only radionuclides of significance in the area of concern, and conventional hand-held instrument survey criteria techniques being conservatively based on Co-60 beta emissions, performing a Class 1 survey applying Building Surface DCGLs has led to a very conservative approach in determining the final status of the Survey Unit. Additionally, applying this approach to evaluating subsurface conditions leaves no unanswered questions should future subsurface structure occupancy arise.

Table 3 $DCGL_W$

Nuclide	**DCGLw** Bldg Surface
Co-60	6.3E+03 dpm/100 cm^2 equal to 8.73 mRem/y
Cs-137	2.2E+04 dpm/100 cm^2 equal to 8.73 mRem/y

5.1.4 Measurements

Error tolerances and characterization sample population statistics drove the selection of the number of fixed point measurements. 15 measurements were needed in the event the Sign test may have been used. In addition to the 15 statistical measurements needed, 10 additional samples were added to the statistical measurements.

The direct measurement sampling grid was developed as a systematic grid with spacing consisting of a triangular pitch pattern with a random starting point. Sample measurement locations are provided in Attachment A.

5.2 Survey Implementation Activities

Table 3 provides a summary of daily activities performed during the Final Status Survey of Survey Unit in SVC-01.

Table 4 FSS Activity Summary for SVC-01 Survey Area

Survey Unit	Date	Activity
SVC-01-18	11-17-05	Performed walk-down of Survey Unit
	11-17-05	Established Isolation and Controls
	11-17-05	Performed Job Hazard Analysis
	11-22-05	Performed Unit Classification
	11-22-05	Performed Sample Quantity Calculations, established DQOs
	11-23-05	Generated FFS Sample Plans
	11-30-05 to 12-01-05	Initiated Scans, and Direct measurements.
	09-09-06	Performed DQA, FSS Complete

5.3 Surveillance Surveys

5.3.1 Periodic Surveillance Surveys

Upon completion of the FSS of Survey Area SVC-01, the Survey Unit footprint was placed into the program for periodic surveillance surveys on a quarterly basis in accordance with YNPS procedure DP-8860, "*Area Surveillance Following Final Status Survey.*" These surveys provide assurance that areas with successful FSS remain unchanged until license termination.

5.3.2 Resurveys

No resurveys were performed.

5.3.3 Investigations

No additional investigations were required for this Survey Unit due to surveillance surveys.

5.4 Survey Results

Direct measurement surveys indicated that no Survey Unit's systematic measurements exceeded the $DCGL_W$, depicted in Attachment B. Retrospective power curves were generated and demonstrated that an adequate number of measurements were collected to support the Data Quality Objectives. Therefore, the null hypothesis (H_o) (that the Survey Unit exceeds the release criteria) is rejected.

Table 5 Direct Measurement Summary (DPM/100cm2)

Sample Description	Activity
SVC-01-18-001-F-FM	576
SVC-01-18-002-F-FM	809
SVC-01-18-003-F-FM	991
SVC-01-18-004-F-FM	825
SVC-01-18-005-F-FM	809
SVC-01-18-006-F-FM	892
SVC-01-18-007-F-FM	1254
SVC-01-18-008-F-FM	825
SVC-01-18-009-F-FM	2165
SVC-01-18-010-F-FM	875
SVC-01-18-011-F-FM	1024
SVC-01-18-012-F-FM	1605
SVC-01-18-013-F-FM	958
SVC-01-18-014-F-FM	1190
SVC-01-18-015-F-FM	742
SVC-01-18-016-F-FM	1041
SVC-01-18-017-F-FM	1804
SVC-01-18-018-F-FM	858
SVC-01-18-019-F-FM	958
SVC-01-18-020-F-FM	1041
SVC-01-18-021-F-FM	1200
SVC-01-18-022-F-FM	2460
SVC-01-18-023-F-FM	759
SVC-01-18-024-F-FM	560
SVC-01-18-025-F-FM	643
Max	2460
Average	1075
Standard Deviation	471

5.5 Data Quality Assessment

The Data Quality Assessment phase is the part of the FSS where survey design and data are reviewed for completeness and consistency, ensuring the validity of the results, verifying that the survey plan objectives were met, and validating the classification of the Survey Unit.

A preliminary data review was performed. The retrospective power curve possessed adequate power to pass the survey with the final standard deviation less than the projected standard deviation. The data set was within three standard deviations and displayed a normal dispersion about the mean. The quantile plot exhibits some asymmetry in the lower quartile due to the number of low values, however the posting plot does not clearly reveal any systematic spatial trends. The data set verifies the assumptions of the statistical test.

The sample design and the data acquired were reviewed and found to be in accordance with applicable YNPS procedures DP-8861, "*Data Quality Assessment*"; DP-8856, "*Preparation of Survey Plans*"; DP-8853, "*Determination of the Number and Locations of FSS Samples and Measurements*"; DP-8857, "*Statistical Tests*"; DP-8865, "*Computer Determination of the Number of FSS Samples and Measurements*" and DP-8852, "*Final Status Survey Quality Assurance Project Plan*".

The Data Quality Assessment power curves, scatter, quantile and frequency plots are found in Attachment B. Posting Plots are found in Attachment A.

6.0 QUALITY ASSURANCE AND QUALITY CONTROL

6.1 Instrument QC Checks

Operation of the E-600 w/SPA-3 was in accordance with DP-8535,"*Setup and Operation of the Eberline E-600 Digital Survey Instrument,*" with QC checks preformed in accordance with DP-8540, "*Operation and Source Checks of Portable Friskers.*" Instrument response checks were performed prior to and after use for the E-600 w/SPA-3. All instrumentation involved with the FSS of SVC-01 satisfied the above criteria for the survey. QC records are found in Attachment C.

6.2 Split Samples and Recounts

DP-8864,"*Split Sample Assessment for Final Status Survey*" deals strictly with soil samples and provides no criteria for fixed-point measurements therefore no measurement comparison were made.

6.3 Self-Assessments

No self-assessments were performed during the FSS of SVC-01.

7.0 CONCLUSION

The FSS of SVC-01 has been performed in accordance with YNPS LTP and applicable FSS procedures. Evaluation of the direct measurement data has shown none of the systematic direct measurements exceeded the $DCGL_W$, depicted in Attachment B. Retrospective power curves were generated and demonstrated that an adequate number of samples were collected to support the Data Quality Objectives. Therefore, the null hypothesis (H_o) is rejected.

SVC-01 meets the objectives of the Final Status Survey.

Based upon the evaluation of the data acquired for the FSS, SVC-01 meets the release requirements set forth in the YNPS LTP. The Total Effective Dose Equivalent (TEDE) to the average member of the critical group does not exceed 25 mRem/yr, including that from groundwater. 10CFR20 Subpart E ALARA requirements have been met as well as the site release criteria for the administrative level DCGLs that ensure that the Massachusetts Department of Public Health's 10 mRem/yr limit will also be met.

List of Appendices

List of Attachments

(In the electronic version, every Table of Contents, Figures, Appendices and Attachments, as well as every mention of a Figure, Appendix or Attachment is a hyperlink to the actual location or document.)

GENERAL SECTION

Survey Area #: SVC-01	Survey Unit #: 18
Survey Unit Name: Service Building Foundation – South Vertical Edge	
FSSP Number: YNPS-FSSP-SVC01-18-00	

PREPARATION FOR FSS ACTIVITIES

Check marks in the boxes below signify affirmative responses and completion of the action.

1.1 Files have been established for survey unit FSS records. ☑

1.2 ALARA review has been completed for the survey unit. ☑

1.3 The survey unit has been turned over for final status survey. ☑

1.4 An initial DP-8854 walkdown has been performed and a copy of the completed Survey Unit Walkdown Evaluation is in the survey area file. ☑

1.5 Activities conducted within area since turnover for FSS have been reviewed. ☑

Based on reviewed information, subsequent walkdown: ☑ not warranted ☐ warranted

If warranted, subsequent walkdown has been performed and documented per DP-8854. ☐

OR

The basis has been provided to and accepted by the FSS Project Manager for not performing a subsequent walkdown. ☐

1.6 A final classification has been performed. ☑

Classification: CLASS 1 ☑ CLASS 2 ☐ CLASS 3 ☐

DATA QUALITY OBJECTIVES (DQO)

1.0 Statement of problem:

The service building foundation was exposed during the excavation campaigns to remove radiologically contaminated soil and PCB-contaminated soil from the "alley way" (unit NOL01-04). Survey Unit SVC01-18 serves as the north boundary for survey unit NOL01-04. It is approximately 512 ft^2 ($48m^2$) of concrete surface area. The data collected under this plan will be used to determine whether or not residual plant-related radioactivity on the exposed concrete surface of Survey Unit SVC01-18 meets LTP release criteria.

The planning team for this effort consists of the FSS Project Manager, FSS Radiological Engineer, FSS Field Supervisor, and FSS Technicians. The FSS Radiological Engineer will make primary decisions with the concurrence of the FSS Project Manager.

2.0 Identify the decision:

Does residual plant-related radioactivity, if present in the survey unit, exceed LTP release criteria? Alternative actions that may be implemented in this effort are investigations and remediation followed by re-surveying.

3.0 Identify the inputs to the decision:

Sample media: concrete

Types of measurements: Fixed-point measurements, beta scans, and gamma scans.

Radionuclides-of-concern: Co-60 (assumed as a conservative measure for the reasons stated in YNPS-FSSP-BRT01-10-00).

FSS planning for unit SVC01-18 used the FSS data from unit BRT01-10 because there is no reason to expect the radiological characteristics of SVC01-18 to be different from BRT01-10 (the 2 units are adjacent).

The mean value of fixed-point measurements from BRT01-10 was 1.8E3 dpm/100cm^2 ± 4.8E2 dpm/100cm^2. The FSS net measurements ranged from no detectable to 2.8E3 dpm/100cm^2 (or 44% of the DCGL for Co-60).

Average radiation level: 1.8E3 dpm/100cm^2 (mean of FSS data for BRT01-10)

Standard deviation (σ): 4.8E2 dpm/100cm^2 (standard deviation of FSS data for BRT01-10)

DCGLs:

(1) Applicable $DCGL_w$: 6.3E3 dpm/100cm^2 (Co-60 assumed)

Note: the $DCGL_w$ value corresponds to 8.73 mrem/y.

Although most of the concrete of Survey Unit SVC01-18 has a relatively smooth surface, some localized areas contain pits and irregular surfaces (typical depths in these areas are approximately ¼ - ½ inch, although some increase it as much as 1 inch), which will increase the source-to-detector distance for some localized areas under the 100cm^2 window of the detector. These irregularities in the concrete surfaces will be taken into account through the efficiency factor applied to the measurements collected with the HP-100. Technical report YA-REPT-00-015-04 provides instrument efficiency factors (ε_i) for various source-to-detector distances. The ε_i value for a source-to-detector distance of 1 inch was selected as a representative efficiency for data collected with the HP-100 from the pitted/irregular surfaces because it accounts for the ½ inch stand-off and the most common depth of pits and surface irregularities (¼ - ½ inch). In contrast to the localized pitted/irregular areas, most of the concrete of the east vertical wall is relatively smooth. The ε_i value for a distance of ½ inch will be applied to HP-100 data collected from smooth concrete surfaces. The efficiency factors provided in YA-REPT-00-015-04 are used below:

- ε_i = 0.2413 c/e for smooth concrete surfaces (reflects a source to detector distance = ½ inch), and
  = 0.149 c/e for pitted/irregular surfaces (reflects a source to detector distance = 1 inch)
- ε_s = 0.25 e/d (consistent with the Co-60 assumption made in this plan)
- total efficiency for smooth surface = $\varepsilon_i \cdot \varepsilon_s$ = 0.2413 c/e · 0.25 e/d = 0.0603 c/d
- total efficiency for pitted/irregular surfaces = $\varepsilon_i \cdot \varepsilon_s$ = 0.149 c/e · 0.25 e/d = 0.0373 c/d

(2) Gross measurement $DCGL_w$ (for HP-100): 6.3E3 dpm/100cm^2

- for smooth concrete surface: 6.3E3 dpm/100cm^2 * 0.0603 c/d = 3.8E2 cpm/100cm^2
- for pitted/irregular surface: 6.3E3 dpm/100cm2 * 0.0373 c/d = 2.3E2 cpm/100cm^2

(3) Applicable $DCGL_{EMC}$ for fixed-point measurements: $DCGL_w$ * AF = 6.3E3 dpm/100cm^2 *2.4 = 1.5E4 dpm/100cm^2

- for smooth concrete surface: 1.5E4 dpm/100cm^2 * 0.0603 c/d = 9.1E2 cpm/100cm^2
- for pitted/irregular surface: 1.5E4 dpm/100cm2 * 0.0373 c/d = 5.6E2 cpm/100cm^2

Note: the DCGL and $DCGL_{EMC}$ value refer to above-background radioactivity.

Investigation Level for fixed-point measurement:

- for smooth (i.e., vertical side) concrete surface: >9.1E2 cpm/100cm^2 above background
- for pitted/irregular (i.e., top) concrete surface: >5.6E2 cpm/100cm^2 above background

Investigation Level for HP-100 scan: Reproducible indication above background using the audible feature with headphones

Investigation Level for SPA-3 scan: Reproducible indication above background using the audible feature with headphones

Scan coverage: Beta scan with HP-100: 100% of the accessible concrete surface area on the vertical walls. Supplemental SPA-3 scans on the irregular surfaces of the vertical walls and cracks in the concrete

MDCR for HP-100: The accompanying table provides MDCR values by various background levels. The expected background for the HP-100 range is 100 - 400 cpm.

MDC($fDCGL_{EMC}$) for HP-100 scans: The accompanying table provides MDC($fDCGL_{EMC}$) values by various background levels.

QC checks and measurements: QC checks for the survey instruments will be performed in accordance with DP-8534. Pre- and post-use instrument QC checks will be performed.

4.0 Define the boundaries of the survey:

Boundaries of SVC01-18 are defined by the termination of the vertical surface of the NE section of the turbine building foundation. The survey will be performed under weather conditions that permit instrument operation and surveying.

5.0 Develop a decision rule:

(a) If all the FSS data show that residual levels of plant-related radioactivity are below the $DCGL_w$, reject the null hypothesis (i.e., Survey Unit meets the release criteria).
(b) If the investigation level is exceeded, then perform an investigation.
(c) If the average of the FSS measurements is below the $DCGL_w$, but some individual measurements exceed the $DCGL_w$, then apply a statistical test as the basis for accepting or rejecting the null hypothesis.
(d) If the average of the FSS measurements exceeds the $DCGL_w$, then accept the null hypothesis (i.e., Survey Unit fails

to meet the release criteria).

6.0 Specify tolerable limits on decision errors:

Null hypothesis: Residual plant-related radioactivity in Survey Unit SVC01-18 exceeds the release criteria.

Probability of type I error: 0.05

Probability of type II error: 0.05

7.0 *LBGR*: 6.3E3 dpm/100 $cm^2 \div 2$ = 3.2E3 dpm/100 cm^2

8.0 Optimize Design:

Type of statistical test: WRS Test ☐ Sign Test ☑

Basis including background reference location (if WRS test is specified): N/A

Number samples (per DP-8853): 15

Biased Measurements: None

GENERAL INSTRUCTIONS

1. The FSS Field Supervisor is responsible for contacting the QA Department regarding the FSS activities identified as QA notification points.

2. Mark the sampling points at the locations as follows:

   (a) Locate and mark the random start point for the grid at a point 9ft, 5inches from the east end of the service building foundation and 1 ft, 11 inches from the top of the foundation.

   (b) Locate and mark other fixed-point measurement locations at intervals of 63 inches to the west and east of the random start location. These locations are also 1 ft, 11 inches from the top of the foundation.

   (c) If a measurement location shown in Figure 1 falls at a location that is obstructed (e.g., by soil) or from which a fixed-point measurement cannot be collected, select an alternate location in accordance with DP-8856.

Note: The dimensions used in planning allow the collection of 19 fixed-point measurements. It may be necessary to add or delete some measurement locations based on the actual length of the survey unit. These adjustments to the grid are acceptable as long as the random start point is used, the general grid structure is maintained, and at least 15 fixed-point measurement locations are identified.

3. Collect a series of ambient background measurements in accordance with step B.1.c in DP-8866 with the following variation of step B.1.c.2) using the HP-100 that is to be used to collect the fixed-point measurements:

   (a) Cover the detector with a 1/8-inch Lucite (or equivalent) shield and collect 7 one-minute readings with the shielded detector facing towards but approximately 1m from the concrete surface (and approximately 1 m above the soil) at the west end, center, and east end of the survey unit.

   (b) Record the background data on the attached Form 1(even if the measurement was logged).

4. Collect a fixed-point (1-min) measurement in accordance with DP-8534 at each of the marked locations.

   (a) Designate the fixed-point measurements as SVC-01-18-001-F-FM through SVC-01-18-019-F-FM, as shown in Figure 1.

   (b) Record each fixed-point measurement "as read" (in units of cpm) on the attached Form 2 (even if the reading was logged).

   (c) When recording the measurements on Form 2, identify those measurements collected from an irregular concrete surface with an asterisk (*).

   (d) Note on Form 2 any measurement location that was omitted or added due to field adjustments of the planned grid.

5. Perform HP-100 and SPA-3 scans as described in the Specific Instructions.

6. Survey instrument: Operation of the E-600 will be in accordance with DP-8534. Pre- and post-use QC checks for survey instruments are to be performed.

7. The applicable job hazards associated with this survey will be addressed in the Yankee Rowe Project Daily Activity Plan and reviewed by the FSS Field Supervisor during the pre-survey briefing.

8. All personnel participating in this survey shall be trained in accordance with DP-8868.

SPECIFIC INSTRUCTIONS

1. Beta scans:

   (a) Perform the HP-100 scans by moving the detector at a speed no greater than 2 inches per second, using a ½ inch standoff.

(b) FSS Technicians will wear headphones while scanning and the survey instrument will be in the rate-meter mode. Surveyors will listen for upscale readings and respond to readings that exceed the investigation level.

(c) If the HP-100 scan investigation level is exceeded:

(1) confirm that the elevated scan reading is reproducible and not the result of a nearby source (e.g., waste pile or container),

(2) if a nearby source is identified, have it removed or shielded, document the finding on DP-8856.2, and repeat the scan,

(3) if reproducible and not caused by a nearby source, collect a fixed-point measurement at the location of the greater-than-investigation level reading,

(4) the designation for a fixed-point measurement collected during a first-level investigation will be SVC-01-18-0XX-F-FM-I, where "XX" continues the numbering sequence for fixed-point measurements. Record all investigation fixed-point measurements "as read" (in units of cpm) on the attached Form 2 (even if the measurement was logged).

(5) mark the location of the fixed-point measurement location for further investigation if it exceeds the investigation level for a fixed-point measurement. If a fixed-point measurement location has been identified for further investigation, the investigation will be conducted under a separate survey plan.

(d) The FSS Field Supervisor will record information relevant to the HP-100 scans on DPF-8856.2.

2. Perform SPA-3 scans:

(a) Perform SPA-3 of the irregular surfaces and over cracks in the concrete by moving the detector slowly (no greater than 0.25m/s) and keeping it < 3 inches from the surface.

(b) FSS Technicians will wear headphones while scanning and the survey instrument will be in the rate-meter mode. Surveyors will listen for upscale readings and respond to readings that exceed the SPA-3 investigation level.

(c) If a SPA-3 reading exceeds the investigation level:

(1) confirm that the above-background indication is reproducible and cannot be attributed to a nearby source,

(2) if a nearby source is identified, have it removed or shielded, document the finding on DP-8856.2, and repeat the scan,

(3) if the reading is reproducible and not caused by a nearby source, collect a fixed-point measurement with the HP-100 at the highest reading observed during the scan and clearly mark that location.

(4) Designate the investigation fixed-point measurement as described in step 1(c)(4) above.

(5) Record all investigation fixed-point measurements "as read" (in units of cpm) on the attached Form 2 (even if the measurement was logged). If further investigation is required, it will be conducted under a separate survey plan.

(d) The FSS Field Supervisor will record information relevant to the SPA-3 scans on DPF-8856.2

NOTIFICATION POINTS

QA notification* point(s) (y/n) y

(1) Date/time of initial pre-survey briefing — QA signature: ______

(2) Date/time of commencement of HP-100 measurements — QA signature: ______

(3) Date/time of commencement of SPA-3 measurements — QA signature: ______

(4) Time(s) of daily pre-shift briefing (for each shift that the FSS is performed) — QA signature: ______

* Voice mail notification or E-mail notification to Trudeau@yankeerowe.com with a copy to Marchi@cyapco.com satisfies this step.

FSI point(s) (y/n) n   Specify: ______

Prepared by J. Brown (signature), FSS Radiological Engineer — Date 11-23-05

Reviewed by Martin C. Erickson (signature), FSS Radiological Engineer — Date 11/23/05

Approved by D.C. Smith (signature), FSS Project Manager — Date 11/23/05

MDCR/MDC Table for Survey Unit SVC01-18

Background (cpm)	scan speed (in/s)	MDCR (cpm)	MDC(fDCGL(emc))
400	2	151	0.38
500	2	169	0.42
1000	2	239	0.60

detector = HP-100 (effic factor for 1in)

Form 1
Background Data

Survey Unit SVC01-18
Instrument No.: ___________

Location	Measurement No.	Measurement (cpm)
BG location 1	1	
	2	
	3	
	4	
	5	
	6	
	7	
BG location 2	1	
	2	
	3	
	4	
	5	
	6	
	7	
BG location 3	1	
	2	
	3	
	4	
	5	
	6	
	7	

Form 2
FSS Fixed-Point Measurements

Survey Unit SVC01-18
Instrument No.: __________

Location	Measurement (cpm/100cm^2)
SVC-01-18-001-F-FM	
SVC-01-18-002-F-FM	
SVC-01-18-003-F-FM	
SVC-01-18-004-F-FM	
SVC-01-18-005-F-FM	
SVC-01-18-006-F-FM	
SVC-01-18-007-F-FM	
SVC-01-18-008-F-FM	
SVC-01-18-009-F-FM	
SVC-01-18-010-F-FM	
SVC-01-18-011-F-FM	
SVC-01-18-012-F-FM	
SVC-01-18-013-F-FM	
SVC-01-18-014-F-FM	
SVC-01-18-015-F-FM	
SVC-01-18-016-F-FM	
SVC-01-18-017-F-FM	
SVC-01-18-018-F-FM	
SVC-01-18-019-F-FM	

TECHNICAL REPORT TITLE PAGE

COPY

Instrument Efficiency Determination for Use in Minimum Detectable Concentration Calculations in Support of the Final Status Survey at Yankee Rowe

Title

YA-REPT-00-015-04
REV. 0

Technical Report Number

Approvals	(Print & Sign Name)		
Preparer:	[signature]	Date:	10-7-04
Reviewer:	James R. Hummer	Date:	10/7/04
Approver (Cognizant Manager):	[signature]	Date:	10/7/04

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Tables

Appendix

1.0 Executive Summary:

The minimum detectable concentration (MDC) of the field survey instrumentation is an important factor affecting the quality of the final status survey (FSS). The efficiency of an instrument inversely impacts the MDC value. The objective of this report is to determine the instrument and source efficiency values used to calculate MDC. Several factors were considered when determining these efficiencies and are discussed in the body of this report. Instrument efficiencies (ε_i), and source efficiencies (ε_s), for alpha beta detection equipment under various field conditions, and instrument conversion factors (E_i), for gamma scanning detectors were determined and the results are provided herein.

2.0 Introduction:

Before performing Final Status Surveys of building surfaces and land areas, the minimum detectable concentration (MDC) must be calculated to establish the instrument sensitivity. Table 5.4 of the License Termination Plan (LTP) [8.6] lists the available instrumentation and nominal detection sensitivities; however for the purposes of this basis document, efficiencies for the 100cm^2 gas proportional and the 2"x2" NaI (Tl) detectors will be determined. Efficiencies for the other instrumentation listed in the LTP shall be determined on an as needed basis. The 100 cm^2 gas proportional probe will be used to perform surveys (i.e. fixed point measurements). A 2" x2" NaI (Tl) detector will be used to perform gamma surveys (i.e., surface scans) of portions of land areas and possibly supplemental structural scans at the Yankee Rowe site. Although surface scans and fixed point measurements can be performed using the same instrumentation, the calculated MDCs will be quite different. MDC is dependent on many factors and may include but is not limited to:

- instrument efficiency
- background
- integration time
- surface type
- source to detector geometry
- source efficiency

A significant factor in determining an instrument MDC is the total efficiency, which is dependent on the instrument efficiency, the source efficiency and the type and energy of the radiation. MDC values are inversely affected by efficiency, as efficiencies increase, MDC values will decrease. Accounting for both the instrument and source components of the total efficiency provides for a more accurate assessment of surface activity.

3.0 Calibration Sources:

For accurate measurement of surface activity it is desirable that the field instrumentation be calibrated with source standards similar to the type and energy of the anticipated contamination. The nuclides listed in Table 3.1 illustrate the nuclides found in soil and building surface area DCGL results that are listed in the LTP.

Instrument response varies with incident radiations and energies; therefore, instrumentation selection for field surveys must be modeled on the expected surface activity. For the purposes of this report, isotopes with max beta energies less than that of C-14 (0.158 MeV) will be considered difficult to detect (reference table 3.1). The detectability of radionuclides with max beta energies less than 0.158 MeV, utilizing gas proportional detectors, will be negligible at typical source to detector distances of approximately 0.5

inches. The source to detector distance of 1.27 cm (0.5 inches) is the distance to the detector with the attached standoff (DP-8534 "Operation and Source Checks of Proportional Friskers")[8.5]. Table 3.1 provides a summary of the LTP radionuclides and their detectability using Radiological Health Handbook [8.4] data.

Table 3.1
Nuclides and Major Radiations: Approximate Energies (Reference 8.4)

Nuclide	α Energy (MeV)	$E_{\beta max}$ (MeV)	Average E_β (MeV)	Photon Energy (MeV)	α Detectable w/ Gas Proportional	β Detectable w/ Gas Proportional	γ Detectable w/ NaI 2x2"
H-3		0.018	0.005				
C-14		0.158	0.049				
Fe-55				0.23 (0.004%) bremsstrahlung			
Co-60		0.314	0.094	1.173 (100%), 1.332 (100%)		√	√
Ni-63		0.066	0.017				
Sr-90		0.544 2.245 (Y-90)	0.200 0.931			√	
Nb-94		0.50	0.156	0.702 (100%), 0.871 (100%)		√	√
Tc-99		0.295	0.085			√	
Ag-108m		1.65 (Ag-108)	0.624 (Ag-108)	0.434 (0.45%), 0.511 (0.56%) 0.615 (0.18%), 0.632 (1.7%)			√
Sb-125		0.612	0.084	0.6, 0.25, 0.41, 0.46, 0.68, 0.77, 0.92, 1.10, 1.34		√	√
Cs-134		1.453	0.152	0.57 (23%), 0.605 (98%) 0.796 (99%), 1.038 (1.0%) 1.168 (1.9%), 1.365 (3.4%)		√	√
Cs-137		1.167	0.195	0.662 (85%) Ba-137m X-rays		√	√
Eu-152		1.840	0.288	0.122 (37%), 0.245 (8%) 0.344 (27%), 0.779 (14%) 0.965 (15%), 1.087 (12%) 1.113 (14%), 1.408 (22%)		√	√
Eu-154		1.850 (10%)	0.228				
Eu-155		0.247	0.044	0.087 (32%), 0.105 (20%)		√	
Pu-238	5.50 (72%) 5.46 (28%)			0.099 (8E-3%) 0.150 (1E-3%) 0.77 (5E-5%)	√		
Pu-239	5.16 (88%) 5.11 (11%)			0.039 (0.007%), 0.052 (0.20%), 0.129 (0.005%)...	√		
Pu-241	4.90 (0.0019%) 4.85 (0.0003%)	0.021	0.005	0.145 (1.6E-4%)			
Am-241	5.49 (85%) 5.44 (13%)			0.060 (36%), 0.101 (0.04%)...	√		
Cm-243	6.06 (6%) 5.99 (6%) 5.79 (73%) 5.74 (11.5%)			0.209 (4%), 0.228 (12%), 0.278 (14%)	√		

NUREG-1507 and ISO 7503-1 provide guidance for selecting calibration sources and their use in determining total efficiency. It is common practice to calibrate instrument efficiency for a single beta energy; however the energy of this reference source should not be significantly greater than the beta energy of the lowest energy to be measured.

Tc-99 (0.295 MeV max) and Th-230 (4.68 MeV at 76% and 4.62 MeV at 24%) have been selected as the beta and alpha calibration standards respectively, because their energies conservatively approximate the beta and alpha energies of the plant specific radionuclides.

4.0 Efficiency Determination:

Typically, using the instrument 4π efficiency exclusively provides a good approximation of surface activity. Using these means for calculating the efficiency often results in an under estimate of activity levels in the field. Applying both the instrument 2π efficiency and the surface efficiency components to determine the total efficiency allows for a more accurate measurement due to consideration of the actual characteristics of the source surfaces. ISO 7503-1 [8.2] recommends that the total surface activity be calculated using:

$$A_s = \frac{R_{S+B} - R_B}{(\varepsilon_i)(W)(\varepsilon_s)},$$

where:
A_s is the total surface activity in dpm/cm^2,
R_{S+B} is the gross count rate of the measurement in cpm,
R_B is the background count rate in cpm,
ε_i is the instrument or detector 2π efficiency
ε_s is the efficiency of the source
W is the area of the detector window (cm^2)

4.1 Alpha and Beta Instrument Efficiency (ε_i):

Instrument efficiency (ε_i) reflects instrument characteristics and counting geometry, such as source construction, activity distribution, source area, particles incident on the detector per unit time and therefore source to detector geometry. Theoretically the maximum value of ε_i is 1.0, assuming all the emissions from the source are 2π and that all emissions from the source are detected. The ISO 7503-1 methodology for determining the instrument efficiency is similar to the historical 4π approach; however the detector response, in cpm, is divided by the 2π surface emission rate of the calibration source. The instrument efficiency is calculated by dividing the net count rate by the 2π surface emission rate ($q_{2\pi}$) (includes absorption in detector window, source detector geometry). The instrument efficiency is expressed in ISO 7503-1 by:

$$\varepsilon_i = \frac{R_{S+B} - R_B}{q_{2\pi}}$$

where:
R_{S+B} is the gross count rate of the measurement in cpm,
R_B is the background count rate in cpm,
$q_{2\pi}$ is the 2π surface emission rate in reciprocal seconds

Note that both the 2π surface emission rate and the source activity are usually stated on the certification sheet provided by the calibration source manufacturer and certified as National Institute of Standards and Technology (NIST) traceable. Table 4.1 depicts instrument efficiencies that have been determined during calibration using the 2π surface emission rate of the source.

Table 4.1
Instrument Efficiencies (ε_i)

Source	Emission	Active Area of Source (cm^2)	Effective Area of Detector	100 cm^2 Gas Proportional HP-100 Instrument Efficiency (ε_i) (Contact)
Tc-99	β	*15.2*	100 cm^2	0.4148
Th-230	α	*15.2*	100 cm^2	0.5545

4.2 Source to Detector Distance Considerations:
A major factor affecting instrument efficiency is source to detector distance. Consideration must be given to this distance when selecting accurate instrument efficiency. The distance from the source to the detector shall to be as close as practicable to geometric conditions that exist in the field. A range of source to detector distances has been chosen, taking into account site specific survey conditions. In an effort to minimize the error associated with geometry, instrument efficiencies have been determined for source to detector distances representative of those survey distances expected in the field. The results shown in Table 4.2 illustrate the imposing reduction in detector response with increased distance from the source. Typically this source to detector distance will be 0.5 inches for fixed point measurements and 0.5 inches for scan surveys on flat surfaces, however they may differ for other surfaces. Table 4.2 makes provisions for the selection of source to detector distances for field survey conditions of up to 2 inches. If surface conditions dictate the placement of the detector at distances greater than 2 inches instrument efficiencies will be determined on an as needed basis.

4.2.1 Methodology:
The practical application of choosing the proper instrument efficiency may be determined by averaging the surface variation (peaks and valleys narrower than the length of the detector) and adding 0.5 inches, the spacing that should be maintained between the detector and the highest peaks of the surface. Select the source to detector distance from Table 4.2 that best reflects this pre-determined geometry.

Table 4.2
Source to Detector Distance Effects on Instrument Efficiencies for α- β Emitters

Source to Detector Distance (cm)	**Instrument Efficiency (ε_i)**	
	Tc-99 Distributed	**Th-230 Distributed**
Contact	0.4148	0.5545
1.27 (0.5 in)	0.2413	0.1764
2.54 (1 in)	0.1490	0.0265
5.08 (2 in)	0.0784	0.0002

4.3 Source (or Surface) Efficiency (ε_s) Determination:

Source efficiency (ε_s), reflects the physical characteristics of the surface and any surface coatings. The source efficiency is the ratio between the number of particles emerging from surface and the total number of particles released within the source. The source efficiency accounts for attenuation and backscatter. ε_s is nominally 0.5 (no self-absorption/attenuation, no backscatter)--backscatter increases the value, self-absorption decreases the value. Source efficiencies may either be derived experimentally or simply selected from the guidance contained in ISO 7503-1. ISO 7503-1 takes a conservative approach by recommending the use of factors to correct for alpha and beta self-absorption/attenuation when determining surface activity. However, this approach may prove to be too conservative for radionuclides with max beta energies that are marginally lower than 0.400 MeV, such as Co-60 with a βmax of 0.314 MeV. In this situation, it may be more appropriate to determine the source efficiency by considering the energies of other beta emitting radionuclides. Using this approach it is possible to determine weighted average source efficiency. For example, a source efficiency of 0.375 may be calculated based on a 50/50 mix of Co-60 and Cs-137. The source efficiencies for Co-60 and Cs-137 are 0.25 and 0.5 respectively, since the radionuclide fraction for Co-60 and Cs-137 is 50% for each, the weighted average source efficiency for the mix may be calculated in the following manner:

$$(0.25)(0.5)+(0.5)(0.5)=0.375$$

Table 4.3 lists guidance on source efficiencies from ISO 7503-1.

Table 4.3
Source Efficiencies as listed in ISO 7503-1

	$> 0.400\ MeV_{max}$	$\leq 0.400\ MeV_{max}$
Beta emitters	$\varepsilon_s = 0.5$	$\varepsilon_s = 0.25$
Alpha emitters	$\varepsilon_s = 0.25$	$\varepsilon_s = 0.25$

It should be noted that source efficiency is not typically addressed for gamma detectors as the value is effectively unity.

5.0 Instrument Conversion Factor (E) (Instrument Efficiency for Scanning):

Separate modeling analysis (Microshield™) was conducted using the common gamma emitters with a concentration of 1 pCi/g of uniformly distributed contamination throughout the volume. MicroShield is a comprehensive photon/gamma ray shielding and dose assessment program, which is widely used throughout the radiological safety community. An activity concentration of 1 pCi/g for the nuclides was entered as the source term. The radial dimension of the cylindrical source was 28 cm, the depth was 15 cm, and the dose point above the surface was 10 cm with a soil density of 1.6 g/cm^3. The instrument efficiency when scanning, E_i, is the product of the modeled exposure rate (MicroShield™) in mRhr^{-1}/pCi/g for and the energy response factor in cpm/mR/hr as derived from the energy response curve provided by Eberline Instruments (Appendix O). Table 5.1 demonstrates the derived efficiencies for the major gamma emitting isotopes listed in Table 3.1.

TABLE 5.1

Energy Response and Efficiency for Photon Emitting Isotopes

Isotope	Calculations for E_i See appendix A through L	E_i (cpm/pCi/g)
Co-60	See Appendix Aand B	379
Nb-94	See Appendix C and D	416
Ag-108m	See Appendix E and F	637
Sb-125	See Appendix G and H	210
Cs-134	See Appendix I and J	506
Cs-137	See Appendix K and L	188
Eu-152	See Appendix M and N	344

When performing gamma scan measurements on soil surfaces the effective source to detector geometry is as close as is reasonably possible (less than 3 inches).

6.0 Applying Efficiency Corrections Based on the Effects of Field Conditions for Total Efficiency:

The total efficiency for any given condition can now be calculated from the product of the instrument efficiency ε_i and the source efficiency ε_s.

$$\varepsilon_{tot} = \varepsilon_i \times \varepsilon_s$$

The following example illustrates the process of determining total efficiency. For this example we will assume the following:

- Surface activity readings need to be made in the Primary Auxiliary Building (PAB) on the concrete wall surfaces using the E-600 and C-100 gas proportional detector.
- Data obtained from characterization results from the PAB indicate the presence of beta emitters with energies greater than 0.400 Mev.
- The source (activity on wall) to detector distance is 1.27 cm (0.5 in detector stand off). To calculate the total efficiency, ε_{tot}, refer to Table 4.2 "Source to Detector Distance Effects on Instrument Efficiencies for α- β Emitters" to obtain the appropriate ε_i value.
- Contamination on all surfaces is distributed relative to the effective detector area.

- When performing fixed point measurements with gas proportional instrumentation the effective source to detector geometry is representative of the calibrated geometries listed in Table 4.2 "Source to Detector Distance Effects on Instrument Efficiencies for α- β Emitters".
- Corrections for temperature and pressure are not substantial.

In this example, the value for ε_i is 0.2413 as depicted in Table 4.2 "Source to Detector Distance Effects on Instrument Efficiencies for α- β Emitters". The ε_s value of 0.5 is chosen refer to Table 4.3 "Source Efficiencies as listed in ISO 7503-1". Therefore the total efficiency for this condition becomes $\varepsilon_{tot} = \varepsilon_i \times \varepsilon_s = 0.2413 \times 0.5 = 0.121$ or 12.1%.

7.0 Conclusion:

Field conditions may significantly influence the usefulness of a survey instrument. When applying the instrument and source efficiencies in MDC calculations, field conditions must be considered. Tables have been constructed to assist in the selection of appropriate instrument and source efficiencies. Table 4.2 "Source to Detector Distance Effects on Instrument Efficiencies for α-β Emitters" lists instrument efficiencies (ε_i) at various source to detector distances for alpha and beta emitters. The appropriate ε_i value should be applied, accounting for the field condition, i.e. the relation between the detector and the surface to be measured.

Source efficiencies shall be selected from Table 4.3 "Source Efficiencies as listed in ISO 7503-1". This table lists conservative ε_s values that correct for self-absorption and attenuation of surface activity. Table 5.1 "Energy Response and Efficiency for Photon Emitting Isotopes" lists E_i values that apply to scanning MDC calculations. The Microshield™ model code was used to determine instrument efficiency assuming contamination conditions and detector geometry cited in section 5.6.2.4.4 "MDCs for Gamma Scans of Land Areas" of the License Termination Plan [8.6].

Detector and source conditions equivalent to those modeled herein may directly apply to the results of this report.

8.0 References

8.1 NUREG-1507, "Minimum Detectable Concentrations with Typical Radiation Survey Instruments for Various Contaminants and Field Conditions," 1998

8.2 ISO 7503-1, "Evaluation of Surface Contamination – Part I: Beta Emitters and Alpha Emitters," 1988-08-01.

8.3 ISO 8769, "Reference Sources for the Calibration of Surface Contamination Monitors-Beta-emitters (maximum beta energy greater 0.15MeV) and Alpha-emitters," 1988-06-15.

8.4 "Radiological Health Handbook," Revised Edition 1970.

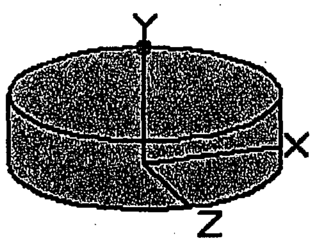
8.5 DP-8534, "Operation and source Checks of Portable Friskers".

8.6 Yankee Nuclear Plant Site License Termination Plan, Rev.0, November 2003.

MicroShield v6.02 (6.02-00253)

Page	:1	**File Ref**	:	
DOS File	:SPA3-EFF-Co-60.ms6	**Date**	:	
Run Date	: September 10, 2004	**By**	:	
Run Time	: 8:56:50 AM	**Checked**	:	
Duration	: 00:00:00			

Case Title: SPA3-EFF-Co-60
Description: SPA-3 Soil scan - 28 cm radius 1pCi/cm3 Co-60
Geometry: 8 - Cylinder Volume - End Shields



Source Dimensions:

Height	15.0 cm	(5.9 in)
Radius	28.0 cm	(11.0 in)

Dose Points

A	X	Y	Z
# 1	0 cm	25 cm	0 cm
	0.0 in	9.8 in	0.0 in

Shields

Shield N	Dimension	Material	Density
Source	3.69e+04 cm³	Concrete	1.6
Air Gap		Air	0.00122

Source Input : Grouping Method - Actual Photon Energies

Nuclide	curies	becquerels	μCi/cm³	Bq/cm³
Co-60	3.6945e-008	1.3670e+003	1.0000e-006	3.7000e-002

Buildup : The material reference is - Source
Integration Parameters

Radial	20
Circumferential	10
Y Direction (axial)	10

Results

Energy MeV	Activity Photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.6938	2.230e-01	9.055e-06	1.590e-05	1.748e-08	3.070e-08
1.1732	1.367e+03	1.098e-01	1.669e-01	1.962e-04	2.982e-04
1.3325	1.367e+03	1.293e-01	1.904e-01	2.244e-04	3.303e-04
Totals	**2.734e+03**	**2.391e-01**	**3.573e-01**	**4.205e-04**	**6.286e-04**

APPENDIX B

Co-60 Microsoft Excel E_i Calculation Sheet					
	Energy MeV	Energy keV	Exposure Rate (mR/hr-1pCi/g)	Energy Response (cpm/mR/h)	E_i (cpm/pCi/g)
694	0.6938	694	3.07E-08	1,112.630	0
1173	1.1732	1,173	2.98E-04	660.557	197
1333	1.3325	1,333	3.30E-04	552.233	182
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
				(E_i) Total:	**379**

APPENDIX C

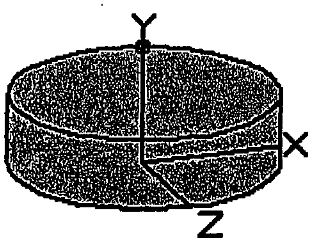
MicroShield v6.02 (6.02-00253)

Page	:1		**File Ref**	:
DOS File	:SPA3-EFF-Nb-94.ms6		**Date**	:
Run Date	: September 16, 2004		**By**	:
Run Time	: 3:22:38 PM		**Checked**	:
Duration	: 00:00:00			

Case Title: SPA3-EFF-Nb-94
Description: SPA-3 Soil scan - 28 cm radius 1pCi/cm3 Nb-94
Geometry: 8 - Cylinder Volume - End Shields

Source Dimensions:

Height	15.0 cm	(5.9 in)
Radius	28.0 cm	(11.0 in)



Dose Points

A	X	Y	Z
# 1	0 cm	25 cm	0 cm
	0.0 in	9.8 in	0.0 in

Shields

Shield N	Dimension	Material	Density
Source	3.69e+04 cm³	Concrete	1.6
Air Gap		Air	0.00122

Source Input : Grouping Method - Actual Photon Energies

Nuclide	curies	becquerels	μCi/cm³	Bq/cm³
Nb-94	3.6945e-008	1.3670e+003	1.0000e-006	3.7000e-002

Buildup : The material reference is - Source
Integration Parameters

Radial	20
Circumferential	10
Y Direction (axial)	10

Results

Energy MeV	Activity Photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.0023	9.067e-02	1.391e-10	1.430e-10	1.861e-10	1.913e-10
0.0174	4.834e-01	8.762e-09	9.129e-09	4.729e-10	4.927e-10
0.0175	9.260e-01	1.719e-08	1.792e-08	9.104e-10	9.491e-10
0.0196	2.720e-01	7.924e-09	8.356e-09	2.925e-10	3.085e-10
0.7026	1.367e+03	5.643e-02	9.872e-02	1.088e-04	1.904e-04
0.8711	1.367e+03	7.464e-02	1.228e-01	1.405e-04	2.312e-04
Totals	**2.736e+03**	**1.311e-01**	**2.216e-01**	**2.493e-04**	**4.216e-04**

APPENDIX D

Nb-94					
	Energy MeV	Energy keV	Exposure Rate (mR/hr-1pCi/g)	Energy Response (cpm/mR/h)	Ei (cpm/pCi/g)
2	0.0023	2	1.91E-10		0
17	0.0174	17	4.93E-10		0
18	0.0175	18	9.49E-10		0
20	0.0196	20	3.09E-10		0
703	0.7026	703	1.90E-04	1,110,370	211
871	0.8711	871	2.31E-04	884,689	205
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
				(E) Total:	416

APPENDIX E

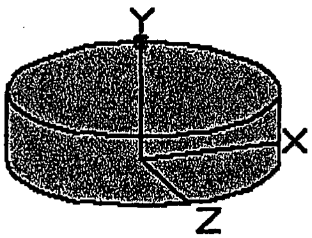
MicroShield v6.02 (6.02-00253)

Page	:1	**File Ref**	:
DOS File	:SPA3-EFF-Ag-108m.ms6	**Date**	:
Run Date	: September 16, 2004	**By**	:
Run Time	: 3:30:40 PM	**Checked**	:
Duration	: 00:00:00		

Case Title: SPA3-EFF-Ag-108m
Description: SPA-3 Soil scan - 28 cm radius 1pCi/cm3 Ag-108m
Geometry: 8 - Cylinder Volume - End Shields

Source Dimensions:

Height	15.0 cm	(5.9 in)
Radius	28.0 cm	(11.0 in)



Dose Points

A	X	Y	Z
# 1	0 cm	25 cm	0 cm
	0.0 in	9.8 in	0.0 in

Shields

Shield N	Dimension	Material	Density
Source	3.69e+04 cm³	Concrete	1.6
Air Gap		Air	0.00122

Source Input : Grouping Method - Actual Photon Energies

Nuclide	curies	becquerels	µCi/cm³	Bq/cm³
Ag-108m	3.6945e-008	1.3670e+003	1.0000e-006	3.7000e-002

Buildup : The material reference is - Source
Integration Parameters

Radial	20
Circumferential	10
Y Direction (axial)	10

Results

Energy MeV	Activity Photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.0028	6.580e+01	1.252e-07	1.287e-07	1.351e-07	1.388e-07
0.003	7.853e+00	1.568e-08	1.612e-08	1.612e-08	1.657e-08
0.021	2.491e+02	9.534e-06	1.015e-05	2.824e-07	3.007e-07
0.0212	4.727e+02	1.862e-05	1.985e-05	5.389e-07	5.744e-07
0.022	7.024e+00	3.202e-07	3.434e-07	8.233e-09	8.831e-09
0.0222	1.330e+01	6.251e-07	6.714e-07	1.568e-08	1.685e-08
0.0238	1.501e+02	9.273e-06	1.010e-05	1.863e-07	2.029e-07
0.0249	4.289e+00	3.145e-07	3.464e-07	5.492e-09	6.050e-09
0.0304	2.902e-04	4.431e-11	5.248e-11	4.230e-13	5.010e-13
0.0792	9.687e+01	2.008e-04	4.802e-04	3.190e-07	7.629e-07
0.4339	1.229e+03	2.705e-02	5.514e-02	5.294e-05	1.079e-04
0.6144	1.236e+03	4.282e-02	7.808e-02	8.347e-05	1.522e-04
0.7229	1.237e+03	5.300e-02	9.194e-02	1.019e-04	1.768e-04
Totals	**4.768e+03**	**1.231e-01**	**2.257e-01**	**2.398e-04**	**4.389e-04**

APPENDIX F

Ag-108m
Microsoft Excel E_i Calculation Sheet

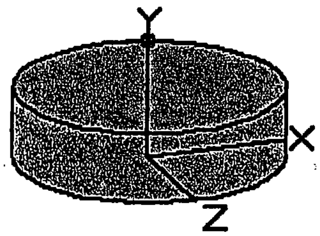
	Energy MeV	Energy kev	Exposure Rate (mR/hr / 1/pCi/g)	Energy Response cpm/mR/h	E_i (cpm/pCi/g)
3	0.0028	3	1.39E-07		0
3	0.003	3	1.66E-08		0
21	0.021	21	3.01E-07		0
21	0.0212	21	5.74E-07		0
22	0.022	22	8.83E-09		0
22	0.0222	22	1.69E-08		0
24	0.0238	24	2.03E-07		0
25	0.0249	25	6.05E-09		0
30	0.0304	30	5.01E-13	1086720	0
79	0.0792	79	7.63E-07	11696000	9
434	0.4339	434	1.08E-04	2061265	222
614	0.6144	614	1.52E-04	1402440	213
723	0.7229	723	1.77E-04	1086291	192
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
				(E_i) Total:	637

APPENDIX G

MicroShield v6.02 (6.02-00253)

Page	:1	**File Ref**	:
DOS File	:SPA3-EFF-Sb-125.ms6	**Date**	:
Run Date	: September 16, 2004	**By**	:
Run Time	: 3:34:07 PM	**Checked**	:
Duration	: 00:00:00		

Case Title: SPA3-EFF-Sb-125
Description: SPA-3 Soil scan - 28 cm radius 1pCi/cm3 Sb-125
Geometry: 8 - Cylinder Volume - End Shields



Source Dimensions:

Height	15.0 cm	(5.9 in)
Radius	28.0 cm	(11.0 in)

Dose Points

A	X	Y	Z
# 1	0 cm	25 cm	0 cm
	0.0 in	9.8 in	0.0 in

Shields

Shield N	Dimension	Material	Density
Source	3.69e+04 cm³	Concrete	1.6
Air Gap		Air	0.00122

Source Input : Grouping Method - Actual Photon Energies

Nuclide	curies	Becquerels	μCi/cm³	Bq/cm³
Sb-125	3.6945e-008	1.3670e+003	1.0000e-006	3.7000e-002

Buildup : The material reference is - Source
Integration Parameters

Radial	20
Circumferential	10
Y Direction (axial)	10

Results

Energy MeV	Activity Photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.0038	6.762e+01	1.708e-07	1.756e-07	1.388e-07	1.427e-07
0.0272	1.748e+02	1.785e-05	2.020e-05	2.376e-07	2.689e-07
0.0275	3.262e+02	3.453e-05	3.922e-05	4.461e-07	5.067e-07
0.031	1.132e+02	1.857e-05	2.221e-05	1.670e-07	1.997e-07
0.0355	5.693e+01	1.492e-05	1.918e-05	9.090e-08	1.169e-07
0.117	3.568e+00	1.380e-05	3.715e-05	2.146e-08	5.778e-08
0.159	9.531e-01	5.634e-06	1.499e-05	9.416e-09	2.505e-08
0.1726	2.478e+00	1.634e-05	4.295e-05	2.787e-08	7.326e-08
0.1763	9.422e+01	6.392e-04	1.674e-03	1.096e-06	2.870e-06
0.2041	4.410e+00	3.630e-05	9.230e-05	6.435e-08	1.636e-07
0.2081	3.324e+00	2.805e-05	7.103e-05	4.994e-08	1.264e-07
0.2279	1.796e+00	1.708e-05	4.229e-05	3.098e-08	7.670e-08
0.321	5.701e+00	8.474e-05	1.899e-04	1.620e-07	3.632e-07
0.3804	2.045e+01	3.792e-04	8.052e-04	7.364e-07	1.564e-06
0.408	2.486e+00	5.051e-05	1.049e-04	9.853e-08	2.047e-07
0.4279	4.009e+02	8.668e-03	1.774e-02	1.695e-05	3.470e-05
0.4435	4.130e+00	9.356e-05	1.894e-04	1.832e-07	3.709e-07
0.4634	1.415e+02	3.395e-03	6.781e-03	6.658e-06	1.330e-05
0.6006	2.430e+02	8.174e-03	1.501e-02	1.595e-05	2.930e-05
0.6066	6.864e+01	2.340e-03	4.283e-03	4.564e-06	8.355e-06
0.6359	1.548e+02	5.609e-03	1.012e-02	1.091e-05	1.967e-05
0.6714	2.478e+01	9.640e-04	1.710e-03	1.867e-06	3.311e-06
Totals	**1.916e+03**	**3.060e-02**	**5.901e-02**	**6.046e-05**	**1.158e-04**

APPENDIX H

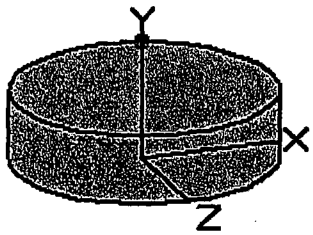
Sb-125					
	Energy Mev	Energy keV	Exposure Rate (mR/hr-1 pCi/g)	Energy Response (cpm/mR/h)	Ei (cpm/pCi/g)
4	0.0038	4	1.43E-07	6,618,312	0
27	0.0272	27	2.69E-07	510,290	0
28	0.0275	28	5.07E-07	554,334	0
31	0.031	31	2.00E-07	1,219,281	0
36	0.0355	36	1.17E-07	2,418,948	0
117	0.117	117	5.78E-08	9,167,000	1
159	0.159	159	2.51E-08	8917000	0
173	0.1726	173	7.33E-08	6859000	1
176	0.1763	176	2.87E-06	6192600	18
204	0.2041	204	1.64E-07	6011300	1
208	0.2081	208	1.26E-07	4073050	1
228	0.2279	228	7.67E-08	3110500	0
321	0.321	321	3.63E-07	3000500	1
380	0.3804	380	0.000001564	2348000	4
408	0.408	408	2.047E-07	2155800	0
428	0.4279	428	0.0000347	2083165	72
444	0.4435	444	3.709E-07	2026225	1
463	0.4634	463	0.0000133	1953590	26
601	0.6006	601	0.0000293	1452810	43
607	0.6066	607	0.000008355	1430910	12
636	0.6359	636	0.00001967	1323965	26
671	0.6714	671	0.000003311	1194390	4
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
				(Ei) Total:	210

APPENDIX I

MicroShield v6.02 (6.02-00253)

Page	:1	**File Ref**	:
DOS File	:SPA3-EFF-Cs-134.ms6	**Date**	:
Run Date	: September 16, 2004	**By**	:
Run Time	: 3:39:09 PM	**Checked**	:
Duration	: 00:00:00		

Case Title: SPA3-EFF-Cs-134
Description: SPA-3 Soil scan - 28 cm radius 1pCi/cm3 Cs-134
Geometry: 8 - Cylinder Volume - End Shields



Source Dimensions:

Height	15.0 cm	(5.9 in)
Radius	28.0 cm	(11.0 in)

Dose Points

A	X	Y	Z
# 1	0 cm	25 cm	0 cm
	0.0 in	9.8 in	0.0 in

Shields

Shield N	Dimension	Material	Density
Source	3.69e+04 cm³	Concrete	1.6
Air Gap		Air	0.00122

Source Input : Grouping Method - Actual Photon Energies

Nuclide	curies	becquerels	μCi/cm³	Bq/cm³
Cs-134	3.6945e-008	1.3670e+003	1.0000e-006	3.7000e-002

Buildup : The material reference is - Source

Integration Parameters

Radial	20
Circumferential	10
Y Direction (axial)	10

Results

Energy MeV	Activity Photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.0045	1.222e+00	3.658e-09	3.760e-09	2.507e-09	2.577e-09
0.0318	2.931e+00	5.271e-07	6.386e-07	4.391e-09	5.320e-09
0.0322	5.407e+00	1.014e-06	1.236e-06	8.157e-09	9.943e-09
0.0364	1.968e+00	5.611e-07	7.321e-07	3.188e-09	4.160e-09
0.2769	4.839e-01	5.931e-06	1.391e-05	1.113e-08	2.610e-08
0.4753	1.996e+01	4.950e-04	9.808e-04	9.712e-07	1.924e-06
0.5632	1.146e+02	3.545e-03	6.648e-03	6.940e-06	1.302e-05
0.5693	2.109e+02	6.619e-03	1.237e-02	1.295e-05	2.421e-05
0.6047	1.334e+03	4.529e-02	8.300e-02	8.836e-05	1.619e-04
0.7958	1.167e+03	5.668e-02	9.564e-02	1.079e-04	1.820e-04
0.8019	1.193e+02	5.852e-03	9.853e-03	1.113e-05	1.874e-05
1.0386	1.367e+01	9.377e-04	1.472e-03	1.717e-06	2.696e-06
1.1679	2.461e+01	1.964e-03	2.990e-03	3.514e-06	5.349e-06
1.3652	4.156e+01	4.055e-03	5.936e-03	6.993e-06	1.024e-05
Totals	**3.058e+03**	**1.254e-01**	**2.189e-01**	**2.405e-04**	**4.202e-04**

APPENDIX J

Cs-134
Microsoft Excel Ei Calculation Sheet

	Energy MeV	Energy keV	Exposure Rate (mR/hr-1/pCi/g)	Energy Response (cpm/mR/h)	Ei (cpm/pCi/g)
5	0.0045	5	2.58E-09		0
32	0.0318	32	5.32E-09	1.406947	0
32	0.0322	32	9.94E-09	1.505273	0
36	0.0364	36	4.16E-09	2.696122	0
277	0.2769	277	2.61E-08	3.637000	0
475	0.4753	475	1.92E-06	1.910155	4
563	0.5632	563	1.30E-05	1.589320	21
569	0.5693	569	2.42E-05	1.567055	38
605	0.6047	605	1.62E-04	1.437845	233
796	0.7958	796	1.82E-04	998082	182
802	0.8019	802	1.87E-05	939149	18
1039	1.0386	1,039	2.70E-06	752085	2
1168	1.1679	1,168	5.35E-06	664161	4
1365	1.3652	1,365	1.02E-05	573136	6
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
				(Ei) Total:	**506**

APPENDIX K

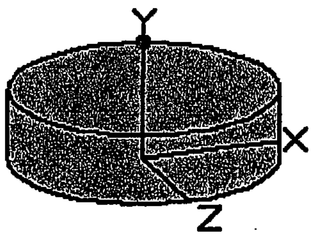
MicroShield v6.02 (6.02-00253)

Page	:1	**File Ref**	:
DOS File	:SPA3-EFF-Cs-137.ms6	**Date**	:
Run Date	: September 10, 2004	**By**	:
Run Time	: 8:52:18 AM	**Checked**	:
Duration	: 00:00:00		

Case Title: SPA3-EFF-Cs-137
Description: SPA-3 Soil scan - 28 cm radius 1pCi/cm3 Cs-137 and Daughters
Geometry: 8 - Cylinder Volume - End Shields

Source Dimensions:

Height	15.0 cm	(5.9 in)
Radius	28.0 cm	(11.0 in)



Dose Points

A	X	Y	Z
# 1	0 cm	25 cm	0 cm
	0.0 in	9.8 in	0.0 in

Shields

Shield N	Dimension	Material	Density
Source	3.69e+04 cm³	Concrete	1.6
Air Gap		Air	0.00122

Source Input : Grouping Method - Actual Photon Energies

Nuclide	curies	becquerels	μCi/cm³	Bq/cm³
Ba-137m	3.4950e-008	1.2932e+003	9.4600e-007	3.5002e-002
Cs-137	3.6945e-008	1.3670e+003	1.0000e-006	3.7000e-002

Buildup : The material reference is - Source
Integration Parameters

Radial	20
Circumferential	10
Y Direction (axial)	10

Results

Energy MeV	Activity Photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.0045	1.342e+01	4.020e-08	4.133e-08	2.755e-08	2.833e-08
0.0318	2.677e+01	4.815e-06	5.834e-06	4.011e-08	4.860e-08
0.0322	4.939e+01	9.260e-06	1.129e-05	7.452e-08	9.084e-08
0.0364	1.797e+01	5.126e-06	6.688e-06	2.912e-08	3.800e-08
0.6616	1.164e+03	4.442e-02	7.913e-02	8.611e-05	1.534e-04
Totals	**1.271e+03**	**4.444e-02**	**7.915e-02**	**8.628e-05**	**1.536e-04**

APPENDIX L

Cs-137
Microsoft Excel E_i Calculation Sheet

	Energy MeV	Energy kev	Exposure Rate (mR/h 1/pCi/g)	Energy Response (cpm/mR/h)	E_i (cpm/pCi/g)
5	0.0045	5	2.83E-08		0
32	0.0318	32	4.86E-08	1,406,947	0
32	0.0322	32	9.08E-08	1,505,273	0
36	0.0364	36	3.80E-08	2,696,122	0
662	0.6616	662	1.53E-04	1,228,700	188
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
				(Ei) Total:	**188**

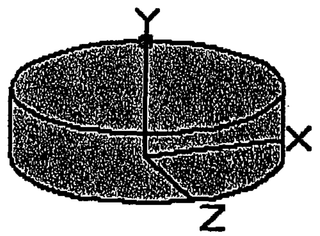
APPENDIX M

MicroShield v6.02 (6.02-00253)

Page	:1
DOS File	:SPA3-EFF-Eu-152.ms6
Run Date	: October 7, 2004
Run Time	: 11:25:11 AM
Duration	: 00:00:00

File Ref	:
Date	:
By	:
Checked	:

Case Title: SPA-3-EFF-Eu-152
Description: SPA-3 Soil scan - 28cm radius 1 pCi/cm3 Eu-152
Geometry: 8 - Cylinder Volume - End Shields



Source Dimensions:

Height	15.0 cm	(5.9 in)
Radius	28.0 cm	(11.0 in)

Dose Points

A	X	Y	Z
# 1	0 cm	25 cm	0 cm
	0.0 in	9.8 in	0.0 in

Shields

Shield N	Dimension	Material	Density
Source	3.69e+04 cm³	Concrete	1.6
Air Gap		Air	0.00122

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

Nuclide	curies	becquerels	μCi/cm³	Bq/cm³
Eu-152	3.6945e-008	1.3670e+003	1.0000e-006	3.7000e-002

Buildup : The material reference is - Source
Integration Parameters

Radial	20
Circumferential	10
Y Direction (axial)	10

Results

Energy MeV	Activity Photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.015	2.077e+02	2.087e-06	2.146e-06	1.790e-07	1.841e-07
0.04	8.088e+02	3.131e-04	4.331e-04	1.385e-06	1.916e-06
0.05	2.022e+02	1.507e-04	2.467e-04	4.014e-07	6.572e-07
0.1	3.887e+02	1.189e-03	3.118e-03	1.819e-06	4.770e-06
0.2	1.024e+02	8.207e-04	2.097e-03	1.448e-06	3.700e-06
0.3	3.696e+02	5.029e-03	1.151e-02	9.540e-06	2.184e-05
0.4	8.590e+01	1.701e-03	3.555e-03	3.314e-06	6.926e-06
0.5	7.711e+00	2.043e-04	3.984e-04	4.010e-07	7.819e-07
0.6	5.797e+01	1.948e-03	3.579e-03	3.802e-06	6.985e-06
0.8	2.434e+02	1.190e-02	2.005e-02	2.263e-05	3.813e-05
1.0	5.849e+02	3.820e-02	6.058e-02	7.042e-05	1.117e-04
1.5	3.171e+02	3.490e-02	4.999e-02	5.871e-05	8.411e-05
Totals	**3.376e+03**	**9.635e-02**	**1.556e-01**	**1.740e-04**	**2.817e-04**

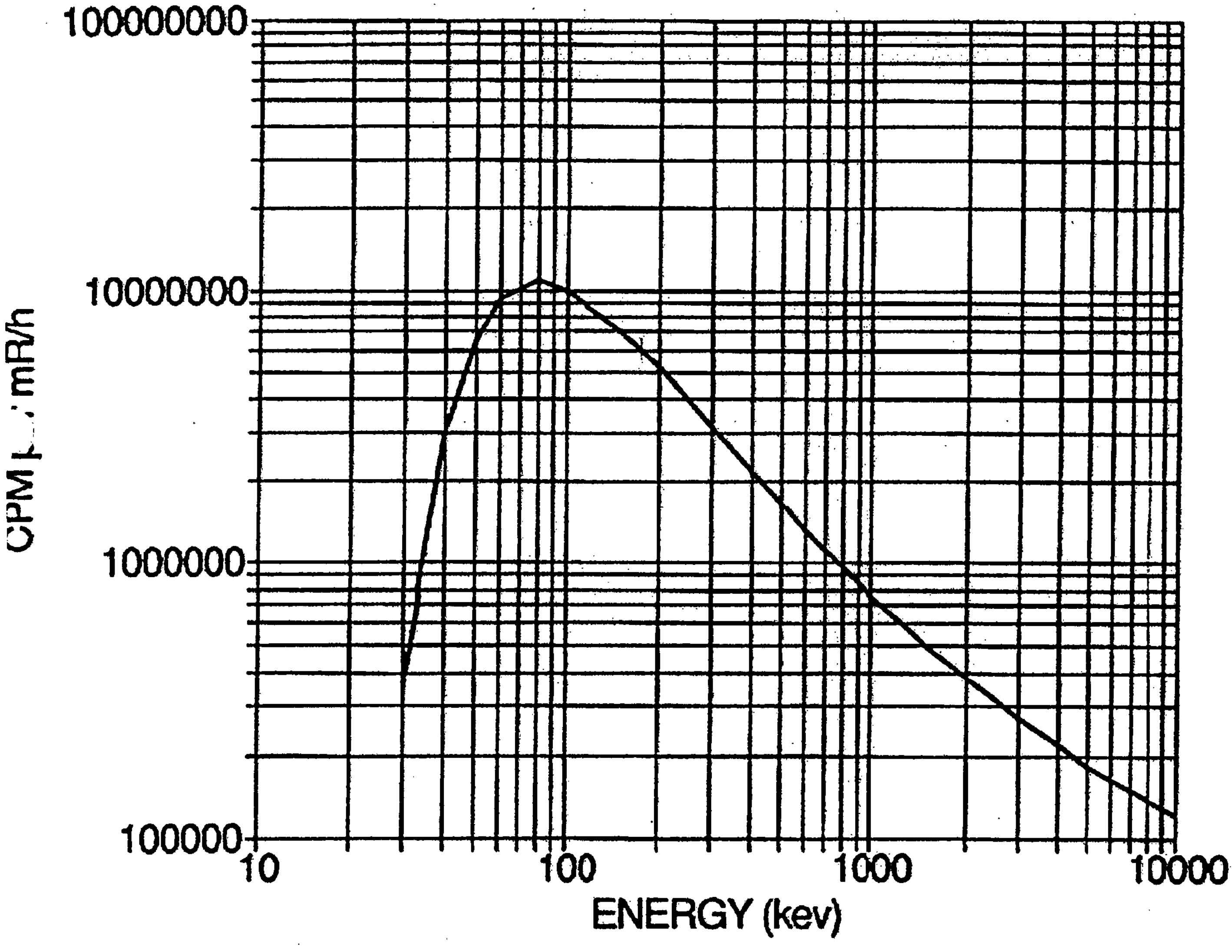
APPENDIX N

Eu-152					
	Energy MeV	Energy keV	Exposure Rate (mR/hr 1 pCi/g)	Energy Response (cpm/mR/h)	E1 (cpm/pCi/g)
15	0.015	15	1.84E-07		0
40	0.04	40	1.92E-06	3,897,600	7
50	0.05	50	6.57E-07	6,500,000	4
100	0.1	100	4.77E-06	9,958,333	48
200	0.2	200	3.70E-06	4,850,000	18
300	0.3	300	2.18E-05	3,200,000	70
400	0.4	400	6.93E-06	2,185,000	15
500	0.5	500	7.82E-07	1,820,000	1
600	0.6	600	6.99E-06	1,455,000	10
800	0.8	800	3.81E-05	993,000	38
1000	1	1,000	1.12E-04	783,019	87
1500	1.5	1,500	8.41E-05	530,000	45
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
				(E1) Total:	**344**

APPENDIX O

Calculated Energy Response (Eberline Instruments)

CPM/mR/h



ALARA Analysis Worksheet

Survey Area: SVC-01 **Survey Unit:** 18 .

A. Estimation of Total Cost ($Cost_T$)

1. Cost of performing remediation work ($Cost_R$) (assume 3-staff crew for 1 day@average $60 per hour; cost for heavy equipment not included)	$ 1800
2. Cost of waste disposal ($Cost_{WD}$) = (2.a) · (2.b) a. estimated waste volume: 1 m^3 b. cost of waste disposal: $670/$m^3$	$ 670
3. Cost of workplace accident ($Cost_{ACC}$) = $3,000,000 $person^{-1}$ · 4.2x10^{-8} h^{-1} · (3.a) a. time to perform remediation action: 30 person-hours	$ 3.78
4. Cost of traffic fatality ($Cost_{TF}$) = {$3,000,000 · 3.8x$10^{-8}$ km^{-1} · (2.a) · (4.a)}/(4.b) a. total distance traveled per shipment: 4100 km b. waste volume per shipment: 13.6 m^3, if unknown, use 13.6m^3 as a default value	$ 34.37
5. Cost of worker dose ($Cost_{WDose}$) = $2,000 per person-rem · (5.a) · (5.b) a. worker TEDE: ____________ rem/h b. remediation exposure time __________ person-hour	$ 0
$Cost_T$	$ 2508

B. Survey Unit Radiological Information

Radionuclide	Average Concentration	Relative Fraction[a]	Half-Life (y)	Decay Constant[b] (y^{-1})
1. Co-60	a. 6622 dpm/100cm^2	b. 1	c. 5.271	d. 0.13
2.	a.	b.	c.	d.
3.	a.	b.	c.	d.
4.	a.	b.	c.	d.
5.	a.	b.	c.	d.
6.	a.	b.	c.	d.
7.	a.	b.	c.	d.
8.	a.	b.	c.	d.

Total Concentration: ______________

[a] Relative fraction = average concentration divided by the total concentration.

[b] Decay constant = 0.693 divided by half-life.

C. Calculation of ALARA Action Level (AL)

1. Removable fraction for remediation action being evaluated: 1.0

2. Monetary discount rate: $0.03\ y^{-1}$

3. Number of years over which the collective dose is calculated: 1000 y

4. Population density for the critical group: $0.0004\ people/m^2$

5. Area being evaluated: $100\ m^2$

6. AL for each radionuclide-of-interest:

a. $AL = \{Cost_T/(\$2000 \cdot C.4 \cdot 0.025 \cdot C.1 \cdot C.5)\} \cdot \{(C.2 + B.1.d)/(1-e^{-(C.2+B.1..d) \cdot C.3}\} \cdot \{B.1.b\} =$ 1356

b. $AL = \{Cost_T/(\$2000 \cdot C.4 \cdot 0.025 \cdot C.1 \cdot C.5)\} \cdot \{(C.2 + B.2.d)/(1-e^{-(C.2+B.2..d) \cdot C.3}\} \cdot \{B.2.b\} =$ ________

c. $AL = \{Cost_T/(\$2000 \cdot C.4 \cdot 0.025 \cdot C.1 \cdot C.5)\} \cdot \{(C.2 + B.3.d)/(1-e^{-(C.2+B.3..d) \cdot C.3}\} \cdot \{B.3.b\} =$ ________

d. $AL = \{Cost_T/(\$2000 \cdot C.4 \cdot 0.025 \cdot C.1 \cdot C.5)\} \cdot \{(C.2 + B.4.d)/(1-e^{-(C.2+B.4..d) \cdot C.3}\} \cdot \{B.4.b\} =$ ________

e. $AL = \{Cost_T/(\$2000 \cdot C.4 \cdot 0.025 \cdot C.1 \cdot C.5)\} \cdot \{(C.2 + B.5.d)/(1-e^{-(C.2+B.5..d) \cdot C.3}\} \cdot \{B.5.b\} =$ ________

f. $AL = \{Cost_T/(\$2000 \cdot C.4 \cdot 0.025 \cdot C.1 \cdot C.5)\} \cdot \{(C.2 + B.6.d)/(1-e^{-(C.2+B.6..d) \cdot C.3}\} \cdot \{B.6.b\} =$ ________

g. $AL = \{Cost_T/(\$2000 \cdot C.4 \cdot 0.025 \cdot C.1 \cdot C.5)\} \cdot \{(C.2 + B.7.d)/(1-e^{-(C.2+B.7..d) \cdot C.3}\} \cdot \{B.7.b\} =$ ________

h. $AL = \{Cost_T/(\$2000 \cdot C.4 \cdot 0.025 \cdot C.1 \cdot C.5)\} \cdot \{(C.2 + B.8.d)/(1-e^{-(C.2+B.8..d) \cdot C.3}\} \cdot \{B.8.b\} =$ ________

7. .... Sum of ALs (= ALARA AL) = 1356

D. ALARA Evaluation

Radionuclide	DCGL	DCGL Fraction[a]
1. Co-60	a 6622 dpm/100cm^2	b. (B.1.a)/(D.1.a) = 1.0
2. ________	a. ________	b. (B.2.a)/(D.3.a) = ________
3. ________	a. ________	b. (B.3.a)/(D.4.a) = ________
4. ________	a. ________	b. (B.4.a)/(D.5.a) = ________
5. ________	a. ________	b. (B.5.a)/(D.6.a) = ________
6. ________	a. ________	b. (B.7.a)/(D.7.a) = ________
7. ________	a. ________	b. (B.8.a)/(D.8.a) = ________
8. ________	a. ________	b. (B.9.a)/(D.9.a) = ________

9. .... Sum of DCGL Fractions = 1.0

[a] DCGL fraction = average residual concentration in survey unit (from Section B) divided by the DCGL.

10. Comparison of the sum of the DCGL fractions (D.9) to ALARA AL (C.7):

Check one: Sum of the DCGL Fractions < ALARA AL ✓ Sum of the DCGL Fractions > ALARA AL _____

12. **Decision Criteria**: If the sum of the DCGL fractions < AL, then additional remediation is not cost beneficial. If the sum of the DCGL fractions > AL, then additional remediation is cost beneficial.

Check one: Additional remediation **IS NOT** cost beneficial ✓

Additional remediation **IS** cost beneficial _____

Prepared by J. Buson Date 11-9-05

FSS Radiological Engineer

Reviewed by J. C. Smith/J. C. Smith Date 11/23/05

FSS Project Manager

1 of 19

Use Of In-Situ Gamma Spectrum Analysis To Perform Elevated Measurement Comparisons In Support Of Final Status Surveys

YA-REPT-00-018-05

Approvals	**(Print & Sign Name)**	
Preparer: Greg Astrauckas/	[signature]	Date: 10/10/05
Preparer: Gordon Madison, CHP/	[signature]	Date: 10/11/05
Reviewer: Jim Hummer, CHP/	[signature]	Date: 10/18/05
Approver (FSS Manager): Dann Smith, CHP/	[signature]	Date: 11/4/05

γ

Technical Report YA-REPT-00-018-05, Rev. 0

Use Of In-Situ Gamma Spectrum Analysis To Perform Elevated Measurement Comparisons In Support Of Final Status Surveys

TABLE OF CONTENTS

Attachments

3

1.0 REPORT

1.1 Introduction

The ISOCS In-Situ Gamma Spectrum detector system manufactured by Canberra Industries is being employed to perform elevated measurement comparison (EMC) surveys in support of the Final Status Surveys at Yankee Atomic's Yankee Rowe facility. This system uses an HPGe detector and specialized efficiency calibration software designed to perform in-situ gamma-spectroscopy assays. The ISOCS system will primarily be employed to evaluate survey units for elevated measurement comparisons. The ISOCS system can obtain a static measurement at a fixed distance from a pre-determined location. Count times can be tailored to achieve required detection sensitivities. Gamma spectroscopy readily distinguishes background activity from plant-related licensed radioactivity. This attribute is particularly beneficial where natural radioactivity introduces significant investigation survey efforts. Additionally, background subtraction or collimation can be employed where background influences are problematic due to the presence of stored spent fuel (ISFSI).

This technical report is intended to outline the technical approach associated with the use of ISOCS for implementing a MARSSIM-based Final Status Survey with respect to scanning surveys for elevated measurement comparisons for both open land areas and building surfaces. While the examples and discussions in this report primarily address open land areas, the same approach and methodology will be applied when deriving investigation levels, grid spacing and measurement spacing for evaluating building surfaces.

Validation of the ISOCS software is beyond the scope of this technical report. Canberra Industries has performed extensive testing and validation on both the MCNP-based detector characterization process and the ISOCS calibration algorithms associated with the calibration software. The full MCNP method has been shown to be accurate to within 5% typically. ISOCS results have been compared to both full MCNP and to 119 different radioactive calibration sources. In general, ISOCS is accurate to within 4-5% at high energies and 7-11% at 1 standard deviation for low energies. Additionally, the ISOCS technology has been previously qualified in Yankee Atomic Technical Report YA-REPT-00-022-04, "Use Of Gamma Spectrum Analysis To Evaluate Bulk Materials For Compliance With License Termination Criteria."

1.2 Discussion

1.2.1 Detector Description

Two ISOCS-characterized HPGe detectors manufactured by Canberra Industries have been procured. Each detector is a reverse-electrode HPGe detector rated at 50% efficiency (relative to a NaI detector). Resolution for these detectors is 2.2 keV @ 1332 keV. As the project progresses, other ISOCS detectors (e.g. standard electrode coaxial), if available, may be used to increase productivity. The key element regarding the use of other types of ISOCS® detectors is that specific efficiency calibrations will be developed to account for each detector's unique characteristics.

The HPGe detector is mounted on a bracket designed to hold the detector / cryostat assembly and associated collimators. This bracket may be mounted in a wheeled cart or in a cage-like frame. Both the wheeled cart and frame permit the detector to be oriented (pointed) over a full range from a horizontal to vertical position. The frame's design allows the detector to be suspended above the ground. Photographs of the frame-mounted system are presented in Attachment 1. During evaluations of Class1 areas for elevated radioactivity, the detector will generally be outfitted with the 90-degree collimator. Suspending the detector at 2 meters above the target surface yields a nominal field-of-view of 12.6 m^2.

The InSpector (MCA) unit that drives the signal chain and the laptop computer that runs the acquisition software (Genie-2000) are mounted either in the frame or on the wheeled cart. These components are battery powered. Back-up power supplies (inverter or UPS) are available to support the duty cycle. A wireless network has been installed at the site so that the laptop computers used to run the systems can be completely controlled from any workstation at the facility. This configuration also enables the saving of data files directly to a centralized file server. Radio communication will be used to coordinate system operation.

1.2.2 Traditional Approach

With respect to Class 1 Survey Units, small areas of elevated activity are evaluated via the performance of scan surveys. The size of the potential area of elevated activity affects the $DCGL_{EMC}$ and is typically determined by that area bounded by the grid points used for fixed measurements. This area in turn dictates the area factor(s) used for deriving the associated $DCGL_{EMC}$.

These scan surveys are traditionally conducted with hand-held field instruments that have a detection sensitivity sufficiently low to identify areas of localized activity above the $DCGL_{EMC}$. Occasionally, the detection sensitivity of these instruments is greater than the $DCGL_{EMC}$. In order to increase the $DCGL_{EMC}$ to the point where hand-held instrumentation can be reasonably employed, the survey design is augmented to require additional fixed-point measurements. The effect of these additional measurement points is to tighten the fixed measurement grid spacing, thus reducing the area applied to deriving the $DCGL_{EMC}$ and increasing the detection sensitivity criteria.

Background influences (from the ISFSI) and natural terrestrial sources further impact the sensitivity of these instruments. To address these impacts, the fixed-point grid spacing would again need to be reduced (requiring even more samples) in order to increase the $DCGL_{EMC}$ to the point where hand-held instrumentation can be used. Generally, the collection of additional fixed measurements (i.e. samples) increases project costs.

Survey designs for Class 2 and Class 3 survey units are not driven by the elevated measurement comparison because areas of elevated activity are not expected. In Class 2 areas, any indication of activity above the $DCGL_W$ requires further investigation. Similarly, in Class 3 areas, any positive indication of licensed radioactivity also requires further investigation. Because the $DCGL_{EMC}$ is not applicable to Class 2 or Class 3 areas, adjustments to grid spacing do not occur. However, the increased field-of-view associated with the in-situ gamma spectroscopy system improves the efficiency of the survey's implementation.

1.2.3 Innovative Approach

In-situ assays allow fixed-point grid spacing to be uncoupled from the derivation of applicable investigation levels. In contrast to the traditional approach where the $DCGL_{EMC}$ (based on grid size) determines both investigation levels and detection sensitivities, the use of this technology provides two independent dynamics as follows:

- Detection sensitivity is determined by the $DCGL_{EMC}$ associated with the (optimal) fixed-point grid spacing.
- Investigation levels are based on the detector's field-of-view and adjusted for the smallest area of concern (i.e. 1 m^2).

1.2.4 Investigation Level

Development of the investigation (action) levels applied to in-situ assay results is a departure from the traditional approach for implementing a MARSSIM survey. Examples are provided for both open land areas (i.e. soil) and for building surfaces, however the approach for both is identical.

To support the use of in-situ spectroscopy to evaluate areas of elevated activity the HPGe detector's field-of-view was characterized. Attachment 2 presents data from the field-of-view characterization for a detector configured with a 90-degree collimator positioned 2 meters from the target surface. Alternate configurations will be evaluated in a similar manner before being employed. As exhibited in Attachment 2, when the detector is positioned at 2 meters above the target surface the field-of-view has a radius of at least 2.3

meters. This value was rounded down to 2.0 meters for implementation purposes, introducing a conservative bias (approximately 9%) in reported results. The example provided in this technical report assumes a 2-meter source-to-detector distance, yielding a nominal field-of-view surface area of 12.6 m^2.

Occasionally, alternate source-to-detector distances (using the 90-degree collimator) may be employed, particularly in a characterization or investigation capacity. In such cases, the detector's field-of-view will be calculated by setting the radius equal to the source-to-detector distance, thereby maintaining the conservative attribute previously described. If alternative collimator configurations are used to perform elevated measurement comparisons, then specific evaluations will be documented in the form of a technical evaluation or similar. Associated investigation levels will be derived using the same approach and methodology outlined below in this section.

After the detector's field-of-view is determined, an appropriate investigation level is developed to account for a potential one-meter square area of elevated activity. $DCGL_{EMC}$ values for a one-square meter area are presented in Table 1.

TABLE 1, SOIL $DCGL_{EMC}$ FOR 1 m^2

	Soil $DCGL_W$ (pCi/g) (NOTE 1)	Soil $DCGL_W$ (pCi/g) (NOTE 2)	Area Factor for 1 m^2 (NOTE 3)	$DCGL_{EMC}$ for 1 m^2 (pCi/g) (NOTE 4)
Co-60	3.8	1.4	11	15
Ag-108m	6.9	2.5	9.2	23
Cs-134	4.7	1.7	16	28
Cs-137	8.2	3.0	22	66

NOTE 1 – LTP Table 6-1
NOTE 2 – Adjusted to 8.73 mRem/yr
NOTE 3 – LTP Appendix 6Q
NOTE 4 – Soil $DCGL_W$ (adjusted to 8.73 mRem/yr) for a 1 m^2 area

The ${}^{1m2}DCGL_{EMC}$ values listed in Table 1 do not account for a source positioned at the edge of the field-of-view. Therefore, the ${}^{1m2}DCGL_{EMC}$ values are adjusted via a correction factor. To develop this correction factor, a spectrum free of plant-related radioactivity was analyzed using two different efficiency calibrations (i.e. geometries). The first scenario assumes radioactivity uniformly distributed over the detector's 12.6 m^2 field-of-view. The second scenario assumes radioactivity localized over a 1 m^2 situated at the edge of the detector's field-of-view. The resultant MDC values were compared to characterize the difference in detection efficiencies between the two scenarios. As expected, the condition with localized (1 m^2) radioactivity at the edge of the detector's field-of-view yielded higher MDC values. The ratio between the reported MDC values for the two scenarios is used as a correction factor. This correction factor is referred to as the offset geometry adjustment factor. The investigation levels for soils presented in Table 2 were calculated as follows:

$$\text{Nuclide Investigation Level (pCi/g)} = (DCGL_{EMC}) * CF$$

Where: $DCGL_{EMC} = (DCGL_W \text{ or } DCGL_{SURR}) * AF_{(1\ m^2)}$, and
CF = Mean offset geometry adjustment factor

TABLE 2, SOIL INVESTIGATION LEVEL DERIVATION

	MDC pCi/g (NOTE 1)	MDC pCi/g (NOTE 2)	RATIO (NOTE 3)	$DCGL_{EMC}$ for 1 m^2 (NOTE 5)	INVESTIGATION LEVEL pCi/g (NOTE 6)
Co-60	0.121	1.86	0.0651	15	1.0
Ag-108m	0.184	2.82	0.0652	23	1.5
Cs-134	0.189	2.90	0.0652	28	1.8
Cs-137	0.182	2.78	0.0655	66	4.3
Offset Geometry Adjustment Factor (NOTE 4)			**0.0653**		

NOTE 1 – Assumed activity distributed over the 12.6 m^2 field-of-view.
NOTE 2 – Efficiency calibration modeled for a 1 m^2 area situated (off-set) at the edge of the detector's field-of-view. The model assumes that all activity is distributed within the 1 m^2.
NOTE 3 – Ratio = (12.6 m^2 MDC ÷ 1 m^2 MDC).
NOTE 4 – The mean value of the ratios is applied as the off-set geometry adjustment factor.
NOTE 5 – $DCGL_{EMC}$ values for 1 m^2 (from Table 1)
NOTE 6 – Investigation levels derived by applying of the off-set geometry adjustment factor (e.g. 0.0653) to the $DCGL_{EMC}$ for a 1 m^2 area for each radionuclide.

With respect to building surfaces, the development of the investigation level is identical to that for soil surfaces. The one-meter square $DCGL_{EMC}$ for building surfaces are presented in Table 3.

TABLE 3, BUILDING SURFACE $DCGL_{EMC}$ FOR 1 m^2

	Bldg $DCGL_W$ (dpm/100m²) (NOTE 1)	Bldg $DCGL_W$ (dpm/100cm²) (NOTE 2)	Area Factor For 1 m^2 (NOTE 3)	$DCGL_{EMC}$ For 1 m^2 (dpm/100cm²) (NOTE 4)
Co-60	18,000	6,300	7.3	46,000
Ag-108m	25,000	8,700	7.2	62,600
Cs-134	29,000	10,000	7.4	74,000
Cs-137	63,000	22,000	7.6	167,000

NOTE 1 – LTP Table 6-1
NOTE 2 – Adjusted to 8.73 mRem/yr
NOTE 3 – LTP Appendix 6S
NOTE 4 – Building $DCGL_W$ (adjusted to 8.73 mRem/yr) for a 1 m^2 area

Using the same approach described for soils, a correction factor to account for efficiency differences due to geometry considerations is developed the one-meter square $DCGL_{EMC}$. ISOCS efficiency calibrations for activity distributed over the detector's field-of-view and for activity within one-square meter located at the edge of the detector's field-of-view were developed. The MDC values for these two geometries were compared to characterize the difference in detection efficiencies. As expected, the condition with localized (1 m^2)

radioactivity at the edge of the detector's field-of-view yielded higher MDC values. The ratio between the reported MDC values for the two scenarios is used as the offset geometry adjustment factor. The MDC values, the associated ratios, and the derived investigation level for building surfaces are presented in Table 4.

TABLE 4, BUILDING SURFACE INVESTIGATION LEVEL DERIVATION

	12.6 m^2 MDC (dpm/100cm²) (NOTE 1)	1 m^2 MDC (dpm/100cm²) (NOTE 2)	RATIO (NOTE 3)	$DCGL_{EMC}$ For 1 m^2 (dpm/100cm²) (NOTE 5)	BUILDING SURFACE INVESTIGATION LEVEL (dpm/100cm²) (NOTE 6)
Co-60	785	12,400	0.0633	46,000	2,900
Ag-108m	839	13,000	0.0645	62,600	3,900
Cs-134	900	14,200	0.0634	74,000	4,700
Cs-137	922	14,600	0.0632	167,000	10,600
Offset Geometry Adjustment Factor (NOTE 4)			**0.0636**		

NOTE 1 – Assumed activity distributed over the 12.6 m^2 field-of-view.
NOTE 2 – Efficiency calibration modeled for a 1 m^2 area situated (off-set) at the edge of the detector's field-of-view. The model assumes that all activity is distributed within the 1 m^2.
NOTE 3 – Ratio = (12.6 m^2 MDC ÷ 1 m^2 MDC).
NOTE 4 – The mean value of the ratios is applied as the off-set geometry adjustment factor.
NOTE 5 – $DCGL_{EMC}$ values for 1 m^2 (from Table 3)
NOTE 6 – Investigation levels derived by applying of the off-set geometry adjustment factor (e.g. 0.0636) to the one-square meter $DCGL_{EMC}$.

In summary, effective investigation levels for both open land areas (i.e. soils) and for building surfaces can be derived and applied to in-situ gamma spectroscopy results. Note the MDC values associated with the detector's field-of-view were well below the derived investigation levels.

The investigation levels presented in Table 2 and Table 4 do not address the use of surrogate DCGLs. Use of surrogate DCGLs will be addressed in Final Status Survey Plans, particularly where it is necessary to evaluate non-gamma emitting radionuclides on building surfaces. When surrogate DCGLs are employed, investigation levels will be developed on a case-by-case basis using the approach outlined in this document. Similarly, the offset geometry adjustment factor presented in Table 2 and Table 4 will vary for different geometries. Although unlikely, if different geometries are employed, this value will be determined on a case-by-case basis using the methodology reflected in Table 2 and will be documented in the applicable Final Status Survey Plan.

For both open land areas and for building surfaces, when an investigation level is encountered, investigatory protocols will be initiated to evaluate the presence of elevated activity and bound the region as necessary. Such evaluations may include both hand-held field instrumentation as well as the in-situ HPGe detector system. After investigation activities are completed, subsequent (follow-up) scanning evaluations will most likely be conducted using the in-situ gamma spectroscopy system.

1.2.5 Detector Sensitivity

For Class 1 scan surveys, the minimum detectable concentration is governed by the $DCGL_{EMC}$ associated with the grid area used to locate fixed-point measurements. The system's count time can be controlled to achieve the required detection sensitivity. Therefore, the grid spacing for the fixed-point measurements can be optimized thus eliminating unnecessary increases to the number of fixed-point measurements while ensuring that elevated areas between fixed measurement locations can be identified and evaluated.

Based on preliminary work, it has been determined that a count time of 900 seconds will yield an acceptable sensitivity for many areas on the site. This count time provides MDC values well below the investigation levels presented in Table 2 and Table 4. Count times will be adjusted as necessary as survey unit-specific investigation levels are derived or where background conditions warrant to ensure that detection sensitivities are below the applicable investigation level. Since each assay report includes a report of the MDC values achieved during the assay, this information is considered technical support that required MDC values were met.

1.2.6 Area Coverage

Based on the nominal 12.6 m^2 field-of-view, a 3-meter spacing between each survey point will result in well over 100% of the survey unit to be evaluated for elevated activity. This spacing convention typically employs a grid pattern that is completely independent from the grid used to locate fixed-point measurements. An example of the grid pattern and spacing is presented in Attachment 3.

Alternate spacing conventions may be applied on a case-by-case basis. For instance, spacing may be decreased when problematic topographies are encountered. Note that decreased grid spacing in this context is not associated to the fixed-point measurements. Occasionally it may be necessary to position the detector at one meter or less from the target surface to evaluate unusual (e.g. curved) surfaces or to assist in bounding areas of elevated activity. In cases where it may be desirable to increase the field-of-view via collimator or source-to-detector distances, grid-spacing conventions (and applicable investigation levels) will be determined using the approach described in this document.

1.2.7 Moisture Content in the Soil Matrix

In-situ gamma spectroscopy of open land areas is inherently subject to various environmental variables not present in laboratory analyses. Most notably is the impact that water saturation has on assay results. This impact has two components. First, the total activity result for the assay is assigned over a larger, possibly non-radioactive mass introduced by the presence of water. Secondly, water introduces a self-absorption factor.

The increase in sample mass due to the presence of water is addressed by the application of a massimetric efficiency developed by Canberra Industries. Massimetric efficiency units are defined as [counts per second]/[gammas per second per gram of sample]. Mathematically, this is the product of traditional efficiency and the mass of the sample. When the efficiency is expressed this way, the efficiency asymptotically approaches a constant value as the sample becomes very large (e.g. infinite). Under these conditions changes in sample size, including mass variations from excess moisture, have little impact on the counting efficiency. However, the massimetric efficiency does not completely address attenuation characteristics associated with water in the soil matrix.

To evaluate the extent of self-absorption, (traditional) counting efficiencies were compared for two densities. Based on empirical data associated with the monitoring wells, typical nominally dry in-situ soil is assigned a density of 1.7 g/cc. A density of 2.08 g/cc, obtained from a technical reference publication by Thomas J. Glover, represents saturated soil. A density of 2.08 g/cc accounts for a possible water content of 20%. A summary of this comparison is presented in Table 5.

TABLE 5, COUNTING EFFICIENCY COMPARISONS

keV	Efficiencies 1.7 g/cc	Efficiencies 2.08 g/cc	Deviation due to density increase (excess moisture)
434	3.3 E-6	2.7 E-6	-18.7%
661.65	2.9 E-6	2.4 E-6	-17.5%
1173.22	2.5 E-6	2.1 E-6	-15.4%
1332.49	2.4 E-6	2.1 E-6	-14.8%

In cases when the soil is observed to contain more than "typical" amounts of water, potential under-reporting can be addressed in one of two manners. One way is to adjust the investigation level down by 20%. The second way is to reduce the sample mass by 20%. Either approach achieves the same objective: to introduce a conservative mechanism for triggering the investigation level where the presence of water may inhibit counting efficiency. The specific mechanism to be applied will be prescribed in implementing procedures.

The presence of standing water (or ice or snow) on the surface of the soil being assayed will be accounted for in customized efficiency calibrations applied during data analysis activities.

1.2.8 Discrete Particles in the Soil Matrix

Discrete particles are not specifically addressed in the License Termination Plan. However, an evaluation was performed assuming all the activity in the detector's field-of-view, to a depth of 15 cm, was situated in a discrete point-source configuration. A concentration of 1.0 pCi/g (Co-60), corresponding to the investigation level presented in Table 2, correlates to a discrete point-source of approximately 3.2 μCi. This activity value is considered as the discrete particle of concern. Since the presence of any discrete particles will most likely be accompanied by distributed activity, the investigation level may provide an opportunity to detect discrete particles below 3.2 μCi.

Discrete particles exceeding this magnitude would readily be detected during characterization or investigation surveys. The MDCs associated with hand-held field instruments used for scan surveys are capable of detecting very small areas of elevated radioactivity that could be present in the form of discrete point sources. The minimum detectable particle activity for these scanning instruments and methods correspond to a small fraction of the TEDE limit provided in 10CFR20 subpart E. Note that the MDC values presented in Table 2 are significantly lower than those published in Table 5-4 of the License Termination Plan.

When the investigation level in a Class 1 area is observed, subsequent investigation surveys will be performed to include the use of hand-held detectors. The detection sensitivities of instruments used for these surveys have been previously addressed in the LTP. Furthermore, discrete point sources do not contribute to the uniformly distributed activity of the survey unit. It is not expected that such sources at this magnitude would impact a survey unit's ability to satisfy the applicable acceptance criteria.

Noting that Class 2 or Class 3 area survey designs do not employ elevated measurement comparisons, associated investigation levels are based on positive indications of licensed radioactivity above the $DCGL_W$ or above background. Because such areas are minimally impacted or disturbed, potential discrete particles would most likely be situated near the soil surface where detection efficiencies are highest.

1.2.9 Procedures And Guidance Documents

General use of the portable ISOCS system is administrated by departmental implementing procedures that address the calibration and operation activities as well as analysis of the data. These procedures are listed as follows:

- DP-8869, "In-Situ (ISOCS) Gamma Spectrum Assay System Calibration Procedure."
- DP-8871, "Operation Of The Canberra Portable ISOCS Assay System."
- DP-8872, "ISOCS Post Acquisition Processing And Data Review."

Where the portable ISOCS® system is used for Final Status Surveys, the applicable FSS Plan will address detector and collimator configurations, applicable (surrogated) investigation levels, MDC requirements, and appropriate Data Quality Objectives, as applicable.

A secondary application of the portable ISOCS® system is to assay surfaces or bulk materials for characterization or unconditional release evaluations. Use of the portable ISOCS® system for miscellaneous evaluations will be administrated under a specific guidance document (e.g. Sample Plan, etc.). Operating parameters such as physical configuration, efficiency calibrations, count times, and MDCs will be applied so as to meet the criteria in the associated controlling documents. Such documents will also address any unique technical issues associated with the application and may provide guidance beyond that of procedure AP-0052, "Radiation Protection Release of Materials, Equipment and Vehicles."

1.2.10 Environmental Backgrounds

If background subtraction is used, an appropriate background spectrum will be collected and saved. Count times for environmental backgrounds should exceed the count time associated with the assay. In areas where the background radioactivity is particularly problematic (e.g. ISFSI), the background will be characterized to the point of identifying gradient(s) such that background subtractions are either appropriate or conservative. Documentation regarding the collection and application of environmental backgrounds will be provided as a component of the final survey plan.

1.2.11 Quality Control

Quality Control (QC) activities for the ISOCS system ensure that the energy calibration is valid and detector resolution is within specifications. A QC file will be set up for each detector system to track centroid position, FWHM, and activity. Quality Control counts will be performed on a shiftly basis prior to the system's use to verify that the system's energy calibration is valid. The Na-22 has a 1274.5 keV photon which will be the primary mechanism used for performance monitoring. If the energy calibration is found to be out of an acceptable tolerance (e.g. greater than ±4 channels), then the amplifier gain may be adjusted and a follow-up QC count performed. If the detector's resolution is found to be above the factory specification, then an evaluation will be performed to determine if the detector should be removed from service and/or if the data is impacted. Evaluations associated with QC counts shall be documented. Such documentation may be limited to a remark directly on the applicable QC report or in a logbook if the resolution does not render the system out of service. Otherwise the evaluation should be separately documented (e.g. Condition Report, etc.) so as to address the impact of any assay results obtained since the last acceptable QC surveillance.

Where it is determined that background subtraction is necessary, a baseline QC background will be determined specific to that area or region. When background subtraction is required, a QC background surveillance will be performed before a set of measurements are made to verify the applicability of the background to be subtracted. Due to the prevailing variability of the background levels across the site, the nature and extent of such surveillances will be on a case-by-case basis and should be addressed in the documentation associated with the applicable survey plan(s).

In addition to the routine QC counts, each assay report is routinely reviewed with respect to K-40 to provide indications where amplifier drift impacts nuclide identification routines. This review precludes the necessity for specific (i.e. required) after-shift QC surveillances. It also minimizes investigations of previously collected data should the system fail a before-use QC surveillance on the next day of use.

1.2.12 Data Collection

Data collection to support FSS activities will be administered by a specific Survey Plan. Survey Plans may include an index of measurement locations with associated spectrum filenames to ensure that all the required measurements are made and results appropriately managed. Personnel specifically trained to operate the system will perform data collection activities.

Data collection activities will address environmental conditions that may impact soil moisture content. Logs shall be maintained so as to provide a mechanism to annotate such conditions to ensure that efficiency calibration files address the in-situ condition(s). In extreme cases (e.g. standing water, etc.) specific conditions will be addressed to ensure that analysis results reflect the conditions. As previously discussed with respect to water, when unique environmental conditions exist that may impact analysis results, conservative compensatory factors will be applied to the analysis of the data.

1.2.13 Efficiency Calibration

The central feature of the portable ISOCS technology is to support in-situ gamma spectroscopy via the application of mathematically derived efficiency calibrations. Due to the nature of the environment and surfaces being evaluated (assayed), input parameters for the ISOCS efficiency calibrations will be reviewed on a case-by-case basis to ensure the applicability of the resultant efficiency. Material densities applied to efficiency calibrations will be documented. In practice, a single efficiency calibration file may be applied to the majority of the measurements.

The geometry most generally employed will be a circular plane assuming uniformly distributed activity. Efficiency calibrations will address a depth of 15 cm for soil and a depth up to 5 cm for concrete surfaces to account for activity embedded in cracks, etc. Other geometries (e.g. exponential circular plane, rectangular plane, etc.) will be applied if warranted by the physical attributes of the area or surface being evaluated. Efficiency calibrations are developed by radiological engineers who have received training with respect to the ISOCS® software. Efficiency calibrations will be documented in accordance with procedure DP-8869, "In-Situ (ISOCS) Gamma Spectrum Assay System Calibration Procedure."

1.2.14 Data Management

Data management will be implemented in various stages as follows:

- An index or log will be maintained to account for each location where evaluations for elevated activity are performed. Raw spectrum files will be written directly or copied to a central file server.

- Data Analysis – After the spectrum is collected and analyzed, a qualified Radiological Engineer will review the results. The data review process includes application of appropriate background, nuclide libraries, and efficiency calibrations. Data reviews also verify assay results with respect to the applicable investigation levels and the MDCs achieved. Data reviews may include monitoring system performance utilizing K-40. When the data analysis is completed, the analyzed data file will be archived to a unique directory located on a central file server.

- Data Reporting – The results of data files whose reviews have been completed and are deemed to be acceptable may be uploaded to a central database for subsequent reporting and statistical analysis.

- Data Archiving – Routinely (daily) the centralized file server(s) where the raw and analyzed data files are maintained will be backed up to tape.

1.3 Conclusions/Recommendations

The in-situ gamma spectroscopy system is a cost-effective technology well-suited to replace traditional scanning survey techniques to evaluate areas for elevated radioactivity. The static manner in which this system is operated eliminates many variables and limitations inherent to hand-held detectors moving over a surface. This system provides a demonstrably lower detection sensitivity than those offered by hand-held field instruments. This attribute qualifies this system as an alternative technology in lieu of hand-held NaI field instruments in areas where background radiation levels would prohibit the use of such detectors to evaluate for elevated gross activity. The MDC to which this system will be operated satisfies (or exceeds) criteria applied to traditional scan surveys using hand-held field instruments.

Effective investigation levels for both open land areas (i.e. soils) and for building surfaces can be derived and applied to in-situ gamma spectroscopy results. Where surrogate DCGLs are employed, investigation levels will developed on a case-by-case basis using the approach outlined in this document.

The manner in which investigation levels are derived employs several conservative decisions and assumptions. Additionally, adequate spacing applied to scanning survey locations yields an overlap in surface coverage providing 100-percent coverage of Class 1 areas and redundant opportunities in a significant portion of the survey area to detect localized elevated activity.

1.4 <u>References</u>

1. YNPS License Termination Plan, Revision 1
2. Multi-Agency Radiation Survey And Site Investigation Manual (MARSSIM) Revision 1, 2000
3. Canberra User's Manual Model S573 ISOCS Calibration Software, 2002
4. Decommissioning Health Physics - A Handbook for MARSSIM Users, E.W. Abelquist, 2001
5. Canberra's Genie 2000 V3.0 Operations Manual, 2004
6. In-Situ (ISOCS) Gamma Spectrum Assay System Calibration Procedure DP-8869, Revision 0
7. Operation of the Canberra Portable ISOCS Assay System DP-8871 Revision 0
8. Technical Ref., by Thomas J. Glover.

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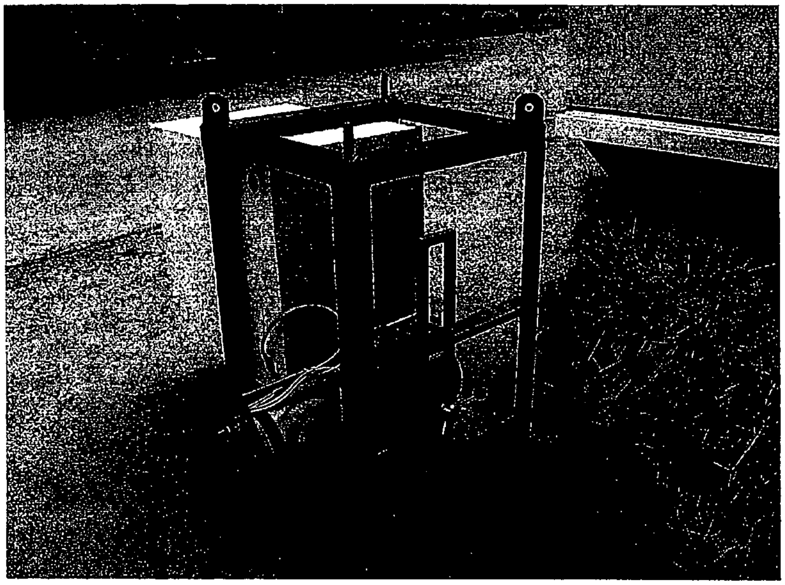
Attachment 1
Portable ISOCS® Detector System Photos



Attachment 2
Field-Of-View Characterization

Generally, the HPGe detector will be outfitted with a 90-degree collimator situated at 2 meters perpendicular to the surface being evaluated. Note that characterizing the detector's field-of-view could be performed without a source by comparing ISOCS-generated efficiencies for various geometries. If a different collimator configuration is to be employed, a similar field-of-view characterization will be performed.

To qualify the field-of-view for this configuration, a series of measurements were made at various off-sets relative to the center of the reference plane. The source used for these measurements was a 1.2 µCi Co-60 point-source with a physical size of approximately 1 cm^3. Each spectrum was analyzed as a point source both with and without background subtract. It was observed that the detector responded quite well to the point source.

Figure 1 presents the results with background subtraction applied. Note that there is a good correlation with the expected nominal activity and that outside the 2-meter radius of the "working" field-of-view (i.e. at 90 inches) some detector response occurs. This validates that the correct attenuation factors are applied to the algorithms used to compute the efficiency calibration.

FIGURE 1

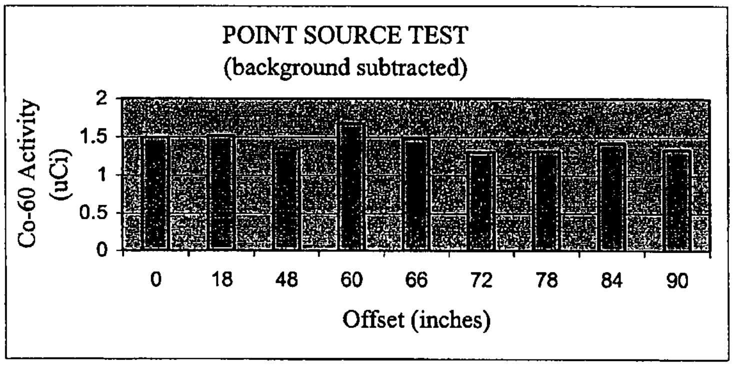
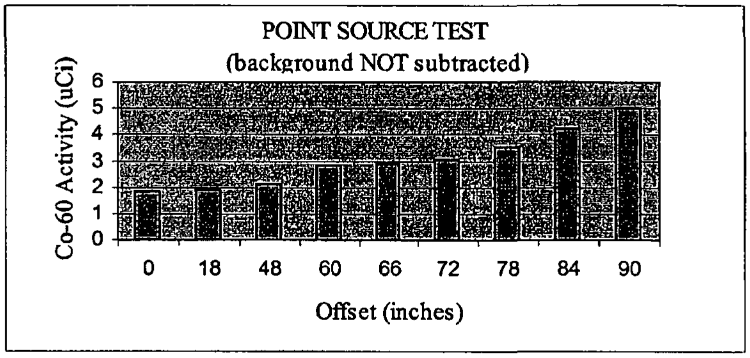
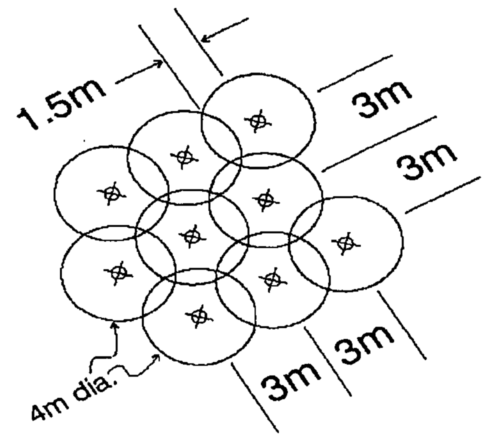


Figure 2 shows the effect of plant-derived materials present in the reference background, which indicates an increasing over-response the further the point source is moved off center. Detector response outside the assumed (i.e. 2-meter) field-of-view would yield conservative results. Normally, source term adjacent to the survey units should be reduced to eliminate background interference.

FIGURE 2


POINT SOURCE TEST
(background NOT subtracted)
Co-60 Activity (uCi)
6
5
4
3
2
1
0
0
18
48
60
66
72
78
84
90
Offset (inches)

Attachment 3
Typical Grid Pattern For In-Situ Gamma Spectroscopy



Typical Scan Grid Pattern
(For 2m scan height using 90° collimator.)

=Scan Point Location   =Scan Area Footprint (4m dia. for 2m scan height)

Attachment A – Maps and Posting Plots

List of Figures

Figure 1 SVC-01 Relative to Structures

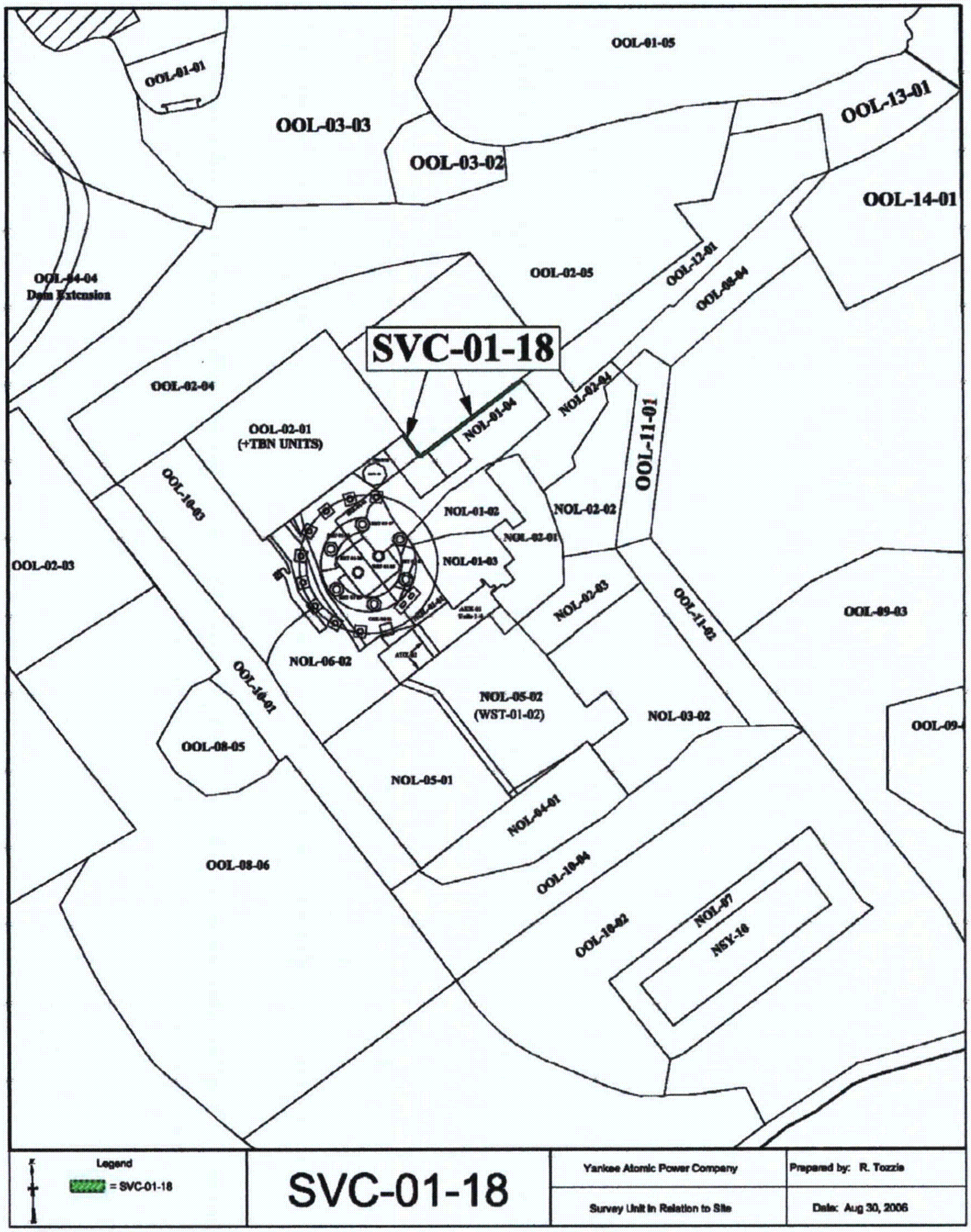
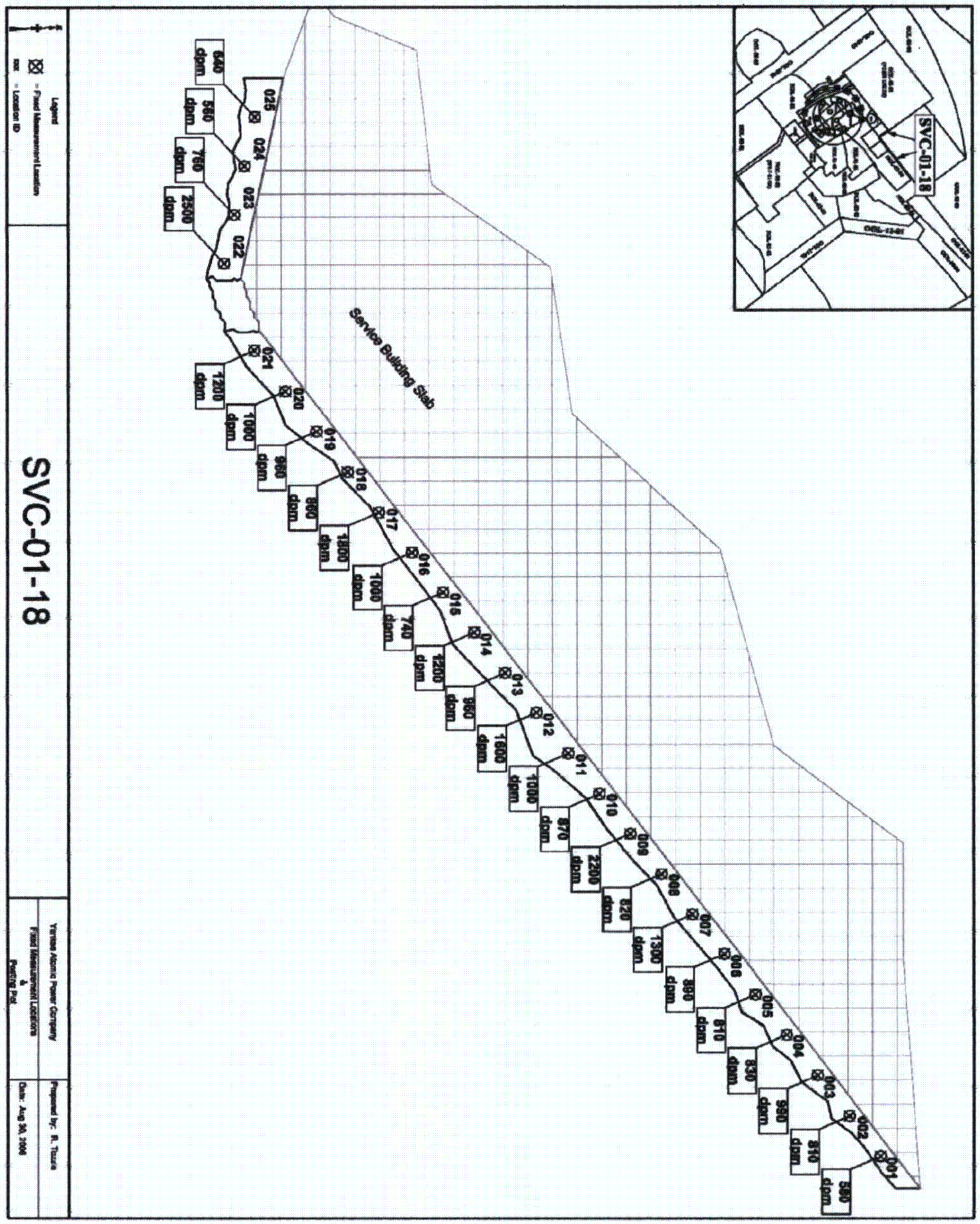


Figure 2 SVC-01-18 Survey Unit



Attachment B

Data Quality Assessment Plots and Curves

List of Figures

Figure Page

The LBGR on the Power Curves have been adjusted to demonstrate the actual power of the survey.

Figure 1 SVC-01-18 Prospective Power Curve

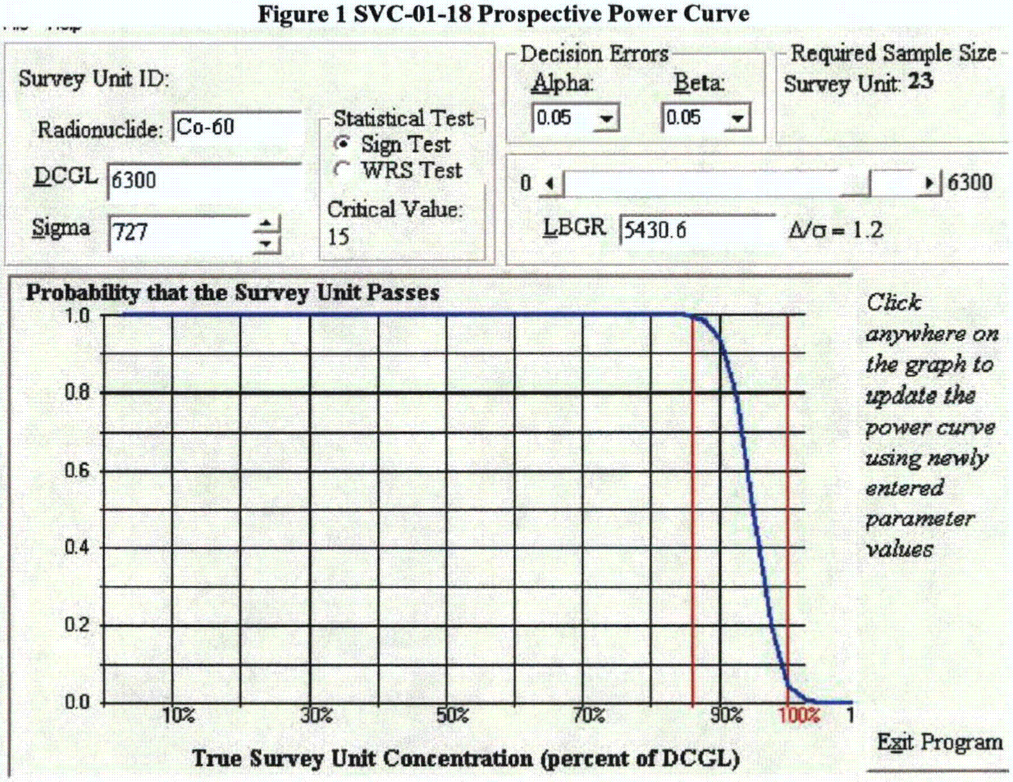


Figure 2 SVC-01-18 Retrospective Power Curve

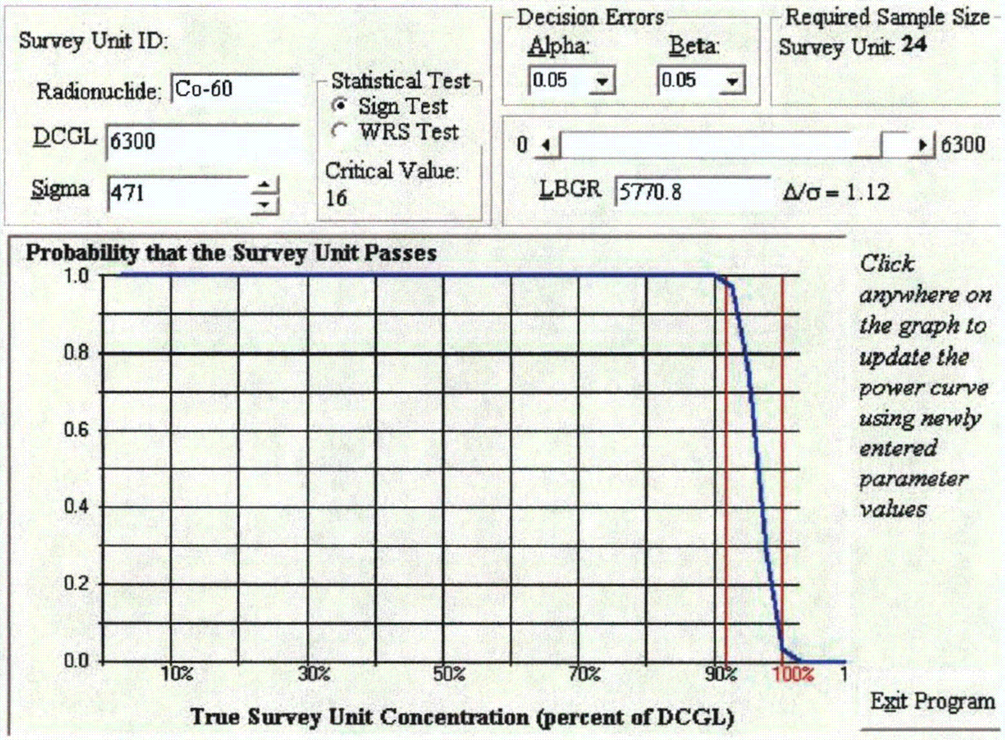


Figure 3 SVC-01-18 Total Activity Scatter Plot

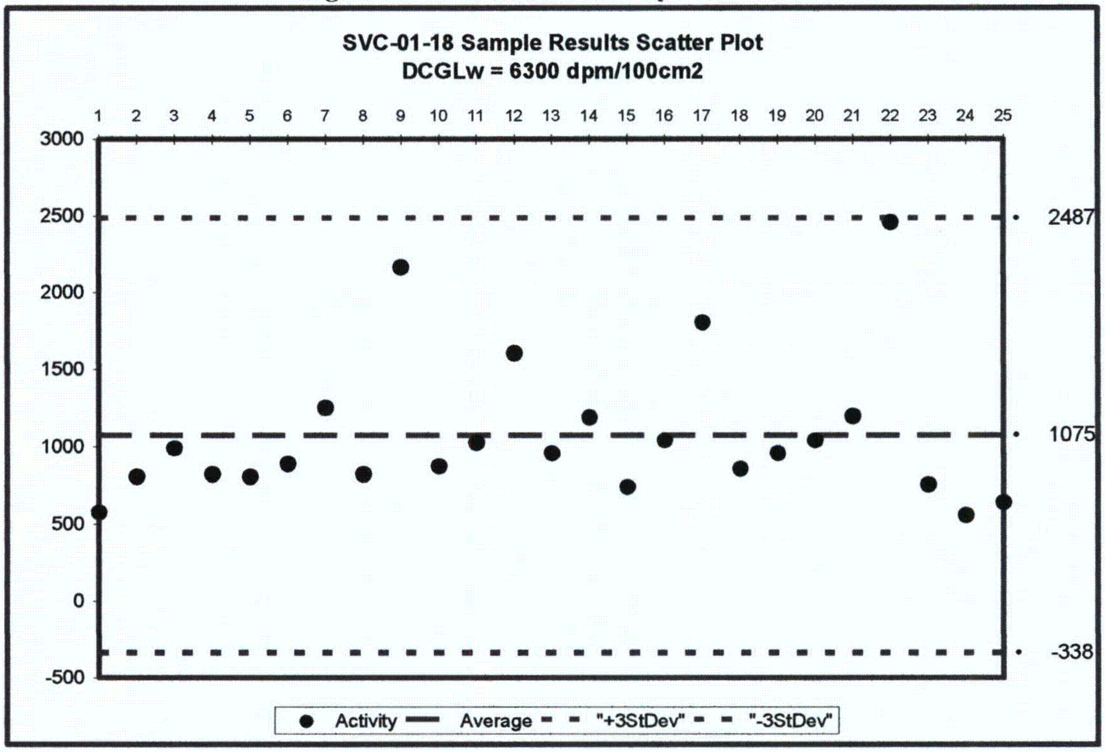


Figure 4 SVC-01-18 Total Activity Quantile Plot

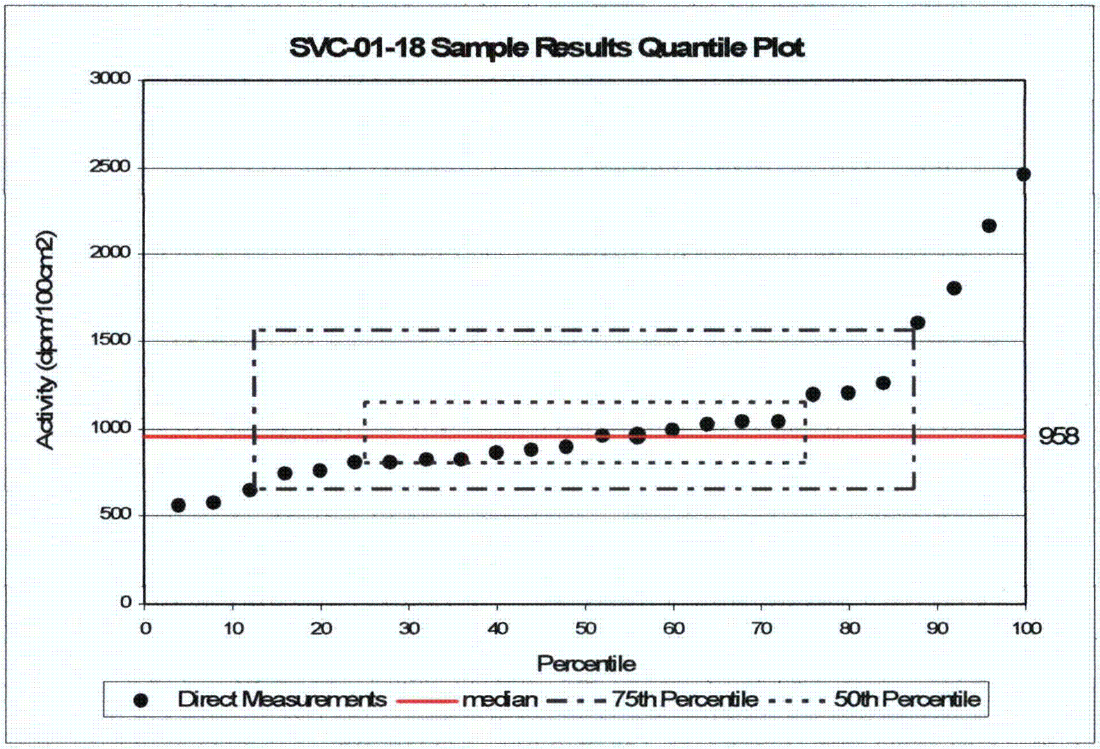
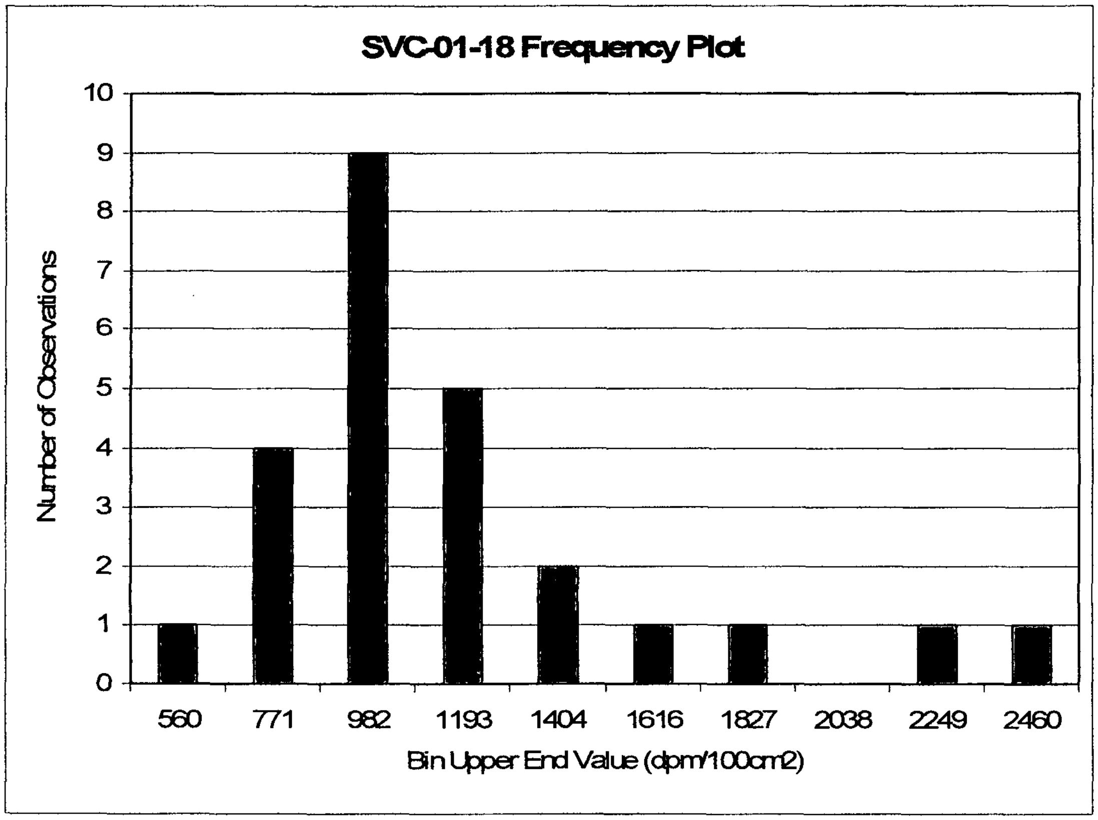


Figure 5 SVC-01-18 Total Activity Frequency Plot



Daily Survey Journal

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Survey Area No.: SVC-01	Survey Area Name:	Survey Date: 11-30-05
Survey Unit No. and Name: SVC-01-18		12-01-05

Specific instructions for using the Daily Survey Journal.

1 The Daily Survey Journal provides the means to record those items required by the FSSP Worksheet as well as any deviations or anomalies that should be brought to the attention of the cognizant FSS Radiological Engineer or the FSS Project Manager.

2 All documentation will be complete and legible.

TIME	NOTES FOR SURVEY DATE
0700	Pre Job brief for FSSP SVC-01-~~0~~18 see APF 0626.2
	Survey Team members R. Shippee T. Mayer C. Crosier
1400	Collected ambient background measurements IAW,
	Step 3 Gen. Instructions + OP 8866 using See Attached Form.
	E-600 # 5156 Cal Due 2-22-06 +
	HP-100C # 51597 Cal Due 2-~~22~~ 28-06 eff .135
	Pre Ops Source check "SAT"
1450	Collected 25 Fixed Point Measurements IAW
	step 4 + OP 8534. All FPMs are < the investigation
	action level. For instrument data see Bkgd measurements
late entry 0800	established the random start grid locations for
	FPM IAW. step 2 of the plan. A total of 25 FPM.
	locations were marked on the concrete surface.
12-01-05	
0800	Post Ops Source check of instruments "SAT"

Completed by *Ronald J. Shippee* Date 12-01-05
FSS Field Supervisor

Reviewed by *J. Buxton* Date 12-14-05
FSS Radiological Engineer

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Form 2
FSS Fixed-Point Measurements

11-30-05
1450

Tammy Moyers
Charles Crosier
Ron Shippee

Survey Unit SVC01-18
Instrument No.: E600 #5156 / 2-22-06 cdd
100c #51597 / .135 eff / 2-~~22~~ 28-06 cdd

Location	Measurement (cpm/100cm²)	
SVC-01-18-001-F-FM	255	
SVC-01-18-002-F-FM	269	
SVC-01-18-003-F-FM	280	
SVC-01-18-004-F-FM	270	
SVC-01-18-005-F-FM	269	
SVC-01-18-006-F-FM	274	
SVC-01-18-007-F-FM	267	
SVC-01-18-008-F-FM	251	
SVC-01-18-009-F-FM	301	
SVC-01-18-010-F-FM	273	
SVC-01-18-011-F-FM	282	
SVC-01-18-012-F-FM	317	
SVC-01-18-013-F-FM	278	
SVC-01-18-014-F-FM	292	
SVC-01-18-015-F-FM	265	
SVC-01-18-016-F-FM	283	
SVC-01-18-017-F-FM	329	
SVC-01-18-018-F-FM	272	
SVC-01-18-019-F-FM	278	
SVC-01-18-020-F-FM	283	
SVC-01-18-021-F-FM	265	*
SVC-01-18-022-F-FM	312	*
SVC-01-18-023-F-FM	266	
SVC-01-18-024-F-FM	254	
SVC-01-18-025-F-FM	259	

CONTROL POINT

PORTABLE INSTRUMENT ACCOUNTABILITY FORM

Instrument Type & YAEC or DE&S #	Batt ✓	Cal Due ✓	Src ✓ Out	Location and/or Reason For Use	Date and Time Out	Tech Name	Date and Time In	Srce ✓ In
E-600 #01643 SPA-3 #51844	✓	✓	✓	———	———	———	———	*
E-600 # 02491 SPA-3 # 2056	✓	✓	✓	———	———	———	———	*
E-600 # 02488 SPA-3 # 51034	✓	✓	✓	———	———	———	———	*
E-600 #02490 SHP-100 # 51598	✓	✓	✓	Alley Way	11-30-05 0825	Moyers	11-30-05 2200	✓
E-600 # 5156 SHP100 # 51597	✓	✓	✓	Alley Way	11-30-05 0826	Moyers	12-1-05 0600	✓

RP Supervisor Review [signature] (1)

(1) If any post-use source check failures occur, ensure that the condition is documented by a Condition Report.

* Not Used.

PORTABLE/GAMMA [illegible] SOURCE CHECK FORM

E-600	HP100C	51597	E-21	18236	~~23754~~ 27354 DN 11-30-05
Meter Type	Detector Type	Detector Number	Source ID	Net Acceptance Criteria - 20%	Net Acceptance Criteria + 20%

PRE USE CHECKS								POST USE CHECKS							
Date	Time	Audible Check	Alarm Check	BKG Counts	SRC Counts	Net Counts	Int	Date	Time	Audible Check	Alarm Check	BKG Counts	SRC Counts	Net Counts	Int
11-30-05	0824	SAT	N/A	208	22800	22592	WD	12-1-05	0730	SAT	N/A	155	22200	22045	DN
12-1-05	0730	SAT	N/A	155	22200	22045	DN	12-1-05	1240	SAT	N/A	143	21800	21657	DN
12-1-05	1240	SAT	N/A	143	21800	21657	DN	12-1-05	1420	SAT	N/A	165	19670	19505	DN
12-2-05	1000	SAT	N/A	247	22400	22153	DN	12-5-05	0630	SAT	N/A	216	23200	22984	WB
12-5-05	0630	SAT	N/A	216	23200	22984	WB								**
12-6-05	0605	SAT	N/A	281	23400	23119	DN	12-6-05	~~1315~~ 1515	SAT	N/A	181	22300	22119	DN
* 12-6-05	0945	SAT	N/A	118	19690	19572	DN	* 12-6-05	1330	SAT	N/A	197	21400	21203	VB
* 12-6-05	1330	SAT	N/A	197	21400	21203	VB	* 12-6-05	1445	SAT	N/A	134	21000	20866	DN
12-7-05	0615	SAT	N/A	234	23100	22866	DN								**
*** 12-7-05	1415	SAT	N/A	146	26800	26654	DN	*** 12-7-05	1700	SAT	N/A	152	19630	19478	DN
12-8-05	0700	SAT	N/A	225	22600	22375	DN								**

RP Supervisor Review: [signature] (1)

(1) If any post-use source check failures occur, ensure that the condition is documented by a Condition Report.

* Source check "SAT" 28° F per SAS.
** Not Used.
*** Source check "SAT" 17°F per SAS.

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Daily Survey Journal

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Survey Area No.: SVC-01	Survey Area Name:	Survey Date: 12-1-05
Survey Unit No. and Name: SVC-01-18		

Specific instructions for using the Daily Survey Journal.

1. The Daily Survey Journal provides the means to record those items required by the FSSP Worksheet as well as any deviations or anomalies that should be brought to the attention of the cognizant FSS Radiological Engineer or the FSS Project Manager.
2. All documentation will be complete and legible.

TIME	NOTES FOR SURVEY DATE
0630	Pre Job brief for FSSP SVC-01-18-00
	See APF 0626.2 Concrete scan survey
	Survey Team
	RShippee Sup. T. Moyers, C Crosier
	Performed concrete scan surveys @ the following inst
	instruments:
	E-600 02490 — Cal Due: 2-15-06
	HP-100-C 51598 — 2-8-06 Eff 0.146
	E-600 5156 — 2-22-06
	HP-100-C 51597 — 2-28-06 Eff 0.135
	E-600 02488 — 3-15-06
	SPA-3 61034 — 12-22-~~06~~ 05 Eff 233 cpm/pci/g
	E-600 01645 — 3-30-06
	SPA-3 51846 — 12-02-05 Eff 271 cpm/pci/g
1240	Commenced scan survey @ E-600/HP-100C @ ½" distance
	scan speed 2"/sec. Irregular concrete surface also scanned
	@ E-600/SPA-3 @ 3" distance, scan speed .25 m/sec.
1600	All scansurveys complete No Scan Indication Identified
	Post Ops source check "SAT"

Completed by Ronald Shippee (signature) FSS Field Supervisor Date 12-1-05

Reviewed by J. Brisan (signature) FSS Radiological Engineer Date 12-14-05

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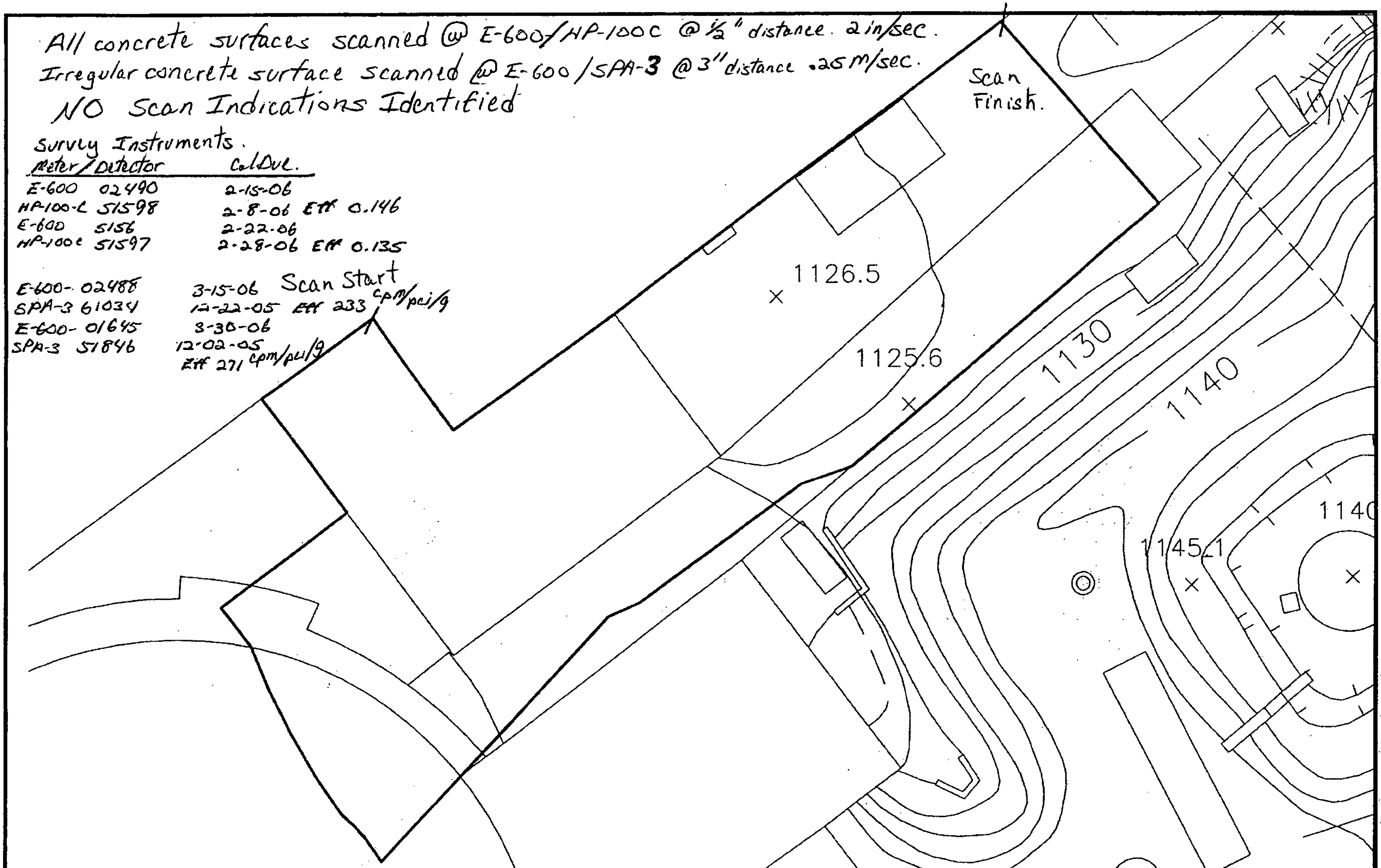

Legend ~ = Survey Unit Boundary DPF-8865.1	Map current as of November 14, 2005	SVC-01-18 12-01-05 Scan Survey 1240 RShippee TMoyers C Crosier	Yankee Atomic Power Company	Reviewed by: Date:

CONTROL POINT

PORTABLE INSTRUMENT ACCOUNTABILITY FORM

Instrument Type & YAEC or DE&S #	Batt ✓	Cal Due ✓	Src ✓ Out	Location and/or Reason For Use	Date and Time Out	Tech Name	Date and Time In	Srce ✓ In
E600# 02491 SPA-3# 2056	✓	✓	✓	WST	12-1-05 0700	Reid	12-1-05 1615	✓
E-600# 01645 SPA-3# 51646	✓	✓	✓	FSS	12-1-05 0640	Moyers	12-1-05 1410	✓
E600# 02488 SPA-3# 61034	✓	✓	✓	FSS	12-1-05 0640	Moyers	12-1-05 1415	✓
E600# 02490 HP100C# 51598	✓	✓	✓	FSS	12-1-05 0730	Moyers	12-1-05 1215	✓
E600# 5156 HP100C# 51597	✓	✓	✓	FSS	12-1-05 0730	Moyers	12-1-05 1620	✓
E600# 01606 SPA-3# 70051	✓	✓	✓	~~FSS~~ 12-01-05 MAXY	12-1-05 1100	Spruniski	12-1-05 1400	✓
E600# 02490 HP100C# 51598	✓	✓	✓	FSS	12-1-05 1215	Moyers	12-1-05 1615	✓
E600# 5156 HP100C# 51597	✓	✓	✓	FSS	12-1-05 1215	Moyers	12-1-05 1620	✓
E600# 01606 SPA-3# 70051	✓	✓	✓	—	—	—	—	*

RP Supervisor Review ______________________ (1)

(1) If any post-use source check failures occur, ensure that the condition is documented by a Condition Report.

* Not Issued.

DPF-8504.1
Rev. 17

PORTABLE/GAMMA [illegible] SOURCE CHECK FORM

E-600	HP100C	51597	E-21	18236	~~23754~~ 27354 DN 11-30-05
Meter Type	Detector Type	Detector Number	Source ID	Net Acceptance Criteria - 20%	Net Acceptance Criteria + 20%

	PRE USE CHECKS								POST USE CHECKS							
	Date	Time	Audible Check	Alarm Check	BKG Counts	SRC Counts	Net Counts	Int	Date	Time	Audible Check	Alarm Check	BKG Counts	SRC Counts	Net Counts	Int
	11-30-05	0824	SAT	N/A	208	22800	22592	WD	12-1-05	0730	SAT	N/A	155	22200	22045	DN
	12-1-05	0730	SAT	N/A	155	22200	22045	DN	12-1-05	1240	SAT	N/A	143	21800	21657	DN
	12-1-05	1240	SAT	N/A	143	21800	21657	DN	12-1-05	1420	SAT	N/A	165	19670	19505	DN
	12-2-05	1000	SAT	N/A	247	22400	22153	DN	12-5-05	0530	SAT	N/A	216	23200	22984	WD
	12-5-05	0530	SAT	N/A	216	23200	22984	WD								**
	12-6-05	0605	SAT	N/A	281	23400	23119	DN	12-6-05	~~1315~~ 1515 DN 12-6-05	SAT	N/A	181	22300	22119	DN
*	12-6-05	0945	SAT	N/A	118	19690	19572	DN	* 12-6-05	1330	SAT	N/A	197	21400	21203	VB
*	12-6-05	1330	SAT	N/A	197	21400	21203	VB	* 12-6-05	1445	SAT	N/A	134	21000	20866	DN
	12-7-05	0615	SAT	N/A	234	23100	22866	DN								**
***	12-7-05	1415	SAT	N/A	146	26800	26654	DN	* 12-7-05	1700	SAT	N/A	152	19630	19478	DN
	12-8-05	0700	SAT	N/A	225	22600	22375	DN								**

N/A

RP Supervisor Review: [signature] (1)

(1) If any post-use source check failures occur, ensure that the condition is documented by a Condition Report.

*Source check "SAT" 28° F per SAS.

**Not Used.

***Source check "SAT" 17°F per SAS.

DPF-8504.5
Rev. 17

00010

PORTABLE/GAMMA [illegible] SOURCE CHECK FORM

E-600	HP100C	51598	E-21	19392	29088
Meter Type	Detector Type	Detector Number	Source ID	Net Acceptance Criteria - 20%	Net Acceptance Criteria + 20%

PRE USE CHECKS								POST USE CHECKS							
Date	Time	Audible Check	Alarm Check	BKG Counts	SRC Counts	Net Counts	Int	Date	Time	Audible Check	Alarm Check	BKG Counts	SRC Counts	Net Counts	Int
11-7-05	1000	SAT	N/A	271	23800	23529	DN	11-7-05	1235	SAT	N/A	182	21000	20818	DN
11-8-05	0715	SAT	N/A	276	23900	23624	DN	11-8-05	1535	SAT	N/A	229	20600	20371	DN
11-28-05	0850	SAT	N/A	205	22900	22695	DN								**
11-30-05	0817	SAT	N/A	200	23400	23200	WS	12-1-05	0700	SAT	N/A	158	22500	22342	DN
12-1-05	0700	SAT	N/A	158	22500	22342	DN	12-1-05	1215	SAT	N/A	200	22200	22000	DN
12-1-05	1215	SAT	N/A	200	22200	22000	DN	12-1-05	1415	SAT	N/A	152	21700	21548	DN
12-2-05	1000	SAT	N/A	250	23600	23350	DN	12-3-05	1024	SAT	N/A	201	23700	23499	WS
12-3-05	1024	SAT	N/A	201	23700	23499	VS	12-5-05	0812	SAT	N/A	199	23600	23401	WS
12-5-05	0812	SAT	N/A	199	23600	23401	WS								**
12-6-05	0610	SAT	N/A	225	23700	23475	DN	12-6-05	1515	SAT	N/A	210	23300	23090	DN
* 12-6-05	0940	SAT	N/A	101	20000	19899	DN	* 12-6-05	1330	SAT	N/A	196	23400	23204	VB
* 12-6-05	1330	SAT	N/A	196	23400	23204	VB	* 12-6-05	1445	SAT	N/A	108	23400	23292	DN
12-7-05	0615	SAT	N/A	215	23400	23185	DN	12-8-05	0600	SAT	N/A	200	23200	23000	DN
12-8-05	0600	SAT	N/A	200	23200	23000	DN								**
~~12-8~~					~~22600~~		~~DN~~								

DN 12.13.05 DN 12.13.05 DN 12.13.05

RP Supervisor Review: [signature] (1)

(1) If any post-use source check failures occur, ensure that the condition is documented by a Condition Report.

*Source CK "SAT" 28° F per SAS.

** Not Used.

DPF-8504.5
Rev. 17

00014

PORTABLE/GAMMA [illegible] SOURCE CHECK FORM

E-600	SPA-3	51846	277	237662	356492
Meter Type	Detector Type	Detector Number	Source ID	Net Acceptance Criteria - 20%	Net Acceptance Criteria + 20%

PRE USE CHECKS								POST USE CHECKS							
Date	Time	Audible Check	Alarm Check	BKG Counts	SRC Counts	Net Counts	Int	Date	Time	Audible Check	Alarm Check	BKG Counts	SRC Counts	Net Counts	Int
11-21-05	0610	SAT	N/A	6570	295000	288430	DN	11-21-05	1030	SAT	N/A	6830	295000	288170	DN
11-22-05	0605	SAT	N/A	6770	294000	287230	DN	11-23-05	0605	SAT	N/A	6260	296000	289740	DN
11-29-05	0610	SAT	N/A	6620	277000	270380	DN	11-30-05	0730	SAT	N/A	5820	294000	288180	DN
12-1-05	0605	SAT	N/A	5970	276000	270030	DN	12-1-05	1610	SAT	N/A	6880	295000	288120	DN

N/A

RP Supervisor Review: [signature] [1]

[1] If any post-use source check failures occur, ensure that the condition is documented by a Condition Report.