CHARACTERIZATION REPORT

Californium Neutron Flux Multiplier (CFX)

NRC License: SNM-1513

Docket 7001703

Kodak

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PREPARED BY:

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Revision 0

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EASTMAN KODAK COMPANY

Californium Neutron Flux Multiplier Characterization Report

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1 INTRODUCTION

1.1 PURPOSE

1.1.1 The purpose of this report is to document the radiological condition of Kodak's facility in Rochester, NY which used to house their Californium Neutron Flux Multiplier (CFX) system pursuant to decommissioning the facility and releasing it unconditionally from U.S. Nuclear Regulatory Commission (NRC) Special Nuclear Material License SNM-1513 issued in 1975. The CFX fuel plates were removed to the Department of Energy (DOE) facility at Savannah River in South Carolina in November of 2007, and the remaining structural components and equipment have been either released or disposed of.

1.2 LICENSEE IDENTIFICATION

1.2.1 The Eastman Kodak Company (EKC), whose principal address is 343 State Street, Rochester, New York 14650, holds NRC license SNM-1513 issued in 1975 for the operation of the CFX. The license is assigned NRC docket number 7001703. The license was amended in 1989 (Amendment 1), in 2002 (Amendment 2), and in 2007 (Amendment 3). Amendment 3 was issued to permit dismantlement of the CFX and removal of the fuel to Savannah River. The expiration date of the current license is September 30, 2008.

1.3 BACKGROUND

1.3.1 The EKC Research Facility, Building 82, was established in 1966 to provide a dedicated research and development facility for conducting chemical and radiological analyses, doing small quantity bench and batch scale research and development studies on manufacturing processes, and investigating new chemicals of interest to the Corporation's various operating divisions. In this facility, EKC conducted R&D work utilizing the CFX to investigate various chemical irradiations. Work with enriched uranium fuel plates in the CFX required that EKC have a Special Nuclear Materials license.

1.3.2 EKC used special nuclear material (SNM) consisting of enriched uranium clad in aluminum alloy. The sealed source material was manufactured in the form of Materials Testing Research

(MTR)-type fuel plates which have been removed from the facility and returned to the Department of Energy (DOE) for final disposition or disposal.

1.3.3 A Californium-252 (Cf-252) source supplied additional neutrons which drove the CFX assembly to a sub-critical K_{eff}[1] of 0.99 and supplied a steady stream of high energy and thermal neutrons for research purposes. The Californium source was licensed by the State of New York under Kodak's license number 1347-0255. It was permanently removed on July 12, 2006 and the license inventory has been altered to reflect the change.

1.3.4 EKC managed work force safety and material accountability in accordance with the Company's Radiation Protection Program. The Radiation Safety Officer (RSO) is responsible for conformance to the Plan's requirements.

1.3.5 Typical dose monitoring results, using film badges, routinely showed occupational exposures to be less than 25 mRem/month (non-detectable) for those individuals authorized to work within the immediate vicinity of the CFX. Routine monitoring of laboratory and work areas documented that surfaces were less than 1,000 dpm/100cm^2 for tritium and 100 pCi/100 cm^2 for other β-emitters. These routine monitoring results demonstrated that activities within the vicinity of the CFX were performed in a manner that maintained exposures to radioactive materials ALARA[2] and did not result in contamination of work areas or personnel. There were never any instances where SNM contamination was encountered.

1.3.6 EKC no longer uses the licensed material and the facility is therefore being decommissioned to allow for license termination and unrestricted release. EKC decommissioning activities include removal of the CFX[3], radiological surveys, removal of any residual contamination that may be discovered, and the release of portions of property where the CFX was used. When completed, the facility will meet all applicable unrestricted release criteria.

1.3.7 Decommissioning will be performed under written policies and procedures, incorporating appropriate methods outlined in NUREG-1757[4] as required. In accordance with NUREG-1757 criteria, EKC decommissioning activities fall under the Group 3 facility requirements since some of the surrounding materials have been activated by neutron bombardment during the course of normal operations.

1.4 PROJECT ORGANIZATION

1.4.1 NEXTEP Consulting Group, Inc. (NEXTEP) has been engaged to provide technical support services for the Decommissioning Project and to perform the Characterization surveys described in this plan. The joint organization responsible for performing these tasks is

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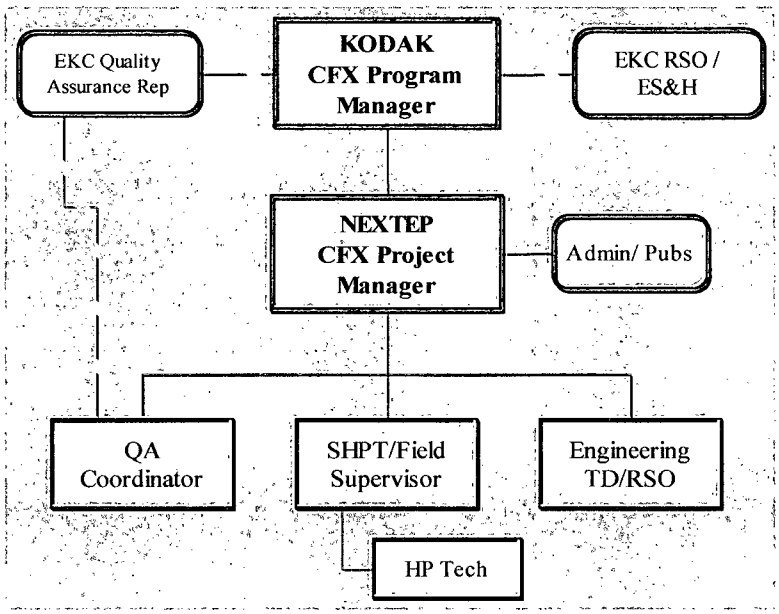
1 Keff is the effective neutron multiplication factor - defined as the number of neutrons in a generation divided by the number of neutrons in a preceding generation. Values of K_{eff}=1 indicate that a system is self sustaining, values in excess of one indicate that a system is super-critical.

2 As Low As Reasonably Achievable

3 Performed under License Amendment 3 in November, 2007.

4 In September 2003, the U.S. Nuclear Regulatory Commission (NRC) published a three-volume NUREG report, NUREG-1757, "*Consolidated NMSS Decommissioning Guidance*." NUREG-1757 provides guidance on: planning and implementing license termination under the License Termination Rule (LTR) in 10 CFR Part 20, Subpart E; complying with the radiological criteria for license termination; and complying with the requirements for financial assurance and recordkeeping for decommissioning and timeliness in decommissioning of materials facilities.

described in the Decommissioning Plan (DPlan) and the De-Fueling Work Plan, and is illustrated in Figure 1.1.



Project Management Organization
Figure 1.1

2 SCOPE OF THE CHARACTERIZATION SURVEY

2.1 SURVEY UNIT DESCRIPTION

2.1.1 The underground labyrinth which housed the CFX consists of a stairwell containing a metal circular stair and an electric hoist, a passageway winding 180 degrees over a distance of about 80 feet, and a cavity room which houses two large neutron generating machines and which used to house the CFX equipment in the southwest corner. A drawing of the labyrinth is presented in Attachment A, Figure A-2.1[5].

2.1.2 The labyrinth was subdivided into five rooms as shown in Figure A-2.1 and four of them were surveyed as part of the Characterization Survey. Rooms C1 through C4 were combined into three survey units as shown in Figure A-2.2 and as described in Table 2.1. Their classification as class 1 and 2 was presumptive based upon historical use and routine radiation safety surveys taken over the years. Further changes in classification will be based upon the results of this characterization survey. A standard summary description of the survey units is presented as it was output from the project database in Attachment B.

[5] All figures or tables beginning with an alphabetical character are included in the corresponding attachment. The attachment designation will be left out of future references to such figures and tables.

Table 2.1
Defined Survey Units for the CFX Labyrinth

Survey Unit	*Physical Description*	*Classification*
101	Portion of the cavity which housed the CFX equipment extending 8 ft. from the corner. Includes room C1.	Class 1
102	Portion of the cavity room excluding 6 ft. of the eastern end which houses the neutron generating machines and related equipment. Room C2.	Class 2
103	Labyrinth passageway beginning at the security gate and encompassing rooms C3 and C.4	Class 2

2.2 REPRESENTATIVE BACKGROUND REFERENCE AREAS

2.2.1 Surface Beta Background

2.2.1.1 Representative background areas were selected in the control room on the basement level above the labyrinth. Five beta background measurements were taken on two matrix substrates: bare concrete (C) and vinyl floor tile over concrete (VT). The data are stored in the Radiation Database and a summary is presented in Table 2.2.

Table 2.2
Beta Background Levels by Matrix

ID	Date	Serial Number	Gamma	Counts Open	Counts Closed	Net Counts	Integrated Minutes	Beta (dpm/100cm^2)
Concrete Matrix								
263084	10-Jan-08	162414	2,257	259	200	59	1	568
263085	10-Jan-08	162414	2,151	269	171	98	1	944
263086	10-Jan-08	162414	2,289	254	181	73	1	703
263087	10-Jan-08	162414	2,320	231	199	32	1	308
263088	10-Jan-08	162414	2,275	254	215	39	1	376
			Sum	1,267	966	301	5	2,900
Es =	*0.600*		*Max*	269	215	98		944
Ei =	*0.173*		*Average*	**253**	193	**60**		**580**
			Stdev	14	17	27		257
Vinyl Tile Matrix								
263089	10-Jan-08	162414	2,128	176	185	(9)	1	(87)
263090	10-Jan-08	162414	2,194	196	164	32	1	308
263091	10-Jan-08	162414	2,196	219	193	26	1	250
263092	10-Jan-08	162414	2,172	205	192	13	1	125
263093	10-Jan-08	162414	2,142	204	235	(31)	1	(299)
			Sum	1,000	969	31	5	299
Es =	*0.600*		*Max*	219	235	32		308
Ei =	*0.173*		*Average*	**200**	194	**6**		**60**
			Stdev	16	26	26		251

2.2.1.2 Beta/gamma background for scans was computed as the average of the open window measurements from the background table. These data are also included in Table 2.2.

2.2.2 Gamma Background

2.2.2.1 Gamma background was measured in the cavity during the Characterization survey in November, 2007. The reading was taken for one minute in the middle of room C2, and the value recorded was **3,512 cpm**.

2.2.2.2 Gamma surveys taken in February after the removal of the concrete mounting pad yielded an average gamma background of **2,791 cpm**. A description of this survey is presented in Figure C-1.

2.3 RADIONUCLIDES OF INTEREST

2.3.1 Contamination with Licensed Materials

2.3.1.1 NRC license SNM-1513 authorizes the possession and use of enriched U-235 in the form of MTR Type fuel plates. During the operating history of the CFX, the licensed material remained in place within the CFX fuel assembly and was not disturbed. Leak tests to date indicate that no licensed material has been released from the fuel plates, and they should be considered sealed sources.

2.3.1.2 Radiological surveys performed during de-fueling operations revealed no evidence that fuel plate handling during removal, inventory, and packaging may have generated contamination from the licensed material.

2.3.1.3 Contamination from licensed material, however generated, would be indicated by the presence of licensed U-235, its natural progeny, and the products of fission produced from operations.

2.3.1.4 Modeling of the residual activity and fission product buildup was performed by the SCALE[6] system, and is described in detail in NEXTEP Technical Memorandum (TM) 0519[7]. This analysis showed that the activity from fission products would dominate the mix of any contaminants found in the CFX cavity[8]. Moreover, among the products of fission, Sr-90, Cs-137 and their progeny dominated by at least one order of magnitude, and were present in approximately equal quantities. Since Cs-137 and Sr-90 are both strong beta emitters, the primary means for detecting evidence of contamination was beta detection by direct measurements and scans.

2.3.2 Induced Radioactivity due to Neutron Activation

2.3.2.1 Radiological activity above background in building surfaces and equipment may also come from induced radioactivity caused by neutron activation. A theoretical analysis of the likely results from 30 years of activation is presented in TM0520[9]. According to that

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6 *SCALE:* A Modular Code System for Performing Standardized Computer Analyses for Licensing Evaluations, ORNL/TM-2005/39, Version 5, Vols. I-III, April 2005.

7 NEXTEP TM0519, *Core Residual Activities and Dose Rates From the Kodak CFX Facility*, A.H.Thatcher, CHP

8 The total predicted activity from fission products was 330 mCi compared to the total activity due to U-235 and its daughters of 7 mCi.

9 NEXTEP TM 0520, *Neutron Activation Analysis for Kodak CFX Facility,* A.H. Thatcher, CHP

analysis, it is reasonable to expect that the only activation of significance will be that caused within the surrounding concrete and embedded reinforcing bars in room C1.

2.3.2.2 During de-fueling operations, the concrete pad[10] on which the CFX structure was mounted was sampled and measured in a low background Germanium detector system to identify the radionuclides present in the concrete from neutron activation. The results are presented in Figure C-1 and are tabulated in Table 2.3.

Table 2.3
Concrete Activation Analysis

Isotope	Normalized Activity
^{60}Co	7.66 pCi/gm
^{152}Eu	14.65 pCi/gm
^{154}Eu	0.95 pCi/gm

2.3.2.3 Since all the radioisotopes shown in Table 2.3 are strong gamma emitters and, since activation products in concrete would be distributed with depth and so attenuate some of the beta emissions, gamma surveys were the primary means used to detect activation products in the concrete surrounding the CFX (Room C1).

2.4 RELEASE CRITERIA FOR BUILDING SURFACES & FIXED EQUIPMENT

2.4.1 Since no Decommissioning Plan (DPlan) had been approved at the time of the Characterization Surveys there were no applicable release criteria save the license criteria for surface contamination. In order to conduct the Characterization Survey, presumptive values for release criteria were derived for both surface contaminants and activated nuclides in concrete. The data were evaluated against these criteria and the results will be used to recommend formal release criteria in the DPlan submitted to NRC.

2.4.2 Release Criteria for Surface Contamination

2.4.2.1 The basis for release of equipment or materials is contained in Attachment 2 to License SNM-1513[11] (the Guidelines). A copy of Table 1 to that reference is presented in Figure A-2.3.

2.4.2.2 This table specifies acceptable levels of contamination for four different groups of radionuclides in terms of disintegrations per minute (dpm) for alpha and beta/gamma emissions, applied independently to each.

2.4.2.3 Any contamination found in the CFX cavity would of necessity be the result of a breach in one or more of the MTR fuel plates. Therefore Cs-137 and Sr-90 could be expected to exist in equal quantities and they would dominate the activity measured from any contamination found.

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[10] This mortar pad was used for leveling the CFX and had been poured on top of the cavity floor. After CFX removal, the pad was broken up and removed as well. Scan measurements on the floor of C1 were repeated in the absence of the leveling pad.

[11] NRC license SNM-1513, Attachment 2, *Guidelines for Decontamination of Facilities and Equipment Prior to Release for Unrestricted use or Termination of Licenses for Byproduct, Source, or Special Nuclear Material,* US NRC, 1993

2.4.2.4 Sr-90 and its progeny fall in the third category of nuclides listed in Figure A-2.3 (the "License Criteria"), and they have a release limit of 1,000 dpm/100 cm^2 averaged over one square meter. Cs-137 and its progeny fall into the fourth category of beta-gamma emitters and they have an average limit of 5,000 dpm/100 cm^2.

2.4.2.5 Since half of the activity would be subject to the 5,000 dpm/100 cm^2 limit, and half to the 1,000 dpm/100 cm^2 limit, composite limits were calculated in TM0713[12] (Attachment E) for the mix most likely to be found in the CFX cavity. These composite limits are presented in Table 2.4, and they were applied to beta surveys in the cavity.

Table 2.4
Release Limits[a] for Building Surface Contamination
(dpm/100 cm²)

Nuclide	Average ($1m^2$)	Maximum ($100cm^2$)	Removable ($100cm^2$)
Sr-90	1,000	3,000	200
Cs-137	5,000	15,000	1,000[b]
50/50 mix	**1,667**	**5,000**	**333[b]**

[a] Above background
[b] β/γ only

2.4.3 Release Criteria for Activated Surfaces

2.4.3.1 The Guidelines included in the License declare that the limits in Table 1 of the Guidelines "do not apply to premises, equipment, or scrap containing induced radioactivity for which the radiological considerations pertinent to their use may be different. The release of such facilities or items from regulatory control is considered on a case-by-case basis."

2.4.3.2 After the removal of the CFX from the cavity, the concrete pad on which it rested was crushed and analyzed for its isotopic content.[13] Release limits were developed to ensure a maximum annual dose to members of the critical group of no more than 25 mRem. The technical basis for development of the release limits and investigation thresholds applicable to radioactivity from neutron activated materials is presented in TM0604[14] which is included in Attachment D. The limits derived for activation products in concrete are listed in Table 2.5.

[12] NEXTEP TM0713 *Technical Basis Document for Kodak Beta Measurements*, A.H. Thatcher, CHP
[13] The activated radionuclides present in the concrete were Co-60, Eu-152 and Eu-154.
[14] NEXTEP TM0604 - *Kodak CFX: Development of Release Limits for Activated Surfaces and Material*, A.H. Thatcher, CHP

Table 2.5
Proposed Release Limits[a] for Neutron-Activated Building Surfaces

Isotope	Activity (pCi/g)
Co-60	150
Eu-152	290
Eu-154	19

[a] Above background

2.4.3.3 The release criteria for building surfaces were also applied to fixed equipment that is not expected to be removed. Any data measurements falling on fixed equipment were subject to the release criteria of the underlying building surface.

2.4.4 Action Thresholds

2.4.4.1 Systematic grids of integrated (direct)[15] beta and gamma readings were taken in the cavity, along with scans which were used to confirm that neither contaminants nor small areas of elevated induced radioactivity are present in between the grid points.

2.4.4.2 Investigation thresholds for direct beta measurements and β/γ scans were developed and documented in TM0713[16] which is presented in Attachment E. Derivation of a gamma threshold was developed and presented in TM0801[17] which is presented in Attachment F. A summary of these action thresholds is presented in Table 2.6.

Table 2.6
Action Thresholds

Survey Type	Net	Gross[c]	
		C	VT
Gamma (scan or direct)	360,000 cpm	363,000 cpm	N/A
Direct Beta[a]	174 cpm	235 cpm	181 cpm
β/γ Scan[b]	370 cpm	623 cpm	570 cpm

[a] Open window minus closed window (Co-Cc)
[b] Open window only (Co)
[c] Including matrix background from concrete (C) and Vinyl Tile (VT)

2.5 MINIMUM DETECTABLE CONCENTRATION (MDC)

2.5.1 The terminology adopted to reflect the measurement (detection) capability of an instrument is the "Lower Limit of Detection" (LLD) or the "Minimum Detectable Concentration" (MDC). It refers to the intrinsic detection capability of the entire measurement process. The MDC is the lowest level of radioactivity that will yield a net count, above system blank, that will be

[15] Direct beta measurements are integrated measurements taken with the detector stationary over the survey location of interest. Most survey measurements were integrated for 1 minute. The terms direct and integrated are used interchangeably throughout this TM.
[16] NEXTEP TM0713, Ibid.
[17] NEXTEP TM0801 *CFX Gamma Conversion Factors and Survey Thresholds*, A.H. Thatcher, CHP

detected with at least 95% probability with no greater than a 5% probability of falsely concluding that a blank observation represents a real signal. For a first pass scan the statistics were chosen to provide a 60% chance of false positive and a 5% chance of a false negative.[18]

2.5.2 The MDC requirements for CFX surveys have been developed in accordance with MARSSIM[19] Chapter 4 guidelines. The target MDC for beta direct is 50% of the composite average limit (DCGLw)[20]; for β/γ scans it is equal to the maximum ($DCGL_{EMC}$)[21]; and for gamma direct or scan it is 50% of the calculated gamma threshold from TM0801 (Attachment F).

2.5.3 Details concerning the selection and calculation of MDC's for beta measurements and scans are presented in TM0713, Attachment E, and the derivation of the MDCR for gamma measurements is presented in TM0801, Attachment F. A summary comparison of the MDCs calculated for the L43-89 α/β scintillation detector and the 2"x2" NaI gamma detector with the requirements is provided in Table 2.7.

Table 2.7
Minimum Detectable Concentration (MDC or MDCR) Comparison[a]

Survey Type	Target MDC(R)	Calculated MDC(R)
Direct Beta	833 dpm/100 cm^2	757 dpm/100 cm^2
β/γ Scan	5,000 dpm/100 cm^2	1,640 dpm/100 cm^2
Gamma (scan or direct)	180,000 cpm	910 cpm

[a] All Values given are net of background. Only the matrix with the highest value for MDC is shown.

[18] See §4.3, TM0713, Attachment E.
[19] NUREG 1575, *Multi Agency Radiation Survey and Site Investigation Manual.*
[20] $DCGL_w$ refers to the Derived Concentration Guideline Level as defined in §2.2 of MARSSIM. The "w" refers to the Wilcoxson rank sum test used to evaluate the average contaminant level over a given area.
[21] $DCGL_{EMC}$ refers to the guideline used to evaluate small areas of elevated activity according to the Elevated Measurement Comparison guidelines in MARSSIM.

3 SURVEY METHODS AND INSTRUMENTATION

3.1 PROCEDURES

3.1.1 Operations during de-fueling and subsequently during the Characterization Survey were conducted in accordance with the Kodak Health and Safety Plan, the NEXTEP Radiation Safety Plan and the NEXTEP Quality Management Plan. The requirements of these governing documents were implemented through adherence to the project radiation protection (RP) and quality assurance (QA) procedures. The procedures used during the Characterization Survey are listed in Figure A-3.1.

3.2 MEASUREMENTS AND INSTRUMENTATION

3.2.1 Concrete Sample Laboratory Analysis.

3.2.1.1 Isotopic analysis for activated radionuclides in the concrete surrounding the CFX was performed using Kodak's high purity Germanium gamma spectrometer at the Rochester facility.

3.2.2 Direct Beta Measurements

3.2.2.1 The instrument used to take beta measurements was the Ludlum 43-89 scintillation probe paired with an L2224-1 rate meter. It has a probe area of 125 cm^2 and an effective area of 100 cm^2.

3.2.2.2 Integrated measurements of beta radioactivity were performed using an open/closed window methodology. Two readings were taken at each location of interest including background locations. The closed window reading was taken through a 1/2" thick Lexan plate which is sufficient to block out the betas of interest. By subtracting the two readings, those counts due primarily to beta emissions were isolated from the gamma background. Equation 1 was used to calculate the activity density in dpm/100 cm^2.

Equation 1

$$AD = \frac{C_o - C_c}{\epsilon_i \epsilon_s T (\frac{A_e}{100})}$$

Where:

AD = *Area Activity Density (dpm/100 cm^2)*
C_o = *Open Window Counts*
C_c = *Closed Window Counts*
ϵ_i = *Instrument 4π efficiency for Sr-90*
ϵ_s = *Surface Efficiency*[22]
T = *Integration time in minutes for each count*
A_e = *The effective area of the probe in cm^2*

3.2.2.3 All beta measurements were taken on either concrete or vinyl tile matrix substrates. The surface efficiency was taken from the range of efficiencies for sealed concrete given in Table 5-4 of NUREG-1507[23] as an estimate for the CFX cavity ($\epsilon_s = 0.60$).

[22] Surface efficiency includes all the effects of surface geometry and backscatter characteristics on the source emissions. Total efficiency is the product of the instrument efficiency, ϵ_i, and the surface efficiency, ϵ_s.

3.2.2.4 Integrated beta measurements were taken on each grid location as described in Section 3.3. Integration time was one minute.

3.2.3 Beta-Gamma Scans

3.2.3.1 Beta-gamma scans were performed with the same instrument and covered 100% of all surfaces in SU-101 and 10% of all surfaces in the other two survey units. Selection of the portion of each surface to be scanned was left up to the HP Technician taking the survey.

3.2.3.2 Scans were performed open window at a probe height of 0.5 cm above the surface to be scanned. The scan speed was approximately 5 cm/sec for the first pass. This yielded an observation window of approximately 2 seconds.

3.2.3.3 Scan measurements were recorded in counts per minute and compared with the scan threshold calculated in TM0713, Attachment E.

3.2.4 Gamma Measurements

3.2.4.1 A Ludlum-4410 2"x2" NaI gamma detector probe paired with an L2221 rate meter was used for surveys in room C-1 where activation was likely to have occurred. The probe was shielded by approximately 1/8" of lead. Integrated measurements were taken for one minute at each grid location where a beta measurement was made in room C-1 except for the ceiling surface. Grid spacing was 30 inches.

3.2.4.2 In lieu of a gamma scan in the activated areas, a second, more detailed gamma survey was taken on the floor and two walls of room C-1 after removal of the concrete mounting pad from the floor. This survey used the same instrument with an integration time of 6 seconds and a grid spacing of six inches, and it extended six feet in all directions from the corner of room C-1. Details concerning this survey are presented in Figure C-1.

3.2.5 Dose Rate (μR)

3.2.5.1 All μR data were taken in connection with routine radiation protection surveys using Ludlum Model 19 field instruments. A Bicron Micro-Rem meter was used to take measurements in the corner that were used to confirm the dose model for activated materials discussed in TM0604, Attachment D.

3.2.6 Removable Gross Alpha/Beta

3.2.6.1 Removable contamination was collected using swipes which were counted in a Tennelec Series 5, low background, Gas Flow Proportional Alpha/Beta counting system. A swipe sample was collected from each MARSSIM grid location on all the surfaces in room C-1, and on the floor surfaces of the other rooms.

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[23] NUREG 1507 - *Minimum Detectable Concentrations with Typical Radiation Survey Instruments for Various Contaminants and Field Conditions*, Abelquist. E.W., et.al., June 1998.

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 each survey unit. The minimum number of points required and their spacing were calculated in accordance with the statistical guidance given in MARSSIM Section 5.5.2.

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 3.1.

Table 3.1
VSP Inputs for CFX Survey Units

DQO	Value
Type I error rate	5%
Type II error rate	5%
Width of Gray Region	200 dpm/100cm^2
Level (DCGLw)	3,000 dpm/100cm^2
Estimated Std Deviation	200 dpm/100cm^2
Excess % sample points	20%

3.3.1.3 A rectangular grid was used for all three survey units. The maximum grid interval spacing, L, was calculated from the total area of each survey unit, A, and the required number of data points, N, according to equation 2, and the grid descriptions are given in Table 3.2.

Equation 2

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

Table 3.2
Calculated Grid Point Separation

Survey Unit	Class	N	A (ft^2)	L (in)
SU-101	1	24	208	30
SU-102	2	24	842	60
SU-103	2	24	1,974	96

3.3.1.4 Integrated beta measurements were collected at each point on the grid. Swipe samples were processed for each grid point that fell on all the surfaces of room C-1 and on the floor of the other rooms. One minute gamma readings were obtained at all grid points in room C-1 except on the ceiling.

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

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.

3.3.3 Reference Coordinate System

3.3.3.1 A unified reference system was prescribed for the location of all data points taken on all building surfaces and fixed equipment. 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 3.3. 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 Figure A-3.2.

Table 3.3
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 DATA EVALUATION

3.4.1 All of the direct, swipe and scan data were entered into the Kodak CFX Radiation Database (RDB) for easy access and analysis. The direct beta measurements are the primary means for documenting the surveys for licensed contamination. Within the database, a special report was programmed to perform the tests specified in MARSSIM, and to provide a clear report of the results for evaluation. The calculations in this report have been validated and verified as described in TM0231[25].

3.4.2 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.

3.4.3 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

[25] NEXTEP TM0231, *Validation and Verification of the C-T Database Analysis Report,* B. Anderson.

generate a single PASS/FAIL verdict for the entire data set. The tests are described in the following paragraphs. An abbreviated summary of these tests is presented in Table 3.4.

3.4.4 Background Screen

3.4.4.1 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 3

$$T_{bk}(m) = \overline{BK}(m) + 3 * \sigma_{bk}(m)$$

3.4.4.2 T_{bk} is equal to the mean of the background readings $(\overline{BK})$ for a given matrix plus three times its standard deviation (3σ).

3.4.4.3 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.

3.4.5 Min/Max Test

3.4.5.1 Find the maximum direct survey result, in dpm/100cm^2, for the survey data set.

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

3.4.5.3 If the difference between these two values is greater than $DCGL_w$ the MIN/MAX test fails for the survey unit.

3.4.6 $DCGL_w$ Screen

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

Equation 4

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

3.4.6.2 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 $DCGL_w$ screen test for the survey unit.

3.4.7 EMC Screen

3.4.7.1 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 9,000 dpm/100 cm^2.[26]

[26] The maximum composite limit for surface contamination from Table 2.4.

3.4.7.2 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.

3.4.8 DCGL Average Test

3.4.8.1 For each matrix material in the survey unit, calculate the mean activity density (in dpm/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 5

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

3.4.9 Statistical Tests

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

3.4.9.2 The Wilcoxon Rank Sum Test[27] 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[28] was used.

3.4.10 The output of the Threshold Comparison Test Report (TCTR) was used for analysis of the data for the CFX labyrinth surfaces, and the results are presented in Attachment G. The TCTR is divided into eight sections which are briefly described in the following paragraphs to assist the unfamiliar reader.

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

3.4.10.2 Survey Unit Table: building surface included, fixed equipment (if any), and total surface area of the survey unit.

3.4.10.3 Initialization Data: On startup of the TCTR 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 $DCGL_W$ 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.

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

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

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27 Described in Appendix I of MARSSIM.
28 Described in NEXTEP Tech Memo 0231, Ibid. and in NUREG-1505.

3.4.10.6 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.

3.4.10.7 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.

3.4.10.8 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 statistical test. 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 3.4
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 T_{bk}
$DCGL_w$	All samples must be no more than $DCGL_w + T_{bk}$
$DCGL_{avg}$	The average of all net survey values must be less than $DCGL_w$
EMC	All samples must be less than $DCGL_{EMC} + T_{bk}$
Sign Test for Paired Data	The Sign Test for Paired Data is described in detail in NUREG 1505[29]
Wilcoxon Rank Sum Test	This statistical test is described in detail in MARSSIM, Appendix I.

3.4.11 Provided all additional considerations such as scan data, swipes, and gamma surveys for activated materials indicate that the survey unit meets the release criteria, the release of the survey unit can be determined from the test report according to Table 3.5.

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

Table 3.5
Requirements for SU Release[30]

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.

3.5 DATA COLLECTION FORMS

3.5.1.1 The forms used for the characterization survey are presented in Attachment A. The scan data collection form is given in Figure A-3.3. The primary form used for gamma and beta measurements and swipe sample collection is presented in Figures A-3.4 and A-3.5. Sample collection locations were filled out in accordance with the applicable procedures.

[30] See MARSSIM, Chapter 8, Table 8.2

4 RESULTS AND DISCUSSION

4.1 SURVEY UNIT 101 EVALUATION

4.1.1 Activated Concrete

4.1.1.1 In November, 2007 Sodium Iodide (NaI) gamma readings were taken on the floor and walls of room C1[31] to determine the level and extent of activation in the surrounding concrete surfaces. Measurements were integrated over one minute and the locations surveyed were on the statistical grid used for beta measurements except for the ceiling surface which was omitted. A map showing the position and level of the gamma readings in room C1 is presented in Figure H-1, and the data are presented in Table I-1 in Attachment I. The highest reading obtained during this survey was 45,849 cpm – well below the threshold of 360,000 cpm given in Table 2.6.

4.1.1.2 To further characterize the activation of the surrounding concrete, a more detailed gamma survey was performed in February, 2008 after the concrete mounting pad had been removed. Measurements were located on a six inch square grid as shown in Figure 4.1. Integration time was six seconds and background for this survey was 2,791 cpm. A more detailed description of these surveys is presented in Figure C-1.

February Gamma Survey Grid
Figure 4.1

4.1.1.3 Data plots showing the net gamma values and locations on each surveyed surface are presented in Figures H-2, 3 and 4. The plots are color-coded to show the distribution of higher levels of activity.

4.1.1.4 A summary evaluation of all the gamma data collected in room C1 is presented in Table 4.1. Examination of the data show that the levels of activity due to activated Cobalt and Europium are less than 15% of the proposed release limits presented in Tables 2.5 and 2.6.

[31] The corner of the cavity where the CFX was mounted.

Table 4.1
SU-101 Gamma Survey Data Summary

	Floor	South	West	Total
Initial Survey				
Background				3,512
Count	7	9	9	25
Average gamma	16,716	2,415	2,706	6,524
Std. Deviation	17,319	5,771	5,210	11,715
Maximum	45,849	17,388	15,417	45,849
Minimum	245	(982)	(589)	(982)
Second Survey				
Background				2,791
Count	117	120	120	357
Average gamma	12,319	7,282	7,997	9,173
Std. Deviation	15,083	10,095	11,352	12,498
Maximum	50,939	41,909	44,619	50,939
Minimum	679	389	19	19

4.1.2 Direct Beta Measurements

4.1.2.1 A statistical grid was laid out in Survey Unit 101, and beta surveys were performed as described in Section 3. 27 measurements were taken on the floor, ceiling and two walls. All of them were included in the systematic grid. A data table of all the measurements taken in the survey unit is presented in Table I-2. A map showing the beta measurements by location and range of values is presented in Figure H-5.

4.1.2.2 A summary of the direct measurement results for SU-101 is presented in Table 4.2 and shows that the average activity measured on concrete, net of background, was 300 dpm/100cm^2. The maximum value for the survey unit was 1,380 dpm/100cm^2, which was less than the composite average release limit of 1,667 dpm/100cm^2 from Table 2.4.

Table 4.2
SU-101 Direct Beta Measurements Summary

Matrix	Points	Avg Net Activity (dpm/100cm^2)	Max Net Activity (dpm/100cm^2)
Concrete	26	300	1,380
Metal	1	115	115

4.1.3 Direct Beta Measurement Statistics and Threshold Tests

4.1.3.1 All the direct measurements in the survey unit were analyzed using the Threshold Comparison Test Report (TCTR) and the results are presented in Attachment G for SU-101. The TCTR limits were initialized at 1,667 and 5,000 dpm/100cm^2, and the Wilcoxon Rank Sum Test was selected because of the uniformity of the matrix background for the areas where the measurements were taken.

4.1.3.2 The TCTR report contains a complete listing of all the direct beta measurements taken within SU-101 sorted by room, surface, and activity. The summary pages indicate that all tests described in Section 3.4 passed except for the Min/Max and Background Tests. The Min/Max test failed because one measurement fell on a metal manifold mounted on the wall for which the background value was assumed to be zero.[32]

4.1.3.3 It should also be noted that activated radionuclides within the concrete contributed additional beta activity in the areas where activation was significant. All tests required for release of a Class 2 survey unit were passed in spite of the beta contribution of activated nuclides. A comparison of test results and requirements for release of the survey unit is presented in Table 4.3.

Table 4.3
Requirements for SU-101 Release[a]

Test	Class 1	SU-101
Min/Max	Not required	FAIL
Background	Not required	FAIL
$DCGL_w$	Not required	PASS
$DCGL_{avg}$	PASS	PASS
EMC	PASS	PASS
Wilcoxon Rank Sum Test	PASS	PASS

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

4.1.4 Measurements of removable contamination

4.1.4.1 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-101 Removable Contamination Summary

Sfc	Points	Avg Gross Alpha (dpm/100cm^2)	Max Gross Alpha (dpm/100cm^2)	Avg Gross Beta (dpm/100cm^2)	Max Gross Beta (dpm/100cm^2)
C	3	0.56	1.12	4.46	5.39
F	6	0.61	4.66	1.40	5.99
S	9	0.56	1.12	4.52	6.39
W	9	0.81	2.24	4.12	5.79

4.1.4.2 The results show that removable contamination averaged near zero dpm/100cm^2 and varied between 1.4 and 6.4 dpm/100cm^2. Gross beta averaged about one percent of the composite limit for removable contamination in Table 2.4. The data confirm that virtually no removable contamination is present within SU-101.

[32] If no background data were collected for a given matrix, the value was conservatively assumed to be zero.

4.1.5 Beta/Gamma Scan Measurements

4.1.5.1 β/γ scans were performed on 100% of the surfaces of SU-101. The scan threshold used for these surveys was 370 cpm (net of background) as listed in Table 2.6.

4.1.5.2 During the surveys the maximum and average gross count rates were recorded for each area scanned. Net scan values were obtained by subtracting the average open window background count rate obtained from Table 2.2 for each matrix. The β/γ scan data for SU-101 are reproduced in full in Table I-4 and a summary is presented in Table 4.5.

Table 4.5
SU-101 Scan Measurements Summary

Surface	Areas	Matrix	Maximum[a] (cpm)	Average[a] (cpm)
F[b]	1	C	1,747	1,247
C	1	C	(3)	(33)
S	4	C	997	378
W	6	C	947	327

[a] All values are net of background.
[b] Floor scans include the CFX mounting pad which was subsequently removed.

4.1.5.3 A diagram of the areas surveyed is presented in Attachment H, Figure H-6. Areas which exceeded the gross threshold for concrete (623 cpm) corresponded to those surfaces where activation produced a significant gamma component to the scan reading. The effects of activation on the direct beta measurements were suppressed because of the open/closed window process[33] which cancelled out most of the gamma.

4.1.5.4 The maximum net β/γ scan value exceeded the action threshold only in those areas where activation contributed a significant gamma component.

4.1.6 SU-101 Summary

4.1.6.1 The Characterization Survey of this class 1 survey unit revealed localized areas of activation in the concrete floor and walls that did not exceed 15% of the proposed release limit gamma threshold. Beta surveys for evidence of contamination showed no levels of beta activity in excess of the license limits in spite of the fact that the Cobalt and Europium nuclides contributed additional beta in activated regions. All the threshold tests required for release of a Class 1 survey unit passed. So did the Wilcoxon Rank Sum Test as applied to beta grid measurements. β/γ scans showed no elevated readings between the direct beta measurements except in the activated regions where the gamma signal from activated nuclides drove up the readings. Swipe readings analyzed for gross alpha and beta demonstrated that there is zero removable contamination in the survey unit. Within the scope of these surveys and the proposed release limits for activated surfaces, SU-101 meets all of the requirements for unrestricted release.

[33] For β/γ scans, only the open window reading is recorded.

4.2 SURVEY UNIT 102 EVALUATION

4.2.1 Direct Beta Measurements

4.2.1.1 A statistical grid was laid out in Survey Unit 102 and beta surveys were performed as described in Section 3. 23 measurements were taken on the floor, ceiling and three walls. All of them were included in the systematic grid. A data table of all the measurements taken in the survey unit is presented in Table I-5. A map showing the beta measurements by location and range of values is presented in Figure H-7.

4.2.1.2 A summary of the direct measurement results for SU-102 is presented in Table 4.6 and shows that the average activity measured, net of background, was (92) dpm/100cm^2. The maximum value for the survey unit was 596 dpm/100cm^2, which was less than the composite average release limit of 1,667 dpm/100cm^2 from Table 2.4.

Table 4.6
SU-102 Direct Beta Measurements Summary

Matrix	Points	Avg Net Activity (dpm/100cm^2)	Max Net Activity (dpm/100cm^2)
Concrete	15	(147)	596
Vinyl Tile	8	10	191
SU-102	23	(92)	596

4.2.2 Direct Beta Measurement Statistics and Threshold Tests

4.2.2.1 All the direct measurements in the survey unit were analyzed using the Threshold Comparison Test Report (TCTR) and the results are presented in Attachment G for SU-102. The TCTR limits were initialized at 1,667 and 5,000 dpm/100cm^2, and the Sign Test for Paired Data was selected because of the presence of non-similar matrix backgrounds (Concrete and Vinyl Tile) for the areas where the measurements were taken.

4.2.2.2 The TCTR report contains a complete listing of all the direct beta measurements taken within SU-102 sorted by room, surface, and activity. The summary pages indicate that all tests described in Section 3.4 passed for this survey unit. A comparison of test results and requirements for release of the survey unit is presented in Table 4.7.

Table 4.7
Requirements for SU-102 Release[a]

Test	Class 2	SU-102
Min/Max	Not required	PASS
Background	Not required	PASS
$DCGL_w$	PASS	PASS
$DCGL_{avg}$	PASS	PASS
EMC	PASS	PASS
Sign Test for Paired Data	PASS	PASS

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

4.2.3 Measurements of removable contamination

4.2.3.1 Swipes were taken on the floor surface only at each location where a direct grid measurement was performed. The data are presented in Table I-6 , and a summary of the measurements is presented in Table 4.8.

Table 4.8
SU-102 Removable Contamination Summary

Sfc	Points	Avg Gross Alpha (dpm/100cm^2)	Max Gross Alpha (dpm/100cm^2)	Avg Gross Beta (dpm/100cm^2)	Max Gross Beta (dpm/100cm^2)
F	5	0.73	1.12	4.63	5.79

4.2.3.2 The results show that removable contamination averages near zero dpm/100cm^2. Gross beta averaged about one percent of the composite limit for removable contamination in Table 2.4. The data confirm that virtually no removable contamination is present within SU-102.

4.2.4 Beta/Gamma Scan Measurements

4.2.4.1 β/γ scans were performed on 10% of the surfaces of SU-102. The scan threshold used for these surveys was 370 cpm (net of background) as listed in Table 2.6.

4.2.4.2 During the surveys the maximum and average gross count rates were recorded for each area scanned. Net scan values were obtained by subtracting the average open window background count rate obtained from Table 2.2 for each matrix. The beta scan data for SU-102 are reproduced in full in Table I-4.

4.2.4.3 The maximum net β/γ scan value was 57 cpm, well below the 370 cpm threshold listed in Table 2.6.

4.2.5 SU-102 Summary

4.2.5.1 The Characterization Survey of this class 2 survey unit revealed no levels of beta activity in excess of the license limits. All the threshold tests required for release of a Class 2 survey unit passed. So did the Sign Test for Paired Data as applied to beta grid measurements. β/γ scans showed no elevated readings between the direct beta

measurements. Swipe measurements of removable activity were analyzed for gross alpha and beta and demonstrated that there is zero removable contamination in the survey unit. Within the scope of these surveys, SU-102 meets all of the requirements for unrestricted release.

4.3 SURVEY UNIT 103 EVALUATION

4.3.1 Direct Beta Measurements

4.3.1.1 A square statistical grid was laid out in Survey Unit 103 with a grid spacing of 8 feet, and beta surveys were performed as described in Section 3. 31 measurements were taken on the floor, ceiling and two walls, and all of them were included in the systematic grid. A data table of all the measurements taken in the survey unit is presented in Table I-8. Diagrams of rooms C3 and C4 showing the beta measurements by location and range of values are presented in Figures H-8 and H-9.

4.3.1.2 A summary of the direct measurement results for SU-103 is presented in Table 4.9 and shows that the average activity measured, net of background, was (111) dpm/100cm^2. The maximum value for the survey unit (635 dpm/100cm^2) was less than the composite average release limit of 1,667 dpm/100cm^2 from Table 2.4.

Table 4.9
SU-103 Direct Beta Measurements Summary

Matrix	Points	Avg Net Activity (dpm/100cm^2)	Max Net Activity (dpm/100cm^2)
Room C3	7		
Concrete	5	264	635
Vinyl Tile	2	(204)	(40)
Room C4	24		
Concrete	18	(188)	403
Vinyl Tile	6	(163)	114
SU-103	31	(111)	635

4.3.2 Direct Beta Measurement Statistics and Threshold Tests

4.3.2.1 All the direct measurements in the survey unit were analyzed using the Threshold Comparison Test Report (TCTR) and the results are presented in Attachment G for SU-103. The TCTR limits were initialized at 1,667 and 5,000 dpm/100cm^2, and the Sign Test for Paired Data was selected because of the presence of non-similar matrix backgrounds (Concrete and Vinyl Tile) for the areas where the measurements were taken.

4.3.2.2 The TCTR report contains a complete listing of all the direct beta measurements taken within SU-103 sorted by room, surface, and activity. The summary pages indicate that all tests described in Section 3.4 passed for this survey unit. A comparison of test results and requirements for release of the survey unit is presented in Table 4.10.

Table 4.10
Requirements for S-103 Release[a]

Test	Class 2	SU-103
Min/Max	Not required	PASS
Background	Not required	PASS
$DCGL_w$	PASS	PASS
$DCGL_{avg}$	PASS	PASS
EMC	PASS	PASS
Sign Test for Paired Data	PASS	PASS

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

4.3.3 Measurements of removable contamination

4.3.3.1 Swipes were taken on the floor surface only at each location where a direct grid measurement was performed. The data are presented in Table I-9 , and a summary of the measurements is presented in Table 4.11.

Table 4.11
SU-103 Removable Contamination Summary

Room	Points	Avg Gross Alpha (dpm/100cm^2)	Max Gross Alpha (dpm/100cm^2)	Avg Gross Beta (dpm/100cm^2)	Max Gross Beta (dpm/100cm^2)
C3	2	0.28	0.28	3.50	3.79
C4	6	0.61	1.12	5.06	7.39

4.3.3.2 The results show that removable contamination averages near zero dpm/100cm^2. Gross beta averaged about one percent of the composite limit for removable contamination in Table 2.4. The data confirm that virtually no removable contamination is present within SU-103.

4.3.4 Beta/Gamma Scan Measurements

4.3.4.1 β/γ scans were performed on 10% of the surfaces of SU-103. The scan threshold used for these surveys was 370 cpm (net of background) as listed in Table 2.6.

4.3.4.2 During the surveys the maximum and average gross count rates were recorded for each area scanned. Net scan values were obtained by subtracting the average open window background count rate obtained from Table 2.2 for each matrix. The gross β/γ scan data for SU-103 are reproduced in full in Table I-10.

4.3.4.3 The maximum net β/γ scan value was 67 cpm, well below the 370 cpm threshold listed in Table 2.6.

4.3.5 SU-103 Summary

4.3.5.1 The Characterization Survey of this class 2 survey unit revealed no levels of beta activity in excess of the license limits. All the threshold tests required for release of a Class 2 survey unit passed. So did the Sign Test for Paired Data as applied to beta grid

measurements. β/γ scans showed no elevated readings in between the direct beta measurements. Swipe measurements of removable activity were analyzed for gross alpha and beta and demonstrated that there is zero removable contamination in the survey unit. Within the scope of these surveys, SU-103 meets all of the requirements for unrestricted release.

5 CONCLUSIONS

5.1 SURVEY UNIT-101

5.1.1 The Characterization Survey of this class 1 survey unit revealed localized areas of activation in the concrete floor and walls that did not exceed 15% of the proposed release limit gamma threshold. (Par 4.1.1.4)

5.1.2 Beta surveys for evidence of contamination showed no levels of beta activity in excess of the license limits in spite of the fact that the Cobalt and Europium nuclides contributed additional beta in activated regions. (Par 4.1.2.2)

5.1.3 All the threshold tests required for release of a Class 1 survey unit passed. So did the Wilcoxon Rank Sum Test as applied to beta grid measurements. (Par 4.1.3.3)

5.1.4 β/γ scans showed no elevated readings between the direct beta measurements except in the activated regions where the gamma signal from activated nuclides drove up the readings. (Par 4.1.5.4)

5.1.5 Swipe readings analyzed for gross alpha and beta demonstrated that there is zero removable contamination in the survey unit. (Par 4.1.4.2)

5.1.6 Within the scope of these surveys and the proposed release limits for activated surfaces, SU-101 meets all of the requirements for unrestricted release. (Par 4.1.6.1)

5.2 SURVEY UNITS-102 AND 103

5.2.1 The Characterization Survey of these class 2 survey units revealed no levels of beta activity in excess of the license limits. (Par 4.2.1.2, 4.3.1.2)

5.2.2 All the threshold tests required for release of a Class 2 survey unit passed. So did the Sign Test for Paired Data as applied to beta grid measurements. (Par 4.2.2.2, 4.3.2.2)

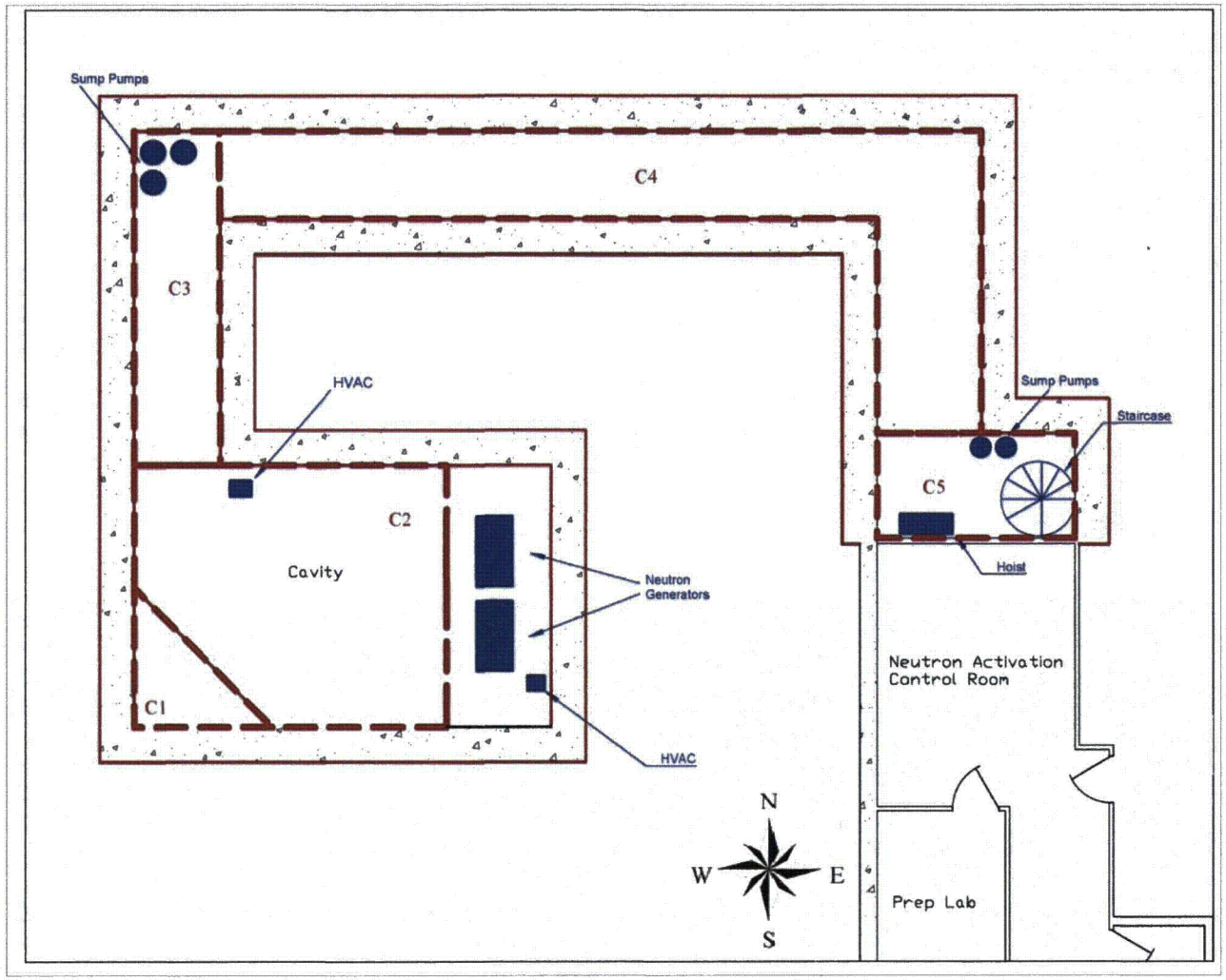
5.2.3 β/γ scans showed no elevated readings between the direct beta measurements. (Par 4.2.4.3, 4.3.4.3)

5.2.4 Swipe measurements of removable activity were analyzed for gross alpha and beta and demonstrated that there is zero removable contamination in the survey units. (Par 4.2.3.2, 4.3.3.2)

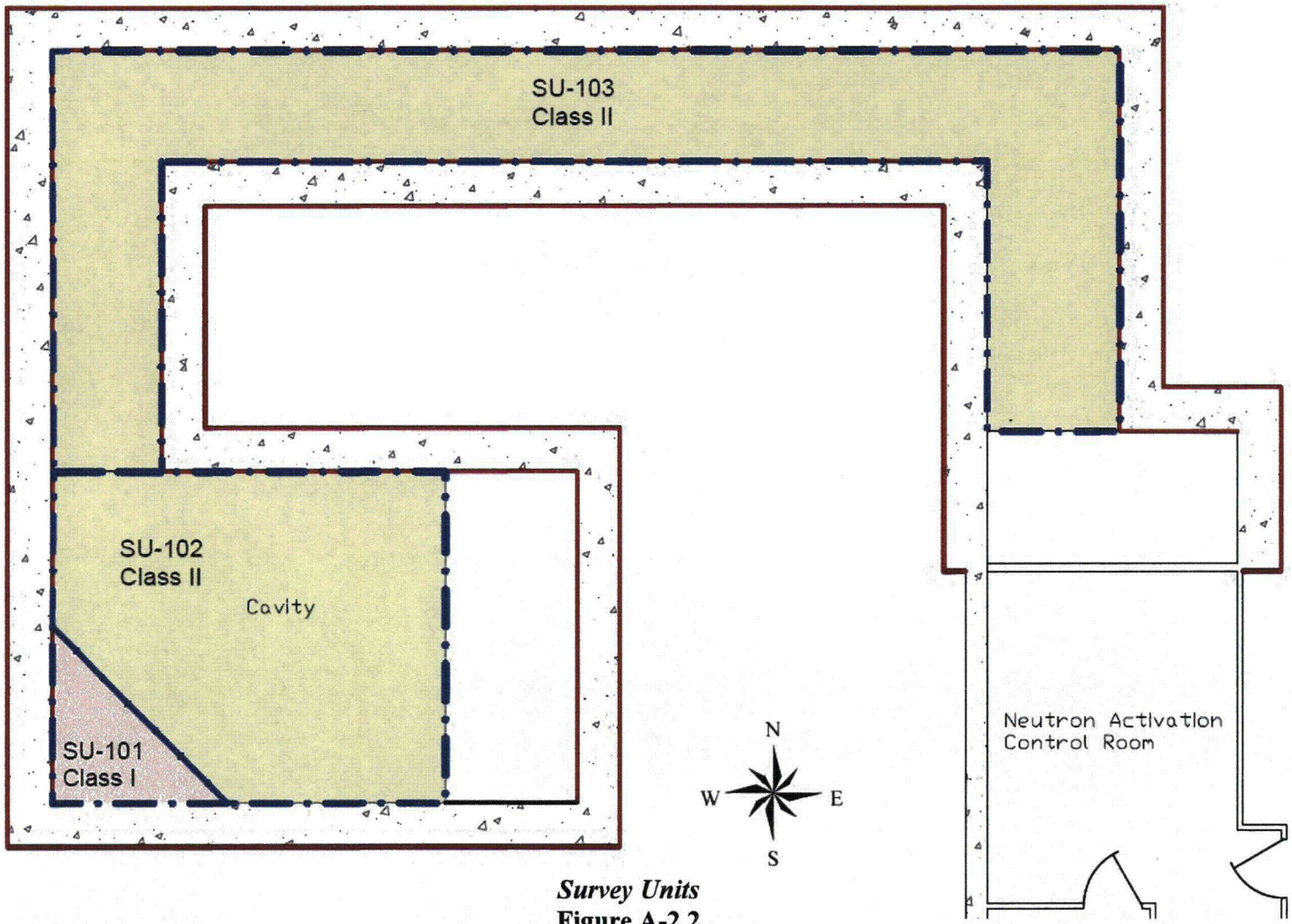
5.2.5 Within the scope of these surveys, SU-102 meets all of the requirements for unrestricted release. (Par 4.2.5.1)

5.2.6 Within the scope of these surveys, SU-103 meets all of the requirements for unrestricted release. (Par 4.3.5.1)

ATTACHMENT A
Figures



CFX Cavity and Labyrinth
Figure A-2.1



Survey Units
Figure A-2.2

TABLE 1

ACCEPTABLE SURFACE CONTAMINATION LEVELS

NUCLIDES (1)	AVERAGE (2, 3, 6)	MAXIMUM (2,4,6)	REMOVABLE (2,5,6)
U-nat, U-235, U-238, and associated decay products	5,000 dpm a/100 cm2	15,000 dpm a/100 cm2	1,000 dpm a/100 cm2
Transuranics, Ra-226, Ra-228, Th-230, Th-22, Pa-231, Ac-227, I-125, I-129	100 dpm/100 cm2	300 dpm /100 cm2	20 dpm/100 cm2
Th-nat, Th-232, Sr-90, Ra-223, Ra-224, U-232, I-126, I-131, I-133	1000 dpm/100 cm2	3000 dpm/100 cm2	200 dpm/100 cm2
Beta-gamma-emitters (nuclides with decay modes other than alpha emission or spontaneous fission) except Sr-90 and others noted above.	5000 dpm by/100 cm2	15,000 dpm b/100 cm2	1000 dpmby/100 cm2

(1) Where surface contamination by both alpha- and beta-gamma-emitting nuclides exists, the limits established for alpha- and beta-gamma-emitting nuclides should apply independently.

(2) As used in this table, dpm (disintegrations per minute) means the rate of emission by radioactive material as determined by correcting the counts per minute observed by an appropriate detector for background, efficiency, and geometric factors associated with the instrumentation.

(3) Measurements of average contaminant should not be averaged over more than 1 square meter. For objects of less surface area, the average should be derived for each such object.

(4) The maximum contamination level applies to an area of not more than 100 cm2.

(5) The amount of removable radioactive material per 100 cm2 of surface area should be determined by wiping that area with dry filter or soft absorbent paper, applying moderate pressure, and assessing the amount of radioactive material on the wipe with an appropriate instrument of known efficiency. When removable contamination on objects of less surface area is determined, the pertinent levels should be reduced proportionally and the entire surface should be wiped.

(6) The average and maximum radiation levels associated with surface contamination resulting from beta-gamma-emitters should not exceed 0.2 mrad/hr at 1 cm and 1.0 mrad/hr at 1 cm, respectively, measured through not more than 7 milligrams per square centimeter of total absorber.

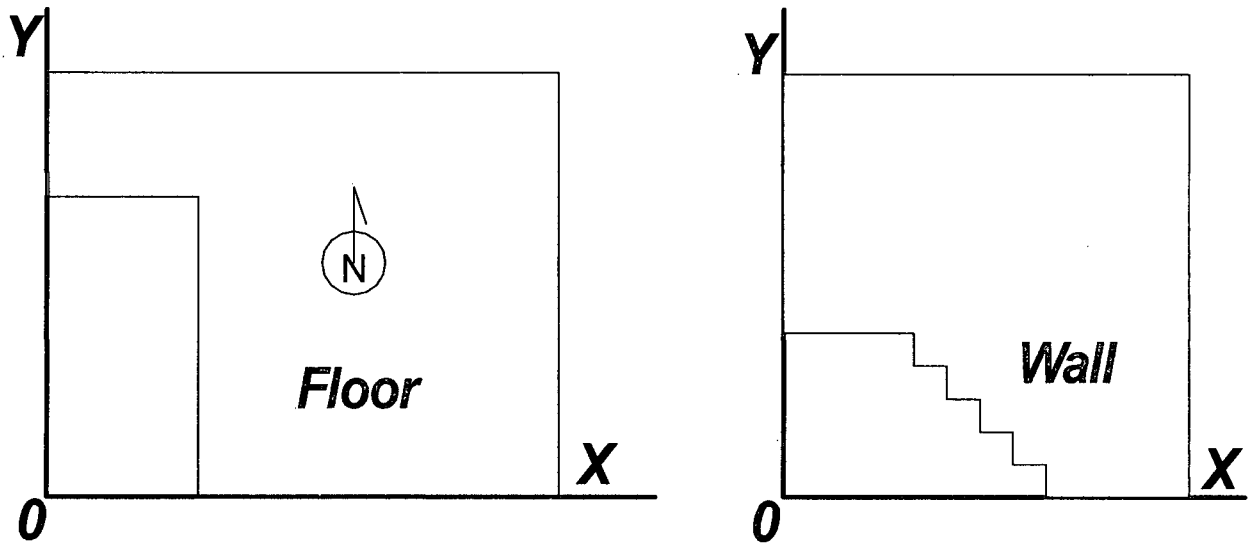
License Release Criteria

(from License SNM-1513, Attachment 2)

Figure A-2.3

Subject	*CFX Proc.*	*Approved Title*
Surveys	**CFX-RP-39**	**Performance of Radiation, Contamination, and Airborne Radioactivity Surveys**
	CFX-RP-40	**Survey Documentation and Review**
Instrument Calibration & Control	**CFX-QA-60**	**Calibration and Control of Measuring and Survey Equipment**
Instrument Source Ck & Operation	**CFX-RP-80**	**Operation of the L19 Micro-R Meter**
	CFX-RP-70	**Operation of the L2224/43-89 Scintillation Detector**
Document Control	**CFX-QA-51**	**Controlled Documents**
	CFX-QA-10	**Quality Assurance Records**
Access Control	**CFX-RP-13**	**Access Control**
Stop Work	**CFX-QA-92**	**Stop Work Orders**
Corrective Action	**CFX-QA-91**	**Corrective Action Request**
Exposure Monitoring	**CFX-RP-17**	**Exposure Monitoring**
Personnel survey & Decon	**CFX-RP-31**	**Personnel Survey and Decontamination**
Decontamination	**CFX-RP-33**	**Decontamination of Tools, Equipment, Materials, and Surfaces**
Unconditional release	**CFX-RP-36**	**Unconditional release of materials and equipment**
Emergency Response	**CFX-RP-86**	**CFX Criticality Safety Training**
	CFX-RP-88	**Nuclear Criticality Emergency Response**
Dosimetry records	**CFX-RP-19**	**Dosimetry records**
Admin and Regulatory Dose Limits	**CFX-RP-16**	**Regulatory and Administrative Dose Limits**
Rad Training	**CFX-RP-26**	**Radiation Protection Training**
LLD Calculations	**TM0710**	**Technical Basis Document for CFX FSS**

CFX Project Procedures
Figure A-3.1



Coordinate System
Figure A-3.2

KODAK
CFX Decommissioning

Characterization Survey SCAN Measurement Form

Date:		Instrument:	
Building:	82	Instrument ID #:	
Survey Unit:		Background:	cpm
Technician:		Cal Date:	
Limit Threshold :	CPM	Cal Due:	

		Beta-Gamma Scan Measurements		
Room	Map ID	Area Surveyed	Beta/Gamma Response Range (cpm)	Over Limit Threshold (Y/N)

Reviewed: _____ ***QA Approved:*** _____

CFX Scan Data Collection Form
Figure A-3.3

KODAK
CFX Decommissioning

Characterization Survey DIRECT Measurement Form

			3" NaI Detector:	Alpha/Beta Detector	
Date:		Detector:			
Building:	B82	Detector ID #:			
Survey Unit:	2	Background:	cpm	Alpha: cpm	Beta: cpm
Technician:		Cal Date:			
		Cal Due:			

Room	Sfc.	X (In)	Y (In.)	Matrix	Meas. Type	ALPHA (Counts Open)	BETA/ GAMMA (Counts Open)	BETA/ GAMMA (Counts Closed)	Count Time (Min.)	3" NaI (Counts)	Smear ID	Remarks
C2	N	76	24.5		RG				1			
		136	24.5		RG				1			
		196	24.5		RG				1			
		76	84.5		RG				1			
		136	84.5		RG				1			
		196	84.5		RG				1			
C2	S	19.5	17.5		RG				1			
		79.5	17.5		RG				1			
		19.5	77.5		RG				1			
		79.5	77.5		RG				1			
												NEXTEP CONSULTING GROUP

Page ____ of ____ *Reviewed:* _____ *QA Approved:* _____

Sample CFX Data Collection Form (front)
Figure A-3.4

Reference Data:

Matrix Codes:

CODE	MATERIAL
A	Asphalt
B	Brick
C	Concrete
CB	Concrete Block
CT	Ceramic Tile
CTP	Counter Top – Lab
CTX	Celotex Ceiling Tile
G	Glass
GB	Gypsum Board
M	Metal
P	Plastic
PL	Plaster
TR	Tar/Roofing
VT	Vinyl Tile
W	Wood

Measurement Type:

CODE	TYPE
RG	Regular MARSSIM Grid
BI	Bias
BK	Background
CH	Characterization
QA	Quality Control
PR	Post Remediation

NOTES:

1. Regular grid points that fall on fixed equipment will be treated as if they were part of the wall, ceiling or floor. Note in the remarks that it fell on fixed equipment and what it was.

2. Bias data pts taken on fixed equipment will be recorded as follows: The surface code should be the equipment identifier (Q1, Q2, etc.). Since no location coordinates apply, the X coordinate field will contain the sequence number of the data point from the floor plan drawing where it should be drawn.

Surface Code (sfc):

CODE	Surface
F	Floor
C	Ceiling
N	North Wall
S	South Wall
E	East Wall
W	West Wall
R	Roof
Q1	Eqpt ID

3. X, Y coordinates proceed North and East from the SW corner of the floor and ceiling; Right and Up from the lower LH corner of walls as you face the surface. For walls broken by jogs in room shape, parallel planes are considered as one surface.

4. Surveyors: annotate survey forms sufficiently such that measurement locations may be unambiguously identified

If direct measurements exceed the DCGLw or if scan measurements exceed the threshold value, the surveyor will take additional scans and direct readings to confirm and define the nature and extent of the activity. If scanning the floor with a NaI detector remove tile as necessary to take adequate direct readings.

FOR SCANS:
All readings to be taken Open Window. All scans within 0.5 inches of surface. Scan at rates <= 2 inches per sec. Scan locations will be identified on the room floor plan by letter ID's recorded in column two. Always take one ambient sample for background.

CFX Data Sheet (backside)
Figure A-3.5

ATTACHMENT B
Survey Unit Listing Report

Building Survey Unit Listing

	SurfaceCode	*Xmax*	*Ymax*	*Area (sq.ft.)*	*Description*
SurveyUnitID: 101					
Room C1					
	F	8.0	8.0	32	
	C	8.0	8.0	32	
	S	8.0	9.0	72	
	W	8.0	9.0	72	
Summary for Room C1 (4 detail records)				*208*	*Sq. Ft.*
TOTAL for Survey Unit				*208*	Sq. Ft.

Building Survey Unit Listing

	SurfaceCode	*Xmax*	*Ymax*	*Area (sq.ft.)*	*Description*
SurveyUnitID: 102					
Room C2					
	F	14.0	15.0	178	
	C	14.0	15.0	178	
	N	14.0	9.0	81	
	S	14.0	9.0	54	
	W	15.0	9.0	63	
Summary for Room C2 (5 detail records)				554	Sq. Ft.
TOTAL for Survey Unit				554	Sq. Ft.

Building Survey Unit Listing

	SurfaceCode	*Xmax*	*Ymax*	*Area (sq.ft.)*	*'Description*
SurveyUnitID: 103					
Room C3					
	F	5.0	19.0	95	
	C	5.0	19.0	95	
	N	5.0	9.0	45	
	E	19.0	9.0	126	
	W	19.0	9.0	171	
Summary for Room C3 (5 detail records)				532	Sq. Ft.
Room C4					
	F	43.8	17.2	294	
	C	43.8	17.2	294	
	N	43.8	9.0	394	
	S	43.8	9.0	340	
	E	17.2	9.0	155	
	W	17.2	9.0	110	
Summary for Room C4 (6 detail records)				1,587	Sq. Ft.
TOTAL for Survey Unit				2,119	Sq. Ft.

Monday, January 28, 2008 ***Page 3 of 3***

ATTACHMENT C
Feeder Reports

Miscellaneous Information for CFX Corner Surveys (Feb-12-2008 M.Morse, J.Heyer)

Instrument: 2" x 2" NaI probe, with 7mm total lead shielding thickness

Background measurements: Bicron in unaffected area (cavity hallway) = 5-6 micro R/hour

NaI middle area of cavity floor (with tile removed) = 2893 c/min
(Actual NaI floor background data was 14463 counts / 5 min)

W wall = 2727 c/min
S wall = 2753 c/min
W and S wall backgrounds taken at 12 feet horizontal
and 4 feet vertical distance from CFX corner of floor/walls
Hallway around corner from CFX room = 2476 c/min

Other: A grid was laid out 72" in horizontal length and 60" in vertical distance from the origin of the CFX corner. Wall designations match the original survey map for C1.

Data points were taken every 6" using a 6 second count time. The meter readout was then multiplied by 10 to get counts/minute.

The following tables have heavy black lines indicating the corner location common to the walls (for the wall readings), or indicating the wall/floor seem (for the floor readings).

Each data point is for the grid intersection of that column and row.

On the floor scan, a 72" x 72" grid was laid out, with outer areas reaching the tiled area of the floor. Data was not collected in the tiled area, and this is indicated on the data table.

A photo of the grid is included.

February Gamma Characterization Report
Figure C-1

Kodak Internal Memo December 19, 2007

To: Mark Morse, OCTO US CORP ENG SPECTRO +MICRO, Kodak Research Labs

From: Albert J. Filo, Image Sensor Solutions, Kodak Research Labs.

Subject: Analysis of activation by-products in the mortar support of the CFX frame.

Please refer to the Internal Memo dated May 24, 2007 for reference to the general description of the CFX and the counting procedure for the concrete mixture from the CFX shield.

The sample that was currently measured was a mortar matrix that was used to level the concrete floor below the CFX Aluminum frame assembly. The 3,423 gm sample of the mortar matrix was removed and placed in a 3-liter Marinelli beaker and the activity was measured on a low background high efficiency Ge detector. The primary activity that was measured was due to the activation products of ^{152}Eu, ^{154}Eu, and ^{60}Co. Their activity is presented in the following table and is normalized by weight. The activity does not reflect the effects of self-absorption within the sample.

Isotope	Normalized Activity
^{60}Co	7.66 pCi/gm
^{152}Eu	14.65 pCi/gm
^{154}Eu	0.95 pCi/gm

Concrete Sample Test Report
Figure C-2

ATTACHMENT D

TM0604 – Kodak CFX: Development of Release Limits for Activated Surfaces and Material

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TECHNICAL MEMORANDUM 0604

May 1, 2008

Originator: Andrew H. Thatcher, CHP, Technical Director

Subject: Kodak CFX: Development of Release Limits for Activated Surfaces and Material

Revision: 2

ENDORSEMENT: This document contains the results of research and technical analysis which have been reviewed and approved for publication by:	
	5/1/2008
Barton P. Anderson, Principal	Date

1. INTRODUCTION

1.1. PURPOSE

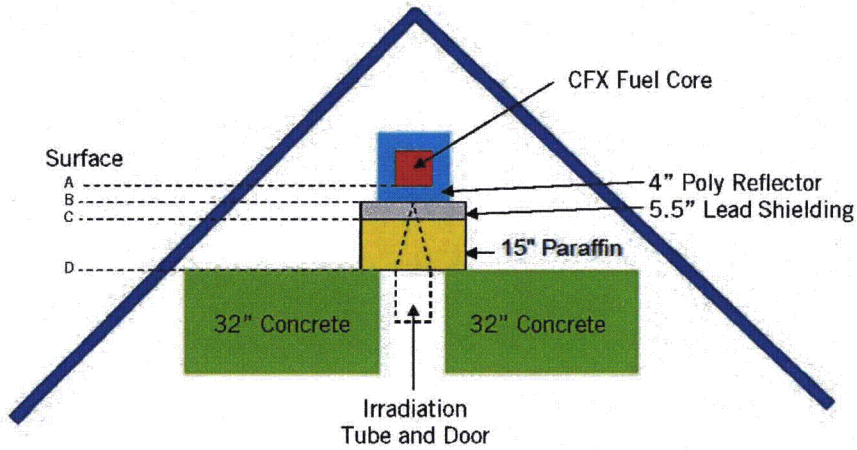
1.1.1. This Technical Memorandum (TM) develops the limits for activated building surfaces and removable materials pursuant to their release in connection with the Kodak Californium Neutron Flux Multiplier (CFX) decommissioning Project. This TM explains the technical basis and assumptions used in developing the activation release limits for an occupational exposure scenario.

1.2. BACKGROUND

1.2.1. The CFX began operations in 1975 and has been shutdown since June of 2006. The CFX was a sub-critical assembly of uranium 235 utilizing a californium 252 source to drive up the production of fast and thermal neutrons from fission to high sub-critical levels[34]. The californium source remained inserted into the CFX for most of its life such that the total estimated operational hours are 252,000 at an average power of 5.8 watts. A diagram of the CFX system as it was mounted in the corner of the sub-basement labyrinth underneath the Kodak Research Complex in Rochester, NY is presented in Figure 1.1.

[34] The CFX was designed to never exceed a K_{eff} <0.99.

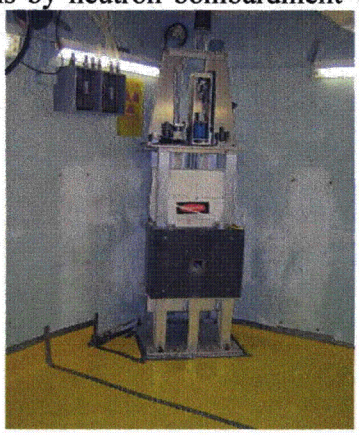
Further details of the CFX assembly and its characteristics are presented in the EKC Scoping Study.[35]



CFX Operational Configuration
Figure 1.1

1.2.2. The potential for activation of the surrounding materials by neutron bombardment was assessed in TM0520[36]. The study predicted that, apart from some of the actual structural components and shielding of the CFX, the only materials that would require release surveys after removal of the system from the labyrinth were the concrete wall surfaces and the concrete blocks that were mounted closest to the fuel assembly.

1.2.3. The CFX was dismantled in November, 2007 and removed from its mountings in the corner of the sub-basement labyrinth located in the Kodak Research Complex in Rochester, NY. A picture of the CFX with all the shielding materials removed is presented in Figure 1.2.



CFX Structure & Mount
Figure 1.2

1.2.4. All of the structural and shield materials that showed levels of radioactivity above background except the concrete blocks have been disposed of as radioactive waste. Only the concrete surfaces in the corner of the CFX cavity and some of the concrete shield blocks remain to be released for unrestricted use or disposal as a part of the decommissioning process.

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35 NEXTEP TM0703 *Eastman Kodak Company CFX Decommissioning Project Scoping Study*, Robert Newman and Ning Zhang

36 NEXTEP TM0520 *Neutron Activation Analysis for Kodak CFX Facility,* Andrew H. Thatcher, CHP

1.2.5. Kodak NRC license SNM-1513 specifies that the requirements for unrestricted release are those contained in the NRC Guidelines[37]. These guidelines do not apply to surfaces, equipment or scrap containing induced radioactivity. The release of such facilities or items is to be considered on a case by case basis.

1.2.6. This TM will address the development of release criteria for the concrete walls and floor of the CFX cavity and the concrete shield blocks which show evidence of neutron activation.

2. SCOPE

2.1. The analysis is divided between concrete building surfaces and removable concrete blocks used in the shield assembly.

2.2. For the release of activated building surfaces, the proposed unrestricted release limits are based upon a 2,000 hour occupational scenario, assuming a worker spends a fraction of his/her time in the underground labyrinth near the former location of the CFX. The limits are based upon the Total Effective Dose Equivalent (TEDE) to an average member of the critical group of no more than 0.25 mSv/yr (25 mRem/yr) from all pathways.

2.3. Possible activation of material is only of concern in close proximity to the CFX location. All other areas within the labyrinth that are potentially contaminated should conform with the release values specified in the license[38] and presented in Attachment A.

2.4. The proposed unrestricted release criteria for the concrete blocks are based upon an effective dose equivalent (EDE) of 1 mRem/year delivered to the critical groups for concrete rubble from the concentrations tabulated in NUREG-1640.[39]

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37 U.S. NRC, *Guidelines for Decontamination of Facilities and Equipment Prior to Release for Unrestricted use or Termination of Licenses for Byproduct, Source, or special Nuclear Material,* 1993.

38 A copy of Table 1 from NRC License SNM-1513 is reproduced in Attachment A, Figure A-1.

39 NUREG-1640, *Radiological Assessment for Clearance of Materials from Nuclear Facilities,* Anigstein, R, Chmelynski, H.J. et al, June 2003

3. METHODS

3.1. BUILDING SURFACES

3.1.1. The floor and wall surfaces in the corner of the CFX cavity were modeled using the Microshield® computer code[40]. Exposure rates from each of the surfaces were calculated individually and then summed to obtain an estimate of the total exposure rate in the corner of the cavity from a given concentration of activated nuclides. The assumptions used to create and interpret the models are as follows:

- Activated radionuclides in the concrete are those obtained by gamma spectroscopy analysis from the concrete pad on which the CFX was mounted.
- The relative percentages of activity from each radionuclide were assumed to remain the same as those measured in the mounting pad.
- The depth of the activated material was assumed to be 30 cm. Throughout this 30 cm of concrete, the activation products were assumed to be uniformly distributed.
- Since no removable material was identified above background in the swipes obtained near the CFX or in the labyrinth, only the external exposure pathway was considered.
- A rotational geometry was assumed for all external exposures[41].
- In all instances, the exposure distance was assumed to be 1 meter.

3.1.2. The Microshield model was run using the measured concentrations of the radionuclides found in the concrete mounting pad as a benchmark to be compared with a measurement of the exposure rate taken in the corner of the cavity after the CFX and all the shield materials had been removed.

3.1.3. Occupational Exposure Scenario

3.1.3.1. An occupational scenario was developed to represent a worst-case exposure to individuals working in the underground labyrinth using NUREG 5512[42] as its basis. This scenario was used in conjunction with the Microshield model to derive the activation release limits.

3.1.3.2. The individual chosen was someone who performs maintenance on two neutron generators also located in the CFX cavity.

3.1.3.3. The occupational exposure scenario involves only external exposures.

3.1.3.4. The exposure analysis assumes that an individual spends 10% of his/her time (200 hours/year) in the labyrinth[43]. Of this time in the labyrinth, 25% of the time is assumed to be in the corner of the cavity approximately 1 meter from the activated surfaces (50 hours/year). Given the size of the labyrinth and the fact that the area

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40 Grove Engineering, Microshield, Version 5.03, Rockville, MD. 1998.

41 In reality this would seldom be the case as non-uniform exposures from the various line sources would dominate and would result in doses less than those predicted from a rotational geometry.

42 Kennedy, W.E., Jr. and D.L. Strenge, *Residual Radioactive Contamination from Decommissioning: Technical Basis for Translating Contamination Levels to Annual Total Effective Dose Equivalent*, NUREG/CR-5512, PNL-7994, Washington, D.C., 1992.

43 Morse, M. Email to A.H. Thatcher. Historically, the estimated time spent in the labyrinth has been just a few hours per year over the last three years for generator repair work and maintenance. None of this work would be in the vicinity of the former CFX location. March 28. 2006.

formerly used by the CFX will have no stated purpose, it is highly unlikely that any individual would spend 50 hours in this location. The remaining 150 hours in the labyrinth were assumed to be at a distance of 3 meters from the activated location.

3.1.4. The assumed concentrations in the concrete were increased until the model predicted a total exposure rate for the occupational scenario just under .25 mSv/yr (25 mRem/yr). Those concentrations were designated as the release limits for activated concrete.

3.1.5. The model was modified to represent the possibility of contamination on top of the activated concrete surfaces by assuming a surface contamination of 3,000 dpm/100 cm^2 of Cs-137. The resulting dose was compared with the dose due to activation to gain insight into the relative magnitude and influence of each source.

3.1.6. The release criteria for the concrete blocks were derived from Table 6.5 of NUREG 1640 and compared with the concentrations measured by gamma spectroscopy from the concrete blocks that were closest to the CFX fuel assembly and which had the highest level of measured activity.

4. RESULTS AND DISCUSSION

4.1. The CFX structure was mounted atop a small concrete mortar pad which was removed, crushed, and analyzed by gamma spectroscopy to determine the activated isotopes of interest in the surrounding concrete. The pad is visible under the base of the support structure in Figure 1.2.

4.2. All the concrete in this pad was crushed and mixed to form a composite sample for assay using Kodak's high purity Germanium gamma spectrometer. Analysis of the mortar pad identified the activation products of interest, their average activity levels, and relative proportions. The results are presented in Table 4.1, and a copy of the report[44] is presented in Attachment A, Figure A-2.

Table 4.1
CFX Mounting Pad Analysis

Isotope	Normalized Activity	Relative Abundance
^{60}Co	7.66 pCi/gm	33%
^{152}Eu	14.65 pCi/gm	63%
^{154}Eu	0.95 pCi/gm	4%

4.3. BENCHMARK COMPARISON

4.3.1. The Microshield model was run using concentrations equal to those listed in Table 4.1 and the results are presented in Attachment B. Figure B-2 predicts a dose rate of 5.15 E-05 mSv/hr at 1 meter for a rotational geometry. Combining this for the three surfaces results in an estimated dose of 15.4 E-02 μSv/hr or 15.4 μR/hr.

[44] Filo, A.J., *Analysis of activation byproducts in the mortar support of the CFX frame,* Kodak Internal Memo to Mark Morse, December 19, 2007.

4.3.2. After the defueling and removal of the CFX assembly and all the shield materials from the CFX cavity, a measurement of the dose rate was taken with a Bicron μRem meter at 1 meter above the floor in the approximate location where the CFX fuel assembly had been. The reading obtained was 0.2 μSv/hr (20 μR/hr) gross with a background of 0.05 μSv/hr (5 μR/hr), resulting in a net 0.15 μSv/hr (15 μR/hr).

4.3.3. Comparison of the predicted exposure rate with the actual measurement shown in Table 4.2 shows agreement within 3%.

Table 4.2
Model Benchmark Comparison

	Dose Rate	
Units	**Predicted**	**Actual**
μRem/hr	15.4	15.0

4.4. CALCULATED RELEASE LIMIT FOR ACTIVATED BUILDING SURFACES

4.4.1. The concentrations of the radionuclides in Table 4.1 were raised by a factor of 20 while maintaining their relative proportions. The values used are shown in Table 4.3.

Table 4.3
Proposed Limit Concentrations for Activated Surfaces

Isotope	**Activity** (pCi/g)
^{60}Co	150
^{152}Eu	290
^{154}Eu	19

4.4.2. The Microshield model was run using the concentrations from Table 4.3 to predict the dose rate at one meter and at three meters. The results are presented in Attachment C. The calculation of the annual dose predicted from these results is given by Equation 1.

Equation 1

$$D = \sum_i (3 * \dot{D}_i * T_i)$$

Where:
D = *Annual Dose*
$\dot{D}_i$ = *Hourly dose rate from 1 surface @ a given distance (Attachment C)*
T_i = *Elapsed Time in hours over one year*

4.4.3. Using the numbers for rotational exposure given in Attachment C along with the time durations assumed in the occupational scenario, the results were calculated as follows:

$$D = [3 * (1.029 * 10^{-3}) * 50] + [3 * (1.613 * 10^{-4}) * 150] = 0.227\ mSv$$

4.4.4. Using the Limit concentrations listed in Table 4.3, the annual dose from activated concrete based upon the occupational scenario was 0.227 mSv (22.7 mRem). Since the computed dose is less than 0.25 mSv (25 mRem), the limit concentrations in concrete listed in Table 4.3 should be used as the release criteria for activated concrete.

4.4.5. The release criteria listed in Table 4.3 have been translated into counts per minute (cpm) for a 2x2" NaI gamma detector in TM0801.[45] The derived scan threshold is 360,000 cpm.

4.5. Additional Dose from Contaminated Building Surfaces

4.5.1. Kodak does not expect any contamination in the labyrinth and no measurements to date have demonstrated the existence of licensed material contamination anywhere. However, were contamination to be discovered in the CFX Cavity, the only possible source would be the fuel plates themselves, and the underlying assumption for long lived contamination would be that fission products and source material in the fuel plates had somehow escaped.

4.5.2. To evaluate the incremental dose attributable to possible contamination on top of an activated surface, the Microshield model was modified to calculate the dose contribution from fixed contamination in a 36 m^2 indoor environment. A uniform concentration of 3,000 dpm/100 cm^2 Cs-137 (for maximum dose) was assumed, and Attachment D shows the result to be 2.6 E-06 mSv/hr. Assuming 2,000 hours annual exposure, the total annual dose from contamination at the composite surface release limit is 5.20μSv (0.52 mRem).

4.5.3. Since any contamination on activated surfaces would provide negligible additional dose over and above the effects of activated radionuclides, the gamma threshold calculated for activated concrete can be used for release of building surfaces which are dominated by activated radionuclides.

4.6. Calculated Release Limit for Removable Concrete Block

4.6.1. Any activated materials within the concrete shield blocks are not considered an internal hazard due to their form. The proposed release criteria for these blocks are based upon the mean concentrations of radioactive material as stated in NUREG 1640 in the section concerning release of radionuclides in concrete rubble.

4.6.2. The free release limits for the concrete blocks are derived from Table 6.5 of NUREG 1640. They represent the concentration of the activated radionuclides in the concrete sufficient to produce an annual dose of 10 μSv/yr (1.0 mRem/yr). The release values for the radionuclides found in the CFX concrete are listed in Table 4.4.

[45] NEXTEP TM0801 - *CFX Gamma Conversion Factors and Survey Threshold*, A.H. Thatcher, CHP

Table 4.4
Free Release Limits for Concrete Block

Element	Solid Concentration (Bq/g)	Solid Concentration (pCi/g)	Analyzed Activity (pCi/g)
Co-58	0.132	3.6	0.14
Co-60	0.033	0.9	0.33
Eu-152	0.081	2.2	0.03

4.6.3. One of the concrete blocks closest to the CFX fuel assembly was crushed and a 1700g sample was analyzed by gamma spectroscopy. The results are tabulated in Table 4.4 and a copy of the report is presented in Attachment A, Figure A-3. The measured activity in the concrete shield block is significantly less than the NUREG 1640 release limits and it may be free released.

5. CONCLUSIONS AND RECOMMENDATIONS

5.1. The Microshield model prediction of dose rate at approximately one meter from the activated surfaces in the former location of the CFX agreed with the on-site measurement to within 3%. (Par. 4.3.3)

5.2. The limit concentrations listed in Table 4.3 should be used as the release criteria for activated concrete. (Par. 4.4.4)

5.3. Since any contamination on activated surfaces would provide negligible additional dose over and above the effects of activated radionuclides, the gamma threshold calculated for activated concrete can be used for release of building surfaces which are dominated by activated radionuclides. (Par. 4.5.3)

5.4. The free release limits for the concrete shield blocks are listed in Table 4.4. (Par. 4.6.2)

5.5. Analysis of a concrete shield block taken from the area of highest neutron flux alongside the CFX showed levels of activation well below the calculated limits. (Par 4.6.3)

TM0604
ATTACHMENT A
License Release Limits and Analytical Reports

TABLE 1

ACCEPTABLE SURFACE CONTAMINATION LEVELS

NUCLIDES (1)	AVERAGE (2, 3, 6)	MAXIMUM (2,4,6)	REMOVABLE (2,5,6)
U-nat, U-235, U-238, and associated decay products	5,000 dpm a/100 cm2	15,000 dpm a/100 cm2	1,000 dpm a/100 cm2
Transuranics, Ra-226, Ra-228, Th-230, Th-22, Pa-231, Ac-227, I-125, I-129	100 dpm/100 cm2	300 dpm /100 cm2	20 dpm/100 cm2
Th-nat, Th-232, Sr-90, Ra-223, Ra-224, U-232, I-126, I-131, I-133	1000 dpm/100 cm2	3000 dpm/100 cm2	200 dpm/100 cm2
Beta-gamma-emitters (nuclides with decay modes other than alpha emission or spontaneous fission) except Sr-90 and others noted above.	5000 dpm by/100 cm2	15,000 dpm b/100 cm2	1000 dpmby/100 cm2

(1) Where surface contamination by both alpha- and beta-gamma-emitting nuclides exists, the limits established for alpha- and beta-gamma-emitting nuclides should apply independently.

(2) As used in this table, dpm (disintegrations per minute) means the rate of emission by radioactive material as determined by correcting the counts per minute observed by an appropriate detector for background, efficiency, and geometric factors associated with the instrumentation.

(3) Measurements of average contaminant should not be averaged over more than 1 square meter. For objects of less surface area, the average should be derived for each such object.

(4) The maximum contamination level applies to an area of not more than 100 cm2.

(5) The amount of removable radioactive material per 100 cm2 of surface area should be determined by wiping that area with dry filter or soft absorbent paper, applying moderate pressure, and assessing the amount of radioactive material on the wipe with an appropriate instrument of known efficiency. When removable contamination on objects of less surface area is determined, the pertinent levels should be reduced proportionally and the entire surface should be wiped.

(6) The average and maximum radiation levels associated with surface contamination resulting from beta-gamma-emitters should not exceed 0.2 mrad/hr at 1 cm and 1.0 mrad/hr at 1 cm, respectively, measured through not more than 7 milligrams per square centimeter of total absorber.

Acceptable Surface Contamination Values
from License SNM-1315, Table 1
Figure A-1

Kodak Internal Memo December 19, 2007

To: Mark Morse, OCTO US CORP ENG SPECTRO +MICRO, Kodak Research Labs

From: Albert J. Filo, Image Sensor Solutions, Kodak Research Labs.

Subject: Analysis of activation by-products in the mortar support of the CFX frame.

Please refer to the Internal Memo dated May 24, 2007 for reference to the general description of the CFX and the counting procedure for the concrete mixture from the CFX shield.

The sample that was currently measured was a mortar matrix that was used to level the concrete floor below the CFX Aluminum frame assembly. The 3,423 gm sample of the mortar matrix was removed and placed in a 3-liter Marinelli beaker and the activity was measured on a low background high efficiency Ge detector. The primary activity that was measured was due to the activation products of ^{152}Eu, ^{154}Eu, and ^{60}Co. Their activity is presented in the following table and is normalized by weight. The activity does not reflect the effects of self-absorption within the sample.

Isotope	Normalized Activity
^{60}Co	7.66 pCi/gm
^{152}Eu	14.65 pCi/gm
^{154}Eu	0.95 pCi/gm

Concrete Mortar Pad Gamma Spec' Analysis Report
Figure A-2

Kodak Internal Memo May 24, 2007

To: Mark Morse, Foundation Science and Technology Center, Kodak Research Labs.

From: Albert J. Filo, Image Sensor Solutions, Kodak Research Labs.

Subject: Analysis of activation by-products in concrete shielding from the CFX.

A sample of concrete that was used as shielding for the CFX was recently analyzed in order to measure the activity of any activation by-products. The CFX consisted of a thread of ^{252}Cf surrounded by enriched Uranium (^{235}U) and was used as a neutron source for Neutron Activation Analysis. The neutron flux in the center of the CFX was approximately 2E+09 n/cm^2/sec and dropped off rapidly as you went to the external shield. The CFX was in operation for more than 30 years before being decommissioned in June of 2006. The CFX was surrounded on two sides by a shield of concrete blocks. A concrete block, that was located in a region of highest neutron flux, was removed from the shield to be analyzed. The block was broken and crushed into fine particles and then placed in a 3 liter Marinelli Beaker which supplied a uniform and reproducible measurement geometry for the analysis. There was also a second concrete block that was not part of the CFX shield that was treated in the same fashion to act as a blank.

The gamma-ray activity, from the concrete samples, was measured in an ultra low background lead shield on a low background high efficiency Ge detector, manufactured by EG&G Ortec. The measurement efficiency was determined using a 3 liter Marinelli Beaker that contained a gel matrix containing appropriate radioactive sources spanning the energy region of 88 keV thru 1836 keV. The radioactive standard was manufactured by Analytics from Atlanta, Ga. and was traceable to the NIST. The Marinelli Beaker standard was originally fabricated as an efficiency source for low-level water samples, but was used for this measurement. The difference in absorption coefficients between the gel (water matrix) and the concrete matrix was not used in these calculations. In order to minimize any error that may occur, only gamma rays greater than 1 MeV were used for the analysis.

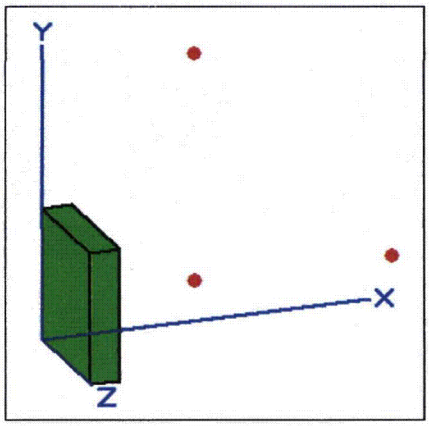
The concrete samples used for the analysis weighed 1,706 gm for the activated shield block and 1685 gm for the blank sample. The only activity that was measured in the blank was that due to U and Th and their daughters as well as ^{40}K. The sample of the concrete block that was used for the CFX shielding contained only the activated products of ^{60}Co, ^{152}Eu, and ^{154}Eu. Their activity is presented in the following table and is normalized by weight.

Isotope	Normalized Activity
^{60}Co	0.14 pCi/gm
^{152}Eu	0.33 pCi/gm
^{154}Eu	0.03 pCi/gm

Concrete Shield Block Gamma Spec' Analysis Report
Figure A-3

TM0604
ATTACHMENT B
Microshield Benchmark Results

Case Title: Concrete exposure
Description: Concrete wall and floor contribution
Geometry: 13 - Rectangular Volume



Source Dimensions

Length	30.0 cm	11.8 in
Width	135.0 cm	4 ft 5.1 in
Height	135.0 cm	4 ft 5.1 in

Dose Points

A	X	Y	Z
# 1	130 cm	67.5 cm	67.5 cm
	4 ft 3.2 in	2 ft 2.6 in	2 ft 2.6 in
# 2	130 cm	300 cm	67.5 cm
	4 ft 3.2 in	9 ft 10.1 in	2 ft 2.6 in
# 3	330 cm	67.5 cm	67.5 cm
	10 ft 9.9 in	2 ft 2.6 in	2 ft 2.6 in

Shields

Shield Name	Dimension	Material	Density
Source	5.47e+05 cm³	Concrete	2.35
Air Gap		Air	0.00122
Immersion		Air	0.00122

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

Nuclide	curies	becquerels	µCi/cm³	Bq/cm³
Co-60	1.9683e-004	7.2827e+006	3.6000e-004	1.3320e+001
Eu-152	3.7179e-004	1.3756e+007	6.8000e-004	2.5160e+001
Eu-154	2.4087e-005	8.9120e+005	4.4054e-005	1.6300e+000

Microshield Activity and Exposure Configuration for Benchmark Test
Figure B-1

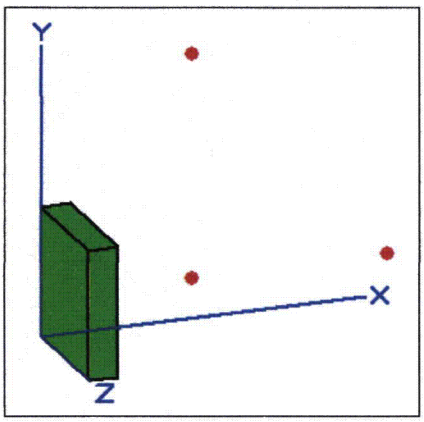
FILE: C:\MS5\DATA\KODAK\CONCRE~1\FINALCAL.MS5
Case Title: Concrete exposure
This case was run on Tuesday, February 26, 2008 at 9:29:38 PM
Dose Point # 1 - (130,67.5,67.5) cm

Results (Summed over energies)	Units	Without Buildup	With Buildup
Photon Fluence Rate (flux)	Photons/cm²/sec	2.043e+000	4.099e+000
Photon Energy Fluence Rate	MeV/cm²/sec	2.074e+000	3.936e+000
Exposure and Dose Rates:			
Exposure Rate in Air	mR/hr	3.661e-003	6.969e-003
Absorbed Dose Rate in Air	mGy/hr	3.196e-005	6.084e-005
"	mrad/hr	3.196e-003	6.084e-003
Deep Dose Equivalent Rate	(ICRP 51 - 1987)		
o Parallel Geometry	mSv/hr	3.672e-005	7.011e-005
o Opposed	"	3.115e-005	5.920e-005
o Rotational	"	3.114e-005	5.919e-005
o Isotropic	"	2.780e-005	5.284e-005
Shallow Dose Equivalent Rate	(ICRP 51 - 1987)		
o Parallel Geometry	mSv/hr	3.897e-005	7.439e-005
o Opposed	"	3.738e-005	7.128e-005
o Rotational	"	3.738e-005	7.128e-005
o Isotropic	"	2.947e-005	5.603e-005
Effective Dose Equivalent Rate	(ICRP 51 - 1987)		
o Anterior/Posterior Geometry	mSv/hr	3.290e-005	6.279e-005
o Posterior/Anterior	"	3.007e-005	5.726e-005
o Lateral	"	2.369e-005	4.494e-005
o Rotational	"	2.705e-005	5.146e-005
o Isotropic	"	2.381e-005	4.522e-005

Exposure and Dose Rate at 1 meter
Figure B-2

TM0604
ATTACHMENT C
Microshield Results at the Proposed Release Limit

Case Title: Concrete exposure
Description: Concrete wall and floor contribution
Geometry: 13 - Rectangular Volume



Source Dimensions

Length	30.0 cm	11.8 in
Width	135.0 cm	4 ft 5.1 in
Height	135.0 cm	4 ft 5.1 in

Dose Points

A	X	Y	Z
# 1	130 cm	67.5 cm	67.5 cm
	4 ft 3.2 in	2 ft 2.6 in	2 ft 2.6 in
# 2	130 cm	300 cm	67.5 cm
	4 ft 3.2 in	9 ft 10.1 in	2 ft 2.6 in
# 3	330 cm	67.5 cm	67.5 cm
	10 ft 9.9 in	2 ft 2.6 in	2 ft 2.6 in

Shields

Shield Name	Dimension	Material	Density
Source	5.47e+05 cm³	Concrete	2.35
Air Gap		Air	0.00122
Immersion		Air	0.00122

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

Nuclide	curies	becquerels	µCi/cm³	Bq/cm³
Co-60	9.8415e-006	3.6414e+005	1.8000e-005	6.6600e-001
Eu-152	1.8590e-005	6.8781e+005	3.4000e-005	1.2580e+000
Eu-154	1.2029e-006	4.4505e+004	2.2000e-006	8.1400e-002

Microshield Activity and Exposure Configuration for Proposed Release Limit
Figure C-1

FILE: C:\MS5\DATA\KODAK\CONCRE~1\FINAL20X.MS5
Case Title: Concrete exposure
This case was run on Tuesday, February 26, 2008 at 9:30:47 PM
Dose Point # 1 - (130,67.5,67.5) cm

Results (Summed over energies)	Units	Without Buildup	With Buildup
Photon Fluence Rate (flux)	Photons/cm²/sec	4.087e+001	8.199e+001
Photon Energy Fluence Rate	MeV/cm²/sec	4.149e+001	7.873e+001
Exposure and Dose Rates:			
Exposure Rate in Air	mR/hr	7.323e-002	1.394e-001
Absorbed Dose Rate in Air	mGy/hr	6.393e-004	1.217e-003
"	mrad/hr	6.393e-002	1.217e-001
Deep Dose Equivalent Rate	(ICRP 51 - 1987)		
o Parallel Geometry	mSv/hr	7.343e-004	1.402e-003
o Opposed	"	6.230e-004	1.184e-003
o Rotational	"	6.228e-004	1.184e-003
o Isotropic	"	5.561e-004	1.057e-003
Shallow Dose Equivalent Rate	(ICRP 51 - 1987)		
o Parallel Geometry	mSv/hr	7.795e-004	1.488e-003
o Opposed	"	7.477e-004	1.426e-003
o Rotational	"	7.477e-004	1.426e-003
o Isotropic	"	5.893e-004	1.121e-003
Effective Dose Equivalent Rate	(ICRP 51 - 1987)		
o Anterior/Posterior Geometry	mSv/hr	6.580e-004	1.256e-003
o Posterior/Anterior	"	6.015e-004	1.145e-003
o Lateral	"	4.738e-004	8.989e-004
o Rotational	"	5.409e-004	1.029e-003
o Isotropic	"	4.762e-004	9.045e-004

Exposure and Dose Rate at 1 meter at Proposed Release Limit
Figure C-2

FILE: C:\MS5\DATA\KODAK\CONCRE~1\FINAL20X.MS5
Case Title: Concrete exposure
This case was run on Tuesday, February 26, 2008 at 9:30:47 PM
Dose Point # 3 - (330.67,5.67,5) cm

Results (Summed over energies)	Units	Without Buildup	With Buildup
Photon Fluence Rate (flux)	Photons/cm²/sec	6.259e+000	1.280e+001
Photon Energy Fluence Rate	MeV/cm²/sec	6.394e+000	1.234e+001
Exposure and Dose Rates:			
Exposure Rate in Air	mR/hr	1.128e-002	2.184e-002
Absorbed Dose Rate in Air	mGy/hr	9.849e-005	1.907e-004
"	mrad/hr	9.849e-003	1.907e-002
Deep Dose Equivalent Rate	(ICRP 51 - 1987)		
o Parallel Geometry	mSv/hr	1.131e-004	2.197e-004
o Opposed	"	9.599e-005	1.856e-004
o Rotational	"	9.597e-005	1.855e-004
o Isotropic	"	8.569e-005	1.656e-004
Shallow Dose Equivalent Rate	(ICRP 51 - 1987)		
o Parallel Geometry	mSv/hr	1.201e-004	2.331e-004
o Opposed	"	1.152e-004	2.234e-004
o Rotational	"	1.152e-004	2.234e-004
o Isotropic	"	9.081e-005	1.756e-004
Effective Dose Equivalent Rate	(ICRP 51 - 1987)		
o Anterior/Posterior Geometry	mSv/hr	1.014e-004	1.968e-004
o Posterior/Anterior	"	9.267e-005	1.795e-004
o Lateral	"	7.303e-005	1.409e-004
o Rotational	"	8.335e-005	1.613e-004
o Isotropic	"	7.338e-005	1.418e-004

Exposure and Dose Rate at 3 meters at Proposed Release Limit
Figure C-3

TM0604

ATTACHMENT D

Exposure Rate from Surface Contamination at the Average Limit

FILE: C:\MS5\DATA\KODAK\CONCRE~1\TABLE1.MS5
Case Title: Case 7
This case was run on Wednesday, February 27, 2008 at 9:14:16 PM
Dose Point # 1 - (100,300,300) cm

Results (Summed over energies)	Units	Without Buildup	With Buildup
Photon Fluence Rate (flux)	Photons/cm²/sec	2.889e-001	2.989e-001
Photon Energy Fluence Rate	MeV/cm²/sec	1.802e-001	1.858e-001
Exposure and Dose Rates:			
Exposure Rate in Air	mR/hr	3.526e-004	3.638e-004
Absorbed Dose Rate in Air	mGy/hr	3.078e-006	3.176e-006
"	mrad/hr	3.078e-004	3.176e-004
Deep Dose Equivalent Rate	(ICRP 51 - 1987)		
o Parallel Geometry	mSv/hr	3.646e-006	3.761e-006
o Opposed	"	2.905e-006	2.996e-006
o Rotational	"	2.902e-006	2.993e-006
o Isotropic	"	2.567e-006	2.648e-006
Shallow Dose Equivalent Rate	(ICRP 51 - 1987)		
o Parallel Geometry	mSv/hr	3.875e-006	3.998e-006
o Opposed	"	3.668e-006	3.783e-006
o Rotational	"	3.668e-006	3.783e-006
o Isotropic	"	2.749e-006	2.836e-006
Effective Dose Equivalent Rate	(ICRP 51 - 1987)		
o Anterior/Posterior Geometry	mSv/hr	3.205e-006	3.305e-006
o Posterior/Anterior	"	2.821e-006	2.909e-006
o Lateral	"	2.090e-006	2.155e-006
o Rotational	"	2.522e-006	2.601e-006
o Isotropic	"	2.147e-006	2.214e-006

Exposure Rate from Average Surface Contamination Limit
Figure D-1

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ATTACHMENT E

TM0713 – Technical Basis Document for Kodak Beta Measurements

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TECHNICAL MEMORANDUM 0713

May 1, 2008

Originator: Andrew H. Thatcher, CHP, Technical Director

Subject: Technical Basis Document for Kodak Beta Measurements

Revision: 1

ENDORSEMENT: This document contains the results of research and technical analysis which have been reviewed and approved for publication by:	
	5/1/2008
Barton P. Anderson, Principal	Date

1. INTRODUCTION

1.1. PURPOSE

1.1.1. This Technical Memorandum (TM) provides the technical basis for calculations related to beta instrumentation used in connection with the Kodak Californium Neutron Flux Multiplier (CFX) Decommissioning Project. The beta instruments discussed were used for de-fueling and release of non activated removable equipment and building surfaces.

1.2. BACKGROUND

1.2.1. The CFX began operations in 1975 and has been shutdown since June of 2006. The CFX was a sub-critical assembly of uranium 235 utilizing a californium 252 source to drive up the production of fast and thermal neutrons from fission to high sub-critical levels[46]. The californium source remained inserted into the CFX for most of its life such that the total estimated operational hours are 252,000 at an average power of 5.8 watts. Further details about the CFX assembly and its characteristics are presented in the CFX Scoping Study.[47]

1.2.2. The fuel assembly at the center of the CFX contained 181 Materials Testing Reactor (MTR) type fuel plates. Each plate contained a core fuel matrix consisting of U/Al alloy which was 20% uranium by weight. The fuel matrix core was covered all around by a uniform 0.010" thick Aluminum cladding which made each plate a sealed source. All licensed material in the CFX was contained in these sealed source fuel plates.

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46 The CFX was designed to never exceed a K_{eff} <0.99.

47 NEXTEP TM0703 *Eastman Kodak Company CFX Decommissioning Project Scoping Study*, Robert Newman and Ning Zhang

1.2.3. During 30 years of continuous operation, radioisotopes from fission of the uranium built up within the fuel plates. Any contamination in the CFX cavity from licensed material will of necessity come from a breach in the fuel plates, and will contain quantities of Sr-90 and Cs-137. Since both are strong beta emitters, evidence of contamination from licensed materials will be obtained using beta instrumentation and will be governed by the limits contained in NRC License SNM-1513 as they apply to these two radionuclides.

2. SCOPE

2.1. This document specifically addresses the following issues:

2.1.1. Composite Release Limits for beta measurements.

2.1.2. Required and calculated Minimum Detectable Concentration (MDC) for direct (integrated) beta measurements[48]

2.1.3. Required and calculated MDC for beta scans

2.1.4. Investigation thresholds for direct and scan beta measurements

3. METHODS

3.1. BETA MEASUREMENT AND CALCULATION

3.1.1. Integrated Beta Measurements

3.1.1.1. Integrated measurements of beta radioactivity made in connection with the CFX project will be performed using an open/closed window methodology. Two readings will be taken at each location of interest including background locations. The closed window reading will be taken through a 1/2" thick Lexan plate which is sufficient to block out the betas of interest. By subtracting the two counts, those counts due primarily to beta emissions can be isolated from the gamma background. Equation 1 will be used to calculate the results.

Equation 1

$$AD = \frac{C_o - C_c}{\epsilon_i \epsilon_s T(\frac{A_e}{100})}$$

Where:

AD = *Area Activity Density (dpm/100 cm²)*
C_o = *Open Window Counts*
C_c = *Closed Window Counts*
ϵ_i = *Instrument 4π efficiency for Sr-90*
ϵ_s = *Surface Efficiency*[49]
T = *Integration time in minutes for each count*
A_e = *The effective area of the probe in cm²*

---

48 Direct beta measurements are integrated measurements taken with the detector stationary over the survey location of interest. Most survey measurements were integrated for 1 minute. The terms direct and integrated are used interchangeably throughout this TM.

49 Surface efficiency includes all the effects of surface geometry and backscatter characteristics on the source emissions. Total efficiency is the product of the instrument efficiency, ϵ_i, and the surface efficiency, ϵ_s.

3.1.1.2. The instrument that will be used to take beta measurements is the Ludlum 43-89 scintillation detector. It has a probe area of 125 cm^2 and an effective area of 100 cm^2.

3.1.1.3. All beta measurements were taken on either concrete or vinyl tile matrix substrates. The surface efficiency used in these calculations is taken from the range of values given for sealed concrete in Table 5-4 of NUREG-1507[50], and is used for both matrix materials as an estimate of the surface efficiency encountered in the CFX cavity ($\epsilon_s = 0.60$).

3.1.2. Beta Scans

3.1.2.1. Beta scans will be performed open window at a probe height of 0.5 cm above the surface to be scanned. The scan speed will be approximately 5 cm/sec for the first pass. This will yield an observation window of approximately 2 seconds.

3.1.2.2. Scan measurements will be recorded in counts per minute and compared with the scan threshold calculated in this TM. Any scan measurement which exceeds the threshold will be amplified with integrated beta measurements as required.

4. RESULTS AND DISCUSSION

4.1. COMPOSITE RELEASE LIMITS FOR DIRECT BETA MEASUREMENTS

4.1.1. The basis for release of equipment or materials is contained in Attachment 2 to License SNM-1513[51] (the Guidelines). This table specifies acceptable levels of contamination for four different groups of radionuclides in terms of disintegrations per minute (dpm) for alpha and beta emissions, applied independently to each.

4.1.2. Any contamination discovered within the CFX cavity would, of necessity, originate from a rupture or breach of one or more MTR fuel plates. Modeling of the residual activity and fission product buildup in the fuel plates was performed using the SCALE[52] system, and is described in detail in NEXTEP TM0519[53]. This analysis showed that the activity from fission products would dominate the mix of such contaminants[54]. Moreover, among the products of fission, Sr-90, Cs-137 and their progeny dominated by at least one order of magnitude, and were present in approximately equal quantities.

4.1.3. Sr-90 and its progeny fall in the third category of nuclides listed in the License Criteria, and they have a release limit of 1,000 dpm/100 cm^2 averaged over 1m^2. Cs-137 and its progeny fall into the fourth category of beta-gamma emitters and they have an average limit of 5,000 dpm/100 cm^2.

---

50 NUREG 1507 - *Minimum Detectable Concentrations with Typical Radiation Survey Instruments for Various Contaminants and Field Conditions*, Abelquist. E.W., et.al., June 1998.

51 NRC license SNM-1513, Attachment 2, *Guidelines for Decontamination of Facilities and Equipment Prior to Release for Unrestricted use or Termination of Licenses for Byproduct, Source, or Special Nuclear Material,* US NRC, 1993

52 *SCALE:* A Modular Code System for Performing Standardized Computer Analyses for Licensing Evaluations, ORNL/TM-2005/39, Version 5, Vols. I-III, April 2005.

53 NEXTEP TM0519, *Core Residual Activities and Dose Rates From the Kodak CFX Facility*, A.H.Thatcher, CHP

54 The total predicted activity from fission products was 330 mCi compared to the total activity due to U-235 and its daughters of 7 mCi.

4.1.4. Since Cs-137 and Sr-90 are both strong beta emitters, the primary means for detecting evidence of contamination is beta detection by direct measurements and scans. Therefore a composite release limit was developed using the unity rule as shown in Equation 2.

Equation 2

$$\frac{^{137}Cs}{5{,}000} + \frac{^{90}Sr}{1{,}000} \leq 1$$

4.1.5. If the cesium and strontium activities are equal, then their sum must be no greater than 1,667 dpm/100 cm^2. Using the same method a set of composite release limits for the mix was calculated and is presented in Table 4.1.

Table 4.1
Composite Release Limits[a] for Building Surface Contamination
(α or β)

Nuclide	Average ($1m^2$)	Maximum ($100cm^2$)	Removable ($100cm^2$)
Sr-90	1,000	3,000	200
Cs-137	5,000	15,000	1,000[b]
50/50 mix	**1,667**	**5,000**	**333[b]**

[a] Above background
[b] β/γ only

4.1.6. If surface contamination has been detected in excess of the composite release limits in Table 4.1, either the contamination will be cleaned up to the release criteria, or samples will be sent out to a laboratory for isotopic analysis and a composite limit will be calculated based upon the radionuclides actually present in the samples.

4.2. Calculated and Required MDC for Direct Beta Measurements

4.2.1. The required MDC for direct beta measurements is 50% of the composite release limit presented in Table 1.1 or 833 dpm/100 cm^2.

4.2.2. Background data were collected on concrete and vinyl tile substrates in the control room above the labyrinth containing the CFX. The data collected are presented in Attachment A, Table A-1. For the purposes of these calculations the five successive one-minute counts on each matrix are combined and treated as a single 5 minute background count.

4.2.3. The Minimum Detectable Concentration for integrated beta measurements was calculated using the methods outlined in NUREG 1507.[55] The formula for unequal count times is given in Equation 3.

[55] NUREG-1507, Ibid., Equation 3-11 provides the basis for this calculation.

Equation 3

$$MDC = \frac{3 + 3.29\sqrt{R_b * t_{s+b}\left(1 + \frac{t_{s+b}}{t_b}\right)}}{\epsilon_i * \epsilon_s * t_{s+b}}$$

Where:

R_b = *Sum of open and closed window background counting rates (cpm)*
ϵ_i = *efficiency for the 43-89*[56] *= 17.4%*
ϵ_s = *Surface Efficiency*
t_b = *Background count time (5 minutes)*
t_{s+b} = *Sample count time (1 minute)*

4.2.4. Because direct measurements result from the difference between open and closed window count rates, R_b (background counting rate) reflects the sum of the two.

4.2.5. The formula was applied to the background data on file for both concrete and vinyl tile, and the results are listed in Table 4.2.

4.2.6. Since the effective area of the L43-89 is 100 cm^2, no area correction factor was applied to the instrument efficiency.

Table 4.2
Integrated Beta MDC Calculations

Matrix	Sum of count Rates	Surface Efficiency	Instrument Efficiency	MDC
	(cpm)	(cpm/dpm)	(cpm/dpm)	(dpm/100 cm^2)
Concrete	447	0.60	17.43%	757
Vinyl Tile	394	0.60	17.43%	713

4.2.7. The derived MDC for integrated beta measurements is less than 50% of the release limit and is adequate for CFX beta surveys.

4.3. INVESTIGATION THRESHOLD FOR INTEGRATED BETA MEASUREMENTS

4.3.1. The net investigation threshold for direct beta measurements is simply the release limit in dpm/100 cm² converted to cpm by taking into consideration the matrix-specific surface efficiency (ϵ_s) and the instrument efficiency (ϵ_i). This can be obtained by solving Equation 1 for the difference in count rates at an activity level of 1,667 dpm/100 cm^2.

Equation 4

$$[1{,}667] * \epsilon_i * \epsilon_s = C_o - C_c = Th_D$$

Where:

Th_D = *The Direct Beta Measurement Threshold in cpm*

Note:

T = *1 minute*
Ae = *100 cm^2*

[56] The efficiency used is the 4 π efficiency for a Sr-90/Y-90 source. Sr/Y is the overwhelming contributor to beta counts from the fuel plates.

4.3.2. The Investigation Threshold for direct beta measurements was calculated for both concrete and vinyl tile substrates. By applying the background count rates[57] for each matrix taken from the data in Attachment A, the Gross value of Th_D was also calculated. The results are presented in Table 4.3.

Table 4.3
Calculated Values for Th_D

Matrix	Surface Efficiency	Instrument Efficiency	Net Th_D (Co-Cc)	Average BK Counts	Gross Th_D
	(cpm/dpm)	(cpm/dpm)	(cpm)	(cpm)	(cpm)
Concrete	0.60	17.43%	174	60	235
Vinyl Tile	0.60	17.43%	174	6	181

4.3.3. The investigation threshold for direct beta measurements is 174 cpm (net of background) and 235 and 181 cpm including background for concrete and vinyl tile respectively. The threshold values presented in Table 4.3 should be used during Characterization and Final Status Surveys to evaluate integrated beta field readings

4.4. SCAN MDC FOR BETA MEASUREMENTS

4.4.1. The required MDC for beta scan measurements must be equal to or less than the maximum composite concentration limit shown in Table 4.1 (5,000 dpm/100 cm²).

4.4.2. The methodology used to determine the Minimum Detectable Count Rate (MDCR) and scan MDC is outlined in Chapter 6 of MARSSIM[58] and Chapter 6 of NUREG-1507.

4.4.3. The minimum detectable net count rate (MDCR) of a scanning instrument is given by Equation 5:[59] The Index of Sensitivity, *d'*, was selected to provide a 60% probability of a false positive detection and a 5% probability of a false negative. These values are typical for a first pass detection situation.

Equation 5

$$MDCR = d'\sqrt{b_i}\left(\frac{60}{i}\right)$$

Where:

MDCR = *minimum detectable net count rate (cpm)*

d' = *1.38 when decision error, (α) = 0.60, and correct decision fraction, (1-β) = 0.95*[60]

i = *observation interval (sec) = (detector area)*$^{1/2}$*/scan speed*[61] *= 2 sec*

b_i = *background counts in the observation interval* $b_i = \overline{C_o} * (i/60)$[62]

60 = *conversion, 60 (sec/min)*

---

57 Combine all 5 background measurements for the matrix and calculate (Co-Cc)/T.

58 NUREG-1575, *Multi-Agency Radiation Survey and Site Investigation Manual*, Revision 1, August 2000.

59 NUREG-1507, Ibid., §6.1.

60 NUREG-1507, Ibid., Table 6.1, p 6-26

61 Using the most conservative detector area of 100cm² and a scan speed of 5.1 cm/sec, $i = \sqrt{100}/5.1 = 2\ sec$

62 $\overline{C_o}$ is the average open window count rate for background measurements on file that were taken on a given matrix material.

4.4.4. Given the MDCR, the scan MDC is calculated from Equation 6.[63]

Equation 6

$$Scan\ MDC = \frac{MDCR}{\sqrt{p} * \epsilon_i * \epsilon_s * (A_e/100)}$$

Where:

p = *Surveyor efficiency, assumed to be 0.5.*
ϵ_i = *efficiency for the 43-89*[64] *= 17.3%*
ϵ_s = *Surface Efficiency (0.6)*[65]

Table 4.4
Scan MDCR and MDC

Matrix	Background (C_o/T)	Counts in 2 seconds	Scan MDCR	MDC
	(cpm)	(counts)	(cpm)	(dpm/100 cm^2)
Concrete	253	8.4	120.3	1,640
Vinyl Tile	200	6.7	106.9	1,457

4.4.5. Given a probe observation interval of 2 seconds (representing a first pass scan), the corresponding values for MDCR and Scan MDC are presented in Table 4.4. The maximum value for MDC is 1,640 dpm/100cm^2 and is less than the required Scan MDC of 5,000 dpm/100cm^2 and is adequate for characterization or final status surveys connected with the CFX project.

4.5. INVESTIGATION THRESHOLD FOR BETA-GAMMA SCANS

4.5.1. The purpose of beta scans on building surfaces and equipment is to supplement systematic grid measurements and to ensure that the areas in between the integrated measurements contain no localized regions in excess of the maximum. The net investigation threshold for beta scan measurements can be calculated by solving Equation 5 for the count rate and setting the concentration term to the maximum limit from Table 1.1 (5,000 dpm//100 cm^2) as shown in Equation 7.

Equation 7

$$Th_s = [5{,}000]\sqrt{p} * \epsilon_i * \epsilon_s * (A_e/100)$$

Where:
Th_s = *Net Scan Investigation Threshold (cpm)*

[63] NUREG-1507, Ibid., Equation 6-9
[64] The efficiency used is the 4 π efficiency for a Sr-90/Y-90 source. Sr/Y is the overwhelming contributor to beta counts from the fuel plates. Since the effective area of the L43-89 = 100 cm^2, no area correction is applied.
[65] Table 5.4, NUREG 1507. 0.6 represents a beta source efficiency for sealed concrete. This value includes the effects of backscatter and surface roughness on efficiency.

4.5.2. By applying the average of the open window background counts for each matrix, values for the gross threshold can also be calculated. The net and gross scan investigation thresholds are presented in Table 4.5 and should be used for scan measurements in the Characterization and Final Status surveys.

Table 4.5
Scan Investigation Thresholds

Matrix	Net Th_S (Co)	Average BK Counts	Gross Th_S
	(cpm)	(cpm)	(cpm)
Concrete	370	253	623
Vinyl Tile		200	570

5. CONCLUSIONS AND RECOMMENDATIONS

5.1. Using the unity rule, the license release limits, and the assumption that cesium and strontium activities are equal, a set of composite release limits for the mix was calculated and is presented in Table 4.1. (Par. 4.1.5)

5.2. The derived MDC's for integrated beta measurements are presented in Table 4.2. They are less than 50% of the release limit and are adequate for CFX beta surveys. (Par. 4.2.7)

5.3. The investigation threshold for direct beta measurements is 174 cpm (net of background) and 235 and 181 cpm including background for concrete and vinyl tile respectively. The threshold values presented in Table 4.3 should be used during Characterization and Final Status Surveys to evaluate integrated beta field readings. (Par. 4.3.3)

5.4. Given a probe observation interval of 2 seconds (representing a first pass scan), the corresponding values for MDCR and Scan MDC are presented in Table 4.4. The maximum value for MDC is 1,640 dpm/100cm^2 and is less than the required scan MDC of 5,000 dpm/100cm^2, and it is adequate for characterization or final status surveys connected with the CFX project.(Par. 4.4.5)

5.5. The net and gross scan investigation thresholds are presented in Table 4.5 and should be used for scan measurements in the Characterization and Final Status surveys. (Par. 4.5.2)

TM0713
ATTACHMENT A
Background Data

Table A-1
CFX Background Data

ID	Date	Serial Number	Gamma	Counts Open	Counts Closed	Net Counts	Integrated Minutes	Beta (dpm/100cm^2)
Concrete Matrix								
263084	10-Jan-08	162414	2,257	259	200	59	1	568
263085	10-Jan-08	162414	2,151	269	171	98	1	944
263086	10-Jan-08	162414	2,289	254	181	73	1	703
263087	10-Jan-08	162414	2,320	231	199	32	1	308
263088	10-Jan-08	162414	2,275	254	215	39	1	376
			Sum	1,267	966	301	5	2,900
Es =	*0.600*		*Max*	269	215	98		944
Ei =	*0.173*		*Average*	**253**	193	**60**		**580**
			Stdev	14	17	27		257
Vinyl Tile Matrix								
263089	10-Jan-08	162414	2,128	176	185	(9)	1	(87)
263090	10-Jan-08	162414	2,194	196	164	32	1	308
263091	10-Jan-08	162414	2,196	219	193	26	1	250
263092	10-Jan-08	162414	2,172	205	192	13	1	125
263093	10-Jan-08	162414	2,142	204	235	(31)	1	(299)
			Sum	1,000	969	31	5	299
Es =	*0.600*		*Max*	219	235	32		308
Ei =	*0.173*		*Average*	**200**	194	**6**		**60**
			Stdev	16	26	26		251

ATTACHMENT F

TM0801 – CFX Gamma Conversion Factors and Survey Thresholds

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TECHNICAL MEMORANDUM 0801

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Originator: Andrew H. Thatcher, CHP, Technical Director

Subject: ***CFX Gamma Conversion Factors and Survey Threshold***

Revision: 0

ENDORSEMENT: This document contains the results of research and technical analysis which have been reviewed and approved for publication by:	
	3/20/2008
Barton P. Anderson, Principal	Date

1. INTRODUCTION

1.1. PURPOSE

1.1.1. The purpose of this Technical Memorandum (TM) is to determine the ability of a 2"x2" NaI gamma detector to detect activation products in the concrete walls and floor of the Kodak Californium Neutron Flux Multiplier (CFX) basement cavity, to establish conversion coefficients for the isotopes of interest known to be in the concrete, to establish a scan threshold and to calculate a Minimum Detectable concentration for the detector which can be used for the Characterization Survey and the Final Status Survey.

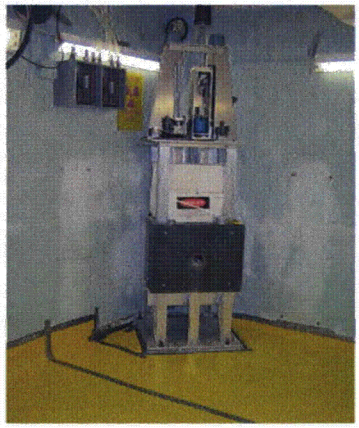
1.2. BACKGROUND

1.2.1. The CFX began operations in 1975 and has been shutdown since June of 2006. The CFX was a sub-critical assembly of uranium 235 utilizing a californium 252 source to drive up the production of fast and thermal neutrons from fission to high sub-critical levels[66]. The californium source remained inserted into the CFX for most of its life such that the total estimated operational hours are 252,000 at an average power of 5.8 watts. Further details of the CFX assembly and characteristics are presented in the EKC Scoping Study.[67]

[66] The CFX was designed to never exceed a K_{eff} <0.99.

[67] NEXTEP TM0703 *Eastman Kodak Company CFX Decommissioning Project Scoping Study*, Robert Newman and Ning Zhang

1.2.2. The CFX was dismantled in November, 2007 and removed from its mountings in the corner of the basement labyrinth located in the Kodak Research Complex in Rochester, NY. A picture of the CFX with all the shielding materials removed is presented in Figure 1.1. The structure was mounted atop a small concrete mortar pad which was removed, crushed, and analyzed by gamma spectroscopy to determine the activated isotopes of interest in the surrounding concrete.



CFX Structure and Mount
Figure 1.1

1.2.3. Concrete analysis of the mortar pad beneath the CFX identified the activation products of interest and their average relative proportions. The results[68] are presented in Table 1.1.

1.2.4. In order to verify that no elevated contamination greater than the release criteria remain it is necessary to ensure that the instrument used for scanning can adequately detect contamination at the release limit.

Table 1.1
Concrete Activation Analysis Results

Isotope	Concentration		Relative Abundance
	(Bq/g)	(pCi/g)	(%)
Co-60	0.284	7.66	33
Eu-152	0.543	14.65	63
Eu-154	0.0035	0.95	4

1.2.5. Kodak NRC license SNM-1513 specifies the requirements for unrestricted release in the guidelines[69]. However, the guidelines do not apply to surfaces, equipment or scrap containing induced radioactivity. The release of such facilities or items must be considered on a case by case basis. The limits for release of surfaces and materials containing activated isotopes have been analyzed and calculated for the CFX project in NEXTEP TM0604[70]. They are presented for reference in Table 1.2.

68 Filo, A.J., *Analysis of activation byproducts in the mortar support of the CFX frame,* Kodak Internal Memo to Mark Morse, December 19, 2007. (Included in NEXTEP TM0604)

69 U.S. NRC, *Guidelines for Decontamination of Facilities and Equipment Prior to Release for Unrestricted use or Termination of Licenses for Byproduct, Source, or special Nuclear Material*, 1993.

70 NEXTEP TM0604 *Development of release limits for activated surfaces and material*, Andrew H Thatcher, CHP

Table 1.2
Proposed Release Limits

Isotope	Concentration	
	(Bq/g)	(pCi/g)
Co-60	5.7	150
Eu-152	11.0	290
Eu-154	0.7	19

2. SCOPE

2.1. This analysis derives a correlation between concrete specific activity and the count rate expected using a cylindrical 2"x 2" NaI gamma detector wrapped in approximately 1/8th inch thick lead shielding.

2.2. The initial assumptions for all calculations are as follows:

2.2.1. The detector is held at 0.5 cm from the ground surface.

2.2.2. The Co-60 and Europium isotopes are distributed uniformly in concrete to a depth of 30 cm out to a radius of 34.3 cm[71].

2.2.3. The three isotopes of interest exist in the concrete at the proportions measured from the mounting pad as listed in Table 1.1.

2.2.4. Photon fluxes at the observation points are as calculated using the Microshield[72] code.

2.2.5. Mass attenuation coefficients are calculated by the Microshield code using a detector crystal density of 3.67 g/cm^3 and 83.3% weight percentage for Iodine.

2.2.6. The proposed release limit for the three isotopes of interest is specified in TM 0604[73].

2.2.7. Two activated wall surfaces at right angles to each other contribute to the count rates from a nominal distance of 18 inches (46 cm).

3. METHODS

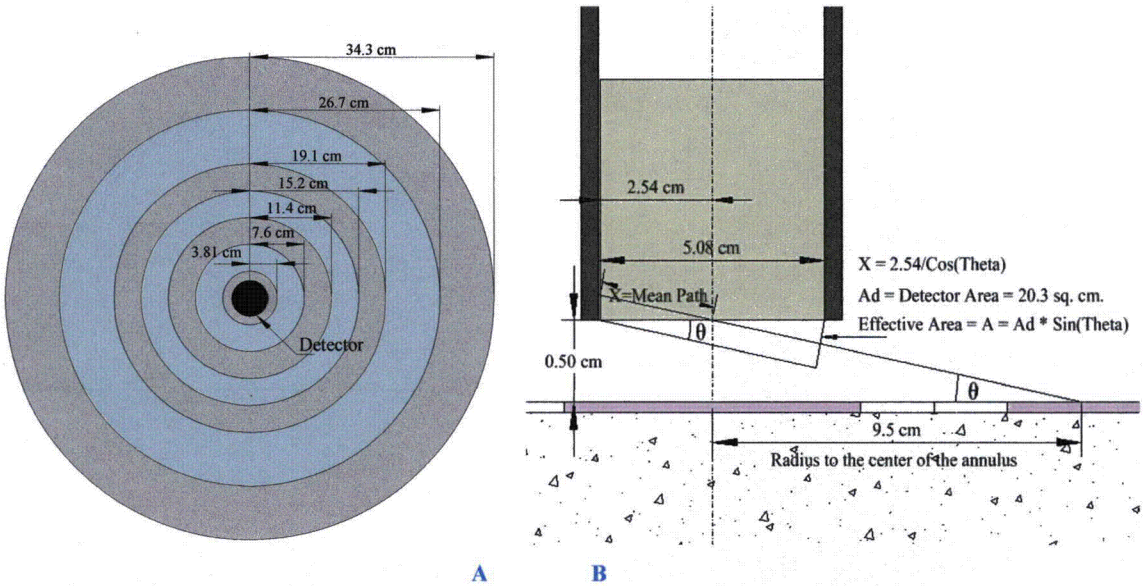
3.1. The calculation for converting a given contaminant[74] to counts for the NaI detector involves a number of steps. Conceptually, the conversion is performed by determining the photon fluence rate due to a normalized concentration of contaminant in concrete as seen by the detector at its location within a geometric model of substrate, contaminant and detector placement. The attenuation at that point is then calculated for NaI and adjusted for the source geometry, the detector and shield material, and the nominal path length through the crystal. The steps as they were performed for this analysis are as follows.

---

71 This distance is based upon the actual extent of elevated measurements in survey unit C-1.
72 Grove Engineering, Microshield code, version 5.05.
73 Ibid.
74 The term "contaminant" as used in this discussion refers to products of neutron activation present in the concrete structural surfaces of the CFX cavity.

3.2. UNSHIELDED PHOTONS

3.2.1. In developing the model geometry for the Microshield software, the concrete below the detector was divided into seven concentric circles with radii ranging from 3.81 cm out to 34.3 cm as depicted in Figure 2a. A normalized amount (1pCi/g) of one of the three contaminants was distributed evenly throughout the concrete below the detector to a depth of 30 cm.



Unshielded Geometry
Figure 2

3.2.2. Using the Microshield computer code, the fluence rate was calculated from photons arriving at the center of the unshielded face of the detector which was positioned 0.50 cm above the surface of the concrete. Microshield runs were prepared for each of the seven circles shown in Figure 2a. The contribution for each circle was tabulated in finite energy increments. To obtain the fluence from each concentric ring about the detector, each circle's fluence rate was subtracted from the next circle's fluence rate. The calculated photon fluence rates for the concentric ring increments (annulus numbers 0 through 6) are presented for Co-60, Eu-152 and Eu-154 in Attachment A.

3.2.3. The effective area for the photons impinging upon the unshielded face of the detector was calculated from the geometry shown in Figure 2b. The photon mean path, X, travelling through the NaI crystal was also calculated as illustrated and shown in Figure 2b.

3.2.4. The predicted counts registered by the detector were calculated for each annulus about the detector and each energy level using Equation 1.

Equation 1

$$[(\Phi_i - \Phi_{i-1})A_d Sin\theta][1 - e^{-\mu(X\rho)}]$$

Where:

$\Phi_i - \Phi_{i-1}$ = *Microshield photon flux for each annulus.*[75]

Ad = *Area of the unshielded face of the detector (20.3 cm²)*

θ = *The angle of incidence to the center of each annulus.*

μ = *Mass Attenuation Coefficient for NaI from Microshield.*

$X\rho$ = *Density thickness of the detector (g/cm²)*[76]

3.2.5. These values were summed over the energy levels, and the predicted unshielded counts from each annulus are presented for each normalized radionuclide under annulus numbers 0 through 6 in the spreadsheets provided in Attachment A.

3.3. SHIELDED PHOTONS

3.3.1. Photons registered by the detector which pass through the 1/8" lead shield were calculated from two sources: the floor and the two adjacent walls.

3.3.2. FLOOR. The first source was modeled as two concentric discs of concrete underneath the detector: one extending out to radius of 3.81 cm (annulus 0), and another extending out to 34.3 cm (the combination of annuli 1-6). The discs were contaminated with a normalized amount of each radionuclide as in the unshielded case. 1/8" of lead shielded was modeled between the photon source and the detector, and the observation point for calculating the photon flux was fixed in the center of the detector, 3.0 cm above the concrete. The geometry for the shielded photon calculations is presented in Figure 3.

3.3.3. The photon fluence from the smaller disc (Annulus 0) was subtracted from the larger disc since virtually all of those photons were accounted for in the unshielded case. Other assumptions used for shielded photons are as follows:

3.3.3.1. The effective detector area is the full 2D side view of the cylinder (height x width) which, for a 2x2 detector, is 25.81 cm².

3.3.3.2. The mean path through the detector is approximately equal to the mean chord of a circle (4R/3) or 3.6 cm.[77]

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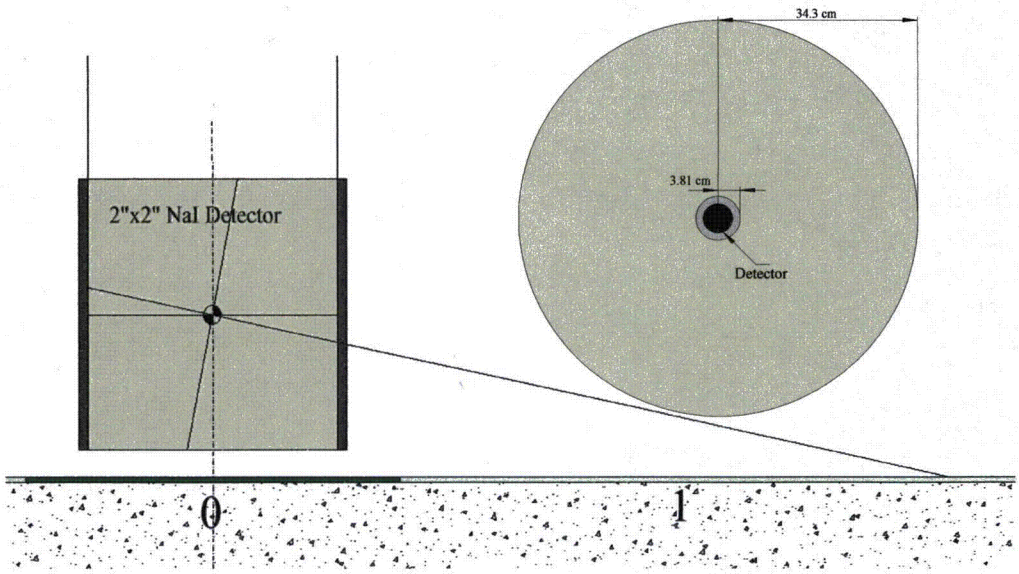
[75] $\Phi_0 = 0$ so that Φ_1 is simply the flux from the central disc beneath the detector.

[76] X is the mean path in cm shown in Figure 2b, and ρ is the density of the NaI crystal (3.67 g/cm³).

[77] As the outer area is treated as a single photon source, the chord length varies from 3.8 cm to 3.4 cm depending upon the incident geometry of the photon. A fixed value of 3.6 cm is used for a density thickness of 13.2 g/cm².



Shielded Geometry for Floor Counts
Figure 3

3.3.4. The fluence rates for each energy band were obtained using the Microshield code and the net values are presented in Attachment A under Annulus # F.

3.3.5. Counts registered in the detector were calculated like they were for the unshielded case using Equation 2.

Equation 2

$$\Phi_s A_d [1 - e^{-\mu(X\rho)}]$$

Where:

Φ_s = *Microshield photon flux for the annulus about the inner circle.*[78]
Ad = *2D Area of the shielded face of the detector (25.8 cm²)*
μ = *Mass Attenuation Coefficient for NaI from Microshield.*
$X\rho$ = *Density thickness of the detector (13.2g/cm²)*[79]

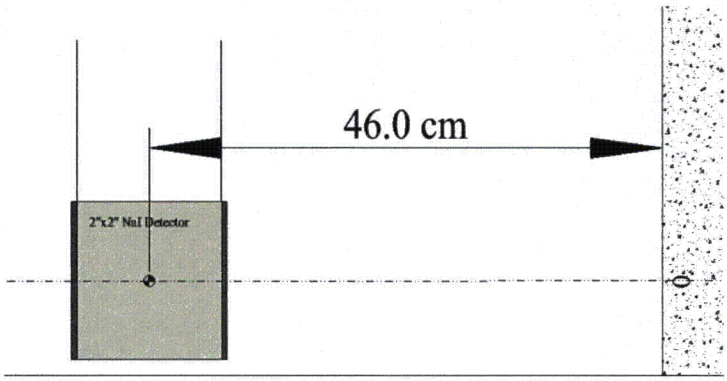
3.3.6. These values were summed over the energy levels, and the predicted shielded counts from floor contamination are presented for each normalized radionuclide under annulus number F in the spreadsheets provided in Attachment A.

3.3.7. WALLS. The wall source was modeled as a single concrete plane at 46 cm distance from the detector. The wall concrete was contaminated with a normalized amount of each radionuclide and all the photons received by the detector from this source were assumed to come through the lead shield. The observation point, effective detector area and mean path through the detector were the same as used in the previous section (shielded floor counts). A diagram of the geometry modeled for one wall surface is presented in Figure 4.

[78] This is the flux for the large disc minus the flux from the central disc beneath the detector.
[79] X is the mean chord in cm, and ρ is the density of the NaI crystal (3.67 g/cm³).

3.3.8. The photon fluence rates calculated at the observation point within the detector are presented in the spreadsheets in Attachment A under annulus #W. The fluence rate numbers are for one wall.

3.3.9. Counts registered in the detector were calculated like they were for the floor using Equation 2, only the values obtained were multiplied by 2 to account for the two walls. These values are summed and presented for each radionuclide in the spreadsheets contained in Attachment A under annulus #W.



Shielded Counts from the Wall
Figure 4

3.4. By summing all the counts, shielded and unshielded from the floor and surrounding walls an estimated count value for the normalized amount of each radionuclide was calculated and applied to further calculations and comparisons with the data.

3.5. From the calculated conversion factors and data taken on the CFX mounting pad on the floor of the CFX cavity, a scan threshold was calculated and compared with the actual scan survey conducted in February on the floor after the mortar pad was removed.

3.6. The Minimum Dectectable Count Rate (MDCR) was calculated using common assumptions and Equation 6-10 from MARSSIM.[80]

4. RESULTS AND DISCUSSION

4.1. COUNT CONVERSION FACTORS

4.1.1. The calculations described in Section 3 are presented in three spreadsheets in Attachment A and they provide a predicted count rate in the detector for 1 pCi/g concentrations of each of the three radionuclides of interest. These unit count conversion factors are presented in Table 4.1.

[80] NUREG 1575, *Multi-Agency Radiation Survey and Site Investigation Manual,* Rev.1, August,2000

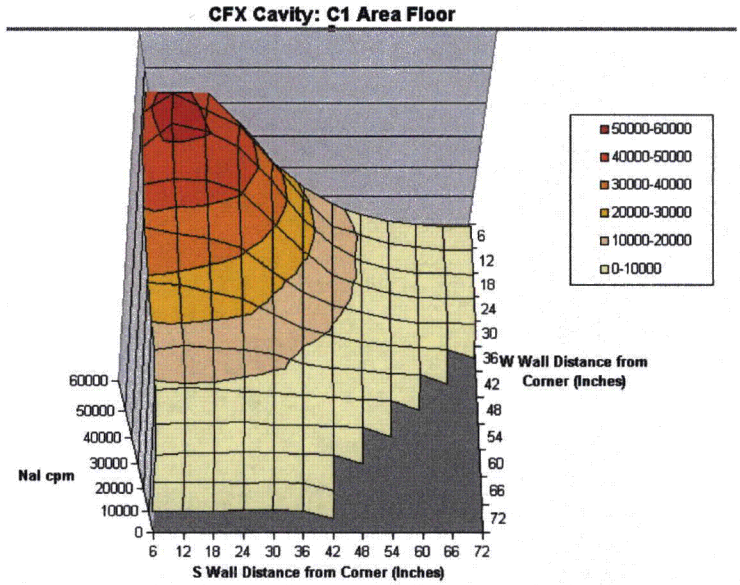
Table 4.1
Unit conversion for Uniform Radionuclide Concentration in Concrete to CPM for the 2" x 2" NaI Detector

Radionuclide	Unit Conversion Factors	
	(cpm/Bq/g)	(cpm/pCi/g)
Co-60	38	1,030
Eu-152	24	660
Eu-154	24	660

4.2. BENCHMARK COMPARISON

4.2.1. One direct measurement of 37,000 cpm was made on the center of the CFX mortar pad prior to its removal. Subtracting a gamma background value of 2,890 cpm yielding a net survey value of 34,110 cpm.

4.2.2. Using the results of the spectrographic analysis of the concrete from the mortar pad presented in Table 1.1 and applying the unit conversion factors presented in Table 4.1, the predicted count rate over the pad is 18,000 cpm. Although the predicted value is much lower than the measured value from the center of the pad, it should be noted that the values in Table 1.1 are from a homogenized, composite sample made from the entire mortar pad while the direct measurement was made at the center of the pad.



CFX Cavity Floor Scan Results
Figure 5

4.2.3. Figure 5 is a plot of the activity measured on the floor of the CFX cavity after the mortar pad was removed. It shows that activation of the concrete is highly non-uniform with a very narrow peak directly underneath the CFX core. It is not unrealistic that the count

rate predicted for the average concentration of radionuclides in the pad is just over half the actual count rate measured close to the peak. To the extent that the predicted value understates the measured values, the conversion factors from Table 4.1 will yield a conservative threshold for surveys, and these factors are adequate for the Final Status Survey.

4.3. GAMMA SCAN THRESHOLD

4.3.1. Using the unit conversion factors from Table 4.1 and the limit concentrations for activated radionuclides in the concrete presented in Table 1.2 the composite threshold is calculated using Equation 3.

Equation 3

$$T = \sum_{i=1}^{3} L_i U_i = 360{,}000 cpm$$

Where:

T = *Gamma Scan Threshold (cpm)*
L_i = *Radionuclide Release Limit (pCi/g)*
U_i = *Unit Conversion Factor (cpm/pCi/g)*

4.3.2. The largest gross scan survey reading from the February survey depicted in Figure 5 was 54,000 cpm[81]. The concentrations of the radionuclides of interest should therefore be well below the release levels prescribed in Table 1.2.

4.3.3. Using the reference activity from each of the radionuclides in Table 1.1 and the unit conversion factors presented in Table 4.1, the maximum survey value can be evaluated against the release limits in Table 1.2. beginning with Equation 4.

Equation 4

$$N = \sum C_i U_i$$

Where:

N = *Net count rate measured (cpm)*
C_i = *Concentration of a radionuclide (pCi/g)*
U_i = *Unit Conversion Factor (cpm/pCi/g)*

4.3.4. Based upon the assumption that the relative proportions of each activity measured will be the same as the proportions among the reference nuclides listed in Table 1.1, two of the desired concentrations can be expressed in terms of the third as shown in Equation 5.

Equation 5

$$C_1 = \frac{R_1}{R_2} C_2 \text{ and } C_3 = \frac{R_3}{R_2} C_2$$

Where:

R_i = *Reference Concentration of a radionuclide from Table 1.1 (pCi/g)*
C_i = *Survey Concentration of a radionuclide (pCi/g)*

[81] Feb 12, 2008 survey by M. Morse and J. Heyer. Gamma background was recorded as 2,890 yielding a net reading of 51,100 cpm.

4.3.5. The solution for nuclide C_2 can be given by Equation 6 and then Equation 5 can be used to compute the other two.

Equation 6

$$C_2 = \frac{N}{\left[\frac{R_1}{R_2}U_1 + U_2 + \frac{R_3}{R_2}U_3\right]}$$

4.3.6. The results of these calculations are presented in Table 4.2.

Table 4.2
Conversion to Activity for the Maximum Survey Count Rate

Survey Reading	Radionuclide	Activity	
(cpm)		*(Bq/g)*	*(pCi/g)*
51,100	Co-60	0.8	21.5
	Eu-152	1.5	41.2
	Eu-154	0.1	2.7

4.3.7. All of these activities are well below the release limits specified in Table 1.2. A more detailed presentation of the results of this survey is presented in the Characterization Survey Report.

4.4. MINIMUM DETECTIBLE COUNT RATE (MDCR)

4.4.1. Scans are performed in order to ensure that elevated activity between the grid sample locations is adequately identified. The gamma scan threshold derived in Section 4.3 is adequate to detect activated products in concrete above the release limits provided the detector, as it is employed for the scan surveys, can be demonstrated to be capable of detecting signals at or below this threshold. Using the methodology described in MARSSIM, Chapter 6, the MDCR for a 2x2" Gamma detector is calculated as follows.

4.4.2. Several constraints are encountered when evaluating the ability of a technician to identify elevated areas when performing scans. They include the surface efficiency, the surveyor efficiency, and grid registration errors

4.4.2.1. For Gamma scans, a surface efficiency of 80% is assumed. This is a conservative value since gamma contamination is not affected by surface terrain as are beta or alpha measurements.

4.4.2.2. The surveyor efficiency is typically chosen to be 50%.

4.4.2.3. Grid registration errors are those errors made as a result of the surveyor not passing directly over the area of elevated activity but instead passing over a fraction of the area. The net result is a smaller observation window and a lower count rate. For a given grid spacing and elevated area of interest, grid registration errors can range from 100% coverage (surveyor scanning over the centroid of the elevated area) to ¼ of the peak area. The average grid registration error is assumed to be 50%. The loss in counts due to grid registration errors is taken into consideration by accounting for

the effective detection area for each time increment as the instrument passes through the elevated area[82].

4.4.2.4. The average background count used is 2,890 cpm,

4.4.3. Equation 7 is used to calculate the Scan MDCR (or $MDCR_{surveyor}$)[83].

Equation 7

$$ScanMDCR = \frac{MDCR}{\sqrt{P} * \varepsilon_R * \varepsilon_s}$$

Where:

$MDCR$ = *minimum detectable count rate for the ideal observer*

ε_s = *surface efficiency*[84] = *0.8*

ε_R = *grid registration errors = 0.5*

p = *surveyor efficiency = 0.5*

4.4.4. Equation 8 is needed to calculate the MDCR for the ideal observer.

Equation 8

$$MDCR = d'\sqrt{b_i}(60/i)$$

Where:

i = *The scan observation interval in seconds.*

d' = *desired scanning performance*[85].

b_i = *number of background counts in the probe observation interval*

4.4.5. Scan MDCR Calculations

4.4.5.1. The following calculations are based upon an assumed scan (probe) speed of 10 cm/s across a $1m^2$ region of activation.[86]

$$b_I = 2{,}890\ cpm * 5\ sec * (1\ min/60\ sec) = 240\ counts$$

$$MDCR = 1.38 * \sqrt{240} * (60/5) = 257\ cpm$$

4.4.5.2. A value for the Index of Sensitivity, d' = 1.38, was selected from Table 6.5 in MARSSIM which corresponds to 95% correct detections and 60% false positives.[87]

$$Scan\ MDCR = \frac{257}{\sqrt{0.5} * 0.8 * 0.5} = 910\ cpm\ net\ or\ 3{,}800\ cpm\ gross$$

---

82 NEXTEP TM0311 *NaI Scan Survey Thresholds for Uranium and Thorium in Soil at the Kerr-McGee Cushing Site*. This memo provides the effective detection area for a number of areas. The actual area for each time increment was calculated using circular sector integration.

83 Equation 6-10 of MARSSIM modified to report in terms of a count rate.

84 80% is a reasonable value attributed to the attenuation of surface gamma photons for smooth soils.

85 See Table 6.5 of MARSSIM.

86 At this scan speed, five seconds corresponds to the amount of time that the detector (with an effective radius of r=26cm) will pass across a $1m^2$ area - the maximum area between the fixed measurement points spaced 30 in. apart in a rectangular grid.

87 For a first pass scan, one would generally accept a higher number of false positives in order to obtain a high rate of true positives.

4.4.5.3. The Scan MDCR for the 2" x 2" NaI detector used to scan concrete surfaces is 3,800 cpm (910 cpm net). This number is adequate to detect concentrations at or above the release limits given a site background of approximately 3,000cpm or less.

5. CONCLUSIONS

5.1. The gamma count conversion factors for activated radionuclides found in the concrete surrounding the CFX are presented in Table 4.1. They will yield a conservative threshold for surveys, and are adequate for the Final Status Survey. (Par. 4.2.3)

5.2. The gamma scan threshold corresponding to concentrations of activated radionuclides in the concrete near the CFX at the proposed release limits is 360,000 cpm. (Par. 4.3.1)

5.3. The Scan MDCR for the 2" x 2" NaI detector used to scan concrete surfaces is 3,800 cpm (910 cpm net). This number is adequate for gamma scan measurements to detect concentrations at or above the release limits given a site background of 3,000 cpm or less. (Par. 4.4.5.3)

TM0801
ATTACHMENT A
Count Conversion Calculations

Detectability Analysis for a shielded 2"x2" NaI gamma detector probe

	Radius to (cm):		Radius to:		Radius to:		Radius to:		Radius to:		Radius to:		Radius to:		Radius to:
R (cm)	3.81		7.61		11.43		15.24		19.05		26.66		34.27	3.81 to	100.00
Theta (deg)	90.00		5.00		3.00		2.10		1.67		1.25		0.94		0.00
Ae (sq. cm)	20.27		0.44		0.27		0.19		0.15		0.11		0.08		25.81
X (cm)	5.08		2.55		2.54		2.54		2.54		2.54		2.54		3.60
Annulus #	**0**	**1**		**2**		**3**		**4**		**5**		**6**		**F**	**W**

UNSHIELDED PHOTON FLUX FOR EACH ANNULUS BY ENERGY / ***SHIELDED PHOTON FLUX***

Energy increment (MeV)	Fluence rate from the center (Photons/cm²/s)	Combined fluence rate to new radius (photon/cm²/s)	Fluence rate from the annulus (photons/cm²/s)	Combined fluence rate to new radius (photon/cm²/s)	Fluence rate from the annulus (photons/cm²/s)	Combined fluence rate to new radius (photon/cm²/s)	Fluence rate from the annulus (photons/cm²/s)	Combined fluence rate to new radius (photon/cm²/s)	Fluence rate from the annulus (photons/cm²/s)	Combined fluence rate to new radius (photon/cm²/s)	Fluence rate from the annulus (photons/cm²/s)	Combined fluence rate to new radius (photon/cm²/s)	Fluence rate from the annulus (photons/cm²/s)	Fluence Rate through shield from floor (photons/cm²/s)	Fluence Rate through shield from ONE wall (photons/cm²/s)	NaI mass attenuation coefficients (cm²/g)
0.020																5.340
0.030																1.760
0.040																18.307
0.050																10.164
0.100																1.580
0.200																6.230
0.300																0.155
0.400																0.111
0.500																0.091
0.600	3.10E-05	5.37E-05	2.27E-05	6.84E-05	1.47E-05	7.76E-05	9.17E-06	8.31E-05	5.55E-06	8.84E-05	5.31E-06	9.02E-05	1.82E-06	2.87E-05	6.50E-06	0.080
0.800																0.066
1.000	1.90E-01	3.34E-01	1.44E-01	4.34E-01	9.95E-02	5.01E-01	6.75E-02	5.45E-01	4.43E-02	5.94E-01	4.87E-02	6.14E-01	2.03E-02	2.74E-01	8.69E-02	0.058
1.500	1.90E-01	3.36E-01	1.46E-01	4.38E-01	1.02E-01	5.08E-01	7.05E-02	5.55E-01	4.71E-02	6.09E-01	5.33E-02	6.32E-01	2.32E-02	2.96E-01	9.84E-02	0.046
Total all energies	0.380	0.670	0.290	0.871	0.201	1.009	0.138	1.101	0.091	1.203	0.102	1.246	0.044	0.570	0.185	

UNSHIELDED COUNTS PER SEC (CPS) FROM A 2" X 2" NaI GAMMA DETECTOR / ***SHIELDED CPS***

	Cps from the center		Cps from the Annulus		Cps from the Annulus		Cps from the Annulus		Cps from the Annulus		Cps from the Annulus		Cps from the Annulus	Shielded cps from Floor	Shielded cps from TWO Walls	Total cps per pCi/g Co-60
0.020	-		-		-		-		-		-			-	-	-
0.030	-		-		-		-		-		-			-	-	-
0.040	-		-		-		-		-		-		-	-	-	-
0.050	-		-		-		-		-		-		-	-	-	-
0.100	-		-		-		-		-		-		-	-	-	-
0.200	-		-		-		-		-		-		-	-	-	-
0.300	-		-		-		-		-		-		-	-	-	-
0.400	-		-		-		-		-		-		-	-	-	-
0.500	-		-		-		-		-		-		-	-	-	-
0.600	0.00		0.00		0.00		0.00		0.00		0.00		0.00	0.00	0.00	0.00
0.800	-		-		-		-		-		-		-	-	-	-
1.000	2.54		0.11		0.04		0.02		0.01		0.01		0.00	3.77	2.39	8.90
1.500	2.23		0.09		0.04		0.02		0.01		0.01		0.00	3.50	2.33	8.24
Total all energies	4.78		0.20		0.08		0.04		0.02		0.02		0.01	7.28	4.73	17.1
															Unit Conversion (cpm/pCi/g)	**1,028.4**

COBALT 60

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Detectability Analysis for a shielded 2"x2" NaI gamma detector probe

	Radius to (cm):		Radius to:		Radius to:		Radius to:		Radius to:		Radius to:		Radius to:		Radius to:	
R (cm)	3.81		7.61		11.43		15.24		19.05		26.66		34.27	3.81 to	100.00	
Theta (deg)	90.00		5.00		3.00		2.10		1.67		1.25		0.94		0.00	
Ae (sq. cm)	20.27		0.44		0.27		0.19		0.15		0.11		0.08		25.81	
X (cm)	5.08		2.55		2.54		2.54		2.54		2.54		2.54		3.60	
Annulus #	**0**	**1**		**2**		**3**		**4**		**5**		**6**		**F**	**W**	
UNSHIELDED PHOTON FLUX FOR EACH ANNULUS BY ENERGY														***SHIELDED PHOTON FLUX***		
Energy increment (MeV)	Fluence rate from the center (Photons/cm²/s)	Combined fluence rate to new radius (photon/cm²/s)	Fluence rate from the annulus (photons/cm²/s)	Combined fluence rate to new radius (photon/cm²/s)	Fluence rate from the annulus (photons/cm²/s)	Combined fluence rate to new radius (photon/cm²/s)	Fluence rate from the annulus (photons/cm²/s)	Combined fluence rate to new radius (photon/cm²/s)	Fluence rate from the annulus (photons/cm²/s)	Combined fluence rate to new radius (photon/cm²/s)	Fluence rate from the annulus (photons/cm²/s)	Combined fluence rate to new radius (photon/cm²/s)	Fluence rate from the annulus (photons/cm²/s)	Fluence Rate through shield from floor (photons/cm²/s)	Fluence Rate through shield from ONE wall (photons/cm²/s)	NaI mass attenuation coefficients (cm²/g)
0.020																5.340
0.030																1.760
0.040	2.35E-02	2.55E-02	2.06E-03	2.60E-02	4.50E-04	2.62E-02	1.90E-04	2.63E-02	1.30E-04	2.64E-02	8.00E-05	2.64E-02	3.00E-05	2.33E-27	5.07E-27	18.307
0.050	1.01E-02	1.17E-02	1.60E-03	1.20E-02	3.20E-04	1.21E-02	1.10E-04	1.22E-02	5.00E-05	1.23E-02	8.00E-05	1.23E-02	4.00E-05	1.91E-27	1.31E-27	10.164
0.100	4.65E-02	7.12E-02	2.47E-02	8.04E-02	9.21E-03	8.38E-02	3.42E-03	8.51E-02	1.33E-03	8.60E-02	8.80E-04	8.62E-02	2.10E-04	7.14E-21	5.09E-10	1.580
0.200	1.34E-02	2.31E-02	9.73E-03	2.82E-02	5.14E-03	3.08E-02	2.56E-03	3.20E-02	1.25E-03	3.30E-02	9.10E-04	3.32E-02	2.50E-04	6.08E-06	5.47E-07	6.230
0.300	4.73E-02	8.39E-02	3.66E-02	1.05E-01	2.15E-02	1.17E-01	1.18E-02	1.24E-01	6.40E-03	1.29E-01	5.20E-03	1.30E-01	1.50E-03	2.14E-03	3.66E-04	0.155
0.400	1.08E-02	1.94E-02	8.60E-03	2.47E-02	5.31E-03	2.78E-02	3.13E-03	2.96E-02	1.78E-03	3.12E-02	1.57E-03	3.17E-02	4.90E-04	2.13E-03	4.91E-04	0.111
0.500	9.61E-04	1.74E-03	7.76E-04	2.23E-03	4.96E-04	2.54E-03	3.04E-04	2.72E-03	1.81E-04	2.89E-03	1.69E-04	2.94E-03	5.60E-05	3.91E-04	1.02E-04	0.091
0.600	7.16E-03	1.30E-02	5.85E-03	1.68E-02	3.83E-03	1.93E-02	2.42E-03	2.07E-02	1.48E-03	2.22E-02	1.45E-03	2.27E-02	5.20E-04	4.60E-03	1.25E-03	0.080
0.800	2.99E-02	5.47E-02	2.48E-02	7.15E-02	1.68E-02	8.27E-02	1.11E-02	8.98E-02	7.12E-03	9.72E-02	7.45E-03	1.00E-01	2.88E-03	3.43E-02	9.24E-03	0.066
1.000	7.19E-02	1.32E-01	6.05E-02	1.74E-01	4.20E-02	2.03E-01	2.87E-02	2.22E-01	1.89E-02	2.43E-01	2.08E-02	2.52E-01	8.70E-03	1.22E-01	3.09E-02	0.058
1.500	3.91E-02	7.30E-02	3.39E-02	9.75E-02	2.45E-02	1.15E-01	1.76E-02	1.27E-01	1.22E-02	1.42E-01	1.47E-02	1.49E-01	6.90E-03	1.24E-01	2.53E-02	0.046
Total all energies	0.301	0.510	0.209	0.639	0.130	0.721	0.081	0.771	0.051	0.825	0.053	0.846	0.022	0.289	0.068	
UNSHIELDED COUNTS PER SEC (CPS) FROM A 2" X 2" NaI GAMMA DETECTOR														***SHIELDED CPS***		
	Cps from the center		Cps from the Annulus		Cps from the Annulus		Cps from the Annulus		Cps from the Annulus		Cps from the Annulus		Cps from the Annulus	Shielded cps from Floor	Shielded cps from TWO Walls	Total cps per pCi/g Eu-152
0.020	-		-		-		-		-		-					-
0.030	-		-		-		-		-		-					-
0.040	0.476		0.00		0.00		0.00		0.00		0.00		0.00	0.00	0.00	0.480
0.050	0.205		0.00		0.00		0.00		0.00		0.00		0.00	0.00	0.00	0.208
0.100	0.943		0.04		0.01		0.00		0.00		0.00		0.00	0.00	0.00	1.000
0.200	0.27		0.02		0.01		0.00		0.00		0.00		0.00	0.00	0.00	0.297
0.300	0.90		0.05		0.02		0.01		0.00		0.00		0.00	0.05	0.02	1.05
0.400	0.19		0.01		0.00		0.00		0.00		0.00		0.00	0.04	0.02	0.27
0.500	0.02		0.00		0.00		0.00		0.00		0.00		0.00	0.01	0.00	0.03
0.600	0.11		0.01		0.00		0.00		0.00		0.00		0.00	0.08	0.04	0.24
0.800	0.43		0.02		0.01		0.00		0.00		0.00		0.00	0.52	0.28	1.26
1.000	0.96		0.04		0.02		0.01		0.00		0.00		0.00	1.68	0.85	3.57
1.500	0.46		0.02		0.01		0.00		0.00		0.00		0.00	1.47	0.60	2.57
Total all energies	4.97		0.22		0.08		0.03		0.01		0.01		0.00	3.84	1.81	11.0
															Unit Conversion (cpm/pCi/g)	**658.2**

EUROPIUM 152

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Detectability Analysis for a shielded 2"x2" NaI gamma detector probe

	Radius to (cm):		Radius to:		Radius to:		Radius to:		Radius to:		Radius to:		Radius to:		Radius to:
R (cm)	3.81		7.61		11.43		15.24		19.05		26.66		34.27	3.81 to	100.00
Theta (deg)	90.00		5.00		3.00		2.10		1.67		1.25		0.94		0.00
Ae (sq. cm)	20.27		0.44		0.27		0.19		0.15		0.11		0.08		25.81
X (cm)	5.08		2.55		2.54		2.54		2.54		2.54		2.54		3.60
Annulus #	0	1		2		3		4		5		6		F	W

UNSHIELDED PHOTON FLUX FOR EACH ANNULUS BY ENERGY / ***SHIELDED PHOTON FLUX***

Energy increment (MeV)	Fluence rate from the center (Photons/cm²/s)	Combined fluence rate to new radius (photon/cm²/s)	Fluence rate from the annulus (photons/cm²/s)	Combined fluence rate to new radius (photon/cm²/s)	Fluence rate from the annulus (photons/cm²/s)	Combined fluence rate to new radius (photon/cm²/s)	Fluence rate from the annulus (photons/cm²/s)	Combined fluence rate to new radius (photon/cm²/s)	Fluence rate from the annulus (photons/cm²/s)	Combined fluence rate to new radius (photon/cm²/s)	Fluence rate from the annulus (photons/cm²/s)	Combined fluence rate to new radius (photon/cm²/s)	Fluence rate from the annulus (photons/cm²/s)	Fluence Rate through shield from floor (photons/cm²/s)	Fluence Rate through shield from ONE wall (photons/cm²/s)	NaI mass attenuation coefficients (cm²/g)
0.020																5.340
0.030																1.760
0.040	8.08E-03	8.79E-03	7.10E-04	8.94E-03	1.53E-04	9.01E-03	6.70E-05	9.05E-03	4.60E-05	9.08E-03	2.70E-05	9.09E-03	9.00E-06	1.96E-26	1.75E-27	18.307
0.050	3.53E-03	4.09E-03	5.59E-04	4.20E-03	1.12E-04	4.24E-03	3.90E-05	4.26E-03	1.80E-05	4.28E-03	2.60E-05	4.30E-03	1.30E-05	1.30E-26	4.57E-28	10.164
0.100	6.62E-02	1.01E-01	3.51E-02	1.14E-01	1.31E-02	1.19E-01	4.90E-03	1.21E-01	1.90E-03	1.22E-01	1.20E-03	1.23E-01	3.00E-04	1.50E-21	7.25E-10	1.580
0.200	1.22E-02	2.10E-02	8.86E-03	2.57E-02	4.69E-03	2.81E-02	2.34E-03	2.92E-02	1.13E-03	3.00E-02	8.30E-04	3.03E-02	2.30E-04	9.01E-06	4.98E-07	6.230
0.300																0.155
0.400	1.23E-03	2.20E-03	9.76E-04	2.80E-03	6.03E-04	3.16E-03	3.55E-04	3.36E-03	2.03E-04	3.54E-03	1.78E-04	3.60E-03	5.60E-05	4.39E-04	5.58E-05	0.111
0.500	3.69E-04	6.67E-04	2.98E-04	8.57E-04	1.90E-04	9.74E-04	1.17E-04	1.04E-03	6.90E-05	1.11E-03	6.50E-05	1.13E-03	2.20E-05	2.35E-04	3.92E-05	0.091
0.600	1.36E-02	2.47E-02	1.11E-02	3.20E-02	7.29E-03	3.66E-02	4.60E-03	3.95E-02	2.83E-03	4.22E-02	2.75E-03	4.32E-02	9.90E-04	1.18E-02	2.37E-03	0.080
0.800	6.54E-02	1.20E-01	5.44E-02	1.57E-01	3.69E-02	1.81E-01	2.43E-02	1.97E-01	1.56E-02	2.13E-01	1.63E-02	2.19E-01	6.40E-03	7.94E-02	2.02E-02	0.066
1.000	5.17E-02	9.52E-02	4.35E-02	1.25E-01	3.02E-02	1.46E-01	2.06E-02	1.60E-01	1.36E-02	1.75E-01	1.49E-02	1.81E-01	6.40E-03	7.54E-02	2.22E-02	0.058
1.500	6.58E-02	1.23E-01	5.70E-02	1.64E-01	4.12E-02	1.94E-01	2.96E-02	2.14E-01	2.06E-02	2.39E-01	2.46E-02	2.51E-01	1.17E-02	1.23E-01	4.26E-02	0.046
Total all energies	0.288	0.501	0.212	0.635	0.134	0.722	0.087	0.778	0.056	0.839	0.061	0.865	0.026	0.290	0.088	

UNSHIELDED COUNTS PER SEC (CPS) FROM A 2" X 2" NaI GAMMA DETECTOR / ***SHIELDED CPS***

	Cps from the center		Cps from the Annulus		Cps from the Annulus		Cps from the Annulus		Cps from the Annulus		Cps from the Annulus		Cps from the Annulus	Shielded cps from Floor	Shielded cps from TWO Walls	Total cps per pCi/g Eu-154
0.020	-		-		-		-		-		-					-
0.030	-		-		-		-		-		-					-
0.040	0.164		0.00		0.00		0.00		0.00		0.00		0.00	0.00	0.00	0.165
0.050	0.072		0.00		0.00		0.00		0.00		0.00		0.00	0.00	0.00	0.073
0.100	1.342		0.06		0.01		0.00		0.00		0.00		0.00	0.00	0.00	1.424
0.200	0.25		0.02		0.00		0.00		0.00		0.00		0.00	0.00	0.00	0.271
0.300																
0.400	0.02		0.00		0.00		0.00		0.00		0.00		0.00	0.01	0.00	0.03
0.500	0.01		0.00		0.00		0.00		0.00		0.00		0.00	0.00	0.00	0.01
0.600	0.21		0.01		0.00		0.00		0.00		0.00		0.00	0.20	0.08	0.51
0.800	0.94		0.04		0.02		0.01		0.00		0.00		0.00	1.19	0.61	2.82
1.000	0.69		0.03		0.01		0.01		0.00		0.00		0.00	1.04	0.61	2.40
1.500	0.77		0.04		0.02		0.01		0.00		0.00		0.00	1.46	1.01	3.31
Total all energies	4.47		0.20		0.07		0.03		0.01		0.01		0.00	3.80	2.31	11.0
															Unit Conversion (cpm/pCi/g)	**660.8**

EUROPIUM 154

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ATTACHMENT G
Threshold Comparison Test Reports

KODAK CFX
DECOMMISSIONING PROJECT
Threshold Comparison Test Report - Buildings

Run Date: Wednesday, April 30, 2008

Survey Unit Number: 101 Class: 1 Data Points: Beta Grid Type: R

SURVEY UNIT TABLE

Bldg	*Rm*	*Surfaces*	*Fixed Equipment*		*Surface Area Included (sq. ft)*	*Remarks*
B82	C1	FCSW			208	CFX Corner of the cavity
				Total Area	208	

INITIALIZATION DATA

Measurement Types Selected: RG, PR, PG, BI, CH

Date Range: All

Number of Points: 27

Thresholds:

EMC: 5,000 DCGLw: 1,667

SURVEY UNIT TEST STATUS

Test Performed	**Status**		Matrix	Dpm/100cm2
Min/Max	Fail	Maximum Survey Value	C	1,960
Background	Fail	Minimum Background	M	0
DCGLw	Pass	Difference		1,960
DCGLavg	Pass	Average Activity		851
EMC	Pass	Average Below DCGL		770
Wilcoxon Rank Sum Test	Pass	Average Background		580
Sign Test for Paired Data	N/A			

KODAK CFX
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 # 101 Building: B82

Room:	SFC	X (ft)	Y (ft)	Mtx	Meas. Type	Min.	SID	Gross Activity (Dpm/100cm2)	Remarks	Exc.	Res.
C1	F	0.4	0.6	C	RG	1	2293	1,539.0		C	
C1	S	3.8	6.9	M	RG	1	2320	115.0	On vacume manifold	C	
C1	W	3.1	2.1	C	RG	1	2305	1,960.0		C	
C1	W	0.6	2.1	C	RG	1	2304	1,779.0		C	

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

Survey Unit # 101 Building: B82

Room:	SFC	X (ft)	Y (ft)	Mtx	Meas. Type	Min.	SID	Gross Activity (Dpm/100cm2)	Remarks	Exc.	Res.
C1	C	4.1	0.6	C	RG	1	2302	861.0			
C1	C	1.6	3.1	C	RG	1	2303	861.0			
C1	C	1.6	0.6	C	RG	1	2301	172.0			
C1	F	2.9	0.6	C	RG	1	2295	1,195.0			
C1	F	0.4	5.6	C	RG	1	2299	1,033.0			
C1	F	0.4	3.1	C	RG	1	2297	650.0			
C1	F	5.4	0.6	C	RG	1	2296	354.0			
C1	F	2.9	3.1	C	RG	1	2298	287.0			
C1	S	1.3	1.9	C	RG	1	2313	1,186.0			
C1	S	3.8	4.4	C	RG	1	2317	1,147.0			
C1	S	1.3	4.4	C	RG	1	2316	1,128.0			
C1	S	6.3	1.9	C	RG	1	2315	1,090.0			
C1	S	6.3	6.9	C	RG	1	2321	727.0			
C1	S	3.8	1.9	C	RG	1	2314	421.0			
C1	S	6.3	4.4	C	RG	1	2318	402.0			
C1	S	1.3	6.9	C	RG	1	2319	363.0			

KODAK CFX
DECOMMISSIONING PROJECT
Threshold Comparison Test Report - Buildings

C1	W	0.6	4.6	C	RG	1	2307	1,224.0
C1	W	5.6	7.1	C	RG	1	2312	1,186.0
C1	W	3.1	7.1	C	RG	1	2311	822.0
C1	W	5.6	2.1	C	RG	1	2306	803.0
C1	W	5.6	4.6	C	RG	1	2309	650.0
C1	W	3.1	4.6	C	RG	1	2308	555.0
C1	W	0.6	7.1	C	RG	1	2310	478.0

Summary of Background Data and Thresholds Used in this Analysis

Measurement Type: BK *DCGL:* 1,667 *EMC:* 5,000

Matrix	*Number of Data Points*	*Average Background (dpm/100 cm2)*	*Sigma (dpm/100 cm2)*	*Background Threshold (Tbk) (dpm/100 cm2)*	*DCGLw Threshold (Td) (dpm/100 cm2)*	*EMC Threshold (Tc) (dpm/100 cm2)*
C	5	580.4	257.1	1,351.6	3,019	6,352
M	0	0.0	0.0	0.0	1,667	5,000

STATISTICAL TEST RESULTS

Run Date: 4/30/2008 12:33:00 PM

Survey Unit Number 101 Class: 1

Selected Test: **WILCOXON RANK SUM TEST**

Test Status Pass

Thresholds:

EMC 5,000 DCGL 1,667

DATA SUMMARY TABLE

5 Background Points and 27 Survey points processed

Wr = 150 **Wc =** 114

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

WARNING: There are fewer background points than survey points.
(RG = 27 / BK = 5)

KODAK CFX
DECOMMISSIONING PROJECT
Threshold Comparison Test Report - Buildings

Run Date: Wednesday, April 30, 2008

Survey Unit Number: 102 Class: 2 Data Points: Beta Grid Type: R

SURVEY UNIT TABLE

Bldg	*Rm*	*Surfaces*	*Fixed Equipment*	*Surface Area Included (sq. ft)*	*Remarks*
B82	C2	FCNSW		554	West portion of Cavity less C1 Portion of Cavity west of neutron gens
			Total Area	554	

INITIALIZATION DATA

Measurement Types Selected: RG, PR, PG, BI, CH

Date Range: All

Number of Points: 23

Thresholds:

EMC: 5,000 DCGLw: 1,667

SURVEY UNIT TEST STATUS

Test Performed	**Status**		Matrix	Dpm/100cm2
Min/Max	Pass	Maximum Survey Value	C	1,176
Background	Pass	Minimum Background	VT	-299
DCGLw	Pass	Difference		1,475
DCGLavg	Pass	Average Activity		307
EMC	Pass	Average Below DCGL		307
Wilcoxon Rank Sum Test	N/A	Average Background		320
Sign Test for Paired Data	Pass			

KODAK CFX
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:

NONE

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

Survey Unit # 102 Building: B82

Room:	SFC	X (ft)	Y (ft)	Mtx	Meas. Type	Min.	SID	Gross Activity (Dpm/100cm2)	Remarks	Exc.	Res.
C2	C	11.3	2.5	C	RG	1	2329	752.0			
C2	C	11.3	12.5	C	RG	1	2344	386.0			
C2	C	6.3	7.5	C	RG	1	2331	366.0			
C2	C	1.3	7.5	C	RG	1	2330	328.0			
C2	C	6.3	12.5	C	RG	1	2343	77.0			
C2	C	11.3	7.5	C	RG	1	2332	19.0			
C2	C	6.3	2.5	C	RG	1	2328	-39.0			
C2	C	1.3	12.5	C	RG	1	2342	-212.0			
C2	F	11.3	8.5	VT	RG	1	2327	251.0			
C2	F	11.3	13.5	VT	RG	1	2335	251.0			
C2	F	1.3	8.5	VT	RG	1	2325	135.0			
C2	F	6.3	8.5	VT	RG	1	2326	116.0			
C2	F	1.3	13.5	VT	RG	1	2333	77.0			
C2	F	6.3	13.5	VT	RG	1	2334	39.0			
C2	F	6.3	3.5	VT	RG	1	2323	-116.0			
C2	F	11.3	3.5	VT	RG	1	2324	-193.0			
C2	N	11.3	2.0	C	RG	1	2337	1,176.0			
C2	N	11.3	7.0	C	RG	1	2339	771.0			
C2	N	6.3	7.0	C	RG	1	2338	694.0			
C2	N	6.3	2.0	C	RG	1	2336	636.0			
C2	S	6.6	6.5	C	RG	1	2341	752.0			
C2	S	6.6	1.5	C	RG	1	2340	386.0			
C2	W	8.5	3.6	C	RG	1	2345	405.0			

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DECOMMISSIONING PROJECT
Threshold Comparison Test Report - Buildings

Summary of Background Data and Thresholds Used in this Analysis

Measurement Type: BK *DCGL:* 1,667 *EMC:* 5,000

Matrix	Number of Data Points	Average Background (dpm/100 cm2)	Sigma (dpm/100 cm2)	Background Threshold (Tbk) (dpm/100 cm2)	DCGLw Threshold (Td) (dpm/100 cm2)	EMC Threshold (Tc) (dpm/100 cm2)
C	5	580.4	257.1	1,351.6	3,019	6,352
VT	5	59.6	251.3	813.6	2,481	5,814

STATISTICAL TEST RESULTS

Run Date: 4/30/2008 12:35:37 PM

Survey Unit Number 102 Class: 2

Selected Test: SIGN TEST FOR PAIRED DATA

Test Status Pass

Thresholds:

EMC 5,000 DCGL 1,667

DATA SUMMARY TABLE

23 Survey points processed and 2 matrices processed

S+ = 23 **Wc =** 15

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

KODAK CFX
DECOMMISSIONING PROJECT
Threshold Comparison Test Report - Buildings

Run Date:	Wednesday, April 30, 2008						
Survey Unit Number:	103	Class:	2	Data Points:	Beta	Grid Type:	R

SURVEY UNIT TABLE

Bldg	*Rm*	*Surfaces*	*Fixed Equipment*	*Surface Area Included (sq. ft)*	*Remarks*
B82	C3	FCNEW		532	West section of the labyrinth
B82	C4	FCNSEW		1587	Longest leg of the labyrinth
			Total Area	2119	

INITIALIZATION DATA

Measurement Types Selected:	RG, PR, PG, BI, CH
Date Range:	All
Number of Points:	31
Thresholds:	
EMC: 5,000	DCGLw: 1,667

SURVEY UNIT TEST STATUS

Test Performed	**Status**		Matrix	Dpm/100cm2
Min/Max	Pass	Maximum Survey Value	C	1,215
Background	Pass	Minimum Background	VT	-299
DCGLw	Pass	Difference		1,514
DCGLavg	Pass	Average Activity		335
EMC	Pass	Average Below DCGL		335
Wilcoxon Rank Sum Test	N/A	Average Background		320
Sign Test for Paired Data	Pass			

KODAK CFX
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:

NONE

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

Survey Unit # 103 Building: B82

Room:	SFC	X (ft)	Y (ft)	Mtx	Meas. Type	Min.	SID	Gross Activity (Dpm/100cm2)	Remarks	Exc.	Res.
C3	E	15.3	6.0	C	RG	1	2349	810.0			
C3	E	8.0	6.0	C	RG	1	2350	636.0			
C3	F	2.0	3.7	VT	RG	1	2346	19.0			
C3	F	2.0	11.0	VT	RG	1	2347	-308.0			
C3	N	2.0	3.8	C	RG	1	2348	675.0			
C3	W	3.7	6.0	C	RG	1	2351	1,215.0			
C3	W	11.0	6.0	C	RG	1	2352	887.0			
C4	C	14.6	15.7	C	RG	1	2358	386.0			
C4	C	6.6	15.7	C	RG	1	2357	193.0			
C4	C	30.6	15.7	C	RG	1	2374	0.0			
C4	C	38.6	7.7	C	RG	1	2376	-58.0			
C4	C	22.6	15.7	C	RG	1	2359	-174.0			
C4	C	38.6	15.7	C	RG	1	2375	-289.0			
C4	E	12.4	7.1	C	RG	1	2372	675.0			
C4	E	4.5	7.1	C	RG	1	2371	655.0			
C4	F	38.6	12.8	VT	RG	1	2363	174.0			
C4	F	14.6	12.8	VT	RG	1	2354	135.0			
C4	F	30.6	12.8	VT	RG	1	2356	58.0			
C4	F	22.6	12.8	VT	RG	1	2355	-116.0			
C4	F	6.6	12.8	VT	RG	1	2353	-174.0			
C4	F	38.6	4.8	VT	RG	1	2364	-694.0			
C4	N	22.6	4.2	C	RG	1	2362	655.0			

KODAK CFX
DECOMMISSIONING PROJECT
Threshold Comparison Test Report - Buildings

C4	N	14.6	4.2	C	RG	1	2361	636.0
C4	N	6.6	4.2	C	RG	1	2360	540.0
C4	N	30.6	4.2	C	RG	1	2365	463.0
C4	N	38.6	4.2	C	RG	1	2366	443.0
C4	S	21.4	4.9	C	RG	1	2368	636.0
C4	S	29.4	4.9	C	RG	1	2369	598.0
C4	S	13.4	4.9	C	RG	1	2367	424.0
C4	S	37.4	4.9	C	RG	1	2370	289.0
C4	W	4.8	1.4	C	RG	1	2373	983.0

Summary of Background Data and Thresholds Used in this Analysis

Measurement Type: BK *DCGL:* 1,667 *EMC:* 5,000

Matrix	*Number of Data Points*	*Average Background (dpm/100 cm2)*	*Sigma (dpm/100 cm2)*	*Background Threshold (Tbk) (dpm/100 cm2)*	*DCGLw Threshold (Td) (dpm/100 cm2)*	*EMC Threshold (Tc) (dpm/100 cm2)*
C	5	580.4	257.1	1,351.6	3,019	6,352
VT	5	59.6	251.3	813.6	2,481	5,814

STATISTICAL TEST RESULTS

Run Date: 4/30/2008 12:36:46 PM

Survey Unit Number 103 Class: 2

Selected Test: **SIGN TEST FOR PAIRED DATA**

Test Status Pass

Thresholds:

EMC 5,000 DCGL 1,667

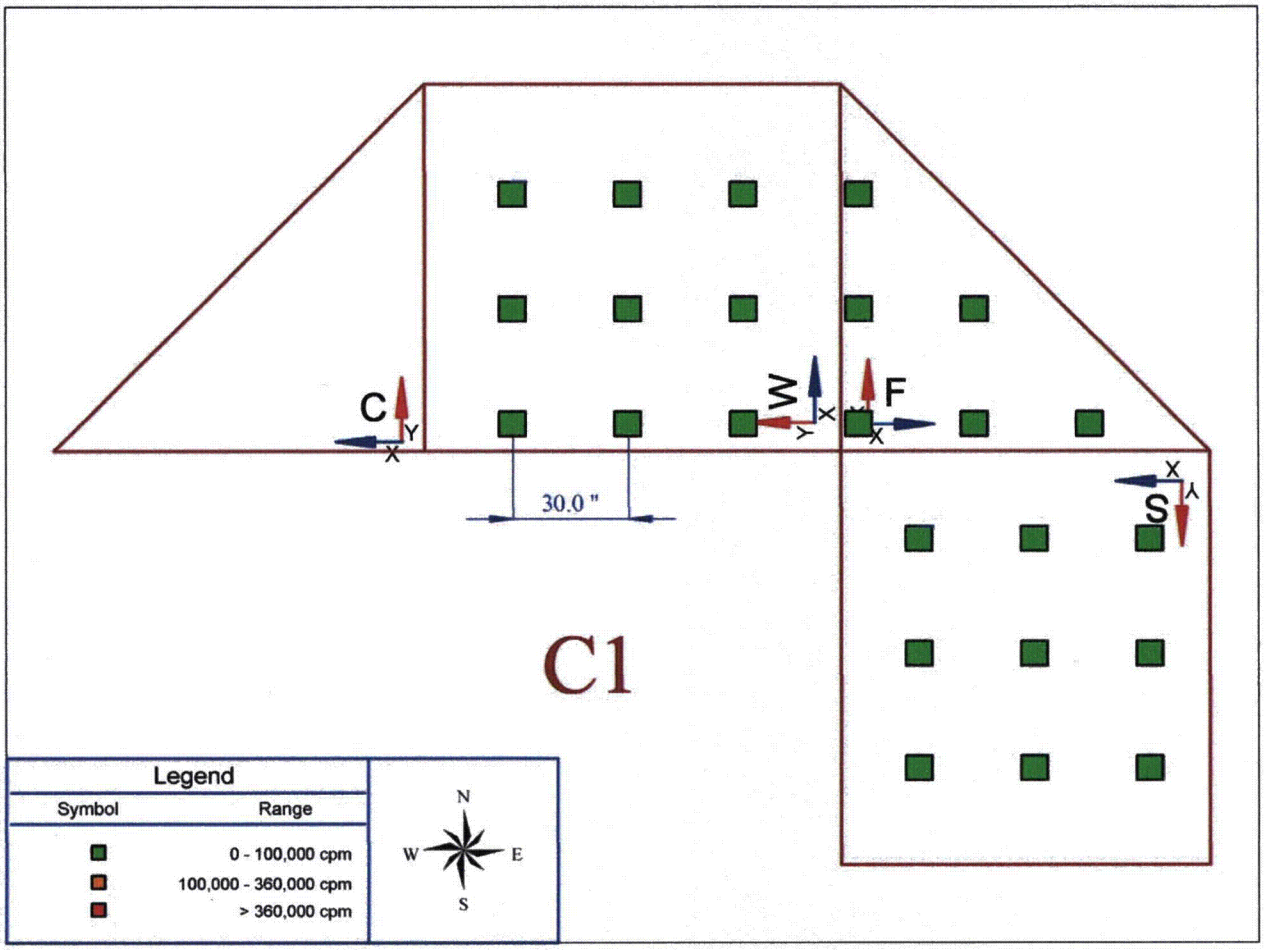
DATA SUMMARY TABLE

31 Survey points processed and 2 matrices processed

S+ = 31 **Wc =** 20

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

ATTACHMENT H
Data Maps



Survey Unit 101 Gamma Survey
Figure H-1

W wall

Data in counts/minute

(Horizontal inches)

(Vertical inches)	6	12	18	24	30	36	42	48	54	60	66	72
60	1,139	1,509	1,269	1,249	969	939	769	469	229	679	79	139
54	1,989	2,199	1,609	2,399	1,729	1,589	999	709	779	549	709	429
48	2,329	3,639	3,789	3,909	2,589	2,369	1,959	429	539	459	19	69
42	4,859	6,249	6,519	5,669	3,639	2,689	1,569	1,739	1,649	1,019	909	489
36	7,749	11,069	11,139	7,109	5,259	3,429	2,159	2,689	1,489	1,389	679	699
30	11,389	16,029	18,689	11,919	7,559	5,239	4,009	3,029	2,389	1,689	1,159	1,009
24	14,639	20,209	21,549	16,949	11,319	7,729	4,369	3,589	2,529	1,829	1,319	1,029
18	24,619	29,799	28,579	25,619	20,259	14,079	7,589	4,449	3,019	1,639	669	749
12	36,389	41,049	38,829	36,339	29,199	19,829	9,979	4,819	2,829	1,509	779	579
6	40,379	44,619	42,649	39,519	34,009	22,559	11,319	5,529	2,919	1,549	689	429

Gamma Background: 2,791

Average	7,997
Max	44,619
Count	120

CFX West Wall Net Gamma Survey

Figure H-2

S wall

Data in counts/minute

(Horizontal inches)

72	66	60	54	48	42	36	30	24	18	12	6	(Vertical Inches)
769	1,139	949	959	1,169	1,519	1,549	1,439	1,449	929	1,429	649	60
819	389	1,149	1,139	1,249	1,459	1,479	1,579	1,919	1,769	1,059	739	54
839	599	1,059	969	1,579	1,629	1,699	2,339	2,669	2,979	2,429	1,669	48
739	659	1,029	1,639	2,199	2,569	2,639	3,369	4,859	6,019	5,519	3,969	42
1,009	1,439	1,789	2,439	2,689	3,139	3,739	5,879	7,709	11,099	10,329	6,089	36
959	1,019	1,549	2,469	3,349	3,949	4,509	7,099	10,569	15,659	14,869	11,619	30
1,079	1,469	1,979	3,009	3,949	4,579	6,469	9,909	13,699	19,029	18,829	13,519	24
909	1,569	1,609	2,299	4,049	7,349	9,759	15,039	21,719	27,249	26,799	26,329	18
1,149	1,109	1,899	3,539	5,729	9,129	14,289	23,959	31,089	37,269	39,249	34,799	12
879	929	1,369	2,929	4,819	8,769	14,109	23,239	30,369	38,379	41,409	41,909	6

Average 7,282
Max 41,909
Count 120

Gamma Background: 2,791

CFX South Wall Net Gamma Survey
Figure H-3

Floor

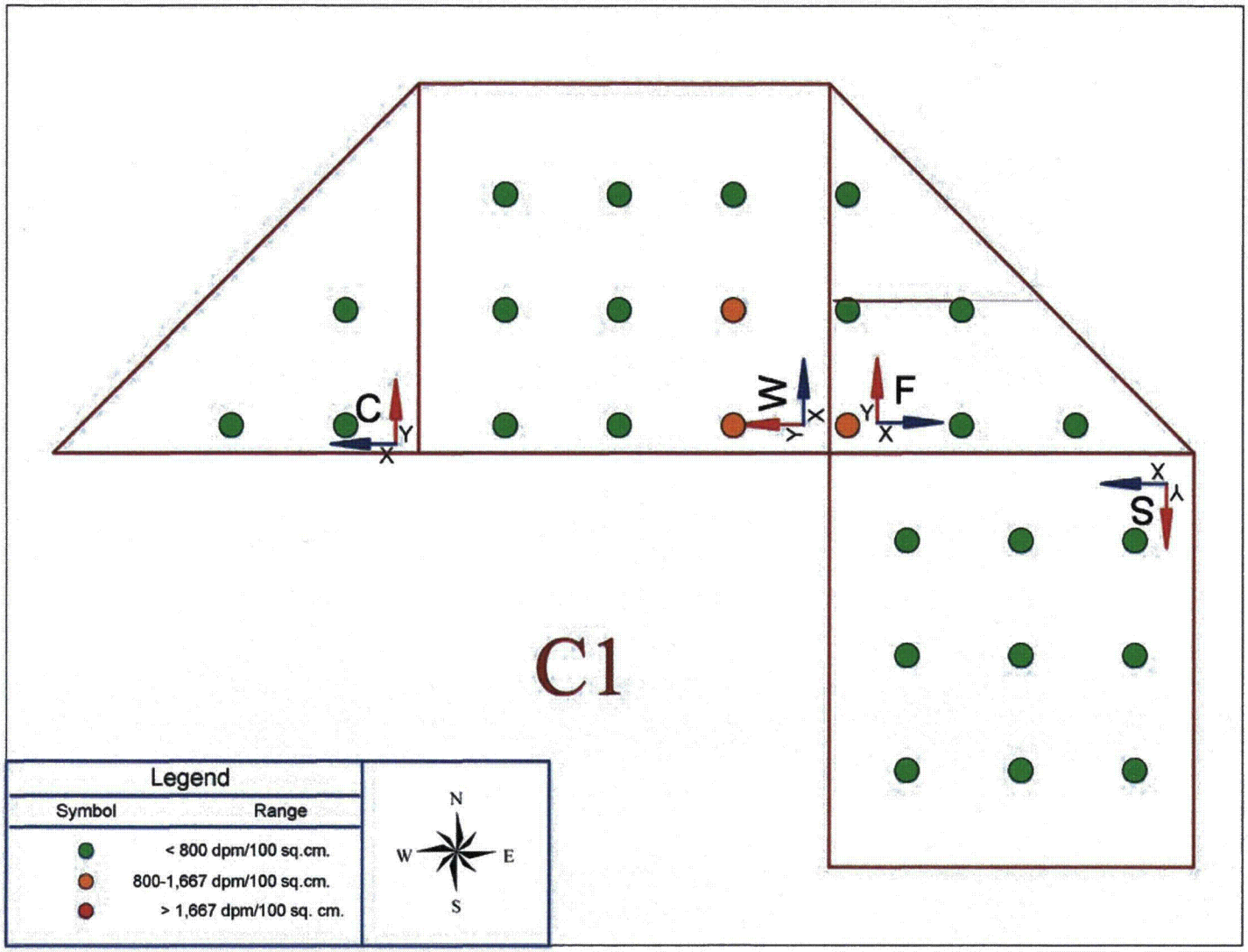
Data in counts/minute

(S wall - inches) \ (W wall - inches)	6	12	18	24	30	36	42	48	54	60	66	72
6	43,989	45,489	43,269	40,089	34,879	25,839	11,089	5,959	2,859	979	1,199	689
12	44,019	50,939	50,009	41,489	32,929	25,029	12,619	6,649	2,949	1,989	1,259	679
18	43,579	46,169	47,929	41,349	31,749	22,349	11,649	6,359	2,929	2,049	1,239	699
24	34,149	41,769	43,369	38,009	28,349	20,209	10,959	5,179	3,459	2,189	949	969
30	22,629	30,629	33,089	28,199	20,389	14,299	9,179	4,429	2,259	1,939	1,189	1,189
36	14,419	19,099	20,839	18,589	12,979	9,039	5,449	3,519	2,389	1,349	859	679
42	8,789	9,589	11,919	10,169	8,419	6,499	3,719	2,899	1,779	1,169		
48	5,099	6,559	6,019	6,029	5,349	3,829	2,779	1,849	1,399			
54	2,799	3,359	3,229	3,409	2,999	2,489	1,839	1,289				
60	1,509	2,399	1,759	1,789	1,409	1,549	1,079					
66	789	989	1,479	1,089	1,249	969						
72	849	959	979	1,159	979							

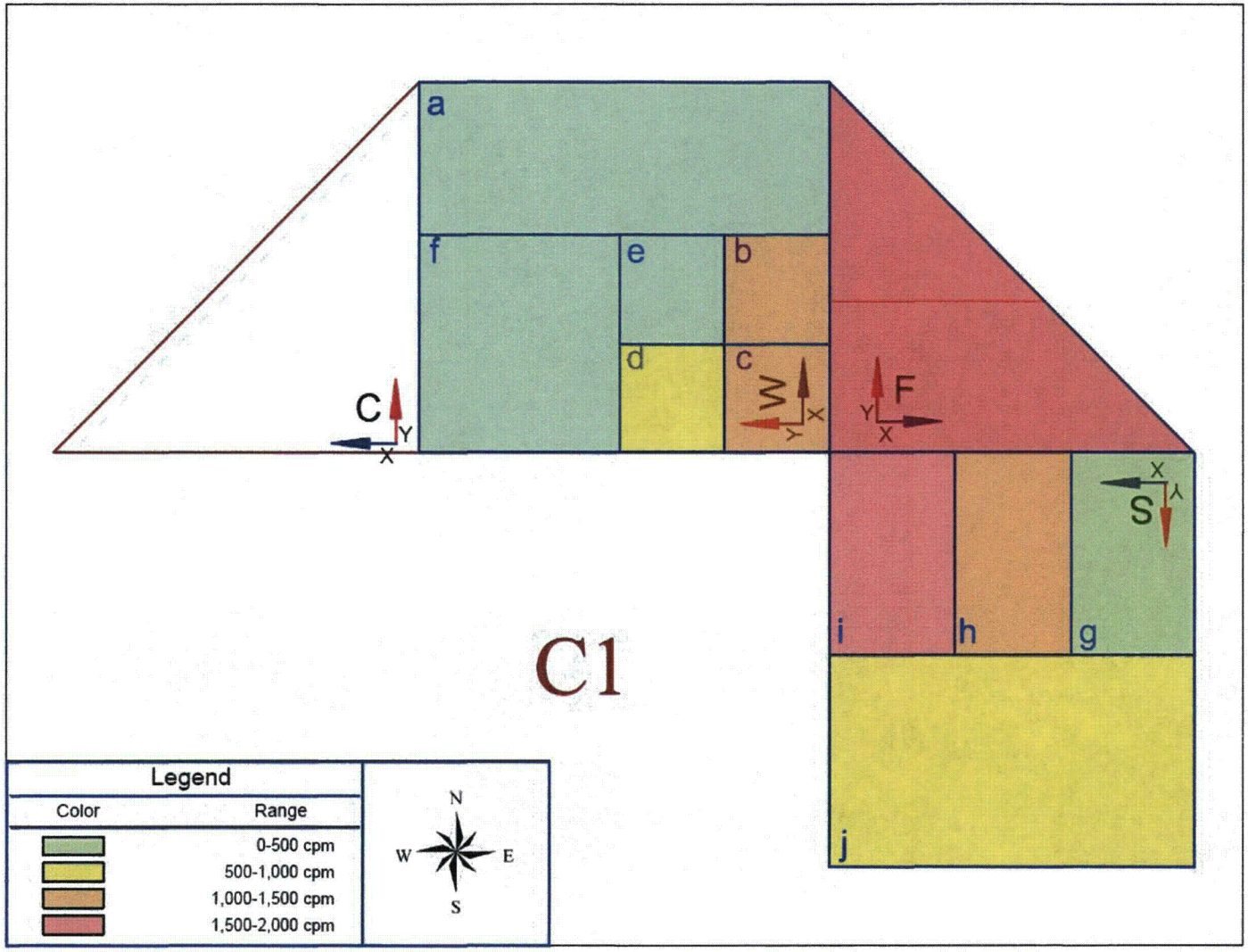
Floor:
Average: 12,319
Max: 50,939
Count: 117

Total Survey:
Average: 9,173
Max: 50,939
Count: 357

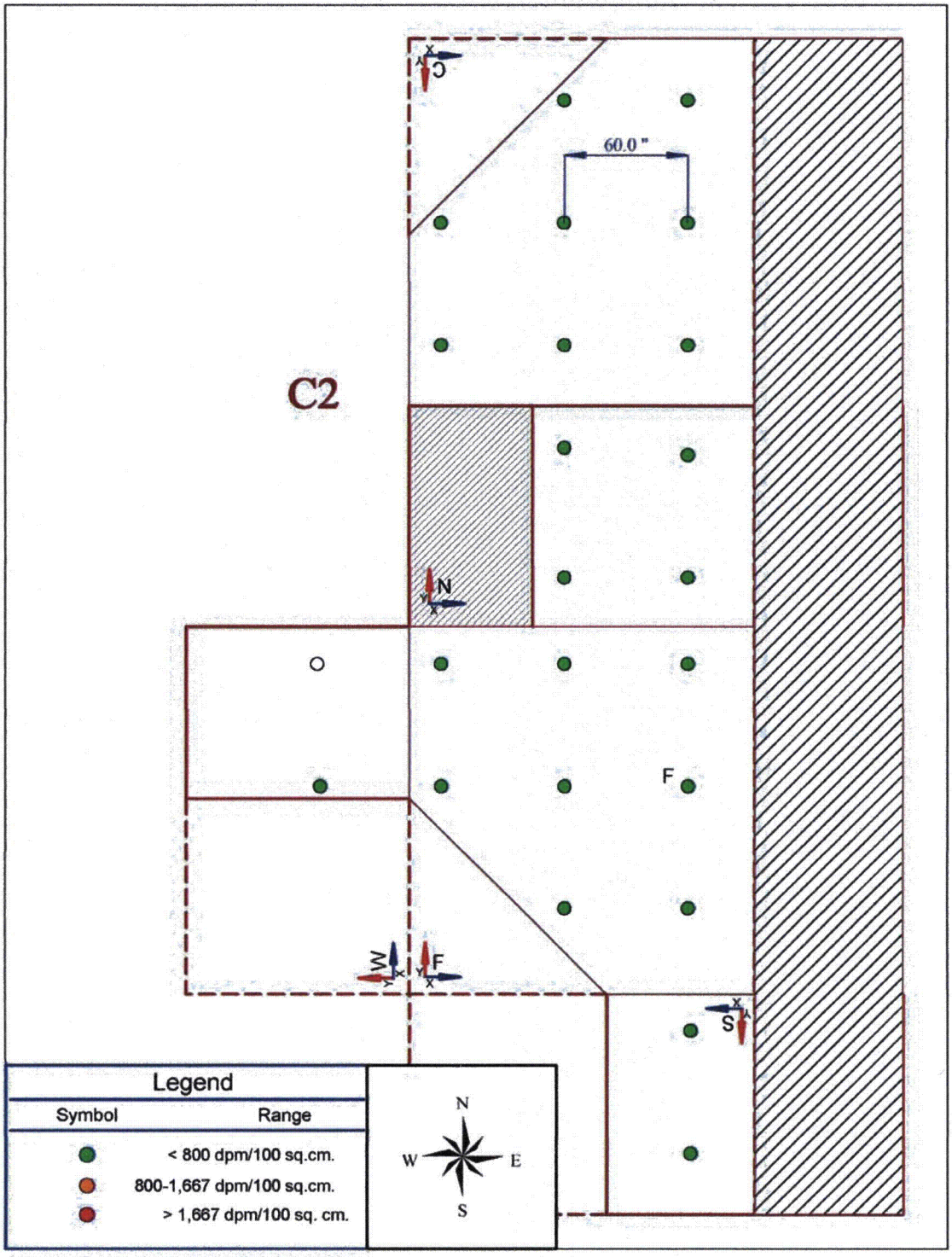
CFX Floor Net Gamma Survey
Figure H-4



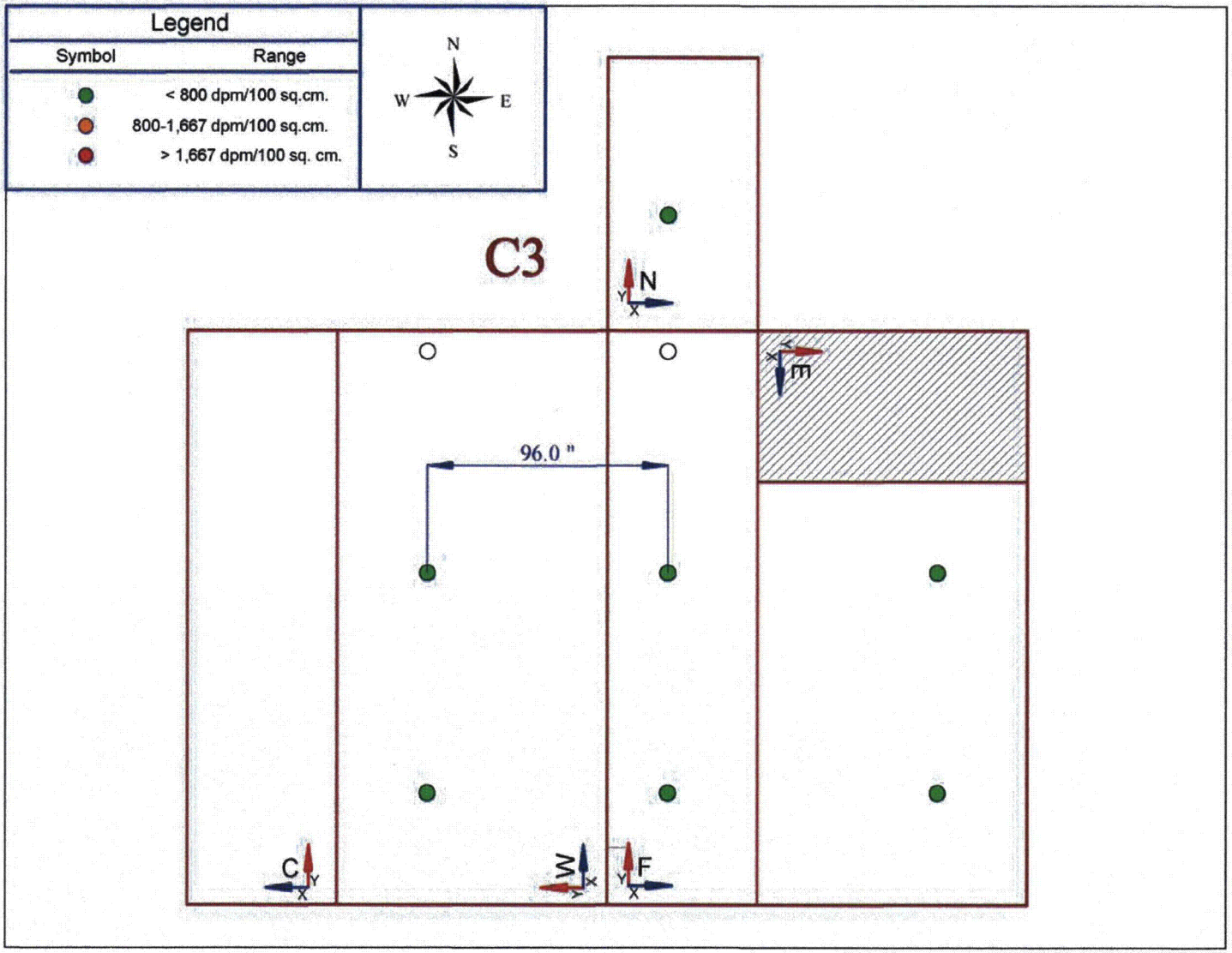
SU-101 Beta Surveys
Figure H-5



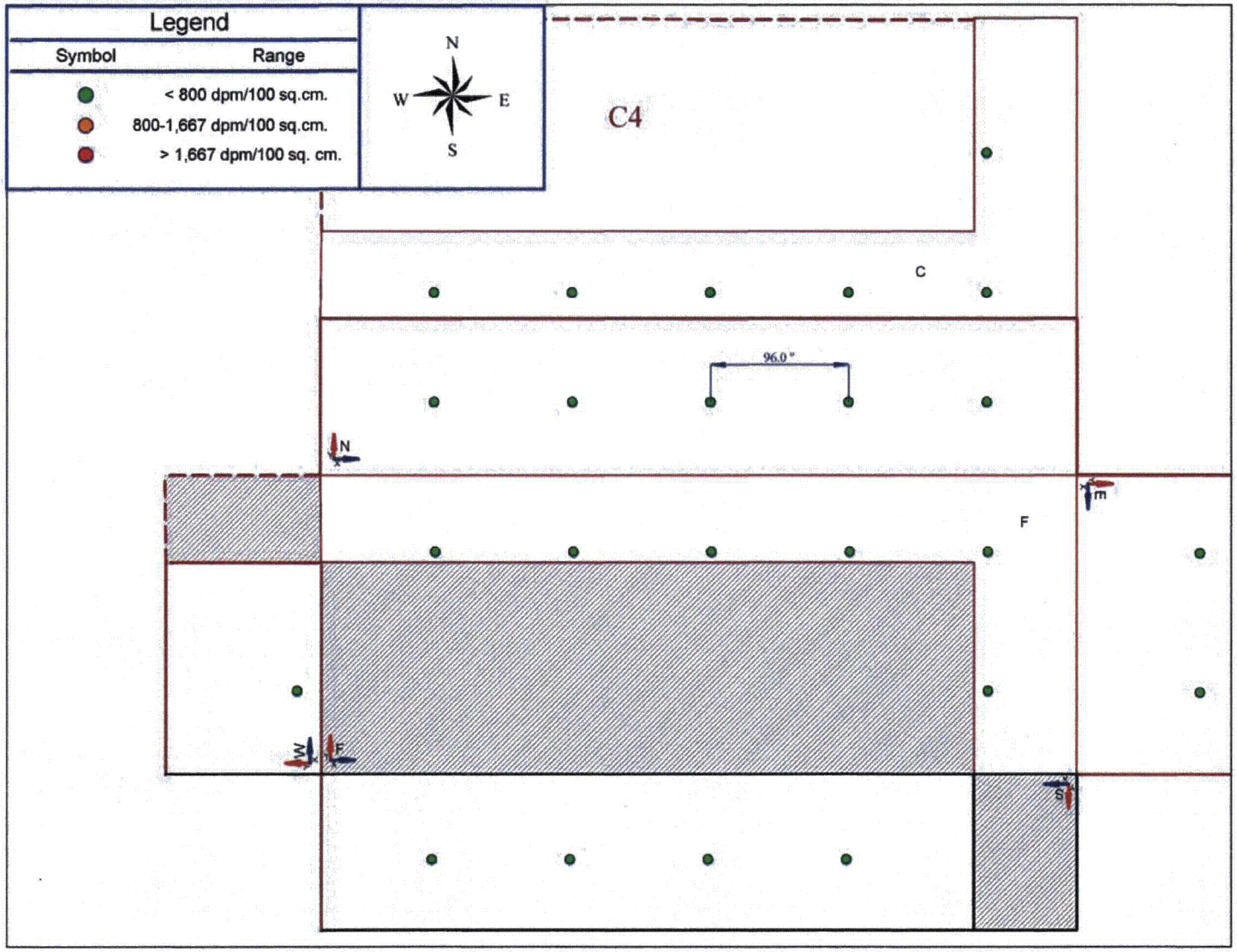
SU-101 β/γ Scans-Maximum Values
Figure H-6



SU-102 Beta Surveys
Figure H-7



SU-103 Room C3 Beta Surveys
Figure H-8



SU-103 Room C4 Beta Surveys
Figure H-9

ATTACHMENT I
Data Tables

Table I-1
SU-101 Gamma Survey

Surface	Matrix	X (ft)	Y (ft)	NetGamma (cpm)
F	C	0.42	0.58	45,849
F	C	0.42	3.08	14,718
F	C	0.42	5.58	245
F	C	1.67	2.00	34,192
F	C	2.92	0.58	15,026
F	C	2.92	3.08	6,455
F	C	5.42	0.58	527
S	C	1.25	1.92	58
S	C	1.25	4.42	(288)
S	C	1.25	6.92	(982)
S	C	3.75	1.92	3,267
S	C	3.75	4.42	879
S	C	6.25	1.92	17,388
S	C	6.25	4.42	1,930
S	C	6.25	6.92	75
S	M	3.75	6.92	(589)
W	C	0.58	2.08	15,417
W	C	0.58	4.58	1,391
W	C	0.58	7.08	(12)
W	C	3.08	2.08	6,456
W	C	3.08	4.58	979
W	C	3.08	7.08	(108)
W	C	5.58	2.08	661
W	C	5.58	4.58	158
W	C	5.58	7.08	(589)
			Average	6,524
			Max	45,849

Table I-2
SU-101 Beta Surveys

ID	Date	Inst	Rm	SFC	Remarks	Matrix	X (ft)	Y (ft)	Open (counts)	Closed (counts)	Delta (Co-Cc)	Gross Beta (dpm/100 cm²)	T (min)	BKG (dpm/100 cm²)	NetBeta (dpm/100 cm²)
2293	11/30/2007	162411	C1	F		C	0.4	0.6	1811	1650	161	1539	1	580	960
2295	11/30/2007	162411	C1	F		C	2.9	0.6	752	627	125	1195	1	580	615
2296	11/30/2007	162411	C1	F		C	5.4	0.6	210	173	37	354	1	580	-226
2297	11/30/2007	162411	C1	F		C	0.4	3.1	732	664	68	650	1	580	70
2298	11/30/2007	162411	C1	F		C	2.9	3.1	460	430	30	287	1	580	-293
2299	11/30/2007	162411	C1	F		C	0.4	5.6	284	176	108	1033	1	580	453
2301	11/30/2007	162411	C1	C		C	1.6	0.6	204	186	18	172	1	580	-408
2302	11/30/2007	162411	C1	C		C	4.1	0.6	260	170	90	861	1	580	281
2303	11/30/2007	162411	C1	C		C	1.6	3.1	258	168	90	861	1	580	281
2304	11/30/2007	162411	C1	W		C	0.6	2.1	872	686	186	1779	1	580	1199
2305	11/30/2007	162411	C1	W		C	3.1	2.1	481	276	205	1960	1	580	1380
2306	11/30/2007	162411	C1	W		C	5.6	2.1	272	188	84	803	1	580	223
2307	11/30/2007	162411	C1	W		C	0.6	4.6	336	208	128	1224	1	580	644
2308	11/30/2007	162411	C1	W		C	3.1	4.6	284	226	58	555	1	580	-25
2309	11/30/2007	162411	C1	W		C	5.6	4.6	240	172	68	650	1	580	70
2310	11/30/2007	162411	C1	W		C	0.6	7.1	250	200	50	478	1	580	-102
2311	11/30/2007	162411	C1	W		C	3.1	7.1	266	180	86	822	1	580	242
2312	11/30/2007	162411	C1	W		C	5.6	7.1	274	150	124	1186	1	580	606
2313	11/30/2007	162411	C1	S		C	1.3	1.9	258	134	124	1186	1	580	606
2314	11/30/2007	162411	C1	S		C	3.8	1.9	362	318	44	421	1	580	-159
2315	11/30/2007	162411	C1	S		C	6.3	1.9	762	648	114	1090	1	580	510
2316	11/30/2007	162411	C1	S		C	1.3	4.4	262	144	118	1128	1	580	548
2317	11/30/2007	162411	C1	S		C	3.8	4.4	316	196	120	1147	1	580	567
2318	11/30/2007	162411	C1	S		C	6.3	4.4	294	252	42	402	1	580	-178
2319	11/30/2007	162411	C1	S		C	1.3	6.9	204	166	38	363	1	580	-217
2320	11/30/2007	162411	C1	S	On vacume manifold	M	3.8	6.9	186	174	12	115	1	0	115
2321	11/30/2007	162411	C1	S		C	6.3	6.9	268	192	76	727	1	580	147

Average	89
St Dev	49
Max	205

Average	293
St Dev	451
Max	1380
Count	27

Table I-3
SU-101 Removable Contamination Surveys

ID	Sfc	Gross Alpha (dpm/100 cm^2)	Gross Beta (dpm/100 cm^2)
2302	C	0.28	4.79
2301	C	0.28	5.39
2303	C	1.12	3.20
2295	F	0.84	5.59
2299	F	0.28	5.99
2293	F	0.28	4.39
2298	F	0.56	4.79
2297	F	0.28	3.00
2296	F	1.40	4.19
2314	S	0.00	3.59
2315	S	1.12	6.39
2320	S	0.00	4.19
2316	S	1.12	3.59
2317	S	0.56	3.99
2318	S	0.00	6.19
2319	S	0.84	3.79
2321	S	0.56	5.79
2313	S	0.84	3.20
2309	W	1.40	4.99
2304	W	1.12	3.79
2305	W	0.56	3.59
2306	W	2.24	4.19
2308	W	0.56	3.59
2310	W	0.28	4.39
2311	W	0.28	3.39
2312	W	0.00	3.39
2307	W	0.84	5.79

Table I-4
SU-101 β/γ Scan Surveys[a]

ID	ScanDate	Room	Sfc	Sub-Surface	Matrix	ScanAvg (cpm)	ScanMax (cpm)	Person	Inst
23	30-Nov-07	C1	C		C	220	250	Thatcher	162411
16	30-Nov-07	C1	F		C	1,500	2,000	Thatcher	162411
24	30-Nov-07	C1	S	G	C	200	280	Thatcher	162411
25	30-Nov-07	C1	S	H	C	800	1,000	Thatcher	162411
26	30-Nov-07	C1	S	I	C	1,250	2,000	Thatcher	162411
27	30-Nov-07	C1	S	J	C	275	600	Thatcher	162411
17	30-Nov-07	C1	W	A	C	250	380	Thatcher	162411
18	30-Nov-07	C1	W	B	C	1,200	1,300	Thatcher	162411
19	30-Nov-07	C1	W	C	C	900	1,100	Thatcher	162411
20	30-Nov-07	C1	W	D	C	600	800	Thatcher	162411
21	30-Nov-07	C1	W	E	C	250	400	Thatcher	162411
22	30-Nov-07	C1	W	F	C	280	350	Thatcher	162411

[a] All values include β/γ background for concrete (253 cpm). Shaded values exceed the threshold in Table 2.6

Table I-5
SU-102 Beta Surveys

ID	Date	Inst	Rm	SFC	Remarks	Matrix	X (ft)	Y (ft)	Open (counts)	Closed (counts)	Delta (Co-Cc)	Gross Beta (dpm/100 cm^2)	T (min)	BKG (dpm/100 cm^2)	NetBeta (dpm/100 cm^2)
2323	11/30/2007	162414	C2	F		VT	6.3	3.5	210	222	(12)	(116)	1	60	(175)
2324	11/30/2007	162414	C2	F		VT	11.3	3.5	214	234	(20)	(193)	1	60	(253)
2325	11/30/2007	162414	C2	F		VT	1.3	8.5	204	190	14	135	1	60	75
2326	11/30/2007	162414	C2	F		VT	6.3	8.5	194	182	12	116	1	60	56
2327	11/30/2007	162414	C2	F		VT	11.3	8.5	214	188	26	251	1	60	191
2328	11/30/2007	162414	C2	C		C	6.3	2.5	246	250	(4)	(39)	1	580	(619)
2329	11/30/2007	162414	C2	C		C	11.3	2.5	300	222	78	752	1	580	172
2330	11/30/2007	162414	C2	C		C	1.3	7.5	234	200	34	328	1	580	(252)
2331	11/30/2007	162414	C2	C		C	6.3	7.5	260	222	38	366	1	580	(214)
2332	11/30/2007	162414	C2	C		C	11.3	7.5	244	242	2	19	1	580	(561)
2333	11/30/2007	162414	C2	F		VT	1.3	13.5	194	186	8	77	1	60	17
2334	11/30/2007	162414	C2	F		VT	6.3	13.5	208	204	4	39	1	60	(21)
2335	11/30/2007	162414	C2	F		VT	11.3	13.5	214	188	26	251	1	60	191
2336	11/30/2007	162414	C2	N		C	6.3	2	250	184	66	636	1	580	56
2337	11/30/2007	162414	C2	N		C	11.3	2	304	182	122	1,176	1	580	596
2338	11/30/2007	162414	C2	N		C	6.3	7	272	200	72	694	1	580	114
2339	11/30/2007	162414	C2	N		C	11.3	7	282	202	80	771	1	580	191
2340	11/30/2007	162414	C2	S		C	6.6	1.5	232	192	40	386	1	580	(194)
2341	11/30/2007	162414	C2	S		C	6.6	6.5	284	206	78	752	1	580	172
2342	11/30/2007	162414	C2	C		C	1.3	12.5	208	230	(22)	(212)	1	580	(792)
2343	11/30/2007	162414	C2	C		C	6.3	12.5	238	230	8	77	1	580	(503)
2344	11/30/2007	162414	C2	C		C	11.3	12.5	222	182	40	386	1	580	(194)
2345	11/30/2007	162414	C2	W		C	8.5	3.6	210	168	42	405	1	580	(175)

Average	32
St Dev	37
Max	122

Average	(92)
St Dev	319
Max	596
Count	23

Table I-6
SU-102 Removable Contamination Surveys

ID	Sfc	X (ft)	Y (ft)	Gross Alpha (dpm/100 cm^2)	Gross Beta (dpm/100 cm^2)
2327	F	11.33	8.54	0.28	4.99
2326	F	6.33	8.54	0.28	3.99
2325	F	1.33	8.54	1.12	5.79
2324	F	11.33	3.54	1.12	4.39
2323	F	6.33	3.54	0.84	3.99

Table I-7
SU-102 β/γ Scan Surveys[a]

ID	ScanDate	Room	Sfc	Matrix	ScanAvg (cpm)	ScanMax (cpm)	Person	Inst
3	30-Nov-07	C2	C	C	260	310	Freudiger	162414
5	30-Nov-07	C2	F	VT	210	230	Freudiger	162414
1	30-Nov-07	C2	N	C	270	310	Freudiger	162414
2	30-Nov-07	C2	S	C	250	300	Freudiger	162414
4	30-Nov-07	C2	W	C	200	210	Freudiger	162414

[a] All values include β/γ background (see §2.2).

Table I-8
SU-103 Beta Surveys

ID	Date	Inst	Rm	SFC	Remarks	Matrix	X (ft)	Y (ft)	Open (counts)	Closed (counts)	Delta (Co-Cc)	Gross Beta (dpm/100 cm^2)	T (min)	BKG (dpm/100 cm^2)	NetBeta (dpm/100 cm^2)
2346	11/30/2007	162414	C3	F		VT	2.0	3.7	200	198	2	19	1	60	(40)
2347	11/30/2007	162414	C3	F		VT	2.0	11.0	176	208	(32)	(308)	1	60	(368)
2348	11/30/2007	162414	C3	N		C	2.0	3.8	252	182	70	675	1	580	95
2349	11/30/2007	162414	C3	E		C	15.3	6.0	256	172	84	810	1	580	230
2350	11/30/2007	162414	C3	E		C	8.0	6.0	214	148	66	636	1	580	56
2351	11/30/2007	162414	C3	W		C	3.7	6.0	278	152	126	1,215	1	580	635
2352	11/30/2007	162414	C3	W		C	11.0	6.0	266	174	92	887	1	580	307
2353	11/30/2007	162414	C4	F		VT	6.6	12.8	186	204	(18)	(174)	1	60	(233)
2354	11/30/2007	162414	C4	F		VT	14.6	12.8	168	154	14	135	1	60	75
2355	11/30/2007	162414	C4	F		VT	22.6	12.8	202	214	(12)	(116)	1	60	(175)
2356	11/30/2007	162414	C4	F		VT	30.6	12.8	188	182	6	58	1	60	(2)
2357	11/30/2007	162414	C4	C		C	6.6	15.7	190	170	20	193	1	580	(387)
2358	11/30/2007	162414	C4	C		C	14.6	15.7	198	158	40	386	1	580	(194)
2359	11/30/2007	162414	C4	C		C	22.6	15.7	182	200	(18)	(174)	1	580	(753)
2360	11/30/2007	162414	C4	N		C	6.6	4.2	232	176	56	540	1	580	(40)
2361	11/30/2007	162414	C4	N		C	14.6	4.2	264	198	66	636	1	580	56
2362	11/30/2007	162414	C4	N		C	22.6	4.2	228	160	68	655	1	580	76
2363	11/30/2007	162414	C4	F		VT	38.6	12.8	226	208	18	174	1	60	114
2364	11/30/2007	162414	C4	F		VT	38.6	4.8	184	256	(72)	(694)	1	60	(754)
2365	11/30/2007	162414	C4	N		C	30.6	4.2	240	192	48	463	1	580	(117)
2366	11/30/2007	162414	C4	N		C	38.6	4.2	282	236	46	443	1	580	(137)
2367	11/30/2007	162414	C4	S		C	13.4	4.9	248	204	44	424	1	580	(156)
2368	11/30/2007	162414	C4	S		C	21.4	4.9	238	172	66	636	1	580	56
2369	11/30/2007	162414	C4	S		C	29.4	4.9	230	168	62	598	1	580	18
2370	11/30/2007	162414	C4	S		C	37.4	4.9	222	192	30	289	1	580	(291)
2371	11/30/2007	162414	C4	E		C	4.5	7.1	300	232	68	655	1	580	76
2372	11/30/2007	162414	C4	E		C	12.5	7.1	310	240	70	675	1	580	95
2373	11/30/2007	162414	C4	W		C	4.8	1.4	308	206	102	983	1	580	403
2374	11/30/2007	162414	C4	C		C	30.6	15.7	188	188	-	-	1	580	(580)
2375	11/30/2007	162414	C4	C		C	38.6	15.7	250	280	(30)	(289)	1	580	(869)
2376	11/30/2007	162414	C4	C		C	38.6	7.7	300	306	(6)	(58)	1	580	(638)

Average	37
St Dev	45
Max	126

Average	(111)
St Dev	358
Max	635
Count	31

Table I-9
SU-103 Removable Contamination Surveys

ID	Room	Sfc	X (ft)	Y (ft)	Gross Alpha (dpm/100 cm^2)	Gross Beta (dpm/100 cm^2)
2347	C3	F	1.96	11.04	0.28	3.20
2346	C3	F	1.96	3.71	0.28	3.79
2364	C4	F	38.60	4.75	0.56	5.19
2363	C4	F	38.60	12.75	0.28	3.79
2356	C4	F	30.60	12.75	0.28	4.79
2355	C4	F	22.63	12.75	0.84	5.39
2354	C4	F	14.63	12.75	1.12	7.39
2353	C4	F	6.63	12.75	0.56	3.79

Table I-10
SU-103 β/γ Scan Surveys[a]

ID	ScanDate	Room	Sfc	Matrix	ScanAvg (cpm)	ScanMax (cpm)	Person	Inst
7	30-Nov-07	C3	E	C	240	260	Freudiger	162414
9	30-Nov-07	C3	F	VT	180	210	Freudiger	162414
6	30-Nov-07	C3	N	C	180	220	Freudiger	162414
8	30-Nov-07	C3	W	C	270	280	Freudiger	162414
15	30-Nov-07	C4	C	C	220	310	Freudiger	162414
12	30-Nov-07	C4	E	C	300	320	Freudiger	162414
14	30-Nov-07	C4	F	VT	190	230	Freudiger	162414
10	30-Nov-07	C4	N	C	250	290	Freudiger	162414
11	30-Nov-07	C4	S	C	230	250	Freudiger	162414
13	30-Nov-07	C4	W	C	280	310	Freudiger	162414

[a] All values include β/γ background (see §2.2).