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August 7, 2003

Mr. John T. Buckley
U.S. Nuclear Regulatory Commission
Low-Level Waste & Decommissioning Projects Branch
Division of Waste Management
Office of Nuclear Material Safety & Safeguards
11545 Rockville Pike
Rockville, Maryland 20852

Re: Docket No. 04006563; License No. STB-401
Final Status Survey Report (FSSR) for Survey Unit 235 Roof

Enclosure: (1) FSSR Survey Unit 235 Roof

Dear Mr. Buckley:

Enclosed is Mallinckrodt Inc.'s FSSR for Survey Unit 235: Building 235, roof.

Due to some leakage and safety concerns of leakage getting worse, we really need to maintain and replace our roof and therefore, we have decided that we need to have this area released similar to Building 250 Locker Rooms. We need to perform this work before we get into winter weather and October 15 to November 1 approval would work perfect with our schedule.

Please contact me at 314-654-1344 if you have any questions

Sincerely yours,

Mark Puett

Mark Puett
Project Director
Mallinckrodt CT Project

NMSS01

Final Status Survey Report
Building 235 Roof

Survey Units 235R, 235R1, 235R2,
235R3,
235R4, & 235R5

PREPARED BY

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C-T PROJECT – PHASE I

FINAL STATUS SURVEY REPORT

Building 235 Roof

Survey Units 235R, 235R1, 235R2, 235R3, 235R4, & 235R5

Revision 0

Prepared by

BMNX
Joint Venture

Approved by: _____ Date: 7/31/03
Survey Designer

Approved by: Mark Puett Date: 8/5/03
Mallinckrodt C-T Decommissioning Project Manager

Approved by: Jim C. Woodford Date: 8-1-03
Mallinckrodt Radiation Safety Officer

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BMNX Environment, Safety and Health Representative

Issued by: Brian K. Carson Date: 8/5/03
BMNX Quality Assurance Manager

MALLINCKRODT, Inc.

C-T PROJECT – PHASE I

FINAL STATUS SURVEY REPORT

Building 235 Roof

Executive Summary

A final status survey (FSS) was performed on the roof of building 235 in accordance with requirements within the Mallinckrodt C-T Decommissioning Plan (D Plan). FSS data and detailed analyses are presented within the attached document. Initial surveys performed in March, 2003 indicated contamination between the upper asphalt layer and roof decking surface which exceeded the surface release criteria established in the D Plan. Mallinckrodt made the decision to remediate the entire western section of roof on building 235 rather than to remove only those sections which were above the release criteria. FSS performed during and subsequent to remediation operations demonstrate compliance with all release criteria, at levels which are similar to background in the remediated areas. The survey unit meets all criteria for release.

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C-T PROJECT – PHASE I

FINAL STATUS SURVEY REPORT

Table of Contents

1. INTRODUCTION 4
1.1. PURPOSE 4
1.2. HISTORICAL BACKGROUND 4
2. SCOPE OF FINAL STATUS SURVEY (FSS) 5
2.1. DEFINITION AND CLASSIFICATION OF SURVEY UNITS (SU) 5
2.2. IDENTIFICATION OF THE RADIOLOGICAL CONTAMINANTS 6
2.3. REFERENCE BACKGROUND LEVELS 6
2.4. RELEASE CRITERIA 7
2.5. SURVEY INSTRUMENTS 8
2.6. LOWER LIMITS OF DETECTION (LLD) AND DETECTION THRESHOLDS 9
2.7. INSTRUMENT SENSITIVITY, BACKSCATTER AND PAINT ATTENUATION 11
3. SURVEY METHODS 12
3.1. SURVEY PROCEDURES 12
3.2. SURVEY MEASUREMENTS 13
3.3. MEASUREMENT LOCATIONS 14
3.4. REFERENCE COORDINATE SYSTEM 15
3.5. DATA EVALUATION 16
4. FSS RESULTS AND DISCUSSION 21
4.1. CHARACTERIZATION DATA 21
4.2. CLASS 1 SURVEY UNITS 21
4.3. CLASS 2 SURVEY UNIT 25
5. CONCLUSIONS 27
6. RECOMMENDATIONS 28
APPENDIX 1 BUILDING SURVEY UNIT LISTING BUILDING 235 ROOF 29
APPENDIX 2 FIGURES 36
APPENDIX 3 CALIBRATION SHEETS 44
APPENDIX 4 TECHNICAL MEMORANDUM 02-30 57
APPENDIX 5 THRESHOLD COMPARISON TEST REPORTS (TCTR) 69

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C-T PROJECT – PHASE I

FINAL STATUS SURVEY REPORT

Building 235 Roof

Survey Units 235R, 235R1, 235R2, 235R3, 235R4, & 235R5

Revision 0

1. INTRODUCTION

1.1. PURPOSE

1.1.1. This Final Status Survey Report (FSSR) is being submitted by Mallinckrodt, Inc. to the U.S. Nuclear Regulatory Commission (NRC) for the roof of Building 235 on the Mallinckrodt St. Louis site (designated as Survey Units (SU) 235R and 235R1-235R5). This report is being provided in accordance with the Mallinckrodt C-T Project, Phase I Decommissioning Plan. This FSS was performed in accordance with the Field Instruction CT-FI-001 (FI)[1] to demonstrate that the established guidelines for unrestricted release have been met. The results of the FSS are presented in this FSSR as justification for release of this SU from License STB-401 for unrestricted use.

1.2. HISTORICAL BACKGROUND

1.2.1. From 1942 to 1961 Mallinckrodt was involved in radiological activities outside of the scope of this report which terminated in 1977. Mallinkrodt's facilities have either been released from the applicable license or are being remediated by the US

1 CT-FI-001, *Final Status Survey Guide for Survey Unit 235R: Building 235 Roof.*

Army Corps of Engineers in the affected areas. License STB-401 was issued to Mallinckrodt in 1961 by the Atomic Energy Commission (AEC) (later the Nuclear Regulatory Commission (NRC)) to allow extraction of columbium and tantalum (C-T) from natural ores and tin slag, since the ores and byproducts of processing contain uranium and thorium isotopes. Mallinckrodt has not performed C-T extraction since 1987. On July 12, 1993, NRC amended License STB-401 to possession-only for D&D and license termination.

1.2.2. Initial surveys during the month of May, 2003 revealed elevated levels of contamination on the western half of the roof of building 235. Surveys were discontinued and the roofing material in the affected areas was removed. During removal operations the exposed concrete and steel roof deck materials were surveyed.

2. SCOPE OF FINAL STATUS SURVEY (FSS)

2.1. DEFINITION AND CLASSIFICATION OF SURVEY UNITS (SU)

2.1.1. The roof of building 235 has been divided into six survey units (SU). SU-235R1 through SU-235R5 consist of the areas that were remediated due to elevated levels of radioactivity discovered early in the FSS process. All the roofing material in these areas was removed for disposal and, during the remediation process, beta surveys were performed on the concrete and steel deck material beneath. These survey units were classified as Class 1.

2.1.2. SU-235R consists of the remaining portion of the roof that was not remediated. It was classified as Class 2.

2.1.3. A summary report listing all the surfaces and fixed apparatus assigned to SU-235R and 235R1 through 235R5 is presented in Appendix 1. A drawing of the survey units showing the location of key fixed apparatus items is presented in Appendix 2, Figure 1.1.

2.1.4. These survey units cover the entire roof of Building 235 and all affected fixed equipment on the roof.

2.1.5. Table 2.1 below contains the descriptions provided in Appendix A of the D Plan for the areas referenced by this FSSR. Although Appendix A of the D Plan classified both areas as Class 2, subsequent survey measurements directed reclassification of areas toward the western end of the roof. These areas are now classified as Class 1.

Table 2.12
Survey Area Descriptions

Area	Surface	Location / Surface
82	Roof	Roof Piping and Equipment: several new roof penetrations since CT operations. New piping and conduit installed across roof on supports with sleepers for hydrogenation room expansion.
83	Roof	Roof

2.2. IDENTIFICATION OF THE RADIOLOGICAL CONTAMINANTS

2.2.1. Based upon the knowledge of the C-T extraction process and C-T project operations, the radionuclides on the St. Louis site under license STB-401 are the uranium and thorium series. Both series are assumed to be in radioactive equilibrium and to exist in a uranium-to-thorium ratio of two to one.3

2.3. REFERENCE BACKGROUND LEVELS

2.3.1. When the initial characterization (CH) surveys were performed from 1992 through 1996, beta backgrounds were determined for several matrix materials. Where additional background measurements were required for the FSS, they were taken on unaffected surfaces nearby or offsite. All background levels were determined by taking direct readings on the specified matrix on unaffected surfaces using the same methods and type equipment as were used for the FSS. Natural background levels for the contaminants of interest in the survey units are presented in Table 2.2.

Table 2.2
Background Reference Data

Matrix	Mean ($Dpm_\beta/100cm^2$)4	Standard Deviation ($Dpm_\beta/100cm^2$)
Asphalt	74	49
Concrete	36	19

2.3.2. Gamma background. NaI gamma background was collected on Building 25 Roof.5 The average and standard deviations were 4,079 cpm and 196 cpm respectively. These values were used for both direct and scan gamma surveys.

2 Appendix A of D Plan

3 Mallinckrodt C-T Project D Plan Appendix D

4 $Dpm_\beta/100\ cm^2$ refers to the disintegrations per minute per 100 cm^2 for the combined nuclide series.

5 See Appendix A of NEXTEP Tech Memo 0230, *Technical Basis Document for Mallinckrodt Final Status Survey*. A.H. Thatcher, CHP.

2.4. RELEASE CRITERIA

2.4.1. Table 2.3 displays the Derived Concentration Guideline (DCGLw) for measurements on building surfaces and fixed equipment. This value is the primary release criterion from the D Plan and is applied net of background to building surfaces such as roofs. It also applies to items of installed apparatus such as drains, HVAC units, and piping.

2.4.2. To limit the dose from residual materials as much as possible an Administrative Release Guideline (ARG)6 was developed and was used during the FSS as if it were the DCGLw with certain exceptions.7

2.4.3. In SU-235R, since gamma values recorded in the field exceeded the ARG, the release criterion used was the DCGLw although the ARG was still used for the investigation threshold.

Table 2.3
Building Surface and Installed Apparatus Release Criteria

Criterion	($Dpm_p/100\ cm^2$)
DCGLw	13,000
ARG	2,600

2.4.4. Elevated Measurements Criterion (EMC).

2.4.4.1. The magnitude by which the concentration of radioactivity within a small area can exceed the DCGLw while maintaining compliance with the release criterion is defined as the area factor. It is calculated as the ratio of two composite dose factors and is presented graphically in Appendix C to the D Plan as a function of area. The area curve has been reduced to a calculation in the CT Design Guide8. Using the derived equation from the Design Guide a localized release limit for elevated concentrations was defined as:

Equation 1

$$DCGL_{EMC} = 23.4 * DCGLw * A_0^{-0.6721}$$

Where A_0 is the area, in square meters containing the elevated level of radioactivity.

2.4.4.2. The smaller the area of contamination the higher the permissible value for $DCGL_{EMC}$ up to a maximum of 10 times9 the DCGLw.

6 NEXTEP Tech Memo 0211, *Recommendation for an Administrative Release Guideline for the Mallinckrodt C-T Project,* A.H. Thatcher, CHP.
7 Final Status Survey Design Guide (Phase I), Section 3.2, covers the rules governing use of the ARG.
8 Final Status Survey Plan Design Guide (Phase I), Section 5.4.
9 D Plan, Appendix C.

2.4.4.3. The area factor was also applied to the ARG to produce an administrative release guideline, ARG_{EMC}, for elevated concentrations above the ARG. in the same manner. Equation 1 was used substituting ARG for DCGLw.

2.4.4.4. For Class 1 survey units, an "a priori $DCGL_{EMC}$" was specified based upon the area of the largest circle that could be drawn within the grid of direct measurements without including a direct measurement. This limit (or it's corresponding ARG_{EMC}) was used for determining the ability of scan instruments to detect elevated areas of contamination which were not picked up by the grid measurements.10

2.5. SURVEY INSTRUMENTS

2.5.1. The instrumentation utilized to generate FSS data was maintained, calibrated, and tested according to the requirements of the D Plan. All procedures, responsibilities, and schedules for calibrating and testing equipment have been documented.

2.5.2. Maintenance information and use limitations provided in the vendor documentation of the instruments used during this FSS were adhered to. Measuring and analyzing equipment were tested and calibrated before initial use and were recalibrated periodically and whenever previous calibrations were invalidated. Field and laboratory equipment specifically used for obtaining final radiological survey data were calibrated based on standards traceable to NIST. Minimum frequencies for calibrating equipment have been established and documented.

2.5.3. Measuring equipment were tested at least once on each day the equipment was used for FSS. Test results were recorded in tabular or graphic form and compared to predetermined, acceptable performance ranges. Equipment not conforming to the performance criteria was promptly removed from service and any data gathered in the interim evaluated for quality until the deficiencies were resolved.

2.5.4. All calibration and source check records were completed, reviewed, signed-off and retained in accordance with the Mallinckrodt Quality Assurance Program. The original Calibration Sheets for the instruments used in this FSS are provided in Appendix 3 along with a calibration summary report from the C-T Radiation Database showing the normalized sensitivity (AB-100 only) calculated for each instrument at each calibration cycle.

2.5.5. L2221/AB-100 – The primary instrument used for the detection of surface radioactivity was the AB-100 scintillation detector configured for beta detection. The AB-100 detector houses a ZnS/BC-408 organic scintillator and is paired with the Ludlum 2221 scaler/ratemeter for fixed and scan surveys. The window of the AB-100 was modified to increase the thickness of the mylar to 7-9 mg/cm^2 for the

10 Final Status Survey Plan Design Guide (Phase I), Section 5.4.

purpose of alpha attenuation11. The detector window was unshielded (open) for a time period during counting at each sample location, and shielded (closed) for the same time period at the same location12. The difference in the two readings is attributable to beta emissions above 80 KeV in energy.13 The sensitivity of the AB-100 was derived from experiments by Lucas and Colyott which were reported in Attachment 3 to the D Plan.14 The actual instruments used were calibrated and normalized to the reference instrument tested by Lucas and Colyott as prescribed in CT-QA-6.115 .

2.5.6. L2241-2/AB-100 – The AB-100 detector mentioned above paired with the Ludlum 2241-2 scaler/ratemeter was used in the same way for direct and/or scan beta measurements.

2.5.7. L3030 – The Ludlum Model 3030 alpha/beta scaler houses ZnS(Ag) and plastic scintillators and was used to count removable contamination collected on paper swipes. Smear papers were counted in the laboratory and results were reported in βpm/100 cm^2. Removable contamination measurements were not compared with the release criteria for purposes of releasing the survey unit, but only to confirm that the removable fraction was less than 20% of the DCGLw.

2.5.8. L2221/3x3NaI - When beta measurements could not be taken, the 3"x3" Sodium Iodide (NaI) detector was used. This instrument was calibrated off site and no modification or normalization (as was required for the AB-100) was performed.

2.6. Lower Limits of Detection (LLD) and Detection Thresholds

2.6.1. The terminology adopted to reflect the measurement (detection) capability is the lower limit of detection (LLD) or the minimum detectable activity (MDA); it refers to the intrinsic detection capability of the entire measurement process. The LLD, or MDA, is the smallest concentration of radioactive material in a sample that will yield a net count, above system blank, that will be detected with at least 95% probability with no greater than a 5% probability of falsely concluding that a blank observation represents a real signal. It is desirable to express the MDA as minimum detectable areal density (MDAD) or minimum detectable concentration (MDC) in units comparable to a regulatory limit with which a measurement may be compared. For a more detailed discussion regarding LLD and equations involved in calculation of LLD, refer to CT-QA-6.1.16

---

11 As specified in Appendix D of the D Plan. Measurements taken with only the mylar covering the probe were "open window" measurements.

12 The "closed window" reading was taken with a 1/8" soft Aluminum plate covering the face of the detector. It is sufficient to exclude β rays from the U and Th series.

13 Internal Conversion Electrons (ICE) will also be included in this number but are a second order effect and may be ignored.

14 *Energy Dependent Calibrations for the Bicron Model AB-100 Beta Ray Survey Probe,* A. Lucas, CHP and L. Colyott, Phd., submitted as Attachment 3 to the Mallinckrodt Phase I Decommissioning Plan.

15 CT-QA-6.1 - Calibration and Control of Measuring and Survey Equipment

16 Ibid.

2.6.2. The LLD requirements for the FSS have been developed in accordance with MARSSIM 17Chapter 4 guidelines. They are contained in the Design Guide and are listed in Table 2.4.

Table 2.4
MDC Requirements for CT FSS

Measurement Type	MDC Requirement18
Direct Beta	50% of ARG
Class 1 Beta Scans	ARG_{EMC}
Class 2 or 3 Beta Scans	ARG

2.6.3. The MDCs for the instruments used in the FSS were calculated according to Appendix D of the D Plan.19 A comparison of the MDCs calculated for the AB-100 with the requirement for this FSS is provided in Table 2.5.

2.6.4. Action thresholds based upon the release criteria were calculated for each instrument in both direct and scan modes of operation. All thresholds were based on the ARG and are presented in Table 2.5. Details of the MDC calculations and derivation of the action thresholds are provided in Appendix 4.

17 NUREG 1575, Multi Agency Radiation Survey and Site Investigation Manual.
18 Requirements are stated in terms of the ARG which may be adjusted upward by the area factor or paint attenuation factor as described in Section 3.2 of the Design Guide.
19 NEXTEP Tech Memo 0230, *Technical Basis Document for Mallinckrodt Final Status Surveys*, A.H. Thatcher CHP.

Table 2.5
LLD and Action Thresholds[20]

Measurement	Units	Calculated Value	Required Value	
BETA DIRECT			*Class 1*	*Class 2*
MDC	$Dpm_p/100\ cm^2$	100	1,300	1,300
Tinv21	cpm		2,900	2,900
BETA SCAN				
MDC	$Dpm_p/100\ cm^2$	760	13,000	2,600
Tinv	cpm		2,000	2,000
GAMMA DIRECT				
MDC (non-Gravel)	$Dpm_p/100\ cm^2$	950	1,300	1,300
Tinv (non-Gravel)	cpm		1,950	1,950
GAMMA SCAN				
MDC (Gravel)	$Dpm_p/100\ cm^2$	1,200	13,000	2,600
Tinv (Gravel)	cpm		800	800

2.7. INSTRUMENT SENSITIVITY, BACKSCATTER AND PAINT ATTENUATION

2.7.1. Beta direct measurements taken in the field were converted to $dpm_p/100\ cm^2$ of the parent nuclide series in accordance with Section 9 of the Design Guide using the following equation:

Equation 2

$$AD = \frac{Co - Cc}{PAF * S_i * S_b(m) * t}$$

Where:

AD	=	Areal Density in $dpm_p/100\ cm^2$ for the parent nuclides
Co	=	Counts measured in the open window configuration
Cc	=	Counts measured in the closed window configuration
PAF	=	Paint attenuation factor derived from the number of coats of paint applied to the surface since C-T operations ceased.
S_i	=	Normalized Instrument sensitivity without backscatter.
$S_b(m)$	=	Backscatter factor (a function of matrix)
t	=	Integration time in minutes.

20 All Values given are net of background.
21 Investigation Threshold

2.7.2. No painted surfaces were surveyed on the roof of building 235 so the paint attenuation factor (PAF) was always equal to one.

2.7.3. Justification and calculations for separation of backscatter (as a function of the matrix) and instrument sensitivity were presented in Nextep Tech Memo 0215.[22] Reference backscatter coefficients for several matrix materials were generated using an MCNP model and are described in Nextep Tech Memo 0213.[23] These coefficients were stored in the Matrix table in the Database and were used in the calculations according to the matrix material upon which the measurement was taken.

3. SURVEY METHODS

3.1. SURVEY PROCEDURES

3.1.1. The FSS conformed to the procedures and plans listed in Table 3.1. The primary guidance for the FSS is contained in the Design Guide and the FI.

Table 3.1

Survey Procedures and Documents
CT Decommissioning Plan (Phase I)
CT Decommissioning Project, Final Status Survey Design Guide (Phase I)
CT-FI-001, Final Status Survey Guide for Survey Unit 235R
CT-QA-6.1: Calibration and Operation of Measuring and Survey Equipment
CT-RP-66: Operation of Scalers, Rate Meters, and Contamination Detectors
CT-RP-39: Performance of Radiation and Contamination Surveys
CT-RP-40: Survey Documentation and Review

22 NEXTEP Tech Memo 0215: *Separation of Backscatter & Derivation of Instrument Sensitivity*, A.H. Thatcher CHP. (Included with FSSR 2501)

23 NEXTEP Tech Memo 0213: *Beta Backscatter Factors for Several Materials at the Mallinckrodt Site*, N. Zhang and D. Wilson. (Included with FSSR 2501)

3.1.2. All FSS data recorded in the field was submitted to the Quality Assurance Coordinator for processing and review. The data collection forms and annotated drawings were signed by the technician taking the data and reviewed by the Radiation Protection, Health & Safety (RPHS) Manager or designee overseeing the survey. After data entry and review, QA approved the data sheets and filed them with the permanent Mallinckrodt records. The QA checklist24 developed for quality verification of FSS data was used as a guide to data verification.

3.1.3. All the data generated by the surveys were entered into the CT Radiation Database (RDB) and analyzed as outlined in Section 4.4 of the D Plan.

3.2. SURVEY MEASUREMENTS

3.2.1. Beta Measurements:

3.2.1.1. *Direct* – A systematic grid of direct measurements were obtained on the roof surfaces as described in the FI. For the five Class 1 survey units, direct beta measurements were collected on the metal deck beneath the old roof after the roofing material was removed. Bias measurements were taken on building surfaces and fixed apparatus at locations determined by the surveyor and to more fully characterize the fixed apparatus.

3.2.1.2. *Scans* - Beta scans were performed using the same instruments used for the direct beta measurements. Beta Scans were performed on all fixed apparatus and all Class 1 survey units. Scans were performed at a scan rate of less than one detector width per second with a probe height less than one inch from the surface being scanned.

3.2.2. Gamma Measurements:

3.2.2.1. *Direct* - Because the roof of building 235 had been at least partially replaced and was covered with gravel, it was not possible to detect residual contaminants beneath the surface with beta detectors. Instead, a 3"x3" Sodium Iodide (NaI) gamma detector was used in both the direct and scan modes to survey the roof in SU-235R. For direct measurements the detector was placed on the roof surface after the loose gravel had been cleared away and counts were taken for 1-minute.

24 NEXTEP Tech Memo 0206, *QA Data Verification for MI CT Final Status Survey Data*, B. Anderson, (Included with FSSR 2501)

3.2.2.2. *Scans* - Gamma Scans were performed in straight lines 5 cm above the surface of the roof in SU-235R with each scan line separated from the next by 1 meter. The scan rate did not exceed 1 ft/s.

3.2.3. Removable Contamination Measurements:

3.2.3.1. *Swipes* - Removable contamination samples were collected at 10% of all Class 2 regular grid locations on the roof. In Class 1 survey units, removable contamination samples were collected at every location where a direct grid measurement was taken. The swipes were counted in the laboratory and recorded in the database. Sampling of removable contamination was performed to confirm the assumption, used in derivation of the DCGLw, that the removable fraction measures less than 20% of the DCGLw[25].

3.3. MEASUREMENT LOCATIONS

3.3.1. Statistical Grid Data Points

3.3.1.1. The *Visual Sample Plan*© (VSP)[26] software was used to develop a MARSSIM grid for all six survey units. The minimum number of points required and their spacing were calculated in accordance with the statistical guidance given in MARSSIM Sections 5.5.2.2 and 5.5.2.5.

3.3.1.2. VSP contains the Data Quality Objectives (DQO) input values and assumptions necessary to calculate the number of measurement points, N, required to satisfy MARSSIM statistical guidance. The calculations include 20% excess to allow for inaccessible locations. A summary of all the input parameters used with VSP for this Report is presented in Table 3.2.

Table 3.2
VSP Inputs for Building 235 Roof

DQO	Value
Type I error rate	5%
Type II error rate	5%
Width of Gray Region	200 $Dpm_p/100cm^2$
Level (ARG)	2,600 $Dpm_p/100cm^2$
Estimated Std Deviation	200 $Dpm_p/100cm^2$
Excess % sample points min.	20%

25 Section 3.3 of the CT Design Guide.
26 NEXTEP Techmemo 0008, Verification and *Validation of Applicable Portions of VSP Software, A.* H. Thatcher, CHP.

3.3.1.3. A rectangular grid was used for all six survey units. The grid interval spacing, L, was calculated from the area of the total SU and the required number of data points, N, according to the following equation:

Equation 3

$$L \leq \sqrt{\frac{A}{N}}$$

3.3.1.4. Table 3.3 presents the calculated values for L and N for each survey unit on the roof of building 235.

Table 3.3
SU 235 Calculated Grid Point Separation

Survey Unit	Class	N Number of Data Points	A (ft^2) (SU Area)	L (ft)
SU-235R	2	29	5,789	18.527
SU-235R1	1	29	932	5.7
SU-235R2	1	29	961	5.8
SU-235R3	1	29	725	5.0
SU-235R4	1	29	968	5.8
SU-235R5	1	29	924	5.6

3.3.2. Bias Measurement Locations

3.3.2.1. Bias direct measurements (gamma on Class 2 roof surfaces, beta on Class 1 roof surfaces, and beta on fixed apparatus) were taken at the discretion of the HP technician performing the survey.

3.3.2.2. Bias surveys were also taken at hot spot locations identified by scans as directed in the Hot Spot Protocol28.

3.4. REFERENCE COORDINATE SYSTEM

3.4.1. A unified reference system was prescribed for the location of all data points taken on all building surfaces and on the surface of installed apparatus. A description of the reference coordinate system is provided below.

3.4.2. A data point's unique location is specified by a combination of the following data elements: building, room, surface ID, X, and Y. The surface ID refers to the four

27 Based upon the original Class 2 survey unit area of 9,925 sq. ft. When the Class 1 survey units were broken off of SU-235R, the grid spacing was not changed and the data already collected was used.

28 CT-FI-004, Final Status Survey Guide for Survey Unit 2504

walls, floor, ceiling and roof as shown in Table 3.2. X and Y are distances from the origin measured as shown in the table. An example of X and Y axes for floors and walls is presented in Appendix 2, Figure 3.1

Table 3.2

Coordinate System Locators

Location	Identifier	X	Y
North Wall	N	Feet right from leftmost edge of the wall surface	Feet up from floor or the lowest point in the room
South Wall	S		
East Wall	E		
West Wall	W		
Floor	F	Feet east from western most edge of the surface	Feet North of southernmost edge
Ceiling	C		
Roof	R		

3.4.3. The surface ID for a roof applies only in the case when measurements are being made on the exterior surface of a building. In this unique case the "room" assigned has the special number "999".

3.4.4. For the roof of building 235, the roof surface had to be divided into six surfaces in order to accommodate the smaller area requirement for Class 1 survey units. However, to facilitate the collection and plotting of the data, the origin of the coordinate system for all six survey units remained in the southwest corner of the building.

3.4.5. Systematic grid data points which fell on external surfaces of installed apparatus were located with the primary coordinate system. The ID code of the apparatus was recorded in the remarks. For example: Let Q2 be identified as a large air conditioning unit. Any systematic grid measurement points for the roof surface which landed on the air conditioner would have been identified using the X and Y coordinates from the southwest corner of the roof. "Q2 – A/C unit" would be noted in the remarks. The surface ID would be "R".

3.4.6. All bias data points taken on installed apparatus were numbered and located on the drawings provided. This number was recorded as the X coordinate on the data sheet and amplifying information was entered in the remarks section.

3.5. DATA EVALUATION

3.5.1. All of the direct, swipe and scan data were entered into the CT Radiation Database (RDB) for easy access and analysis. The direct beta measurements are the primary means for documenting the survey unit and justifying its release. Therefore, a special report was programmed to perform all the tests specified in Section 4.4.8 of the D Plan and to provide a clear report of the results for

evaluation. The calculations in this report have been validated and verified as described in NEXTEP Techmemo 023129.

3.5.2. The purpose of the screening software is to compare each direct beta reading taken in the survey unit with specified threshold levels, to apply the statistical tests called for in MARSSIM when appropriate, and to present the results in a clear and useful manner so that an analyst can accurately assess the action to be taken or declare the survey unit meets the requirements for release.

3.5.3. Some of the screening tests apply to each record in the survey unit and failure of one data point results in failure of the survey unit. Other tests do not apply to each survey record but generate a single PASS/FAIL verdict for the entire data set. The tests are described in the following paragraphs30. An abbreviated summary of these tests is presented in Table 3.5.

3.5.4. *Background Screen.*

3.5.4.1. For each MATRIX code in the database, calculate the mean background reading, its standard deviation, and its minimum value. Calculate and store the Background Threshold, T_{bk}, with its matrix code according to the following equation:

Equation 4

$$T_{bk}(m) = \overline{BK}(m) + 2 * \sigma_{bk}(m)$$

3.5.4.2. T_{bk} is equal to the mean of the background readings $(\overline{BK})$ for a given matrix plus two times its standard deviation (2σ).

3.5.4.3. Compare each data point in the filtered survey unit with T_{bk}. If the survey reading > T_{bk} the data point fails the test. One data point failure implies failure of the background screen test for the survey unit.

3.5.5. *Min/Max Test.*

3.5.5.1. Find the maximum direct survey result, in $dpm_p/100cm^2$, for the survey data set.

3.5.5.2. Find the minimum background reading among all the background data points having MATRIX codes that match those in the data set.

3.5.5.3. If the difference between these two values is greater than DCGLw the MIN/MAX test fails for the survey unit.

3.5.6. *DCGLw Screen.*

29 NEXTEP Techmemo 0231, *Validation and Verification of the C-T Database Analysis Report,* B. Anderson (included with FSSR 2501)

30 A more detailed explanation is provided in the Design Guide.

3.5.6.1. For each matrix code calculate and store a DCGLw Threshold (T_d). T_d is calculated by adding the value of DCGLw to T_{bk}.

Equation 5

$$T_d(m) = T_{bk} + DCGLw$$

3.5.6.2. Compare each data point in the survey unit with T_d. If the survey reading > T_d the data point fails the test. One data point failure implies failure of the DCGLw screen test for the survey unit.

3.5.7. *EMC Screen.*

3.5.7.1. For each matrix code calculate and store an EMC Threshold (T_e). T_e is calculated by adding the value of EMC to T_{bk}. The EMC value selected is normally dependent upon the area involved. However, if no specific area was known, the EMC was normally set to the a priori $DCGL_{EMC}$.

3.5.7.2. Compare each data point in the filtered survey unit with T_e. If the survey reading > T_e the data point fails the test. One data point failure implies failure of the EMC test for the survey unit.

3.5.8. *DCGL Average Test.*

3.5.8.1. For each matrix material in the survey unit, calculate the mean activity density, (in $dpm_p/100cm^2$), in the survey data set. Subtract from this value, the mean value of background activity for the same matrix. If the remainder is greater than DCGLw for any matrix in the survey unit, the test fails.

3.5.9. Statistical Tests.

3.5.9.1. The statistical tests prescribed by MARSSIM operate only on the data points of MEASUREMENT TYPE = RG (Regular Grid). The program narrows the filter to include only these points before proceeding.

3.5.9.2. The Wilcoxon Rank Sum Test[31] is applicable for survey units with measurements on a single matrix type or on matrices with similar background characteristics. Where more than one matrix was present, the Sign Test for Paired Data[32] was used.

3.5.10. The output of the Threshold Comparison Test Report (TCTR) was used for analysis of the data for the building 235 roof and the results are presented in Appendix 5. Each TCTR is divided into eight sections which are briefly described in the following paragraphs to assist the unfamiliar reader.

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31 Described in Appendix I of MARSSIM.

32 Described in NEXTEP TechMemo 0231, *Verification of the Mallinckrodt CT Database Analysis Report*, B.P. Anderson.

3.5.10.1. General: date, survey unit number, class, and grid information.

3.5.10.2. Survey Unit Table: building surface included, affected fixed apparatus, and total surface area of the survey unit.

3.5.10.3. Initialization Data: On startup of the analysis report program, the analyst must tell the program which parameters to use while running the tests described in this section. The *Initialization Data* section of the report output displays the options that were chosen for the run. The measurement types listed are those chosen by the analyst to be included in the report. The date range chosen is also listed. The default value is "All Dates". Values for DCGLw (ARG) and $DCGL_{EMC}$ are also specified at the start of the run and are listed in this section. If remediated data points are included in the run, it will be noted in this section. Normally they will be excluded.

3.5.10.4. Survey Unit Test Status: Lists Pass/Fail status of all tests and gives a high level summary of key activity levels in the SU.

3.5.10.5. Points that failed tests: Lists all points that failed each specified threshold test (EMC, DCGL, and Background).

3.5.10.6. Points that passed all the tests: This includes the remainder of all the points in the data set. These data points have passed all the tests.

3.5.10.7. Summary of background data used in the calculations. This table includes the matrix materials included in the survey and the thresholds calculated for each of the tests discussed in this section.

3.5.10.8. Statistical Test Results: This page lists the results of the Sign Test for Paired Data or the Wilcoxon Rank Sum test, whichever is selected. If the Test Status line reads Pass then the survey unit passes the Sign Test for Paired Data. The Data Summary section lists the number of background points and the number of survey points used from the data set. If the operator selects the option to show all data, a table of all data points used in the test is printed out.

Table 3.5
Threshold Screening Tests

Test	Test Criteria for PASS
Min/Max	Difference between minimum background measurement and maximum survey value less than DCGLw
Background	All samples must be less than the background threshold[a]
$DCGL_w$	All samples must be no more than $DCGL_w$ + the background threshold
$DCGL_{avg}$	The average of all net survey values must be less than $DCGL_w$
EMC	All samples must be less than $DCGL_{EMC}$ + the background threshold
Sign Test for Paired Data	The Sign Test for Paired Data is described in detail in NUREG 150533
Wilcoxon Rank Sum Test	This statistical test is described in detail in MARSSIM, Appendix I.

[a] *The background threshold is equal to the mean background value plus twice σ_{BK}. .*

3.5.11. Provided all additional considerations such as scan data, swipes, sampling of removable contamination or sludge from traps, etc. indicate that the survey unit meet the release criteria, the release of the survey unit can be determined from the test report according to Table 3.6.

Table 3.6
Requirements for SU Release34

Test	Class 1	Class 2	Class 3
Min/Max	not required[a]	not required[a]	PASS
Background	not required	not required	PASS
$DCGL_w$	not required	PASS	PASS
$DCGL_{avg}$	PASS	PASS	PASS
EMC	PASS	PASS	PASS
Sign Test for Paired Data	PASS	PASS	PASS

[a] *Class 1 or 2 survey units which pass Min/Max may be released without further consideration.*

33 Nureg 1505, A Nonparametric Statistical Methodology for the Design and Analysis of Final Status Decommissioning Surveys.
34 See MARSSIM, Chapter 8, Table 8.2

4. FSS RESULTS AND DISCUSSION

4.1. CHARACTERIZATION DATA

4.1.1. The characterization data taken in this survey unit from 1992 to 1996 was very limited. Since the data on file in the characterization report were all taken with an HP-210 instrument they cannot be normalized to the AB-100 calibration standards and therefore are not included in the data set. Also, much of the roof surface covered by the characterization data has recently been removed and replaced which would render the old data set for these surfaces inapplicable.

4.2. CLASS 1 SURVEY UNITS

4.2.1. The five Class 1 survey units were surveyed as the roof material was removed during remediation. Measurements were taken directly on the concrete deck below the tar and gravel materials.

4.2.2. Direct Beta Measurements.

4.2.2.1. 160 direct beta measurements were taken on the newly remediated roof surfaces of Building 235 before the new roofing material was laid down. Almost all of these were included in the systematic grid. A diagram of the roof layout with the beta measurements taken in each survey unit is presented in Appendix 2, Figure 4.1. Points depicted as circles were part of the regular MARSSIM grid and were included in the statistical calculations. Points depicted as triangles were bias data points. No bias readings were taken on the fixed equipment since all of the installed apparatus on the roof was included in SU-235R.

4.2.2.2. A summary of the direct measurement results is presented in Table 4.1 and shows that the maximum activity measured, net of background, was 160 $dpm_p/100cm^2$ for the Class 1 survey units. The average value for the five Class 1 survey units was 76 $dpm_p/100cm^2$.

Table 4.1
SU-235 Roof Direct Measurements Summary

Survey Unit	Points	Avg Net Activity[a] ($Dpm_p/100cm^2$)	Max Net Activity ($Dpm_p/100cm^2$)
235R	18	1,421	4,556
235R1	33	78.9	149.1
235R2	33	75.6	160.1
235R3	30	71.5	143.6
235R4	32	68.7	120.3
235R5	32	87.1	121.0

[a] DPMp refers to disintegrations per minute of the parent nuclide series

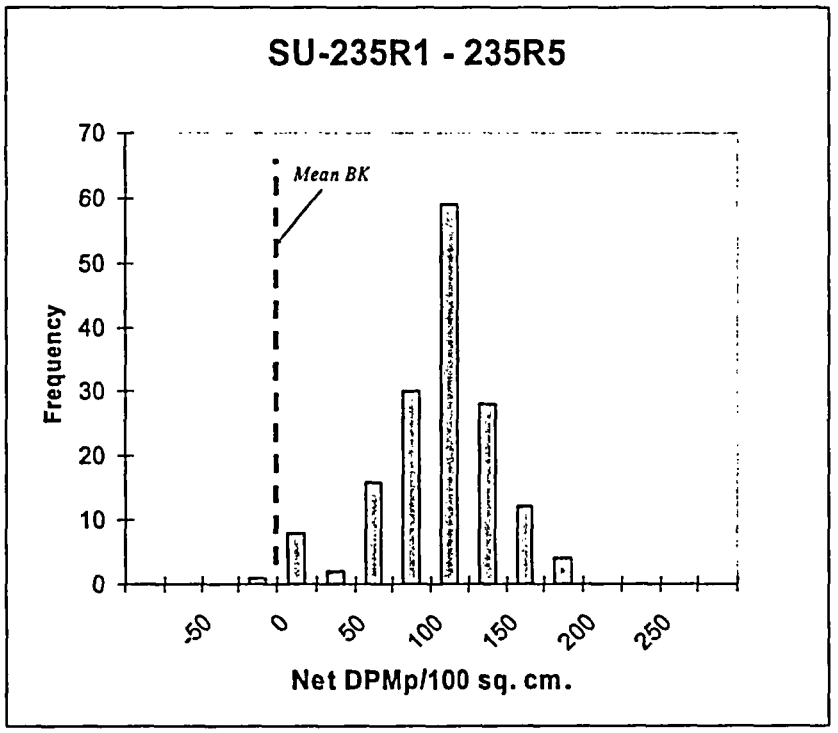
4.2.2.3. A histogram of the net activity values found in the five Class 1 survey units is provided in Figure 4.1. The distribution appears to be bimodal with the majority of the data centered about a mode at approximately 11335 $dpm_p/100cm^2$ above mean background with a second mode at 13 $dpm_p/100cm^2$. This is consistent with a normal distribution of residual radioactivity concentrated just above the background level and well below the ARG.

?

113 dpm

4.2.2.4. The lower mode is most likely representative of the actual background on this roof, which is approximately 13 $dpm_p/100cm^2$ higher than the average background for concrete in the background data set (37 $dpm_p/100cm^2$). Therefore the average background activity for concrete on this roof is most likely approximately 50 $dpm_p/100cm^2$.

4.2.2.5. Since it is more conservative to use the background data on file, unless otherwise stated, the 50 $dpm_p/100cm^2$ figure will not be used. All TCTR reports were run using the lower background data set.



Histogram of Net Direct Beta Measurements

Figure 4.1

4.2.2.6. All the direct measurements in the survey unit were analyzed using the Threshold Comparison Test Report and the results are presented in

35 Actually this mode represents the number of occurrences where the activity fell between 100 and 125 $dpm_p/100cm^2$.

Appendix 5 for each survey unit. The TCTR reports in Appendix 5 contain a complete listing of all the beta direct measurements taken in the Final Status Survey within the Class 1 survey units sorted by test failed and by activity. The summary pages indicate that all tests described in the D Plan passed except background. All tests required to release the Class 1 survey units in accordance with the Mallinckrodt license and D Plan were met. A comparison of test results and requirements for release of the survey unit is presented in Table 4.2.

Table 4.2
Requirements for SU Release

Test	Class 1	SU-235R1	SU-235R2	SU-235R3	SU-235R4	SU-235R5
Min/Max	not required[a]	P	P	P	P	P
Background	not required	F	F	F	F	F
$DCGL_w$	not required	P	P	P	P	P
$DCGL_{avg}$	PASS	P	P	P	P	P
EMC	PASS	P	P	P	P	P
Sign Test for Paired Data	PASS	P	P	P	P	P

[a] *Class 1 survey units which pass Min/Max may be released without further consideration.*

4.2.2.7. As the histogram in Figure 4.1 shows, some residual radioactivity exists above the background level but far below the administrative release guideline of 2,600 $dpm_p/100cm^2$ and even farther below the release criteria of 13,000 $dpm_p/100cm^2$ given in the D Plan.

4.2.3. Measurements of removable contamination

4.2.3.1. Swipes were taken at each location where a direct grid measurement was performed. The results of the measurements are presented in Table 4.3.

Table 4.3
SU-235 Roof Removable Contamination Summary

Survey Unit	Points	Avg Net Beta ($\beta pm/100cm^2$)	Max Net Beta ($\beta pm/100cm^2$)	Avg Net Activity[a] ($Dpm_p/100cm^2$)	Max Net Activity ($Dpm_p/100cm^2$)
235R	2	-2.95	2.90	-0.61	0.60
235R1	33	-4.76	22.00	-0.99	4.58
235R2	31	-0.74	28.00	-0.15	5.83
235R3	28	0.00	31.00	0.00	6.46
235R4	32	-2.75	33.00	-0.57	6.88
235R5	32	-1.59	31.00	-0.33	6.46

[a] Activity was converted to $dpm_p/100\ cm^2$ from $\beta pm/100\ cm^2$ using an approximate figure of 4.8 betas per disintegration.

4.2.3.2. Removable contamination measurements from the laboratory are expressed in terms of $\beta pm/100cm^2$ rather than $Dpm_p/100cm^2$. An approximate comparison may be made by dividing the beta value by 4.8. The results show that removable contamination averages very near zero

$dpm_p/100cm^2$ and varies between -8.8 and +6.9 $dpm_p/100cm^2$. The data confirm that virtually no detectable removable contamination is present within the survey unit.

4.2.4. Beta Scan Measurements

4.2.4.1. Beta scans were performed on 100% of the roof surface in each Class 1 survey unit. Diagrams of the areas surveyed are presented in Appendix 2, Figures 4.4 through 4.8. Since the entire survey unit was scanned in each case the drawing was annotated with the maximum readings every five feet.

4.2.4.2. The scan threshold used for these surveys was 2,000 cpm (net of background) which corresponds to the ARG of 2,600 $dpm_p/100cm^2$. The calculation of threshold count rate and MDC for scans is presented in Nextep TechMemo 023036.

4.2.4.3. The average background value used for analysis of the raw data was obtained from the average of all the open window beta readings (in cpm) taken in the background data set. For concrete this value was 377 cpm and it compared favorably with the average open window reading for beta measurements in the survey units (394 cpm).

4.2.4.4. During the surveys the maximum and average gross count rates were recorded for each area scanned. The beta scan data are summarized for SU-235R1 through R5 and presented in Table 4.4.

Table 4.4
SU-235 Scan Measurements Summary

Survey Unit	Points	Maximum (cpm)	Average (cpm)	Max Net (dpm_p/ $100cm^2$)	Avg Net ($dpm_p/100cm^2$)
235R[a]	1	8000	6315	5,228	2,981
235R1	1	280	200	7.9	-46.9
235R2	1	260	200	-5.8	-46.9
235R3	1	200	180	-46.9	-60.6
235R4	1	250	190	-12.7	-53.8
235R5	1	260	200	-5.8	-46.9

[a] Gamma (cpm) measured using shielded 3" x 3" NaI detector in 235R only

4.2.4.5. The maximum net beta scan value in the Class 1 Survey Units of 7.9 is essentially at background level.

36 Ibid.

4.2.5. The scan summary data in Table 4.4 confirm that the scans performed in SU-235R1 through R5 indicated that residual radioactivity is very close to background levels. No scan data were observed above the beta scan threshold of 2,000 cpm.

4.3. CLASS 2 SURVEY UNIT

4.3.1. SU-235R is the remnant of the roof left over when the five Class 1 survey units were broken off for remediation. The original roof affected by CT operations has been at least partially covered with new roofing material and gravel. Therefore, beta detection methods are not adequate to characterize the survey unit and gamma methods were employed instead.

4.3.2. Direct Gamma Measurements.

4.3.2.1. 18 direct gamma measurements were taken on the unremediated portion of the roof of Building 235. All of these were included in the systematic grid. A diagram of the roof layout with the gamma measurements taken in the survey unit is presented in Appendix 2, Figure 4.2.

4.3.2.2. Gamma direct measurements were converted to $dpm_p/100cm^2$ using a conversion factor calculated for ½ inch asphalt binder overlaying the contamination as described in NEXTEP TechMemo 022937. The conversion factor was 0.75 cpm/dpm_p. This conversion factor was used because all direct measurements were made with the gravel on the roof surface scraped away and the detector standing directly on the asphalt binder material underneath.

4.3.2.3. A summary of the direct measurement results for SU-235R is presented in Table 4.1 and shows that the maximum activity measured, net of background, was 4,556 $dpm_p/100cm^2$. The average was 1,421 $dpm_p/100cm^2$.

4.3.2.4. Four of the 18 gamma measurements exceeded the ARG value of 2,600 $dpm_p/100cm^2$ but all were less than 35% of the DCGLw. Inspection of Figure 4.2 in Appendix 2 shows that the elevated measurements occurred on the edge of the survey unit closest to the remediated areas.

4.3.2.5. All the direct measurements in the survey unit were less than the DCGLw. Therefore the direct measurements in SU-235R pass all the tests except background and min/max. A comparison of test results and requirements for release of the SU-235R is presented in Table 4.5.

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37 NEXTEP TechMemo 1229, *MCNP Gamma Modeling of Mallinckrodt Roof Surfaces*, N.Zhang

Table 4.5
Requirements for SU Release

Test	Class 2	SU-235R
Min/Max	not required[a]	F
Background	not required	F
$DCGL_w$	PASS	P
$DCGL_{avg}$	PASS	P
EMC	PASS	P
Sign Test for Paired Data	PASS	P

[a] *Class I survey units which pass Min/Max may be released without further consideration..*

4.3.2.6. The direct gamma measurements show that SU-235R passed all the tests required for release of a Class 2 survey unit.

4.3.3. Measurements of Removable Contamination

4.3.3.1. Swipes were taken at 10% of the locations where a direct measurement was performed. The results of these measurements are presented in Table 4.3. The results show that removable contamination in SU-235R ranges between –0.61 and +0.60 $dpm_p/100cm^2$ and averages very near zero $dpm_p/100cm^2$. No significant removable contamination is present in SU-235R.

4.3.4. Installed Apparatus

4.3.4.1. All 23 items of installed apparatus which are listed in Appendix 1 were surveyed by direct beta measurements. A summary of the measurements taken is provided in Table 4.6 sorted by matrix material. The values observed ranged from –16 to 216 $dpm_p/100cm^2$. All values were less than 10% of the ARG and less than 2% of the DCGLw. The data confirm that no significant residual radioactivity was found on the 23 items of uninstalled apparatus in SU-235R.

Table 4.6
SU-235R Fixed Equipment Direct Measurements Summary

Matrix	Points	Avg Net DPMp[a] ($Dpmp/100cm^2$)	Max Net DPMp ($Dpmp/100cm^2$)
Fiberglass	14	19.3	59.7
Metal	52	19.7	59.2
Plastic	6	6.0	24.2
Tar/Roofing	2	213.8	215.7
Wood	6	40.6	61.9

[a] DPMp refers to DPM of the parent nuclide series

4.3.5. Gamma Scan Measurements

4.3.5.1. Gamma scans were performed on 100% of SU-235R. A diagram of the area surveyed is presented in Appendix 2, Figure 4.3. Since the entire survey unit was scanned the drawing was annotated with the maximum readings every five feet.

4.3.5.2. The scan threshold used for these surveys was 800 cpm (net of background) which corresponds to the ARG of 2,600 $dpm_p/100cm^2$.

4.3.5.3. The average background value used for analysis of the raw data was 4,079 cpm as described in paragraph 2.3.

4.3.5.4. During the surveys the maximum and average gross count rates were recorded for each area scanned. The gamma scan data for SU-235R are summarized and presented in Table 4.4.

4.3.5.5. Both the average and maximum scan readings exceeded the ARG-based investigation threshold of 800 cpm above background which is consistent with the presence of residual activity above the ARG discussed in Section 4.3.2. Using a conversion factor of 0.44 cpm/dpm_p for scans over gravel[38], the scan threshold which corresponds to the DCGLw is 5,720 cpm above background. The maximum net scan value observed in SU-235R was 3,921 cpm. The scan data show that all scan readings taken in SU 235R were less than 69% of the DCGLw (converted to cpm for gamma scans.)

5. CONCLUSIONS

5.1. The distribution of direct survey measurements net of background in the Class 1 survey units is bimodal with the majority of the data centered about a mode at approximately 113$dpm_p/100cm^2$ above mean background with a second mode at 13 $dpm_p/100cm^2$. This is consistent with a normal distribution of residual radioactivity concentrated just above the background level and well below the ARG (Par. 4.2.2.3).

5.2. The Class 1 survey units passed all the tests described in the D plan except background. All the tests required for release of a Class 1 Survey unit were passed. (Par. 4.2.2.6)

5.3. Virtually no removable contamination is present within the Class 1 survey units. (Par. 4.2.3.2)

5.4. No beta scan data were observed in the Class 1 survey units above the scan threshold of 2,000 cpm. (Par. 4.2.7)

5.5. Scans performed in the Class 1 survey units indicated that residual radioactivity is very close to background levels. (Par. 4.2.7)

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38 NEXTEP Tech Memo 0229, ibid.

5.6. SU-235R1 through R5 meet all the requirements of the D Plan and MARSSIM for unconditional release.

5.7. The Class 2 Survey Unit (SU-235R) passed all the tests described in the D Plan except Min/Max and background. All the tests required for release of a Class 2 survey unit were passed. (Par 4.3.2)

5.8. Four of the 18 gamma measurements on SU-235R exceeded the ARG but all were less than 35% of the DCGLw. (Par 4.3.2.4)

5.9. No significant residual radioactivity was measured on the 23 items of installed apparatus in SU-235R.(Par. 4.3.4.1)

5.10. Virtually no removable contamination is present within the Class 2 survey unit. (Par. 4.3.3.1)

5.11. Although some gamma scan readings exceeded the ARG-based threshold, all scan readings taken in SU-235R were less than 69% of the DCGLw (converted to cpm for gamma scans). (Par. 4.3.5.5)

5.12. SU-235R meets all the requirements of the D Plan and MARSSIM for unconditional release.

6. RECOMMENDATIONS

6.1. SU-235R, SU-235R1, SU-235R2, SU-235R3, SU-235R4, and SU-235R5 should be released from the license.

Appendix 1
Building Survey Unit Listing for
Building 235 Roof

Building Survey Unit Listing

SurveyUnitID: 235R *Class:* 2

Room 999

SurfaceCode	Xmax	Ymax	Area (sq.ft.)	Paint (Coats)	Description
R	77.0	83.0	5,789	0.0	Class 2 portion only
Q1			0	0.0	Access stairwell and associated supports to B236 roof
Q2			0	0.0	Piping and supports that run North/South
Q3			0	0.0	Large pipe and supports ~1' off roof
Q4			0	0.0	Exhaust fan/electrical box
Q5			0	0.0	A/C unit and associated penetrations/supports and piping
Q6			0	0.0	Green shelter
Q7			0	0.0	Northern side ladder and railing
Q8			0	0.0	Piping/pipe supports
Q9			0	0.0	Abandoned Vent Pipes (18 in the Northeast corner of roof)
Q11			0	0.0	Small mechanical device
Q12			0	0.0	Roof Drain
Q13			0	0.0	Piping and supports
Q14			0	0.0	Southern access ladder and associated caging
Q15			0	0.0	Roof curbing and Steel framing (total of 4 locations)
Q16			0	0.0	A/C unit and associated penetrations/supports and ducting
Q17			0	0.0	Large diameter piping, mechanicals, supports
Q18			0	0.0	Next set of piping running in North/South direction
Q19			0	0.0	Eastern most set of pipes
Q20			0	0.0	Piping near Q17
Q21			0	0.0	Existing vents
Q22			0	0.0	Yellow >2" piping and valves
Q23			0	0.0	Yellow 2" pipe

Summary for Room 999 (23 detail records) ***5,789*** **Sq. Feet**

TOTAL for Survey Unit 235R ***5,789*** **Sq. Feet**

Building Survey Unit Listing

SurfaceCode	*Xmax*	*Ymax*	*Area (sq.ft.)*	*Paint (Coats)*	*Description*

SurveyUnitID: 235R1 *Class:* 1

Room *999R1*

R	62.0	15.3	949	0.0

Summary for Room 999R1 (1 detail record) ***949*** **Sq. Feet**

TOTAL for Survey Unit 235R1 ***949*** **Sq. Feet**

Building Survey Unit Listing

	SurfaceCode	*Xmax*	*Ymax*	*Area (sq.ft.)*	*Paint (Coats)*	*Description*
SurveyUnitID: 235R2						*Class:* 1
Room 999R2						
	R	62.0	15.3	949	0.0	
Summary for Room 999R2 (1 detail record)					***949*** **Sq. Feet**	
TOTAL for Survey Unit 235R2					***949*** **Sq. Feet**	

Building Survey Unit Listing

SurfaceCode	*Xmax*	*Ymax*	*Area (sq.ft.)*	*Paint (Coats)*	*Description*

SurveyUnitID: 235R3 *Class:* 1

Room *999R3*

R	50.0	14.5	725	0.0

Summary for Room 999R3 (1 detail record) **725 Sq. Feet**

TOTAL for Survey Unit 235R3 **725 Sq. Feet**

Building Survey Unit Listing

SurfaceCode	*Xmax*	*Ymax*	*Area (sq.ft.)*	*Paint (Coats)*	*Description*

SurveyUnitID: 235R4 *Class:* 1

Room *999R4*

R	44.0	22.0	968	0.0

Summary for Room 999R4 (1 detail record) ***968*** **Sq. Feet**

TOTAL for Survey Unit 235R4 ***968*** **Sq. Feet**

Building Survey Unit Listing

SurfaceCode	*Xmax*	*Ymax*	*Area (sq.ft.)*	*Paint (Coats)*	*Description*

SurveyUnitID: 235R5 *Class:* 1

Room *999R5*

R	44.0	16.3.0	719	0.0	

Summary for Room 999R5 (1 detail record) ***719*** **Sq. Feet**

TOTAL for Survey Unit 235R5 ***719*** **Sq. Feet**

APPENDIX 2

Figures

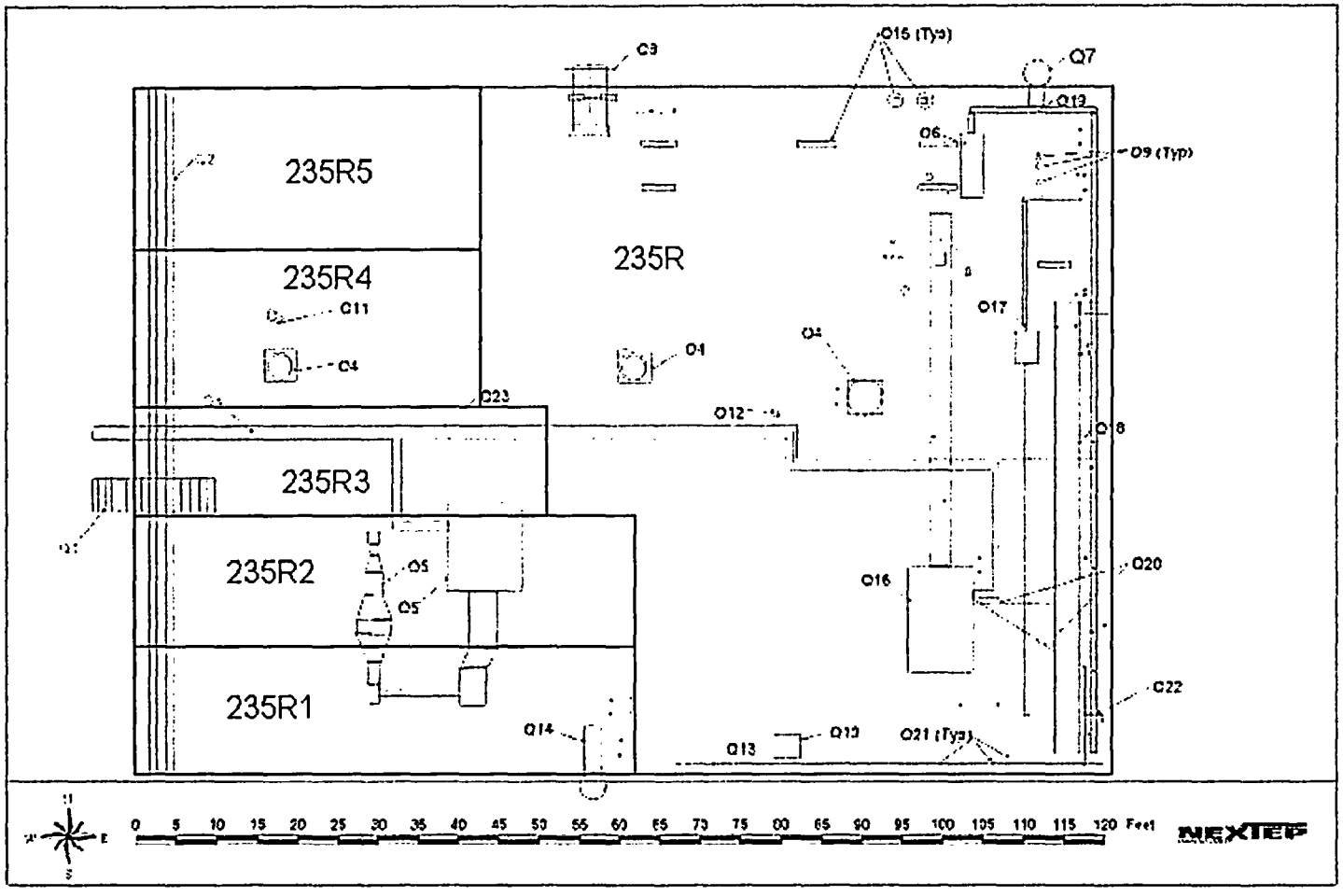
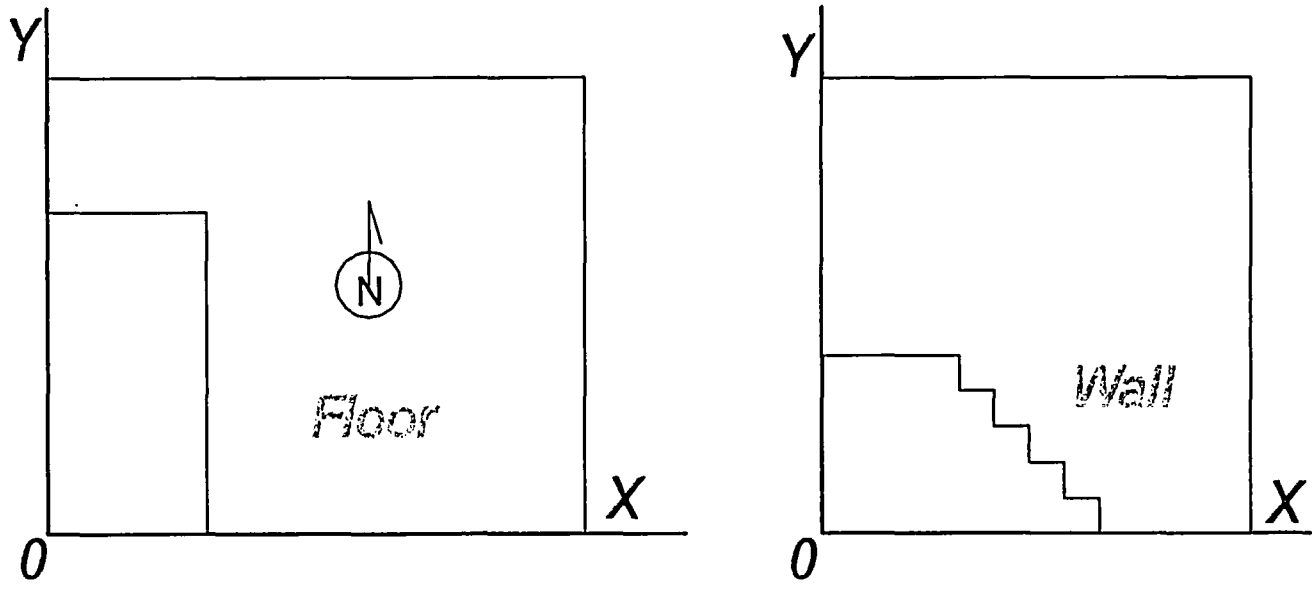
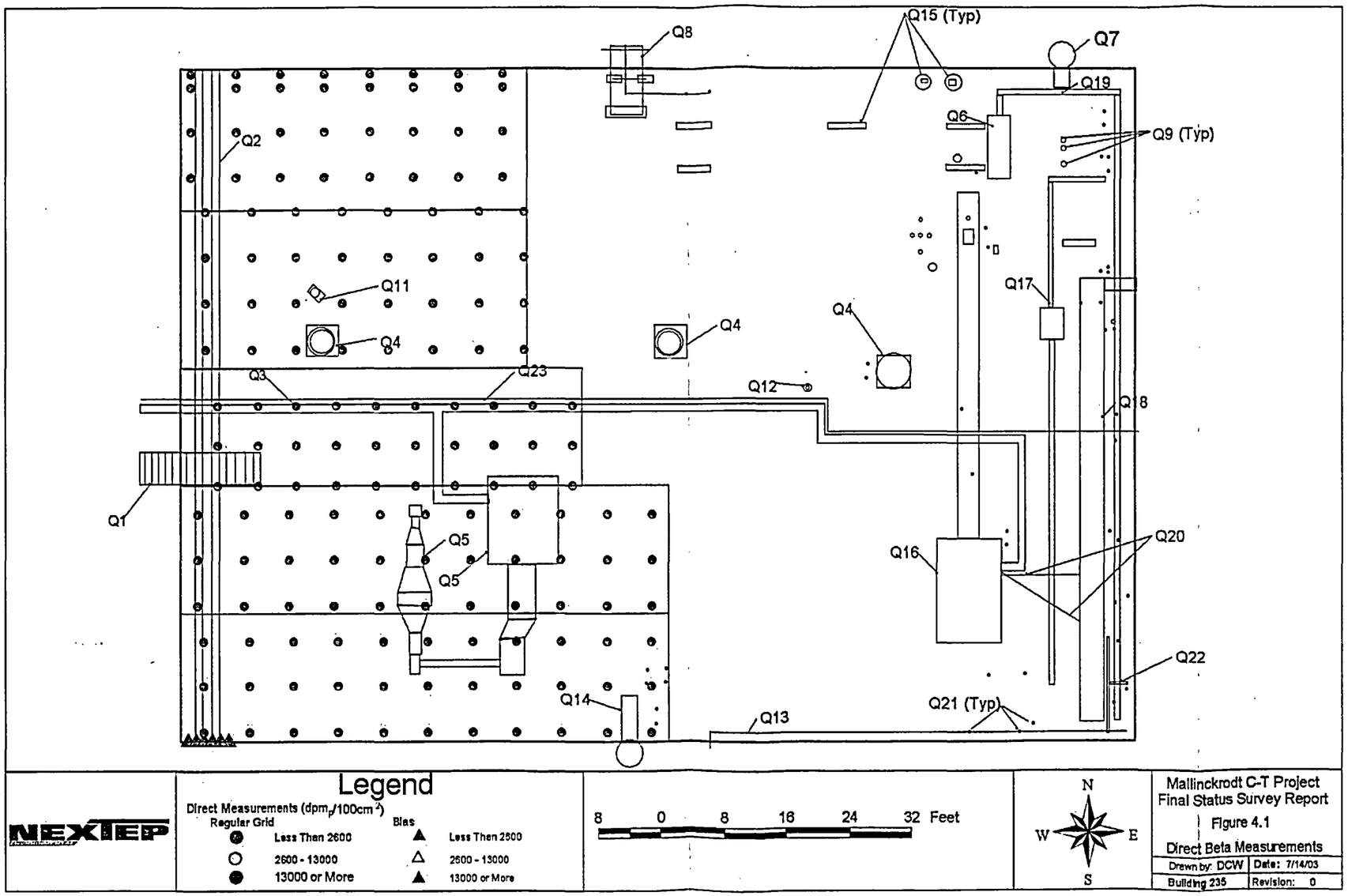


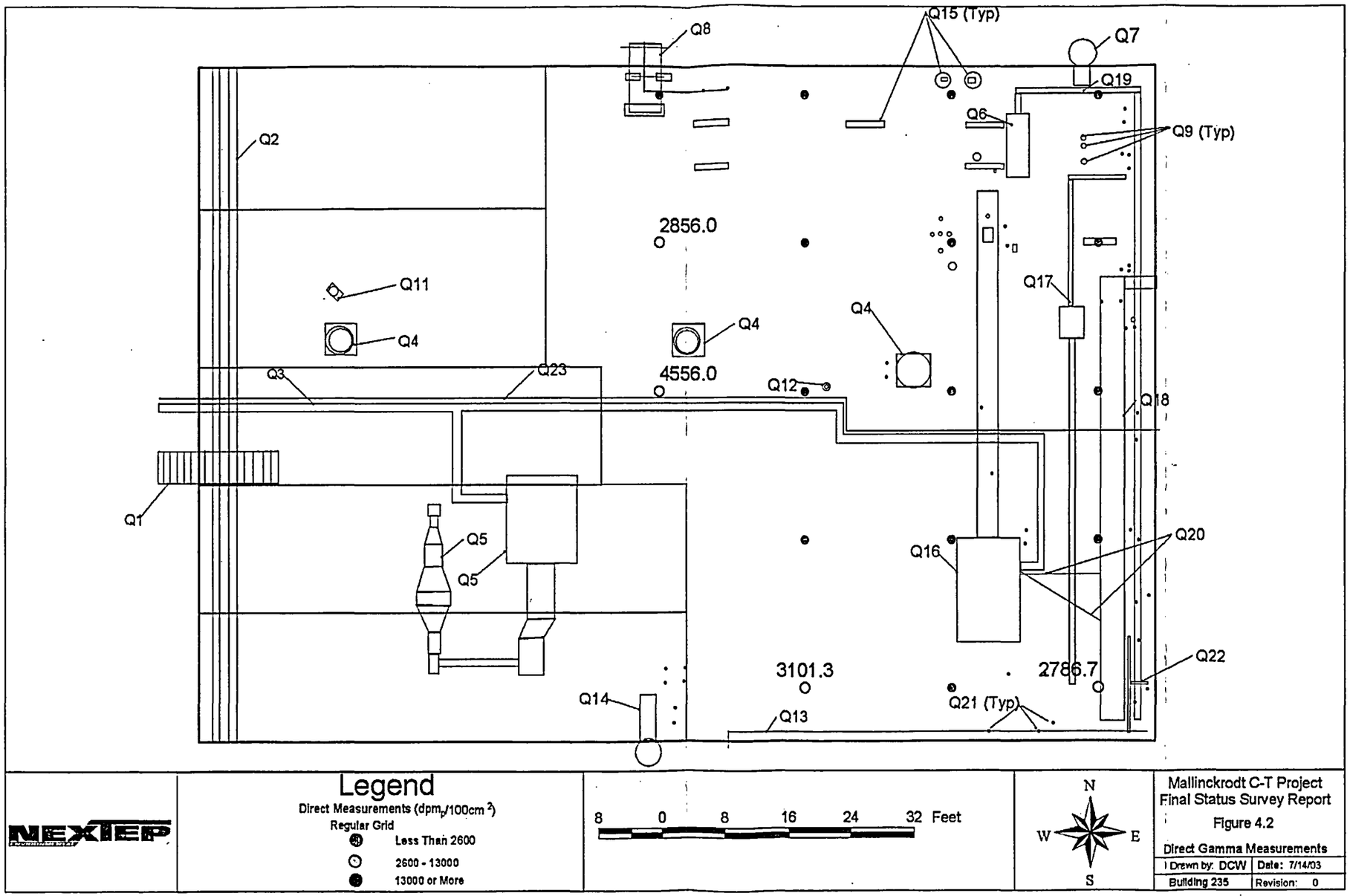
Figure 1.1
Building 235R



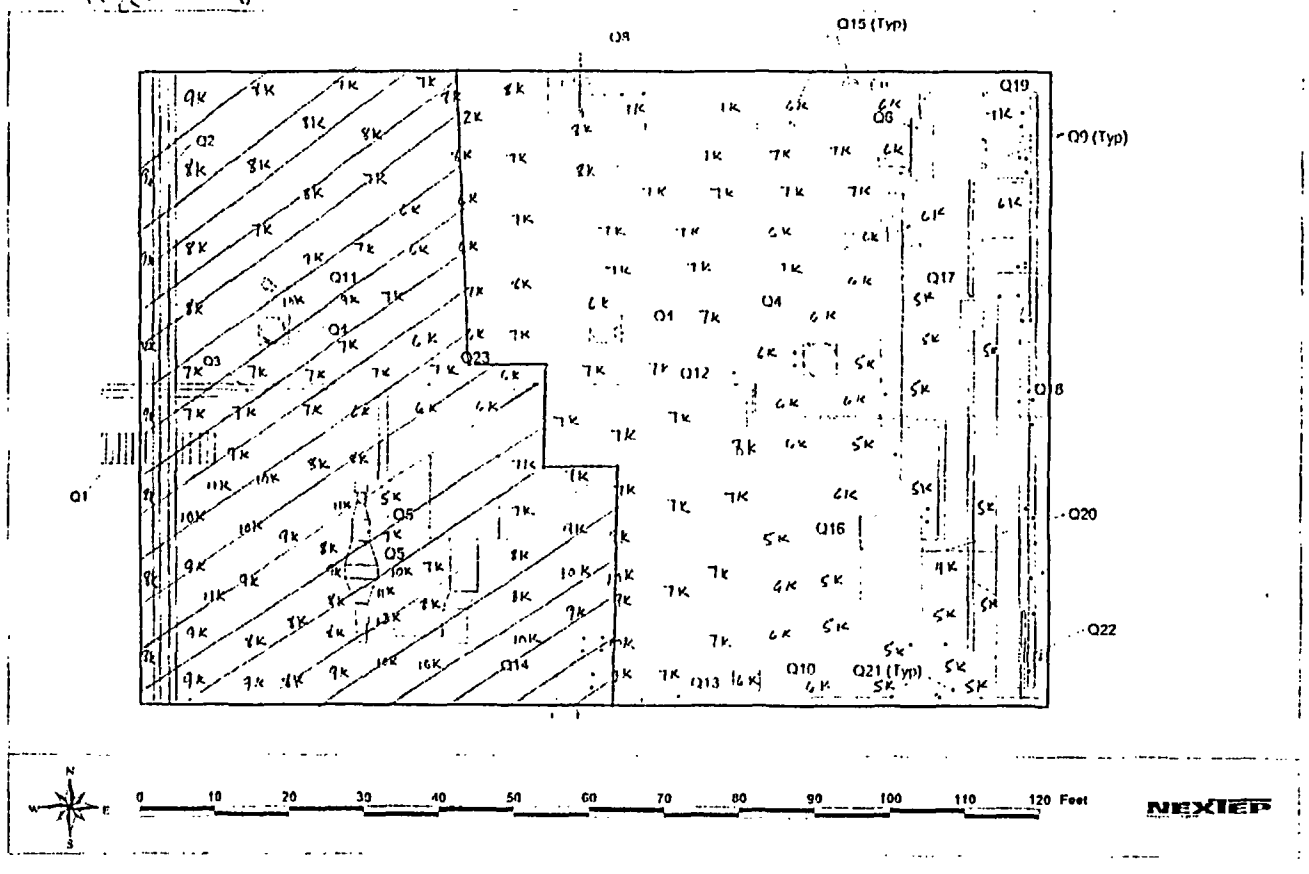
Coordinate System

Figure 3.1


Q8
Q15 (Typ)
Q7
Q19
Q6
Q9 (Typ)
Q2
Q11
Q4
Q4
Q4
Q17
Q3
Q23
Q12
Q18
Q1
Q5
Q5
Q16
Q20
Q22
Q14
Q13
Q21 (Typ)
Legend
Direct Measurements (dpm$_\beta$/100cm^2)
Regular Grid
Less Than 2600
2600 - 13000
13000 or More
Bias
Less Than 2600
2600 - 13000
13000 or More
8 0 8 16 24 32 Feet
N
W
E
S
Mallinckrodt C-T Project
Final Status Survey Report
Figure 4.1
Direct Beta Measurements
Drawn by: DCW
Date: 7/14/03
Building 235
Revision: 0


Q8
Q15 (Typ)
Q7
Q19
Q6
Q9 (Typ)
Q2
2856.0
Q11
Q4
Q4
Q4
Q17
Q3
Q23
4556.0
Q12
Q18
Q1
Q5
Q5
Q16
Q20
Q22
3101.3
2786.7
Q14
Q13
Q21 (Typ)
Legend
Direct Measurements (dpm/100cm²)
Regular Grid
Less Than 2600
2600 - 13000
13000 or More
8 0 8 16 24 32 Feet
N
W
E
S
Mallinckrodt C-T Project
Final Status Survey Report
Figure 4.2
Direct Gamma Measurements
Drawn by: DCW
Date: 7/14/03
Building 235
Revision: 0

Remediated as of 5/1/03 D.C.



page 5 of 5

Figure 4.3
Survey Unit- 235R Gamma Scans (cpm)

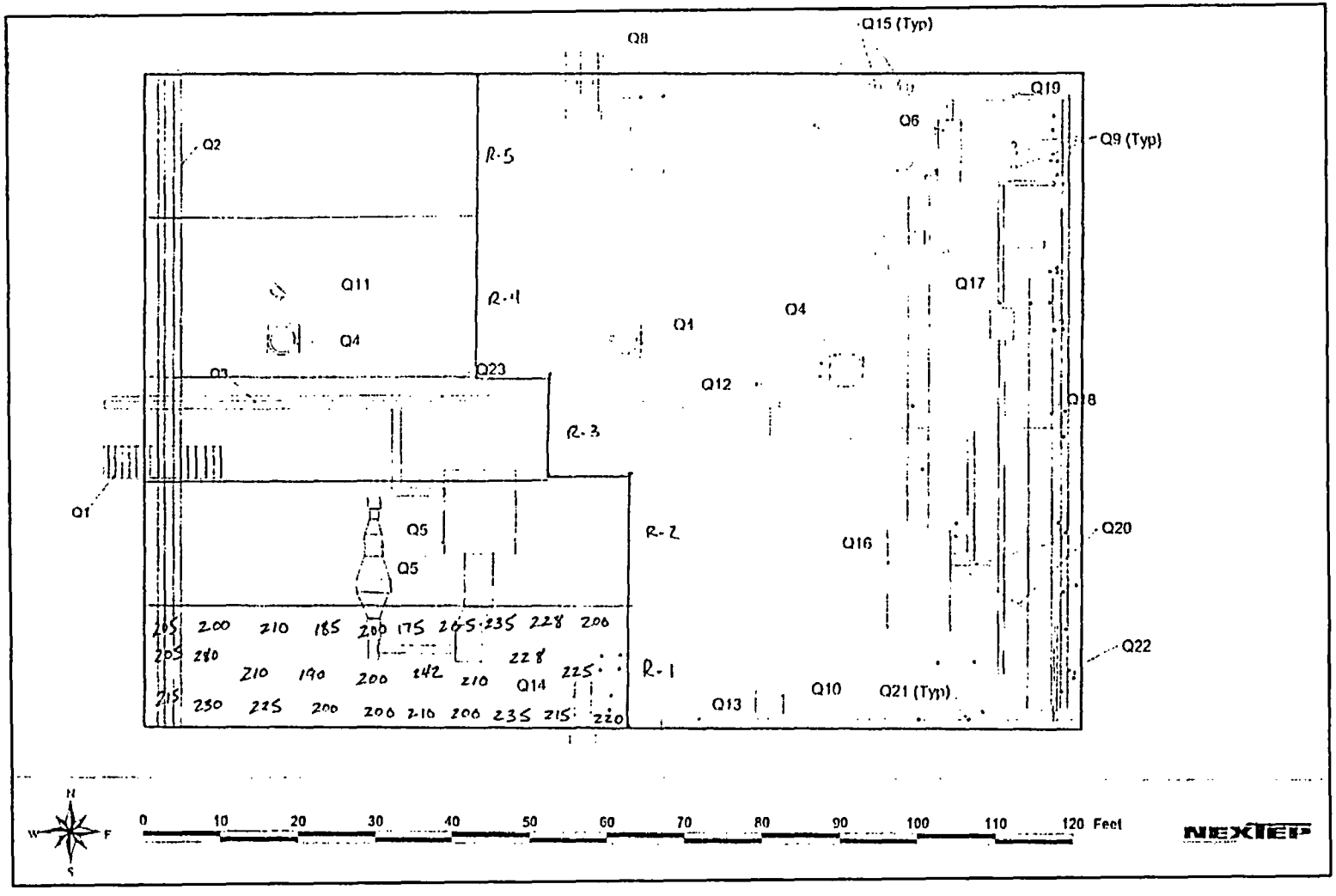


Figure 4.4
Survey Unit- 235R1 Beta Scans (cpm)

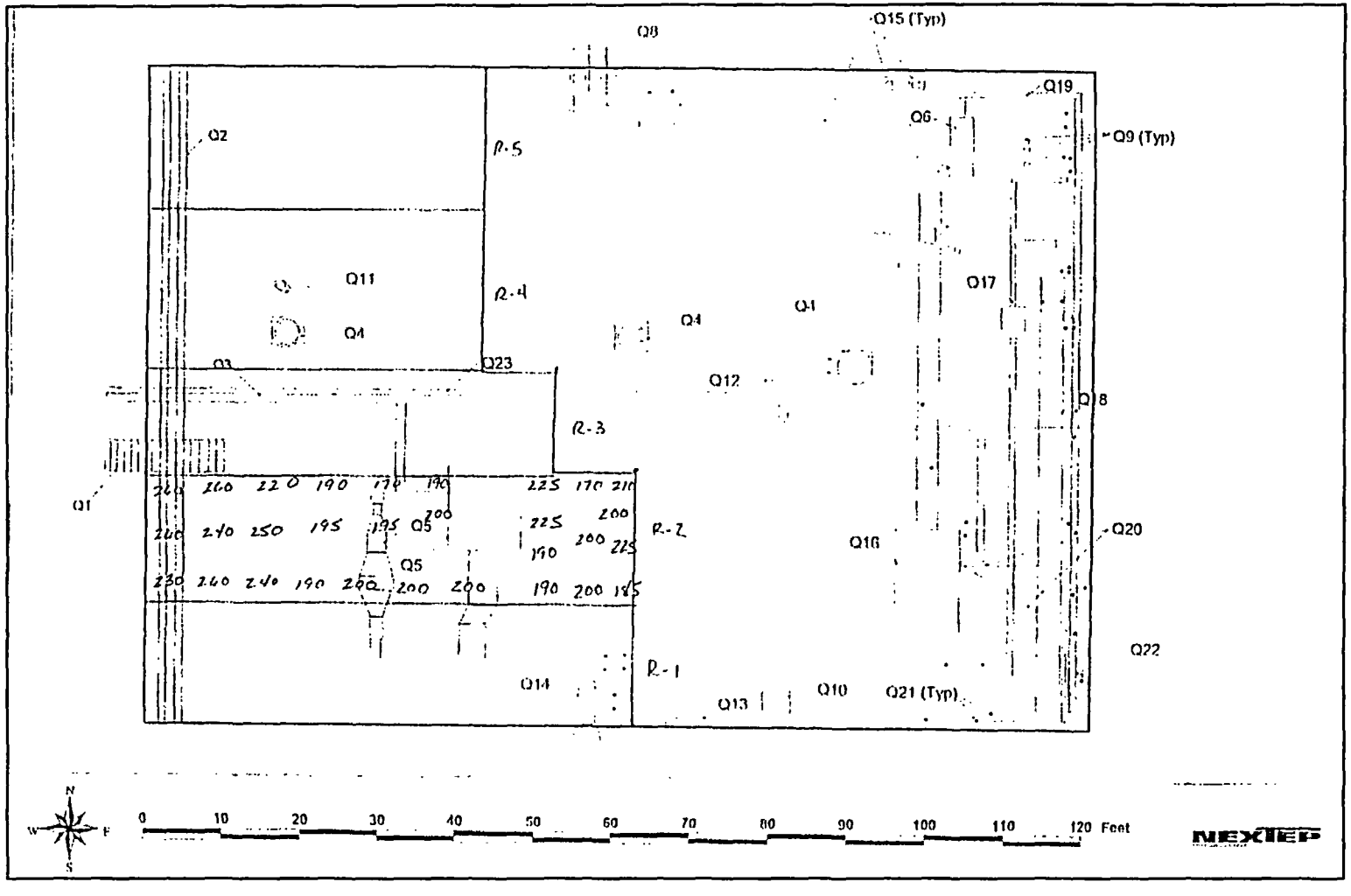


Figure 4.5
Survey Unit- 235R2 Beta Scans (cpm)

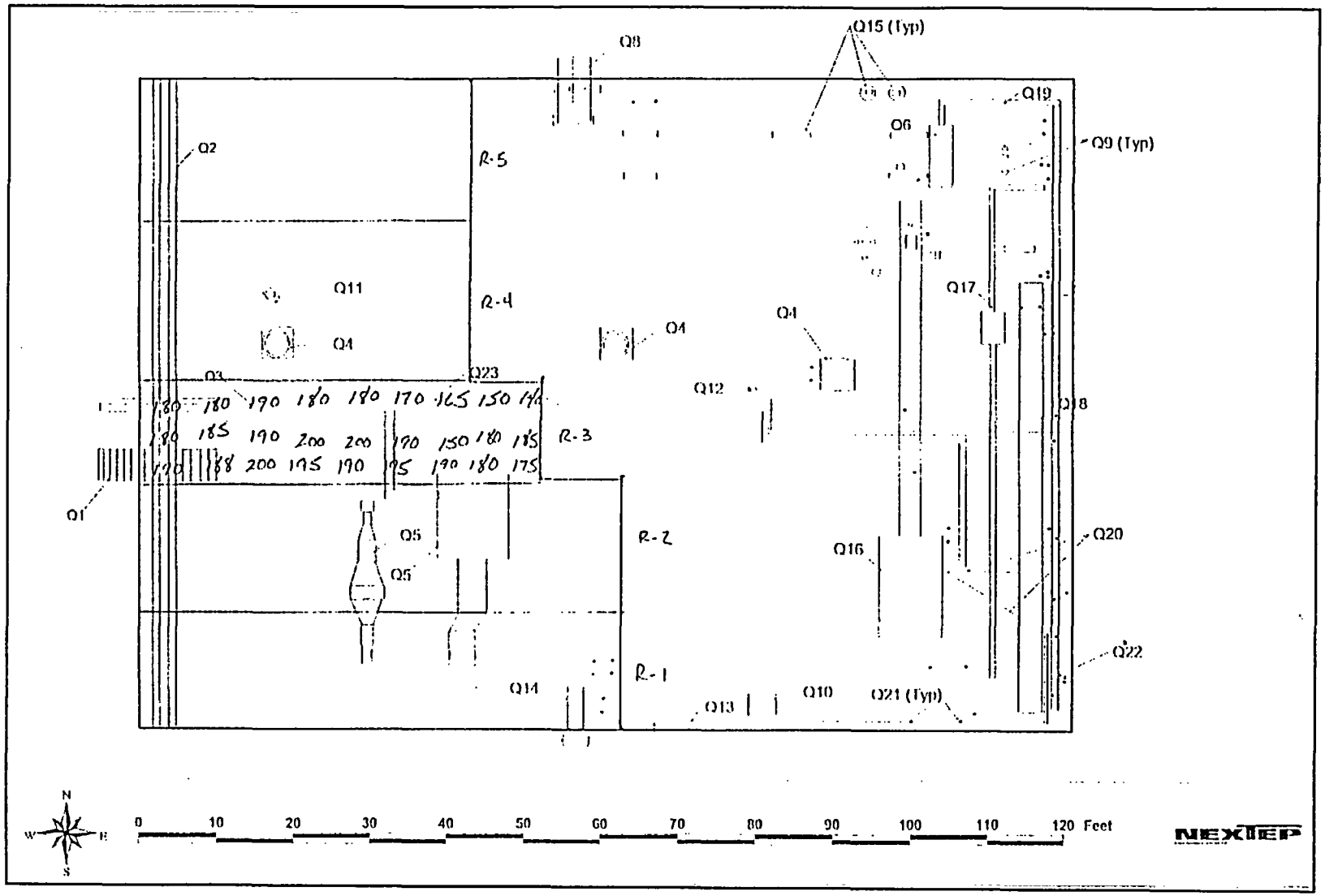


Figure 4.6
Survey Unit- 235R3 Beta Scans (cpm)

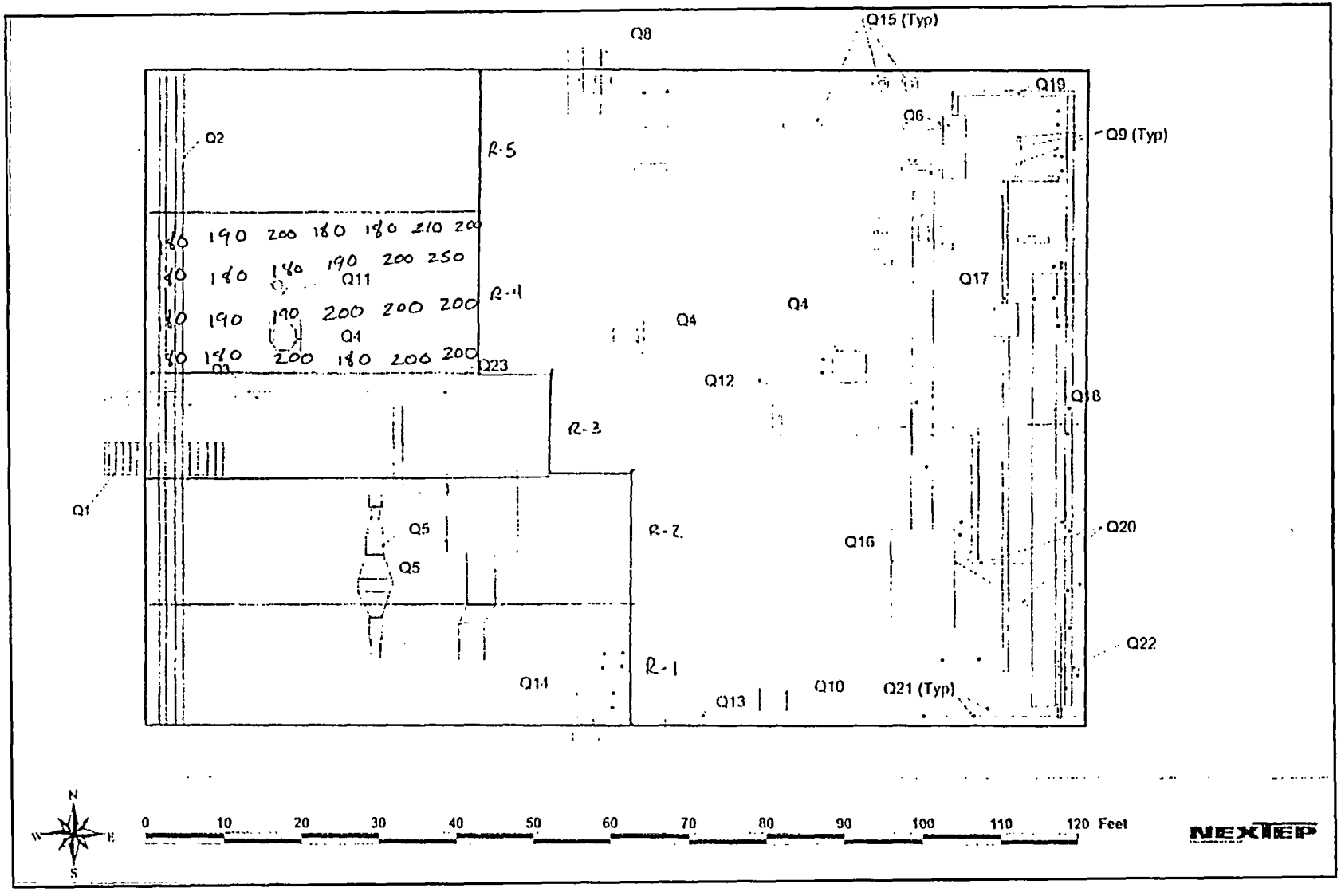


Figure 4.7

Survey Unit-235R4 Beta Scans (cpm)

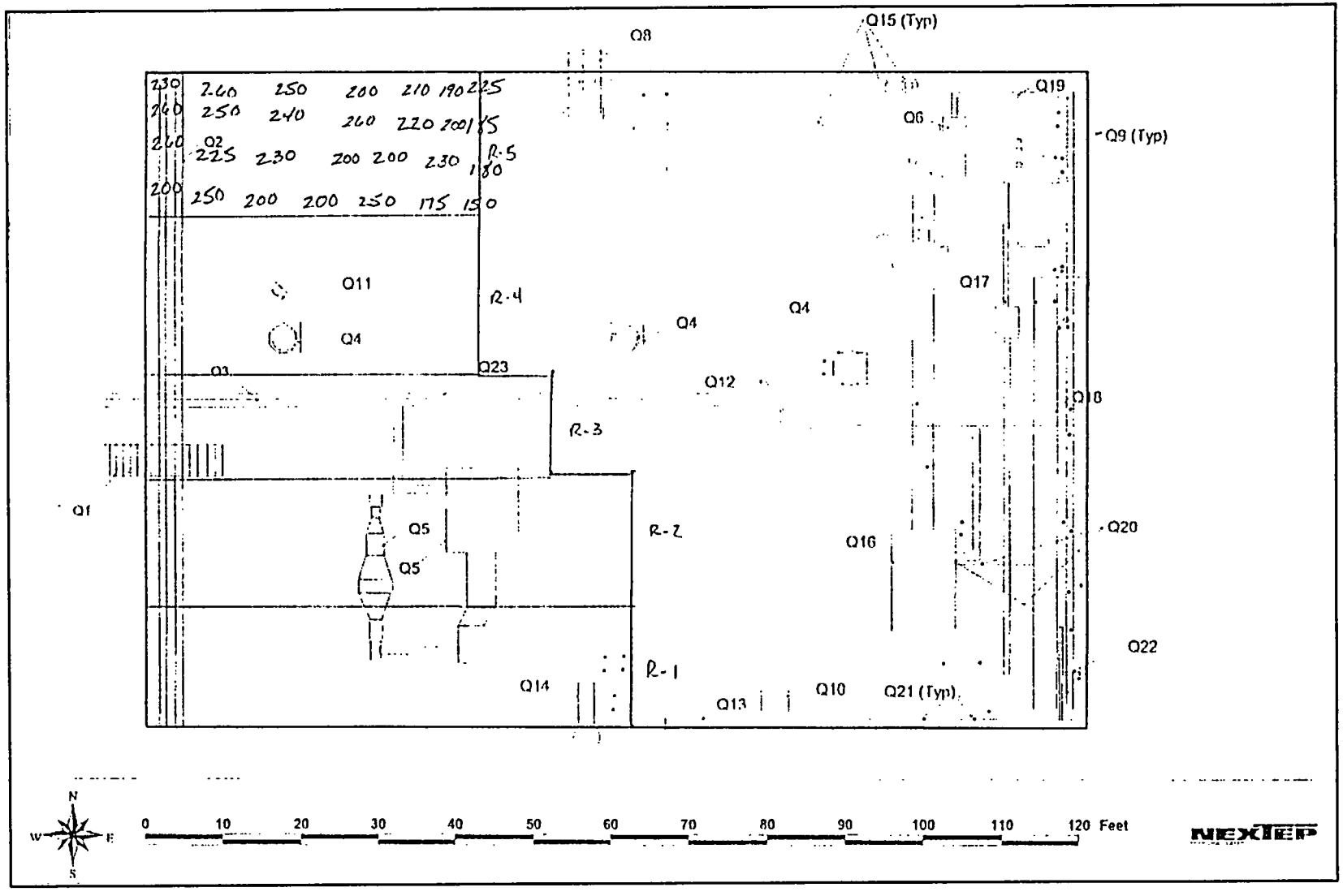


Figure 4.8
Survey Unit-235R5 Beta Scans (cpm)

APPENDIX 3
Calibration Sheets

Instrument Calibration

Instrument: CH-L2000/AB-100 Cal Interval: 6 Months

Serial	Calibration Date	Sensitivity
281	1/5/1995	0.814
B861N	4/12/2000	1.150
	9/18/1999	1.188
	12/15/1997	1.153
	12/16/1996	1.156
	7/18/1996	1.130
	1/18/1996	1.130
	2/23/1995	0.937
	1/18/1995	0.947

Instrument: CH-L2221/AB-100 Cal Interval: 6 Months

Serial	Calibration Date	Sensitivity
446	10/21/1999	1.022
	1/17/1995	0.770
447	10/21/1999	0.921
	1/10/1997	0.889
	1/18/1996	0.739
	11/15/1995	0.553
	1/17/1995	0.675
448	10/6/1996	0.721
	2/22/1996	0.759
	1/17/1995	0.730
B859N	9/7/1999	1.092
	12/16/1997	1.153
	12/16/1996	1.147
	1/18/1996	1.080
	1/6/1995	0.921
B860N	4/12/2000	1.182

Thursday, July 17, 2003 Page 1 of 3

B860N	10/20/1999	**1.139**
	9/18/1999	**1.150**
	12/15/1997	**1.144**
	1/8/1997	**1.109**
	9/5/1996	**1.026**
	3/5/1996	**1.026**
	1/18/1996	**1.089**

Instrument: CH-L2350/AB-100 Cal Interval: 6 Months

Serial	Calibration Date	Sensitivity
B244W	1/1/1996	**0.244**

Instrument: L 3030 Cal Interval: 6 Months

Serial	Calibration Date	Sensitivity
179562	11/8/2002	
179577	2/26/2003	

Instrument: L2221/3X3 Cal Interval: 6 Months

Serial	Calibration Date	Sensitivity
157020	11/8/2002	

Instrument: L2221/AB-100 Cal Interval: 6 Months

Serial	Calibration Date	Sensitivity
117362/425W	10/20/1999	**1.089**
127210/B426W	4/12/2000	**1.199**
127220/B426W	10/6/1999	**1.211**
163666/B426W	1/16/2003	**1.140**
	3/21/2002	**1.013**
	9/12/2001	**0.916**

163666/B426W	9/14/2000	**1.208**

Instrument: L2241-2/43-89 Cal Interval: 6 Months

Serial	Calibration Date	Sensitivity
131410/188707	4/16/2003	**0.560**

Instrument: L2241-2/AB-100 Cal Interval: 6 Months

Serial	Calibration Date	Sensitivity
131410/B860N	11/7/2002	**1.340**
131415/B426W	5/15/2002	**1.128**
	4/11/2001	**1.147**

Instrument: L2350/AB-100 Cal Interval: 6 Months

Serial	Calibration Date	Sensitivity
110648/B425W	5/17/2000	**1.156**
	5/10/1999	**1.179**
	2/11/1998	**1.049**
	11/5/1996	**1.086**

Thursday, July 17, 2003 Page 3 of 3

JUL.16'2003 16:50 314 654 1251 MALLINCKRODT #2114 P.002

of Scientific and Industrial Instruments

CERTIFICATE OF CALIBRATION

LUDLUM MEASUREMENTS, INC.
POST OFFICE BOX 810 PH. 915-235-5494
501 OAK STREET FAX NO. 915-235-4672
SWEETWATER, TEXAS 79556, U.S.A.

CUSTOMER TYCO/HEALTHCARE/MALLINCKRODT ORDER NO. 288367 / 268024

Mfg. Ludlum Measurements, Inc. Model 2221 Serial No. 137050

Mfg. Ludlum Measurements, Inc. Model 43-65 Serial No. PR 154105

Cal. Date 8-Nov-02 Cal Due Date 8-May-03 Cal. Interval 6 Months Meterface 202-159

Check mark ☑ applies to applicable instr. and/or detector IAW mfg. spec. T. 72 °F RH 32 % Alt 699.8 mm Hg

☐ New Instrument Instrument Received ☑ Within Toler. +-10% ☐ 10-20% ☐ Out of Tol. ☐ Requiring Repair ☐ Other-See comments

☑ Mechanical ck. ☑ Meter Zeroed ☐ Background Subtract ☑ Input Sens. Linearity
☑ F/S Resp. ck ☑ Reset ck. ☑ Window Operation ☑ Geotropism
☑ Audio ck. ☐ Alarm Setting ck. ☑ Batt. ck. (Min. Volt) 5.0 VDC

☑ Calibrated in accordance with LMI SOP 14.8 rev 12/05/89. ☐ Calibrated in accordance with LMI SOP 14.9 rev 02/07/97.

Instrument Volt Set 600 V Input Sens. 25 mV Det. Oper. 600 V at 25 mV Threshold Dial Ratio 100 = 10 mV

☑ HV Readout (2 points) Ref./Inst. 498 / 500 V Ref./Inst. 1997 / 2000 V

COMMENTS:
Eff. for Th-230 s/n 9802110121, 2080cpm, read 79(4) cpm = 38% 2pi
Firmware: 66010

Gamma Calibration: G/M detectors positioned perpendicular to source except for M 44-9 in which the front of probe faces source.

RANGE/MULTIPLIER	REFERENCE CAL POINT	INSTRUMENT REC'D "AS FOUND READING"*	INSTRUMENT METER READING*
X 1000	400K cpm	400	400
X 1000	100 K cpm	100	100
X 100	40 K cpm	400	400
X 100	10 K cpm	100	100
X 10	4 K cpm	400	400
X 10	1 K cpm	100	100
X 1	400 cpm	400	400
X 1	100 cpm	100	100

*Uncertainty within ± 10% C.F. within ± 20% ALL Range(s) Calibrated Electronically

	REFERENCE CAL POINT	INSTRUMENT RECEIVED	INSTRUMENT METER READING*		REFERENCE CAL POINT	INSTRUMENT RECEIVED	INSTRUMENT METER READING*
Digital Readout	400 K cpm	399.81	399.81	Log Scale	500 K cpm	450.2	450.4
	40 K cpm	39.949	39.949		50 K cpm	50.2	50.1
	4 K cpm	3.995	3.995		5 K cpm	5.4	5.4
	400 cpm	400	400		500 cpm	500	500
	40 cpm	40	40				

Ludlum Measurements, Inc. certifies that the above instrument has been calibrated by standards traceable to the National Institute of Standards and Technology, or to the calibration facilities of other International Standards Organization members, or have been derived from accepted values of natural physical constants or have been derived by the ratio type of calibration techniques. The calibration system conforms to the requirements of ANSI/NCSL Z540-1-1994 and ANSI N323-1978 State of Texas Calibration License No. LO-1963

Reference Instruments and/or Sources:

Cs-137 Gamma S/N ☐ 1162 ☐ G112 ☐ M565 ☐ S105 ☐ T1008 ☐ T879 ☐ E552 ☐ E551 ☐ Neutron Am-241 Be S/N T-304

☑ Alpha S/N Th-230 ☐ Beta S/N ☐ Other

☑ m 500 S/N 134709 ☐ Oscilloscope S/N ☑ Multimeter S/N 57390613

Calibrated By: [signature] Date 8/10/02

Reviewed By: [signature] Date 11/Nov 02

This certificate shall not be reproduced except in full, without the written approval of Ludlum Measurements, Inc.
FORM C22A 10/31/2001

AC Inst. Only ☐ Passed Dielectric (Hi-Pot) and Continuity Test ☐ Failed:

Designer and Manufacturer of Scientific and Industrial Instruments

LUDLUM MEASUREMENTS, INC.
POST OFFICE BOX 810 PH: 915-235-5494
501 OAK STREET FAX NO. 915-235-4672
SWEETWATER, TEXAS 79556 U.S.A.

Bench Test Data For Alpha Detector

Detector 43-65 Serial No. PR 04/105

Customer TYCO/HEALTHCARE/MALLINCKRODT Order #. 288367 / 268024

Counter 2221 Serial No. 157080 Counter Input Sensitivity 35 mV

Count Time 6 second source, 6 second background Distance Source to Detector Surface

Isotope Th-230 20 dpm Other

43-4/43-44 HV Adjust for Altitude

Altitude	High Voltage
Sea Level	2050 V
1000 foot	2025 V
2000 foot	2000 V
3000 foot	1975 V
4000 foot	1950 V
5000 foot	1925 V
6000 foot	1900 V
7000 foot	1875 V

Alpha Scintillation Detector

HV Plateau	Background	Source Count
500	0	55
550	0	72
600	1	74
650	1	79
700	31	84

Operating Voltage Set at 600 V

Air Proportional	43-5	43-65	43-90	Background	Meter Reading	Range/Scale
Toe	Toe	L/S*	Toe	0	72	
Center	Center	Center	Center	0.1	74	
Heel	Heel	Other**	Heel	0	73	

☑ Uniformity (± 10%) Average Efficiency 35 %

* Least Sensitive Position (Heel of Detector)
** Opposite Least Sensitive Position (Top of Detector)

Signature [signature] Date 8/20/02

FCM C21 01/22/99

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Thermo NUTECH
A ThermoRetec Company
601 Scarboro Road
Oak Ridge, TN 37830

LUDLUM 2221
CALIBRATION DATA SHEET

ThermoRetec
Smart Solutions. Positive Outcomes.

(423) 481-0683 Phone
(423) 481-0121 Fax
www.thermoretec.com

Ludlum2221S/N: 163666 Property Of

Battery Check OK @ 5.6 PHS
Replace @6.4

High Voltage Check

HV Meter: Fluke 29 S/N: 65410232 Cal Exp. Date 1-30-03

Meter Reading	Pre Cal	Post Cal	Tolerance
600 Volts	660	605	10 %
1000 Volts	1100	1003	10 %
1400 Volts	1540	1410	10 %

Input Sensitivity:

(Threshold @ 10 mv) Pre Cal: 35 mv , Post Cal: 35 mv
MP-2 S/N: 684 Calibration Exp. Date: 1-29-03

Rate/ Meter	MP-2	2221	Display Digital	Display Analog	Tol
400 CPM	x1		400	400	10%
4K CPM	x10		3998	4000	10%
40K CPM	x100		39999	40000	10%
400K CPM	x1000		400080	400000	10%
Scaler:					
100K CPM		0.5 sec	50010	100000	10%
100K CPM		1.0 min	100020		10%
100K CPM		2.0 min	200039		10%
100K CPM		5.0 min	500097		10%

Log 400 400 4K 4K 40K 40K 400k 400k

Functional Check:

Ext Count ✓ Reset ✓ Speaker ✓ Headphones ✓ Light ✓

Date Of Calibration: 1-16-03 Expiration Date: 7-16-03

Calibrated By: Randall H. Selk (Print) (Signature)

Reviewed By: M A Date: 1/30/03

A subsidiary of Thermo TerraTech Inc.,
a Thermo Electron company

Thermo NUtech
For Mallinckrodt Chemical, Inc

NATIONAL NUCLEAR ABP-100
MATERIAL SPECIFIC CALIBRATION DATA SHEET

ABP-100 SN: B426W HIGH VOLTAGE: 875 V PROPERTY OF: ~~TYCO~~ RHS E.S.

READOUT INST: Lud 2221 SN: 163666 CAL EXPIRE DATE: 7-16-03

ABP-100 EFFICIENCY TO SrY-90 ON 47 mm DISK: 42.0 % CAL DATE: 1-22-03

SURFACE MATERIAL	BACKGROUND OPEN Cts/2 min	BACKGROUND SHIELD Cts/2 min	BR NET CPM	SOURCE OPEN Cts/1 min	SOURCE SHIELD Cts/1 min	SR NET CPM		SA Source #	SA Source Activity	Efficiency SR-BR/SA
Concrete	561	416	73	6857	232	6625		6-A	33250	19.9
				6853	246	6607				19.9
				6846	242	6601				19.9
				6784	236	6548				19.7
266 X 125 = ~~335~~ 215 dpm 33250									Average =	19.9
									Std Dev =	0.1
Wood	0	0	0	5222	238	4984		M-2	22250	22.4
	0	0	0	5281	240	5041				22.3
	0	0	0	5181	224	4957				22.3
	0	0	0	5296	232	5064				22.8
178 dpm X 125 = 22250									Average =	22.5
									Std Dev =	0.2
Masonite	0	0	0	5296	232	5064		M-2	22250	22.8
	0	0	0	5302	234	5068				22.8
	0	0	0	5311	248	5063				22.8
	0	0	0	5366	236	5130				23.1
178 dpm x 125 = 22250									Average =	22.9
									Std Dev =	0.2
Aluminum	0	0	0	6037	223	5814		M-2	22250	26.1
	0	0	0	5706	236	5470				24.6
	0	0	0	6013	248	5765				25.9
	0	0	0	5892	227	5665				25.5
178 dpm x 125 = 22250									Average =	25.5
									Std Dev =	0.7

DATE OF CALIBRATION: 1-29-03 EXPIRATION DATE: 7-29-03

CALIBRATED BY: Randall H. Sells (Print Name) Randall H. Sells (Signature)

REVIEWED BY: [signature] DATE: 11-30-03

LUDLUM MEASUREMENTS, INC.
POST OFFICE BOX 810 PH. 915-235-5494
501 OAK STREET FAX NO. 915-235-4672
SWEETWATER, TEXAS 79556, U.S.A.

of Scientific and Industrial Instruments

CERTIFICATE OF CALIBRATION

CUSTOMER TYCO / MALLINCKRODT ORDER NO. 292439 / 270031

Mfg. Ludlum Measurements, Inc. Model 3030 Serial No. 179577

Cal. Date 26-Feb-03 Cal Due Date 26-Aug-03 Cal. Interval 6 Months

Check mark ☑ applies to applicable instr. and/or detector IAW mfg. spec. T. 72 °F RH 20 % Alt 701.8 mm Hg

☐ New Instrument Instrument Received ☑ Within Toler. +-10% ☐ 10-20% ☐ Out of Tol. ☐ Requiring Repair ☐ Other-See comments

☑ Mechanical ck. ☑ Window Operation

☑ Audio ck.

Alpha Sensitivity 120 mV Beta Sensitivity 4 mV Beta Window 50 mV

☑ Calibrated in accordance with LMI SOP 14.8 rev 12/05/89.

Instrument Volt Set 725 V High Voltage set with detector connected.

☑ HV Readout (2 points) Ref./Inst. 498 / 500 V Ref./Inst. 1486 / 1500 V

QC mode turned OFF.

Firmware version: 390/2412

Overload set at 1/4 turn past OFF.

Battery voltage measured at 13.27 Vdc.

C-14 Efficiency = 11 %(4 pi) Net

(EEPROM Settings)

(PC) Count Time: 1.0

Alpha Alarm: 999999 cpm

Beta Alarm: 999999 cpm

Alpha/Beta Alarm: 999999 cpm

Calibration Due Date: 08/26/2003

LOC (Loss of Count) time = 30 minutes (default)

	REFERENCE CAL POINT	INSTRUMENT RECEIVED	INSTRUMENT METER READING*
Alpha Channel Digital Readout	400K cpm	399414	399414
	40K cpm	39944	39944
	4K cpm	3995	3995
	400 cpm	400	400
	40 cpm	40	40

	REFERENCE CAL POINT	INSTRUMENT RECEIVED	INSTRUMENT METER READING*
Beta/Gamma Channel Digital Readout	400K cpm	399439	399439
	40K cpm	39945	39945
	4K cpm	3995	3995
	400 cpm	400	400
	40 cpm	40	40

*Uncertainty within ± 10% C.F. within ± 20% (D) Indicates 0.1 minute count

COMMENTS:
Eff. for Sr-90/Y-90 S/N 4036, 445Kcpm, read 28782 in one minute = 60% Eff
Eff. for Tl-204 S/N 2348-00, 3000 cpm, read 2444 in one minute = 80% Eff

Ludlum Measurements, Inc. certifies that the above instrument has been calibrated by standards traceable to the National Institute of Standards and Technology, or to the calibration facilities of other International Standards Organization members, or have been derived from accepted values of natural physical constants or have been derived by the ratio type of calibration techniques. The calibration system conforms to the requirements of ANSI/NCSL Z540-1-1994 and ANSI N323-1978. State of Texas Calibration License No. LO-1963

Reference Instruments and/or Sources:

☑ Alpha S/N Pu-239 3944 ☑ Beta S/N Tc-99 Ni-63 ☐ Other

☑ m 500 S/N 134709 ☐ Oscilloscope S/N ☐ Multimeter S/N

Calibrated By: Conrad Galindo Date 26 Feb 03

Reviewed By: Shah Hani Date 4 March 03

This certificate shall not be reproduced except in full without the written approval of Ludlum Measurements, Inc.
FORM C25-3 10/02/2002

AC Inst. Only ☑ Passed Dielectric (Hi-Pot) and Continuity Test ☐ Failed:

Lucium Measurements, Inc.

Model 3030 Plateau Data

2/26/03
1:38:50 PM

Header 1: John Q Public
Header 2: Serial4179577
Header 3: Site:Building 1
Header 4: Room 7 EastWall
Header 5: More Comments?
Header 6: More Comments?

Calibration Due Date: 2/26/04

Model 3030 Date: 2/26/03
Model 3030 Time: 11:42:00 AM

User PC Time: 1.0

Alpha Isotope: Pu-239
Alpha Source Size (dpm): 365000
Alpha Source Size (µCi): 0.164414414

Beta Isotope: Tc-99
Beta Source Size (dpm): 22600
Beta Source Size (µCi): 0.01018018

Starting High Voltage: 675
Starting High Voltage: 800
High Voltage Increment: 25

Plateau Count Mode: SCALER
Source Count Time (min): 0001.0
Background Count Time (min): 1.0

	ALPHA				BETA			
HV	Source (Beta)	Background	Eff	CrossTalk	Source (Alpha)	Background	Eff	Crosstalk
675	137685 (3889)	0	37.7%	2.8%	6010 (1)	36	26.4%	0.0%
700	137877 (3657)	0	37.8%	2.6%	6966 (1)	45	30.6%	0.0%
725	138583 (2500)	2	38.0%	1.8%	7969 (1)	49	35.0%	0.0%
750	137851 (1483)	0	37.8%	1.0%	8551 (3)	50	37.6%	0.0%
775	137047 (1071)	1	37.5%	0.7%	9470 (1)	70	41.6%	0.0%
800	137105 (783)	1	37.6%	0.4%	10082 (2)	203	43.7%	0.0%

Model 3650 MDA Calculation Data

2/26/03
14:39:06 PM

Alpha Background(cpm): 1.0
Beta Background(cpm): 49.0

Alpha Efficiency %: 48.0
Beta Efficiency %: 36.0

Confidence Level: 95%

Count Time	Alpha MDA(dpm)	Beta MDA(dpm)
0.1	111.9	295.7
0.5	35.3	129.5
1.0	24.4	100.8
2.0	18.6	84.5
5.0	14.8	73.6
10.0	13.6	69.8
60.0	12.5	66.5
PC (1.0)	24.4	100.8

Designer and Manufacturer of Scientific and Industrial Instruments

LUDLUM MEASUREMENTS, INC.
POST OFFICE BOX 810 PH. 915-235-5494
501 OAK STREET FAX NO. 915-235-4672
SWEETWATER, TEXAS 79556 U.S.A.

CERTIFICATE OF CALIBRATION

CUSTOMER TYCO/HEALTHCARE/MALLINCKRODT ORDER NO. 288367 / 268024

Mfg. Ludlum Measurements, Inc. Model 3030 Serial No. 179568

Cal. Date 8-Nov-02 Cal Due Date 8-May-03 Cal. Interval 6 Months

Check mark ☑ applies to applicable instr. and/or detector IAW mfg. spec. T. 72 °F. RH 32 % Alt 699.8 mm Hg

☐ New Instrument Instrument Received ☑ Within Toler. +-10% ☐ 10-20% ☐ Out of Tol. ☐ Requiring Repair ☐ Other-See comments

☑ Mechanical ck. ☑ Window Operation

☑ Audio ck.

Alpha Sensitivity 120 mV Beta Sensitivity 4 mV Beta Window 60 mV

☑ Calibrated in accordance with LMI SOP 14.8 rev 12/05/89.

Instrument Volt Set 625 V High Voltage set with detector connected.

☑ HV Readout (2 points) Ref./Inst. 499 / 500 V Ref./Inst. 1506 / 1500 V

Instrument in DPM mode.
QC mode turned OFF.
Firmware version: 2801/10
Overload set at 1/4 turn past OFF.
Battery voltage measured at 12.40 Vdc.
C-14 Efficiency = 9 %(4 pi) Net

(EEPROM Settings)
(PC) Count Time: 10
Alpha Alarm: 50000 cpm
Beta Alarm: 50000 cpm
Alpha/Beta Alarm: 50000 cpm
Calibration Due Date: 8 May 03
LOC (Loss of Count) time = 30 minutes (default)

	REFERENCE CAL POINT	INSTRUMENT RECEIVED	INSTRUMENT METER READING*
Alpha Channel Digital Readout	400K cpm	399264	399264
	40K cpm	39927	39927
	4K cpm	3993	3993
	400 cpm	400	400
	40 cpm	40	40

	REFERENCE CAL POINT	INSTRUMENT RECEIVED	INSTRUMENT METER READING*
Beta/Gamma Channel Digital Readout	400K cpm	399449	399449
	40K cpm	39950	39950
	4K cpm	3995	3995
	400 cpm	400	400
	40 cpm	40	40

*Uncertainty within ± 10% C.F. within ± 20% (D) Indicates 0.1 minute count

COMMENTS:
Eff. for Th-230 s/n 2748-00, 3070cpm, read 1155 in 1 minute = 80% 2pi

Ludlum Measurements, Inc. certifies that the above instrument has been calibrated by standards traceable to the National Institute of Standards and Technology, or to the calibration facilities of other International Standards Organization members, or have been derived from accepted values of natural physical constants or have been derived by the ratio type of calibration techniques. The calibration system conforms to the requirements of ANSI/NCSL Z540-1-1994 and ANSI N323-1978. State of Texas Calibration License No. LO-1963

Reference Instruments and/or Sources:

☑ Alpha S/N Th-230 2748-00, Z-138 [illegible] ☑ Beta S/N Tc-99 Ni-63 ☐ Other

☑ m 500 S/N 134709 ☐ Oscilloscope S/N ☐ Multimeter S/N

Calibrated By: Conrad [illegible] Date 8 Nov 02

Reviewed By: Rhonda Harris Date 11 Nov 02

This certificate shall not be reproduced except in full, without the written approval of Ludlum Measurements, Inc.
FORM C25-2 05/03/2002

AC Inst. Only ☐ Passed Dielectric (Hi-Pot) and Continuity Test ☐ Failed:

JUL.16'2003 16:53 314 654 1251 MALLINCKRODT #2114 P.011

Ludlum Measurements, Inc.
Model 3030 Plateau Data

11/11/02
11:25:35 AM

Header 1: John Q Public
Header 2: Serial#179562
Header 3: Site:Building 1
Header 4: Room 7 Eastwall
Header 5: More Comments?
Header 6: More Comments?

Calibration Due Date: 5/8/03

Model 3030 Date: 11/8/02
Model 3030 Time: 10:16:23 AM

User PC Time: 1.0

Alpha Isotope: Pu-239
Alpha Source Size (dpm): 25200
Alpha Source Size (µCi): 0.011351351

Beta Isotope: Tc-99
Beta Source Size (dpm): 22600
Beta Source Size (µCi): 0.01018018

Starting High Voltage: 625
Starting High Voltage: 750
High Voltage Increment: 25

Plateau Count Mode: SCALER
Source Count Time (min): 0001.0
Background Count Time (min): 1.0

	ALPHA				BETA			
HV	Source (Beta)	Background	Eff	CrossTalk	Source (Alpha)	Background	Eff	Crosstalk
625	9306 (348)	1	36.9%	3.5%	5347 (10)	25	23.5%	0.0%
650	9467 (311)	2	37.6%	2.9%	6243 (4)	40	27.6%	0.0%
675	9632 (328)	3	38.2%	3.0%	7209 (3)	41	31.7%	0.0%
700	9755 (340)	5	38.7%	3.0%	8087 (1)	43	35.6%	0.0%
725	9627 (267)	2	38.2%	2.1%	8928 (3)	68	39.2%	0.0%
750	9773 (316)	3	38.8%	1.4%	9646 (3)	183	41.9%	0.0%

JUL.16'2003 16:53 314 654 1251 MALLINCKRODT #2114 P.010

Ludlum Measurements, Inc.
Model 3030 MDA Calculation Data

11/11/02
11:26:19 AM

Alpha Background(cpm): 3.0
Beta Background(cpm): 41.0

Alpha Efficiency %: 38.2
Beta Efficiency %: 31.7

Confidence Level: 95%

Count Time	Alpha MDA(dpm)	Beta MDA(dpm)
0.1	120.4	305.9
0.5	40.0	132.2
1.0	28.2	102.5
2.0	21.8	85.7
5.0	17.8	74.5
10.0	16.4	70.6
50.0	15.2	67.1
2C (1.0)	28.2	102.5

APPENDIX 4

Technical Memorandum 02-30

Revision 2

Technical Basis Document for MI FSS

NEXTEP Environmental

808 Lyndon Lane, Suite #201
Louisville, KY 40222

Phone: (502) 339-9767
Fax: (502) 339-9275

TECHNICAL MEMORANDUM 02-30

June 18, 2003

Originator: A.H. Thatcher, CHP, Senior HP Scientist

Subject: Technical Basis Document for Mallinckrodt Final Status Surveys

Revision: 2

ENDORSEMENT: This document contains the results of research and technical analysis which have been reviewed and approved for publication by the Technical Director, NEXTEP Environmental, Inc. All calculations have been reviewed and confirmed in accordance with CT-QA-4.2.

Harry J. Newman, CHP, Technical Director — Date

Introduction:

This document provides the technical basis for calculations for the Final Status Survey Plan for building surfaces. This document specifically addresses the following issues:

- Required and calculated MDC for direct beta measurements
- Required and calculated scan MDC for beta measurements
- Investigation thresholds for direct and scan beta measurements
- Required and calculated MDC for direct gamma measurements
- Required and calculated scan MDC for gamma measurements
- Investigation thresholds for direct and scan gamma measurements

Calculated and Required MDC for Direct Beta Measurements

For Class 1, 2, and 3 survey units, the required MDC for direct beta measurements is 50% of the Administrative Release Guideline (ARG), or 1,300 $dpm_p/100\ cm^2$. Direct beta measurements for final status surveys will include an open and closed window measurement at the location of interest and a matrix specific background open and closed window measurement. The formulas for calculating the MDC are provided in Attachment 6.1-2 of CT-QA-6.1. In most instances for final status surveys, background count times will be greater than the sample count times. Equation 1 provides the formula for unequal count times for an AB-100 detector39:

Equation 1

$$MDC = \frac{3 + 3.29\sqrt{R_b\, t_{s+b}\left(1 + \frac{t_{s+b}}{t_b}\right)}}{S_i\, S_b\, t_{s+b}} = 100\ dpm_p\ /100cm^2$$

Where:

R_b = Sum of open and closed window background counting rates (cpm), 552 cpm and 354 cpm, respectively40

S_b = Matrix Specific Backscatter Factor (1.0 for brick)41

S_i = Instrument sensitivity for the AB-100 ($cpm/dpm_p/100cm^2$)= 1.099742

t_b = Background count time (5 minutes)

t_{s+b} = Sample count time (1 minute)

The formula was applied to the background data on file for a brick matrix (the matrix with the highest background count) and therefore represents a conservative estimate of MDC. The resulting MDC for beta measurements assuming a brick matrix is 100 $dpm_p/100\ cm^2$ and is less than the required MDC of 1,300 $dpm_p/100\ cm^2$.

Investigation Threshold for Direct Beta Measurements

39 CT-QA-6.1, Calibration and Control of Measuring and Survey Equipment.

40 The open and closed window cpm are the site average of 30 open and closed window background measurements recorded for a brick matrix material. These data were collected using 5 minute count times.

41 NEXTEP Tech Memo 0213, *Beta Backscatter Factors for Several Materials at the Mallinckrodt Site,* N. Zhang and D. Wilson.

42 NEXTEP Tec Memo 0215, *Separation of Backscatter Factor and Derivation of Instrument Sensitivity,* A. H. Thatcher. 1.0997 is the average instrument sensitivity for the brick matrix background data set on file.

The investigation threshold for direct beta measurements for a class 1 or 2 Survey Unit is simply the ARG in dpm/100 cm² converted to cpm by taking into consideration the matrix specific backscatter factor and the instrument sensitivity. For the brick background used in the calculations, the result is:

Equation 2

Investigation Threshold for direct beta measurements = $ARG * S_i * S_b = 2{,}900 cpm$

The 2,900 cpm investigation value is net of background.

The Investigation threshold for a class 3 survey unit is the greater of the mean background (in cpm) plus two standard deviations or the MDC.

Scan MDC for Beta Measurements

For Class 1 survey units, the required MDC for beta scan measurements is equal to the ARG_{EMC} (13,000 dpm_p/100 cm²). For Class 2 and 3 survey units, the required MDC should be equal to or less than the ARG, or 2,600 dpm_p/100 cm². The formula for calculating the Scan MDC (for a brick background) for the same detector is given by Equations 3 and 4:

The minimum detectable net count rate (MDCR) of a scanning instrument43 is

Equation 3

$$MDCR = d'\sqrt{b_i} \cdot \frac{60}{i} = 180\ cpm$$

Where for the AB-100:

MDCR	=	minimum detectable net count rate (ct/min)
d'	=	1.38 when decision error, (α) = 0.60, and correct decision fraction, (1-β) = 0.9544
i	=	observation interval (sec) = (detector area)$^{1/2}$/scan speed45 = 2 sec
b_i	=	background counts in observation interval (552 cpm/(2/60) = 18.4 cts) 46
60	=	conversion, 60 (sec/min)

43 Abelquist. E.W., et.al., Minimum Detectable Concentrations with Typical Radiation Survey Instruments for Various Contaminants and Field Conditions, NUREG-1507, §6.1, Dec. 1997.

44 Abelquist, E.W., Table 6.1 p 6.23

45 Using the most conservative detector area of 110cm² and a scan speed of 5.1 cm/sec, $i = \frac{\sqrt{110}}{5.1} = 2\,\text{sec}$

46 552 cpm is the average open window count rate for background measurements on file that were taken on a brick matrix material.

Based upon the calculated MDCR of 180 cpm, the Scan MDC for the AB-100 is:

Equation 4

$$Scan\ MDC = \frac{MDCR}{\sqrt{p}\, S_i\, S_b\, E_s} = 760\ dpm_p / 100cm^2$$

Where:

p = Surveyor efficiency, assumed47 to be 0.5.

E_s = Surface Efficiency (0.3)48

Given a probe observation interval of 2 second (representing a first pass scan), the corresponding Scan MDC equals 760 $dpm_p/100cm^2$ and is less than the lowest required Scan MDC of 2,600 $dpm_p/100cm^2$.

Investigation Level for Beta Scans

The investigation threshold for a class 1 or 2 survey unit is the direct measurement investigation threshold multiplied by surveyor efficiency. For the AB-100 on a brick matrix, the calculation of the investigation level is as follows:

Equation 5

Investigation Threshold for beta scan measurements (Class 1 or 2) =

$$ARG * S_i * S_b * \sqrt{p} = 2{,}000\ cpm$$

For a class 3 survey unit, the investigation threshold is the greater of the MDC or the matrix mean background plus two standard deviations. The background threshold would generally be the greater value (in cpm). For a brick background, this is approximately 700 cpm49.

Direct MDC for Gamma Measurements on Building Surfaces

For Class 1, 2 and 3 survey units, the required MDC for direct measurements is 50% of the Administrative Release Guideline (ARG), or 1,300 $dpm_p/100\ cm^2$. Several building roofs and

47 Abelquist, E.W., et.al., §6.7.1.

48 Table 5.3, NUREG 1507. 0.3 represents a beta source efficiency for a distributed source on sealed concrete.

49 Using the brick background open window average value of 552 cpm +(2*71 cpm) = 700 cpm.

internal surfaces are covered by material that makes it necessary to determine compliance by gamma measurements as opposed to beta measurements. Using the most conservative derived gamma conversion factor for direct measurements50, the calculated direct MDC for gamma measurements is as follows:

The calculated MDC for gamma measurements uses a modified Equation 1:

Equation 6

$$\text{Calculated Gamma Direct MDC} = \frac{2.71 + 3.29 * \sigma_b * \sqrt{\left(1 + \frac{t_{s+b}}{t_b}\right)}}{F_g * t_{s+b}} \left(dpm_p / 100cm^2\right)$$

Where:

σ_b = Shielded gamma background sample standard deviation51 (196 cpm)

F_g = gamma conversion factor52

t_b = Background count time (5 minutes)

t_{s+b} = Sample count time (1 minute)

The estimated Direct MDC for a gravel roof is 1,500 $dpm_p/100\ cm^2$ and is slightly greater than 50% of the ARG53. For a configuration without the gravel, equation 6 results in an estimated Direct MDC of 950 $dpm_p/100\ cm^2$, well less than 50% of the ARG.

Investigation Threshold for Direct Gamma Measurements

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50 NEXTEP Tech Memo 0229, *MCNP Gamma Modeling for Mallinckrodt Roof Surface,* N. Zhang and D. Thatcher. And NEXTEP Tech Memo 0317, *Use of the 3" x 3" NaI Detector for Measurement of Contamination on Concrete through Vinyl Tile and Carpet,* N. Zhang.

51 The sample standard deviation is based upon 5 measurements obtained on Building 25. See Appendix A.

52 0.48 $cpm/dpm_p/100cm^2$ for a gravel roof; 0.75 $cpm/dpm_p/100cm^2$ for a non-gravel roof.

53 Although the roof configuration slightly exceeds the criteria of 50% of the ARG, the actual requirement is 50% of the $DCGL_w$. The Direct MDC is 11.5% of the $DCGL_w$.

The investigation threshold for direct gamma measurements for a class 1 or 2 survey unit is the ARG in dpm/100 cm² converted to cpm by using the gamma conversion factor. For the most conservative conversion factor from TM 0229 of 0.48 cpm/dpm$_p$/100 cm²:

Equation 7

Investigation Threshold for roofs without a gravel layer for direct gamma measurements for a class 1 or class 2 survey unit =

$$ARG * F_g = 1{,}950\, cpm$$

The Investigation threshold for roofs with a gravel layer is similarly calculated as 1,250 cpm for a Class 1 or 2 survey unit.

For a class 3 survey unit for roofs without a gravel layer, the investigation threshold will generally be the calculated MDC of 950 cpm as this will be greater than the mean background plus two standard deviations value.

Scan MDC for Gamma Measurements

The required MDC for gamma scan measurements for class 1 or 2 survey units should be equal to or less than the ARG, or 2,600 dpm$_p$/100 cm². The calculations below utilize the background from building 25 and the lowest conversion factor for scan measurements derived from TM 0229 or TM 031754 and can therefore apply to all gamma scans performed. The formula for calculating the Scan MDC is provided by equations 9 and 10 and is as follows:

Equation 8

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

Where:

MDCR = minimum detectable net count rate (ct/min) = 376 cpm

d' = 1.38 when decision error, $\alpha = 0.60$, and correct decision fraction, $1-\beta = 0.9555$

i = observation interval56 (sec) = (detector area)$^{1/2}$/scan speed = 3.33

b_i = background counts in observation interval57 (4080 cpm/(60/3.3) = 224 cts)

54 NEXTEP Tech Memo 0229: MCNP Gamma Modeling for Mallinckrodt Roof Surface. N. Zhang and D. Thatcher. November 2002; and NEXTEP Tech Memo 0317: Use of the 3" x 3" NaI Detector for Measurement of Contamination on Concrete through Vinyl Tile and Carpet. N. Zhang. March 2003.

55 Abelquist, E.W., Table 6.1 p 6.23.

56 The observation interval is based upon a scan speed of 30 cm/s and an effective detector area of 10,000 cm² (see TM 0229).

57 The background value is the mean measurement from building 25 and is the lowest available background for the surfaces under consideration for the gamma surveys.

60 = conversion, 60 (sec/min)

The MDCR is calculated as 376 cpm.

Equation 9

$$Scan\ MDC = \frac{MDCR}{F_g \sqrt{p}}$$

Where:

p= surveyor efficiency, assumed58 to be 0.5

F_g= gamma conversion factor for scans59

The shielded NaI probe is assumed to be set up at a fixed height of 5 cm above the roof surface, moving at a speed of 30 cm/s yielding an observation interval of 3.3 seconds for an assumed contaminated area of 1 m^2 in size. The corresponding Scan MDC for a roof with a gravel surface equals 1,200 $dpm_p/100cm^2$ and is less than the required Scan MDC of 2,600 $dpm_p/100cm^2$. Similarly, the Scan MDC for a roof without a gravel surface is estimated as 830 $dpm_p/100cm^2$.

Investigation Threshold for Gamma Scans

The investigation threshold for a Class 1 or 2 survey unit for a roof without a gravel layer over the contamination is calculated as follows:

Equation 10

Investigation Threshold for gamma scan measurements (Class 1 or 2) =

$$ARG * F_g \sqrt{p} = 1{,}200\, cpm$$

Where:

F_g= the conversion factor (0.64) for a non-gravel roof

The investigation threshold for gravel roofs for a Class 1 or 2 survey unit is similarly calculated as 800 cpm.

58 Abelquist, E.W., et.al., §6.7.1.

59 0.44 for gravel roof; 0.64 $cpm/dpm_p/100\ cm^2$ for a non-gravel roof.

For a Class 3 survey unit on a roof with or without a gravel surface, the investigation threshold is the greater of the calculated MDC or the mean background plus two standard deviations. The class 3 investigation threshold should be calculated for each roof surface.

The investigation threshold for Class 1, 2 and 3 survey units for roofs with a gravel layer over the contamination are limited by the calculated Scan MDC of 1,200 $dpm_p/100cm^2$.

For a class 3 survey unit, the investigation threshold is the greater of the MDC or the matrix mean plus two standard deviations. Depending upon the background, scan speeds for a class 3 survey unit may need to be significantly reduced in order to achieve sufficient statistics in order to discern slightly elevated counts from background.

Conclusions and Recommendations

Table 1 summarizes the information calculated above. In all cases, the calculated value under the assumed conditions is less than what is required as shown in Table 1.

In the event that measurements are performed in areas with elevated background, the calculations in this memorandum may not be conservative. In such cases, recalculation of the MDCs and scan thresholds must be performed and validated. Investigation thresholds for all Class 3 surveys units should be calculated for each surface as appropriate.

Table 1
Summary of Calculations60

Measurement	Units	Calculated AB-100 Value	Required Value		
BETA DIRECT			*Class 1*	*Class 2*	*Class 3*
MDC	$Dpm_p/100\ cm^2$	100	1,300	1,300	1,300
Tinv61	cpm		2,900	2,900	MDC or T_{bk}62
BETA SCAN					
MDC	$Dpm_p/100\ cm^2$	760	13,000	2,600	2,600
Tinv	cpm		2,000	2,000	MDC or T_{bk}
GAMMA DIRECT					
MDC (Gravel)	$Dpm_p/100\ cm^2$	1,500	6,50063	6,500	6,500
Tinv (Gravel)	cpm		1,250	1,250	MDC or T_{bk}
MDC (non-Gravel)	$Dpm_p/100\ cm^2$	950	1,300	1,300	1,300
Tinv (non-Gravel)	cpm		1,950	1,950	MDC or T_{bk}
GAMMA SCAN					
MDC (Gravel)	$Dpm_p/100\ cm^2$	1,200	13,000	2,600	2,600
Tinv (Gravel)	cpm		800	800	MDC or T_{bk}
MDC (non-Gravel)	$Dpm_p/100\ cm^2$	830	13,000	2,600	2,600
Tinv (non-Gravel)	cpm		1,200	1,200	MDC or T_{bk}

60 All Values given are net of background.
61 Investigation Threshold
62 Background threshold, T_{bk}, is a standard term used in the CT Radiation Database for mean background plus 2 standard deviations.
63 Because the calculated value of the MDC is greater than 50% of the ARG, the higher limit of 50% of $DCGL_w$ is recognized.

APPENDIX A

BUILDING 25 SUPPORTING DATA

Individual counts for Building 25 roof, 3" x 3" NaI detector in a shielded configuration, 5 minute count time

19242	
21511	
21316	
19863	
20034	
4078.64	Average (cpm)
195.87	Std deviation (cpm)

APPENDIX 5

Threshold Comparison Test Reports (TCTR)

MALLINCKRODT C-T DECOMMISSIONING PROJECT

Threshold Comparison Test Report

Run Date: Wednesday, July 16, 2003

Survey Unit Number: 235R1 Class: 1 Data Points: Beta Grid Type: R Spacing: 5.7 ft

SURVEY UNIT TABLE

Bld	*Rm*	*Surface*	*Fixed Equipment*	*Surface Area Included (sq. ft)*	*Remarks*
B235	999R	R		949	
			Total	949	

INITIALIZATION DATA

Measurement Types Selected: RG, PR, BI, CH

Unit Range: All

Thresholds

EMC: 29,317 DCGLw: 2,600

SURVEY UNIT TEST STATUS

Test Performed	Status		Mtx	$Dpm_n/100cm^2$
Max Max	Pass	Maximum Survey	C	186.0
Background	Fail	Minimum	C	2.0
DCGLw	Pass	Difference		183.0
DCGLavg	Pass	Average Activity	115.5	
EMC	Pass	Average Below	115.5	
Wilcoxon Rank Sum Test	Pass	Average Background	36.6	
Sign Test for Paired Data	N/A			

MALLINCKRODT C-T DECOMMISSIONING PROJECT

Threshold Comparison Test Report

THE FOLLOWING DATA POINTS FAILED THE EMC TEST:

NONE

THE FOLLOWING DATA POINTS FAILED THE DCGLw TEST:

NONE

THE FOLLOWING DATA POINTS FAILED THE BACKGROUND

Survey Unit 235R1 Building B235

Room	SFC	X (ft)	Y (ft)	Mtx	Meas. Type	Min	SID	Gross Activity (dpm/100cm²)	Remarks	Exc	Res.
999R1	R	8.7	6.8	C	RG	1	5885	185.7		C	
999R1	R	20.0	1.0	C	RG	1	5898	165.8		C	
999R1	R	20.0	6.8	C	RG	1	5887	159.0		C	
999R1	R	8.7	1.0	C	RG	1	5896	154.2		C	
999R1	R	14.3	6.8	C	RG	1	5886	147.3		C	
999R1	R	25.7	12.3	C	RG	1	5877	143.9		C	
999R1	R	42.7	6.8	C	RG	1	5891	138.4		C	
999R1	R	8.7	12.3	C	RG	1	5874	132.3		C	
999R1	R	3.0	12.3	C	RG	1	5873	131.6		C	
999R1	R	54.0	12.3	C	RG	1	5882	130.2		C	
999R1	R	31.3	6.8	C	RG	1	5889	130.2		C	
999R1	R	25.7	1.0	C	RG	1	5899	129.5		C	
999R1	R	37.0	6.8	C	RG	1	5890	122.7		C	
999R1	R	31.3	12.3	C	RG	1	5878	122.7		C	
999R1	R	42.7	1.0	C	RG	1	5902	121.3		C	
999R1	R	59.7	12.3	C	RG	1	5883	119.2		C	
999R1	R	3.0	6.8	C	RG	1	5884	117.9		C	
999R1	R	54.0	6.8	C	RG	1	5893	115.1		C	
999R1	R	48.3	1.0	C	RG	1	5903	111.0		C	
999R1	R	14.3	1.0	C	RG	1	5897	104.9		C	
999R1	R	37.0	12.3	C	RG	1	5879	102.8		C	
999R1	R	31.3	1.0	C	RG	1	5900	102.8		C	
999R1	R	59.7	6.8	C	RG	1	5894	101.4		C	
999R1	R	37.0	1.0	C	RG	1	5901	101.4		C	
999R1	R	20.0	12.3	C	RG	1	5876	101.4		C	
999R1	R	14.3	12.3	C	RG	1	5875	91.8		C	
999R1	R	42.7	12.3	C	RG	1	5880	87.7		C	
999R1	R	48.3	6.8	C	RG	1	5892	85.0		C	
999R1	R	3.0	1.0	C	RG	1	5895	84.3		C	
999R1	R	25.7	6.8	C	RG	1	5888	80.2		C	

MALLINCKRODT C-T DECOMMISSIONING PROJECT

Threshold Comparison Test Report

THE FOLLOWING DATA POINTS PASSED BACKGROUND, DCGLw, AND EMC SCREENING TESTS:

Survey Unit 235R1 Building B235

Room	SFC	X (ft)	Y (ft)	Mtx	Meas. Type	Min	SID	Gross Activity (dpm/100cm²)	Remarks	Exc	Res.
999R1	R	54.0	1.0	C	RG	1	5904	67.2			
999R1	R	59.7	1.0	C	RG	1	5905	65.1			
999R1	R	48.3	12.3	C	RG	1	5881	58.9			

MALLINCKRODT C-T DECOMMISSIONING PROJECT

Threshold Comparison Test Report

Summary of Background Data and Thresholds Used in this Analysis

Measurement Type: BK *DCGL:* 2,600 *EMC:* 29,317

Matrix	*Number of Data Points*	*Average Background*	*Sigma*	*Background Threshold (Tbk)*	*DCGLw Threshold (Td)*	*EMC Threshold (Te)*
		(dp m_r/100cm^2)	(dp m_r/100cm^2)	(dp m_r/100cm^2)	(dp m_r/100cm^2)	(dp m_r/100cm^2)
C	60	36.6	19.3	75.1	2,675	29,392

MALLINCKRODT C-T DECOMMISSIONING PROJECT

Threshold Comparison Test Report

STATISTICAL TEST

Run Date	7/16/2003 3:42:36
Survey Unit	235R Class 1
Selected Test	WILCOXON RANK SUM TEST
Test Result	Pass
Thresholds	

EMC 29,317 DCGL 2,600

DATA SUMMARY TABLE

60 Background Points 33 Survey points processed

Wr = 3810 Wc = 3025

******** The survey unit has passed the WILCOXON RANK SUM TEST ********

MALLINCKRODT C-T DECOMMISSIONING PROJECT

Threshold Comparison Test Report

Date: Wednesday, July 16, 2003

Survey Unit Number: 235R2 Class: 1 Data Points: Beta Grid Type: R Spacing: 5.8 ft

SURVEY UNIT TABLE

Bld	Rm	Surface	Fixed Equipment	Surface Area Included (sq. ft)	Remarks
B235	999R	R		949	
			Total	949	

INITIALIZATION DATA

Measurement Types Selected: RG, PR, BI, CH

Date Range: All

Thresholds:

EMC: 28,639 DCGLw: 2,600

SURVEY UNIT TEST STATUS

Test Performed	Status		Mtx	$Dpm_n/100cm^2$
Max Max	Pass	Maximum Survey	C	197.0
Background	Fail	Minimum	C	2.0
DCGLw	Pass	Difference		194.0
MC Survey	Pass	Average Activity	119.4	
EMC	Pass	Average Recov	119.4	
Wilcoxon Rank Sum Test	Pass	Average Background	36.6	
Sign Test for Paired Data	N/A			

MALLINCKRODT C-T DECOMMISSIONING PROJECT

Threshold Comparison Test Report

THE FOLLOWING DATA POINTS FAILED THE EMC TEST:

NONE

THE FOLLOWING DATA POINTS FAILED THE DCGLw TEST:

NONE

THE FOLLOWING DATA POINTS FAILED THE BACKGROUND

Survey Unit 235R2 Building B235

Room	SFC	X (ft)	Y (ft)	Mtx	Meas. Type	Min	SID	Gross Activity (dpm/100cm²)	Remarks	Exc	Res.
999R2	R	31.0	22.5	C	RG	1	5825	196.7		C	
999R2	R	2.3	22.5	C	RG	1	5820	175.4		C	
999R2	R	8.0	22.5	C	RG	1	5821	170.6		C	
999R2	R	8.0	16.8	C	RG	1	5832	163.1		C	
999R2	R	36.8	16.8	C	RG	1	5837	143.2		C	
999R2	R	36.8	22.5	C	RG	1	5826	143.2		C	
999R2	R	13.8	28.3	C	RG	1	5811	143.2		C	
999R2	R	31.0	28.3	C	RG	1	5814	141.2		C	
999R2	R	13.8	16.8	C	RG	1	5833	139.1		C	
999R2	R	54.0	22.5	C	RG	1	5829	130.2		C	
999R2	R	31.0	16.8	C	RG	1	5836	124.7		C	
999R2	R	54.0	16.8	C	RG	1	5840	124.0		C	
999R2	R	48.3	22.5	C	RG	1	5828	122.7		C	
999R2	R	25.3	22.5	C	RG	1	5824	122.0		C	
999R2	R	48.3	16.8	C	RG	1	5839	121.3		C	
999R2	R	59.8	16.8	C	RG	1	5841	119.9		C	
999R2	R	54.0	28.3	C	RG	1	5818	114.4		C	
999R2	R	13.8	22.5	C	RG	1	5822	113.8		C	
999R2	R	59.8	22.5	C	RG	1	5830	112.4		C	
999R2	R	8.0	28.3	C	RG	1	5810	109.6		C	
999R2	R	42.5	16.8	C	RG	1	5838	109.0		C	
999R2	R	19.5	16.8	C	RG	1	5834	103.5		C	
999R2	R	2.3	28.3	C	RG	1	5809	100.7		C	
999R2	R	36.8	28.3	C	RG	1	5815	100.1		C	
999R2	R	59.8	28.3	C	RG	1	5819	98.0		C	
999R2	R	19.5	22.5	C	RG	1	5823	94.6		C	
999R2	R	48.3	28.3	C	RG	1	5817	90.5		C	
999R2	R	2.3	16.8	C	RG	1	5831	88.4		C	
999R2	R	25.3	28.3	C	RG	1	5813	83.6		C	
999R2	R	19.5	28.3	C	RG	1	5812	79.5		C	

MALLINCKRODT C-T DECOMMISSIONING PROJECT

Threshold Comparison Test Report

THE FOLLOWING DATA POINTS PASSED BACKGROUND, DCGLw, AND EMC SCREENING TESTS:

Survey Unit 235R2 Building B235

Room	SFC	X (ft)	Y (ft)	Mbx	Meas. Type	Min	SID	Gross Activity (dpm/100cm²)	Remarks	Exc	Res.
999R2	R	25.3	16.8	C	RG	1	5835	23.3			

MALLINCKRODT C-T DECOMMISSIONING PROJECT

Threshold Comparison Test Report

Summary of Background Data and Thresholds Used in this Analysis

Measurement Type: BK *DCGL:* 2,600 *EMC:* 28,639

Matrix	*Number of Data Points*	*Average Background*	*Sigma*	*Background Threshold (Tbk)*	*DCGLw Threshold (Td)*	*EMC Threshold (Te)*
		(dp m$_\gamma$/100cm^2)	(dp m$_\gamma$/100cm^2)	(dp m$_\gamma$/100cm^2)	(dp m$_\gamma$/100cm^2)	(dp m$_\gamma$/100cm^2)
C	60	36.6	19.3	75.1	2,675	28,714

MALLINCKRODT C-T DECOMMISSIONING PROJECT

Threshold Comparison Test Report

STATISTICAL TEST

Run Date	7/16/2003 4:03:32
Survey Unit	235R Class 1
Selected Test	WILCOXON RANK SUM TEST
Test Result	Pass
Thresholds	

EMC 28,639 DCGL 2,600

DATA SUMMARY TABLE

60 Background Points 31 Survey points processed

Wr = 3690 Wc = 2956

****** The survey unit has passed the WILCOXON RANK SUM TEST ******

MALLINCKRODT C-T DECOMMISSIONING PROJECT

Threshold Comparison Test Report

Run Date Wednesday, July 16, 2003

Survey Unit Number 235R3 Class 1 Data Points Beta Grid Type R Spacing 5 ft

SURVEY UNIT TABLE

Bld	*Rm*	*Surface*	*Fixed Equipment*	*Surface Area Included (sq. ft)*	*Remarks*
B235	999R	R		725	
			Total	725	

INITIALIZATION DATA

Measurement Types Selected: RG, PR, BI, CH

Date Range All

Thresholds

EMC 34,963 DCGLw 2,600

SURVEY UNIT TEST STATUS

Test Performed	Status		Mtx	$Dpm_\beta/100cm^2$
Min Max	Pass	Maximum Survey	C	180.0
Background	Fail	Minimum	C	2.0
DCGLw	Pass	Difference		178.0
DCGLavg	Pass	Average Activity	115.8	
EMC	Pass	Average Below	115.8	
Wilcoxon Rank Sum Test	Pass	Average Background	36.6	
Sign Test for Paired Data	N/A			

MALLINCKRODT C-T DECOMMISSIONING PROJECT

Threshold Comparison Test Report

THE FOLLOWING DATA POINTS FAILED THE EMC TEST:

NONE

THE FOLLOWING DATA POINTS FAILED THE DCGLw TEST:

NONE

THE FOLLOWING DATA POINTS FAILED THE BACKGROUND

235R3 B235

Room	SFC	X (ft)	Y (ft)	Mtx	Meas. Type	Min	SID	Gross Activity (dpm/100cm²)	Remarks	Exc	Res.
999R3	R	29.8	31.8	C	RG	1	5778	180.2		C	
999R3	R	19.8	36.8	C	RG	1	5766	162.4		C	
999R3	R	19.8	41.8	C	RG	1	5756	159.7		C	
999R3	R	29.8	36.8	C	RG	1	5768	153.5		C	
999R3	R	14.8	31.8	C	RG	1	5775	152.8		C	
999R3	R	24.8	36.8	C	RG	1	5767	148.0		C	
999R3	R	24.8	31.8	C	RG	1	5777	147.3		C	
999R3	R	34.8	31.8	C	RG	1	5779	126.1		C	
999R3	R	39.8	31.8	C	RG	1	5780	124.0		C	
999R3	R	4.8	31.8	C	RG	1	5773	122.7		C	
999R3	R	19.8	31.8	C	RG	1	5776	122.7		C	
999R3	R	14.8	41.8	C	RG	1	5755	122.0		C	
999R3	R	34.8	41.8	C	RG	1	5759	115.1		C	
999R3	R	29.8	41.8	C	RG	1	5758	113.1		C	
999R3	R	39.8	41.8	C	RG	1	5760	109.6		C	
999R3	R	14.8	36.8	C	RG	1	5765	106.2		C	
999R3	R	9.8	31.8	C	RG	1	5774	106.2		C	
999R3	R	4.8	41.8	C	RG	1	5753	100.7		C	
999R3	R	44.8	41.8	C	RG	1	5761	98.0		C	
999R3	R	44.8	36.8	C	RG	1	5771	95.9		C	
999R3	R	9.8	41.8	C	RG	1	5754	93.9		C	
999R3	R	24.8	41.8	C	RG	1	5757	89.1		C	
999R3	R	49.8	41.8	C	RG	1	5762	88.4		C	
999R3	R	34.8	36.8	C	RG	1	5769	87.0		C	
999R3	R	39.8	36.8	C	RG	1	5770	84.3		C	
999R3	R	49.8	36.8	C	RG	1	5772	81.6		C	
999R3	R	9.8	36.8	C	RG	1	5764	78.1		C	

MALLINCKRODT C-T DECOMMISSIONING PROJECT

Threshold Comparison Test Report

THE FOLLOWING DATA POINTS PASSED BACKGROUND, DCGLw, AND EMC SCREENING TESTS:

Survey Unit 235R3 Building B235

Room	SFC	X (ft)	Y (ft)	Mtx	Meas. Type	Min	SID	Gross Activity (dpm/100cm²)	Remarks	Exc	Res.
999R3	R	4.8	36.8	C	RG	1	5763	73.3			

MALLINCKRODT C-T DECOMMISSIONING PROJECT

Threshold Comparison Test Report

Summary of Background Data and Thresholds Used in this Analysis

Measurement Type: BK *DCGL:* 2,600 *EMC:* 34,963

Matrix	*Number of Data Points*	*Average Background*	*Sigma*	*Background Threshold (Tbk)*	*DCGLw Threshold (Td)*	*EMC Threshold (Tc)*
		(dp m_p/100cm^2)	(dp m_p/100cm^2)	(dp m_p/100cm^2)	(dp m_p/100cm^2)	(dp m_p/100cm^2)
C	60	36.6	19.3	75.1	2,675	35,038

MALLINCKRODT C-T DECOMMISSIONING PROJECT

Threshold Comparison Test Report

STATISTICAL TEST

Run Date	7/16/2003 4:13:36
Survey Unit	235R Class 1
Selected Test	WILCOXON RANK SUM TEST
Test Result	Pass
Thresholds	

EMC 34,963 DCGL 2,600

DATA SUMMARY TABLE

60 Background Points 28 Survey points processed

Wr = 3510 Wc = 2854

****** The survey unit has passed the WILCOXON RANK SUM TEST ******

MALLINCKRODT C-T DECOMMISSIONING PROJECT

Threshold Comparison Test Report

Run Date: Wednesday, July 16, 2003

Survey Unit Number: 235R4 Class: 1 Data Points: Beta Grid Type: R Spacing: 5.8 ft

SURVEY UNIT TABLE

Bld	Rm	Surface	Fixed Equipment	Surface Area Included (sq. ft)	Remarks
B235	999R	R		968	
			Total	968	

INITIALIZATION DATA

Measurement Types Selected: RG, PR, BI, CH

Date Range: All

Thresholds

EMC: 28,639 DCGLw: 2,600

SURVEY UNIT TEST STATUS

Test Performed	Status		MIx	$Dpm_p/100cm^2$
Max	Pass	Maximum Survey	C	157.0
Background	Fail	Minimum	C	2.0
[illegible]	Pass	[illegible]		155.0
[illegible]	Pass	Average Activity	105.3	
EMC	Pass	Average Recovery	105.3	
Wilcoxon Rank Sum Test	Pass	Average Background	36.6	
Sign Test for Paired Data	N/A			

MALLINCKRODT C-T DECOMMISSIONING PROJECT

Threshold Comparison Test Report

THE FOLLOWING DATA POINTS FAILED THE EMC TEST:

NONE

THE FOLLOWING DATA POINTS FAILED THE DCGLw TEST:

NONE

THE FOLLOWING DATA POINTS FAILED THE BACKGROUND

Survey Unit 235R4 Building B235

Room	SFC	X (ft)	Y (ft)	Mtx	Meas. Type	Min	SID	Gross Activity (dpm/100cm²)	Remarks	Exc	Res.
999R4	R	43.6	54.7	C	RG	1	5712	156.9		C	
999R4	R	3.2	48.8	C	RG	1	5713	139.1		C	
999R4	R	14.7	60.4	C	RG	1	5699	135.7		C	
999R4	R	20.5	54.7	C	RG	1	5708	132.3		C	
999R4	R	8.9	48.8	C	RG	1	5714	129.5		C	
999R4	R	32.0	54.7	C	RG	1	5710	125.4		C	
999R4	R	3.2	66.2	C	RG	1	5689	119.9		C	
999R4	R	26.3	54.7	C	RG	1	5709	119.9		C	
999R4	R	26.3	66.2	C	RG	1	5693	117.2		C	
999R4	R	3.2	60.4	C	RG	1	5697	115.1		C	
999R4	R	14.7	48.8	C	RG	1	5715	114.4		C	
999R4	R	14.7	54.7	C	RG	1	5707	112.4		C	
999R4	R	26.3	48.8	C	RG	1	5717	111.7		C	
999R4	R	20.5	66.2	C	RG	1	5692	110.3		C	
999R4	R	32.0	66.2	C	RG	1	5694	109.6		C	
999R4	R	14.7	66.2	C	RG	1	5691	109.6		C	
999R4	R	26.3	60.4	C	RG	1	5701	106.9		C	
999R4	R	37.8	66.2	C	RG	1	5695	106.9		C	
999R4	R	8.9	66.2	C	RG	1	5690	106.9		C	
999R4	R	3.2	54.7	C	RG	1	5705	106.2		C	
999R4	R	37.8	54.7	C	RG	1	5711	101.4		C	
999R4	R	43.6	66.2	C	RG	1	5696	100.7		C	
999R4	R	32.0	48.8	C	RG	1	5718	98.0		C	
999R4	R	8.9	54.7	C	RG	1	5706	97.3		C	
999R4	R	20.5	48.8	C	RG	1	5716	93.2		C	
999R4	R	37.8	48.8	C	RG	1	5719	80.9		C	
999R4	R	43.6	48.8	C	RG	1	5720	80.2		C	

MALLINCKRODT C-T DECOMMISSIONING PROJECT

Threshold Comparison Test Report

THE FOLLOWING DATA POINTS PASSED BACKGROUND, DCGLw, AND EMC SCREENING TESTS:

Survey Unit 235R4 Building B235

Room	SFC	X (ft)	Y (ft)	Mtx	Meas. Type	Min	SID	Gross Activity (dpm/100cm²)	Remarks	Exc	Res.
999R4	R	32.0	60.4	C	RG	1	5702	73.3			
999R4	R	8.9	60.4	C	RG	1	5698	72.6			
999R4	R	20.5	60.4	C	RG	1	5700	71.3			
999R4	R	43.6	60.4	C	RG	1	5704	63.7			
999R4	R	37.8	60.4	C	RG	1	5703	51.4			

MALLINCKRODT C-T DECOMMISSIONING PROJECT

Threshold Comparison Test Report

Summary of Background Data and Thresholds Used in this Analysis

Measurement Type: BK *DCGL:* 2,600 *EMC:* 28,639

Matrix	*Number of Data Points*	*Average Background*	*Sigma*	*Background Threshold (Tbk)*	*DCGLw Threshold (Td)*	*EMC Threshold (Te)*
		(dp m$_a$/100cm^2)	(dp m$_a$ 100cm^2)	(dp m$_a$ 100cm^2)	(dp m$_a$/100cm^2)	(dp m$_a$ 100cm^2)
C	60	36.6	19.3	75.1	2,675	28,714

MALLINCKRODT C-T DECOMMISSIONING PROJECT

Threshold Comparison Test Report

STATISTICAL TEST

Run Date	7/16/2003 3:39:35
Survey Unit	235R Class 1
Selected Test	WILCOXON RANK SUM TEST
Test Result	Pass
Thresholds	

EMC 28,639 DCGL 2,600

DATA SUMMARY TABLE

60 Background Points 32 Survey points processed

Wr = 3750 Wc = 2991

******** The survey unit has passed the WILCOXON RANK SUM TEST ********

MALLINCKRODT C-T DECOMMISSIONING PROJECT

Threshold Comparison Test Report

Run Date Wednesday, July 16, 2003

Survey Unit Number 235R5 Class 1 Data Points Beta Grid Type R Spacing 5.6 ft

SURVEY UNIT TABLE

Bld	Rm	Surface	Fixed Equipment	Surface Area Included (sq. ft)	Remarks
B235	999R	R		719	
			Total	719	

INITIALIZATION DATA

Measurement Types Selected RG, PR, BI, CH

Date Range All

Thresholds

[illegible] 30,022 DCGLw 2,600

SURVEY UNIT TEST STATUS

Test Performed	Status		Mtx	$Dpm_\beta/100cm^2$
Max Max	Pass	Maximum Survey	C	158.0
Background	Fail	Minimum	C	2.0
DCGLw	Pass	Difference		155.0
DCGLavg	Pass	Average Activity	87.1	
[illegible]	Pass	Average Below	87.1	
Mann-Whitney Rank Sum Test	N/A	Average Background	36.6	
Sign Test for Paired Data	Pass			

MALLINCKRODT C-T DECOMMISSIONING PROJECT

Threshold Comparison Test Report

THE FOLLOWING DATA POINTS FAILED THE EMC TEST:

NONE

THE FOLLOWING DATA POINTS FAILED THE DCGLw TEST:

NONE

THE FOLLOWING DATA POINTS FAILED THE BACKGROUND

Survey Unit 235R5 Building B235

Room	SFC	X (ft)	Y (ft)	Mtx	Meas. Type	Min	SID	Gross Activity (dpm/100cm²)	Remarks	Exc	Res.
999R5	R	23.9	76.2	C	RG	1	5645	157.6		C	
999R5	R	12.6	76.2	C	RG	1	5643	150.8		C	
999R5	R	18.3	70.5	C	RG	1	5652	143.2		C	
999R5	R	40.8	76.2	C	RG	1	5648	143.2		C	
999R5	R	18.3	76.2	C	RG	1	5644	137.1		C	
999R5	R	1.3	70.5	C	RG	1	5649	135.0		C	
999R5	R	7.0	70.5	C	RG	1	5650	130.2		C	
999R5	R	35.2	76.2	C	RG	1	5647	130.2		C	
999R5	R	1.3	76.2	C	RG	1	5641	109.6		C	
999R5	R	35.2	70.5	C	RG	1	5655	109.0		C	
999R5	R	29.5	76.2	C	RG	1	5646	108.3		C	
999R5	R	23.9	70.5	C	RG	1	5653	106.2		C	
999R5	R	7.0	81.8	C	RG	1	5634	105.5		C	
999R5	R	12.6	70.5	C	RG	1	5651	100.1		C	
999R5	R	1.3	81.8	C	RG	1	5633	98.7		C	
999R5	R	7.0	76.2	C	RG	1	5642	95.9		C	
999R5	R	18.3	81.8	C	RG	1	5636	85.7		C	
999R5	R	29.5	70.5	C	RG	1	5654	82.2		C	
999R5	R	40.8	81.8	C	RG	1	5640	78.8		C	
999R5	R	7.0	83.4	W	RG	1	5626	71.9		C	
999R5	R	12.6	83.4	W	RG	1	5627	54.4		C	
999R5	R	1.3	83.4	W	RG	1	5625	43.9		C	
999R5	R	40.8	83.4	W	RG	1	5632	36.0		C	
999R5	R	29.5	83.4	W	RG	1	5630	17.5		C	
999R5	R	23.9	83.4	W	RG	1	5629	16.7		C	
999R5	R	18.3	83.4	W	RG	1	5628	12.3		C	

MALLINCKRODT C-T DECOMMISSIONING PROJECT

Threshold Comparison Test Report

THE FOLLOWING DATA POINTS PASSED BACKGROUND, DCGLw, AND EMC SCREENING TESTS:

Survey Unit 235R5 Building B235

Room	SFC	X (ft)	Y (ft)	Mtx	Meas. Type	Min	SID	Gross Activity (dpm/100cm²)	Remarks	Exc	Res.
999R5	R	35.2	81.8	C	RG	1	5639	72.6			
999R5	R	29.5	81.8	C	RG	1	5638	69.9			
999R5	R	40.8	70.5	C	RG	1	5656	63.7			
999R5	R	12.6	81.8	C	RG	1	5635	62.4			
999R5	R	23.9	81.8	C	RG	1	5637	61.7			
999R5	R	35.2	83.4	W	RG	1	5631	-4.4			

MALLINCKRODT C-T DECOMMISSIONING PROJECT

Threshold Comparison Test Report

Summary of Background Data and Thresholds Used in this Analysis

Measurement Type: BK *DCGL:* 2,600 *EMC:* 30,022

Matrix	*Number of Data Points*	*Average Background*	*Sigma*	*Background Threshold (Tbk)*	*DCGLw Threshold (Td)*	*EMC Threshold (Te)*
		(dp m$_p$/100cm^2)	(dp m$_p$/100cm^2)	(dp m$_p$/100cm^2)	(dp m$_p$/100cm^2)	(dp m$_p$/100cm^2)
C	60	36.6	19.3	75.1	2,675	30,097
W	0	0.0	0.0	0.0	2,600	30,022

MALLINCKRODT C-T DECOMMISSIONING PROJECT

Threshold Comparison Test Report

STATISTICAL TEST

Run Date	7/16/2003 3:37:11
Survey Unit	235R5 Class 1
Selected Test	SIGN TEST FOR PAIRED DATA
Test Result	Pass
Thresholds	
EMC	30,022 DCGL 2,600

DATA SUMMARY TABLE

32 Survey points processed 2 matrices processed

S+ = 32 Wc = 21

******** The survey unit has passed the SIGN TEST FOR PAIRED DATA ********