FINAL STATUS SURVEY REPORT
BUILDING 240 EXTERIOR

MALLINCKRODT, INC.
COLUMBIUM- TANTULUM PROJECT- PHASE 1

DECEMBER 2003

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C-T PROJECT – PHASE I

FINAL STATUS SURVEY REPORT

Building 240 Exterior

Survey Units 240NER

Revision 0

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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 exterior walls and roof of Building 240 on the Mallinckrodt St. Louis site (designated as Survey Unit (SU) 240NER). This report is being provided in accordance with the Mallinckrodt C-T Project, Phase I Decommissioning Plan. This FSS was performed in accordance with Field Instruction CT-FI-006 (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 these survey units 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. Mallinckrodt's facilities have either been released from the applicable license or are being remediated by the US 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

[1] CT-FI-006, *Final Status Survey Guide for Survey Unit 240NER.*.

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.

2. SCOPE OF FINAL STATUS SURVEY

2.1. DEFINITION AND CLASSIFICATION OF SURVEY UNITS

2.1.1. The affected exterior surfaces of Building 240 have been designated as one survey unit. SU-240NER consists of the roof and the north and east exterior walls of building 240. SU-240NER is classified as Class 2.

2.1.2. Table 2.1 below contains the description provided in Appendix A of the D Plan for the areas referenced by this FSSR.

Table 2.1[2]
Survey Area Descriptions

Area	Surface	Location / Surface
168	E	East Exterior Wall/Ledges
169	N	North Exterior Wall/Ledges
171	R	Roof: Repairs in 2000, new A/C unit in 1999.

2.1.3. A summary report for SU-240NER listing all the surfaces and fixed apparatus assigned to it is presented in Appendix 1. Drawings of the survey unit showing the location of key fixed apparatus items are presented in Appendix 2, Figures 2.1 and 2.2.

2.2. IDENTIFICATION OF THE RADIOLOGICAL CONTAMINANTS

2.2.1. 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 comparable matrices. 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

[2] Appendix A of D Plan.
[3] Mallinckrodt C-T Project D Plan Appendix D.

levels for the contaminants of interest in the survey units are presented in Table 2.2.

Table 2.2
Background Reference Data

Matrix	Mean ($dpm_p/100cm^2$)[4]	Standard Deviation ($dpm_p/100cm^2$)
Concrete Block	96.1	21.7
Metal	24.0	15.7
Tar/Roofing	77.7	51.6

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)[5] was developed and was used during the FSS as if it were the DCGLw with certain exceptions.[6]

Table 2.3
Building Surface and Installed Apparatus Release Criteria

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

2.4.3. <u>Elevated Measurements Criterion (EMC)</u>

2.4.3.1. Because the survey unit is Class, all measurements are required to be less than the DCGLw. Therefore, the EMC criteria do not apply to this FSS.

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,

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[4] $Dpm_p/100\ cm^2$ refers to the disintegrations per minute per 100 cm^2 for the combined nuclide series.
[5] NEXTEP Tech Memo 0211, *Recommendation for an Administrative Release Guideline for the Mallinckrodt C-T Project,* A.H. Thatcher, CHP.
[6] Final Status Survey Design Guide (Phase I), Section 3.2, covers the rules governing use of the ARG.

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 efficiency or normalized sensitivity 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 purpose of alpha attenuation[7]. 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 location[8]. The difference in the two readings is attributable to beta emissions above 80 KeV in energy.[9] The sensitivity of the AB-100 was derived from experiments by Lucas and Colyott which were reported in Attachment 3 to the D Plan.[10] The actual instruments used were calibrated and normalized to the reference instrument tested by Lucas and Colyott as prescribed in CT-QA-6.1[11] .

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

[8] 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.

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

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

[11] CT-QA-6.1 - *Calibration and Control of Measuring and Survey Equipment.*

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. L43-89 – The Ludlum 43-89 is a newer scintillation detector very similar in form and function to the AB-100. It was used in the same manner and was paired with the same scalers or rate meters. Sensitivity of this instrument was derived from experiments by Lucas and Colyott which were reported in Attachment 4 of the D Plan.[12]

2.5.8. 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.

2.5.9. 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 and Detection Thresholds

2.6.1. The terminology adopted to reflect an instrument's 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 lowest level of radioactivity 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.[13]

2.6.2. The LLD requirements for the FSS have been developed in accordance with MARSSIM [14]Chapter 4 guidelines. They are contained in the Design Guide and are listed in Table 2.4.

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[12] *Energy Dependent Calibrations for the Ludlum 43-89 Beta Ray Survey Probe*, A. Lucas, CHP and L. Colyott, Ph.D., submitted as Attachment 4 to the Mallinckrodt Phase I Decommissioning Plan.

[13] CT-QA-6.1, Ibid.

[14] NUREG 1575, *Multi Agency Radiation Survey and Site Investigation Manual.*

Table 2.4
MDC Requirements for C-T FSS

Measurement Type	MDC Requirement[15]
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.[16] A comparison of the MDCs calculated for the AB-100[17] 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 NEXTEP Tech Memo 0230.[18]

Table 2.5
LLD and Action Thresholds[19]

Measurement	Units	Calculated Value	Required Value
BETA DIRECT			*Class 2*
MDC	$dpm_p/100\ cm^2$	100	1,300
Tinv[20]	cpm		2,900
BETA SCAN			
MDC	$dpm_p/100\ cm^2$	760	2,600
Tinv	cpm		2,000

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:

[15] Requirements are stated in terms of the ARG which may be adjusted upward (not to exceed the DCGLw) by the area factor or paint attenuation factor as described in Section 3.2 of the Design Guide.
[16] NEXTEP Tech Memo 0230, *Technical Basis Document for Mallinckrodt Final Status Surveys*, A.H. Thatcher, CHP, (included with FSSR 2501).
[17] MDCs for the AB-100 are typical of those for the L43-89.
[18] NEXTEP Tech Memo 0230, ibid.
[19] All Values given are net of background.
[20] Investigation Threshold.

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 backscater.
$S_b(m)$	=	Backscatter factor (a function of matrix)
t	=	Integration time in minutes

2.7.2. Since no painted surfaces were surveyed on the roof or exterior walls of Building 240, 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.[21] Reference backscatter coefficients for several matrix materials were generated using an MCNP model and are described in NEXTEP Tech Memo 0213.[22] 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 Field Instruction.

[21] NEXTEP Tech Memo 0215, *Separation of Backscatter & Derivation of Instrument Sensitivity*, A.H. Thatcher CHP, (included with FSSR 2501).

[22] NEXTEP Tech Memo 0213, *Beta Backscatter Factors for Several Materials at the Mallinckrodt Site*, N. Zhang and D. Wilson, (included with FSSR 2501)

Table 3.1

Survey Procedures and Documents
CT Decommissioning Plan (Phase I)
CT Decommissioning Project, Final Status Survey Design Guide (Phase I)
CT-FI-006, Final Status Survey Guide for Survey Unit 240NER
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

3.1.2. All FSS data recorded in the field was submitted to the Quality Assurance Manager or designee 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 checklist[23] 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 C-T 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 and wall surfaces as described in the FI. Bias measurements were taken on building surfaces and fixed apparatus at locations determined by the surveyor in an effort to 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. 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.

[23] NEXTEP Tech Memo 0206, *QA Data Verification for MI CT Final Status Survey Data*, B. Anderson, (included with FSSR 2501).

3.2.2. Removable Contamination Measurements:

3.2.2.1. *Swipes* - Removable contamination samples were collected at 100% of both survey units' regular grid locations. 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[24].

3.3. MEASUREMENT LOCATIONS

3.3.1. Statistical Grid Data Points

3.3.1.1. The *Visual Sample Plan*© (VSP)[25] software was used to develop a MARSSIM grid for the survey unit. 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 uses the Data Quality Objective (DQO) input values 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 240 Exterior Walls

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%

3.3.1.3. A rectangular grid was used for both survey units. The maximum grid spacing (L) was calculated from the area (A) of the total survey

[24] Section 3.3 of the C-T Design Guide.
[25] NEXTEP Tech Memo 0008, *Verification and Validation of Applicable Portions of VSP Software,* A.H. Thatcher, CHP.

units and the maximum 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 SU-240NER.

Table 3.3
SU-240NE & 240R Calculated Grid Point Separation

Survey Unit	Class	N	A (ft^2)	L (ft)
SU-240NER	2	29	6,346	14.8

3.3.2. Bias Measurement Locations

3.3.2.1. Bias direct measurements 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 Protocol[26].

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 walls, floor, ceiling and roof as shown in Table 3.4. 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

[26] CT-FI-004, *Final Status Survey Guide for Survey Unit 2504*, Attachment E.

Table 3.4
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. 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 located on the roof. 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".

3.4.4. 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 C-T 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 Tech Memo 0231[27].

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 that 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

[27] NEXTEP Tech Memo 0231, *Validation and Verification of the C-T Database Analysis Report,* B. Anderson, (included with FSSR 2501).

each survey record but generate a single PASS/FAIL verdict for the entire data set. The tests are described in the following paragraphs[28]. 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.*

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.

[28] A more detailed explanation is provided in the Design Guide.

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 13,000 $dpm_p/100\ cm^2$.

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.

Equation 6

$$\overline{AD}(m) - \overline{BK}(m) > DCGL_W$$

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) or PG (Post-Remediation Grid). The program narrows the filter to include only these points before proceeding.

3.5.9.2. The Wilcoxon Rank Sum Test[29] 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[30] was used.

3.5.10. The output of the Threshold Comparison Test Report (TCTR) was used for analysis of the data for the Building 240 exterior walls and roof, and the results are presented in Appendix 4. Each TCTR is divided into eight sections which are briefly described in the following paragraphs to assist the unfamiliar reader.

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.

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[29] Described in Appendix I of MARSSIM.
[30] Described in NEXTEP Tech Memo 0231, ibid.

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 survey unit.

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 1505[31]
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 units meet the release criteria, the release of the survey units can be determined from the test report according to Table 3.6.

Table 3.6
Requirements for SU Release[32]

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.

[31] NUREG 1505, *A Nonparametric Statistical Methodology for the Design and Analysis of Final Status Decommissioning Surveys.*
[32] See MARSSIM, Chapter 8, Table 8.2

4. FSS RESULTS AND DISCUSSION

4.1. CHARACTERIZATION DATA

4.1.1. The characterization data taken in SU-240NER 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.

4.2. SURVEY UNIT 240NER

4.2.1. Direct Beta Measurements on Building Surfaces

4.2.1.1. SU-240NER was surveyed in May 2003. 36 direct beta measurements were taken on the survey unit walls and roof. 35 of these were included in the systematic grid. A diagram of the survey unit with the beta measurements plotted on it is presented in Appendix 2, Figure 4.1.

4.2.1.2. A summary of the direct measurement results taken on building surfaces is presented in Table 4.1. It shows that the maximum activity measured, net of background, was 79 $dpm_p/100cm^2$. The average value for the survey unit was 5.0 $dpm_p/100cm^2$.

Table 4.1
SU-240NER Direct Measurements Summary
(Building Surfaces)

Matrix	Points	Avg Net Activity ($dpm_p/100cm^2$)	Max Net Activity ($dpm_p/100cm^2$)
Concrete Block	9	-37.9	-9.5
Metal	2	-2.7	8.5
Tar Roofing	25	21.1	78.8

4.2.2. Direct Beta Measurements on Installed Apparatus

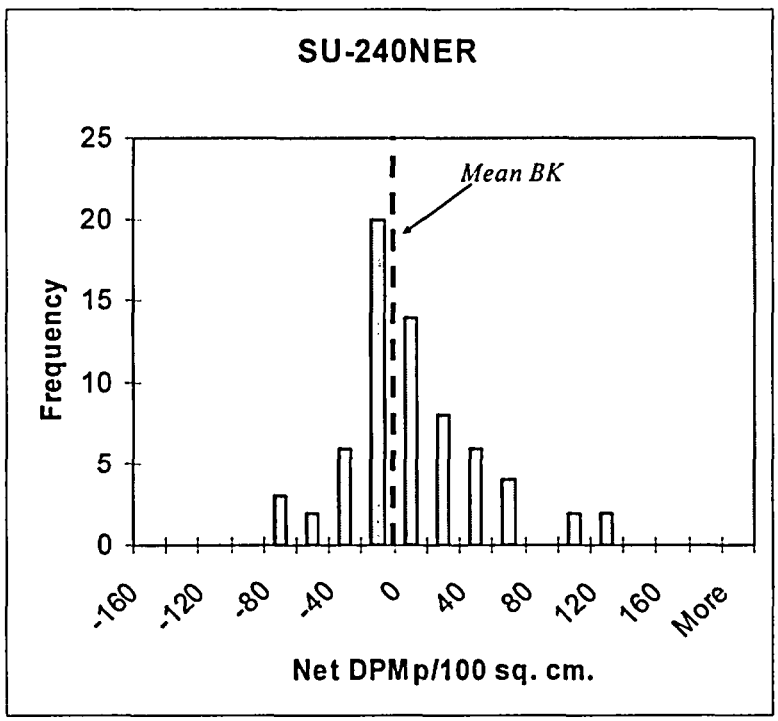
4.2.2.1. All 16 items of installed apparatus which are listed in Appendix 1 were surveyed by direct beta measurements. A summary of the measurements taken is provided in Table 4.2 sorted by matrix material. The net values observed ranged from –39 to 137 $dpm_p/100cm^2$. All values were significantly less than the ARG. The data confirm that no significant residual radioactivity was measured on the 16 items of installed apparatus in SU-240NER.

Table 4.2
SU-240NE Fixed Equipment Direct Measurements Summary

Matrix	Points	Avg Net Activity ($dpm_p/100cm^2$)	Max Net Activity ($dpm_p/100cm^2$)
Metal	29	11.0	136.9
Tar/Roofing	2	91.4	135.8

4.2.3. Direct Beta Measurement Distribution and Threshold Tests

4.2.3.1. A histogram of all the net activity values found in SU240NER is provided in Figure 4.1. The distribution appears to have a single mode with the majority of the data centered at approximately -10[33] $dpm_p/100cm^2$. This is consistent with a normal distribution of background radioactivity. Although several measurements appeared slightly above the level of background, all measurements were well below the ARG.



Histogram of Net Direct Beta Measurements
Figure 4.1

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

[33] Actually this mode represents the number of occurrences where the activity fell between 0 and -20 $dpm_p/100cm^2$.

in Appendix 4. The TCTR contains a complete listing of all the beta direct measurements taken in the Final Status Survey within SU-240NER sorted by test failed and by activity.

4.2.3.3. The summary pages indicate that all tests described in the D Plan passed except background. All the tests required for release of Class 2 survey units were passed. A comparison of test results and requirements for release of the survey unit are presented in Table 4.3.

Table 4.3
SU-240NER Test Results

Test	Class 2	SU-240NE
Min/Max	not requred	P
Background	not required	F
$DCGL_w$	PASS	P
$DCGL_{avg}$	PASS	P
EMC	PASS	P
Sign Test for Paired Data	PASS	P

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

4.2.3.4. As the histogram in Figure 4.1 shows, the survey unit is at or slightly above background levels. These results are consistent with passing all tests except background.

4.2.4. Measurements of Removable Contamination

4.2.4.1. Swipes were taken at each location where a direct grid measurement was performed. The results of the measurements are presented in Table 4.4.

Table 4.4
SU-240NE Removable Contamination Summary

Surface	Points	Avg Net Beta (βpm/100cm^2)	Max Net Beta (βpm/100cm^2)	Avg Net Activity[a] (dpm$_p$/100cm^2)	Max Net Activity (dpm$_p$/100cm^2)
E	7	-7.6	17.0	-1.6	3.5
N	3	-14.7	-3.0	-3.1	-0.6
R	25	7.9	31.0	1.7	6.5

[a] Activity was converted to dpm$_p$/100 cm^2 from βpm/100 cm^2 using an approximate figure of 4.8 betas per disintegration.

4.2.4.2. The results show that removable contamination averages near zero dpm$_p$/100cm^2 and varies between –5.8 and +6.5 dpm$_p$/100cm^2. The data confirm that virtually no removable contamination is present within SU-240NER.

4.2.5. Beta Scan Measurements

4.2.5.1. Beta scans were performed on about 15% of the surface of the exterior walls and roof of Building 240. Diagrams of the areas surveyed are presented in Appendix 2, Figures 4.2 and 4.3.

4.2.5.2. 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 Tech Memo 0230[34].

4.2.5.3. All scans performed on the wall surfaces were taken on concrete block. The average background value used for analysis of the raw data was obtained from the average of all the open window direct beta readings (in cpm) taken in the survey unit. For concrete block this value was 225 cpm. The average of all open window survey readings taken on concrete block in the background data set was 412 cpm. The lower, more conservative value was used for the FSS measurements.

4.2.5.4. All scans performed on the roof were taken on tar/roofing. The average background value used for analysis of the raw data was obtained from the average of all the open window direct beta readings (in cpm) in the background data set. For tar/roofing this value was 267 cpm. The average of all open window survey readings taken in the survey unit on tar/roofing was 305 cpm.

4.2.5.5. During the surveys the maximum and average gross count rates were recorded for each area scanned. The beta scan data are summarized and presented in Table 4.5.

Table 4.5
SU-240NER Scan Measurements Summary

Matrix	Areas Scanned	Maximum (cpm)	Average (cpm)	Max Net (cpm)	Avg Net (cpm)
Concrete Block	4	190	155	-35	-70
Tar/Roofing	1	180	150	-87	-117

4.2.5.6. The maximum net scan value of -35 is well below the scan threshold of 2000 cpm. No beta scan data were observed in SU-240NE above the scan threshold.

[34] NEXTEP Tech Memo 0230, ibid.

5. CONCLUSIONS

5.1. SU-240NER passed all the tests described in the D Plan except background. All tests required for release of a Class 2 Survey unit passed. (Par. 4.2.3.3)

5.2. No significant residual radioactivity was measured on the 16 items of installed apparatus in SU-240NER. (Par. 4.2.2.1)

5.3. Virtually no removable contamination is present within SU-240NER. (Par. 4.2.4.2)

5.4. No beta scan data were observed in SU-240NE above the scan threshold of 2,000 cpm. (Par. 4.2.5.6)

5.5. SU-240NER meets all the requirements of the D Plan for unconditional release.

6. RECOMMENDATIONS

6.1. SU-240NER should be released from the license.

Appendix 1
Building Survey Unit Listing for Building 240 Exterior

Building Survey Unit Listing

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

SurveyUnitID: 240NER ***Class:*** 2

Room 999

N	48.5	13	631	0.0	North Wall Bldg 240 Exterior
E	101	12	1,212	0.0	East Wall Bldg 240 Exterior
R	48.5	101	4,503	0.0	
Q1				0.0	Piping support brackets
Q2				0.0	Lights (4) - two on North wall, two on East wall
Q3				0.0	Awning for entrance (2) - one on North wall and one on East wall
Q4				0.0	Roof flashing
Q5				0.0	Ladder (including portion on roof)
Q6				0.0	Old wiring and support brackets under roofline
Q7				0.0	Overhang along roof line (contains piping, wiring) and associated electrical connections
Q8				0.0	Iron beam attached to SE corner
Q9				0.0	Red piping running NS (2)
Q10				0.0	Blue piping running NS (1)
Q11				0.0	Yellow piping near blue piping (2)
Q12				0.0	Rusted yellow piping running NS (1)
Q13				0.0	Mounting brackets for A.C. unit
Q14				0.0	3 penetrations
Q15				0.0	2 roof penetrations
Q16				0.0	Dome vent

Summary for Room 999 (19 detail records) *6,346* **Sq. Feet**

TOTAL for Survey Unit 240NER ***6,346*** **Sq. Feet**

APPENDIX 2
Figures

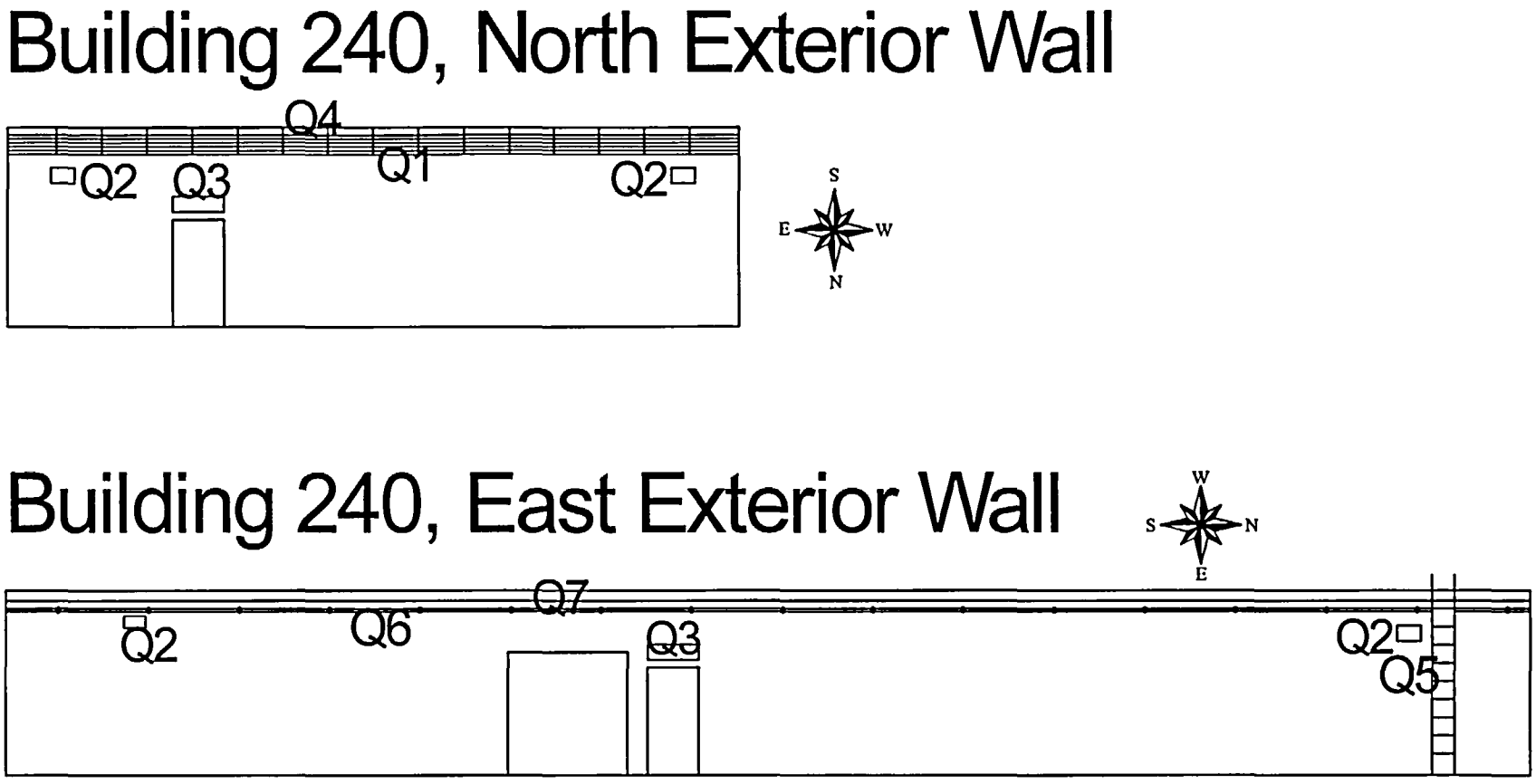


Figure 2.1
SU-240NER Exterior Walls

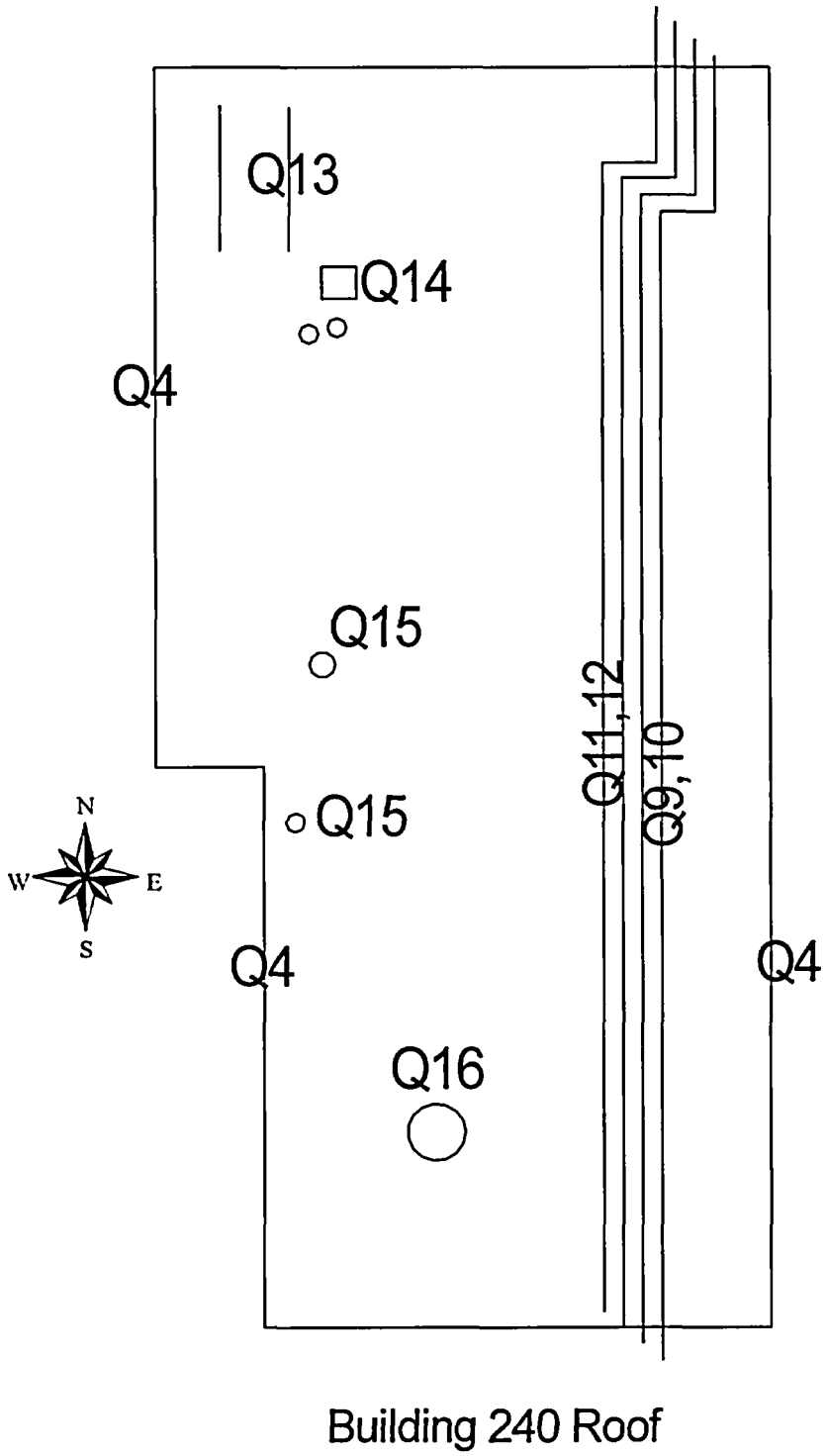
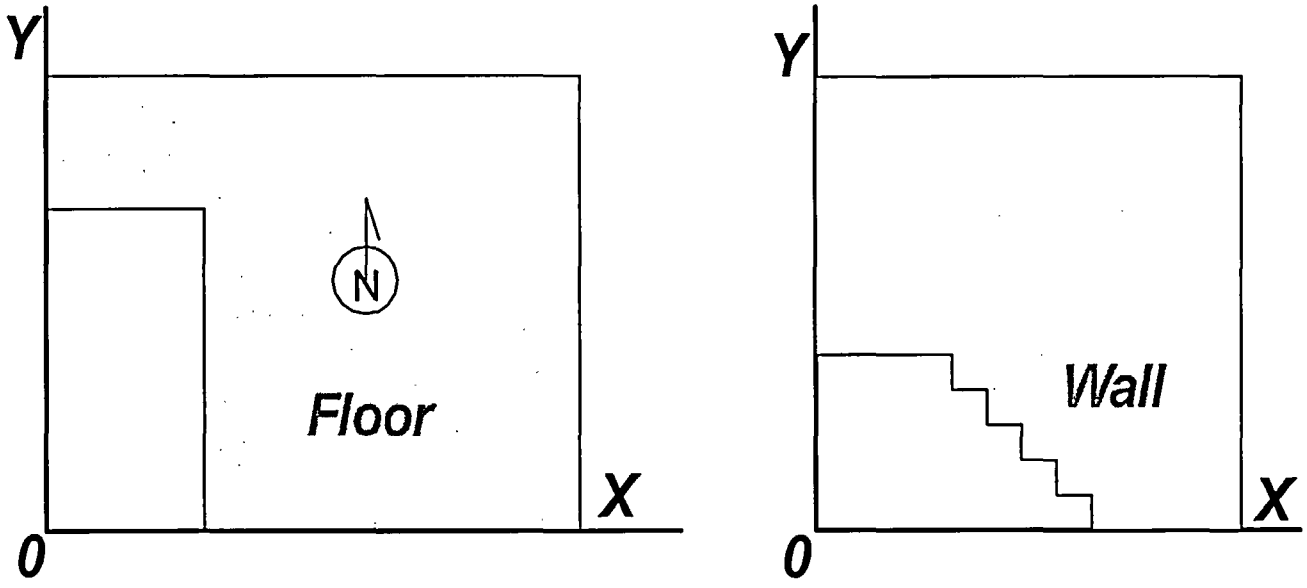
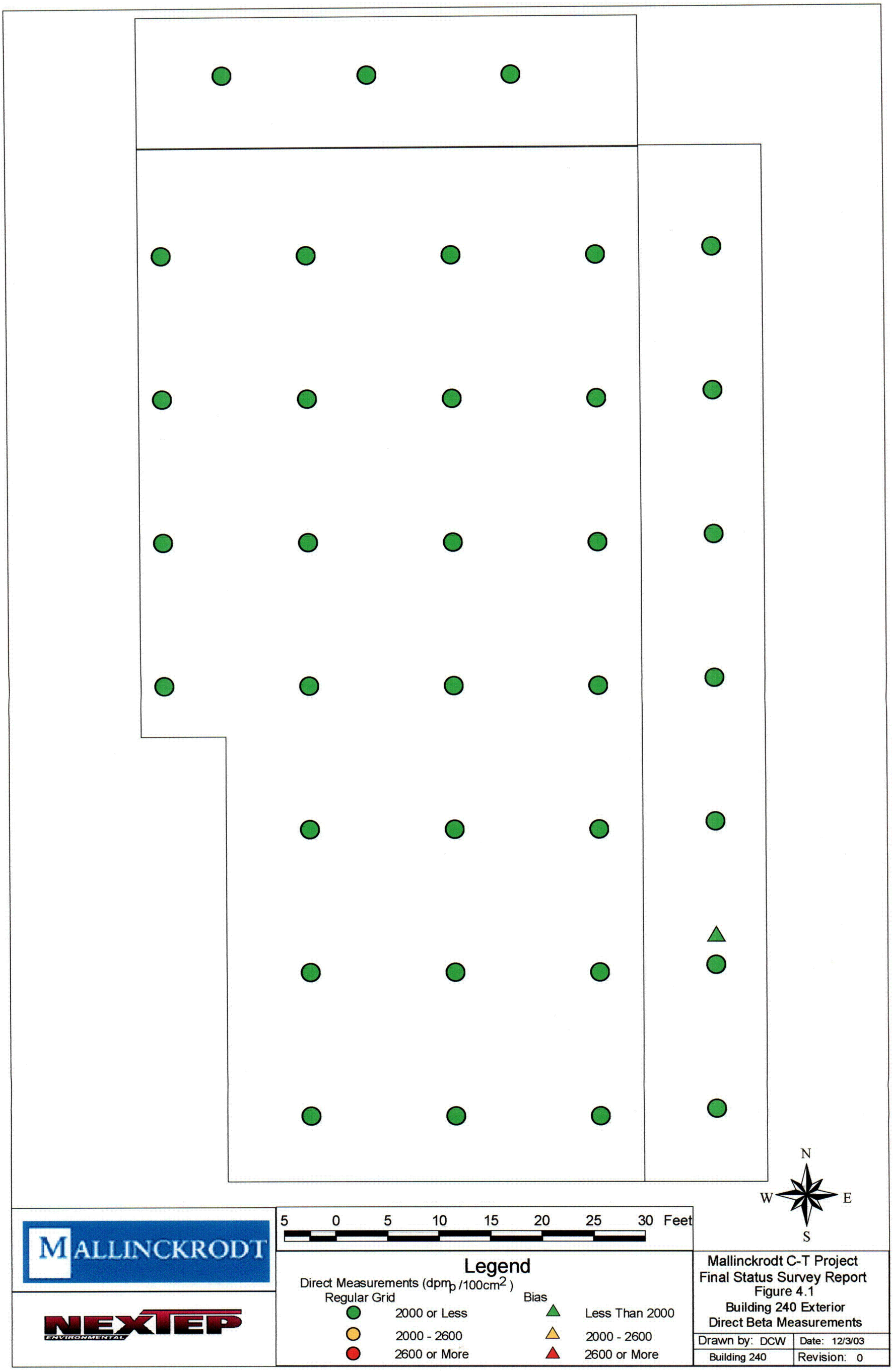


Figure 2.2
SU-240NER Roof



Coordinate System

Figure 3.1


N
W
E
S
5 0 5 10 15 20 25 30 Feet
MALLINCKRODT
NEXTEP ENVIRONMENTAL
Legend
Direct Measurements (dpm$_\beta$/100cm^2)
Regular Grid
2000 or Less
2000 - 2600
2600 or More
Bias
Less Than 2000
2000 - 2600
2600 or More
Mallinckrodt C-T Project
Final Status Survey Report
Figure 4.1
Building 240 Exterior
Direct Beta Measurements
Drawn by: DCW
Date: 12/3/03
Building 240
Revision: 0

C01

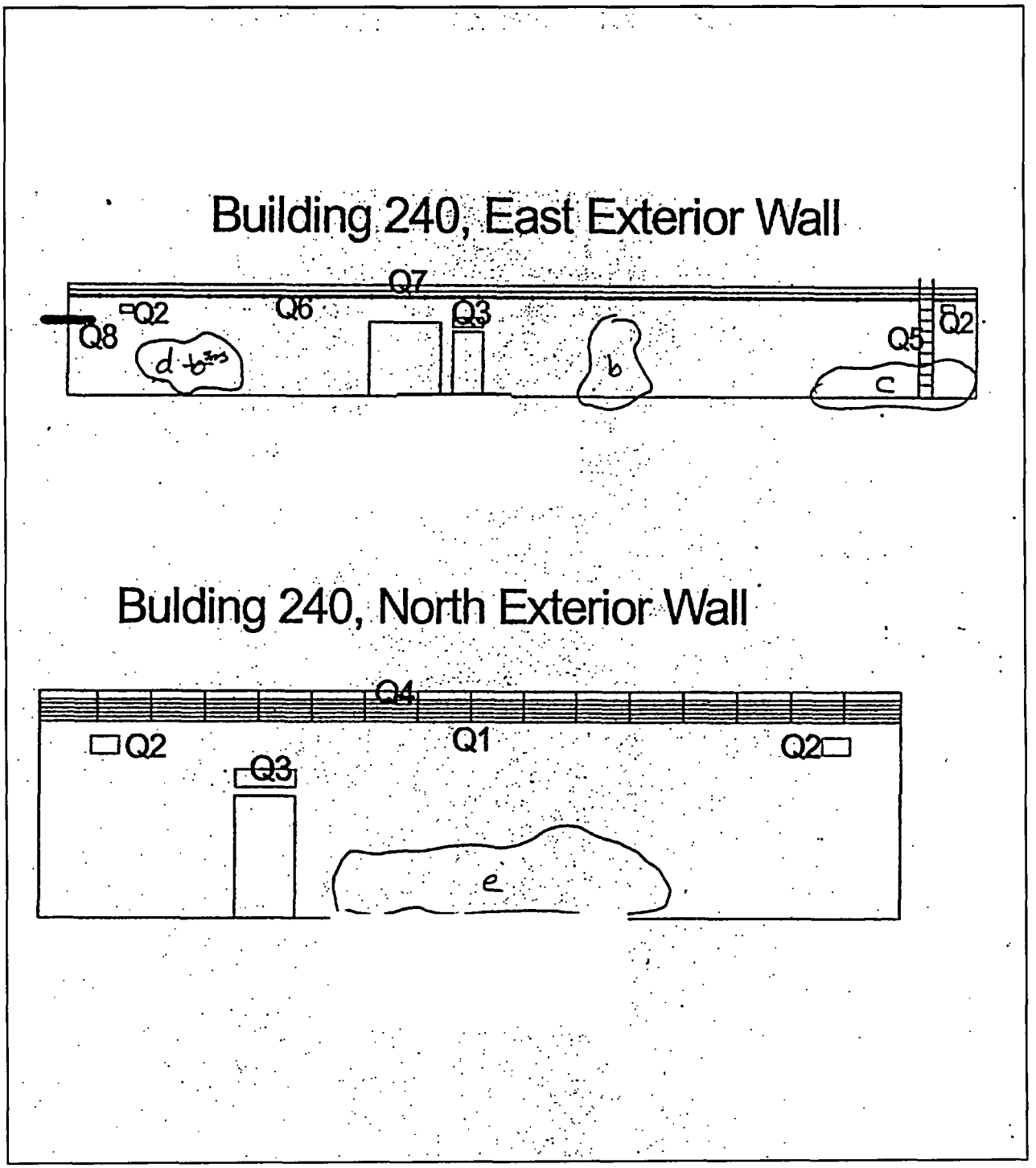


Figure 4.2

Survey Unit 240NE Wall Scans

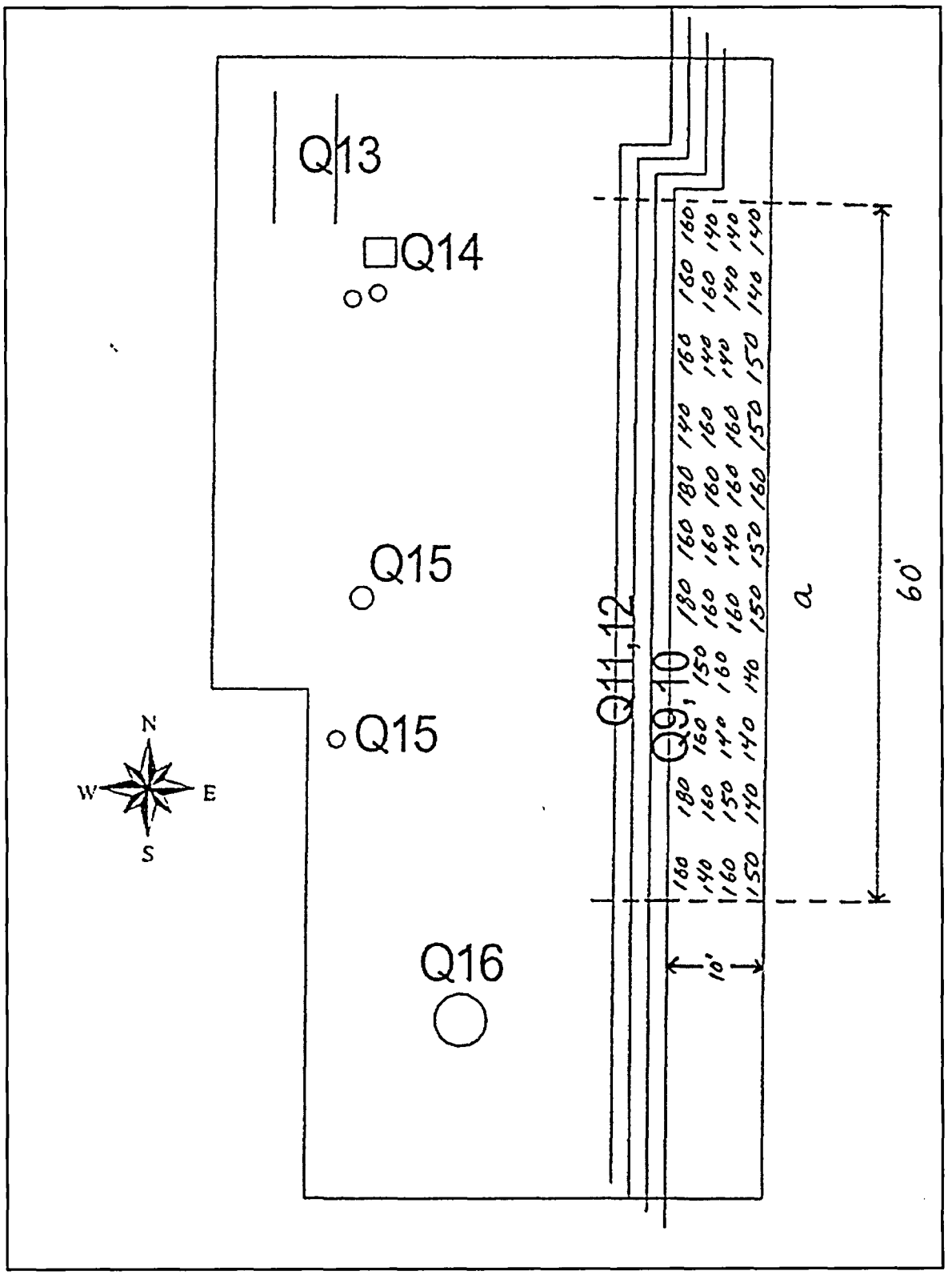


Figure 4.3

Survey Unit 240R Scans

APPENDIX 3
Calibration Sheets

Type	S/N	Cal Date
Beta	163666/B426W	1/16/2003
	131410/188707	4/16/2003
	131415/B426W	5/15/2002
Swipe	179577	2/26/2003

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

ThermoRetec
Smart Solutions. Positive Outcomes.

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

LUDLUM 2221
CALIBRATION DATA SHEET

Ludlum2221S/N: 163666 Property O

Battery Check OK @ 5.6 Bits
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	1005	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. Sells (Print) (Signature)

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

L2221/AB-100
S/N: 163666/B426W
1/16/03

CALN100A

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

	BACKGROUND		BR	SOURCE		SR		SA	Efficiency
SURFACE MATERIAL	OPEN Cts/2 min	SHIELD Cts/2 min	NET CPM	OPEN Cts/1 min	SHIELD Cts/1 min	NET CPM	Source #	Source Activity	SR/SA %
Concrete	561	416	73	6857	232	6625	6-A	33250	19.9
				6853	246	6607			19.9
				6846	242	6604			19.9
				6784	236	6548			19.7
266x125 = ~~335~~ 2115 33250 dpm								Average =	19.9
								Std Dev =	0.1
Wood	0	0	0	5222	238	4984	M-2	22250	[illegible]
	0	0	0	5281	240	5041			[illegible]
	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			[illegible]
178 dpm x 125 = 22250								Average =	[illegible]
								Std Dev =	[illegible]
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: 1/30/03

L2221/AB-100
S/N: 163666/B426W
1/16/03

CT-RP-66
Chi Squared Test

Instrument Model #	2221	Date:	02/04/2003
Instrument Serial#	163666	Source Nuclide:	SrY90
Probe Model #	AB 100	Source Serial #	2178-98
Probe Serial #	B426W	Source dpm (4π):	56489
Window Setting:	3720	Efficiency (cpm/dpm):	0.28
Threshold Setting:	352	Background cpm:	183.4
High Voltage:	875	BKGD N-1	4
		BKGD Count Time (min):	1

Count # (n)	Gross Counts Observed	Expected	Background Counts
1	15380	15546	185
2	15381	15546	193
3	15477	15546	179
4	15662	15546	179
5	15520	15546	181
6	15587	15546	
7	15476	15546	
8	15392	15546	
9	15639	15546	
10	15609	15546	
11	15401	15546	
12	15433	15546	
13	15601	15546	
14	15743	15546	
15	15608	15546	
16	15828	15546	
17	15577	15546	
18	15518	15546	
19	15510	15546	
20	15599	15546	

sample mean (xbar) =	15546	Multiplier to convert to dpm:	3.6
sample variance (s^2) =	15181		
background variance (b^2) =	34.8		
sample sigma (s) =	123		
(95% Confidence) 2.752 s =	339		
(99% Confidence) 3.615 s =	446		
		MDA (cpm) =	66
df = n-1 =	19	MDA (dpm) =	240
chitest = p(x<χ^2) =	4.858E-01		
chisquare (χ^2) =	18.654		
Acceptable χ^2 min =	8.907		
Acceptable χ^2 max =	32.852		
χ^2 test passes (yes/no)?	YES		
99% Conf. Interval Test min =	14917		
95% Conf. Interval Test min =	15023		
Daily Source Check Mean Net Counts	15363		
95% Conf. Interval Test max =	15702		
99% Conf. Interval Test max =	15809		

Test performed by: Steve Struck 2/4/03

Checked by: Jim C. Woodford Date: 2-4-03

L2221/AB-100
S/N: 163666/B426W
1/16/03

Lud
43-89
~~A0-37~~
CALIBRATION DATA SHEET

4389
~~A0-37~~ SN: 188707 Property of: MALT

Readout Inst.: Lud 2241-2 SN: 131410 Cal.Exp.Date: 10-16-03

Beta
~~Alpha~~ Source: Sr-Y-90 SN: 2158/96 Activity: 17100 DPM

Date of Cal.: 10-24-00

PLATEAU:

High Voltage	Source (CPM)	High Voltage	Source (CPM)
600	—	~~1050~~ 750	2657
650	—	~~1100~~ 760	2899
700	1320	~~1150~~ 770	3161
750	2640	~~1200~~ 780	3519
800	4040	1250	N/A
850	N/A	1300	
900		1350	
950		1400	
1000			

High Voltage set at: 770 volts

Background Check

High Voltage	CPM
Op. Voltage ~~-50~~ -10	107
Op. Voltage	111
Op. Voltage ~~+50~~ +10	134

* 47mm Source @ Contact Geometry Center of Probe

Efficiency:
5 Minute Gross Counts:

Pos "A": Pos "B":
Average (A + B)/2: Gross CPM:
Background: CPM: Net CPM:

1min Ct 3196
1min BKG 127
3019 / 17100 cpm
17.7%

$$\text{Efficiency} = \frac{\text{Net CPM}}{\text{DPM}} \times 100 = _____ \%$$

Date of Calibration: 4-16-03 Expiration Date: 10-16-03

Calibrated by: Randall H. Sells (Print Name) (Signature)

Reviewed by: Allen J. Negley Date: 4/22/03

A4.10
Rev: 2
Date: 25 Feb 99

Page 4 of 4

L2241-2/L43-89
S/N: 131410/188707
4/16/03

CALN100A

Thermo NUtech

For Mallinckrodt Chemical, Inc

NATIONAL NUCLEAR ABP-100
MATERIAL SPECIFIC CALIBRATION DATA SHEET

Lud 43-89 ~~ABP-100~~ SN: 180707 HIGH VOLTAGE: 770 V PROPERTY OF: MALT

READOUT INST: Lud 2241-2 SN: 131410 CAL EXPIRE DATE: 10-16-03

ABP-100 EFFICIENCY TO SrY-90 ON 47 mm DISK: 17.7 % CAL DATE: 4-16-03

	BACKGROUND		BR	SOURCE		SR		SA	Efficiency
SURFACE MATERIAL	OPEN Cts/2 min	SHIELD Cts/2 min	NET CPM	OPEN Cts/1 min	SHIELD Cts/1 min	NET CPM	Source #	Source Activity	SrY-90 %
Concrete	264	230	17	4753	277	4476	6-A	25900	[illegible]
				4877	301	4576			[illegible]
				4811	297	4514			17.4
				4705	315	4390			16.5
259 x 100 = 25900								Average =	17.3
								Std Dev =	0.3
Wood	0	0	0	3725	256	3469	M-2	17400	19.9
	0	0	0	3606	243	3363			19.3
	0	0	0	3581	223	3358			[illegible]
	0	0	0	3544	245	3309			[illegible]
174 x 100 = 17400						3299		Average =	19.2
								Std Dev =	0.4
Masonite	0	0	0	3646	318	3328	M-2	17400	19.1
	0	0	0	3713	324	3389			19.5
	0	0	0	3735	319	3416			[illegible]
	0	0	0	3600	327	3273			[illegible]
								Average =	[illegible]
								Std Dev =	[illegible]
Aluminum	0	0	0	4203	193	4010	M-2	17400	[illegible]
	0	0	0	4188	207	3978			22.9
	0	0	0	4119	193	3936			22.6
	0	0	0	4023	195	3828			22.0
								Average =	22.7
								Std Dev =	0.5

DATE OF CALIBRATION: 4-17-03 EXPIRATION DATE: 10-17-03

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

REVIEWED BY: [signature] DATE: 4/22/03

L2241-2/L43-89
S/N: 131410/188707
4/16/03

CT-RP-66
Chi Squared Test

Instrument Model #	2241	Date:	04/28/2003
Instrument Serial#	131410	Source Nuclide:	SrY90
Probe Model #	43-89	Source Serial #	2178-06
Probe Serial #	188707	Source dpm (4π):	56268
Window Setting:		Efficiency (cpm/dpm):	0.14
Threshold Setting:	35 mV	Background cpm:	79.8
High Voltage:	770	BKGD N-1	4
		BKGD Count Time (min):	1

Count # (n)	Gross Counts Observed	Expected	Background Counts
1	7865	7848	82
2	7914	7848	80
3	7726	7848	80
4	8036	7848	82
5	7901	7848	75
6	7851	7848	
7	7923	7848	
8	7889	7848	
9	7693	7848	
10	7890	7848	
11	7874	7848	
12	7831	7848	
13	7929	7848	
14	7861	7848	
15	7700	7848	
16	7852	7848	
17	7828	7848	
18	7861	7848	
19	7724	7848	
20	7805	7848	

sample mean (xbar) =	7848	Multiplier to convert to dpm:	7.2
sample variance (s^2) =	7273		
background variance (b^2) =	8.2		
sample sigma (s) =	85	FSS Normalization	
(95% Confidence) 2.752 s =	235	S_1 =	0.287
(99% Confidence) 3.815 s =	308		
		MDA(cpm) =	45
df = n-1 =	19	MDA(dpm) =	320
chitest = p(x<χ^2) =	5.487E-01		
chisquare (χ^2) =	17.609		
Acceptable χ^2 min =	8.907		
Acceptable χ^2 max =	32.852		
χ^2 test passes (yes/no)?	YES		
99% Conf. Interval Test min =	7459		
95% Conf. Interval Test min =	7533		
Daily Source Check Mean Net Counts	7768		
95% Conf. Interval Test max =	8003		
99% Conf. Interval Test max =	8076		

Test performed by: Steve Struck 4-28-03

Checked by: Jim C. Woolford Date: 4-28-03

L2241-2/L43-89
S/N: 131410/188707
4/16/03

AC-3-7
CALIBRATION DATA SHEET

AB-100 ~~AC-3-7~~ SN: B426W Property of: E.S.

Readout Inst.: 2241-2 SN: 131415 Cal.Exp.Date: 5-15-03

Beta ~~Alpha~~ Source: Sr-Y-90 SN: 2158/96 Activity: 17500 DPM

Date of Cal.: 10-24-00

PLATEAU:

High Voltage	Source (CPM)	High Voltage	Source (CPM)
600	—	1050	
650	998	~~1400~~ 775	5992
700	3053	~~1450~~ 800	6612
750	5422	~~1200~~ 825	6999
800	6698	~~1250~~ 850	7358
850	7550	~~1300~~ 875	8880
900	23305	1350	
950	—	1400	
1000	—		

High Voltage set at: 825 volts

Background Check

High Voltage	CPM
Op. Voltage ~~-50~~ -25	244
Op. Voltage	272
Op. Voltage ~~+50~~ +25	353

*Contact Geometry @ Probe Center

Efficiency:

~~5 Minute Gross Counts~~:

Pos "A": Pos "B":
Average (A + B)/2: Gross CPM:
Background: CPM: Net CPM:

1min Ct 7054
1min Bkg 256
6798/17500 dpm = 38.8 39.0% eff

$$\text{Efficiency} = \frac{\text{Net CPM}}{\text{DPM}} \times 100 = _____ \%$$

Date of Calibration: 5-15-02 Expiration Date: 5-15-03

Calibrated by: Randall H. Sells (Print Name) (Signature)

Reviewed by: Allen Gregory Date: 5/15/02

4.10
Rev: 2
Date: 25 Feb 99

*Replaced Inner & Outer Mylar

Page 4 of 4

L2241-2/AB-100
S/N: 13145/B426W
5/15/02

CALN100A

Thermo NUtech

For Mallinckrodt Chemical, Inc

NATIONAL NUCLEAR ABP-100
MATERIAL SPECIFIC CALIBRATION DATA SHEET

ABP-100 SN: B426W HIGH VOLTAGE: 825 V PROPERTY OF: E.S.

READOUT INST: 2241-2 SN: 131415 CAL EXPIRE DATE: 5-15-~~02~~ 03 RHS

ABP-100 EFFICIENCY TO SrY-90 ON 47 mm DISK: 39.0 % CAL DATE: 5-15-02

	BACKGROUND		BR	SOURCE		SR		SA	Efficiency
SURFACE MATERIAL	OPEN Cts/2 min	SHIELD Cts/2 min	NET CPM	OPEN Cts/1 min	SHIELD Cts/1 min	NET CPM	Source #	Source Activity	SR-BR/ SA
Concrete	648	550	98	8744	294	8450	L-A	33250	25.4
↓	↓	↓	↓	8696	299	8397	↓	↓	25.3
				8522	292	8230			24.8
				8697	294	8403			25.3
125 X ~~266000~~ 2660 dpm = 33250								Average =	25.2
								Std Dev =	0.3
Wood	0	0	0	6691	251	6440	M-2	22250	28.9
↓	↓	↓	↓	6772	282	6490	↓	↓	29.1
				6793	290	6503			29.2
				6588	283	6305			28.3
125 X 178 = 22250								Average =	28.9
								Std Dev =	0.4
Masonite	0	0	0	6682	304	6378	M-2	22250	28.7
↓	↓	↓	↓	6635	268	6367	↓	↓	28.6
				6837	279	6558			29.5
				6626	304	6322			28.4
125 X 178 dpm = 22250								Average =	28.8
								Std Dev =	0.5
Aluminum	0	0	0	7468	312	7156	M-2	22250	32.2
↓	↓	↓	↓	7578	300	7278	↓	↓	32.7
				7411	305	7106			31.9
				7564	296	7268			32.7
125 X 178 dpm = 22250								Average =	32.4
								Std Dev =	0.4

DATE OF CALIBRATION: 5-15-02 EXPIRATION DATE: 5-15-03

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

REVIEWED BY: Alan Gregley DATE: 5/15/02

L2241-2/AB-100
S/N: 13145/B426W
5/15/02

JUL-16-2003 16:52 314 654 1251 MALLINCKRODT #2114 P.006

Ludlum Measurements, Inc. of Scientific and Industrial Instruments

CERTIFICATE OF CALIBRATION

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

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. 495 / 500 V Ref./Inst. 1485 / 1500 V

GO mode turned OFF.

Firmware version: 3901AN3

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

*Operability within ± 10% C.F. within ± 20% (0) indicates 0.1 minute count

COMMENTS:
Eff. for S-Am-241 S/N 4016, 4450dpm, read 2872 in one minute = 64% Eff
Eff. for Tl-204 S/N 2948-00, 3070 dpm, read 1999 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-1063

Reference Instruments and/or Sources:

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

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

Calibrated By: Conrad Galindo Date 26 Feb 03

Reviewed By: Rhesh Hom Date 4 March 03

This certificate shall not be reproduced except in full, without the written approval of Ludlum Measurements, Inc.
FORM 225-3 10/22/2002

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

L3030
S/N: 179577
2/26/03

Ludlum Measurements, Inc.

Model 3030 Plateau Data

2/26/03
1:38:50 PM

Header 1: John Q Public
Header 2: Serial#179577
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): 22500
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%

L3030
S/N: 179577
2/26/03

Model 3030 MDA Calculation Data

2/26/03
1:42:00 PM

Alpha Background(cpm): 2.0
Beta Background(cpm): 49.0

Alpha Efficiency %: 38.0
Beta Efficiency %: 35.0

Confidence Level: 95%

Count Time	Alpha MDA(dpm)	Beta MDA(dpm)
0.1	111.9	295.7
0.5	35.5	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
50.0	12.5	66.5
FC (1.0)	24.4	100.8

L3030
S/N: 179577
2/26/03

APPENDIX 4
Threshold Comparison Test Reports (TCTR)

MALLINCKRODT C-T DECOMMISSIONING PROJECT

Threshold Comparison Test Report -

Run Date: Monday, December 08, 2003
Survey Unit Number: Class: 2 Data Points: Beta Grid Type: R Spacing: 14.8 ft.

SURVEY UNIT TABLE

Bldg	*Rm*	*Surface*	*Fixed Equipment*	*Surface Area Included (sq. ft)*	*Remarks*
B240	999	RNE	Q1-16	6346	North wall, East wall and Roof
			Total Area	6346	

INITIALIZATION DATA

Measurement Types Selected: RG, BI
Date Range: All
Thresholds:
EMC: 13,000 DCGLw: 2,600

SURVEY UNIT TEST STATUS

Test Performed	Status			
Min/Max	Pass	Maximum Survey Value	TR	214.0
Background	Fail	Minimum Background	M	1.0
DCGLw	Pass	Difference		213.0
DCGLavg	Pass	Average Activity	65.5	
EMC	Pass	Average Below DCGL	65.5	
Wilcoxon Rank Sum Test	N/A	Average Background	81.6	
Sign Test for Paired Data	Pass			

MALLINCKRODT C-T ECOMMISSIONING 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 TEST:

Survey Unit # 240NER Building: B240

Room	SFC	X (ft)	Y (ft)	Mtx	Type	Min	SID	Meas. Gross Activity (dpm$_\beta$/100cm^2)	Remarks	Exc	Res.
999	Q14	1.0	0.0	M	BI	1	6091	89.7		C	
999	Q3	1.0	0.0	TR	BI	1	6070	213.5		C	
999	Q4	3.0	0.0	M	BI	1	6074	160.9		C	
999	Q4	2.0	0.0	M	BI	1	6073	141.6		C	
999	Q4	1.0	0.0	M	BI	1	6072	128.4		C	

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

Survey Unit # 240NER Building: B240

Room	SFC	X (ft)	Y (ft)	Mtx	Meas. Type	Min	SID	Gross Activity (dpm$_\beta$/100cm^2)	Remarks	Exc	Res.
999	E	49.0	6.6	CB	RG	1	6041	86.6			
999	E	91.0	6.6	CB	RG	1	6044	85.3			
999	E	35.0	6.6	CB	RG	1	6040	78.8			
999	E	77.0	6.6	CB	RG	1	6043	49.1			
999	E	24.0	6.6	M	BI	1	6097	32.5			
999	E	21.0	6.6	CB	RG	1	6039	32.3			
999	E	7.0	6.6	CB	RG	1	6038	28.4			
999	E	63.0	6.6	M	RG	1	6042	10.1			
999	N	27.8	6.1	CB	RG	1	6036	86.6			
999	N	13.8	6.1	CB	RG	1	6035	56.8			
999	N	41.8	6.1	CB	RG	1	6037	19.4			
999	Q1	2.0	0.0	M	BI	1	6067	36.4			
999	Q1	1.0	0.0	M	BI	1	6066	24.8			
999	Q10	2.0	0.0	M	BI	1	6084	17.8			
999	Q10	1.0	0.0	M	BI	1	6083	14.7			
999	Q11	2.0	0.0	M	BI	1	6086	30.2			
999	Q11	1.0	0.0	M	BI	1	6085	22.4			
999	Q12	2.0	0.0	M	BI	1	6088	14.7			
999	Q12	1.0	0.0	M	BI	1	6087	13.9			
999	Q13	1.0	0.0	M	BI	1	6089	20.9			
999	Q13	2.0	0.0	M	BI	1	6090	-13.2			
999	Q14	3.0	0.0	M	BI	1	6093	48.7			
999	Q14	2.0	0.0	M	BI	1	6092	14.7			
999	Q15	2.0	0.0	M	BI	1	6095	29.4			
999	Q15	1.0	0.0	M	BI	1	6094	9.3			
999	Q16	1.0	0.0	M	BI	1	6096	10.1			
999	Q2	2.0	0.0	M	BI	1	6069	18.6			
999	Q2	1.0	0.0	M	BI	1	6068	-9.3			
999	Q3	2.0	0.0	TR	BI	1	6071	124.8			

MALLINCKRODT C-T ECOMMISSIONING PROJECT

Threshold Comparison Test Report -

Room	SFC	X (ft)	Y (ft)	Mtx	Meas. Type	Min	SID	Gross Activity (dpm/100cm²)	Remarks	Exc	Res.
999	Q5	1.0	0.0	M	BI	1	6075	45.6			
999	Q5	2.0	0.0	M	BI	1	6076	39.5			
999	Q6	2.0	0.0	M	BI	1	6078	54.2			
999	Q6	1.0	0.0	M	BI	1	6077	30.2			
999	Q7	2.0	0.0	M	BI	1	6080	11.6			
999	Q7	1.0	0.0	M	BI	1	6079	-1.5			
999	Q9	2.0	0.0	M	BI	1	6082	25.5			
999	Q9	1.0	0.0	M	BI	1	6081	-14.7			
999	R	16.2	20.3	TR	RG	1	6061	156.6			
999	R	30.2	76.3	TR	RG	1	6050	148.9			
999	R	16.2	48.3	TR	RG	1	6055	138.0			
999	R	44.2	6.3	TR	RG	1	6425	134.5			
999	R	30.2	6.3	TR	RG	1	6065	123.7			
999	R	30.2	90.3	TR	RG	1	6047	119.3			
999	R	44.2	48.3	TR	RG	1	6422	119.3			
999	R	44.2	62.3	TR	RG	1	6421	117.9			
999	R	30.2	48.3	TR	RG	1	6056	115.0			
999	R	30.2	34.3	TR	RG	1	6059	113.9			
999	R	30.2	20.3	TR	RG	1	6062	112.8			
999	R	16.2	34.3	TR	RG	1	6058	101.8			
999	R	2.2	76.3	TR	RG	1	6048	99.6			
999	R	16.2	90.3	TR	RG	1	6046	94.2			
999	R	2.2	62.3	TR	RG	1	6051	90.9			
999	R	44.2	76.3	TR	RG	1	6420	87.4			
999	R	16.2	62.3	TR	RG	1	6052	85.4			
999	R	16.2	6.3	TR	RG	1	6064	85.4			
999	R	44.2	34.3	TR	RG	1	6423	80.4			
999	R	30.2	62.3	TR	RG	1	6053	73.4			
999	R	2.2	48.3	TR	RG	1	6054	64.6			
999	R	44.2	90.3	TR	RG	1	6419	63.8			
999	R	2.2	90.3	TR	RG	1	6045	63.5			
999	R	16.2	76.3	TR	RG	1	6049	43.8			
999	R	44.2	20.3	TR	RG	1	6424	37.4			

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:* 13,000

EMC	*Matrix Data Points*	*Number of Background*	*Average*	*Sigma Threshold (Tbk)*	*Background Threshold (Td)*	*DCGLw Threshold (Tc)*
		($dpm_p/100cm^2$)	($dpm_p/100cm^2$)	($dpm_p/100cm^2$)	($dpm_p/100cm^2$)	($dpm_p/100cm^2$)
CB	51	96.1	21.7	139.4	2,739	13,139
M	10	24.0	15.7	55.3	2,655	13,055
TR	42	77.7	51.6	181.0	2,781	13,181

MALLINCKRODT C-T DECOMMISSIONING PROJECT

Threshold Comparison Test Report -

STATISTICAL TEST RESULTS

Run Date: 12/8/2003 5:45:10 PM
Survey Unit Number 240NER Class: 2
Selected Test: SIGN TEST FOR PAIRED DATA
Test Status Pass
Thresholds:

EMC 13,000 DCGL 2,600

DATA SUMMARY TABLE

35 Survey points processed and 3 matrices processed

S+ = 35 **Wc =** 22

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