

FINAL STATUS SURVEY REPORT BUILDING 200 ROOF

MALLINCKRODT, INC.
COLUMBIUM- TANTULUM PROJECT- PHASE 1

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*Mallinckrodt, Inc.
St. Louis, Missouri*

BURNS & McDONNELL
9400 Ward Parkway
Kansas City, Missouri 64114
Phone (816) 333-9400
Fax (816) 822-3463



NEXTEP ENVIRONMENTAL
808 Lyndon Lane, Suite 201
Louisville, Kentucky 40222
Phone (502) 339-9767
Fax (502) 339-9275

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C-T PROJECT - PHASE I
FINAL STATUS SURVEY REPORT

Building 200 Roof
Survey Units 200EastR & 200WestR
Revision 0

Prepared by

BMNX
Joint Venture

Approved by: [Signature] Date: 12/3/03
Survey Designer

Approved by: [Signature] Date: 12/12/03
Mallinckrodt C-T Decommissioning Project Manager

Approved by: [Signature] Date: 12-11-03
Mallinckrodt Radiation Safety Officer

Approved by: [Signature] Date: 12/5/03
BMNX C-T Decommissioning Project Manager

Approved by: [Signature] Date: 12/5/03
BMNX Environment, Safety and Health Representative

Issued by: [Signature] Date: 1-5-04
BMNX Quality Assurance Manager

BURNS & McDONNELL

9400 Ward Parkway
Kansas City, Missouri 64114
Phone (816) 333-9400
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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 roof of Building 200 on the Mallinckrodt St. Louis site (designated as Survey Units (SU) 200EastR and 200WestR). 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 (FI) CT-FI-010¹ 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. 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-010, *Final Status Survey Guide for Survey Units 200EastR and 200WestR*

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 UNIT

2.1.1. The roof of Building 200 has been designated as two survey units, SU-200EastR and SU-200WestR. Although both were initially Class 3 they have been reclassified as Class 2 based upon evaluation of the data.

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 2.1²
Survey Area Descriptions

| Area | Building | Location / Surface |
|------|----------|---|
| 16 | 200E | Roof: Roof repaired in several spots where old equipment was removed. New roof installed on building annex east side after C-T operations ceased. Original roof decking. |
| 17 | 200E | Roof Equipment: New FRP panels installed on roof and side of stairwell penthouse. All equipment, blowers, condensers, piping and piping supports removed and disposed. New exhaust blower installed on building annex eastside. |
| 18 | 200W | Roof: Roof replaced in spring of 2000, original roof decking. |
| 19 | 200W | Roof Equipment: New FRP scrubber system with FRP ductwork installed in center of building roof. 1 old HVAC system on northwest side of building roof was removed and disposed after C-T operations ceased. |

2.1.3. A summary report for the survey units listing all the surfaces and fixed apparatus assigned to SU-200EastR and SU-200WestR 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 2.1.

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 Appendix A of D Plan.

³ Mallinckrodt C-T Project D Plan Appendix D.

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 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 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) |
|--------------------------|--|---|
| Metal | 20.4 | 13.3 |
| Tar/Roofing ⁵ | 87.5 | 58.2 |

- 2.3.2. Gamma background. NaI gamma background was collected on Building 25 Roof.⁶ The average and standard deviations were 4,079 cpm and 196 cpm respectively. These values were used for both direct and scan gamma surveys.

2.4. 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 vents, air handlers, and piping.
- 2.4.2. To limit the dose from residual materials as much as possible an Administrative Release Guideline (ARG)⁷ was developed and was used during the FSS as if it were the DCGLw with certain exceptions.⁸

⁴ Dpm_p/100 cm² refers to the disintegrations per minute per 100 cm² for the combined nuclide series.

⁵ The tar/roofing matrix consists of an asphalt binder. The asphalt background samples from the database were used as a close approximation of the tar/roofing matrix background.

⁶ See Appendix A of NEXTEP Tech Memo 0230, *Technical Basis Document for Mallinckrodt Final Status Survey*. A.H. Thatcher, CHP.

⁷ NEXTEP Tech Memo 0211, *Recommendation for an Administrative Release Guideline for the Mallinckrodt C-T Project*, A.H. Thatcher, CHP.

⁸ Final Status Survey Design Guide (Phase I), Section 3.2, covers the rules governing use of the ARG.

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. Elevated Measurements Criterion (EMC).

2.4.3.1. Because the two units surveyed in this FSS were Class 2, 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, 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.

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/cm² for the

purpose of alpha attenuation⁹. 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 location¹⁰. The difference in the two readings is attributable to beta emissions above 80 KeV in energy.¹¹ The sensitivity of the AB-100 was derived from experiments by Lucas and Colyott which were reported in Attachment 3 to the D Plan.¹² The actual instruments used were calibrated and normalized to the reference instrument tested by Lucas and Colyott as prescribed in CT-QA-6.1¹³.

- 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 scintillation detector is a newer design that is functionally and physically equivalent to the AB-100. It has a slightly higher efficiency as a rule, and it may be paired on the same ratemeters and scalers.
- 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 β pm/100 cm². 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 LIMIT OF DETECTION AND DETECTION THRESHOLD

- 2.6.1. The terminology adopted to reflect the measurement (detection) capability of an instrument 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

⁹ As specified in Appendix D of the D Plan. Measurements taken with only the mylar covering the probe were "open window" measurements.

¹⁰ 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.

¹¹ Internal Conversion Electrons (ICE) will also be included in this number but are a second order effect and may be ignored.

¹² *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.

¹³ CT-QA-6.1 - *Calibration and Control of Measuring and Survey Equipment*.

(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-6.1.¹⁴

- 2.6.2. The LLD requirements for the FSS have been developed in accordance with MARSSIM¹⁵ Chapter 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 Requirement ¹⁶ |
|-------------------------|-------------------------------|
| 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. 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 NEXTEP Tech Memo 0230.¹⁷

¹⁴ CT-QA-6.1, Ibid.

¹⁵ NUREG 1575, *Multi Agency Radiation Survey and Site Investigation Manual*.

¹⁶ 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.

¹⁷ NEXTEP Tech Memo 0230, *Technical Basis Document for Mallinckrodt Final Status Surveys*, A.H. Thatcher, CHP (included with FSSR 235 Roof).

Table 2.5
LLD and Action Thresholds¹⁸

| Measurement | Units | Calculated Value | Required Value |
|--------------------------------|---------------------------------------|------------------|----------------|
| BETA DIRECT | | | Class 2 |
| MDC | dpm _p /100 cm ² | 100 | 1,300 |
| T _{inv} ¹⁹ | cpm | | 2,900 |
| BETA SCAN | | | |
| MDC | dpm _p /100 cm ² | 760 | 2,600 |
| T _{inv} | cpm | | 2,000 |
| GAMMA DIRECT | | | |
| MDC (non-Gravel) | dpm _p /100 cm ² | 950 | 1,300 |
| T _{inv} (non-Gravel) | cpm | | 1,950 |
| GAMMA SCAN | | | |
| MDC (Gravel) | dpm _p /100 cm ² | 1,200 | 2,600 |
| T _{inv} (Gravel) | cpm | | 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 cm² 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 cm² 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.

¹⁸ All Values given are net of background.

¹⁹ Investigation Threshold.

- 2.7.2. Justification and calculations for separation of backscatter (as a function of the matrix) and instrument sensitivity were presented in NEXTEP Tech Memo 0215.²⁰ Reference backscatter coefficients for several matrices were generated using an MCNP model and are described in NEXTEP Tech Memo 0213.²¹ These coefficients were stored in the Matrix table in the Database and were used in the calculations according to the matrix 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-010, Final Status Survey Guide for Survey Units 200EastR and 200 West R |
| 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 checklist²² 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.

²⁰ NEXTEP Tech Memo 0215, *Separation of Backscatter & Derivation of Instrument Sensitivity*, A.H. Thatcher CHP. (Included with FSSR 2501).

²¹ NEXTEP Tech Memo 0213, *Beta Backscatter Factors for Several Materials at the Mallinckrodt Site*, N. Zhang and D. Wilson. (Included with FSSR 2501).

²² NEXTEP Tech Memo 0206, *QA Data Verification for MI CT Final Status Survey Data*, B. Anderson, (Included with FSSR 2501).

3.2. SURVEY MEASUREMENTS

3.2.1. Beta Measurements:

3.2.1.1. *Direct* – A systematic grid of direct measurements was obtained on the roof surfaces as described in the FI. Direct beta measurements were collected on the asphalt binder layer of the roof. 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 the roof surface. 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 200 west and 200 east annex had been replaced, 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-200WestR. 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.

3.2.2.2. *Scans* - Gamma Scans were performed in straight lines 5 cm above the surface of the roof in SU-200WestR 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 100% of all regular grid locations on the roof. 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 DCGLw²³.

²³ Section 3.3 of the C-T Design Guide.

3.3. MEASUREMENT LOCATIONS

3.3.1. Statistical Grid Data Points

- 3.3.1.1. The *Visual Sample Plan*® (VSP)²⁴ 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 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 12% 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 200 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% |

- 3.3.1.3. A rectangular grid was used for SU-200EastR and SU-200WestR. The maximum grid spacing (L) was calculated from the area (A) of the total survey unit 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 SU-200EastR and SU-200WestR.

²⁴ NEXTEP Tech Memo 0008, *Verification and Validation of Applicable Portions of VSP Software*, A. H. Thatcher, CHP.

Table 3.3
SU-200EastR & SU-200WestR Calculated Grid Point Separation

| Survey Unit | Class | N | A (ft ²) | L (ft) |
|-------------|-------|----|----------------------|--------|
| SU-200EastR | 2 | 29 | 4,801 | 12.9 |
| SU-200EastR | 2 | 29 | 6,410 | 14.9 |

3.3.2. Bias Measurement Locations

3.3.2.1. Bias direct measurements (gamma on SU-200WestR surfaces, beta on SU-200EastR 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 Protocol²⁵.

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.

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. 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".

²⁵ CT-FI-004, *Final Status Survey Guide for Survey Unit 2504*.

- 3.4.4. 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".
- 3.4.5. 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 0231²⁶.
- 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 each survey record but generate a single PASS/FAIL verdict for the entire data set. The tests are described in the following paragraphs²⁷. 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

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

²⁶ NEXTEP Tech Memo 0231, *Validation and Verification of the C-T Database Analysis Report*, B. Anderson, (included with FSSR 2501).

²⁷ A more detailed explanation is provided in the Design Guide.

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 $\text{dpm}_p/100\text{cm}^2$, 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.

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 $\text{dpm}_p/100\text{cm}^2$), 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 Test²⁸ 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 Data²⁹ was used.

3.5.10. The output of the Threshold Comparison Test Report (TCTR) was used for analysis of the data for the Building 200 roof and the results are presented in Appendix 4. The 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.

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 DCGL_W (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

²⁸ Described in Appendix I of MARSSIM.

²⁹ Described in NEXTEP Tech Memo 0231, Ibid.

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 DCGL _w |
| 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 ³⁰ |
| 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.

³⁰ NUREG 1505, *A Nonparametric Statistical Methodology for the Design and Analysis of Final Status Decommissioning Surveys*.

Table 3.6
Requirements for SU Release³¹

| 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.

4. FSS RESULTS AND DISCUSSION

4.1. CHARACTERIZATION DATA

4.1.1. The characterization data taken in these survey units 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 200EASTR

4.2.1. Direct Beta Measurements on Building Surfaces

4.2.1.1. SU-200EastR was surveyed in June and July 2003. Twenty-seven direct beta measurements were taken on the surface of the roof. All 27 of these were included in the systematic grid. A diagram of the survey unit layout of the roof with the beta measurements taken is presented in Appendix 2, Figure 4.1.

4.2.1.2. A summary of the direct measurement results is presented in Table 4.1 and shows that the maximum activity measured, net of background, was 84 dpm_p/100cm². The average value for the survey unit was -22 dpm_p/100cm². The background used for the asphalt binder of the roof (tar/roofing) was the asphalt background in the database.

Table 4.1
SU-200EastR Direct Measurements Summary

| Matrix | Points | Avg Net Activity ^a (dpm _p /100cm ²) | Max Net Activity (dpm _p /100cm ²) |
|-------------|--------|--|---|
| Tar/Roofing | 27 | -21.7 | 84.3 |

^a Dpm_p refers to disintegrations per minute of the parent nuclide series.

³¹ See MARSSIM, Chapter 8, Table 8.2

4.2.2. Installed Apparatus

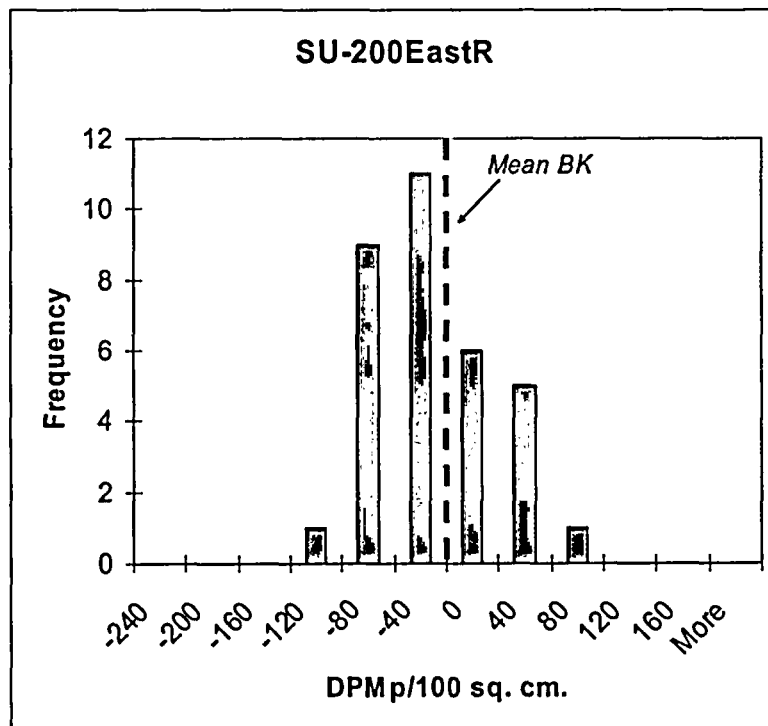
4.2.2.1. All 7 items of installed apparatus assigned to SU-200EastR (listed in Appendix 1) were surveyed by direct beta measurements. A summary of the measurements taken is provided in Table 4.2 sorted by matrix. The net values observed ranged from 5 to 52 dpm_p/100cm². All values were less than 2% of the ARG.

Table 4.2
SU-200EastR Fixed Equipment Direct Measurements Summary

| Matrix | Points | Avg Net Activity (dpm _p /100cm ²) | Max Net Activity (dpm _p /100cm ²) |
|------------|--------|---|---|
| Metal | 2 | 22.8 | 40.2 |
| Plastic | 1 | 11.3 | 11.3 |
| Fiberglass | 3 | 46.1 | 51.7 |

4.2.3. Direct Beta Measurement Distribution and Threshold Tests

4.2.3.1. A histogram of all the beta direct net activity values found in SU-200EastR is provided in Figure 4.1. The distribution appears to have a single primary mode with the majority of the data centered at approximately -20 dpm_p/100cm². This is consistent with a normal distribution of background radioactivity. 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 (TCTR) and the results are presented in Appendix 4 for SU-200EastR. The TCTR contains a complete listing of all the direct beta measurements taken in the Final Status Survey within SU-200EastR sorted by activity. The summary pages indicate that all tests described in the D Plan passed except for the background test. All tests required for release of a Class 2 survey unit passed.

Table 4.3
Requirements for SU Release^a

| Test | Class 2 | SU-200East R |
|------------------------|--------------|--------------|
| Min/Max | not required | P |
| Background | not required | F |
| DCGL _w | PASS | P |
| DCGL _{avg} | PASS | P |
| EMC | PASS | P |
| Wilcoxon Rank Sum Test | PASS | P |

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

- 4.2.3.3. As the histogram in Figure 4.1 shows, these results are consistent with a survey unit that is at background levels.

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-200EastR Removable Contamination Summary

| Surface | Points | Avg Net Beta (β pm/100cm ²) | Max Net Beta (β pm/100cm ²) | Avg Net Activity ^a (dpm _p /100cm ²) | Max Net Activity (dpm _p /100cm ²) |
|---------|--------|---|---|--|---|
| R | 27 | 9.7 | 50 | 2.0 | 10.4 |

^a Activity was converted to dpm_p/100 cm² from β pm/100 cm² 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/100cm² and varies between -4.2 and +10.4 dpm_p/100cm². The data confirm that virtually no removable contamination is present within SU-200EastR.

4.2.5. Beta Scan Measurements

- 4.2.5.1. Beta scans were performed on about 15% of the surfaces of the roof. 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/100cm². The calculation of threshold count rate and MDC for scans is presented in NEXTEP Tech Memo 0230³².

4.2.5.3. All scans performed on the roof surfaces were taken on tar/roofing after sweeping the gravel aside. The background used for the asphalt binder of the roof (tar/roofing) was the asphalt background in the database. The average background value used for analysis of the tar/roofing raw data was obtained from the open window, direct beta readings (in cpm) taken in the survey unit. This value was 253 cpm. The average of all open window survey readings taken on asphalt in the background data set was 267 cpm.

4.2.5.4. During the surveys the maximum and average gross count rates were recorded for each area scanned. The beta scan data are summarized for SU-200EastR and presented in Table 4.5.

Table 4.5
SU-200EastR Scan Measurements Summary

| Matrix | Areas | Maximum (cpm) | Average (cpm) | Max Net (cpm) | Avg Net (cpm) |
|-------------|-------|---------------|---------------|---------------|---------------|
| Tar/Roofing | 3 | 350 | 283 | 83 | 17 |

4.2.5.5. The maximum net scan value of 83 cpm is well below the scan threshold of 2000 cpm. No beta scan data were observed in SU-200EastR above the scan threshold.

4.3. SU-200WestR

4.3.1. The original roof of SU-200WestR affected by C-T operations has been covered with new roofing material. 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. Thirty direct gamma measurements were taken on the roof of SU-200WestR. 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 4.4.

4.3.2.2. Gamma direct measurements were converted to dpm_p/100cm² using a conversion factor calculated for ½ inch asphalt binder overlaying the

³² NEXTEP Tech Memo 0230, Ibid.

contamination as described in NEXTEP Tech Memo 0229³³. The conversion factor was 0.75 cpm/dpm_p.

- 4.3.2.3. A summary of the direct measurement results for SU-200WestR is presented in Table 4.6 and shows that the maximum activity measured, net of background, was -937 dpm_p/100cm². The average was -1,011 dpm_p/100cm².

Table 4.6
SU-200WestR Direct Gamma Measurements Summary

| Matrix | Points | Avg Net Activity ^a (dpm _p /100cm ²) | Max Net Activity (dpm _p /100cm ²) |
|-------------|--------|--|---|
| Tar/Roofing | 30 | -1011 | -937 |

^a Dpm_p refers to disintegrations per minute of the parent nuclide series.

- 4.3.2.4. All the direct measurements in the survey unit were less than the DCGL_w. Therefore the direct measurements in SU-200WestR pass all the tests except background and min/max. A comparison of test results and requirements for release of the SU-200WestR is presented in Table 4.7.

Table 4.7
Requirements for SU Release

| Test | Class 2 | SU-200WestR |
|---------------------------|--------------|-------------|
| Min/Max | not required | F |
| Background | not required | F |
| DCGL _w | PASS | P |
| DCGL _{avg} | PASS | P |
| EMC | PASS | P |
| Sign Test for Paired Data | PASS | P |

- 4.3.2.5. The direct gamma measurements show that SU-200WestR 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 all of the locations where a direct measurement was performed. The results of these measurements are presented in Table 4.8. The results show that removable contamination in SU-200WestR ranges between -5 and +10 dpm_p/100cm² and averages just above zero dpm_p/100cm². No significant removable contamination is present in SU-200WestR.

³³ NEXTEP Tech Memo 0229, *MCNP Gamma Modeling of Mallinckrodt Roof Surfaces*, N.Zhang.

Table 4.8
SU-200WestR Removable Contamination Summary

| Surface | Points | Avg Net Beta ($\beta\text{pm}/100\text{cm}^2$) | Max Net Beta ($\beta\text{pm}/100\text{cm}^2$) | Avg Net Activity ^a ($\text{dpm}_p/100\text{cm}^2$) | Max Net Activity ($\text{dpm}_p/100\text{cm}^2$) |
|---------|--------|---|---|--|---|
| R | 30 | 9.5 | 50.0 | 2.0 | 10.4 |

^a Activity was converted to $\text{dpm}_p/100\text{cm}^2$ from $\beta\text{pm}/100\text{cm}^2$ using an approximate figure of 4.8 betas per disintegration.

4.3.4. Installed Apparatus

4.3.4.1. All 19 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 4.9 sorted by matrix. The values observed ranged from -25.7 to $245\text{ dpm}_p/100\text{cm}^2$. All values were less than 1% of the ARG. The data confirm that no significant residual radioactivity was found on the 54 items of installed apparatus in SU-200WestR.

Table 4.9
SU-235R Fixed Equipment Direct Measurements Summary

| Matrix | Points | Avg Net dpm_p^a ($\text{dpm}_p/100\text{cm}^2$) | Max Net dpm_p ($\text{dpm}_p/100\text{cm}^2$) |
|------------|--------|---|---|
| Fiberglass | 6 | 17.5 | 12.1 |
| Metal | 20 | -5.1 | 24.5 |
| Plastic | 1 | -3.8 | -3.8 |

^a Dpm_p refers to DPM of the parent nuclide series.

4.3.5. Gamma Scan Measurements

- 4.3.5.1. Gamma scans were performed on 15% of SU-200WestR. Diagrams of the areas surveyed are presented in Appendix 2, Figure 4.5 and 4.6.
- 4.3.5.2. The scan threshold used for these surveys was 800 cpm (net of background) which corresponds to the ARG of $2,600\text{ dpm}_p/100\text{cm}^2$ on a gravel roof surface.
- 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-200WestR are summarized and presented in Table 4.10.

Table 4.10
SU-200WestR Scan Measurements Summary

| Matrix | Points | Maximum (cpm) | Average (cpm) | Max Net (cpm) | Avg Net (cpm) |
|--------------------|---------------|--------------------------|--------------------------|--------------------------|--------------------------|
| Gravel/Tar/Roofing | 4 | 4800 | 3375 | 721 | -704 |

4.3.5.5. The maximum net scan value of 721 cpm is below the scan threshold of 800 cpm. No gamma scan data were observed in SU-200WestR above the scan threshold.

5. CONCLUSIONS

- 5.1. SU-200EastR passed all the tests described in the D Plan except background. (Par. 4.2.3.2)
- 5.2. No residual radioactivity was measured above 2% of the ARG on the items of installed apparatus in SU-200EastR. (Par. 4.2.2.1)
- 5.3. Virtually no removable contamination is present within SU-200EastR. (Par. 4.2.4.2)
- 5.4. No beta scan data were observed in SU-200EastR above the scan threshold of 2,000 cpm. (Par. 4.2.5.5)
- 5.5. SU-200EastR meets all the requirements of the D Plan for unconditional release.
- 5.6. SU-200WestR passed all the tests described in the D Plan except background and MIN/MAX. (Par. 4.3.2.5)
- 5.7. No significant residual radioactivity was measured outside of the background distribution on the items of installed apparatus in SU-200WestR. (Par. 4.3.4.1)
- 5.8. No significant removable contamination was measured in SU-200WestR. (Par. 4.3.3.1)
- 5.9. No gamma scan data were observed in SU-200WestR above the scan threshold. (Par. 4.3.5.5)
- 5.10. SU-200WestR meets all the requirements of the D Plan for unconditional release.

6. RECOMMENDATIONS

- 6.1. SU-200EastR should be released from the license.
- 6.2. SU-200WestR should be released from the license.

Appendix 1
Building Survey Unit Listing for
Buildings 200E and 200W Roof

Building Survey Unit Listing

| <i>SurfaceCode</i> | <i>Xmax</i> | <i>Ymax</i> | <i>Area (sq.ft.)</i> | <i>Paint (Coats)</i> | <i>Description</i> |
|---|-------------|-------------|--------------------------|--------------------------|------------------------------------|
| SurveyUnitID: 200EastR | | | Class: 2 | | |
| Room 999AN | | | | | |
| R | 13.7 | 39.6 | 543 | 0.0 | |
| Summary for Room 999AN (1 detail record) | | | 543 Sq. Feet | | |
| Room 999E | | | | | |
| R | 51 | 83.5 | 4,259 | 0.0 | |
| Q1 | | | | 0.0 | posts (8 affected) |
| Q5 | | | | 0.0 | stacks (2) |
| Q7 | | | | 0.0 | supports/support brackets (2 sets) |
| Q17 | | | | 0.0 | stairs/steps (3) |
| Q18 | | | | 0.0 | drains (2) |
| Q19 | | | | 0.0 | roof access ladder (1) |
| Q20 | | | | 0.0 | roof access shelter (1) |
| Summary for Room 999E (8 detail records) | | | 4,259 Sq. Feet | | |
| TOTAL for Survey Unit 200EastR | | | 4,801 Sq. Feet | | |

Building Survey Unit Listing

| SurfaceCode | Xmax | Ymax | Area (sq.ft.) | Paint (Coats) | Description |
|---|------|------|------------------|------------------|------------------------------------|
| SurveyUnitID: 200WestR | | | Class: 2 | | |
| Room 999AS | | | | | |
| R | 27 | 24 | 648 | 0.0 | |
| Q16 | | | | 0.0 | blower (1) |
| Summary for Room 999AS (2 detail records) | | | 648 Sq. Feet | | |
| Room 999W | | | | | |
| R | 69 | 83.5 | 5,762 | 0.0 | |
| Q1 | | | | 0.0 | posts (10 affected) |
| Q2 | | | | 0.0 | exhaust stack (1) |
| Q3 | | | | 0.0 | handrail (1) |
| Q4 | | | | 0.0 | vent (2) |
| Q5 | | | | 0.0 | stacks (3) |
| Q6 | | | | 0.0 | shed (1) |
| Q7 | | | | 0.0 | supports/support brackets (4 sets) |
| Q8 | | | | 0.0 | eyewash and shower (1 of each) |
| Q9 | | | | 0.0 | hatch (4) |
| Q10 | | | | 0.0 | tank (1) |
| Q11 | | | | 0.0 | 2" pipe (9) |
| Q12 | | | | 0.0 | 3" pipe (1) |
| Q13 | | | | 0.0 | 6" pipe (2) |
| Q14 | | | | 0.0 | 8" pipe (2) |
| Q15 | | | | 0.0 | air handler and supports (1) |
| Q16 | | | | 0.0 | blower (3) |
| Q17 | | | | 0.0 | stairs/steps (3) |
| Q18 | | | | 0.0 | drains (3) |
| Q19 | | | | 0.0 | roof access ladder (1) |
| Summary for Room 999W (20 detail records) | | | 5,762 Sq. Feet | | |
| TOTAL for Survey Unit 200WestR | | | 6,410 Sq. Feet | | |

APPENDIX 2

Figures

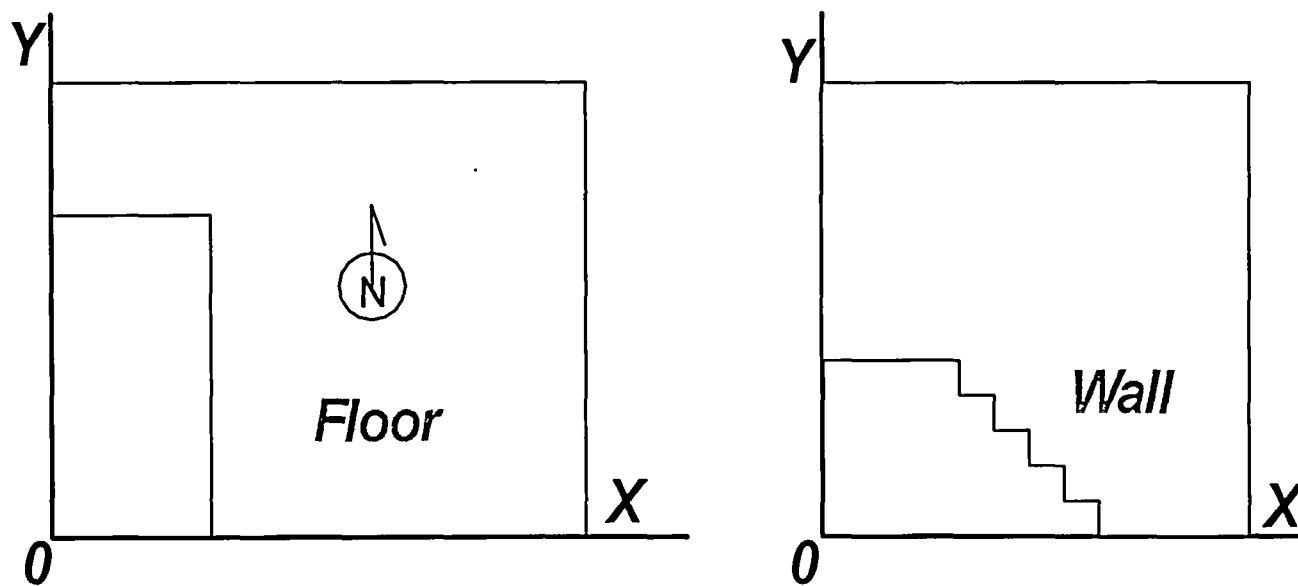
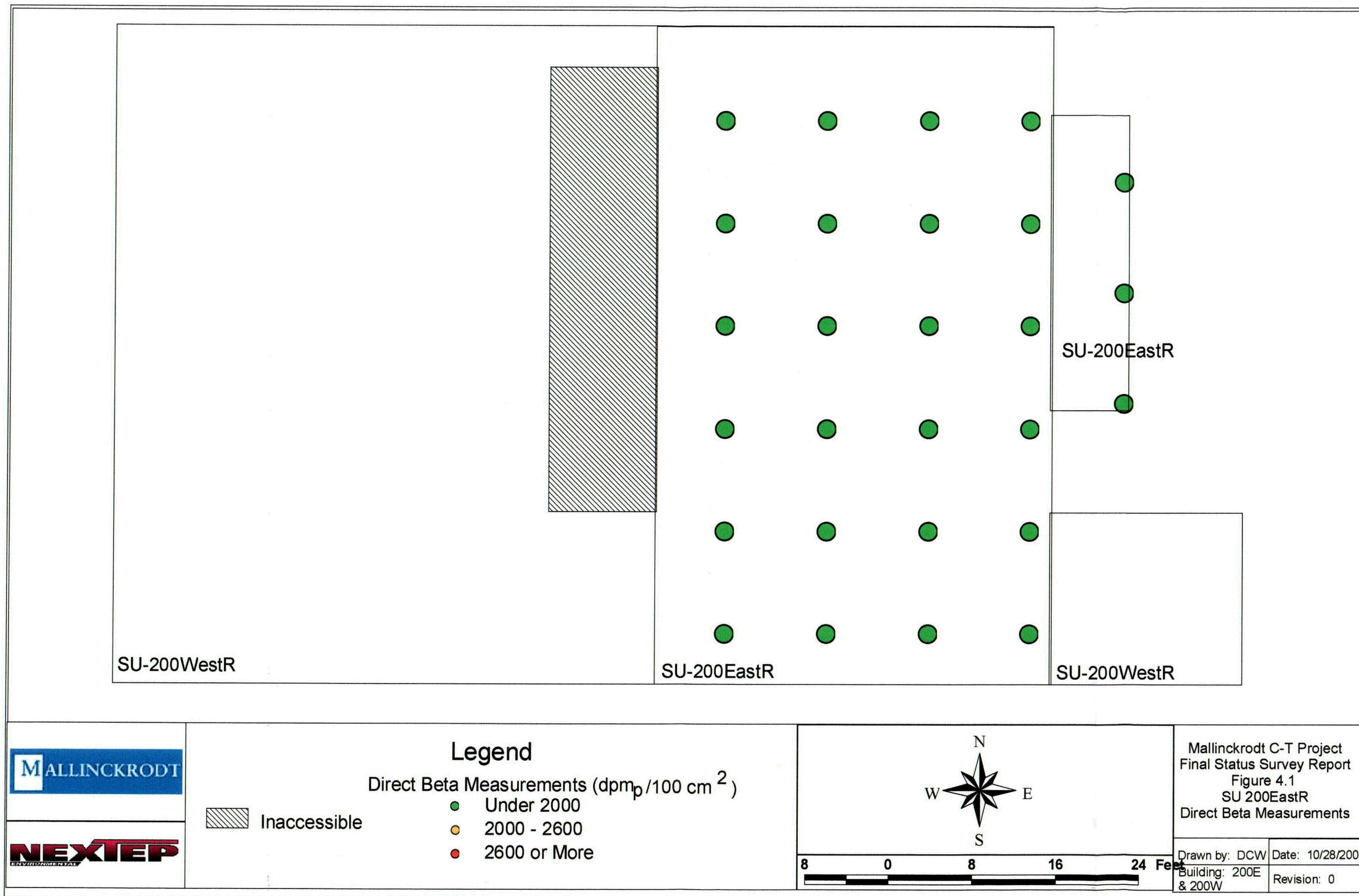


Figure 3.1
Coordinate System



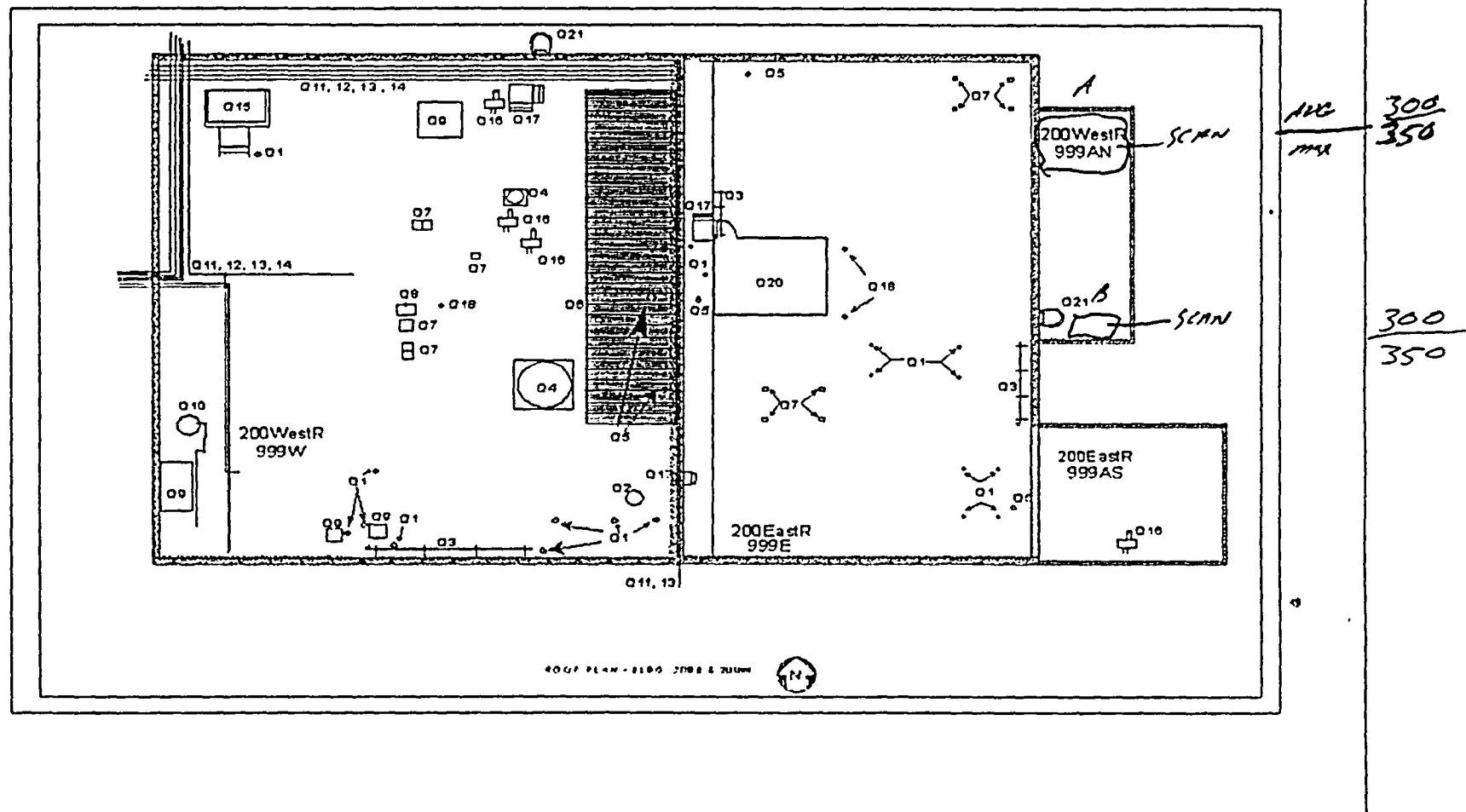
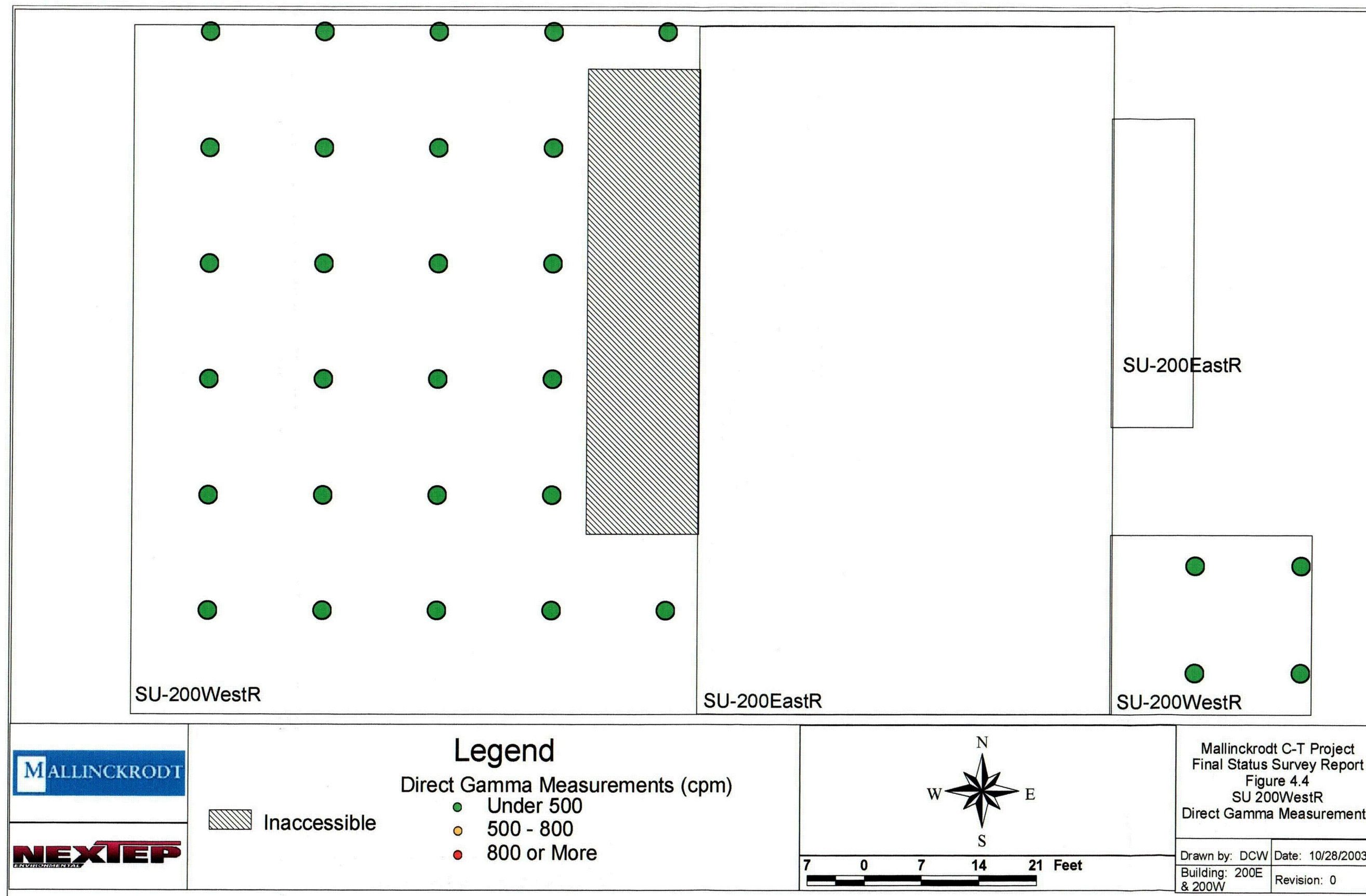


Figure 4.3
Survey Unit 200EastR Scans



APPENDIX 3

Calibration Sheets

| Type | S/N | Cal Date |
|-------------|-----------------|-----------------|
| Beta | 163666/B426W | 1/16/2003 |
| Gamma | 157020/020429-6 | 4/26/2003 |
| Swipe | 179577 | 2/26/2003 |

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

LUDLUM 2221
CALIBRATION DATA SHEET

Ludlum2221S/N: 163666 Property of ThermoReteC
Smart Solutions. Positive Outcomes.

Battery Check OK @ 5.6 Rts
Replace @ 6.4

High Voltage Check

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

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

| Meter Reading | Pre Cal | Post Cal | Tolerance |
|---------------|-------------|-------------|-----------|
| 600 Volts | <u>660</u> | <u>605</u> | 10 % |
| 1000 Volts | <u>1100</u> | <u>1005</u> | 10 % |
| 1400 Volts | <u>1540</u> | <u>1410</u> | 10 % |

Input Sensitivity:

(Threshold @ 10 mv) Pre Cal: 35 mv, Post Cal: 35 mv

MP-2 S/N: 604 Calibration Exp. Date: 1-29-03

Rate/ MP-2 2221 Display Display Tol

| Meter | | Digital | Analog | Tol |
|----------|-------|---------------|---------------|-----|
| 400 CPM | x1 | <u>400</u> | <u>400</u> | 10% |
| 4K CPM | x10 | <u>3998</u> | <u>4000</u> | 10% |
| 40K CPM | x100 | <u>39999</u> | <u>40000</u> | 10% |
| 400K CPM | x1000 | <u>400080</u> | <u>400000</u> | 10% |

| Scaler: | | Digital | Analog | Tol |
|----------|---------|---------------|---------------|-----|
| 100K CPM | 0.5 sec | <u>50010</u> | <u>100000</u> | 10% |
| 100K CPM | 1.0 min | <u>100020</u> | <u>f</u> | 10% |
| 100K CPM | 2.0 min | <u>200039</u> | <u>f</u> | 10% |
| 100K CPM | 5.0 min | <u>500097</u> | <u>f</u> | 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: 1-16-03

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

Reviewed By: M. N. Sells 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: THYS E.S.
 READOUT INST: Lud 2221 SN: 1636666 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 | | BR NET CPM | SOURCE | | SR NET CPM | Source # | SA Source Activity | Efficiency SR-SF % |
|---------------------|----------------|------------------|------------|----------------|------------------|------------|----------|--------------------|--------------------|
| | OPEN Cts/2 min | SHIELD Cts/2 min | | OPEN Cts/1 min | SHIELD Cts/1 min | | | | |
| 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 = 33250 dpm | | | | | | | | | Average = 19.9 |
| | | | | | | | | | Std Dev = 0.1 |

| | | | | | | | | | |
|-----------------------|---|---|---|------|-----|------|-----|-------|----------------|
| Wood | 0 | 0 | 0 | 5222 | 238 | 4984 | M-2 | 22250 | 22.3 |
| ↓ | 0 | 0 | 0 | 5281 | 240 | 5041 | ↓ | ↓ | 22.3 |
| ↓ | 0 | 0 | 0 | 5181 | 224 | 4957 | ↓ | ↓ | 22.3 |
| ↓ | 0 | 0 | 0 | 5296 | 252 | 5064 | ↓ | ↓ | 22.8 |
| 178 dpm x 125 = 22250 | | | | | | | | | Average = 22.5 |
| | | | | | | | | | Std Dev = 0.2 |

| | | | | | | | | | |
|-----------------------|---|---|---|------|-----|------|-----|-------|----------------|
| Waxinite | 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 | ↓ | ↓ | 23.0 |
| 178 dpm x 125 = 22250 | | | | | | | | | Average = 22.8 |
| | | | | | | | | | Std Dev = 0.2 |

| | | | | | | | | | |
|-----------------------|---|---|---|------|-----|------|-----|-------|----------------|
| Aluminum | 0 | 0 | 0 | 6037 | 223 | 5814 | M-2 | 22250 | 26.1 |
| ↓ | 0 | 0 | 0 | 5708 | 256 | 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: 1-29-03EXPIRATION DATE: 7-29-03

CALIBRATED BY:

Randall H. Sells
Print NameRandall H. Sells
Signature

REVIEWED BY:

M. Dwyer

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 # | 2178-96 |
| Probe Serial # | B426W | Source dpm (4σ): | 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 | | Background Counts |
|-------------|--------------|----------|-------------------|
| | Observed | Expected | |
| 1 | 15380 | 15546 | 185 |
| 2 | 15381 | 15546 | 193 |
| 3 | 15477 | 15546 | 179 |
| 4 | 15862 | 15546 | 179 |
| 5 | 15520 | 15546 | 181 |
| 6 | 15587 | 15546 | |
| 7 | 15478 | 15546 | |
| 8 | 15392 | 15546 | |
| 9 | 15639 | 15546 | |
| 10 | 15609 | 15546 | |
| 11 | 15401 | 15546 | |
| 12 | 15433 | 15546 | |
| 13 | 15801 | 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 | |
| sample variance (s^2) = | 15181 | to dpm: | 3.6 |
| background variance (b^2) = | 34.8 | | |
| sample sigma (s) = | 123 | | |
| (95% Confidence) 2.752 s = | 339 | | |
| (99% Confidence) 3.615 s = | 446 | | |

| | | | |
|----------------------|-----------|-------------|-----|
| df = n-1 = | 19 | MDA (cpm) = | 66 |
| chitest = p(x<χ^2) = | 4.858E-01 | MDA (dpm) = | 240 |
| chisquare (χ^2) = | 18.554 | | |

| | |
|---------------------------|--------|
| 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 | 15383 |
| 95% Conf. Interval Test max = | 15702 |
| 99% Conf. Interval Test max = | 15809 |

Test performed by: Steve Struck

Checked by:

Jim C. Woodford

Date:

2-4-03

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



Designer and Manufacturer
of
Scientific and Industrial
Instruments

CERTIFICATE OF CALIBRATION

LUDLUM MEASUREMENTS, INC.
POST OFFICE BOX 810 PH. 325-235-540
501 OAK STREET FAX NO. 325-235-4672
SWEETWATER, TEXAS 79556 U.S.A.

CUSTOMER TYCO/MALLINCKRODT ST LOUIS ORDER NO. 296103/271822
J. Ludlum Measurements, Inc. Model 2221 Serial No. 157020
Mfg. Ludlum Measurements, Inc. Model 3X3 Serial No. 020429-6
Cal. Date 26-Apr-03 Cal Due Date 26-Apr-04 Cal Interval 1 Year Meterface 2221
Check mark ☒ applies to applicable instr. and/or detector IAW mtg. spec. T. 77 °F RH 31 % Alt 4534 ft
☐ New Instrument ☐ Instrument Received ☒ Within Toler. $\pm 10\%$ ☐ 10-20% ☐ Out of Tol. ☐ Requiring Repair ☐ Other-See comments
☒ Mechanical ck ☒ Meter Zeroed ☐ Background Subtract ☒ Input Sens. Uncertainty
☒ F/S Resp. ck ☒ Reset ck. ☒ Window Operation ☒ Geotopism
☒ Audio ck. ☒ Alarm Setting ck. ☒ Batt. ck. (Min. Volt) 6.0 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 Comments V Input Sens. Comments mV Det. Oper. Comments V at Comments Threshold 100 = 10 mV
Dial Ratio 100 = 10
☒ HV Readout (2 points) Ref./Inst. 500 / 499 V Ref./Inst. 2000 / 1990 V

COMMENTS:

| | | |
|---------------------------------|--------------|--------------------------------|
| Peak settings | Gross Counts | Model 2221 currently set |
| High Voltage: <u>434</u> V | <u>650</u> V | for Gross counts |
| Threshold dial: <u>64</u> | 100 (10mV) | High voltage set with detector |
| Window dial: <u>40</u> | n/a | connected. |
| Window Position: <u>"IN"</u> | "OUT" | |
| Resolution for Cs137: <u>10</u> | n/a | Firmware: <u>26 10 10</u> |

Gamma Calibration: GM detector positioned perpendicular to source except for M 44-B in which the front of probe faces source.

| RANGE/MULTIPLIER | REFERENCE CAL. POINT | INSTRUMENT REC'D "AS FOUND READING" | INSTRUMENT METER READING* |
|------------------|-------------------------|--|------------------------------|
| X 1000 | 400 Kcpm | 390 | 390 |
| X 1000 | 100 Kcpm | 100 | 100 |
| X 100 | 40 Kcpm | 390 | 390 |
| X 100 | 10 Kcpm | 110 | 110 |
| X 10 | 4 Kcpm | 390 | 390 |
| X 10 | 1 Kcpm | 110 | 110 |
| X 1 | 400 cpm | 400 | 400 |
| X 1 | 100 cpm | 100 | 100 |

| *Uncertainty within $\pm 10\%$ C.F. within $\pm 20\%$ | | | ALL Range(s) Calibrated Electronics | | |
|---|------------------------|------------------------------|-------------------------------------|------------------------|------------------------------|
| REFERENCE CAL. POINT | INSTRUMENT RECEIVED | INSTRUMENT METER READING* | REFERENCE CAL. POINT | INSTRUMENT RECEIVED | INSTRUMENT METER READING* |
| Digital Readout | 400 Kcpm | 39810 (e) | 500 Kcpm | 450K | 450K |
| | 40 Kcpm | 3984 (e) | 50 Kcpm | 50K | 50K |
| | 4 Kcpm | 398 (e) | 5 Kcpm | 4.5K | 4.5K |
| | 400 cpm | 40 (e) | 500 cpm | 500 | 500 |
| | 40 cpm | 4 (e) | 50 cpm | 55 | 55 |

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 the 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. The calibration system conforms to the requirements of ANSI/NCSL Z540-1-1994 and ANSI N323-1978. State of Texas Calibration License No. LC-1963

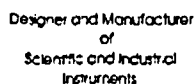
Reference Instruments and/or Sources:

Cs-137 Gamma S/N ☐ 1162 ☐ G112 ☐ M566 ☐ 5105 ☐ T1006 ☐ T879 ☐ E572 ☐ E551 ☐ Neutron Am-241 Ea S/N 1002
☐ Alpha S/N ☐ Beta S/N ☐ Other ☐ m 500 S/N 81084 ☐ Oscilloscope S/N ☒ Multimeter S/N 80040300

Calibrated By: Michael J Thomas Date 26-April-03
Reviewed By: Ronnie Harris Date 30 Apr 03

This certificate shall not be reproduced except in full without the written approval of Ludlum Measurements, Inc. FORM C224 04/09/2000 ☐ AC Inst Only ☐ Passed Dielectric (Hi-Pot) and Continuity Test ☐ Failed

L2221/3x3
S/N: 157020/020429-6
4/26/03



LUDLUM MEASUREMENTS, INC.
POST OFFICE BOX 610 PH. 325-235-5494
501 OAK STREET FAX NO. 325-235-4672
SWEETWATER, TEXAS 79556, U.S.A.

Detector 3X3 Serial No. 020429-6

Customer TYCO/MALLINCKRODT ST LOUIS

Order #. 296703/27 622

Counter 2221 Serial No. 157020

Counter Input Sensitivity 10 mV

Count Time 6 sec

Distance Source to Detector Surface

Other _____

[illegible]

Signature

Michael J Thomas

Date 26-Apr-03

FORM CA 04/69/2003

● *Serving The Nuclear Industry Since 1962* ●

L2221/3x3

S/N: 157020/020429-6

4/26/03

Mallinckrodt C-T Project-Phase I
Final Status Survey Report Building 200 Roof

Revision: 0
APPENDIX 3
December 2003

CT-RP-66

Chi Squared Test

| | | | |
|--------------------|----------------------|------------------------|------------|
| Instrument Model # | 2221 | Date: | 05/07/2003 |
| Instrument Serial# | 157020 | Source Nuclide: | Cs137 |
| Probe Model # | Nal 3x3 | Source Serial # | 2558 |
| Probe Serial # | 020429-6 | Source dpm (4 π): | 21534000 |
| Window Setting: | 3700 3480 | Efficiency (cpm/dpm): | 0.01 |
| Threshold Setting: | 100mV 104 | Background cpm: | 3676.2 |
| High Voltage: | 650V | BKGD N-1 | 4 |
| | | BKGD Count Time (min): | 1 |

| Count # (n) | Gross Counts | | Background Counts |
|-------------|--------------|----------|-------------------|
| | Observed | Expected | |
| 1 | 226601 | 227689 | 3624 |
| 2 | 227278 | 227689 | 3830 |
| 3 | 228251 | 227689 | 3610 |
| 4 | 227614 | 227689 | 3701 |
| 5 | 228344 | 227689 | 3616 |
| 6 | 228647 | 227689 | |
| 7 | 227269 | 227689 | |
| 8 | 227708 | 227689 | |
| 9 | 227138 | 227689 | |
| 10 | 227004 | 227689 | |
| 11 | 227520 | 227689 | |
| 12 | 227819 | 227689 | |
| 13 | 228608 | 227689 | |
| 14 | 228689 | 227689 | |
| 15 | 227778 | 227689 | |
| 16 | 227078 | 227689 | |
| 17 | 227572 | 227689 | |
| 18 | 227573 | 227689 | |
| 19 | 227841 | 227689 | |
| 20 | 227443 | 227689 | |

| | | | |
|---|--------|-----------------------|------|
| sample mean (xbar) = | 227689 | Multiplier to convert | |
| sample variance (s ²) = | 334344 | to dpm: | 94.6 |
| background variance (b ²) = | 8750.2 | | |
| sample sigma (s) = | 586 | | |
| (95% Confidence) 2.752 s = | 1612 | | |
| (99% Confidence) 3.615 s = | 2117 | | |

| | | | |
|-----------------------------|-----------|-------------|-------|
| df = n-1 = | 19 | MDA (cpm) = | 285 |
| chitest = p(x< χ^2) = | 8.537E-02 | MDA (dpm) = | 26948 |
| chisquare (χ^2) = | 27.900 | | |

| | |
|--------------------------------|--------|
| Acceptable χ^2 min = | 8.907 |
| Acceptable χ^2 max = | 32.852 |
| χ^2 test passes (yes/no)? | YES |

| | |
|------------------------------------|--------|
| 99% Conf. Interval Test min = | 221895 |
| 95% Conf. Interval Test min = | 222401 |
| Daily Source Check Mean Net Counts | 224013 |
| 95% Conf. Interval Test max = | 225625 |
| 99% Conf. Interval Test max = | 226130 |

Test performed by: S Struck

Checked by:

Date:

L2221/3x3
S/N: 157020/020429-6
4/26/03

CT-RP-66 Chi Squared Test

| | | | |
|--------------------|----------|------------------------|------------|
| Instrument Model # | 2221 | Date: | 06/04/2003 |
| Instrument Serial# | 157020 | Source Nuclide: | Cs137 |
| Probe Model # | Nal 3x3 | Source Serial # | 2538-99 |
| Probe Serial # | 020429-6 | Source dpm (4π): | 2286800 |
| Window Setting: | 3680 | Efficiency (cpm/dpm): | 0.01 |
| Threshold Setting: | 104mV | Background cpm: | 3985.8 |
| High Voltage: | 650V | BKGD N-1 | 4 |
| | | BKGD Count Time (min): | 1 |

| Count # (n) | Gross Counts Observed | Expected | Background Counts |
|-------------|--------------------------|----------|-------------------|
| 1 | 28742 | 28492 | 4019 |
| 2 | 28702 | 28492 | 4068 |
| 3 | 28477 | 28492 | 3976 |
| 4 | 28166 | 28492 | 3904 |
| 5 | 28711 | 28492 | 3964 |
| 6 | 28701 | 28492 | |
| 7 | 28491 | 28492 | |
| 8 | 28304 | 28492 | |
| 9 | 28412 | 28492 | |
| 10 | 28667 | 28492 | |
| 11 | 28084 | 28492 | |
| 12 | 28349 | 28492 | |
| 13 | 28087 | 28492 | |
| 14 | 28460 | 28492 | |
| 15 | 28454 | 28492 | |
| 16 | 28682 | 28492 | |
| 17 | 28441 | 28492 | |
| 18 | 28718 | 28492 | |
| 19 | 28606 | 28492 | |
| 20 | 28592 | 28492 | |

| | | | |
|---------------------------------|--------|-----------------------|------|
| sample mean (\bar{x}) = | 28492 | Multiplier to convert | |
| sample variance (s^2) = | 44336 | to dpm: | 80.3 |
| background variance (b^2) = | 3699.2 | | |
| sample sigma (s) = | 219 | | |
| (95% Confidence) $2.752 s =$ | 603 | | |
| (99% Confidence) $3.615 s =$ | 792 | | |

| | | | |
|-----------------------------|-----------|-------------|-------|
| df = n-1 = | 19 | MDA (cpm) = | 297 |
| chitest = $p(x < \chi^2)$ = | 5.759E-02 | MDA (dpm) = | 23801 |
| chisquare (χ^2) = | 29.566 | | |

| | |
|--------------------------------|--------|
| Acceptable χ^2 min = | 8.907 |
| Acceptable χ^2 max = | 32.852 |
| χ^2 test passes (yes/no)? | YES |

| | |
|------------------------------------|-------|
| 99% Conf. Interval Test min = | 23714 |
| 95% Conf. Interval Test min = | 23903 |
| Daily Source Check Mean Net Counts | 24508 |
| 95% Conf. Interval Test max = | 25110 |
| 99% Conf. Interval Test max = | 25299 |

Test performed by: S Struck

Checked by:

Date:

L2221/3x3
S/N: 157020/020429-6
4/26/03

FEB 16 2003 16:52 314 654 1251

MALLINCKRODT

#2114 P.007

Lucius Measurements, Inc.

Model 3030 Plateau Data

2/25/03

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): 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

| HV | Source (Beta) | ALPHA | | | CrossTalk | Source (Alpha) | BETA | | |
|-----|---------------|------------|-------|------|-----------|----------------|------------|-------|-----------|
| | | Background | Eff | | | | Background | Eff | Crosstalk |
| 675 | 137685 (3899) | 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

JUL 16 2003 16:52 314 654 1251 MALLINCKRODT #2114 P.008

Model 3030 MDA Calculation Data

2/25/03

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 |
| EC (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 - Buildings

Run Date: Thursday, December 04, 2003

Survey Unit Number: 200EastR Class: 2 Data Points: Beta Grid Type: R Spacing: 13.3 ft.

SURVEY UNIT TABLE

| Bldg | Rm | Surface | Fixed Equipment | Surface Area Included (sq. ft) | Remarks |
|------------|-------|---------|--------------------|--------------------------------------|-----------------------|
| B200EW | 999AN | R | | 543 | 200E Annex north roof |
| B200EW | 999E | R | Q1,5,7,17-20 | 4259 | 200W roof |
| Total Area | | | | 4801 | |

INITIALIZATION DATA

Measurement Types Selected: RG, BI

Date Range: All

Thresholds:

EMC: 13,000 DCGLw: 2,600

SURVEY UNIT TEST STATUS

| Test Performed | Status | | dpm/100 cm ² |
|---------------------------|--------|-------------------------|-------------------------|
| Min/Max | Pass | Maximum Survey Value TR | 162.0 |
| Background | Fail | Minimum Background M | 1.0 |
| DCGLw | Pass | Difference | 161.0 |
| DCGLavg | Pass | Average Activity | 53.2 |
| EMC | Pass | Average Below DCGL | 53.2 |
| Wilcoxon Rank Sum Test | N/A | Average Background | 67.4 |
| Sign Test for Paired Data | Pass | | |

MALLINCKRODT C-T DECOMMISSIONING PROJECT

Threshold Comparison Test Report - Buildings

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 # 200EastR

Building: B200E&W

| Room | SFC | X (ft) | Y (ft) | Mtx | Meas. Type | Min | SID | Gross Activity (dpm/100cm ²) | Remarks | Exc | Res. |
|------|-----|--------|--------|-----|---------------|-----|------|---|---------|-----|------|
| 999E | Q17 | 1.0 | 0.0 | FG | BI | 1 | 6377 | 45.2 | | C | |
| 999E | Q18 | 2.0 | 0.0 | P | BI | 1 | 6380 | 11.3 | | C | |
| 999E | Q19 | 1.0 | 0.0 | FG | BI | 1 | 6381 | 41.3 | | C | |
| 999E | Q20 | 1.0 | 0.0 | FG | BI | 1 | 6382 | 51.7 | | C | |
| 999E | Q7 | 1.0 | 0.0 | M | BI | 1 | 6385 | 64.2 | | C | |

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

Survey Unit # 200EastR

Building: B200E&W

| Room | SFC | X (ft) | Y (ft) | Mtx | Meas. Type | Min | SID | Gross Activity (dpm/100cm ²) | Remarks | Exc | Res. |
|------|-----|--------|--------|-----|---------------|-----|------|---|-----------------|-----|------|
| 999E | Q5 | 2.0 | 0.0 | M | BI | 1 | 6357 | 29.4 | | | |
| 999E | R | 8.8 | 45.3 | TR | RG | 1 | 6296 | 162.0 | | | |
| 999E | R | 21.8 | 32.3 | TR | RG | 1 | 6301 | 148.9 | | | |
| 999E | R | 8.8 | 1.0 | TR | RG | 1 | 6314 | 104.0 | 200 North Anney | | |
| 999E | R | 47.8 | 32.3 | TR | RG | 1 | 6303 | 95.3 | | | |
| 999E | R | 8.8 | 15.0 | TR | RG | 1 | 6313 | 93.1 | 200 North Anney | | |
| 999E | R | 47.8 | 6.3 | TR | RG | 1 | 6311 | 86.5 | | | |
| 999E | R | 21.8 | 58.3 | TR | RG | 1 | 6293 | 77.7 | | | |
| 999E | R | 34.8 | 6.3 | TR | RG | 1 | 6310 | 73.4 | | | |
| 999E | R | 34.8 | 32.3 | TR | RG | 1 | 6302 | 71.2 | | | |
| 999E | R | 21.8 | 6.3 | TR | RG | 1 | 6309 | 70.1 | | | |
| 999E | R | 21.8 | 71.3 | TR | RG | 1 | 6289 | 63.5 | | | |
| 999E | R | 21.8 | 19.3 | TR | RG | 1 | 6305 | 58.0 | | | |
| 999E | R | 8.8 | 6.3 | TR | RG | 1 | 6308 | 54.7 | | | |
| 999E | R | 34.8 | 58.3 | TR | RG | 1 | 6294 | 51.5 | | | |
| 999E | R | 8.8 | 29.0 | TR | RG | 1 | 6312 | 46.0 | 200 North Anney | | |
| 999E | R | 47.8 | 58.3 | TR | RG | 1 | 6295 | 46.0 | | | |
| 999E | R | 8.8 | 58.3 | TR | RG | 1 | 6292 | 38.3 | | | |
| 999E | R | 34.8 | 19.3 | TR | RG | 1 | 6306 | 36.1 | | | |
| 999E | R | 8.8 | 71.3 | TR | RG | 1 | 6288 | 29.6 | 200 East Roof | | |
| 999E | R | 47.8 | 71.3 | TR | RG | 1 | 6291 | 29.6 | | | |
| 999E | R | 47.8 | 45.3 | TR | RG | 1 | 6299 | 28.5 | | | |
| 999E | R | 34.8 | 71.3 | TR | RG | 1 | 6290 | 27.4 | | | |
| 999E | R | 34.8 | 45.3 | TR | RG | 1 | 6298 | 24.1 | | | |
| 999E | R | 8.8 | 19.3 | TR | RG | 1 | 6304 | 10.9 | | | |
| 999E | R | 8.8 | 32.3 | TR | RG | 1 | 6300 | 8.8 | | | |
| 999E | R | 21.8 | 45.3 | TR | RG | 1 | 6297 | 2.2 | | | |
| 999E | R | 47.8 | 19.3 | TR | RG | 1 | 6307 | -25.2 | | | |

MALLINCKRODT C-T DECOMMISSIONING PROJECT

Threshold Comparison Test Report - Buildings

Summary of Background Data and Thresholds Used in this Analysis

Measurement Type: BK *DCGL:* 2,600 *EMC:* 13,000

| <i>Matrix</i> | <i>Number of Data Points</i> | <i>Average Background</i> | <i>Sigma</i> | <i>Background Threshold (Tbk)</i> | <i>DCGLw Threshold (Td)</i> | <i>EMC Threshold (Tc)</i> |
|---------------|----------------------------------|-------------------------------|---------------------------|---|-------------------------------------|-----------------------------------|
| | (dpm/100cm ²) | (dpm/100cm ²) | (dpm/100cm ²) | (dpm/100cm ²) | (dpm/100cm ²) | (dpm/100cm ²) |
| FG | 0 | 0.0 | 0.0 | 0.0 | 2,600 | 13,000 |
| M | 10 | 24.0 | 15.7 | 55.3 | 2,655 | 13,055 |
| P | 0 | 0.0 | 0.0 | 0.0 | 2,600 | 13,000 |
| TR | 42 | 77.7 | 51.6 | 181.0 | 2,781 | 13,181 |

MALLINCKRODT C-T DECOMMISSIONING PROJECT

Threshold Comparison Test Report - Buildings

STATISTICAL TEST RESULTS

Run Date: 12/4/2003 3:41:15 AM
Survey Unit Number 200EastR Class: 2
Selected Test: SIGN TEST FOR PAIRED DATA
Test Status Pass
Thresholds:

EMC 13,000 DCGL 2,600

DATA SUMMARY TABLE

27 Survey points processed and 1 matrices processed

S+ = 27 Wc = 18

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

MALLINCKRODT C-T DECOMMISSIONING PROJECT

Threshold Comparison Test Report - Buildings

Run Date: Thursday, December 04, 2003

Survey Unit Number: 200WestR Class: 2 Data Points: Beta Grid Type: R Spacing: 15.4 ft.

SURVEY UNIT TABLE

| Bldg | Rm | Surface | Fixed Equipment | Surface Area Included (sq. ft) | Remarks |
|------------|------|---------|--------------------|--------------------------------------|-----------------------|
| B200EW | 999A | R | Q16 | 648 | 200E Annex south roof |
| B200EW | 999W | R | Q1-19 | 5762 | 200W roof |
| Total Area | | | | 6410 | |

INITIALIZATION DATA

Measurement Types Selected: BI

Date Range: All

Thresholds:

EMC: 13,000 DCGLw: 2,600

SURVEY UNIT TEST STATUS

| Test Performed | Status | | dpm _p /100 cm ² |
|---------------------------|--------|------------------------|---------------------------------------|
| Min/Max | Pass | Maximum Survey Value M | 65.0 |
| Background | Fail | Minimum Background M | 1.0 |
| DCGLw | Pass | Difference | 64.0 |
| DCGLavg | Pass | Average Activity | 10.8 |
| EMC | Pass | Average Below DCGL | 10.8 |
| Wilcoxon Rank Sum Test | N/A | Average Background | 67.4 |
| Sign Test for Paired Data | Pass | | |

MALLINCKRODT C-T DECOMMISSIONING PROJECT

Threshold Comparison Test Report - Buildings

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 # 200WestR

Building: B200E&W

| Room | SFC | X (ft) | Y (ft) | Mtx | Meas. Type | Min | SID | Gross Activity (dpm/100cm ²) | Remarks | Exc | Res. |
|------|-----|--------|--------|-----|---------------|-----|------|---|---------|-----|------|
| 999W | Q10 | 1.0 | 0.0 | FG | BI | 1 | 6364 | 10.3 | | C | |
| 999W | Q17 | 2.0 | 0.0 | FG | BI | 1 | 6378 | 20.7 | | C | |
| 999W | Q2 | 1.0 | 0.0 | M | BI | 1 | 6383 | 65.0 | | C | |
| 999W | Q2 | 2.0 | 0.0 | FG | BI | 1 | 6351 | 16.8 | | C | |
| 999W | Q5 | 1.0 | 0.0 | M | BI | 1 | 6356 | 55.7 | | C | |
| 999W | Q6 | 3.0 | 0.0 | FG | BI | 1 | 6360 | 47.8 | | C | |
| 999W | Q6 | 2.0 | 0.0 | FG | BI | 1 | 6359 | 24.5 | | C | |
| 999W | Q9 | 1.0 | 0.0 | FG | BI | 1 | 6363 | 34.9 | | C | |

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

Survey Unit # 200WestR

Building: B200E&W

| Room | SFC | X (ft) | Y (ft) | Mtx | Meas. Type | Min | SID | Gross Activity (dpm/100cm ²) | Remarks | Exc | Res. |
|------|-----|--------|--------|-----|---------------|-----|------|---|---------|-----|------|
| 999W | Q1 | 1.0 | 0.0 | M | BI | 1 | 6349 | 20.9 | | | |
| 999W | Q11 | 1.0 | 0.0 | M | BI | 1 | 6365 | 49.5 | | | |
| 999W | Q11 | 2.0 | 0.0 | M | BI | 1 | 6366 | -3.9 | | | |
| 999W | Q12 | 1.0 | 0.0 | M | BI | 1 | 6367 | 36.4 | | | |
| 999W | Q12 | 2.0 | 0.0 | M | BI | 1 | 6368 | 15.5 | | | |
| 999W | Q13 | 2.0 | 0.0 | M | BI | 1 | 6370 | 34.0 | | | |
| 999W | Q13 | 1.0 | 0.0 | M | BI | 1 | 6369 | 7.7 | | | |
| 999W | Q14 | 1.0 | 0.0 | M | BI | 1 | 6371 | 19.3 | | | |
| 999W | Q14 | 2.0 | 0.0 | M | BI | 1 | 6372 | 15.5 | | | |
| 999W | Q15 | 1.0 | 0.0 | M | BI | 1 | 6373 | 17.8 | | | |
| 999W | Q15 | 2.0 | 0.0 | M | BI | 1 | 6374 | 13.2 | | | |
| 999W | Q16 | 2.0 | 0.0 | M | BI | 1 | 6376 | 21.7 | | | |
| 999W | Q16 | 1.0 | 0.0 | M | BI | 1 | 6375 | -7.7 | | | |
| 999W | Q18 | 1.0 | 0.0 | P | BI | 1 | 6379 | -5.7 | | | |
| 999W | Q3 | 1.0 | 0.0 | M | BI | 1 | 6352 | 17.0 | | | |
| 999W | Q4 | 2.0 | 0.0 | M | BI | 1 | 6355 | 29.4 | | | |
| 999W | Q4 | 1.0 | 0.0 | M | BI | 1 | 6354 | 28.6 | | | |
| 999W | Q6 | 1.0 | 0.0 | M | BI | 1 | 6358 | 18.6 | | | |
| 999W | Q8 | 1.0 | 0.0 | M | BI | 1 | 6386 | 14.7 | | | |

MALLINCKRODT C-T DECOMMISSIONING PROJECT

Threshold Comparison Test Report - Buildings

Summary of Background Data and Thresholds Used in this Analysis

Measurement Type: BK DCGL: 2,600 EMC: 13,000

| Matrix | Number of Data Points | Average Background | Sigma | Background Threshold (Tbk) | DCGLw Threshold (Td) | EMC Threshold (Tc) |
|--------|---------------------------|---------------------------|---------------------------|----------------------------------|----------------------------|---------------------------|
| | (dpm/100cm ²) | (dpm/100cm ²) | (dpm/100cm ²) | (dpm/100cm ²) | (dpm/100cm ²) | (dpm/100cm ²) |
| FG | 0 | 0.0 | 0.0 | 0.0 | 2,600 | 13,000 |
| M | 10 | 24.0 | 15.7 | 55.3 | 2,655 | 13,055 |
| P | 0 | 0.0 | 0.0 | 0.0 | 2,600 | 13,000 |
| TR | 42 | 77.7 | 51.6 | 181.0 | 2,781 | 13,181 |

MALLINCKRODT C-T DECOMMISSIONING PROJECT

Threshold Comparison Test Report - Buildings

STATISTICAL TEST RESULTS

Run Date: 12/4/2003 3:51:37 AM
Survey Unit Number 200WestR Class: 2
Selected Test: SIGN TEST FOR PAIRED DATA
Test Status Pass
Thresholds:

EMC 13,000 DCGL 2,600

DATA SUMMARY TABLE

30 Survey points processed and 1 matrices processed

S+ = 30 Wc = 20

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